Designing an Educational and Intelligent Human-Computer Interface for Older Adults

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By

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ABSTRACT
DEVELOPING A FRAMEWORK FOR CREATING ACCESSIBLE HUMAN-COMPUTER INTERFACES FOR OLDER ADULTS

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As computing devices continue to become more heavily integrated into our lives, proper design of human-computer interfaces becomes a more important topic of discussion. Efficient and useful human-computer interfaces need to take into account the abilities of the humans who will be using such interfaces, and adapt to difficulties that different users may face – such as the particular difficulties older users must face. However, various issues in the design of human-computer interfaces for older users yet exist: a wide variance of ability is displayed by older adults, which can be difficult to design for. Motions and notions found intuitive by younger users can be anything but for the older user. Properly-designed devices must also assist without injuring the pride and independence of the users – thus, it's understood that devices designed "for the elderly" may encounter a poor reception when introduced to the ageing community.

Affective computing gives current researchers in HCI a useful opportunity to develop applications with interfaces that detect mood and attention via nonverbal cues and take appropriate actions accordingly. Current work in affective computing applications with older adult users points to possibilities reducing feelings of loneliness in the older adult population via these affective applications. However, we believe that everyday applications – such as chat programs or operating systems – can also take advantage of affective computing principles to make themselves more accessible for older adults, via communication enhancement.

In this thesis, we document a variety of work in the field of developing human-computer interfaces for the older adult user, and the various requirements each of these studies confirm regarding human-computer interaction design for the elderly. We then explain how integration of affective computing can positively affect these designs, and outline a design approach for proper human-computer interfaces for the elderly which take into account affective computing principles. We then develop a case study around a chat application – ChitChat – which takes these principles and guidelines into account from the beginning, and give several examples of real-world applications also built with these guidelines. Finally, we conclude by summarizing the broader impacts of this work.

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CHAPTER 1 : INTRODUCTION

Personal computing devices have become an ever more prominent part of our everyday existence. Computers now enhance many common activities – allowing for communication between those separated by great distances, increased and improved social interactions between business workers, and creating a collaborative and mess-free environment for artists and other hobbyists. The enjoyment of new places is enhanced via the existence of easily accessible guides to unfamiliar metropolitan areas. Furthermore, the growth of mobile devices means that these assisting applications can reach users wherever they may be - a restaurant review app can display relevant reviews of bars and clubs in the area, and GPS software can guide a user through unfamiliar streets to a bus stop the moment they find themselves lost.

Instrumental in creating applications that help rather than hinder is proper design. If the design of an application or device is too poor for a user to thoroughly grasp how to use it, it may be tossed aside in frustration before the benefit is seen! Interface design is further complicated when one realizes that designers must take into consideration that every human on this planet is unique, and equipped with different abilities and preconceived notions of how computers act. When designing for younger people, who are more used to technology, interface designers can be a bit more creative in their design - younger people have different expectations of applications than older adults, and different things might be "intuitive." However, older users more often than not have different abilities, preconceptions regarding computers, and less experience with computers overall – meaning that applications designed for youth may not be understood by an older computer user.

Current research in human-computer interfaces does a good job of getting across the point that when developing applications for the older user, a designer does need to take into consideration age-related impairments: elderly users, or those aged 60 and above [1], often encounter declination of their physical and mental abilities with the onset of old age [2]–[5]. Many older adults find their eyesight and hearing weakening, in addition to decreased dexterity and cognitive abilities. [1] This can cause problems when they try to use flashy applications that attempt to cater to all the senses of the twenty-something user, who might appreciate popups, music, and brightly-colored designs. To make matters worse, many applications lack basic information on how to use the application - for users in their twenties, repeated use of apps reinforces expectations of other applications, enhancing the ability to pick up other interfaces which follow similar trends. For the older adult user, this is often not the case. Coupled with the older adult users' fear of breaking things, [6] a lack of documentation may cause severe problems for new older adult users of various applications.

In response to such issues, many developers create "elderly-friendly" versions of applications, which vastly simplify the application interface overall. This does bring attention to another challenge in developing applications for the older user: understanding the view of the older adult user in relation to the computers that they wish to use. Even an application designed to be useable by an older adult person may go unused [7] – the older adult users preferring to prove their competency by attempting use of the standard version of the application. Particular stigmas are associated with the notion of "being old", and users may want to avoid being related to such notions. [7]

A number of interface solutions have been suggested to assist ageing computer

users – however, some of the most striking success in adapting for user impairments in general has come from the use of intelligent interfaces. Intelligent interfaces build a profile of the user in question via a variety of input from the user, and tailor an appropriate experience based on information and trends in said data. Users with poor vision might receive words with larger fonts, while those with arthritic hands may receive increased sensitivity for mice and touchpads.

These adaptive interfaces are typically user for disabled users, but may be used for the older user as well. To properly overcome the difficulties an older user faces when using an application, an intelligent interface should prepare for a variety of physical abilities [7] due to the variance in older adult ability [4], [7] and allow for proper balance of the interface in relation to the particular abilities of the user. The application should be designed so that each of the portions of the app related to this particular ability would be able to be adjusted. Finally, the intelligence of the application deserves some thought. While existing intelligent interfaces can make decisions based on a users' demonstrated ability during a quick calibration test, or even a questionnaire, [8], [9] how can one make a decision on whether or not a particular interface chosen is actually resulting in a positive response from the user?

Here we introduce the idea of *affective computing* to the challenge of designing a proper user interface for the older user. Affective computing deals with assigning a computer capabilities that previously were only found in human beings: observation and interpretation/generation of affect features. [10] Systems using affective computing typically interpret sensor data relating to the emotional status of the user, such as gestures or facial expressions, or generate such affective markers themselves – such as emotional

speech output. By integrating an already-intelligent interface with affective computing capabilities, we can create interfaces where, as an example, a smile may be logged as proof that a particular setting chosen by software decisions is accurate for a users' abilities. This reduces the manual setting of the system while improving the tailored interface of the system, which makes such a thing ideal for an older user.

As easy as this will make creating new settings in an application, affective computing does not mean one should not explain the features of their application. Heavy use of tutorials is recommended in order to explain various portions of the application in particular as well: one should never assume that a system, no matter how smart or intuitive it was designed to be, will be fully understandable for all users. Tutorials can assist in explanation of an application's use without infringing on an elderly users' independence, and offer a good solution for applications wishing to adapt to different user needs without over-simplification. After all, elderly users can learn how to use computers [6], [7], [11] – they simply opt not to learn applications where the difficulty of use is greater than the benefit of the application.

However, here one might interject with a criticism concerning the nature of products that exist on the market, specially tailored for the older adult user. While it is true that a variety of "elderly-tailored" applications currently exist, a wide variety of them expect particular things of the user, and reduce functionality in favor of a "more understandable" interface. For this reason, we believe that an intelligent interface by itself will reduce some customer concern about being labeled as "old." No functionality will need to be specifically reduced, but menu options and things of that nature would simply be rearranged as the user feels proper for their understanding. Furthermore, as a

user becomes more adept at using the intelligent interface, the interface may rearrange itself to mirror interfaces used by youth - teaching the older adult user how to navigate apps that are not tailored for older adults.

This being said, an application that combines teaching and intelligence in its interface would be the best solution for an elderly adult user: in focusing on both of these features, the application would create an easier interface for the elderly user, offering an easier channel of communication from the user to the computer via the use of nonverbal cues. The application would also offer a channel of communication from the computer to the user, educating them on the best methods of using the machine. The combination of these features would allow for users to enjoy tailored interfaces that do not over-simplify the application for the user, allowing them to retain their pride.

That said, the goals of this thesis in particular are as follows: to show that an intelligent, educational human-computer interface for older adults is one of the requirements for human-computer interfaces when developing applications for an older user, and to prove a design approach for future intelligent interfaces. We will show that intelligent interfaces – especially those integrating aspects of affective computing - show the most promise for the ageing user, due to their automatic customization abilities and ability to teach and receive responses from a user on the fly. A variety of further considerations will be given, from preparing intelligent interfaces for a users' physical abilities, to preparing tutorials in relation to affective data.

The remainder of this thesis is as follows: we'll begin by stating our motivations for looking into the idea of using intelligent interfaces, taking into account several examples of how poor design can prevent the older adult from using devices that

otherwise could enhance their quality of life. We'll then talk about current research that is being done in the area of developing proper human-computer interfaces for older adult people, intelligent interfaces and otherwise. This will be followed by design requirements determined from the features of the existing projects and age-related loss of ability. We'll then discuss how a communication-centric design approach fulfills all considerations, based on the aforementioned requirements, one should take when developing an intelligent. Finally, we'll wrap up by exploring the application of this approach via both a case study and real-world applications, and end with some thought regarding future applications and directions.

CHAPTER 2 : MOTIVATION

All in all, helping older adults become more comfortable with using computers is our priority. We wish to accomplish this goal in two parts: proving to older adult users that computer use is beneficial to them, and recognizing that which impedes older adults wishing to use computers, and overcoming it. As the number of older adults in the world increases, [12] we need to make it a priority to develop ways of improving the attitudes of ageing users towards technology. Software exists that has the potential to be used by older users to improve their everyday living conditions: delivering educational opportunities, telemedical uses, and giving users the opportunity to work from home, among others. [12] What's now important is highlighting how we can show older users the benefits of these tools, and make them easier for older users to pick up.

2.1 Problems Afflicting Older Users of Technology

Problems afflicting technology design can be narrowed down to three particular issues: poor design of a given interface for user abilities, confusion over how to use application interfaces in general, and existing social stigmas relating to older users and technology.

2.1.1 User Interfaces

Poor human-computer interface design can hinder the adoption of technology – meaning, the inherent possibility of existing apps to help users is not realized due to unintuitive design. While an iPhone might help a grandmother speak with her children and grandchildren, she might find that the icons are too small and great in number, and

the sensitivity of the device proves to cause many instances of incorrect input. [13] A screen with threaded messages, common in today's modern email clients, may not be understandable by the older user. [14] All in all, tasks that are simple for teenagers, such as using a mouse or remembering the details of how to view a Facebook photo album, are not so immediately understandable to an older adult. [12] And while some computers offer options to assist older users, such as changing a font or decreasing mouse sensitivity, these options are often buried in the settings for the computer overall and not easily encountered.

