PREVENTIVE COMPUTING TECHNOLOGY FOR SUCCESSFUL AGING

BY

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THESIS

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ABSTRACT

A pervasive societal and personal concern is how we can maintain or improve our quality of life as we age. The purpose of this thesis is to assess the current state of technology as it is (or can be) used in everyday life to support healthy and happy older adults by maintaining physical fitness, cognitive health, and emotional fulfillment. In addressing this problem, much focus has been placed on assistive technology, replacing or compensating for functionality that has declined or been lost, or creating a "safe zone." Our focus is on technology that is not assistive in this sense, but rather supportive in expanding capabilities to remain independent in their current environment. If older adults can retain their capabilities, the need for a myriad of assistive technologies would be postponed. Therefore, the alternative perspective we offer is more preventive and proactive.

ACKNOWLEDGMENTS

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CHAPTER 1: INTRODUCTION

***Our aging population*:**

The older portion of our population in the United States is growing. In 2012, there were 43.1 million older adults aged 65 and over in the US; by 2050, that number is projected to be 83.7 million. While the overall population of the US will also grow from 314 million to 400 million, older adults will comprise a larger percentage of the population – more than 20 percent of it, up from 13.7 percent in 2012 [1].

Costs of an aging population:

This growth of the older portion of our population will bring challenges – especially related to financial resources. The old-age dependency ratio (the potential burden of older, non-working-age individuals) will shift: In 2050 there may be 36 older adults to support per 100 working-age adults, compared to 21 older adults per 100 working-age adults in 2010, meaning there will be relatively fewer workers to provide services and pay taxes that support programs needed by older adults [1]. Consequentially, healthcare and caregiving may demand a larger share of the nation's resources.

Even faced with such a challenge, all hope is not lost. Christensen et al. states that "studies have reported larger improvements in disability-free life expectancy than in life expectancy," and that "gains in life expectancy over recent decades might have added years with moderate difficulties but not years with severe difficulties." Some of this may be due to use of assistive technology, better housing, transportation, accessibility, policies, gender roles, and social perceptions, in addition to disease and disability prevention and treatment, so people over 85 years can better manage their daily lives better than before. However, improvements still need to be made, and one of the best ways to do that is to keep people healthy in the first place:

> "Lubitz and colleagues showed that the expected cumulative lifetime health expenditures for individuals in good health at age 70 years were not greater than were expenditures for less healthy people, despite greater longevity of healthier elderly people. Thus, health promotion efforts aimed at people aged 65 years and younger might improve health and longevity of elderly people

> without increasing health expenditure. Individuals who survive longest have a health profile that is, in many respects, similar to that of individuals who are a decade or so younger. This finding suggests that most individuals can expect to deteriorate physically before death, but postponement of this process enables people to live to advanced ages without great disability." [2]

***Independence and aging in place*:**

In addition to the need to curb societal issues as a reason to focus on the health and well-being of older adults, the older adults themselves have a strong preference to be able to live in their own homes independently as they age, rather than moving or being moved to as assisted living facility or nursing home. This is called "aging in place." The AARP reports:

> "More than nine in ten respondents *somewhat* or *strongly agree* that '*what I would really like to do is continue living on my own for as long as possible*.' More than nine in ten say they would *pay for services that could help them stay in their own home*, and eight in ten say they would be willing to *give up some of their privacy if they needed help to stay in their home*." [3]

As alluded to earlier, there are many interventions aimed at assisting older adults in their goal of aging in place. This "assistive technology" is defined as "any service or tool that helps older adults or persons with disabilities perform activities that might otherwise be difficult or impossible" [4]. In other words, it helps them do things that they cannot easily do anymore due to age-related changes, sometimes even enabling them to remain independent. Some common examples would include Life Alert (an emergency medical alert system), a scooter or walker, and electronic pillboxes.

These interventions are certainly beneficial and have potential to make a difference in the lives of their users. However, there should be an additional perspective – one that does not focus on replacing the functionality that the user lost through use of the intervention, but that focuses on preventing or delaying the declinations so as not to need such assistive technology in the first place, or at least for as long as possible. Healthy habits and a healthy way of living is advisable for people in any stage of their lives, but special attention should also be given to computer technology that can be targeted towards older adults with the intent of retaining independence through prevention.

Prevention:

The idea of preventive healthcare is not a new concept, but has been given more attention recently due to the need for better use of our healthcare system. The National Prevention Strategy was initiated in 2011 as part of the Affordable Care Act and "aims to guide our nation in the most effective and achievable means for improving health and well-being," through "moving the nation from a focus on sickness and disease to one based on prevention and wellness" [5][6]. See Figure 1 for more details.

Figure 1 - "The [National Prevention] Strategy envisions a prevention-oriented society where all sectors recognize the value of health for individuals, families, and society and work together to achieve better health for Americans." [6]

Prevention is good for every stage of life, but in regards to older adults the CDC states that:

> "With better health, seniors keep their independence. Support for older adults who choose to remain in their homes and communities and retain their independence ("aging in place") helps promote and maintain positive mental and emotional health." [5]

Therefore, this thesis focuses on technology that can help older adults in their pursuit of aging in place, specifically from the perspective that Benjamin Franklin made famous: "an ounce of prevention is worth a pound of cure" [7]. Physical fitness, cognitive health, and emotional fulfillment will be discussed as categories for such technology.

CHAPTER 2: ASPIRE – AUTOMATION SUPPORTING PROLONGED INDEPENDENT RESIDENCE FOR THE ELDERLY

This thesis was inspired by work done through the support of a large, interdisciplinary National Science Foundation grant through the National Robotics Initiative, entitled: "ASPIRE – Automation Supporting Prolonged Independent Residence for the Elderly." Our goal is to utilize a system of drones such that it would enable older adults to live independently in their homes – to "age in place".

ASPIRE is intended to be a safe, robust, trusted, intuitive, affordable platform of small drones and small ground robots on which useful applications can be created which will support older adults in their homes. These robots will co-exist and interact with older adults in their homes to help them age in place.

Interdisciplinary efforts are needed for this challenge. The design of multiple coordinated human interface devices for older adults is necessary. High-level Laban-based motion generation is used to translate required tasks into movement styles for flying robots. A virtual reality environment is used for testing and validating movement styles and to model humans' perceived safety using neural networks. Motion planning strategies are based on Bezier curves using Bernstein polynomials to generate real-time trajectories that account for actual and perceived safety, motion styles, and feasibility.

ASPIRE:

Although embedded with smart features and innovations, appliances such as washing machines, microwaves, vacuum cleaners and other household machines are still rigid when it comes to multiple functionalities. Technology that is flexible enough to help us at home, by carrying out multiple distinctive tasks, has been a driving motivation for the robotics community. Efforts with bio inspired ground robots [8] have shown how complicated and large robots can become and how challenging it can be to replace caregivers with such cumbersome robots. Furthermore, finding home assistive robots that have elderly independence as the core development goal is largely unavailable. To engineer an acceptable and useful technology, a framework must prioritize flexibility of operation and usability as the foundation for safe and trusted interaction; user acceptance lies almost solely within the purview of the elderly.

Our human-robot system allows the elderly to cooperate with small flying robots and ground robots through an appropriate interface. This team of small robots is more affordable, more agile, smaller, and can reach higher floors and tighter spaces. We use experimental data to study older adults' perceptions of non-humanoid robots to design a platform that is acceptable and does not interfere with their comfort of living at home.

In order to achieve this flexible and adaptable framework, the project ASPIRE is redesigning the way small aerial vehicles (UAVs) interact with humans. The mechanical simplicity of multi-rotors makes them an affordable platform that has the potential of performing precision flight maneuvers with onboard grasping solutions and sensing hardware, which can be employed in activities that are not attainable by traditional humanoid or ground vehicles, e.g. reaching up high to grab objects. A human-centered design of a flying robotic platform is being developed to achieve the goal of providing caregiving with multi-rotor UAVs.

ASPIRE provides a platform where High-Level Controllers (HLC) can be designed in order to provide a layer of abstraction between the high-level task requests, the perceptual needs of the users, and the physical demands of the robotic platforms, shown in Figure 2 and Figure 3.

Figure 2 - Some of the main concerns that must be handled by the system

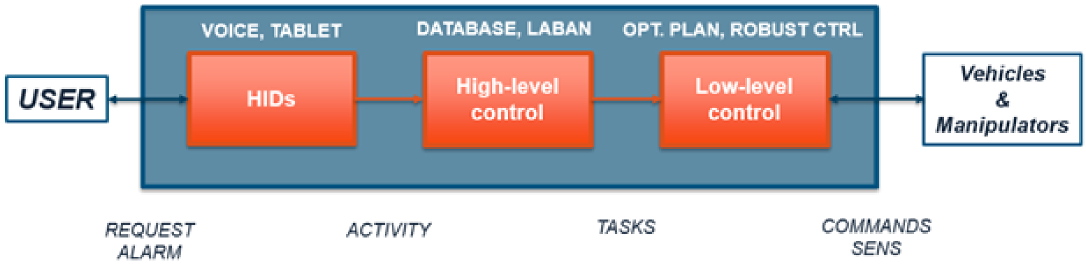

Figure 3 - Overview of the ASPIRE solution integration

With a robust framework that has the capability to account for human perception and comfort level, we can provide perceived safety for older adults, and further, add expressivity that facilitates communication and interaction between the user and the robotic team. To achieve these demanding levels of comfort, predictable and safe navigation must be guaranteed by the underlying Low-Level Controller (LLC), which is fundamental for indoor locomotion of any robotic form. Embedding human perception into the LLC and HLC is done by collecting experimental data from human subjects to understand how humans behave in the presence of these UAVs.

Human Perception and Performance:

The ASPIRE project addresses two fundamental issues that arise when deploying robotic systems to real-life human populated environments: (1) How do we characterize human behavior in the presence of co-located mobile robots? (2) How do we design and control mobile robots to maximize comfort and perceived safety for co-located others? Using current generation VR devices, in combination with physiological recordings, self-report data, and behavioral measures, we are able to generate a detailed model of human behavior in these situations.

VR is a desirable tool in this sense, because it offers a safe and flexible environment in which the investigator has extremely granular control over the user experience. For example, aspects of the robot's physical appearance (e.g. shape, ergonomics, or durability), behavior (e.g. movement, manipulation, or sensing), and environmental context (e.g. low light, noise, or verticality), all constrain a robot's flight path and can be manipulated in isolation to reveal their unique effect on human observers. The human observer, however, also brings with them personal experiences that can influence the perception of a robot's agency; and therefore its trustworthiness, safety, and so on.

For example, our ongoing research with older adults and college-aged students explores the role of uncertainty and perceived safety in non-cooperative multi-rotor UAV interactions. In one version of this experiment, participants wear a VR head-mounted display (HMD) and enter a high fidelity simulation of an urban scene (see Figure 4). During the simulation they experience several unanticipated UAV flybys, the nature of which is manipulated experimentally across subjects (e.g. distance to user, speed, or loudness). Biometric data is sampled continuously throughout the simulation, including galvanic skin response (GSR), photoplethysmography (PPG), and head rotation (e.g. angular (rotational) acceleration (1 rad = S^2) and linear acceleration (1 m = S^2), as a function of time-to-collision. Other demographic information related to athletic activity, UAV experience, and video game playing history, is collected offline and included in subsequent analysis. It is imperative to consider these types of continuous, indirect measures in order to acquire an unmitigated response from the human observer. See Figure 5 and Figure 6 for an example of data collected during the experiment.

Figure 4 – VR simulation of UAV flight during biometric data acquisition

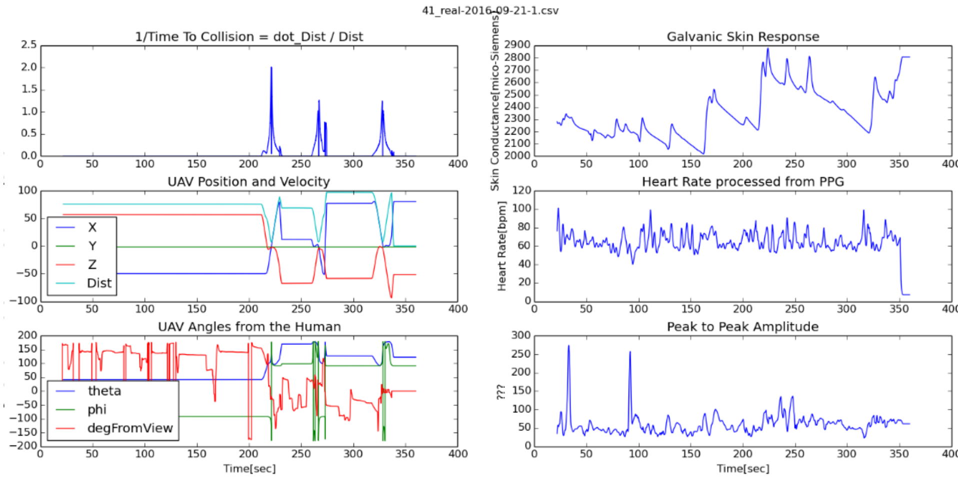

Figure 5 – Example data from VR experiment

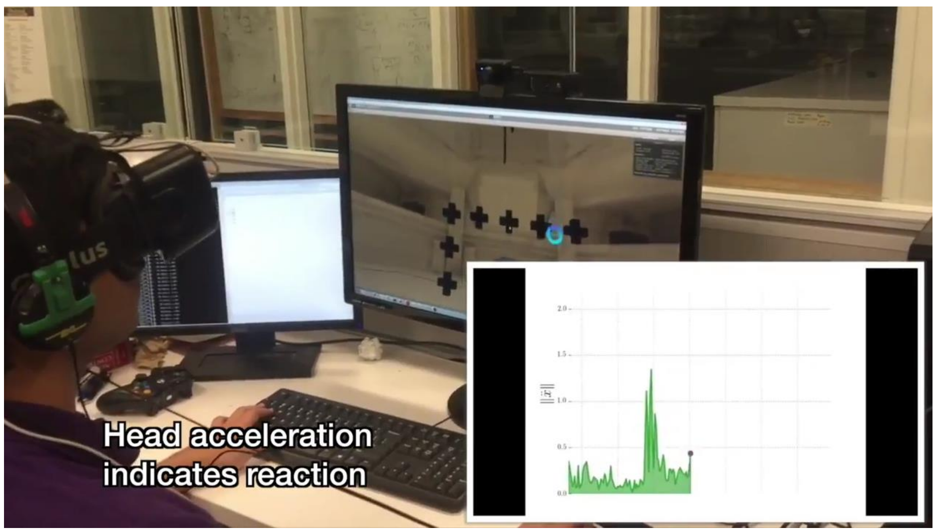

Figure 6 – Head acceleration indicated reaction to passing drone in VR experiment

While it would be possible to simply ask participants to indicate their attitudes about UAV interaction, these types of deliberative questions can often result in an "I don't know" or "I'm not sure" response; this is often because the participant does not want to report the answer, does not understand the question, or legitimately does not know. Indirect measures, like those mentioned above, circumvent these types of self-report issues. For example, in response to the UAV's presence, increased arousal can lead to the sweat glands becoming more active, increasing moisture content on the surface of the skin, and allowing electrical current to pass more easily. This effect is known as skin conductance and is often cited as a measure of arousal or state anxiety [9]. Similarly, using an optical pulse sensor placed near soft tissue, e.g. fingertip or earlobe, a photoplethysmogram signal (PPG) can be acquired and processed to determine the heart rate, which is known to increase with arousal [10]. Together these two signals help provide a comprehensive description of a participant's emotional response during a given UAV interaction. While this methodology provides an indirect assessment of an individual's automatic response to an unanticipated drone interaction, it is equally important to acquire direct measures of behavior and to do so for circumstances in which a UAV interaction is not only expected, but also expected to be cooperative.

