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Master's Thesis
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Audiovisual Content Creation and Evaluation to Support Exercising Activities at Home for the Elderly

Keio University Graduate School of Media Design

Risa Imai

A Master's Thesis
submitted to Keio University Graduate School of Media Design
in partial fulfillment of the requirements for the degree of
MASTER of Media Design

Risa Imai

Thesis Committee:

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Abstract of Master's Thesis of Academic Year 2016

Audiovisual Content Creation and Evaluation to Support Exercising Activities at Home for the Elderly

Category: Design

Summary

Throughout the world, societies are facing a phenomenon of continuous aging population. As the proportion of older people and life expectancy both increase, economic and social costs are expected to rise for elderly care, especially for managing disability and treating chronic disease[1]. Healthcare costs can be alleviated by providing ways for the elderly to remain independent with longer periods of good health and well-being.

Regular walking has been scientifically proven to be an effective method for the elderly to maintain mobility[2], with multiple benefits that can be categorized into physical, cognitive, and psychological benefits. However, outdoor walking can have several drawbacks, especially in terms of safety, which act as barriers to participation. In efforts to assist the elderly in leading a healthy lifestyle, this paper will introduce audiovisual contents to support exercise activities at home for the elderly. Multiple combinations of audio and visual content will be tested along with exercise using the pedal exerciser equipment. These tests will be conducted to determine whether audiovisual contents can help indoor exercise activities in providing the three types of benefits of an outdoor walk, and to determine the most effective type of content.

Various facilities, technology systems, and products provide a way for the user to experience a walk outside in an indoor setting, but are not appropriate for

1 National Institute on Aging: Global Health and Aging `https://www.nia.nih.gov/research/publication/global-health-and-aging/living-longer`

2 Pahor, Marco and Guralnik, Jack M and Ambrosius, Walter T. 2014. *Effect of Structured Physical Activity on Prevention of Major Mobility Disability in Older Adults: The LIFE Study Randomized Clinical Trial.* JAMA 311(23):2387-2396. (Pahor et al. 2014)

enabling the elderly to remain independent and do not focus on providing the three types of benefits. This thesis describes the background, justification, and design of the audiovisual contents, and identifies the most effective combination of audio and visual content to support exercise activities at home with the goal to help the elderly lead both a healthy and independent lifestyle.

Keywords:

Audiovisual Contents, Aging Society, Elderly, Walking Benefits, Indoor Exercise, Pedal Exerciser

Keio University Graduate School of Media Design

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Chapter 1
Introduction

1.1 Aging Society

Populations throughout the world today are older than ever before. This phenomenon of aging population occurs when the age distribution of a population shifts towards older age due to an increase in life expectancy and a decline in fertility rate (Gavrilov and Heuveline 2003). It is not clear when exactly this phenomenon began; however, according to a report prepared by the Population Division of the United Nations, after the year 1980, the global average annual rate of increase of individuals aged 60 years and above greatly surpassed that of the total population (Chamie 2002). By the year 2030, "the number of people in the world aged 60 years or over is projected to grow by 56% ... and by 2050, the global population of older persons is projected to more than double its size in 2015, reaching nearly 2.1 billion" (Bravo et al. 2015). Consequently, this phenomenon has a broad range of implications, as it impacts the economic, political, and social conditions of society.

A shift in the age structure of a population can lead to various consequences, many of which challenge existing social systems. For example, a decline in the fertility rate may not satisfy the increasing demand for inter-generational support systems by the older generations in the long run, since family care becomes more difficult as family size decreases and more women enter the workforce. Additionally, an increase in life expectancy means that post-retirement life will be longer for more individuals, and pensions and other social benefits will extend over a longer period of time. Medical costs and the demand for health-related services are likely to increase as well, since people become more vulnerable to chronic disease as they age with a weakening immune system. This is particularly the case with diseases that are age-related, such as dementia. The risk of dementia increases significantly with age, and the projected costs of caring for those who are affected are extensive. According to the World Alzheimer Report by Alzheimer's Disease

International, “the total estimated worldwide cost of dementia is 818 billion US dollars, and it will become a trillion dollar disease by 2018” (Prince et al. 2016).