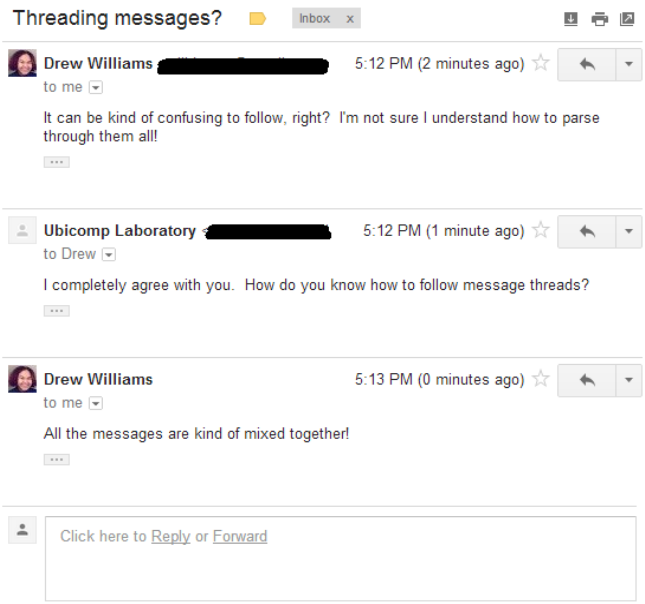

Figure 1: Common threaded message interface from within Gmail. [60]

The following are some particular examples of user interface and usability problems that older users may encounter when attempting to make use of software.

Using a GPS. In order to visit family, an older person might utilize a GPS application to assist them in finding the place of meeting. However, most GPS applications offer a touch-based interface, which can be very sensitive. Older people

with poor dexterity may take more time to use the GPS system and set it up according to where they want to go, than it would take for them to use a map. Thus the older person to turn away from using a GPS, despite the fact that many GPS systems nowadays offer advanced features, such as automatic re-routing and traffic information, that an older person may find quite useful

Using Social Networking. With millions worldwide utilizing social networks in this day and age, an older person might use websites such as Facebook in order to stay in touch with their children and grandchildren. However, multiple menus with colorful designs can often confuse and hinder efforts to use these social networks – older users often have less sensitivity to contrasts in color, and multiple pictures and wallpaper patterns run the risk of confusing a user [1].

Furthermore, many social networking websites feature unfamiliar terms and ideas, which can confuse older users, such as jargon like "status updates" that might be familiar to youth but make no sense to an older user. If this wasn't confusing enough, the incredibly public nature of these websites means that accidental input that gets posted to the social network may cause damage to the older person's confidence in using such technology. Existing problems with confidence in the face of technology have been noted in the older population as being reasons for slow adoption of tech amongst this population. [1]

Remembering Tasks. Finally, in order to organize and remember lists of things to do, an older person might configure a to-do list program, complete with audible reminders when the time to complete a task comes around. This can be useful for someone who needs to remember to take medication, or a diabetic who needs to check

their meter. However, alerts should be configured for the older user: pop ups, for example, may not catch the older user's attention required, [3] and if the pop ups do catch the user's attention, multiple reminders can be distressing – as older users show less of a multitasking ability than younger people. [3] Sometimes, the high pitched beeps of such audible reminders may be missed by the older. [1] Those who are hard of hearing may need to further adjust the levels of the sounds produced, or risk not hearing the reminders and forgetting to do their tasks despite their diligence in creating the reminders to assist themselves. [3]

2.1.2 Lack of Tutorials In-Application

Older adult users are prone to fear of breaking applications, [6] and thus often look for manuals or tutorials for application use. In a study done concerning coaching strategies for helping older adult computer users learn how to perform basic computing tasks, a particular instance of a user complaining because of a lack of printed documentation for the computer was even recorded! [6] This complaint in particular makes sense – appliances, such as televisions and DVD/VHS players, often came with printed instructions for use, and older adult computer users may be uncomfortable with having no such thing for what is arguably the most complex 'appliance' they have come across. Applications nowadays also tend to not make tutorials and the like the forefront of their focus, and this poses problems for the older adult user.

2.1.3 Existing Social Stigmas

Finally, the societal view of older users and technology may impact their use of technology. Older users have reported feeling as if they are "too old" for technology, as a

result of societal reinforcement regarding older adults and technology use. [7] Indeed, it has been a complaint in the literature that current efforts to develop programs for elderly abilities put more emphasis on what they cannot do, reinforcing such notions in the minds of younger and older people. This can hurt the development of applications that include older users in their target market, as even the word "old" gives rise to notions of "a burden" and "not trying." [7] These notions often push other older users cite a need to avoid being associated with being "old," preferring to use the standard versions of applications in lieu of existent "elderly-friendly" applications. [15]

A proper design should not obviously single out the older user playing into stereotypes, but instead target the novice user first, whilst adding adaptations that an older adult user would find useful. The application should also make clear that the benefits of the application outweigh any initial difficulty that the user may face in learning it. Lack of perceived benefit is a major reason for lack of computer use in older adults. [7] By helping an older user learn best practices for using computers right away, we assist in ensuring that an older user sees computers in a positive light, and remains more open to allowing them to assist them in everyday life.

2.2 Benefits of Technology for Older Users

Explaining the benefits of technology for the elderly user is a straightforward process: computers can do a number of things for the older user, from helping them remember to take medications to allowing them to stay in touch with friends and family. However, these many benefits can be whittled into four main categories: improving user abilities to make up for physical and cognitive age-related impairments, entertainment and education, medical use, and improving social interactions.

2.1.1 Improving Sensory Abilities via Computer Technology

Various abilities may deteriorate in older users, as a result of ageing – such sensory abilities may range from a users' vision and hearing, to their cognitive abilities and motor skills. [16] As a result, an older adult may suffer some loss of functional independence, especially in relation to a loss in the users' hearing and vision abilities. [17] This loss of independence can hurt an older adult's sense of pride and confidence, in addition to preventing them from being as mobile as they once were.

However, with mobile and desktop applications, a user can substitute technology for the deteriorating abilities. Instead of relying on a failing memory to determine where a family member lives, an older adult can use a GPS navigation system to find their house. E-readers can make text larger than it might be on traditional paper. Those users whose sensory abilities have not yet begun to deteriorate can keep such abilities sharp via applications that promise brain training, or via internet education. [12]

2.1.2 Entertainment and Educational Possibilities

Another benefit of being able to use technology for the older adult is the number of entertainment and education options that would be made available to them. E-reader software, movie rentals and more are available online, already instantly for the older adult with just the click of a button! For an elderly user who may have reduced mobility due to illness or disability, this could help prevent feelings of social isolation and boredom alike! Furthermore, Alm et al. (2002) also notes the access to computer-delivered education opportunities that older adults who use computers would have access

to. [12] Taking on new learning challenges would assist older users in keeping their mental faculties as sharp as ever! [12]

2.1.3 Medical Possibilities

Alm et al. (2002) also notes the positive benefits of remote access healthcare, coupled with the ability for technology to play a role in a self-help approach to medicine. Teleconferencing allows older adults to make appointments they may otherwise not be able to travel to – such as ones with doctors or specialists that may be out of their way. Being able to use applications to track various health trends, such as sleeping patterns and food eaten, may help doctors when elderly users do schedule in-person appointments – and reminder software can ensure that older users remember to track these parts of their lives!

2.1.4 Reducing Social Isolation

The problem of social isolation and loneliness can threaten the quality of life of an older person, as reduced mobility and the aforementioned deteriorating sensory abilities can reduce their ability to get around. [18] This social isolation can often be bolstered by the onset of depression, which has unfortunately become a common ailment of older adults. [18] However, introducing an older user to the world of the internet and voice/video chat offers a possible solution to feelings of social isolation and loneliness. Recent studies have shown a correlation between computer and internet program use, and the management of feelings of loneliness/improved feelings of social inclusion among older computer users. [18], [19] As increased feelings of loneliness can be linked to

increased mortality rates [20], management of such feelings is essential in keeping the increasing ageing population safe and well.

While these benefits are certainly motivations for the development of proper human-computer interfaces for older adults by themselves, our primary motivations are:

- Creating an interface that can educate a user about computer use in general, and
- Overcoming the various challenges older adults encounter when trying to use computers via development of a better interface for the older adult.

A proper interface will focus on three things: developing with a wide variety of users in mind and making the process of modifying the interface easy (if not automatic), and taking great pains to explain the interface for those users who may not find it easy to use. This said, our question becomes this: how do we create an interface that is both intuitive and educational for older users wishing to learn new things about computers?

What type of interface best fits the needs and expectations of the older adult computer user?

CHAPTER 3 : RELATED WORK

Plenty of work exists in the literature that seeks to answer the question we posed at the end of Chapter 2. Because of the expected aversion to technology that older users often display, different strategies have been explored for quite some time regarding how to introduce the older user to technology in a positive and fun manner. However, the notion of developing *intelligent* interfaces is a more recent one. Likewise, the development of the 'Internet of Things' concept means that the full potential of interfaces that detect emotional data about the user via sensor input is only just being realized!

In this chapter, we're going to briefly cover a variety of existing work applicable to the design of intelligent, interactive and accessible human-computer interfaces for the older adult. This work includes the field of models for approaching development for the older user, elderly-accessible design, intelligent human-computer interface design, and affective computing. The research listed in this chapter is not meant to be an exhaustive record, but rather a relevant sampling considered during the development of this thesis.

3.1 Developing for Elderly Anticipations

Before one begins the act of development, they should ensure what they seek to develop is aligned with what an older user looks for from technology. Older users have particular needs that software tailored to them should try to identify and fulfil. While these needs do include the much-touted physical ability needs (such as deteriorating vision and the like), they also include needs such as that to maintain independence while staying safe. [21] If a developer seeks to understand the mindset of an older user, they

can anticipate problems and work the solutions in accordingly, in the beginning of a particular application – versus shoehorning them in at the end.