To this end, another series of experiments focuses on assessing boundaries of perceived safety by measuring the proximal distance in which users feel comfortable interacting with a co-located UAV. These experiments recruit both college-aged students and older adults, but extend the findings of our previous research by enabling users to locomote freely in a small area and provide commands to the UAV using a hand-tracked controller. This additional layer of complexity helps to better simulate a real-world scenario in which an older adult must cooperate with a UAV in performing a given task. By collapsing across responses from many trials under different conditions, we can generate a boundary of an interaction space within which a human observer feels comfortable interacting with the UAV. Because we expect carebots to be operating also in assisted living communities or elderly care facilities, we can use this data to design parameters for the LLC, such as proximity bounds, velocity profiles, and obstacle avoidance thresholds (see Figure 7). For a model of perceived safety, see Figure 8.

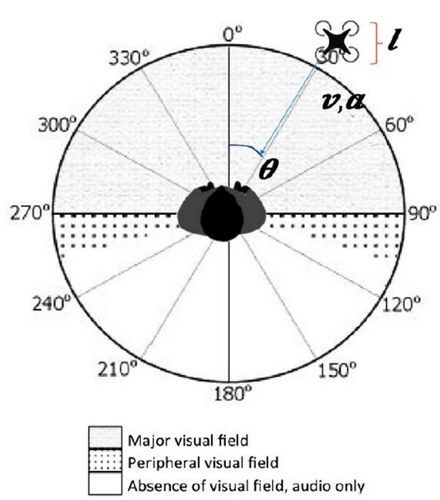

Figure 7 – Example of different physical parameters during experiment to quantify perceived safety

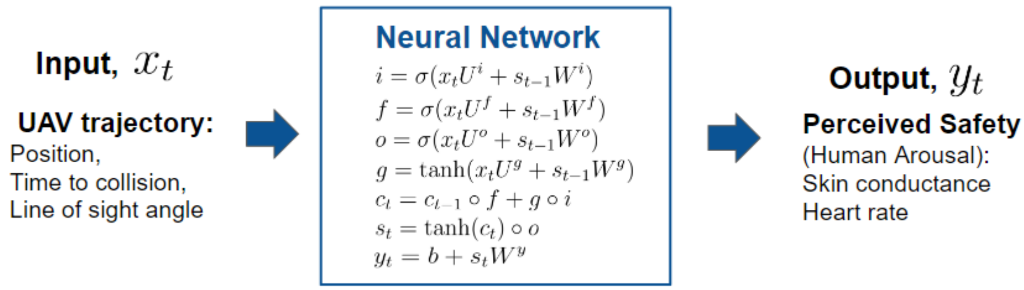

Figure 8 – Modeling perceived safety

Style - Choreography of Expressive Robot Trajectories:

The user's perceived safety of the robot will also be based on their ability to determine the state of the current robot team. This requires communication via expressive robotic movement. For example, if the user requests a task to be accomplished with urgency, they will expect a more aggressive action from the system and thereby the parameters of perceived safety will change. The HLC will combine user requests with expressive actions and communicate new appropriate parameters to the LLC. The team is using Laban/Bartenieff Movement Studies (LBMS) to choreograph these expressive pathways. This system of movement analysis and notation provides a taxonomy with which to describe the robot motion. Principles of body organization and movement quality, mapped to a quantitative measure of platform expressivity and task complexity, will guide the design of the HLC and the commands the user interface support [11]. See Figure 9, Figure 10, and Figure 11.

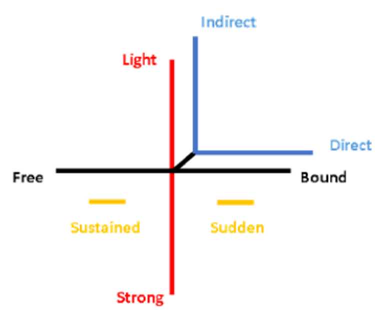

Figure 9 - Laban 'Effort'

Figure 10 - Proposed mapping between Laban 'Effort' and UAV motion generation

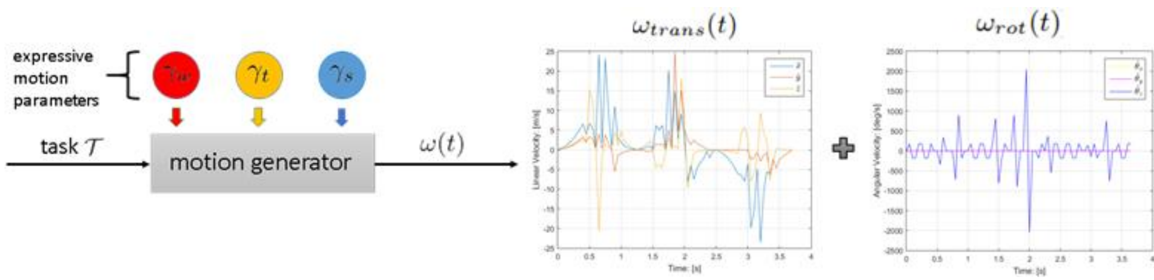

Figure 11 - High-level motion generation method

User Interface:

Our current interface concept, in the form of a tablet computer (shown in Figure 12), takes into account much literature on designing interfaces according to the preferences and abilities of older adults, especially due to physical and cognitive declinations. For example, we eliminate anything that is not crucial, simplify navigation, and highlight important information due to diminished working memory and attention [12]. Future human interface devices will include voice and gesture. The end result will be a natural user interface for intuitive control and interaction.

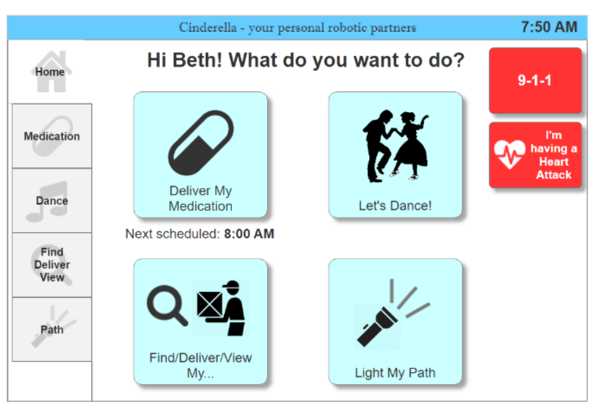

Figure 12 - Tablet-based graphic user interface. Other human interface devices (HIDs) used to interface with the drones may include voice and gesture.

Navigation – Safe Autonomous Flight:

Safe indoor navigation for UAVs is a multi-pronged problem consisting of trajectory generation, collision avoidance, path following and state estimation while also acknowledging the safety concerns of humans in proximity (Figure 13).

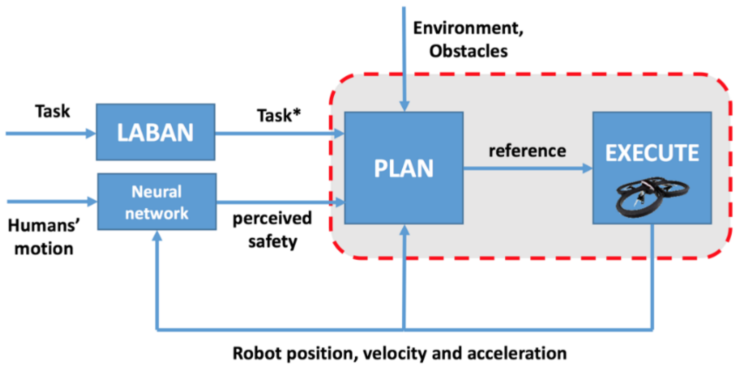

Figure 13 – Task completion architecture

To incorporate a human-centered approach to the navigation problem we propose an optimal control formulation as described in Figure 14 and Figure 15, which includes the perceived safety of humans as a constraint to generate trajectories and collision avoidance (Figure 16) methods to navigate around obstacles in the environment (Figure 17). Since quad-rotor dynamics are differentially flat the optimization can be devised in the output space allowing us to easily add constraints such as velocity, acceleration, distance to obstacles, and human perceived safety directly to the problem formulation. The inference derived from the psychological experiments in virtual reality will provide an expedited method to weigh the importance of these quantities against perceived safety and design constraints for the optimal control problem accordingly.

Safe optimal trajectories for the UAVs can be generated by minimizing the following cost functional:

Optimal control formulation

$$\min_{w_{act}\in\Omega} J = \int_{t_0}^{t_f} \left(w_l||w_{act}(t) - w(t)|| - \underbrace{w_p\mathcal{P}(t)}_{\text{Perceived Safety Model}}\right) dt$$

subject to

Mission specific constraints	$e(w_{act}(t_f), t_f) = 0$
Feasibility and actual safety constraints	$h(w_{act}, \dot{w}_{act}, \ddot{w}_{act}) \leq 0$

where

Desired UAV motion (Laban Effort)	$w(t)$
Actual UAV motion	$w_{act}(t)$
Perceived safety model, soft approach	$\mathcal{P}(t)$
The set of Bezier curves using Bernstein polynomials	Ω

Figure 14 – Optimal control formulation

Figure 15 – Optimal control formulation

Figure 16 – Validated collision avoidance algorithms

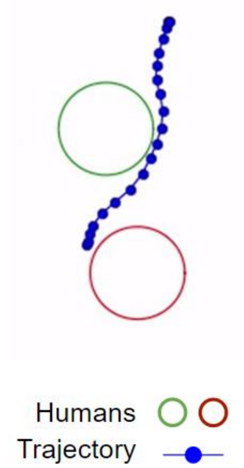

Figure 17 – Real-time trajectory generation

In order to provide a flight that does not adversely affect perceived safety, we must precisely follow the trajectory solved by the optimal control problem. Large deviations from the optimal solutions will disrupt the human's level of comfort. We use nested feedback loops in order to guarantee tight performance bounds. Rate and attitude controllers provide stable flight and can also achieve behavior specific goals, e.g. "friendly" and less aggressive movements, bounds on velocity and acceleration. To fly UAVs through unstructured and cluttered environments in households, we use a trajectory-tracking controller, which guarantees precise locomotion in space. To ensure a predictable flight and guarantee minimal deviation from the designed level of comfort, we use a robust and adaptive control for the inner-loop controller design. The L1 adaptive control architecture is designed for such safety critical systems and provides the required robustness and performance [13].

The Robotic Platform:

Design of a small robot suitable for indoor flight capable of minimizing disruption and discomfort is done by incorporating the findings from the experimental research with humans. Flying multi-rotors pose the hardest design constraints because the desired functionalities (such as flight endurance, payload capabilities and precision manipulation) are contrary to the characteristics needed for human acceptance (compact, quiet and lightweight).

To achieve the highest possible thrust-to-weight ratio while also satisfying payload constraints with commercially available parts, the multi-rotor is chosen to have 208 mm in diameter with desirable maximum total thrust of over 1.6 kg.

A two-degree of freedom serial manipulator was designed with an open truss structure in order to further decrease weight (Figure 18). Although the flight controllers are capable of preventing collisions, a protective enclosure is added on the outer part of the robot (Figure 19). This fully protective enclosure augments the safety of the system, but most importantly, communicates a message of safety to the user.

The system uses an affordable indoor localization system, ultra-wideband radio (Figure 20).

Figure 18 - Robotic arm

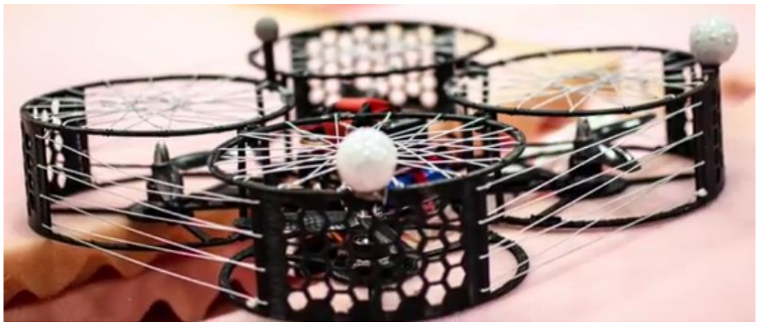

Figure 19 - Propeller protection

Figure 20 - Affordable indoor localization system – ultra wideband radio

Application:

The system could be used to bring prescribed medicine at a scheduled time every day if the user has not already taken it, along with water or food if needed. This could potentially increase medication adherence. The user could also request non-prescription medication (e.g., pain reliever) to be brought to them (Figure 21).

Future work and technological advancements can determine additional applications that will benefit older adults. For example, the robots could be utilized as personal dance partners to help keep users physically and mentally fit and socially fulfilled.

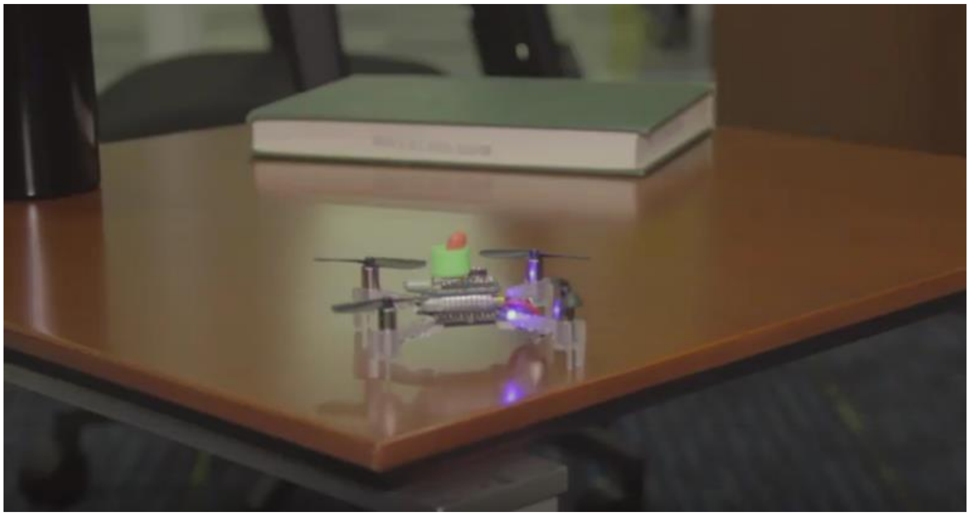

Figure 21- Drones can be used to deliver medication to the user

Broader Impacts:

The impacts of this work reach beyond assistive technology. For example, this work could inform how co-robots could be used effectively in assisting astronauts in spacecraft, manufacturing, healthcare, first responders, and even artistic performance.

CHAPTER 3: SUCCESSFUL AGING CHALLENGES AND ROLES FOR COMPUTING

With the growth of computer technology and its undeniable ability to affect our lives in powerful ways, coupled with the impending challenges that will ensue as our population ages, there is ample opportunity to utilize our computer technology in support of helping older adults live better, independent lives for their own benefit as well as the benefit of our society as a whole. We must first look at what happens as people age, and then consider how technology can fit into the lives of older adults.

Age-related declinations:

As humans age, declinations can occur in an individual's motor skills, cognitive functions, and senses [14]. These can in turn have a negative effect on the individual's ability to age in place.

Motor skills decline: Fine motor skills, balance, strength, bending, and endurance are all negatively affected. Motor limitations are the source of almost 40% of difficulties in completing daily activities (discussed later), and is mostly gross movement as opposed to fine movement [14]. In one study, 32.5% of participants had limitations in locomotion, and 25.5% had limitations in reaching, which were the highest reported physical limitations [14]. In another study, the most common physical limitations were climbing several flights of stairs, moderate activities, vigorous activities, and walking more than a mile [15].

Cognitive functions decline: Overall, attention and memory are most affected by aging. Higher-level cognitive functions show deficits to the extent that the basic cognitive functions which they rely on are impaired. For example, speech and language processing declinations are attributable to sensory and working memory decline (cannot hear or cannot retrieve a word). Decision making, problem solving, and reasoning weaken due to working memory declinations, so older adults tend to rely on prior knowledge rather than new info, or rely on outside sources. Executive control declines, though it is important for novel tasks - management of cognitive processes such as planning, organization, coordination, implementation, and evaluation relies on this. Executive control deficits may be a primary contributor to cognitive decline in older adults [16].