As it is clear from these trends of rising costs, it is crucial for society to develop physical and social infrastructures that will support this ongoing phenomenon of aging population. Efforts should not only be focused on providing care in response to illness and disability, but also on fostering better health and well-being for the elderly so that they can maintain a healthy lifestyle to remain both independent and socially engaged with the rest of society. This way, healthcare costs and economic losses can be greatly reduced. The longer the elderly can remain mobile and look after themselves, the lower the long-term care costs will be to families and the rest of society, and the longer the elderly themselves can continue to participate in and contribute to their country’s economy. Exercise is considered to be one of the most effective ways for humans to maintain mobility. This topic in context of the elderly population will be discussed in the next section.

1.2 Exercise for the Elderly

According to a study conducted by researchers at the University of Florida with adults aged between 70 and 89, even a moderate level of physical activity “helped aging adults maintain their ability to walk at a rate 18% higher than older adults who did not exercise” (Pahor et al. 2014). At the same time, moderate physical activity also helps “prevent the occurrence of long-term mobility loss” (Pahor et al. 2014). This is clear evidence that exercise can help the elderly maintain functional independence, and it is no wonder why physical activity is one of the most popular ways the elderly spend their time. According to a survey conducted by the Bureau of Labor Statistics, the elderly spend the most time on leisure and sports, which involves physical movement (Bureau of Labor Statistics 2015). Additionally, the older the age, the longer the time spent becomes, with 7.5 average hours per day for individuals aged 75 and over. This suggests that individuals recognize the increased importance of exercise as they age.

As for the frequency of doing exercise among the elderly, according to a survey conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) in Japan, over half of individuals aged 70 and above exercise at least 3 times per week (Yamada 2013). This shows that not only do the elderly spend a long time staying active during a single day, but they are also engaged in physical activity multiple times per week. As the elderly population grows and life expectancy increases over time, a growing number of individuals past their retirement age will be engaged in physical activity, and a corresponding increase in demand for exercise related products and services can be expected.

Exercise and physical activity is commonly divided into four categories, which are endurance, strength, balance, and flexibility (Campbell et al. 2012). Since each type is different, participating in activities that fall into more categories increases the effectiveness of the benefits that exercise can provide.

Endurance, also known as aerobic, activities, are those that increase one's breathing and heart rate. Some of the key benefits they provide include: maintaining a healthy heart, lungs, and circulatory system, and improvement of overall fitness. This means that those activities play an important role in delaying or preventing many age-related diseases, such as diabetes and heart disease (Campbell et al. 2012). By staying fit, the elderly can also remain independent for an extended period of time since they can continue to carry out everyday tasks. Examples of endurance activities include brisk walking, dancing, biking, and climbing hills.

Strength activities make the muscles stronger, and they play an equally important role in one's ability to stay independent since muscles are needed for moving the body and surrounding objects. Examples of strength activities include those that train targeted muscles, such as lifting weights and using a resistance band (Campbell et al. 2012).

Balance activities help individuals improve their stability and maintain their balance, and are especially important for the elderly, because they can help prevent falls. In a systematic review of the prevention of falls, the most important components of fall prevention strategies were exercises that challenge balance and strengthen the lower limb muscles (Sherrington et al. 2008). Examples of balance activities include standing on one foot and Tai Chi.

Finally, flexibility exercises stretch the body's muscles and improve flexibility, and are important for maintaining freedom of movement (Campbell et al. 2012). They help slow down the decline in the flexibility of joints, which can prevent pain from the change in the structure of bones and muscles that comes with age. Examples of flexibility exercises include yoga, shoulder stretch, and reach back exercises.