A variety of methods have been suggested for better envisioning the older user's requirements – for example, the University of Applied Sciences JOANNEUM in Graz developed a suit that allows one to understand how an older or disabled user feels performing particular tasks. [22] Others advocate the use of tea parties in eliciting requirements; the informal atmosphere allows those older users testing the software to truly speak their minds regarding how the software performs for them. [23] Yet another approach involved utilizing personas so developers could have a person in mind when creating software – which may lead to different decisions being made in the development process. [3]

However, a big element in developing for older users' anticipations is participatory design or co-development – that is, outright inviting older users to assist with the design of given projects. Users prized simplicity, flexibility, and familiarity in their applications, along with a degree of recognizability – that is, easy visibility. [24] Co-development ended up being incredibly helpful for developers: during at study involving listening to the stories of older users before taking on a development task at the University of Kent, five out of six teams given access to older users' stories while designing an app for older people referred to those stories. [25] Some teams went out of their way to gather additional requirements via interviews as well. [25] Interacting with older users during a design process often brings issues that otherwise might not have been considered to the front of development, such as running an application via the Windows

OS or via an overlay that hides the complicated features of the Windows OS, or using a pen input system versus a keyboard. [14]

Work also has been done in developing various models to guide developers through the process of developing for the older user as well. For example, Peissner et al (2011) developed a design patterns approach to creating adaptive user interfaces for disabled users, not necessary older users, which involved the application of different patterns – generic, interaction, common and transition – to the application depending on feedback from the user. [26] These patterns were stored to a user profile on a per-user basis, and provided UI reorganization, particular interaction features, and more – all triggered for the particular situation of the user, which could be inferred by user difficulty or sensors around the computer in use. [26] However, this system started from a 'default' user setting, [26] eschewing a survey-based beginning that may give older users more of a footing in using the interface. Liu and Joines (2012) suggested the focus of generations versus age: taking into account what users know and their past experiences, versus focusing on their age-related changes. [27] Misunderstanding of user capabilities can lead to frustration and high human error rates. [27]

However, one study noticed that older users did have a bit of trouble envisioning intangible concepts that were being explained to them. [28] For this reason, when communicating with older users to obtain requirements, the use of prototypes when explaining application concepts to the older user is most likely a good idea.

3.2 Elderly Accessibility and Human-Computer Interfaces

After the requirements have been gathered, development can begin. Projects in which a team develops for the abilities of an older user can be broken down into two

categories: hardware development, and software development. Hardware development typically considers the creation of either robotic assistants for the older user, or new hardware devices that allow an older user (often with severe motor or other physical disabilities as a result of old age) to interact with software. Software development involves the rearrangement of graphical user interfaces for the older user's convenience, often based on input from the older user.

3.2.1 Designing Hardware for Elderly Human Factors

The field of assistive technology is full of hardware accessories tailored to make up for sensory deterioration. Oft such devices cross over with those developed for adults with disabilities, but the idea is still the same: computers can make up for a multitude of sensory impairments. Those who find their eyes failing can make use of screen readers, or a voice-based 'typewriter' that transcribes syllables in almost real-time. [29] For the latter, a head-mounted display can make the device more accessible for the older user with hearing impairments. [29] Such hardware devices are created with a particular goal in mind, and work to achieve that goal well.

Additional effort is put into the development of *alternate* interfaces; those that an user who wishes to use the internet or a computer could use to more comfortably interact with previously-existing applications. Alternative input interfaces, such as pen and tablet interfaces, have shown promise in being accepted by older users. [14] Research into using multiple input methods simultaneously, such as gesture and foot input, may be useful for the older user with difficulty making small, precise movements. [30] Finally, much research is being done in developing appropriate touchscreens for the older user. Touchscreens in particular have shown promise in helping older users adjust to using

computers, significantly dissolving their anxiety over the task. [31] This information has led to a variety of unique touchscreen devices, from touchscreen-based 'life-logging' devices for the sake of generating additional memories for a user [32] to haptic touchscreens, which provide much-desired feedback in the form of vibration to a user when interacted with (thus allowing those with visual disabilities to touch and confirm the selection of particular buttons onscreen). [2]

Finally, one study in particular investigated the use of common household objects in allowing an older user to interact with a social network for the purpose of interacting with family members. [33] The aforementioned social network utilized ubiquitous computing, i.e. 'smart' bowls and notebooks and the like, to update status messages and indicate likes/dislikes on a family-oriented social network. [33] This system went over well with volunteers, and resulted in high levels of user confidence and improved social interactions with family members. [33] The creative integration of things that already exist in an older users' home with technology may greatly improve the relationship of older users and tech in the future.

3.2.2 Designing Software for the Abilities of the Elderly.

The purchase of additional hardware can be expensive for older users and their families, so attention has been given to the notion of developing properly-accessible software for the older user – programs that would run on devices the older user already has. Creating software that older users find intuitive, easy to use and useful has become a high priority. Note that we are concentrating on the creation of software that is *intended to be used by the* older *user.*

A variety of all-encompassing overlays for elderly-tailored computers exist, most of which run customized software and/or operating systems for the benefit of simplicity. Eldy, for example, offers a simplified, six-button user interface for helping older adults use Skype and get online quickly. [34] The Telikin computer is similarly marketed as an all-in-one machine friendly to older adult computer users. [34]

Figure 2: Home Screen for Eldy. [59]

Another trend in designing software for older users involves development of interfaces that allow older users to better use the internet. Research has divided the various bits of the internet for individual study. Some work has been done in singling out the best method of creating an email client – choosing to eliminate jargon and opting for a simplified interface. [35] Use of voice augmentation to reduce cognitive load on the

older user when navigating through a website has also been considered, with the idea of a combination highlight/voiceover system gathering particular promise. [36]

The adaptation of mobile devices is an important topic of research. Due to their inherent mobility, smartphones allow for new methods of assisting users without confining them to a single spot. However, a variety of problems exist with mobile applications and operating systems: required plugins, scrolling difficulties, and more. [37] Jargon also pops up as being a problem in mobile apps, often coupled with font size and the like. Solutions offered launch content in mobile apps with large, easy to read buttons and simplified interfaces [37] that users can configure unique to their mobile phones and tablets. Google in particular offers certain accessibility features that are inherent in all Android devices, but must be toggled on to be active – such features include multimodal augmentation, such as TalkBack (which offers voice confirmation of text instructions). [37]

Multimodal interfaces, with the goal of reducing cognitive load, have also been developed with the goal of simplifying the computing process for the older user. [1] In addition to text, pictograms, voices, auditory icons, and tactile input can assist in alerting a user of particular things from within software. [38] This can assist in relieving cognitive load, but care should be taken – Warnock, et. al (2011) found that an increasing error rate in performing a primary task whilst encountering multimodal alerts may not be related to stopping and starting a task in relation to an alert, but an increased mental demand caused by multitasking. [39] Too many simultaneous multimodal notifications may be detrimental for an older adult user.

3.2.3 Intelligent User Interfaces for the Elderly

Adaptable and intelligent user interfaces, with their ability to work for a range of possible users, show some of the most promise in developing software for older users. These systems often boast intelligence based on user-configured variables, such as how much difficulty a user has moving their hands. Such data is often taken from a survey, instead of being generated as a user works with a given application.

Like our hardware mentions, many of these interfaces are developed for disabled users in general: however, they can be adapted for the older adult users' particular abilities. In one attempt, Dickinson et al. (2007) created a customized search and navigation system allowed for three levels of content depending on user ability: a very simplified interface, an interface that included material that had not been simplified, and a third layer of material that was unconstrained by accessibility concerns. [40, p. 200] Magee and Betke (2010) developed HAIL; a hierarchical web browser that works with a system to translate head motions into mouse movements. HAIL also provides the user with a number of levels; each corresponding to increasing complexity of the UI (increasing button size to screen width comparisons). [8] Supple, a popular project from Harvard, creates a model of the users' preferences as a result of preference statements composed by the user, and rearranges its interface accordingly – the sequel project, Supple++, allows for the modeling to occur on the fly after the user works through a series of performance tasks. [9] A similar system proposed by Leiva (2012) gently adjusts a user interface within a website based on users' actions taken navigating the website – for example, if a user makes several poor selections in trying to make a particular selection, padding is added to elements. [41]

Some of these intelligent systems, rather than remaining adaptive, are also reactive. Sycophant, an intelligent calendaring application, can successfully predict a user-preferred alarm type in reaction to data collected from a microphone and webcam. [42] For this reason, mobile phones also show a lot of promise for developing intelligent user interface systems, due to the number of sensors and the amount of data that can be pulled into context recognition algorithms. [43]

Application	**Web/Desktop**	**Abilities Affected**	**Method of Adaptation**
HAIL [8]	Desktop, with web applications.	Visual abilities and Motor Skills	Resizing buttons/increasing complexity of UI in response to user abilities (making buttons easier to navigate to and click on)
SUPPLE/SUPPLE++ [9]	Desktop	Motor skills	Synthesizing preference statements and performance tasks to create new interfaces that are more easily navigated by the user.
Evolvable Interface [5]	Desktop, with web applications	Cognition	Monitoring of user actions and utilization of a neural network and case/rule based reasoning systems to determine what assistance should be given to a user (tips for application function).
User Sensitive Inclusive Design [40]	Web Portal	Cognition and Visual Abilities	Hierarchical arrangement of information to train the user how to interact with the web and avoid overwhelming the user with information.
Interaction-Based User Redesign [41]	Web	Visual Abilities and Motor Skills	Reorganization and spacing of user elements based on user interactions – if a user seems to have difficulty selecting an element, element may be resized (addl. spacing)

Table 1: Comparison of Adaptive Interfaces

However, concerns still hover with the notion of adaptable user interfaces, including but not limited to concerns regarding informed consent when involving elderly users in research studies [44], standardizing the information retrieved and the security

and privacy issues inherent in taking user data for profiling. [45] Adaptive interfaces have also been shown to reduce learnability. [46]

3.3 Affective Computing and Intelligent Human-Computer Interfaces

Finally, the realm of affective computing offers great potential for applications that make intelligent decisions about how to draw their interfaces. Improved methods of detecting emotion via affective markers can greatly assist intelligent systems in making proper decisions for an older user.

3.3.1 Affective Marker Detection Systems

Affective systems analyze various elements of the human demeanor for hints regarding the emotion felt at a given time. A variety of these affective markers can be assessed with current technology. Pupils, for example, can indicate increased cognitive workload. The notion of creating machine learning algorithms that decrease complexity in relation to dilated pupils is entirely feasible. [47] Facial expression detection via principal component analysis and independent component analysis is another staple of affective computing, allowing a user to classify facial expression of a user into various emotions. [10] Extraction of acoustic-prosodic features from the speech of the older user also could provide input in regards to their mood in relation to the task at hand – recognizing negative and positive moods alike. [48] Particular patterns in keystrokes may be able to indicate boredom in users [49], while handwriting can provide inside regarding frustration for users using pen and tablet interfaces. [50] Kapoor et al. developed a system involving the use of a pressure sensitive mouse, a pupil-tracking camera, skin conductance sensor and a pressure sensitive chair that also could predict

user frustration with 79% accuracy ratings. [51] Posture [52] in addition to gaze direction [53] can also indicate current attention status on part of a user.