Basic cognitive functions are affected as follows: attention is affected as selective attention and multitasking gets more difficult, while sustained attention is not as affected. Processing speed declines. Working memory declines (e.g., repeating a number backwards), while short-term memory is not as affected (e.g., repeating a number). Long-term memory is affected as follows: episodic memory declines (memory for specific events/experiences that occurred in the past), autobiographical memory declines (memory of one's past, including episodic and semantic); prospective memory (remembering to do something in the future) is not as affected as long as adequate cues (e.g., calendar, pill box) are available, and semantic, procedural, and implicit memory are not as affected. Perception declinations are attributable to declining sensory capacities [16]. Furthermore, speed, reasoning, and memory decline linearly starting from age twenty [17].

The senses deteriorate: Sensory thresholds (the minimum amount of stimulation required before you become aware of it) are higher. The ability to sense hearing, balance, vision, taste, smell, touch, vibration, and pain are all negatively affected; hearing and vision are most affected [18]. Hearing disabilities affect 21.7% of older adults, and vision disabilities affect 15.3% of older adults [14]. These occur later in life than physical disabilities [15]. Examples of specific concerns that may have an effect on independence include noticing or distinguishing between sounds (such as hazards), not being able to smell gas or smoke as easily, being unable to distinguish between cool/cold or warm/hot (in water temperature or in dressing for the weather), being unaware of or unbothered by sensation (such as pain or discomfort), and being less capable of driving [18].

In addition to these declinations, health conditions are a growing concern as aging progresses. The most common chronic health conditions include arthritis, hypertension, diabetes, and heart disease [15]. However, we will not focus on these specifically because these conditions do not affect every older adult in the same universal way that the aforementioned declinations do. Nevertheless, some of these health conditions may be positively affected by the interventions discussed later (e.g., interventions that facilitate better nutrition may help someone in managing their heart disease, etc.).

Successful aging:

Rowe and Kahn define "successful aging" as "multidimensional, encompassing the avoidance of disease and disability, the maintenance of high physical and cognitive function, and sustained engagement in social and productive activities" [19]. From the perspective of the World

Health Organization (WHO), "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" [20]. This also points to the importance of addressing the whole picture of health, especially from the root of the problems themselves, if possible. The importance of this perspective is also illustrated in the concept of Healthy Life Expectancy (HALE) – a measure used by WHO of how long a person can expect to live in "full health," without disease or injury [21]. The Health Related Quality of Life (HRQOL) model also illustrates what it means to age successfully:

> "HRQOL is a person centered measure that can be modified in a complex way from (i) perceptions of physical and psychological-emotional health; (ii) level of independence; (iii) social role; (iv) relationships; (v) context; and (vi) environmental and working interactions… HRQOL refers to physical, mental and social domains of health that are seen as distinct areas influenced by a person's experiences, beliefs, expectations, and perceptions." [22]

These ideas may be summed up in a common saying: "It's not the years in your life that count. It's the life in your years."

The definitions above make it clear that successful aging should not only be limited to simply living, but living well. Since aging in place is of such importance to older adults, we should furthermore explain successful aging as coinciding with retaining independence as an older adult. The activities which need to be completed in order to remain independent can be separated into three categories. Self-Maintenance Activities of Daily Living (ADLs) include the ability to toilet, feed, dress, groom, bathe, and ambulate (physical movement). Older adults tend to have the most difficulty in this category with walking, getting in and out of bed and chairs, and bathing or showering. Instrumental Activities of Daily Living (IADLs) include the ability to successfully use the telephone, shop, prepare food, do housekeeping and laundry, mange medications and finances, and use transportation. These are more cognitively demanding than ADLs. Older adults have the most difficulties with housekeeping, meal preparation, and outdoor home maintenance, and the most common physical limitations are locomotion and reaching. Lastly, Enhanced Activities of Daily Living (EADLs) include social and enriching activities such as learning skills and hobbies [14]. The percentage of non-institutionalized older adults that struggle with each of these categories is shown in Figure 22.

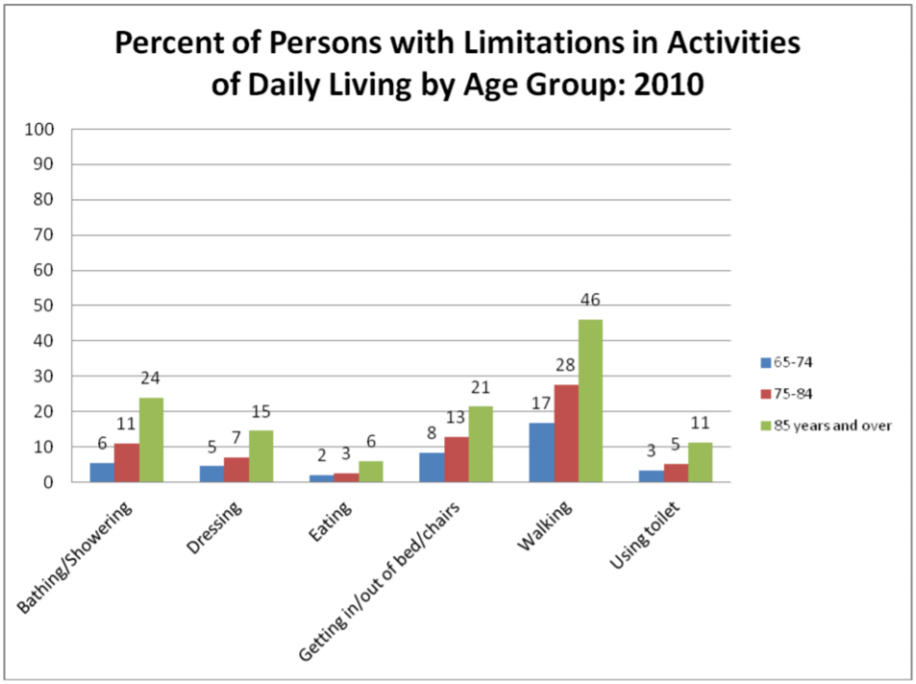

Figure 22 - The percentage of non-institutionalized older adults that experience limitations in activities of daily living by age group [23]

Bedaf et al. aimed to determine functionality of assistive robots or other technology that would best meet the needs of older adults striving to remain independent. Through comprehensive literature searches and focus groups, the authors found that the factors most threatening to the independence of older adults are related to problems with mobility, self-care, and social isolation:

> "(1) Self-care activities: when an elderly person is not able to take care of their personal hygiene, then he or she becomes dependent, especially when getting up in the morning or going to bed in the evening. Consequently, people have to adapt their daily schedule to the schedule of their caregiver.
> (2) Mobility: living independently at home becomes extremely difficult as one is not mobile any more.
> (3) Social isolation: social isolation is caused by the decrease or even lack of activities concerning interpersonal interaction and relationships." [24]

See Table 1 for more details. Even though many activities could be listed as threatening to independence when becoming problematic, no one activity could be blamed, pointing to the reality that the problem has many factors which also vary by person.

Table 1: "Which activities threaten independent living of elderly when becoming problematic: inspiration for meaningful service robot functionality" [24]

From literature review			Clustered problems from focus groups:
Risk factor analysis of activities:	Characteristics of new nursing home entrants:	List of challenging activities:	
mobility (7 studies identified this as a risk factor) changing body position (3) interpersonal interaction and relationship (3) washing oneself (3) toileting (3) feeding (3) dressing (2) taking medication (1) preparing meals (1) walking (1)	**Activities of Daily Living:** washing (50.4% had difficulties with this activity) dressing (48.8%) toileting (28.8%) mobility (26.4%) eating (10.4%) **Instrumental Activities of Daily Living:** cleaning (87.2%) cooking (81.6%) laundry/ironing (75.4%) outside mobility (66.4%) administration (68.0%)	**Mobility related:** walking inside/outside climbing stairs reaching for objects sitting and getting up carrying heavy objects bending **Self-care related:** washing oneself caring for body parts toileting dressing feeding taking medication **Domestic life related:** shopping preparing meals doing housework loneliness reading	**Mobility related:** walking inside climbing stairs sitting/getting up lifting/carrying objects bending **Self-care related:** washing oneself caring for body parts toileting dressing eating drinking taking medication **Social isolation related:** loneliness lack of family/friends safety (alone at night) isolation lack of hobbies

A large study in New Zealand investigated factors that enable older adults to maintain independence. They found from literature the following:

Factors that maintain the health of older people include healthy lifestyles; social, emotional, and mental health; and income.

Environmental factors that help older people maintain their independence include attitudes and perceptions; housing; transport; and friendship and community participation.

Factors which make it more probable that an older person who is ill or has a disability can live independently include family support and care; and management of issues that affect women more negatively such as transport, poor body image, poor self-esteem, lack of confidence, stereotypes, etc.

Personal services, and other initiatives that enable people to stay living independently include preventive public health approaches; the provision of home-based services; approaches to assessing need; and accessibility and appropriateness of services.

They found from research the following:

Personal factors that affect the independence of older people include attitudes of older people such as adapting, optimism, personal responsibility, adventure, determination, confidence, and a sense of humor; social networks including family, neighbors, friends, clubs, and organizations; family relationships; friendship networks; neighbors; interests and activities; volunteering; health and wellness issues (physical activity and mental activity); and financial circumstances.

Environmental factors that affect the independence of older people include attitudes towards older people; housing; transport and local amenities, including safety in moving around; security; and being able to keep up with changes in technology.

Services that help maintain the independence of older people include general services (health promotion and injury prevention, quality general practitioners, other support services such as emergency systems, Meals on Wheels, and grocery or prescription delivery); and personal services (specialist and acute care, illness or disability services, family care, family caregiver strategies, services provided at home, and managing the costs of care).

Their suggestions were that the most critical support issues for older people include financial resources, keeping an active mind, maintaining good relationships with family and friends, good fitness and health, and good self-esteem. Also, more active and explicitly positive attitudes towards ageing would help preserve active roles, confidence, inclusion, and services that meet the needs of older adults. Income, support for personal health/disability/degenerative condition needs, housing and security, transportation access, recreation, education, public amenities, and work are all areas that need addressed [25].

Available assistive technology:

Assistive technology is "any service or tool that helps older adults or persons with disabilities perform activities that might otherwise be difficult or impossible" [4]. The field of assistive technology is large, and is always growing due to the current and future demand of older adults wanting to age in place.

The AARP reports on technology that can be used towards the goal of aging in place. Personal computers are used to keep socially connected – "two-thirds of the 65+ population currently use personal computers to communicate with family and friends by e-mail" – and to get information online – half use it to search for health information. Home safety technology devices are not yet as widely used (less than one in five use one), but they include alarms that sound when a door or window opens or closes unexpectedly, systems that calls for help if someone falls, devices that turn appliances off when unused (e.g., a stove), devices that turn lights on and off, devices that regulate indoor temperature, devices that help track progress in preparing food, and electronic systems that alert family or friends if the user's daily routine changes. Personal health and wellness technologies are used even less often (less than one in ten use them), and they include electronic pill boxes that remind the user which medicine to take and when (and may even coordinate with a health care provider) and health systems that enable video conferencing and communication of medical information with a medical professional [3].

Normie describes that "fundamentally, the purpose of ageing-in-place technology is to create an ambulatory 'safe zone' within which the older resident's functional, physical, medical, and social needs dictate the appropriate type and necessary level of intervention." He describes the state-of-the-art as consisting of interventions that help with declining health and frailty such as medication adherence interventions and personal emergency response systems, interventions to prevent falls, interventions to monitor and detect self-neglect, and smart home technologies that help monitor the older adult and provide them with functional assistance. Future possibilities he lists include smart sensor such as toilets that detect dehydration, malnutrition, diabetes, and hemorrhage, robotics that respond contextually to the user and provide caregiving functions, artificial intelligence for detecting emotional states, and neural interfaces for communicating with the environment via the brain [26].

As of 2011, Smarr et al. identified 147 robots that could assist with activities of daily living (70 for ADLs, 42 for IADLs, and 61 for EADLs). When assisting with ambulation, they either reduce the need to move or support physical movement. "Most of the robots found were developed to support ambulation (an ADL), housekeeping (an IADL), and social communication (an EADL)" [14].

The Center for Technology and Aging lists categories of support for technology that support aging in place. The categories are based on purpose and location, and include: body (support monitoring and management of physiological status and mental health for maintaining wellness and managing chronic conditions), home environment (support monitoring and maintaining the functional status of older adults in their home environment), community (enables older adults to stay socially connected to family, friends, and local communities), and caregiving (support informal and formal caregivers in providing timely and effective care and support). [27] See Figure 23 for examples of technologies in each category.

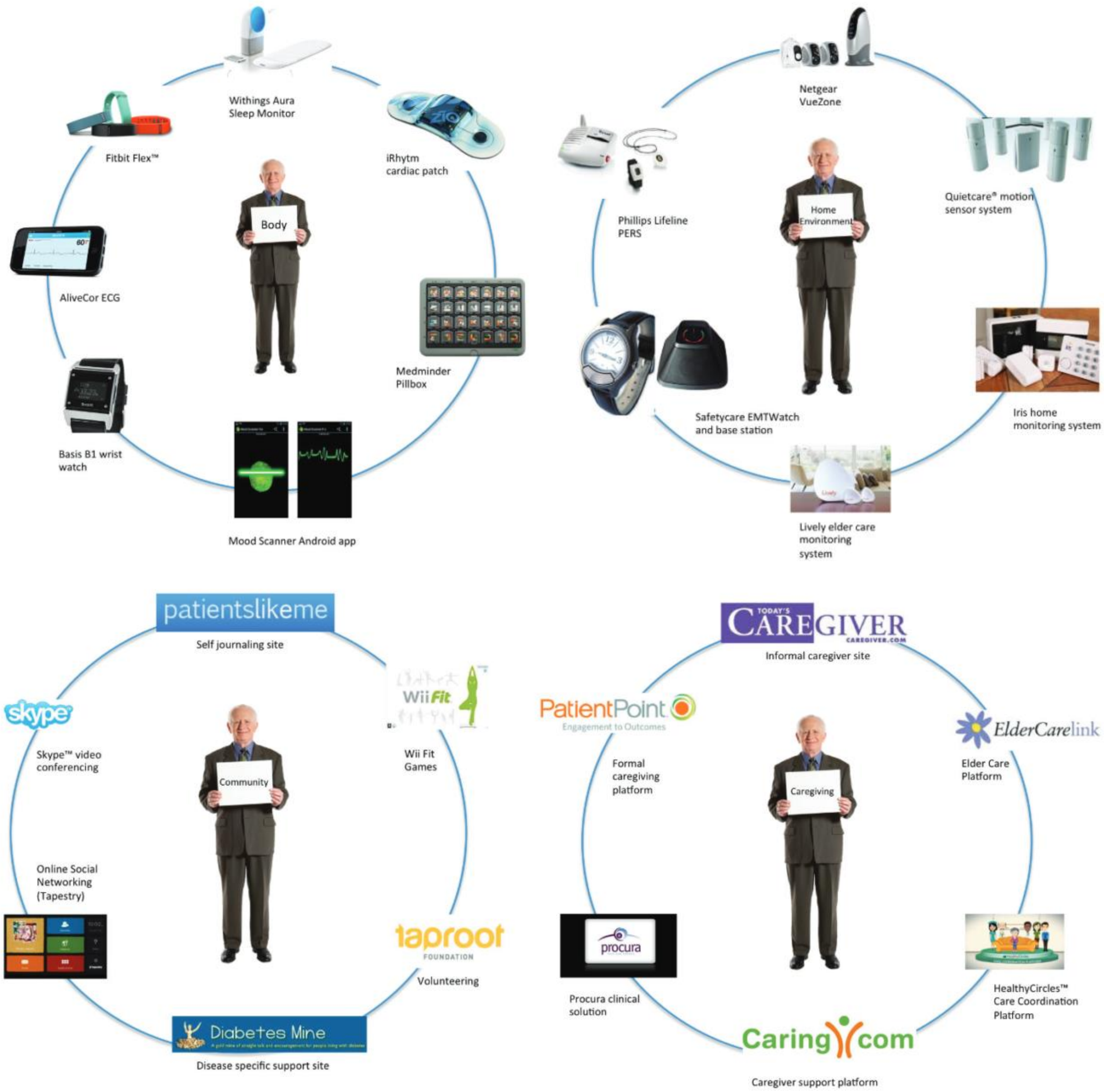

Figure 23 - Connected aging technologies for Body, Home Environment, Community, and Caregiving [27]

"A Roadmap for US Robotics" states that the state-of-the-art in robotics for aging and quality of life improvement include robots that "provide social and cognitive support," that "motivate their users to pursue healthy behaviors, engage them in a therapy program, and provide an easy-to-use natural interface." Challenges include developing models of human behavior, building and maintaining relationships, effective social human-robot interaction and interfaces, manipulation, navigation, and automation [28].