Among the wide range of exercise and physical activity that is available for people to be engaged in today, the most popular activities for individuals aged 55 and above include walking, golfing, and dancing(Bureau of Labor Statistics

2008). In Japan, radio calisthenics are very popular. It is interesting to note that according to a survey conducted by MEXT, 10.2% of respondents aged 70 years and older participated in new forms of sports, such as indiaca (Yamada 2013). Nevertheless, walking is considered to be the most popular sport across borders, and will be further discussed in the next section.

1.3 Outdoor Walking

Walking is the most popular form of exercise among the elderly, most likely because there are low barriers to participation and a long list of benefits. In Japan, walking greatly surpassed all other types of exercise that the elderly often engage in (Statistics Japan 2012).

Walking can be enjoyed in different situations, and there are many ways to make it more fun and interesting. For example, it can be done while window-shopping at a mall or while spending time catching up with friends at the park. For those who own a dog, taking the dog out for a walk in the neighborhood is another option. Varying the walking path and time during the day provides a different view of the surroundings.

Figure 1.1: An elderly couple exercising at a park

There are various reasons why the barriers to participation for outdoor walking is low compared to other forms of exercise. For example, walking is low-impact, meaning that during activity, the feet remain in contact with the ground and there is a relatively small amount of stress on the body, especially on the joints. This means that people do not have to worry about the risks associated with the more vigorous types of exercise. Walking also requires minimal equipment, since no specific sports gear is needed, and most people can enjoy the activity with comfortable clothes and shoes they already own. It is also a very flexible activity, because it can be done any time of the day and the walking pace can be adjusted based on everyone's specific fitness levels. In addition to the low barriers to participation, having multiple benefits is another advantage of walking. These benefits will be discussed in the next section.

1.4 Benefits

Since walking provides a long list of benefits to humans, the benefits have been divided into three categories, which are physical, cognitive, and psychological benefits. Each type of benefit will be discussed here. According to the American College of Sports Medicine (ACSM) and the American Heart Association (AHA), at least 30 minutes of walking per day is needed for the benefits to take into effect (Haskell et al. 2007).

1.4.1 Physical

The physical benefits of walking altogether improve body functions and health, leading to a longer healthy life and a greater ability for the elderly to remain independent. The first benefit of walking is that it lowers the risk and improves the management of high blood pressure and cholesterol, as well as diabetes, to a similar extent as running (Williams and Thompson 2013). This means that walking reduces the risk of heart disease and stroke, and increases cardiovascular and pulmonary fitness. It also helps reduce and maintain weight, since it increases the basal metabolic rate and helps burn fat. This is important for the elderly, because metabolism slows down with age, making the elderly more prone to weight gain. Walking after eating a meal aids in digestion, which is beneficial for the elderly since aging slows down the function of the digestive system (Franke et al. 2008). Walking also reduces the incidence of disability in daily life activities by increasing muscle endurance and improving balance, both of which are important in maintaining mobility and independence. It also reduces arthritis pain, which occurs more frequently with age, and improves the management of conditions such as joint and muscular pain or stiffness (Westby 2001). Additionally, it helps prevent loss of bone mass, or osteoporosis, particularly in women. Walking can also reduce the risk of some cancers, including colon, breast, endometrial, and lung cancer (Centers for Disease Control and Prevention 2015).