3.3.2 Intelligent Systems Using Affective Data

Once data has been gathered, it can be used in intelligent systems to sway various portions of the system. For example, Sarrafzadeh et al. (2008) expressed that affective data has been shown to be great when coupled with intelligent tutoring systems - systems that seek to educate in a similar manner to adult teachers – by picking up on nonverbal cues from students that can be detected via sensors. [54] This setup allows interactions to be customized for the particular student, based on the learning methods that cause the most positive reactions. [54] The computer can then create a model of the best strategies to use with the learner, based on the nonverbal feedback and answers to questions given during the tutoring session. [54] Intelligent assistants specifically for web pages have also been developed, with the intent of using a neural network taking user input to adjust magnification and keyboard settings for a web browser accordingly. [5] This project was one of few that offered assistance that adjusted users' settings automatically based on actions taken by the user in-program. While this assistance did not explain to a user what they needed to do in order to make the changes, it did provide a stress-free solution for editing a user interface to be more in line with a user's abilities.

Thus, it's easy to see that variety of different solutions currently exist in the literature and in practice – however, none synthesize the worlds of developing for the ability of the user, developing for the anticipations of the user, and educating the user. The ideal system needs to put an emphasis on adjusting for the user's difficulties and teaching the user the benefits of using technology.

CHAPTER 4 : FEATURES OF ACCESSIBLE DESIGN FOR OLDER ADULTS

Here we reiterate our overarching question: **what type of interface best fits the needs and expectations of the older adult computer user?** We can begin to answer this question via reviewing what the pre-existing solutions have in common as focuses – and thus, what we should too focus on and expand in the development of human-computer interfaces for older adult users. Pre-existing solutions highlight tweaks that should be made in the requirements-gathering process, process of development for a users' abilities, and process of development for a users' skill level. These features all make themselves known as being necessary for the development of interfaces for the older computer user.

4.1 Pre-Development Suggestions

Before we begin investigating how one should build an application, know that **proper requirements gathering is a must.** You should communicate with your target market – including a wide variety of the older users populating it - before you begin development. In addition, visualization tactics might be a beneficial to understand what elderly users may need from your applications. Listening to elderly users regarding pastimes and the like can also give ideas for interfaces that may better mesh with their generational knowledge [25], [27] allowing them to understand and use said interfaces with improved skill. Involving yourself in conversations with the elderly user can also help you pick up on their habits – learning that an elderly user relies on notes while using

a program [11] may inspire you to create a note saving feature in-app, to improve the ease of use of the application.

Furthermore, even after development has begun, *continued communication with your target market is a very good idea*. This said, something to consider would be the application of an appropriate software design methodology, such as agile development. The agile development methodology has many core principles that line up with these requirements of proper older adult human-computer interface design. As an example, one of the core principles of agile development is communication with one's target audience: both the acts of development of human-computer interfaces and development with agile methodologies in mind will expect such actions to be taken.

Goal	**Role in Agile Development**	**Role in Developing HCI for Older Users**
Adaptability	One should be adaptive to new and changing requirements as a rule; changing requirements are welcomed. [55]	Developers need to be open to adapting their design to allow for improved accessibility for different users.
Simplicity	Maximizing the amount of work that doesn't need doing is important for keeping development timely and efficient. [55]	Overcomplicating applications can confuse the elderly user, and thus simplicity in GUI design and feature layout.
Customer Feedback	It is often suggested that collaboration should occur face-to-face [55], which will assist in reducing miscommunications so regularly seen otherwise.	Constant customer feedback is **highly recommended**, with some even recommending to try co-design with elderly users.

Table 2: Comparison of Goals in Agile Methodology and HCI Development for Older Users

The adaptability of the agile work environment also makes it a perfect fit for developing for the elderly user! Developers taking part in agile development

methodologies seek to communicate with the target audience to best determine requirements – something that is required in elderly interface development. Furthermore, as new requirements come up as a result of user testing (i.e. a color scheme not having enough contrast) an agile development team will find themselves better able to adapt to such things. Adapting to include new physical interfaces for an application – such as pen tablets, haptic touchscreens or gesture-based input – would also be favorable. Newly developed input, although unfamiliar, may offer a better experience for the older user than an existing one.

4.2 Ability-Based Design

Ability-based requirements, such as improved screen contrast due to decreased vision skills, are also common requirements considered when developing applications for the older user. Most "elderly-friendly" applications take such considerations into account by default. While the idea of developing solely for the impairments that may come with old age has come under fire recently [7], considering the different abilities the older user may have could still prevent unnecessary frustration and the like on part of a user.

4.2.1 Visual Elements

Older people often experience a decline in various aspects of their vision, including visual acuity, presbyopia, peripheral vision, dark adaptation [3] and declined recognition of color contrast. [1] Because of this visual degradation, poorly-sized and colored components of a program, such as the buttons, can lead to frustration on part of the user. Properly-designed displays for the older user would have easily adjustable components, with color only used as needed and overly-flashy designs omitted, because

of their distracting qualities. Consistent brightness would be necessary, and pop-ups might be allocated to a particular part of the screen, so they do not overwhelm. In general, simplicity is key when designing visual displays for the older user - while visual displays for teenagers might need flash and bounce to attract their attention, too much color and action in a display will confuse and frustrate an older user. Simplicity can, likewise, be achieved without cutting content for the older user. Reducing an application to something that is over-simplified can result in an older user not wishing to use it. [11]

4.2.2 Auditory Elements

Older folk also commonly experience hearing loss - by 65, 50% of men and 30% of women experience hearing loss so severe it "inhibits their social interaction." [3] Furthermore, even if hearing is not degraded, the pitches that the human ear can hear shift in older age - higher tones, such as those above 2500Hz, are less able to be heard [1]. This said, it's important to make sure that alert tones are not only louder for older users, but the *correct* pitches. Something else to keep in mind is that older users tend to downplay or even deny any hearing loss they might have, in order to avoid stereotypes [3] – so if an interface can make it less work to find the volume controls, so that users in turn don't have to spend too much time thinking about their hearing loss, it may benefit the application overall.

4.2.3 Dexterity and Mobility

In a survey taken of older computer users for a study in coaching older users to properly use a computer, issues with dexterity and computing were most often reported, only tied with fear of making a mistake [6]. Older users often have a more difficult time

finding little targets and make less accurate movements [1]. Arthritis and swollen fingers will inhibit a user's ability to interact with a computer using a keyboard and a mouse [3]. This said, an interface that adapts to a users' dexterity can be quite helpful – such as the previously-mentioned SUPPLE project at Harvard University [9]. If erratic mouse movement is detected, or repeated tries to select a particular element, an interface might want to adjust itself to better match the movements the user can make. In this way, the user will experience less pain and frustration when using the computer, and will more eagerly use the interface, rather than avoiding it for fear of making mistakes.

4.2.4 Cognitive Elements

Finally, while each of these considerations are useful on their own, care should be taken in how they are used – in order to ensure that the device does not inadvertently cause a cognitive overload in its quest to assist a user. If a device uses a very large amount of text or audio in trying to communicate with a user, it might cause the user to become distressed in trying to parse all the data thrown at them. Noise and detail can easily distract older users [1], who have been shown to do worse at multitasking than younger people [3]. There is also the problem of Age Associated Memory Impairment, which causes "a detrimental effect on exploratory learning" – the ability to create mental models of a given task is significantly reduced, and the common problem of older users having more significant problems remembering particular steps in navigation-based tasks. [5] This can often hurt their confidence in using computers, resulting in a fear of making a mistake inhibiting their ability to use a computer. Having these negative emotions associated with using computers can result in not realizing the benefits computers offer the user, and thus increased reluctance to use them. [7]

In order to relieve cognitive efforts, layering different modes of communication should be utilized when necessary [1], especially in order to relieve mental exhaustion that might occur otherwise. Voice augmentation, as mentioned previously, can be particular helpful in doing this. [36] Tutorials are oft-looked for and can greatly help in introducing new programs to older users, and should be designed with the simple visual interfaces that were discussed earlier, and shown more than once. Attention-getting components should be used sparsely, unlike in interfaces designed for younger users, who can deal with many alerts going off at once for various aspects of the computer.

4.3 Design for User Expectations

Finally, there is the issue of developing for the skill and knowledge of an older adult computer user. We have seen examples of this in Chapter Three, where a particular approach in developing for older adult users prioritized development based on generational knowledge. [27] This meant a development of an interface based on knowledge users had, such as colors and tools, rather than the deteriorating abilities many other elderly-specific applications focus on. In a sense, this sort of development *is* sorely needed –it is important to take into account the users' preexisting knowledge. Differences in preexisting knowledge levels can affect which motions older users finds intuitive, what symbols to use in-app as augmentations for user understanding, and even which colors to user in regards to application design.

In particular, preexisting knowledge has been known to affect the understanding of jargon that the user has. The use of jargon within applications has again and again been documented as a problem – older users, more often than not, do not know proper definitions for words such as "icon" and "desktop." [6] Understanding the older users'

language options allows one to fully understand what language within an application is problematic, and what can easily be understood by the user. Likewise, it also allows proper metaphors and language options to be chosen when explaining something to a user – different generations may have different mental models of particular processes, and the best possible method of explanation should be selected to expedite understanding.

Developers should also take the attitudes of the older user in mind. There is a consensus that technology that seeks to be 'mandatory' typically is eschewed [28], as is technology that over-simplifies for the older user. [11] [15] Older users don't like to be reminded of their age. [15] Applications that improve users' confidence and seek to inform and motivate rather than over-simplify and hide functionality have a better chance of being accepted.