Of course, all of these technologies can be useful for older adults and aid them in their independence. However, many of them do not help the individual in preventing further reliance on the devices in the future, because they are not focused on preventing declinations. That is where we must realize the importance of the preventive perspective.

Preventive roles for technology:

Certainly, some of these aforementioned technologies fit the description of "preventive technology." However, rarely are these interventions discussed in this particular frame of mind, which may result in an understatement of their importance and potential for making an impact towards the goal of aging in place. Discussing these interventions from the perspective of preventive technology and highlighting the ones that have the most potential may help these technologies be more successful and spur further research and development into technologies that can even do it better.

To discuss technology that aids in preventing declinations, it is helpful to determine a categorization method. We can look at the National Prevention Strategy. The seven "Priorities" ("evidence-based recommendations that are most likely to reduce the burden of the leading causes of preventable death and major illness") include Tobacco Free Living, Preventing Drug Abuse and Excessive Alcohol Use, Healthy Eating, Active Living, Injury and Violence Free Living, Reproductive and Sexual Health, and Mental and Emotional Well-Being (Figure 1) [6]. Considering those options, and the age-related declinations that affect older adults' abilities to complete activities of daily living (motor skills, cognitive functions, and the senses), we can distill out the most effective areas for focus. Therefore, I will discuss the roles technology can play in prevention within the categories of physical fitness, cognitive health, and emotional fulfillment.

Physical fitness: This can include the Priorities of Healthy Eating and Active Living, and focuses on the age-related declination of motor skills.

Cognitive health: This can include the Priority of Mental and Emotional Well-Being, and focuses on the age-related declination of cognitive functions.

Emotional fulfillment: This can include the Priority of Mental and Emotional Well-Being. While there is not an associated natural age-related declination, there is evidence that older adults can experience a lack of emotional fulfillment due to age-related circumstances, and that this additionally has effects on physical well-being.

This categorization is further supported by the WHO's definition of health as "complete physical, mental and social well-being" [20], by the definition of "successful aging" as encompassing "low probability of disease and disease-related disability, high cognitive and physical functional capacity, and active engagement with life" [19], and by the HRQOL's categorization of "physical, mental, and social domains of health" [22]. This categorization also echoes the hierarchy comprised of ADLs (basic physical tasks), IADLs (more cognitively demanding tasks), and EADLs (emotionally enriching tasks). Furthermore, many of the causes cited in the studies on factors that help or hinder older adults in maintaining independence ([24], [25]) may be directly or indirectly benefited by positive effects within these categories; to name one example, Dwyer, Gray, and Renwick states that factors that maintain the health of older people include healthy lifestyles; social, emotional, and mental health; and income.

Acceptance by older adults of assistive technology:

It is important to consider if older adults would be open to using such technology in the first place. Acceptance of assistive technology in general is promising, due to the strong desire to age in place.

Peek et al. reviewed factors influencing acceptance of technology for aging in place. They found that acceptance of technology at the pre-implementation stage include:

- Concerns regarding technology (high cost, privacy implications and usability factors)
- Expected benefits of technology (increased safety and perceived usefulness)
- Need for technology (perceived need and subjective health status)
- Alternatives to technology (help by family or spouse)
- Social influence (influence of family, friends and professional caregivers)
- Characteristics of older adults (desire to age in place)

Post-implementation factors include many of the same factors as pre-implementation, but also include satisfaction and affect toward the technology [29].

Peek et al. also investigated reasons that older adults use technology while aging in place. They found six themes for the level of technology use: “challenges in the domain of independent living; behavioral options; personal thoughts on technology use; influence of the social network; influence of organizations, and the role of the physical environment” [30].

Mitzner et al. describes acceptance of robots for the home by older adults. Given 48 different possible tasks, older adults specified whether they would prefer help with such a task by either a human or a robot. Most preferred to be aided by robots in household duties (cleaning, daily chores such as dishes and making beds, miscellaneous jobs like changing light bulbs and recycling, errands like grocery shopping, and laundry/ironing) and manual labor (lifting and moving heavy objects, lawn work, gardening, and repairs such as plumbing and painting), followed by life organization (reminders, household monitoring, and warnings) and object retrieval (locating, delivering, and reaching). They usually preferred human assistance for social, decision-making, and personal or intimate activities such as cooking, grooming hair, shaving, entertaining, bathing, eating, calling family/friends, and dressing [15].

General guidelines for technology designed for older adults:

It is a basic rule of the field of Human-Computer Interaction that design of technology should be done with the user in mind. Due to the special challenges that older adults face, it is especially important that designers of technology know how to tailor the design of their products to make them usable for older adults. Many things are known about design guidelines to help older adults use technology effectively.

Czaja and Lee suggest design guidelines that will create more usable technology for older adults, based on age-related declinations. See Figure 24 for the full list.

Minimize visual clutter (e.g., too much information on a webpage) and irrelevant screen information
Present screen information in consistent locations (e.g., error messages) and where possible provide a standardized format across applications
Adhere to principles of perceptual organization (e.g., natural grouping of information)
Highlight important screen information and ensure that options that are most important or used most frequently are visible and easily located
Provide navigational tools such as a site map or a search history tool
Use icons that are easily discriminated and meaningful
Provide location information indicating where the user currently is within an application
Avoid technical jargon and the use of complex command languages
Minimize demands on working memory (e.g., minimize the need to recall complex operating procedures or provide aids)
Avoid automatically scrolling text
Provide feedback about actions such as task completion or text selection
Avoid complex command languages and use simple and familiar language
Minimize opportunities for error by providing action confirmation prompts (e.g., "are you sure you want to delete this text?")
Provide adaptability and system flexibility for different user levels
Ensure there is adequate time to respond to prompts and queries
Use operating procedures that are consistent within and across applications
Provide easy to use on-line aiding and support documentation

Figure 24 – Interface design guidelines for computer systems for older adults [12]

Schieber et al. state that in order to compensate for vision deficits, interfaces should have increased levels of ambient and task illumination, have increased levels of luminance contrast, minimize the need to perform close-up work, have font sizes of at least 12 points for users older than 60 years or 18 points if users are older than 80 years, use lighting strategies that minimize disability glare effects, minimize dependence on peripheral vision, use marking strategies to enhance motion perception and speed estimation, use large color contrast, and use image processing for optimizing legibility of spatial forms [31].

In order to judge if interfaces are well-designed for older adults, Fisk et al. proposes five characteristics for assessment:

Learnability: how difficult it is to learn to use a device, to understand and to integrate functioning instruction. Time needed to complete a task correctly and results obtained in a certain amount of time are possible measure of learnability.

Efficiency: the extent to which technological applications satisfy users' needs, avoiding loss of time, frustration, and dissatisfaction. It can be measured by an experienced user's performance on a task.

Memorability: older adult users' memorability of a device's functioning is very important in order to avoid frustration and loss of time. A simple measure can be obtained by considering the time need to perform a previously experienced task.

Errors: how easily a product can induce errors for older adult users and how easily it helps them recover from the errors.

Satisfaction: users' attitude and adoption of technological applications could be influenced by the pleasure derived from their usage. [32]

Conclusion:

Based on what we know about age-related declinations, successful aging, assistive technology, preventive roles for technology, acceptance by older adults of assistive technology, and guidelines for designing technology for older adults, we should be able to make the most of our technology and design interventions that help older adults age in place through preventing declinations.

CHAPTER 4: COMPUTING SUPPORTING PHYSICAL FITNESS

Physical fitness is comprised of many factors – most notably physical activity or exercise and proper nutrition. Initially, I will focus on physical activity as a contributing factor to physical fitness because of its importance and the potential for computing technology to support older adults in being more physically active.

Importance of physical activity:

Physical fitness is important at every age. It is especially important for older adults to invest in their physical fitness because of its crucial impact on their ability to remain independent in their everyday lives. Physical activity helps to control weight; reduce risk of cardiovascular disease, type 2 diabetes, metabolic syndrome, and some cancers; strengthen bones and muscles; improve mental health and mood; improve ability to do daily activities and prevent falls; and overall increases chances of living longer. Even if older adults already have difficulties in doing everyday activities, "aerobic and muscle-strengthening activities can help improve [their] ability to do these types of tasks" [33]. The Centers for Disease Control and Prevention (CDC) states that:

> "As an older adult, regular physical activity is one of the most important things you can do for your health. It can prevent many of the health problems that seem to come with age. It also helps your muscles grow stronger so you can keep doing your day-to-day activities without becoming dependent on others." [34]

The CDC recommends that older adults need at least 2 hours and 30 minutes of moderate-intensity aerobic activity (or 1 hour and 15 minutes of vigorous-intensity aerobic activity) each week and muscle-strengthening activities working all major muscle groups on at least 2 days each week. Even greater health benefits can be realized through more activity (i.e., 5 hours of moderate-intensity aerobic activity or 2 hours and 30 minutes of vigorous-intensity aerobic activity each week) [34].

Since aerobic activity is classified as anything that "gets you breathing harder and your heart beating faster," it does not have to be limited to typical "exercise" such as walking or jogging; it can even include activities such as mowing the lawn, dancing, and biking [34].

To reinforce the importance of physical activity, King states:

> “It has become increasingly clear that one of the major public health challenges facing the United States and other industrialized societies is to reverse the patterns of increasing inactivity that threaten the health and functional independence of older adults.” [35]

Furthermore, in discussing the importance of a healthy lifestyle in maintaining health in old age, Dwyer, Gray, and Renwick say “increasing levels of physical activity has been described as ‘today’s best buy’ in public health, because of the significant benefits that can be gained.” This is because:

> “According to a National Health Committee report (National Health Committee, 1998), much of the physical decline associated with old age can be attributed to inactivity rather than the ageing process. The report concludes that between one sixth and one fifth of the 7,800 deaths in New Zealand each year from coronary heart disease, colon cancer and diabetes are attributable to physical inactivity. Physical activity can also reduce other risk factors including obesity, high blood pressure and feelings of depression and anxiety. Moderate exercise also helps build and maintain healthy bones, muscles and joints thereby reducing the risk of falling and also improves older people’s ability to perform daily tasks.” [25]

Yet, the CDC reports that “inactivity increase with age. By age 75, about one in three men and one in two women engage in no physical activity” [36]. For adults aged 65 and older that do exercise, “walking and gardening or yard work are, by far, the most popular physical activities.” [36]. Given the importance of physical activity and its potential to prevent declinations, we need to examine why older adults are inactive.

Barriers, motivators, and interventions for physical activity:

It should be noted that most of the subsequently mentioned interventions can and do serve populations other than older adults, especially because physical fitness is a concern that should be important for every human being if a long, healthy life is of interest. Many are designed for the general population, or at least not with older adults specifically in mind. For all of the interventions, and especially those that are not designed specifically for older adults, it should be considered if they can be better tailored to fit older adults in order to meet their special needs, wants, and concerns more effectively.

Fan et al. describes barriers to older adults not getting the recommended amount of physical activity as being categorized into four themes: *awareness of personal limitations, social motivation, establishing and adapting to routines*, and *finding enjoyable activities*. Knowledge of these barriers can help designers of technological interventions be more successful in helping older adults be more active. Older adults who are aware of their limitations and abilities are more confident in choosing activities and have less fear of falling. Social support and an active social life are important for physical activity as they can facilitate activity partners, cheerleaders, and social comparison or collaboration. Habits are developed when older adults can stick to a routine and find a familiar, predictable route to walk. Enjoyable activities do not have to be classic exercises to provide benefit, and can provide similar social and physical benefits [37].

The authors suggest many intervention concepts that incorporate these ideas, such as activity monitors, finding safe routes, finding activity partners, augmented neighborhoods, finding daily flexibility, finding alternative activities, a robot dog, and informative art. The inactive, unmotivated participants only thought one or two of the interventions would be useful, and these included the interventions that made physical activity fun and playful (alternative activities, robot dog, and interactive art) [37].

Schutzer and Graves found that empirical barriers for exercise in older adults include *health*, *environment*, *physician advice*, *knowledge*, and *childhood exercise*. Poor health (and related reasons of illness, pain, or injury) is the leading barrier cited by older adults. Environment plays a part if resources are not conveniently available; access to sidewalks, parks, recreation centers, fitness facilities, and safe neighborhoods may increase exercise participation. Physician advice is key for older adults:

> "Because lifestyle habits and perceived barriers to exercise are often so ingrained in the older population, long-term maintenance of any newly acquired behavior, including exercise, is a challenge. However, as the aging process continues, the frequency of contact between the elderly and their physicians increases substantially. The elderly, in general, also demonstrate great respect for their physicians. In particular, they hold their doctor's directives as orders 'of higher authority' and subsequently are greatly

> influenced by their advice. Even though barriers to exercise may be present, the older adult may be more likely to overcome these at the urging of their physician. Therefore, the physician and other healthcare providers can be the catalyst in the behavioral change process for the elderly." [38]

Lack of knowledge and understanding of the importance of exercise for health is an important barrier, because many older adults "lived through a time period when exercise was not valued or deemed necessary." Finally, childhood exercise experiences may have an impact on older adults; they exercise less if they were forced by their parents to exercise, or more if they participated in team sports [38].

They found that motivators for exercise in older adults include *self-efficacy, prompts, music,* and *demographics*. The motivators can also be highly related to barriers; declining health, more time, having information about exercise benefits, physician recommendation, and living close to a facility can act as motivators. Self-efficacy ("an individual's belief in their ability to successfully perform a specific behavior") is one of the most critical motivators and is composed of performance experience or mastery, vicarious or observational experiences of others, verbal persuasion, and emotional and physiological states. Self-efficacy is especially important for initial adoption, whereas pleasure, satisfaction, and self-regulatory skills such as goal setting, monitoring of progress, and self-reinforcement are important for sustaining exercise. Prompts such as telephone correspondence have been studied, and it was found that they were as effective as face-to-face interventions in ensuring participation in group exercise programs, and were only needed until adoption was successful. Music can add interest to exercise programs, and reduce "the perceptions of difficulty, monotony, and discomforts associated with exercise." Finally, those "who lead an active lifestyle, were more fit at baseline, have lower body mass, have fewer chronic diseases and pain, were nonsmokers, and have higher levels of self-efficacy" are more likely to adhere to regular exercise [38].