1.4.2 Cognitive

Walking not only provides benefits for physical health, but also for the brain, as it improves cognitive functions and memory, thereby slowing mental decline. The effects of aging on the brain are widespread and have many consequences affecting the health and well being of the elderly, especially in their ability to remain independent. These effects are caused by a shrinking brain size, as well as changes in the levels of neurotransmitters and hormones. Nevertheless, there are several protective factors, and walking plays a significant role. For example, walking increases serotonin levels in the brain (University Health News 2012). Serotonin is a neurotransmitter that plays a role in a wide variety of physiological functions and behaviors, including appetitive, emotional, and cognitive (Frazer and Hensler 1999). Walking prevents the brain from shrinking by enhancing neurogenesis, increasing the brain's volume of neurons. It also increases the connections between neurons and improves the connectivity of important brain circuits, which increases the brain's performance of cognitive tasks and prevents the decline in brain function associated with aging (Live Science 2010). It also increases the size of the hippocampus, which is a brain area important for verbal memory and learning, and of the prefrontal cortex, which is involved in planning complex cognitive behavior and decision-making (Erickson et al. 2011). All these positive effects of walking contribute to its benefit of helping prevent and delay the progress of dementia. Walking also helps reduce the brain damage caused by Alzheimer's disease, since it reduces the concentration of Beta amyloid in the brain, a type of protein that forms in the brains of those who are affected (Maesako et al. 2012).

1.4.3 Psychological

The psychological benefits of walking should not be overlooked, as walking improves mood and leads to a positive mental outlook, which can also help the elderly remain independent. Firstly, walking secretes hormones called endorphins, which helps people fight stress, depression, and anxiety, and enhances one's sense of well being (University Health News 2012). An increase in the serotonin levels in the brain not only provides cognitive benefits, but also positively influences mood. Walking also lowers adrenaline levels to help us remain calm and stress-free. It also enables the brain cells to use dopamine more efficiently, increasing one's ability to experience pleasure (University Health News 2012). An increased flow of oxygen to the brain contributes to an improved mood. Walking also improves sleep by boosting the effect of melatonin, which is a natural sleep hormone that plays a role in controlling sleep and wake cycles. It therefore helps in the maintenance of a healthy lifestyle, especially since natural melatonin levels decrease with age (Buman and King 2010).

1.5 Drawbacks

Although walking is considered to be one of the most accessible forms of physical activity with multiple benefits, barriers to walking still exist, especially for the elderly. These barriers may largely come from the dangers of going for a walk outside. A lack of safe and attractive places to walk may be one reason, such as narrow streets, steps, and lack of resting points in a crowded city. Narrow streets and lack of pavements can be dangerous for the elderly, since they can lead to traffic accidents. According to data collected by the National Police Agency in Japan, about half of deaths caused by traffic accidents involved pedestrians (Government of Japan Cabinet Office 2013). The risk of injury and death doubles at night. The frequency of traffic accidents may increase in the future as the elderly population increases, both from an increase in elderly drivers and pedestrians in the streets. Steps and sudden cracks and small obstacles in the pathway can also be dangerous for the elderly, making them more likely to trip and fall. Lack of resting points such as chairs along the pathway also makes walking unattractive, because the elderly may put too much pressure and strain on their body by walking continuously without resting.

Another barrier to going for a walk outside for the elderly is adverse weather conditions. Cold weather can make the elderly prone to illness, and hot temperatures during the summer can lead to heat strokes. Nearly half of heat-related deaths came from individuals aged 65 years and above (Luber et al. 2006). The elderly are at a higher risk at developing heat illnesses, because the body becomes less efficient at regulating temperature with age and it becomes increasingly difficult for the body to cool down. There are multiple reasons that contribute to this. Heart problems make it difficult for the body to dissipate heat with poor blood circulation. Medication can reduce sweating, cause water loss, and worsen the dehydrating effects of high temperature. The body can become exhausted from heat as well, making the elderly feel dizzy and weak.

There are barriers to walking for the elderly that involve not only themselves, but other stakeholders as well. People who take care of their aging loved ones at home become worried about the safety of their elderly parents during the day when they have to leave home for reasons such as work. The elderly can wander out of the house, and face dangers out in the streets, or even get lost and forget how to get back home from memory impairment. Providing family care can be demanding, and worrying about the elderly can affect the daily lives of the caregiver. Even though walking benefits the elderly and can help them remain independent, it may not alleviate the costs associated with long-term care, especially to families, if it means that caregivers need to be concerned about their parents all the time. It is therefore necessary to develop methods for the elderly to exercise in order to stay healthy, while at the same time reassuring family caregivers about their parents' safety during exercise.