On this note, as all technology must be understood to be used, the use of tutorials is a must. Older users learn via manuals and explanations, rather than experimentation and trial-and-error – when compared with younger users attempting to learn how to use a mobile device, older users put more importance on following step-by-step instructions and having device workings explained to them. [56], [57] Older adults also prefer to learn alone, and in a self-paced fashion. [57] Building confidence via tutorials and guides to application use can be helpful in the overall retention of an application. [57] Older users abhor the thought of "breaking" a computer, and thus are very careful in their interactions [1] – the integration of tutorials can assist in assuaging some of their anxiety towards computer use. However, one should be careful to integrate steps on how to get to different parts of the application from all portions of the application – otherwise, a wrong step may lead an older user into a dead end inside the app, resulting in frustration. [56]

CHAPTER 5 : COMMUNICATIVE DESIGN APPROACH FOR INTELLIGENT HUMAN-COMPUTER INTERFACES

Now that we've discussed the different requirements we should consider when creating intelligent interfaces for the elderly user, we can discuss the design approach for our intelligent interface system. Note that, in order to maintain flexibility with upcoming computers and interfaces that may be used with individual applications, we're focusing on the development of software interfaces. Each of these design guidelines helps craft a system that ensures a good balance between diverse design, user respect and developer assistance.

We've previously mentioned that the key to connecting intelligent and educational in human-computer interfaces is proper communication: between the user and the application, and vice versa. What with the previously-mentioned developer requirements, we also can see that a particular level of communication between the developer and the user is important. That said, the best solution for an intelligent and educational human-computer interface design is a *communicative design approach* – that is, a design approach that prioritizes this communication. In this design, three levels of communication are prioritized: that between the developer and the user, that between the user and the application (the use of affective markers in creating proper interfaces), and finally, that between the application and the user (the use of tutorials in explaining the program in question).

5.1 Communication between the Developer and User

In the development stages, proper communication is going to be the most important task. Talk to older adult users who will benefit from your application, and explain to them what your application does in natural, non-technical language (say, "My application tells you what buses are coming closest to your location, and what time they're arriving at their stops."). Then, ask these users what they would like to see from such an application. More often than not, via a discussion with users, you'll reach an agreement regarding a feature that you would have otherwise not considered – even if it's as simple as a method of taking notes in-app.

However, note that you should not only listen to users regarding their expectations of the app, but try to understand other specifics about your older adult user population, such as their habits and lifestyle. This point in development should be a conversation. If the application is meant to work in a particular community that is tight-knit, communication features might be added in in order to strengthen social ties within that older adult community. This sort of knowledge can help you craft different features for your application specific to your user base.

As mentioned, the use of a software development methodology may be appropriate for your application, and the agile development methodology in particular is suggested due to its emphasis on communication and adaptability. Many of the concentrations of the agile development methodology, such as simplicity and conversations with customers, line up perfectly with what one should be doing in developing human-computer interfaces for elderly users.

5.2 Communication between the User and Application

The interface of the application depends on what the user tells it. It adapts to the needs of the user – and because of this, it's our next level of communication. Because of the aforementioned variance in the abilities of older adult users, the interface is not one particular design, but rather depends on the more promising lens of focusing on user ability, and adapting to this. [7], [22], [58] It is split into a series of tiers – lower level tiers indicate ease of use for users with more advanced impairments, higher level tiers bring the application's interface back to looking more like current applications on the market. Equal work must be done in developing the tiers of the interface (i.e. the different levels of customization), and creating the triggers to be used in switching between the tiers.

5.2.1 Developing the Tiered Interface

Tiers should be labeled via a number, each representing a different ability level for a particular ability: motor, vision, auditory, and cognitive. Each tier should also be adjustable depending on a users' preference and the outcome of the affective markers gathered. If a user displays traits that indicate their vision is perfect, but their hearing is poor, the auditory tier may be set at a 1 (greatly increasing the volume of auditory alerts, and perhaps opting for alternative modalities rather than auditory displays) and their vision tier at a 4 (average text size, can handle increased amounts of color in-application). Note that in this example, the tiers *do scale independently*: this is essential in creating a customized application experience. This solution is developed to work best for the elderly population, whose impairments are not limited to a set list.

Note that in developing the tiers, your goal is to develop *for the ability levels* of those users. Concentrating on the abilities of your users, versus whatever impairments and disabilities they may have, and focusing on making your application work relative *to* those abilities will result in a much more human-centric design – and the burden of iterative change will rest on the interface, not the user. [58] This allows the user to have a more customized and comfortable computing experience, which is essential to promote – especially for older adult users who may not trust or like computers due to past experiences. Do not eliminate features in favor of simplicity, but rather hide features in less complex levels, and work to uncover these features in more complex levels.

The particulars of each ability division are as follows:

- The **visual** division controls the visuals of the interface – color, contrast, design complexity, brightness and text size. A user with poor visual abilities will benefit from a simpler design (reduce background patterns to colors or grey tones, increase text size, increase contrast). Younger users, or those with better vision, can handle background patterns, bright colors and smaller text sizes.
- The **auditory** division controls the audio displays within the application, as well as the voice augmentation feature. As mentioned previously, voice augmentation allows a user to break up cognitive loads over text and audio, so such features are often quite necessary. However, a user with poor hearing may not benefit from voice augmentation or audio alerts/earcons, so processing power should not be spent on these features.

- The **cognitive** division controls the way the screen is arranged. While the vision division has to do with the features of the graphic interface, the arrangement – i.e. how many sections of the screen there are, where text alerts are displayed, how many text alerts should be able to stack, etc – depends on a users' cognitive abilities. Deteriorated cognitive abilities will benefit from a simplistic interface with few options on the screen at once/few flashing/eye-catching text alerts.

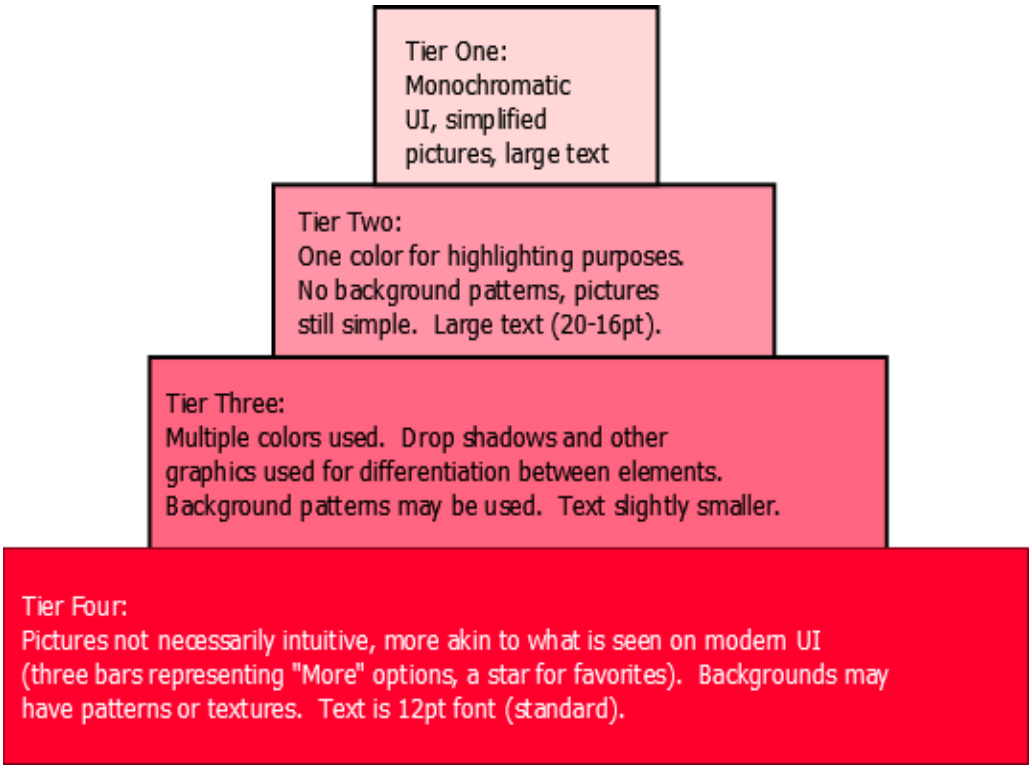

Figure 3: Tiering structure for font size/interface colors

- The **motor skills** division deals with how a user gives input to the system. Users with hand tremors or arthritis may need to have increased or decreased mouse sensitivity. Rather than the scale go from 0 to 5 representing good to

bad, it may be beneficial here to range the scale from 0 to 5 with a 3 being average hand speed, 5 being increased shakiness and 0 being increased pain in hand (slowness) or other disability. Note that in this example, the motor skills division concerns the use of a mouse and keyboard: other interfaces should also be able to be considered and used.

Finally, while this does not necessarily need to be added to the tier system, some thought should be given to handling an introduction to the application for an advanced user versus a beginner user. The advanced user would be able to handle increased amounts of jargon as a result of prior computer training; the beginner user most likely will not be able to handle such things.

5.2.2 Affective Markers and User Profiles

Now, we come to the methods of gathering data to trigger switches between the different levels of the interface. While a variety of different methods of gathering affective marker data exist, we're going to focus on a few easily-obtainable affective markers (i.e. those that do not require advanced equipment such as pressure-sensitive chairs). Note that affective markers are not the only data you want to be collecting: in order to achieve the best results, you want to **gather both user data and affective data**. Rather than relying on a pattern-based approach, [26] the gathering of user data (such as manual changes to the interface) can assist in ensuring that a user *customizes* their interface environment, to their needs, as necessary. Furthermore, user-related data has been used in a great number of intelligent interfaces up until this point [5] and is a good method of error-checking – if in the future an affective marker accidentally causes a problematic change, the user can correct such inputs manually.

A multimodal [10] strategy to obtain data should be employed for the best results. The following data should be considered when creating intelligent interfaces for elderly users. Example triggers that the data controls are also given.

Facial recognition data. In addition to possibly recognizing emotional states, facial recognition technology would be useful in picking up on vision problems a user does not want to admit to. One example trigger would be that if a user furrows their brow and frowns, the application, passively watching the users' face for confusion, may prompt them to ensure they understand what they are doing. Another example trigger would be in the event a user squinted excessively when reading text: the program may make a slight (1-2 pt) adjustment in the font size; if that reduces squinting, the program can make appropriate changes to the vision tier of the program.