Nigg discusses that technology can have a positive influence on physical activity interventions, especially in "the individualization of interventions on a large scale" (individualized feedback), and "the delivery of activity promoting interventions to large populations via differing channels," such as word, sound, pictures, and short movies. Virtual reality may also provide a unique interactive experience in the future, which could "eliminate the paradox of promoting physical activity through sedentary means (sitting in front of a computer)." Another unique suggestion is that “treadmills or stationary bicycles could be… connected with the TV or stereo. For the residents’ to watch or listen they would need to actually use the exercise equipment.” Nigg points out the growing number of websites dedicated to providing physical activity information and other health-promoting/disease-preventing behaviors, such as WebMD, HealthCentral, National Institutes of Health, etc. Health clubs can also provide information and schedules online, as well as using technology in their facilities for a better experience, such as plugging in to audio-visual components on an exercise machine for a more enjoyable workout. Furthermore, there is potential for tailored exercise programs, education, and online personal training [39].

Chase discussed physical activity interventions for older adults. She found that interventions could be characterized by their content as *behavioral-based, cognitive-based,* or *combination cognitive-behavioral*; intervention delivery and dose were other characteristics.

> “Behavioral interventions introduce observable and participatory physical actions to promote behavior change. Examples include supervised exercise sessions, self-monitoring, and prompting. Cognitive strategies aim to alter or enhance thought processes, attitudes, or beliefs related to a specific behavior in order to achieve behavior change. Examples include motivational interviewing, patient education, barriers to identification and management, and decisional balance activities.” [40]

King discussed studies about physical activity interventions targeting older adults. It was found that behavioral and cognitive-behavioral strategies were most effective: “Effective interventions included those that employed behavioral or cognitive-behavioral strategies as opposed to health education or instruction alone. The majority of these studies utilized a combination of behavioral and/or cognitive tools (e.g., goal-setting, self-monitoring, feedback, support, relapse-prevention training).”

Supervision and group-based formats are most promising: “In addition to using cognitive-behavioral strategies, programs that also used either a supervised home-based format, or a combination of group- and home-based formats typically reported comparable or better physical activity adherence relative to programs that used a class or group format only. Ongoing telephone supervision of the physical activity program (used in 7 studies) was shown to be an effective alternative to face-to-face on-site instruction.” Furthermore, “Structured class- or group-based physical activity formats can result in reasonably high short-term… physical activity participation rates." However, "A substantial proportion of older adults prefer to engage in physical activity outside of a formal class or group, [so] additional alternatives to traditional class approaches will be necessary." Less promising, but still beneficial were other mediated interventions: "The few studies that have used fully mediated approaches such as home videotaped physical activity instruction or instruction via telephone-linked computer systems have shown some encouraging, albeit short-term, results."

It was also found that interventions that supported higher-intensity sessions worked better than those that supported more frequent lower-intensity sessions: "In this study, the higher-intensity (walk/jog) three-sessions-per-week home-based program evidenced significantly better adherence at 24 months than did the lower-intensity (brisk walk) five-sessions-per-week home-based program, although adherence at the end of the initial 12-month period had been identical for the two programs. This finding suggests that the added inconvenience of attempting to exercise more frequently during the week may override any benefits to adherence accrued from exercising at a less-intensive level – an exercise-related parameter that has typically been reported to be extremely appealing to middle- and older-aged adults."

To keep older adults active, telephones have the best results: "Telephone-based strategies for encouraging ongoing physical activity participation, either alone or in combination with group-based formats, have received the largest amount of empirical support." [41]

King also outlined factors to consider for promoting physical activity in older adults. Factors that can influence participation in physical activity can be grouped into categories of personal characteristics, program or regimen-based factors, and environmental factors.

Personal characteristics includes demographics, health, knowledge, attitudes, beliefs about physical activity, psychological attributes, behavioral attributes, and skills, which can affect participation in physical activity positively or negatively.

Program or regimen-based factors includes structure, format, complexity, intensity, convenience, and financial and psychological costs.

Environmental factors includes social and physical environmental factors. Support from family, friends, and staff can help increase activity; ease of access is also very important to increasing activity [35].

In a recent review of how to use technology to promote physical activity, Heyward and Gibson separated such technology into seven categories: pedometers, accelerometers, heart rate monitors, combined heart rate monitoring and accelerometry, global positioning system and geographic information system, interactive video games, and persuasive technology.

Pedometers simply count steps taken by the user, which can happen during walking, jogging, or running, and are fairly accurate. They can also sometimes estimate distance, calories burned, and time spent walking. They note that:

> "Pedometer-based walking increases physical activity… on average, pedometer users increase their physical activity by 27%. A key predictor of increased physical activity is setting a step goal… Pedometer-based walking programs are associated with significant decreases in body mass index, body weight, and systolic blood pressure."

Accelerometers record body acceleration, which provides "detailed information about the frequency, duration, intensity, and patterns of movement," and is used to estimate energy expenditure. It can provide an objective measure of compliance to physical activity recommendations.

Heart rate monitors assess exercise intensity. They can also be used to estimate energy expenditure, though heart rate can be affected by other factors as well (temperature, humidity, hydration, and emotional stress).

Combined heart rate monitoring and accelerometry increases accuracy of energy expenditure by 20%.

Global positioning system and geographic information system are used to "calculate geographic locations and accurately track a specific activity. For example, using a portable GPS unit provides information about altitude, distance, time, and average velocity during hiking. A graph depicting the uphill and downhill portions of the terrain is also provided. GPS can be used in conjunction with accelerometers to assess and monitor physical activity." A geographic information system (GIS) "is a computer system that stores information about location and the surrounding environment. With the use of GIS, the impact of the environment (i.e., its form and design) on physical activity can be assessed."

Interactive video games have perhaps the most room for creativity as technology advances. These include video games that increase energy expenditure like Dance Dance Revolution (DDR), Wii Sports, and Wii Fit. Senior centers have begun to offer these video games in order to promote physical activity, especially because they can be played indoors, alone or in groups, and with little training or skill. They can even help transition someone from being inactive to participating in actual sports and other activities.

Dance Dance Revolution challenges users to complete dance moves on a floor pad, and "has been used to promote physical activity and weight loss in obese children and adults." Wii Sports uses a handheld remote "to detect movement in multiple dimensions while mimicking sport activities," including tennis, golf, bowling, and boxing. These games "increased energy expenditure by 2% compared to sedentary computer games," and "energy expenditure and heart rate were significantly greater in Wii boxing (3.2 METs), bowling (2.2 METs), and tennis (2.4 METs) compared to values in sedentary (1.4 METs) gaming." Wii Fit "offers over 40 training activities categorized into four areas: aerobics (e.g., hula hoops and running), strength training (e.g., lunges and leg extensions), yoga, and balance training." It uses a balance board in addition to the remote controller. "Many fitness centers, senior centers, hospitals, and physical therapy centers are now incorporating this interactive technology into their exercise and rehabilitation programs."

Persuasive technology is "intentionally designed to change a person's attitude or behavior" without them knowing. For example, "tools (e.g., pedometer or balance board), media (e.g., video, audio, or both), and social interaction (e.g., playing with another person)" can be used "to persuade individuals to adopt the behavior without their actually knowing it." The interactive video game "Dance Dance Revolution uses video, music, and a dance platform to capture interest and engage children in the activity without their being fully aware that they are exercising," even though it was not explicitly designed with that intent. "The emerging field of persuasive technology has enormous potential for promoting physical activity and healthy behaviors." [42]

The California Healthcare Foundation discusses if baby boomers (aged 52 to 70 in 2016), as they get older, will adopt the emerging field of technology for self-care, including sensor-based activity trackers, wearable patches, mobile applications, and personal health devices. Mobile technologies can be passive (sensors worn on body used to monitor change in movement and behavior patterns) or active (user applies the device to a problem). However, "market acceptance of health apps has been limited and buy-in from the boomer generation has been slow… only half of boomer smartphone owners have downloaded *any* apps, and the top ones are not related to health." Even though the younger boomers are more likely to adopt wearables, smartphones, tablets, and apps, rates are still low. Some of the reasons may be related to design of the products:

“Too often devices are designed with small, unlabeled or nearly invisible buttons and user interfaces that they may not perceive as intuitive.” Eyesight declinations should be considered: “Far-sightedness requires larger print with contrast. Devices must be readable in both bright and dim lighting. Glare is a big issue for people with cataracts.” Also, dexterity should be taken into account: “Arthritis in the hands impacts ability to manage small buttons and dials. Essential tremors and Parkinson’s affect ability to swipe, pinch, and touch screens.” Other form factors such as size and weight should also be considered, and increasing the number of options available may give the user more control over how their experience can meet their individual needs.

Furthermore, use can be hindered by not knowing how to use it in the first place: “An AARP/Catalyst usability study showed the difficulty boomers have even figuring out how to use an activity tracker. Participants had a hard time finding the directions or syncing the data – and had little desire to continue using the device.” It is very important that design issues like this be addressed, especially given that “Innovators often miss the opportunity to verify the utility of designs and services with willing older adults.” Other issues for adoption are the cost of devices and data plans, access to internet, and privacy and security. Due to these issues, “the fitness wearable market is still in its infancy.” However, there is potential.

In the future, it is hoped that some of these challenges will be met. Including older adult users in design of products will help them be better suited for their use. Pre-configured and loaded devices is one way to help users adopt new technology, as was done in 2015 in Japan when “IBM partnered with Apple to provide iPads to 5 million older adults... Many of the 22 pre-loaded apps focus on health and other services.” Lower-cost internet and data plans will help more people be connected. Data from devices will also be an important part of predicting who needs what care or interventions [43].

Activity tracking:

Recent research and development in interventions has mostly revolved around activity trackers - this may be due to the fact that many devices on the modern market can include most of the factors as outlined by Heyward and Gibson: pedometers, combined heart rate monitoring and accelerometry, and global positioning system and geographic information system; they may even be included in the interactive video games and persuasive technology categories if the designers wanted them to fit those categories. This speaks to the power and potential of activity trackers.

The AARP studied what older consumers think about activity and sleep monitoring devices. They gave 92 older adults one of seven different devices to use over six weeks, including the Fitbit Charge, Jawbone UP24, Lumo Lift, Mistif Flash, Spire, Withings Pulse O2, and Withings Activite Pop. Some of these will be discussed later. Overall, they found that:

> "Trackers showed promise for improving overall health with older consumers but presented some usability issues… Consumers 50-plus care about achieving positive health and avoiding illness and see potential in using activity and sleep trackers toward these goals. Yet tapping this market's full potential requires that usability challenges – such as discomfort and perceived inaccuracy of data syncing – be overcome first."

There was promise that older adults are open to using such devices, and that it would help them live healthier lives:

> "77% of participants reported activity and sleep trackers to be – or have the potential to be – useful. For 71% of participants, the devices made them aware of their activity and sleep patterns in general as well as their activity levels at a given moment. 45% reported increased motivation for healthier living, and 46% reported actually being more active, sleeping better or eating more healthfully."

However, there were issues and frustrations, such as perceived inaccuracies, challenges with instructions, perceived malfunctions (especially in syncing), and discomfort. See Figure 25 for the top recommendations from users on improving activity trackers to meet their needs [44].

Participants' top 10 specific recommendations for device design follow, suggesting that an ideal activity and sleep tracker would:

1. Be able to detect more biometric data (such as blood sugar, heart rate and caloric intake)
2. Feature a more comfortable band
3. Explain how tracking works, so users could feel confident in the accuracy of the data
4. Include a display
5. Be accompanied by better, more detailed instructions
6. Have a nicer-looking design
7. Leverage data monitoring to provide more alerts, such as progress toward goals and identification of a health situation
8. Display time like a watch
9. Be waterproof
10. Report non-health functions

Figure 25 – Top recommendations of older adults for activity and sleep trackers [44]

Many activity trackers, other than the ones used in the study, do feature many of these recommendations. An example will be discussed in the next section. This again points to the importance of constant evaluation with users on all types and forms of activity trackers to ensure options are available to meet their wants and needs.

Preusse et al. also recently studied usability of activity monitoring technologies for older adult users. They found usability issues for both the Fitbit Ultra, which attaches to clothing or a bracelet, and MyFitnessPal.com, a website that tracks diet and exercise. For example, readability could be improved for the Fitbit (although this was improved on the next generation device), and issues with sensitivity and knowing the status of the battery were found. Terminology on MyFitnessPal was confusing, and errors, consistency, and navigation presented challenges. Users wanted customizable reminders when they stopped using the technologies (for example, via email or text message), and quick-start training guides were also wanted. Overall, though, the older adults were positive about the technologies [45].

O'Brien et al. recently studied the acceptability of wristband activity trackers – specifically, the Nike Fuel. A week of training was provided to help users acclimate to using the device. They found that using the device did decrease their waist circumference, but did not improve self-efficacy. The device was easy to use for the participants, and overall the device was accepted as a method for recording physical activity [46].

Current market leaders in activity tracking:

As alluded to earlier, the activity trackers of today come in many different forms and have a ranging selection of functions. The most popular form factor is wrist-worn. These can be integrated as part of a smartwatch (e.g., Apple, Samsung) with functionality outside of fitness (e.g., phone calls, emails, etc.). Alternatively, they can be focused solely or mostly on activity tracking. These can have a screen for displaying information, or they can be in a simple, minimal bracelet form - some of which are designed to look like ordinary jewelry to appeal to users who prefer that look (e.g., Jawbone [47]). Other forms include clip-ons or tracking units that may be transformable into many different forms such as bracelets, necklaces, or brooches (e.g., Bellabeat [48], Amazfit [49]) and rings (e.g., OURA [50]). This points to "smart jewelry" being a recent trend. Furthermore, smartphones can also be utilized to track activity, though they are less closely tied to the activity as wearables.

Functionality can range from simply counting steps (pedometers), to measuring heart rate, tracking GPS, and other ways of measuring activity. Many companies, including Fitbit, Garmin, and Jawbone, provide an abundance of models to choose from. For example, the Garmin vívosmart® HR+ (Figure 26) is a wrist-based wearable that tracks steps, distance, calories, floors climbed, activity intensity (counts activity minutes based on heart rate), heart rate, and pace. It can sync with Garmin Connect Mobile to allow users to join fitness challenges, review data, and receive smart coaching. It also measures sleep duration and quality [51].

It is especially important that fitness trackers for older adults sense heart rate and counts activity minutes, which tie directly into the CDC's recommendation that older adults need at least 2 hours and 30 minutes of moderate-intensity aerobic activity (activity that gets you breathing harder and increases heart rate) or 1 hour and 15 minutes of vigorous-intensity aerobic activity each week. This could be an easy way to ensure they meet these goals reliably and give them confidence that they are doing the right thing for their health. Of the categories discussed by

Heyward and Gibson, this device has six out of the seven categories (all except interactive video gaming). It meets many of the recommendations given by older users that they would want an activity tracker to detect heart rate, include a display, provide progress toward goals, display time, be waterproof, and report non-health functions [44].

Figure 26 - Garmin's vívosmart® HR+ [51]

It is worth discussing other notable wearable trackers at this point, even though their main functional goal is not solely to be an activity tracker. However, often their functionality can be combined with activity trackers, and their extra functionality can be utilized for better overall health.

Lumo Lift is a clip-on magnetic clasp that counts steps, distance, and calories, but that has a main goal of tracking the posture of the user and vibrating if the user slouches. Better posture can lead to better confidence, less back pain, and less stress [52]. This can especially aid older adults, because their spines can become bent and hunched over time. Furthermore, "Better posture will not only help prevent curvature of the spine but may also improve breathing by giving lungs more room to expand, may help protect joints by keeping the spine in alignment and will engage core muscles which support your back" [53].

Spire is a clip-on wearable that counts steps and calories, but that has a main goal of measuring breathing through inhalation and exhalation times, breath rate, deep breaths, and apneic events. If it detects several minutes of tense breathing, it will vibrate to remind the user to breathe deeply, and they can use the companion app to view a library of guided meditations [54].

Lively (Figure 27) is a wrist-worn or necklace activity tracker coupled with an app that provides a many-pronged approach to keeping older adults healthy and safe. The wearable has the added functionality of being a personal emergency response device, and the app provides brain challenges and connection with family [55].