1.6 Problem Statement

Although there are drawbacks and dangers associated with outdoor walks for the elderly, the elderly should not be discouraged from undertaking this activity, since it is considered to be one of the most accessible forms of physical activity that provides multiple benefits. As one of the simplest and easiest solutions to the increasing costs of elderly care, the elderly should be encouraged to exercise from outdoor walking in order to remain mobile for an extended period of time to care for themselves. To meet the needs of both the elderly and the family caregivers, the appropriate solution would be to devise a method for the elderly to participate in exercise activities that provide the benefits of walking outdoors while avoiding the associated challenges and dangers. This way, the costs for long-term care for the elderly to families and society can be further alleviated.

1.7 Thesis Overview

This thesis consists of five chapters.

The first chapter serves as an introductory section that presents the background information and context of the research discussed in this thesis. It begins with the larger theme of aging population, gradually narrowing down to the topic of outdoor walks for the elderly. The benefits and drawbacks of outdoor walks are discussed to define the problem statement that this research will address.

The second chapter presents past works that are related to this research in that they provide a way for the elderly to exercise and experience some of the benefits of an outdoor walk in an environment that removes or minimizes the associated dangers and risks. The section provides a description of the related works and a discussion on their application to this research, and ends with a summary and an explanation of the contribution of this research.

The third chapter introduces the design of the research solution, including the preliminary research, the development process, the implementation of the system, and a description of the target persona. An explanation and justification for the different components of the system is provided, along with details on the audiovisual contents creation. The section ends with defining the hypothesis, which serves as the focus of the evaluation.

The fourth chapter describes the evaluation process used in this research to test the hypothesis on the proposed solution, starting with the experiment setting, and a description of the methods used and a discussion of the findings in the evaluation of the physical, cognitive, and psychological benefits.

The fifth and final chapter serves as a concluding section, with a summary of the main points of the research and findings from the experiments. A discussion of limitations and suggestions for future research and practical applications are also included.

Chapter 2
Related Works

This section presents past research and existing solutions that contribute to enabling the elderly to participate in exercise activities that provide the benefits of walking outdoors while avoiding the associated challenges and dangers. The works that are included are the following: Exercise at the Gym, Virtual and Augmented Assistive Technology, and Exercise Chairs. Under each category, a description supporting its relevance to this research is provided, along with attributes that contribute to its effectiveness. Additionally, the possibility of application of the works to this research is discussed to help differentiate this research and make its contribution clear.

2.1 Exercise at the Gym

2.1.1 Description

One of the immediate solutions that serves as a method for the elderly to participate in exercise activities that provide the benefits of walking outdoors while avoiding the associated challenges and dangers is for them to exercise at the gym. A gym, also referred to as a fitness club or center, is a place where people go to engage in physical exercise using exercise equipment. The elderly can exercise and move their body in a similar way as walking outdoors by using exercise machines such as treadmills, or even ellipticals and steppers. The apparatus can be adjusted for various amounts of speed, resistance, and incline, which can provide some variation to the user's exercise experience.

Exercise equipment like treadmills often have a built-in screen, with which users can track their exercise efforts and watch content, such as live television, videos of animated tracks and virtual scenery, and stored personal content from a usb device or smartphone. Videos of animated tracks and virtual scenery can contribute to the user experience of making the users like they are actually moving forward in various settings such as parks, forests, and cities. In this way, treadmills can provide an experience that mimics that of an outdoor walk for the elderly. Since the available content in the equipment may be limited, users can bring their own smart device and place it in front of them on the treadmill stand, if possible, and enjoy content that matches their individual preferences.