Affective Data Collected	**Interface of Collection**	**Common Interface?**	**Resulting Effect on Application**
Gestures	Camera	Yes	Confusion, information regarding whether user is relaxed or tense
Posture	Camera	Yes	Attentiveness detection, information regarding whether user is relaxed or tense
Pupilary Reactions	Camera	Yes	Cognitive Overload
Facial Expression	Camera	Yes	Confusion, frustration, attentiveness detection, information regarding whether user is relaxed or tense
Movement	Camera/Accelerometer	Cameras for movement detection common on desktops, accelerometers common on smartphones	Attentiveness detection, information regarding whether user is relaxed or tense
Input Patterns	Keyboard/Mouse	Yes	Confusion/Frustration
Utterances	Microphone	Yes	Confusion/Frustration

Table 3: Affective Markers and Information Inferred

Pupil recognition data. Dilated pupils, as previously mentioned, relate to cognitive load. [47] This said, if a user's pupils became dilated while using a program, changes to the cognitive tier of the program may be initiated.

Posture data. Posture can hint at user engagement, among other affective states. [52] If a users' posture suggested that they were disengaging from a task they should be engaged in, the program may use an alert (perhaps a multimodal alert) to re-direct their attention to something in particular. Posture can also indicate how open a user is to what they are doing. [52]

Gaze data. Gaze also can determine attention. If a program determined that a users' gaze was not fixed on the application's screens, it might use a multimodal alert the next time it needed to get a users' attention rather than relying on a single mode of alert.

Utterance data. Utterances can indicate positive and negative response to a program. If a program increased the font size due to another affective trigger, and the user gave an utterance correlated with positive feedback, the application might save such reinforcement to the users' profile. Keep in mind that any utterance data taken would need to be done in a quiet environment – in order to ensure proper data, the application should be able to determine if the user environment is noisy, and toggle on/off the utterance data collection appropriately.

This data, along with having proven connections to different affective states, is easily obtainable via the camera and microphone of most computers. Note that if you're developing for a smart phone, some of this data (posture, specifically) would not be available to you, but other data may be available to suffice instead (instead of posture

data, accelerometer data may be used) – triggers may need to be calculated in a different fashion using different sources of data.

After such data is collected, we can continue to creating, using, and storing a user profile – a common idea in affective computing. [10] A user profile should consist of the different tiers relating to a user's application, along with time stamped events of the various affective markers. The design patterns approach mentioned previously in particular used the notion of a user profile, where information about the particular design patterns a user preferred was kept. [26] For example, for a newer user, profile data may indicate that they are a 4132 – a 4 in terms of vision, a 1 in terms of hearing, a 3 in terms of cognitive abilities, and a 2 in terms of motor skills. In layman's terms, their vision is decent, they're quite hard of hearing, they're relatively sharp but a bit overwhelmed by complex interfaces, and their hands encounter a bit of pain now and again that prevents them from making overly-dexterous movements with the mouse. This users' profile may indicate that since using the program, they've grimaced while trying to move a mouse from the left side of the screen across to the right side of the screen 3 times in a week, and due to this their motor skills may be decreased to a 1 (implying decreased motor ability).

A neural network placing higher weights on assessing manual user data, such as manual settings and user input, and medium priority on assessing affective markers, can be used in the update and development of a strong user profile. Trends are sought in order to adjust weights for various input: if a disrupted gaze and odd posture is coupled with the user opening the tutorial, such affective markers may be interpreted to be associated with frustration – which can affect the application elsewhere (i.e if a user

begins to read a tutorial and displays elements of frustration, a pop-up may confirm whether or not the user understands what is being read).

Now, in order to *begin* this instance of a user profile, a survey should be used. Such an idea is prominently used in SUPPLE, where users are queried regarding their preferences for the interface generated. [9] Such a questionnaire may run once when the application is first run (asking questions to develop a preliminary profile), and then frequently (once or twice a month) to maintain that current settings are 'okay' for a user. This allows a user to change settings without seeking out the settings menu in particular. The results of these user surveys will be combined with affective data and manual settings to provide a full picture of user preferences.

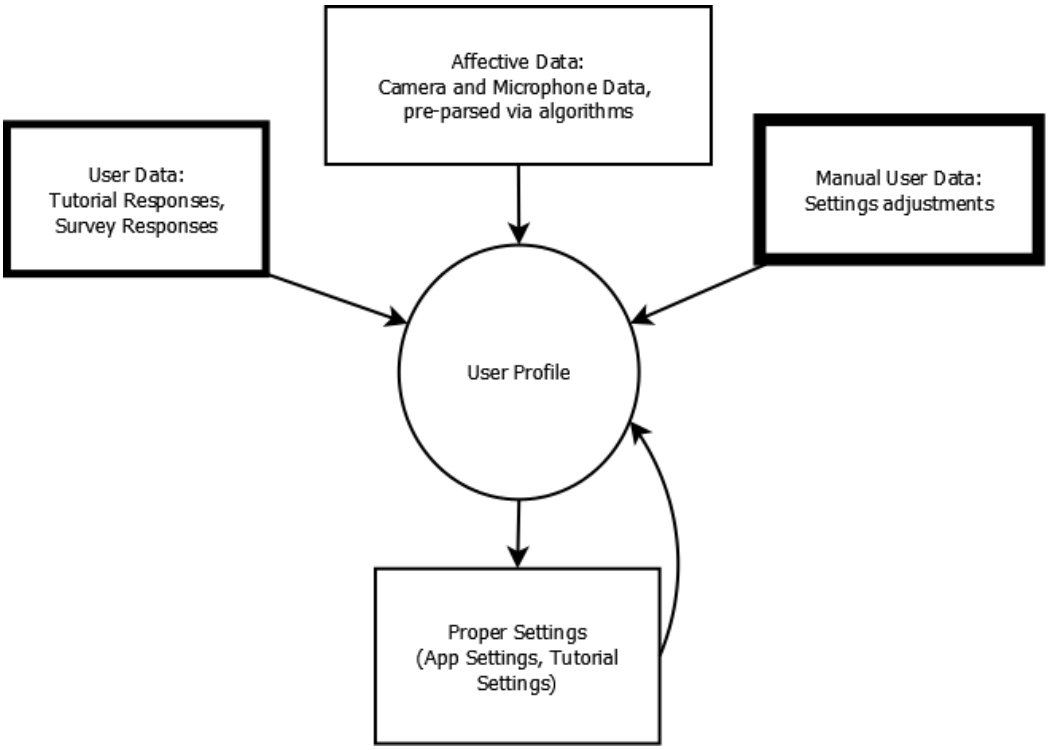

Figure 4: Example of user profile generation workflow.

While the user profile might be stored on the users' computer, the option of storing the profile in the cloud is preferred. If stored in the cloud, the user would be able to apply the profile to all computers that ran a version of the application, or in the case of an application with a mobile counterpart, apply the relevant settings to the mobile counterpart of the application. This would greatly improve the ease of use of the application – a user would not need to worry about re-working the settings in the mobile app to match any accessibility features in the desktop app. In addition, if data regarding a user was stored in the cloud, advanced trend detection via distributed computing (versus taking processing cycles on the users' computer) could be completed – allowing for improved detection of possible affective trends (and solutions via the tiered interface).

In order to retain user security and privacy, one should *not* store the recordings that resulted in the affective marker decisions, but only the decisions. User trust would be vastly impeded if the elderly user was aware that recordings of them were being taken and saved during the duration of program user.

5.2.3 Natural Language and Menus

Now, here we may run into a problem in terms of improper classification: if a user displays frustration while reading a particular part of a page, and the text is adjusted in anticipation of the user experiencing vision problems, it may be incorrect. If in fact the user was frustrated with something unrelated to the program they can simply manually set the text size via the settings menu. While in other applications this may be quite a chore (and the settings menu near impossible to understand), the application should guide a user to various options of the application using natural language on screens instead of menus and other possibly-confusing interface additions.

Figure 5: Menus with Natural Language

All in all, at least for lower tiers in cognition and new users of a given application, menus within the app should be constructed and guided via links on the home page of the application worded in sentences using natural language. As a user becomes more proficient with the application, the user interface may arrange itself to become more like existing applications without older adult user interface guidelines in place – explaining to a user the changes as they happen. These links connect to create hierarchical series of screens controlled by questions and answers for older adult users who may not be used to the typical sight of computer menus. Instead of having to understand what “settings” refers to, a user will be asked, “Do you need help?” on the front page, and clicking this

button opens another series of questions relating to various aspects of the application they may need assistance with. That is to say, on the home screen of the application, one will be able to *easily* find the proper selection to decrease the size of particular text within the app – and manual toggling of features such as this will (as previously mentioned) have a much greater effect on the application's working than the automatic changes due to affective and questionnaire data.

5.3 Communication from Application to User

After the completion of all interface requirements, set time aside to implement a tutorial. Never assume that a user will simply know how to use the application – no matter how easy or intuitive you believe the application to be. The addition of tutorials has shown to be incredibly useful in helping an elderly user use applications, as elderly users typically learn via step-by-step instructions and understanding the workings of a program. [57] In addition, aforementioned problems with usability trade-offs in the face of adaptive design can be undone with the help of integrating support options. [46] But also make sure that these receive the round of user testing and feedback as the other requirements have: tutorials should not be confusing, and any confusion that a tutorial might cause should be eliminated by clarification or simplification as soon as possible.

In general, tutorials should follow a few basic guidelines: they should be picture-heavy, in order to show an older computer user exactly what should be done. They also may involve overlays that highlight or otherwise mark the parts of the screen that are being concentrated on – something that even existing adaptive technologies do to an extent, without invoking an outright tutorial. [9] But no matter what, affective data should

continue to be collected and used in the implementation of the tutorial system in-app; in fact, watching a users' face for confusion can be used as a tutorial trigger. The following are additional design considerations for the use of smart tutorials.

5.3.1 Language Used in-Tutorial

One of the common problems encountered by elderly users is the lack of knowledge of the computer vocabulary. While many elderly users know terms such as "modem" and "monitor", there can be a lot of confusion regarding what terms apply to what parts of the system. When coaching users, this often comes up as a point, with some coaches modifying their own vocabulary to properly communicate problems and solutions with the users. [3] When the notes of users in a study were checked to see what patterns in note-taking were exemplified by older users learning an application, definitions of jargon for the future reference of the user were one of the things found. [11] This said, especially in a system designed for prioritizing communication, great efforts should be taken to avoid overly technical working in favor of simple, understandable sentences. Use metaphor if necessary, to explain functions and the reasons for doing what needs to be done as part of the tutorials. Instead of asking a user to go to their desktop, explicit instructions to click on the small picture of a computer representing the desktop might be given, with an explanation of the desktop as the "main display" of the computer, where one can access all other programs and settings. In doing this, the user learns a bit about their machine, as well as where they might go in the future if they needed to change a setting.