Figure 27 – GreatCall Lively wearable and companion app [55]

Other ways technology can support physical activity:

Technology can also facilitate or provide new ways to be active. As mentioned by Heyward and Gibson, interactive video games and persuasive technology have potential to get older adults moving in novel ways.

Keogh et al. studied the effectiveness of the Nintendo Wii in a nursing home. They found an improvement in physical health-related quality of life, and mention other studies that have also found positive physical results for older adults using the Nintendo Wii [56]. While this is not the setting that is targeted in this thesis, it further points to the importance of considering motivation and rewards for adoption of activity interventions, and an example of the category of interactive video games as used by older adults.

As technology gets more interactive, we can find new categories of interactive video games. Virtual Reality (VR) systems are just beginning to emerge into the consumer market. While they are still in their infancy and not yet very cheap, there may be potential of VR for supporting physical fitness of older adults in the future. However, VR sickness can be a challenge for any user of VR, and it should be determined if deterrents such as this, as well as safety concerns such as balance, will keep older adults from utilizing future iterations of this technology. It is yet to be seen if advancements in this technology will make it a viable product for older adults, and research should be done on this issue. However, if it is viable, possibilities can be endless in the sense that VR can envision any kind of interactive video game imaginable; personalization to interests and needs can be utilized to make the experience engaging, enjoyable, and persuasive.

Mixed and augmented reality technologies are another option for facilitating more physical activity, especially through interactive video games. The recent phenomenon of Pokémon GO effectively changed the behavior of many users who are less active than average to get outside and walk around their neighborhoods and towns in the pursuit of virtual Pokémon [57], [58]. Long-term engagement is questionable, but:

> "Pokémon GO has shown us the potential of augmented reality to impact behaviors at a scale that just a few years ago would have been impossible. This early data from Achievemint offers the best glimpse to date into these healthcare tools of the future. Learning how we can transform the excitement and energy around technologies like Pokémon GO into validated and sustained physical and mental health benefits is both the challenge and opportunity ahead." [58]

While this app was targeted towards younger generations, it is an example of successful activity facilitation (at least in the short-term) that we can learn from and hopefully apply to older adults.

Other areas for intervention:

The focus of this chapter has been on technology that supports physical activity, especially due to its current untapped potential in mitigating declinations. Of course, physical fitness should not be limited to only include physical activity. There is also room and potential for technology to provide benefits in other important areas that support overall physical fitness and health – especially in nutrition, medication adherence, and general healthcare.

Nutrition:

Of older adults living in the community, 6% are malnourished and 32% are at risk of malnutrition [59]. Figure 28 explains the effects that aging has on nutrition and therefore why so many older adults may be malnourished.

EFFECTS OF AGING ON NUTRITION	
Change	→ ***Effect***
Sensory Impairment	
• Decreased sense of taste	→ Reduced appetite
• Decreased sense of smell	→ Reduced appetite
• Loss of vision and hearing	→ Decreased ability to purchase and prepare food
• Oral health / dental problems	→ Difficulty chewing, inflammation, poor quality diet
Altered energy need	→ Diet lacking in essential nutrients
Decreased physical activity	→ Progressive depletion of LBM and loss of appetite
Muscle loss (sarcopenia)	→ Decreased functional ability, assistance needed with ADLs
Psychosocial (isolation)	→ Decreased appetite
Environmental (financial)	→ Limited access to food; poor quality diet
Cumulative Effect	→ ***Progressive Undernutrition***

Figure 28 – Effects of Aging on Nutrition [60]

Diet journals such as MyFitnessPal.com can help older adults keep track of their nutrients, to ensure that they are meeting their nutritional needs from an objective viewpoint. Once the user logs their meal, they can see how they measure up to their nutrient needs in terms of carbohydrates, fats, protein, sodium, sugar, cholesterol, potassium, fiber, vitamin A, vitamin C, calcium, and iron [61].

Meals on Wheels has been a very successful program - it is "the oldest and largest national organization supporting the more than 5,000 community-based senior nutrition programs across the country that are dedicated to addressing senior isolation and hunger” [62]. Of seniors that are served by Meals on Wheels, 83% say it improves their health and 92% say it enables them to remain living at home [62]. While some of those effects can be attributed to the friendly visits and safety checks provided when volunteers deliver the meals, we know that nutrition can be a challenge for older adults and therefore any steady source of balanced nutrition is something that can contribute to successful aging. We can be inspired by this successful model and look to other services that can also provide such benefits.

Amazon Fresh allows users to shop online for groceries you would typically find in a grocery store, including fresh foods such as fruits, vegetables, meat, seafood, bakery products, frozen foods, dairy, deli, prepared foods, and local products, as well as household, health, and beauty products, and more. Groceries are then delivered to your door in a chilled tote at a scheduled time. Users can even use a small device called Dash to scan items or speak to add items to their cart. It is currently available only in select cities [63].

Amazon Prime Now has less selection in groceries than Amazon Fresh and is also only available in select cities, but can deliver groceries, household items, electronics, essentials, and more to your door in just two hours. Users can also order from some restaurants and local stores within one hour [64].

Amazon Prime Pantry is more widely available, and allows users to order pantry-type products (no fresh foods) as well as household items to be delivered to their door [65].

Other grocery delivery services include Google Express [66] and Instacart [67], and many traditional grocery stores such as Safeway also offer online shopping and delivery [68].

Online meal kit delivery services can be under $10 per meal and provide users with an easy way to eat gourmet, nutritionally balanced meals (some are even verified by a dietician). Blue Apron [69], HelloFresh [70], and PeachDish [71] are popular options for this service that send users exactly portioned fresh ingredients with instructions for preparation, in a refrigerated shipping box. Users choose the meals they would like to make online, and meals can be ordered individually or as part of a meal plans.

Dehydration can be a concerning issue in older adults. Not only does aging lower the body’s hydration level and renal (kidney) function, but older adults also have a lower perception of thirst. Diseases, medications, and activity levels can also play a role in dehydration [72]. This is important because of the key role hydration plays in keeping every part of the body functioning properly. Over the past few years, numerous “smart” water bottles have hit the market – water bottles embedded with sensors that track your water consumption and displays that notify you of your progress, as well as connection to your smartphone for a bigger picture. For example, the Moikit Seed tracks water consumption through measuring the amount of air in the bottle, and has an LED display built into the cap to let you check your daily water consumption and how much more you should drink, in the form of a percentage. It will vibrate if you have not taken a drink in while, according to a custom-designed intake schedule based on water intake, body composition, activity level, and temperature, to help you remember to stay hydrated throughout the day and meet your needs. It also informs you of the water temperature and alerts you to hot or stale water, has a year-long battery life, and is compatible with Apple HealthKit [73].

Medication adherence:

Medication adherence is especially important for older adults in preventing the exacerbation of health issues that already exist. Taking medications at the right time and in the right amount is challenging for 40% to 75% of older adults, due to number of medications and providers, as well as physical and cognitive challenges and lack of knowledge. This accounts for “26% of hospital admissions, almost 25% of nursing home admissions and 20% of preventable adverse drug events in community settings” and results in estimated 125,000 years each year [74].

Numerous studies and interventions have been aimed at this problem because of its importance and impact. Costa et al. discusses current interventional tools for improving medication adherence. They found that these include interventions that are behavioral, educational, integrated care, self-management, risk communication, or packaging and daily reminders. Technological interventions include telephone follow-ups (behavioral), which seem to work well; technological self-management interventions include telephone support/counseling, telemedicine/telehealth/home telecare/telemonitoring, web-based interventions/interactive computerized health communication, and cell phones/text messaging. Success varies by health issue overall, but mobile phones and text messaging showed strong evidence of success. Daily reminders can also be technological, and include phone calls, text messages, pagers, interactive voice response systems, video telephone calls, and medication boxes. This category is very successful, as “all studies have showed that reminder in any variation and reminder packaging have a positive impact on medication adherence and often also on clinical results” [75].

With the use of robots, medication can also be directly delivered to the user in their home. However, most robots for medication delivery take the form of humanoid robots that are expensive and cumbersome. As mentioned previously, ASPIRE aims to fix this issue through the use of inexpensive, agile drones that deliver medication directly to users.

General health and healthcare management:

General fitness apps and suites are rapidly saturating the mobile app market. Users can find apps for everything from general health management (Google Fit, S Health for Samsung), to nutrition apps, exercise apps, habit and goal tracking apps, health tip apps, and more [76]. Users also want to use them:

> "Many consumers want to avoid costs by monitoring their own health, and a $26 billion projected global market of mobile health apps will be there to help them do so by 2017… Today there are at least 100,000 self-care health apps available for smartphones/tablets. Well-known ones include apps for diabetes tracking of blood sugar or foods eaten; medication reminders, especially for complex regimens; and activity encouragement." [43]

Kim et al. reviewed how older adults can use mobile phones in healthcare management. They found that categories include:

Health management with mobile phones, which include telemonitoring and telecoaching, transfer of medical information, scheduling hospital visits and medication compliance, increasing drug compliance and treatment adherence, and life-support system for the single-family elderly.

Monitoring health status with medical devices and biosensors, which include glucometer and sphygmomanometer, calorie calculator, activity tracker, acceleration sensor, portable ECG, and other sensors.

Difficulties encountered include physical and cognitive changes due to aging, and the difficulties of using a mobile phone and a decline in learning capabilities.

There is also potential for using mobile phones as health coordinating centres, by integrating various sources of information, like from wearable sensors. However, for older adults, it is especially important that this is done in a way that is easy for them to use, and that the feedback is easily understandable [77].

Telehealth technology has the potential to aid users in many different ways, and hospitals are incentivized to adopt such technology in order to reduce costs. For example, Philips offers home telehealth technology that targets complex care management, chronic disease management, and readmission management, which all "provide daily connection between post-acute caregivers and patients, utilizing technology and clinical process to expand access, improve outcomes and provide a better experience for patients." The goal is to change from reactive treatment to proactive health management. The technology used includes a clinical dashboard used by clinicians to track their patients, a patient app in which patients can log their daily health status, and tools for measuring vitals at home (scale, blood pressure, pulse, blood sugar) that are easy-to-use and automatic [78].

Other telehealth providers include Doctor on Demand [79], Teladoc [80], and American Well [81], which can be used to initiate a session with a doctor over the web in minutes, and may save unnecessary trips to emergency rooms. As the California Healthcare Foundation states, "Interest is growing. Video consultations are expected to reach 158 million per year by 2020" [43].

Telehealth necessarily utilizes connected devices, allowing ordinary users to check their vital signs in their own home. Users can also use some of these regardless of if they are involved in telehealth. A popular example is smart scales that connect to your chosen health management app, such as the Fitbit Aria, which tracks weight, BMI, lean mass, and body fat percentage, and wirelessly syncs to Fitbit's app to display stats and trends [82].

Conclusion:

This chapter has illustrated the many ways in which computing technology can aid older adults in preventing declinations in their physical fitness – specifically through physical activity, nutrition, medication, and general health.

CHAPTER 5: COMPUTING SUPPORTING COGNITIVE HEALTH

Cognitive declinations may be more difficult to directly address than physical declinations, but they are also crucial to maintaining independence. High cognitive functional capacity is cited as a main component of successful aging [19]. Cognition can include "paying attention, learning and reacting to objects in the environment, and using language and memory. If cognition becomes impaired, an individual may have difficulty performing everyday tasks" [83].

Kueider et al. also states the importance of keeping mentally sharp to older adults, and that something can be done about it:

> "Older adults are more likely to fear losing their mental abilities than their physical abilities. But a growing body of research suggests that, for most people, mental decline isn't inevitable and may even be reversible. It is now becoming clear that cognitive health and dementia prevention must be lifelong pursuits, and the new approaches springing from a better understanding of the risk factors for cognitive impairment are far more promising than current drug therapies." [83]

Rowe and Kahn explain that "evidence is accumulating to indicate that [cognitive function] can be enhanced in old age" – this is due to plasticity:

> "The capacity for positive change, sometimes called plasticity, persists in old age; appropriate interventions can often bring older people back to (or above) some earlier level of function… the same interventions may be still more effective with younger subjects, which suggests an age-related reduction in reserve functional capacity. These demonstrations of plasticity in old age are encouraging in their own right and tell us that positive change is possible." [19]

In order to address these cognitive declinations, puzzles such as crosswords and Sudoku have been popular, and recently, there has been a push towards computerized "brain games."

It has been shown recently that these brain-training interventions likely do not improve cognitive health. Results from an extensive review detailed in Simons et al. states:

> "We find extensive evidence that brain-training interventions improve performance on the trained tasks, less evidence that such interventions improve performance on closely related tasks, and little evidence that training enhances performance on distantly related tasks of that training improves everyday cognitive performance." [84]

However, it has been found that brain-training interventions may postpone declinations - which, for the purposes of maintaining independence, is extremely valuable and enough of a reason to employ them. Maintaining current levels of cognitive health is always desirable if the alternative is for cognitive health to decline. McCabe et al. states:

> "Closer inspection indicates that training 'improved' intelligence or academic achievement relative to the control condition because the control group *declined* from the pretest to posttest – that is the training group did not significantly change from pretest to posttest." [85]

Interventions:

Kueider et al. studied computerized cognitive training interventions for older adults, and found that:

> "Overall, findings are comparable or better than those from review of more traditional, paper-and-pencil cognitive training approaches suggesting that computerized training is an effective, less labor intensive alternative." [86]

They classified the computerized programs into three groups:

Classic cognitive training task interventions included those that are targeted in training processing, memory, attention, and perception. They "improved reaction time, processing speed, working memory, executive function, memory, visual spatial ability, and attention."

Neuropsychological software interventions included those that test and enhance multiple domains of cognition, and they "appear to positively impact cognitive performance."

Video game interventions included games that were not originally designed for improving cognitive abilities. These include Rise of Nations, Medal of Honor, Pac Man, Donkey-Kong, Tetris, and Atari games. Nintendo Wii's Big Brain Academy was the only game tested that was designed for improving cognition. They "appear to be an effective means of enhancing reaction time, processing speed, executive function, and global cognition in older adults" [86].

Lumosity is one of the most well-known and publicized interventions, and offers over 50 cognitive games to subscribers. Users start by getting a baseline "Fit Test" score on a set of three games (speed, attention, and memory), and then complete daily workouts of five core cognitive abilities (speed, memory, attention, flexibility, and problem solving) that are tailored to their skill level. Users can track their scores and see insights on their statistics, strengths, weaknesses, and progress [87].

The Aging Well Program is a brain game site made specifically for older adults – "designed for those diagnosed with Mild Cognitive Impairment as well as healthy seniors who may be concerned about their cognitive abilities." Users are encouraged to train for 30 minutes per day, 5 days a week for ideal positive outcomes. User compliance and progress can be made visible to a therapist, if needed. Games are organized into five different modules: memory, executive functions, attention, language, and visual and spatial abilities. It has been involved in fourteen clinical studies from 2001 to present day, and reports positive results such as "40%+ improvements in various cognitive skills performance," "+12% average improvement in 18 weeks," "14% improvement in key skills," and more [88].

CogniFit has many targeted, customized programs to meet a variety of needs and to measure, train, and monitor cognitive skills. A Cognitive Assessment Battery, which is a complete neurocognitive test, is available, as well as many other specific assessments for issues such as ADHD, depression, driving, dyscalculia, dyslexia, and Parkinson's. A personalized brain training program is created to meet the needs of the individual. Physicians can also design and monitor the intervention for their patients [89].