In addition to regular gyms, there are fitness centers that specifically target the elderly. These fitness centers are different in that they provide facilities and exercise programs that cater the needs of the elderly. Fitness coaches understand how to help their clients improve their posture, lower cholesterol, increase bone density, and alleviate joint pain, which all prevent some of the most common diseases and disabilities that come with age. Others provide special training for those who are recovering from surgery. In Japan, Konami Sports Club provides a special program called OyZ that targets people aged 60 years and above (Konami Sports Club 2016).

Figure 2.1: Gym with elderly members

2.1.2 Discussion on Application to This Research

Although fitness centers and gyms provide a safer environment for the elderly to exercise in a similar way as walking outdoors, there are several reasons why they are not ideal for the elderly to remain independent. First of all, fitness centers are not located around every street corner, and are often concentrated in busy areas, and in smaller cities and suburban areas, the locations are even more dispersed. This means that the elderly need to make an effort to access the fitness centers. If they walk, they are exposed to the same dangers as an outdoor walk, and if they use public transportation, they may already be tired by the time they arrive to the gym. Buses and trains may be crowded and noisy, which are unfavorable conditions for the elderly. Getting to the gym by car or bike is also dangerous, since traffic accidents by elderly drivers are becoming increasingly more common.

Although there are fitness centers specifically for the elderly, the majority of the fitness centers are still conventional, meaning that people from all age ranges come to exercise at the gym. This can make the gyms crowded and noisy, and if there are many young clients exercising heavily, the atmosphere can be unwelcoming, intimidating, and overwhelming for the elderly, especially if they have to learn how to exercise properly among such a crowd. Even though there may be some older individuals who already exercise at the gym, the elderly still make up a small percentage of gym clients, especially those in their 70s and above (Yamaguchi 2008). There may also be perceived barriers to exercising at the gym, such as dangers associated with using exercise equipment and risk of falling or injury while doing exercise. Those who think this way will tend to avoid going to the gym.

Exercise equipment such as treadmills may provide a user experience that mimics that of an outdoor walk, but injury and even death from these devices are possible. For example, the elderly can easily slip on the treadmill, and if something hits the treadmill like a balance ball, it may stop abruptly. Also, since most of the equipment runs on electricity, it may cause an electric shock, suddenly malfunction, overheat, or catch fire, all of which were accidents that actually occurred in the United States (Abubakar et al. 2012) . It is also common for users to misuse the equipment, especially the elderly, since the equipment has many functions and buttons which are not always easy to understand. Not using the proper technique can strain the body, such as bad posture leading to back injuries. According to the National Electronic Injury Surveillance System, injuries caused by exercise and exercise equipment increased by almost 45% between 2007 and 2010, and among the different types of equipment, treadmills caused the most injuries (United States Consumer Product Safety Commission 2015). Since treadmills are often the only type of equipment with an embedded screen to show videos of virtual walks, these data make exercise equipment at the gym unsuitable for the elderly to use as a replacement for an outdoor walk.

Even fitness centers specifically targeting the elderly are not ideal for helping the elderly stay independent. As with the regular fitness centers, these facilities are not always easily accessible, and since there are fewer fitness centers targeting specific needs for the elderly, it can be even more difficult to find and access them. If the elderly need to walk outdoors or use some form of transportation to access the fitness centers, family caregivers will continue to stay worried about their elder parents, just like when the elderly wander out of the house to go for a walk outdoors. Also, these fitness centers are different in that they provide special assistance and coaching to the elderly, meaning that the elderly are not completing tasks by themselves to exercise. If the elderly continue to rely on the trainers for instructions on how to use the equipment, and are under constant supervision, these facilities are not maximizing the elderly's ability to remain independent and care for themselves. At the fitness center, if the elderly are surrounded by similar individuals who are dependent on others for care, the environment can be discouraging for the elderly to stay strong and remain independent. They may be over-exposed to the seniors, becoming self-conscious and be reminded of the fact that they have reached old age and are capable of receiving special care, and that they need or can rely on others for help.