This simplified language should come in two different methods: one would be text included in the overlay, and the other, voice augmentation. As even the presence of a voice augmentation for assistance and to reduce cognitive load on the user encounters problems when a user does not understand jargon relating to onscreen elements, the voice augmentation absolutely must follow the simplified language rule. [14]

5.3.2 Hierarchical Tutorial System

As mentioned previously, in applications designed for older adult users, a hierarchy of screens should be apparent: one 'home' or 'desktop' screen leads to a series of other screens, each of which may have options of their own. Thus, in favor of keeping things simplified, users will only receive automatic tutorial options relating to the screen they are currently on. Manual search will allow a user to look up particular actions, but for most users, this method of distributing options will suffice. In addition to keeping actions simplified, it will show the user what the application is capable of from each point within the app.

The tutorial interface should be included as an always-available option – for example, as an overlay. If a user decides they want to view a hierarchical tutorial, they can select a tutorial from the overlay. The overlay on top of the screen will highlight the proper button or mime the proper action to take, and offer a brief text explanation of why said action is appropriate for what the user wants to do. Voice, as previously mentioned, can be toggled to accompany this. If the user does the action and is taken to the next screen, the same hierarchical options show for the next screen. Some special actions that may take a user through several screens will also be included, and will continue to guide

a user until the action (say, taking a photo *and* uploading it to a social network) is complete.

On another level, tutorials should utilize a hierarchy in how they display information to the user. More intense tutorials – i.e. those with advanced explanations used to further the users' understanding of the application overall - may be restricted to users with more experience using the application. Proper management of this tutorial hierarchy allows a user to learn how to best use an application over time, and educate themselves on proper computer use.

5.3.3 Adaptation Based On Affective State

Although a user could go through the tutorials based on the hierarchical system, the suggestion for most users will be to keep the application minimized in 'listening mode', and allow for the dynamic tutorials to display based on motions taken in application, and the affective state of the user. Dynamic tutorials have been previously discussed that take information based on a users' motions in-application, [5] but the introduction of the affect markers can also *ensure* that users are understand the tutorials being explained to them. 'Listening mode' will begin to read data from the microphone, camera, and input devices (keyboard, mouse, tablet, etc.). This data will be mapped against data coming from other input ports to detect frustration or other negative emotions that may imply a user is unable to properly use the computer. If several trends indicate a user is encountering frustration, the screen will ask the user if they need help with the application in questions.

Furthermore, time, program and screen trends will also be saved. In the event that trends relating a user to having negative emotions in relation with a particular screen in

an app come about, the next time the user attempts to use that app, the tutorial display may pop up automatically. Depending on how much trouble a user has with a particular app, the text of the tutorial may adjust itself to being more in-depth as well, seeking to further educate the user in how to use the app rather than giving just a quick overview. Positive reactions from the user in relation to tutorials will also be taken into consideration, and ultimately a profile of the user will be built depending on how they respond to interactions from the application.

Finally, because of the nature of this project, a great deal of user testing would need to be involved in the process of development – other solution-seekers quickly found that they overestimated the amount of knowledge they could expect from elderly users [35], and striking a perfect balance between the knowledge to expect from the user and the lack of knowledge to make up for would be crucial in this project. Testing of the user interface of the operating system, as well as the applications that were modified to work with the operating system, would be crucial.

CHAPTER 6 : EVALUATION

While this design approach is certainly understandable, it helps to see in action to understand how these features might assist older adults in using their computer and mobile devices. In order to properly illustrate their use, we can give a particular case study –using the design guidelines in a desktop computer chat program, and an accompanying mobile application. In doing this, we can show how settings transfer between the two applications, and how the affective, intelligent interface conforms to the needs of the user at hand. We've also begun the implementation of these guidelines in two applications: a rehab engineering application for iOS, and a text messaging system for Native Americans who are quitting smoking.

6.1 ChitChat: A Case Study

To begin with, let's create an imaginary user: Cindy, who is 67 years old. Cindy has so-so vision, fantastic hearing, but her hands have a moderate tremor in them. Cindy does not enjoy using computers, because the interfaces are more often than not overwhelming for her – she is never sure which of the information presented to her is meant for her focus, and what is not.

Cindy has just switched from Skype to using ChitChat, an easy-to-use chat program her friends suggested she try out. ChitChat was developed using our design approach. ChitChat promises to adjust to Cindy's abilities, and offer a full tutorial in how to use the program effectively. Skype did not offer such features, and since ChitChat offers to explain to Cindy the nuances of the program, versus offering an "elderly-friendly" overly-simplified interface to Cindy, she feels more inclined towards

using ChitChat – it does not doubt her independence.

Now, it should be mentioned that during ChitChat's development phase, the developers made great efforts to talk to a variety of users about what they did and did not like about existing chat applications. Doing this allowed the developers to plan an interface that older users would appreciate and expect: because their sampling population was primarily users who had some experience with a keyboard and mouse, the application ended up being keyboard and mouse-based, just like Skype is. However, ChitChat guides a user through a variety of screens by asking questions, rather that depending on a settings menu like most modern software. ChitChat also obscures the desktop when running, as some users would grow confused as to what is a part of the running application, and what

ChitChat installs on her computer as any Microsoft Windows application might, and Cindy launches the application by clicking on the icon installed on her desktop. When ChitChat opens, it immediately takes up the full screen to avoid distractions from other applications. It then immediately launches into a very quick questionnaire. The questionnaire asks Cindy questions about how well she can see, how well she can hear, and her ability to use her mouse and keyboard. After Cindy answers the question regarding her eyes, the text for the remaining questions grows larger – she smiles as a result, and the software, unbeknownst to her, recognizes and logs the smile in relation to the larger text, logging it as positive feedback. The mouse decreases in sensitivity in relation to her feedback, but she frowns at how difficult the mouse seems to be to move. After a moment of trying to move the mouse, it becomes easier to move – her furrowed brow, pursed lips and erratic motions trying to get the mouse to respond were logged, and

the sensitivity of her mouse as a result was improved. The appearance of one affective marker increased the sensitivity of the system for detecting additional affective markers.

After the questionnaire finishes, a brief tutorial to the software – as it is the first time the software has been opened – begins. In this tutorial, voice augmentation explains various features of the application. Because Cindy's eyes aren't better than her ears, captions on screen are not the main source of the tutorial's explanations. The screen is designed to ask a user what they would like to do, and provide a series of answers to that question – again, because of the questionnaire ratings, Cindy's interface is rather plain. If her eyes had been better, it might have been more colorful – and if she had tried to click on a part of the background pattern out of confusion as a result, the color and background patterns would have dimmed, highlighting active buttons.

Cindy leans forward, trying to remember how to launch a text chat, and after a few seconds of thinking, a small tab on the right side of the screen pops out, revealing a summarized list of ChitChat's functions. This was implemented during the user requirements stage by ChitChat developers, after some users with poor memory were seen taking notes on how to properly use the application. It includes a search bar, for searching the many ChitChat tutorials, as well as options for guidance through several common tasks within ChitChat (launching a voice chat, launching a video chat, etc) that can be launched from the home screen that she is currently on. The list launched in connection with what the system determined to be a confused look. If Cindy was actually thinking about something else, and did not need the tutorial, she needs only to close the page – a few times of this, and the profile data containing this model of what is considered a face of frustration for Cindy will adjust itself accordingly. But for now,

Cindy welcomes the tutorial and follows it to start a text chat with her friend.

Over the course of the next few weeks, Cindy uses ChitChat quite frequently, and as a result, the application builds a cohesive profile of her actions: when Cindy taps on the desk and the microphone picks up the slight noise, it indicates frustration more often than a furrowed brow. She often relaxes her shoulders – even just a bit – in response to the application making a decision that pleases her. The tutorials are needed frequently at first, but after a while she remembers how to use the application and no longer furrows her brow or taps her finger on her desk, resulting in the tutorial not popping out for her use – however, it still remains able to be triggered if needed as an option on the front page.

After a successful use experience with ChitChat on her desktop, Cindy hopes to download and use it on her mobile device. Doing this will allow her to chat with friends on the go – however, she does anticipate having to adjust settings on her phone to make the app accessible. However, to her surprise, when she downloads ChitChat, the interface looks similar to her desktop computer – larger text, a non-distracting background, and tutorial pop-ups. The application uses the same profile as her desktop application to generate a UI for her, making the intelligent interface experience seamless. Her smartphone's front facing camera and microphone pick up her positive facial expressions and utterances, and confirm that the settings are correct.

All in all, by utilizing the various application guidelines that we've outlined, we've created an intelligent and easy to use application for chat amongst older adult users. Consulting with users beforehand allowed us to develop a multitude of useful options for the older adult user we have targeted, and an intelligent interface allows the

application to recognize distress and react appropriately, ensuring user retention. This application can help older adults remain in contact with each other and thus preventing social isolation.

6.2 Real World Applications

A case study is always helpful in visualizing a design strategy, but even more helpful is the appearance of real world applications. Bits of this design approach have been used in two applications, both of which will have elderly users involved in testing and use of the applications in their final form. One project, the Access Ratings for Buildings Tools application (or ARB Tools), utilizes the hierarchical tutorial method outlined in this thesis in delivering tutorials to the user of the application. The other, the South Dakota Smoking Cessation study, uses user input to adjust personalized messages directed to the user (as the system is text message-based, and does not rely on a particular interface) to the users' preferences.

6.2.1 The Access Ratings for Buildings Project

The Access Ratings for Buildings project seeks to allow users to rate – and view ratings of – buildings in the surrounding area to determine their accessibility for users for various ability levels. The measurements taken by the Access Ratings for Buildings Tool – and iOS based app that can determine ramp, sign, doorway and other portions of a building – are compared against ADA guidelines to determine how they fare in terms of being accessible by disabled users. This said, while initial efforts are being taken in developing the application for *trained* raters, the option for users to use the ARB Tools application – both those with disabilities and otherwise – may still be initiated.