Lifelong learning is more accessible than ever due to the internet, and "evidence has shown that lifelong learners experience slower brain deterioration than their peers who stop learning in their twenties. Actively pursuing new learning opportunities throughout your entire life can have a positive impact on your mental, social, and economic well-being" [90]. Dwyer, Gray, and Renwick state: "studies have also found that it is possible to slow down or even reverse mental decline associated with ageing through education and training" [25]. Older adults have started to show an interest in online courses – edX reports that 10% of their 1.03 million learners are over 50 years old, and 4% are over 60 years old, and FutureLearn reports that 17% of their 1.2 million learners were 56-65 years old, and 9% were over 66 years old. As an added benefit, online courses may even help ease loneliness for older adults [91]. For these reasons, MOOCs are starting to be seen as an intervention for older adults, and attention is starting to shift towards their needs:

> "The MOOC learning experience of older learners is a crucial missing piece of the MOOC puzzle, an oversight in this era of profound demographic change. Concentrating on accessibility for older learners is important for many reasons, as this group may experience multiple barriers to MOOCs including challenges using technology, auditory and visual decline, and cognitive decline. However, this group may reap the most benefits from MOOCs, and thus deserve to be included in discussions. Given that the over 80 demographic is the fastest growing demographic in the country, as well as the most at-risk for social isolation, cognitive decline, and hearing and vision loss, the MOOC-as-intervention is an especially interesting concept to explore in further research. Potential benefits of MOOCs and the older learner may include advantages for homebound older adults who are able to remain intellectually stimulated and socially engaged as well as the neurocognitive advantages of continuing to learn stimulating new skills and knowledge, such as navigating technology and the multitude of subject areas MOOCs offer." [92]

With more free courses available online than ever, this is a great opportunity to help keep the minds of older adults active. Massive open online course (MOOC) websites including Coursera, edX, and FutureLearn offer thousands of options. Hundreds of universities, even as prestigious as Harvard and Stanford, provide these quality options for free to anyone with an interest and time to dedicate. Furthermore, databases of these online courses help users navigate and find a course that interests them, such as the Open Education Database (OEDb), which collects over 10,000 online courses each year [93].

Technology can also help older adults learn things in a more casual way. For example, learning a new language has never been easier. Duolingo is a free app that lets English-speaking users learn any of the 27 offered languages. Lessons are also provided for non-English-speaking users. Users complete daily "bite-sized" gamified lessons and level up to show their progress, and progress deteriorates if they have not logged in for a while to encourage adherence. Users learn to read, write, listen, and speak the language, and a study has shown that 34 hours on Duolingo is equivalent to a semester at a university [94].

Staying Sharp (Figure 29) is a website provided by AARP that provides interventions and information that span the "five pillars of brain health": relax (managing stress and getting enough sleep), discover (learning new skills, taking on challenges), connect (stay socially connected), nourish (eating smart), and move (keeping fit). The website provides users with a brain health assessment, articles with information pertaining to all five pillars, exercises to try, recipes to make, brain games, personalized recommendations, and tools for tracking progress [95].

Figure 29 – Staying Sharp by AARP spans five pillars of brain health [96]

Physical fitness supports cognitive health:

Bherer et al. reviewed the effects of physical activity and exercise on cognitive and brain functions in older adults. They state that, while it is still not certain whether broad physical activity or exercise have the same benefits for preventing age-related cognitive decline or even at what rate the impact occurs, we do know that "physical exercise is a promising nonpharmaceutical intervention to prevent age-related cognitive decline and neurodegenerative diseases" [97].

The CDC also makes a statement about the between physical activity, fitness and cognitive function:

> "Research has shown that physical activity can affect the physiology of the brain by increasing cerebral capillary growth, blood flow, oxygenation, production of neurotrophins, growth of nerve cells in the hippocampus (center of learning and memory), neurotransmitter levels, development of nerve connections, density of neural network, and brain tissue volume. These changes may be associated with improved cognitive functions including attention, information processing, storage, and retrieval, enhanced coping, enhanced positive affect, reduced sensations of cravings and pain." [98]

Hesseberg et al. also found support for a "strong negative association between cognitive impairment and different aspect of physical fitness":

> "The results support the need for a focus on physical fitness and functioning in older people with MCI [mild cognitive impairment] and early dementia living in the community. Maintaining adequate physical fitness among people who are diagnosed with MCI and dementia may help them to live longer in their own home and reduce the burden of their care takers. Thus, the results suggest that focus on physical activity and physical fitness after the diagnosis may be of importance." [99]

Rowe and Kahn state that "exercise might enhance central nervous system function, particularly memory function," and that "the amount of strenuous physical activity at and around the home was an important predictor of maintaining cognitive function" [19].

Therefore, we can expect that any intervention aimed to support physical activity in older adults may also have positive effects in supporting their cognitive health.

Furthermore, nutrition also supports cognitive health [96], so interventions supporting better nutrition may also support cognitive health.

Social interaction supports cognitive health:

Yeh and Liu found from a large study of 4993 older adults that older adults with greater social support had a higher quality of life as a result of higher cognitive function, and state that “several studies have provided evidence of an association between social support and cognitive function,” both in community-living older adults and those that live in a nursing home. A social network can also lower the chance of dementia. The inhibition of cognitive decline is thought to be due to the “challenge of effective communication and participation in complex interpersonal exchanges.” Furthermore, they state that “research has also shown that social role involvement and personal control were factors not only in slowing age-related decline in physical health, but also in reducing levels of ADL disability,” and they found that IADLs were negatively related to cognitive function. They recommend “social activities for the elderly to promote a better quality of life” [100].

Berkman also explains why social-network structure and social engagement (whether or not older adult are alone, which is distinct from simply living alone), has an impact on cognitive function:

> “Social engagement probably challenges people to communicate effectively and to participate in complex interpersonal exchanges. Such a dynamic environment is likely to engender the mobilization of cognitive capacities, setting in place a ‘use it or lose it’ phenomenon so important to successful ageing. Social engagement also promotes commitment to community and family, provides a sense of purpose and fulfilment that rests on the bidirectionality of commitments.” [101]

Another interesting point is that satisfaction with social engagements may be more important than frequency: “risks are higher among those having unsatisfactory contact with children than among those having no children at all.” Also, being single, whether or not the older adult lives with other people, predicts the highest risk [101].

Therefore, we can expect that any intervention aimed to support social interaction in older adults may also have positive effects in supporting their cognitive health. We will further explore the importance of social interaction in the next chapter.

Conclusion:

This chapter has illustrated the many ways in which computing technology can aid older adults in preventing declinations in their cognitive health – specifically through brain training games, online courses, physical fitness, and social interaction. This chapter in particular has especially highlighted the degree to which all the components of successful aging are interconnected. Interventions supporting one area of successful aging may well have positive effects for other areas of successful aging, even if indirectly. This further underscores the potential for interventions that support any of the areas discussed in this thesis.

CHAPTER 6: COMPUTING SUPPORTING EMOTIONAL FULFILLMENT

Meeting basic needs through physical and cognitive functionality creates an unquestionable foundation for successful aging. However, even with these components covered, we can still be lacking life – or the things that make life seem to be worth living. This can in fact take a physical toll on the body.

Loneliness causes declinations in older adults:

It is a known phenomenon that older couples sometimes die “together” – one closely following the other - and that it is no coincidence. Hart et al. states that “bereaved participants were at a higher risk than non-bereaved participants of dying from any cause” following the death of their spouse [102]. This is called the “widowhood effect,” and “is one of the best documented examples of the effect of social relations on health.” Older adults may be between 30% and 90% more likely to die in the first three months following the death of their spouse, and 15% more likely after that [103].

“Resilience” from bereavement of a spouse can be improved by reliable comfort, social connectedness, and daily functioning [104].

Spousal bereavement is a specific example of how loneliness can directly and indirectly influence the physical health of the older adults. Furthermore, the problem of loneliness of older adults in general is a wider issue that must be addressed, especially in relation to emotional fulfillment. The Administration on Aging states that:

> “About 28% (12.5 million) of all noninstitutionalized older persons in 2014 lived alone (8.8 million women, 3.8 million men). They represented 35% of older women and 19% of older men. The proportion living alone increases with advanced age. Among women aged 75 and over, for example, almost half (46%) lived alone.” [23]

In general, “isolation and lack of connectedness to others have been recognized as predictors of morbidity and mortality,” not only for older adults but for people of all ages – “being part of a social network is a significant determinant of longevity, especially for men” [19].

Perissinotto et al. examined how loneliness in older adults are predictors of functional decline and death. Loneliness predicted many things, including a decline in ADL, difficulties with upper extremity tasks, decline in mobility, and difficulty climbing; furthermore, it was "associated with an increased risk of death" [105].

Holt-Lunstad et al. also found that there is a "50% increased likelihood of survival for participants with stronger social relationships," consistent regardless of age, sex, initial health status, cause of death, and follow-up period. It may even be comparable to quitting smoking in effect, and "it exceeds many well-known risk factors for mortality (e.g., obesity, physical inactivity)" [106].

Rubio et al. reinforced that "participation in recreational activities as part of a community may delay the onset of the dependence associated with ageing," with the resulting model having a predictive value of between 88% and 92% [107].

Also, Dwyer, Gray, and Renwick state that: "there is a consensus within research that the presence or absence of family support is a prime factor in determining whether or not an older person continues to live independently" [25].

With loneliness being such an important factor in the health of older adults, it becomes apparent how important it is for older adults to make connections with other people – especially with their loved ones.

***Interventions that support connection*:**

Coelho and Duarte state that "the main way to fight isolation is satisfying social needs through participation in social networks." In fact, "a growing body of evidence suggests there are many social and cognitive benefits for older adults when they use technology to create content and actively participate in reciprocal information-sharing with family and friends." They recently surveyed the research on older adult use of social network services (SNSs), which allow users to create a self-descriptive profile, connect with other users, and view and traverse their list of connections. The authors found that there is much room for improvement in designing SNSs to meet the needs and wants of older adults. Recommendations for improvement cover thirteen different dimensions:

Family: SNSs need to better support the maintenance of family relationships, support traditional forms of expressing family engagement, provide a family group with its own setting, and support family-related functionalities.

User interface: SNSs should have a user interface that is as simple as possible, that acts as a catalyst, that contains easy-to-understand language instead of computer jargon, and that provides easy-to-understand privacy options and multimodal interaction.

Privacy: SNSs should have an interface focused on facilitating the discovery and access to privacy settings, should change default settings to be more private and give options to gradually reach more contacts or groups, and should tailor privacy settings to fit each mode of communication or interaction.

Photos and media relevance: SNSs should automatically upload photos associated with events and family, provide interaction around photos, support combined media items which make use of photos and audio, and provide short-clip sharing through the direct use of the device's camera.

Multimodality: SNSs should make alternative modalities of interaction non-instructional, should have interactions that are automatically associated with functionalities, should keep traditional ways of interaction as the main interaction mode, should provide gestures as an alternative for spatial and navigation tasks, should provide speech as an alternative for text input tasks, and should adapt availability of modalities to each user.

Direct communication: SNSs should make chat a central role, create incentives for more direct communication, have direct forms of communication capable of capturing both the permanence of asynchronous exchanges and the interactivity of synchronous play, support or increase the visibility of video-chat features, and avoid the creation of new social obligations.

Knowing new people: SNSs should highlight acquaintances over "new friends," provide appropriate terms when referring to individuals the user does not know, and provide options for avoiding friend suggestions and unsolicited emails.

Personalization and adaptation: SNSs should support an interface with adaptation mechanisms, adapt the display of content so users can be prompted to interact with individuals who may benefit from direct communication, resurface or prioritize information as a means of stimulating communication, and adapt the interface to distinct older adults' user profiles.

Grouping: SNSs should provide group-specific functionalities or options, simplify a feature's access focusing on frequency of use, and give the option of naming each group.

Tangible value: SNSs should support the transmission of handwritten messages as a type of media, provide a "letter writing" mode or look-and-feel for sharing functionalities, and support features that enable the virtual representation of real artifacts.

Offline role: SNSs should give attention to functionalities related to events, incorporate phone numbers into SNS contacts, and generate or promote local events close to the user.

Gender: SNSs should not target genders differently.

Reciprocity: SNSs should design features which enable reciprocity and multi-use, evidence and resurface content capable of stimulating communications, and adopt different ways of interaction for each type of user [108].

Braun studied obstacles to social networking website use among older adults. He found that significant predictors of SNS use were perceived usefulness, trust, and frequency of internet use; ease of use and social pressures were not found to be significant predictors (though ease of use has been found to be a factor in the past with older adults and technology, so this may be a result of the sample being comprised completely of internet users). To measure perceived usefulness of SNSs, users were asked to answer questions such as: "Social networking websites allow me to keep in touch with family and friends more frequently.", "I find social networking useful for keeping in touch with friends.", and how much they fit into their lifestyle. To measure trust, users were asked to answer if they thought SNSs were honest, dependable, and concerned about privacy, and if it was safe to share information on them [109]. Therefore, implementing some of the suggestions made by Coelho and Duarte may help reduce or remove the obstacles of perceived usefulness and trust.

Vosner et al. studied the attitudes of active older Internet users towards online social networking, and found that active older internet users do use online social networks often to maintain social relationships and to prevent loneliness (Figure 30). Most participants (92.6%) reported not feeling lonely or isolated, and 38.5% said they felt less lonely because they use online social networks. They found that "participants mostly use online social networks for the following purposes: to write messages (30.8 per cent); to participate in online chat-rooms (26.9 per cent); to write comments (13.5 per cent), and to find new or old friends (11.5 per cent)." Use was relatively evenly spread between Facebook and Skype - Facebook was used most frequently by 44% of users and Skype by 42%. Interestingly, participants between 55 and 64 years old mostly use Facebook, while those between 65 and 74 years mostly use Skype. They note that of older adults that use the internet, 46% use Facebook, which represents 27% of the entire population of older adults. Skype use was fairly frequent – 63% of participants use it, 20.4% use it 2-3 times per month, 29.6% use it once a week, and 13% use it every day; furthermore, “a positive correlation was found between age and the frequency of Skype use.” However, it is important to note that older adults usually must be proficient in web use and social media concepts in order to successfully use online social networks [110].

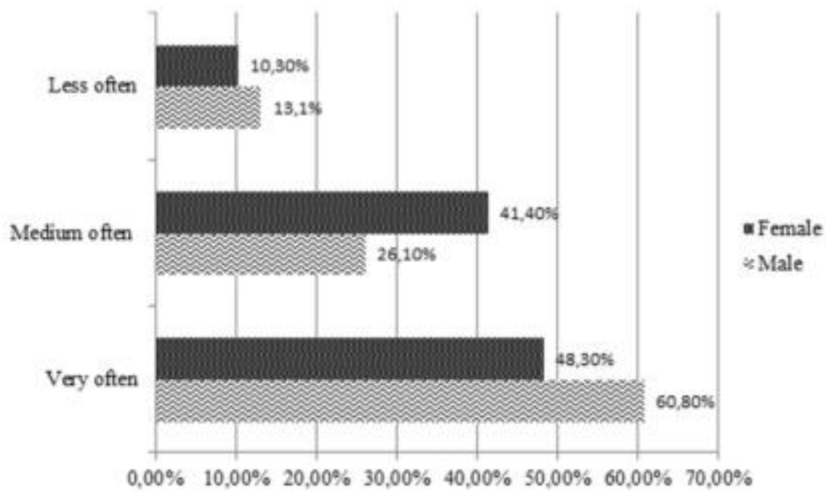

Figure 30 – Frequency of online social network use. Very often indicates several times a day and medium often indicates once a week [110]

Grieve et al. studied whether Facebook connectedness is comparable to offline social connectedness. They found that while “Facebook connectedness [is] distinct from offline social connectedness,” there are still positive outcomes from using Facebook related to anxiety, depression, and subjective well-being. They found that “Facebook use may provide the opportunity to develop and maintain social connectedness in the online environment, and that Facebook connectedness is associated with lower depression and anxiety and greater satisfaction with life” [111].