The familiar aspect of the ARB Tools application, in regards to the communicative design approach mentioned here, involves how the in-application tutorials are handled. The application is separated into audits – each of these audits referring to a particular part of a building. When an audit – say, the ramps audit – is begun, a user is shown *one* tutorial that describes the overall audit measurement process in video form. The second tutorial shows up in the audit taking process itself – a user can ask for help on any particular page within an audit, and further explanation – sometimes with a photograph to further assist – will be displayed.

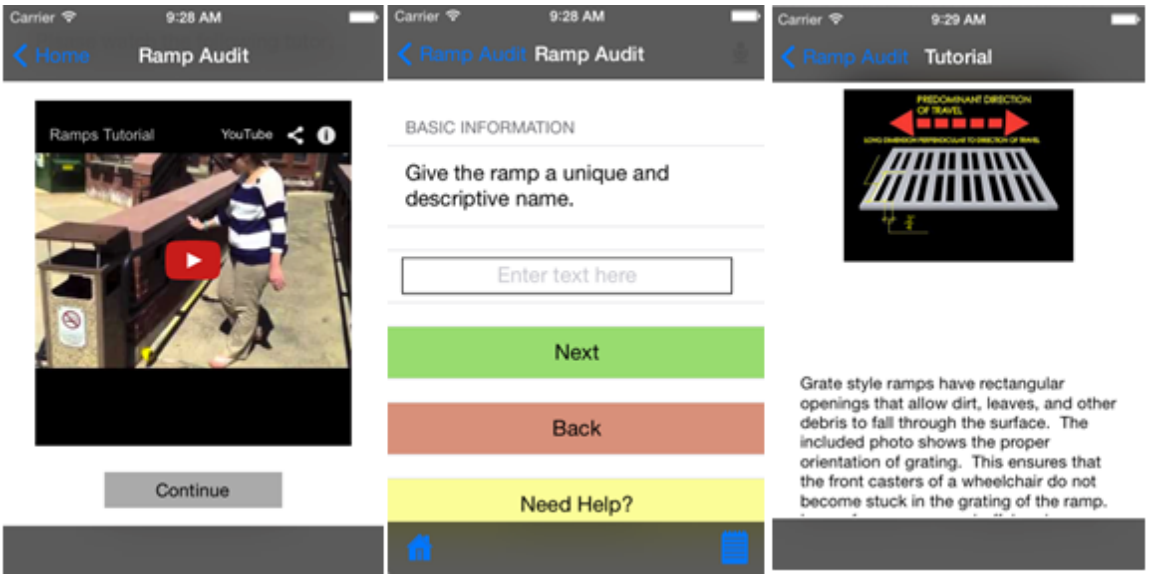

Figure 6: Display of ARB Tool's Tutorial Features and Natural Language

In addition, the application strives to explain its questions in relatively natural language – since the initial version of the application is targeted at trained professionals, particular terms are difficult for the typical user to understand. However, in general, instead of simply displaying a box asking for a ramp's name, the application asks the user to "Give the ramp a unique and descriptive name."

A demonstration of this application was debuted at a user testing event in July of 2013. Resultant feedback regarding the use of these tutorials was quite positive: out of fourteen users queried, eleven state that they could "…complete the…app without additional guidance." Another eleven users stated that the questions in the audit "contributed to…understanding of what requirements a building needs to be determined 'accessible.'" While additional pictures and in-app explanations were requested, when asked what pleased them, users did pick out the ease of use of the application and the tutorials as factors – showing that this communicative design worked well for this application.

6.2.2 The South Dakota Smoking Cessation Study

The South Dakota Smoking Cessation Study was a project that developed a series of applications – including a text messaging server, iPad app, web applications and more - with the main goal of assisting a population of Native Americans in South Dakota to cease smoking. In this application, we used a portion of the design approach outlined here – that is, communication between the user and the application – to create a system of text messages that respond to user preference in regards to what sorts of messages to send the user in an effort to get the user to stop smoking. A user could respond to a daily morning message asking them their preference (similar to the weekly questionnaire suggested by this communicative design approach), and in response to their given preference, they would receive a text message.

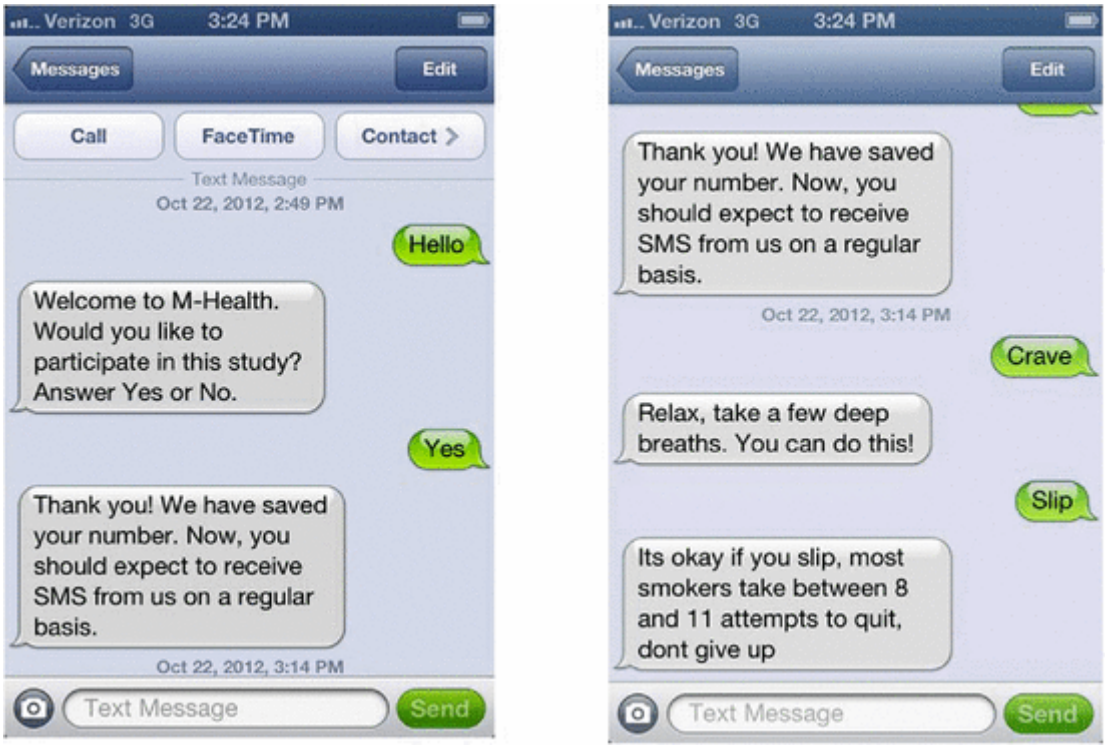

Figure 7: Customized Text Messages for Smoking Cessation.

The system thus far has been received quite well – users were also allowed to customize their text messages if they would like, and a number of users who found the system helpful customized personal text messages they could select during the morning preferences selection as well. Users have reacted so well to the application that they have actually attempted to hold conversations with the text server – which itself is an implication that a fully affective system may be a future consideration in this sort of study.

CHAPTER 7 : CONCLUSIONS

The interface design described here provides a solution for the most frequently considered problems with human-computer interfaces and the older adult user: interfaces that are poorly designed for the abilities of the user, interfaces that the older adult user cannot understand how to use, and interfaces that oversimplify due to believing that older adult users all conform to existing stereotypes of the elder user. Especially as more work is completed in the fields of affective computing and intelligent human-computer interfaces, interface designs such as this one may allow applications to communicate with users – allowing for tailored experiences and particular tutorials (depending on the in-application screen you are on) for younger users as well.

7.1 Summary of Contributions

The most important feature of this thesis is the answer we have specified for our initial question 'What type of interface best fits the needs and expectations of the older adult computer user?' In seeking out this answer, we compiled a vast array of existing works and parsed them for common trends in approach, then named and stated the common approaches. We then took those approaches and went one step further: working them into a design that prioritized communication as a method of helping older adults overcome the outstanding problems with these approaches, and understand the benefits of using computing technology.

This communicative design itself is a novel contribution. Our communicative design approach allowed a user to build a user profile from a variety of data, including user data, survey data, and affective data – a user profile that allowed a system to

conform an interface to the strengths and weaknesses of the user. This in turn allowed the system to understand when settings should be adjusted (watching the affective markers) and confirm that any adjustments made were done correctly. With the ability to transfer the settings to other computers running the same operating system, and even mobile phones with the mobile iteration of this interface installed, a user once restricted by poor design would be able to use a host of devices, and take advantage of many offerings previously not available to them. And due to our specialized design, the user would not feel as if the computing experience needed to be simplified for their ability, thus avoiding feelings of loss of independence – and ensuring a positive experience with our computing system.

To summarize, the contributions of this thesis are as follows.

- We have compiled a list of common trends in approaching older user human-computer interface design.
- We identified that older adult users still encounter problems with computers mainly because of being unable to see the benefits of technology combined with yet-existing barriers (improper interfaces, social stigma, etc.)
- We created a design approach for older user human-computer interfaces that, instead of prioritizing design for impaired abilities or prioritizes three levels of communication and in doing such helps older adults overcome the aforementioned barriers of and see benefits in computing.

7.2 Broader Impacts

This design approach has the short term potential to make using computers easier and more understandable for older adults; using the nonverbal cues that they likely display every day in order to ensure that their computing experience is a positive one. By not only adapting the interface to the needs of the user, but also verifying the changes that are made within the application based on user preferences, this design allows elderly

users to worry less about configuration and display more concern about what applications can be used to best bolster their quality of life.

However, it should be noted that this system also has the long term potential to *educate* the elderly user in regards to the technology they choose to use – thus preparing them to perhaps take on the challenge of using additional software they would not have been brave enough to try before. Tutorials sprinkled throughout the applications using this design approach give guidance to the user, giving older adults confidence with technology that they did not have before. Since older users' confidence with using technology is something that has been noted to be lacking, [6], [11] that something could easily bolster it would have a huge impact on the older adult community.

7.3 Future Work

Finally, this approach is not limited to making life easier for the older adult user: creating intuitive and iterative interfaces such as this, with various modifications, could also assist computer users suffering from degenerative diseases and allow them to continue to use applications that they have grown to enjoy. Likewise, such a design method could also be used in helping children learn about computers. Future work may be allotted to investigating the use of this design approach in applications with younger users; allowing applications designed for younger users to scale up with their understanding of computers, and teach them how to properly use applications that will greatly benefit them in the future.

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