Rodriguez et al. designed and built a home-based communication system for older adults and their remote family – specifically for families split across the border of Mexico and the US. Their system allowed users to share information, personal reminiscences and stories, which was perceived by older adults as "a richer, natural form of communication with their relatives that could facilitate their integration into the networks that currently connect members of their families." Their findings for design guidelines were that future systems should "provide dual interfaces with the same interaction metaphor for presenting messages," "provide simpler and more intuitive user interfaces," and "streamline the capturing process" [112].

The GrandPad (Figure 31) is a tablet device that is notable for its ability to help connect older adults to family and friends. Its design is targeted to allow it to be easily used by older adults. It allows them to make phone and video calls, use email, see and share pictures and videos, listen to music, play games, and view weather. Its functionality is limited to these pre-setup features, but this allows the older adult to be confident in their ability to use the device. Furthermore, purchasing access to the device includes access to a helpline for any difficulties with the device [113].

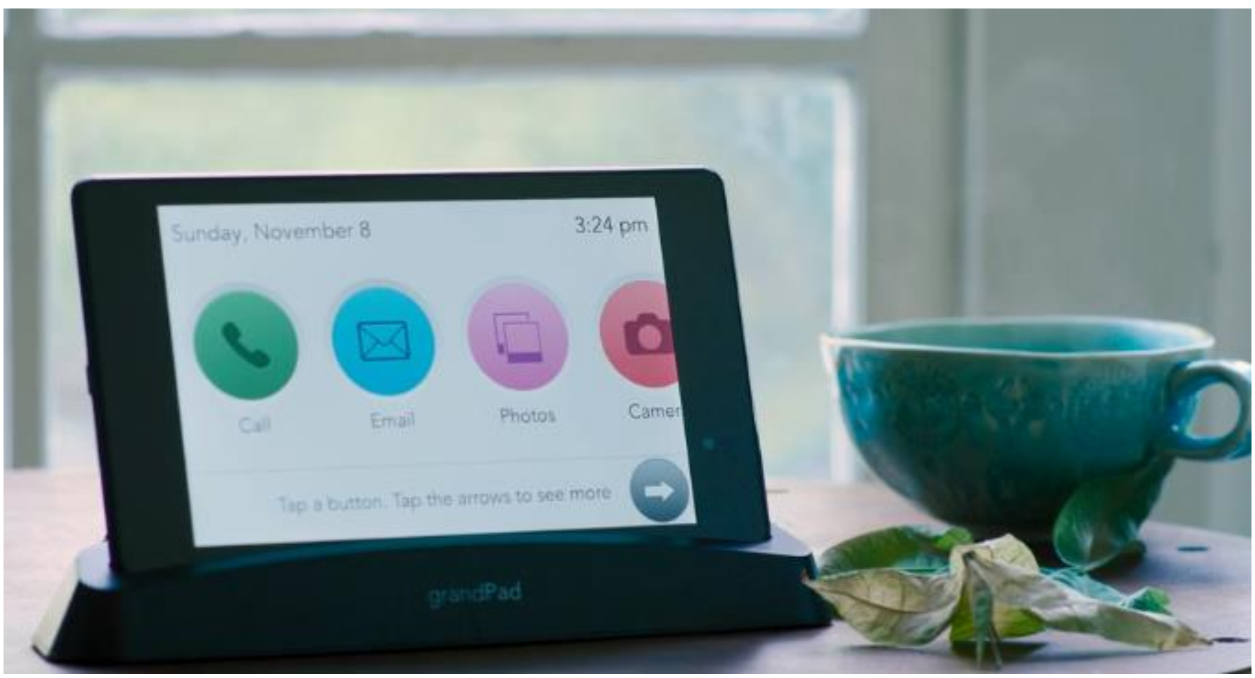

Figure 31 – GrandPad [113]

Unfortunately, connecting with family and friends is not always an option, even with interventions available. Therefore, The Silver Line is a free helpline in the United Kingdom that can be called by any older adult seeking conversation and friendship. Employees can "offer information, friendship and advice; link callers to local groups and services; offer regular friendship calls; and protect and support older people who are suffering abuse and neglect." By signing up for friendship calls, users can have a weekly call with a volunteer who has similar interests and preferences. Telephone numbers are not exchanged, as the service provides the connection. Another option is Silver Letters, a regular exchange of written correspondence for those who are hearing impaired or would prefer it over a phone call. Other options are Silver Circles, which are facilitated group calls, or Silver Line Connects, which provide further help in connecting to local services [114].

Interventions that support work and volunteering:

In addition to simply being connected to people around them, older adults have a basic human need to feel that they are needed. The Dalai Lama says that:

> "In one shocking experiment, researchers found that senior citizens who didn't feel useful to others were nearly three times as likely to die prematurely as those who did feel useful. This speaks to a broader human truth: We all need to be needed. Being 'needed' does not entail selfish pride or unhealthy attachment to the worldly esteem of others. Rather, it consists of a natural human hunger to serve our fellow men and women. As the 13th-century Buddhist sages taught, 'If one lights a fire for others, it will also brighten one's own way.'" [115]

In other words, "their refusal to be content with physical and material security" is rooted in the fact that "feeling superfluous is a blow to the human spirit. It leads to social isolation and emotional pain, and creates the conditions for negative emotions to take root" [115].

Dwyer, Gray, and Renwick also state that "an extensive review of gerontological research shows quite conclusively that regular engagement in meaningful activities contributes to the overall health and welfare of older people." They also state that income is a factor that helps maintain health of older adults – older adults with lower incomes have fewer options for health care, insurance, housing, and goods and services that help maintain health [25].

Furthermore, Rowe and Kahn state that one component of successful aging is engagement with life, which has two elements: maintenance of interpersonal relations, which include "contacts and transactions with others, exchange of information, emotional support, and direct assistance," and of productive activities, which "creates societal value, whether or not it is reimbursed," and could include caring for a disabled family member or volunteering at a church or hospital. This all points again to the need to be needed.

> "Among those aged 60 or more, 39% reported at least 1500 hours of productive activity during the preceding year; 41% reported 500-1499 hours, and 18% reported 1-499 hours… While hours of paid work drop sharply after age 55, hours of volunteer work in organizations peak in the middle years (ages 35-55), and informal help to friends and relatives peaks still later (ages 55-64) and remains significant to age 75 and beyond." [19]

In other words, that means 80% are working at least 10 hours/week on average, and about half of those are work at least 30 hours/week. Predictors of productive activity are functional capacity (high cognitive and physical function make older adults three times more likely to do paid work and twice as likely to volunteer, and functional status predicts the amount of work), education (higher education level predicts sustained productive behavior), and self-efficacy (self-efficacy, mastery and control predict sustained activity) [19]. Here again we see the three categories of physical fitness, cognitive health, and emotional fulfillment intertwining.

In order to support older adults in volunteering, there are many websites devoted to helping match older adults to volunteering opportunities that meet their location, time requirements, and interests. The AARP lists local volunteer opportunities, has a "volunteer wizard" for matching users to opportunities, and a portal that provides tools, information, and resources for current volunteers [116]. Other websites include www.CreateTheGood.org, www.VolunteerMatch.org, www.RetiredBrains.com, www.NationalService.gov, and www.TaprootFoundation.org.

There are also many websites dedicated to helping older adults find paid work. For example, www.SeniorJobBank.org, www.Workforce50.com, www.Seniors4Hire.org, www.RetirementJobs.com, and www.RetiredBrains.com help older adults find jobs by location and type of job. Also, websites such as www.ExperienceWorks.org provide training to help older adults find work.

Technology has also provided new ways of working and making money – in particular with the "sharing economy." The AARP reports that among sellers of the sharing economy, 1 in 4 are over 55 years old [117]. Airbnb allows anyone with extra space in their living quarters to rent out that space to travelers, helping the host make extra money. Airbnb says that 10% of their hosts are over 60 years old. They host mostly for the extra income, but also for other reasons such as staying socially connected and keeping active (Figure 32). While financial motivations are the biggest reason they begin hosting, "most indicate that the social aspects have provided unexpected and welcome benefits that keep them coming back to host more." These benefits should not be overlooked - "78% of hosts said that hosting on Airbnb has helped them stay more physically active than they would otherwise be," "83% of hosts said that hosting on Airbnb has helped them stay more mentally engaged," and "82% of hosts said that hosting on Airbnb has helped them stay more socially and emotionally connected." One older adult host says: "Because I don't have any children and live alone, I love welcoming guests to my home and making them feel like part of my family." This setup is not only very beneficial for the older hosts, but for the travelers as well – "Airbnb 60+ hosts receive 7.5% more five-star reviews than other hosts" [118].

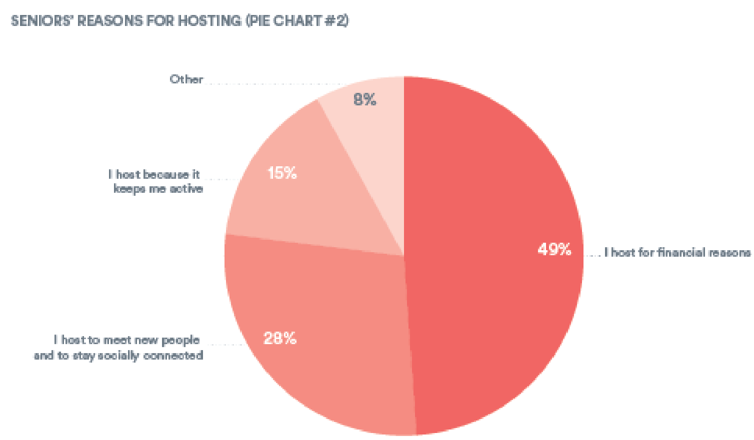

Figure 32 – Seniors' reasons for hosting with Airbnb [118]

Some older adults with the ability to drive also have another option for making money. Uber, the ride-sharing service, "estimates that about 1 in 4 drivers are age 50 or over." All they need are a valid driver's license, a suitable vehicle, car insurance, a clean driving record, and a background check. Also, "Uber offers a special incentive to AARP members who want to become drivers. Members earn a special $35 incentive as Uber drivers after completing 10 rides." Other options that older adults have found for participating in the sharing economy through technology include DogVacay (a pet sitting service), Fiverr (a site to sell creative or professional services for

$5), TaskRabbit (which connects people willing to perform tasks with buyers), RelayRides (another ride-sharing service), and Vayable (which matches tourists with local tour guides) [117].

Other interventions:

The lack of transportation options can have severe negative effects on older adults: 21% of adults aged 65 and older do not drive, and over 50% of those older adults (3.6 million Americans) “stay home on any given day partially because they lack transportation options” [119]. This can exacerbate some of the issues already facing these older adults. Loneliness, doctor visits, shopping trips, and general engagement with life can all be negatively affected.

Dwyer, Gray, and Renwick state that “geographical isolation and lack of public transport limit older people’s ability to be involved in social life,” in part because “older people do not wish to be seen as too demanding and limit their requests to ‘really important errands’ such as doctor’s appointments, minimizing requests for shopping and not asking for transport for reasons such as visits to friends” [25].

To help address this issue, the ride-sharing platform Uber has partnered with the city of Gainesville, Florida to begin a pilot program that gives seniors more affordable access to their service. Users had to pay up to a $5 co-pay, based on their income. They provided technology tutorials to make older adults more comfortable with using the service, and smartphones were even donated by Wells Fargo. It has been a success in taking older adults to grocery stores, churches, shopping malls, community centers, and health care providers, and they will be expanding the program from two neighborhoods to the entire city [120][121].

PARO is a therapeutic robot in the form of a stuffed baby harp seal. It is used in hospitals and extended care facilities to reduce stress and stimulate interaction and socialization with other patients and caregivers. It has sensors for touch, light, sound, temperature, and posture, and responds with movement and sound [122]. While this device’s worth has been demonstrated primarily in facilities, it should serve as a point of evidence of a type of emotional fulfillment that can come from interacting with similar products.

Other benefits:

As an added benefit and even more reason to help older adults maintain social connections, the CDC states that “social support from family and friends has been consistently and positively related to regular physical activity" [36]. Rowe and Kahn also states that "behavioral predictors of maintenance of physical function included moderate and/or strenuous leisure activity and emotional support from family and friends," that "marital status (being married), presumably a source of emotional support, protected against reduction in productive activity," and that "emotional support was a positive predictor of physical performance" [19].

Conclusion:

This chapter has illustrated the many ways in which computing technology can aid older adults in preventing declinations in their emotional fulfillment – specifically through technologies that support direct connection with family members, friends, and new acquaintances such as social networking sites and simple connected devices; technologies that enable older adults to find volunteering and work opportunities; and technologies that allow older adults to get from place to place.

CHAPTER 7: CONCLUSIONS AND FUTURE WORK

The potential of computer technology to help older adults help themselves in remaining independent is enormous. In this thesis, I have focused on technology with benefits that are realized through preventing or postponing declinations in older adults from three angles: physical fitness, cognitive health, and emotional fulfillment. This is done with the goal of empowering older adults to remain independent in the fullest sense. Yet, this area needs more focus from this preventive perspective, especially given the potential it has to help older adults in all areas of their lives, and consequently relieve some of the pressure of our aging population as a whole.

More time should be spent in discussing these interventions in this particular frame of mind of preventive technology. This may help these technologies be more successful and spur further research and development into doing it even better and more effectively. Research should be done on older adults' use of such technology in the context of prevention, and stressing the importance of prevention rather than replacement of functionality as is usually done will help future research better benefit older adults and help realize the potential for them to make an impact in aging in place. This is not to say that less focus should be placed on traditional assistive technology, because there is still a need for it, and prevention does not always work to the extent that is hoped. However, it should not be the only perspective from which we consider these issues on how we can help older adults maintain their independence. I have outlined key areas for focus as including:

Physical fitness interventions, such as physical activity trackers and activity facilitators, nutrition, medication, and general health.

Cognitive health interventions, such as brain training games and online courses, and interventions for physical fitness and social interaction.

Emotional fulfillment interventions, such as technologies like social networking sites and simple connected tablets that support direct connection with family members, friends, and new acquaintances; technologies that enable older adults to find volunteering and work opportunities; and technologies that allow older adults to get from place to place.

Design work on interventions such as these should continuously keep the older adult user in mind. This is to ensure that:

> "In the future, wearable and mobile health technologies will be easier to use for this target market due to a combination of focused laboratories of

> available and willing users (e.g., CITRIS at UC Berkeley); sponsorship of device access by organizations that support older adults; ad agencies that craft more useful messaging (e.g., AARP's Influent50); and incubators and funds that educate entrepreneurs about older adults (e.g., Aging 2.0). The next version of health apps and devices will have readable directions, easy-to-use interfaces, customizable health advice, and right-sized buttons." [43]

Not only should more work be done on the technologies discussed in this thesis in general, but the technology will also need to be designed for subgroups of the older population. Of the 76 million baby boomers, "more than 37 million boomers will be managing more than one chronic condition by 2030. One out of four, or 14 million people, will be living with diabetes; almost half will have arthritis, and more than one-third, or over 21 million, will be classified as obese" [43]. We must get the design of technology right for older adults in general, but we also must get it right for individual needs as well.

A wider variety of types of interventions and options would also be helpful in meeting the preferences, wants, and needs of the wide variety of older adults, thereby hopefully increasing the likelihood that each individual will find an intervention that they can and will use.

A concern that stretches across the board for most interventions is the financial cost associated with them. Older adults are commonly restricted in their income, and even if they have the intention to use interventions, they may not be able to afford them. Work should be done to bring costs down or provide discounts to older adults, not only for the benefit of the older adult users but also for the benefit of society as a whole.

In the future, advancements in technology – including the ones already discussed - will undoubtedly have even more potential to help this population. This potential may be fully realized, especially if attention is paid to this preventive perspective.

There has never been a more important or pivotal time to discuss computing technology in how it can aid older adults in their quest to age successfully and live independently. It is important that we do so from the best perspective possible.

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