2.2 Virtual and Augmented Assistive Technology

2.2.1 Description

Another example of related works that provide an alternative solution to outdoor walks that avoids the associated challenges and dangers includes virtual and augmented assistive technology. This solution is appropriate in the current era of technological revolution, where advancements and new developments in technology are constantly taking place. Virtual reality (VR) technology is a realistic and immersive simulation of an environment to create an interactive experience generated by the computer and software. In most cases, the environment is an artificial world that can be seen on a screen or in goggles. This is an effective way to allow the user to experience the outer world while remaining indoors, so by using virtual reality technology, the elderly can experience a walk outside while remaining indoors, where the environment is safer and free from outdoor dangers and risks. Augmented reality (AR) technology is different in that it provides a live view of an actual physical real-world environment that is augmented using computer-generated input such as graphics and sound. By adding digital components to the real world, augmented reality can make the user experience more engaging and entertaining, which can help make exercise activities more enjoyable for the elderly.

There are various examples of ongoing research being conducted using this technology, many of which are for improving the rehabilitation and enabling assistive technology for people with disabilities. Examples of research that help provide the same or similar benefits as an outdoor walk will be discussed since they are most appropriate for providing a way for the elderly to enjoy those benefits while avoiding the associated challenges and dangers. In the first research study, the effects on the balance abilities of elderly individuals of ball exercise and VR exercise were compared (Park et al. 2015). The VR exercises were games involving heading a soccer ball, passing flags, and making a ball fall into a hole (Park et al. 2015). These exercises helped the elderly move their body in different directions, and it was concluded that VR game exercise was more effective in improving the balance and gait of the elderly (Park et al. 2015). In a similar study, three-dimensional interactive AR was used to improve the lower extremity function and balance in the elderly (Im et al. 2015). The AR system included three different games that helped the elderly move their joints. Based on the results, there were both clinical and kinematic improvements of the lower extremity, proving that AR can play an important role in rehabilitation for the elderly (Im et al. 2015). In another research study, an interactive virtual environment was displayed on a large screen to determine whether VR technology can change the exercise experience specifically for retirement home residents (Brunn-Pedersen et al. 2014). Based on the results, a majority of the users supported the use of VR and preferred using the technology while exercising (Brunn-Pedersen et al. 2014).

2.2.2 Discussion on Application to This Research

Although VR and AR technologies have the potential to revolutionize healthcare by improving rehabilitation and physical therapy for the elderly, and are appropriate for providing some of the benefits of outdoor walking, the technology involved is too complex for the elderly to use for staying independent. Also, since most of the research is conducted for the purpose of rehabilitation and physical therapy, they do not meet the needs of the elderly who still live at home and have the ability to remain independent.

In the examples of research studies discussed, the technology was set-up beforehand, the researchers had to provide instructions on how to use the devices, and the research was conducted in elderly communities and retirement homes. This makes VR and AR technology systems unsuitable to help the elderly remain independent, because they cannot be used by the elderly themselves whenever they want to. These technologies often require the knowledge and skills of those who specialize in the relevant field, and getting assistance from these individuals increases the barrier to utilization. The systems are also costly, meaning that they are not appropriate for individuals to purchase for themselves. They also often take up space, which can make it inconvenient for the elderly and their families. VR and AR technology may be too advanced and complex for the elderly for individual use when there is already a large gap between the elderly and technology in general. According to the Pew Research Center, seniors continue to lag in technology adoption, and Internet and broadband use decrease substantially after the age of 75 years (Smith 2014). The elderly are less likely to enjoy advanced technologies by themselves, since they can feel discouraged or intimidated by them from the complexity and difficulty of use. There is a lot of research on developing assistive technologies for the elderly, but not enough for supporting their daily activities. Consequently, there is still a shortage of basic technology to be used by the elderly despite the increase in the aging population.

2.3 Exercise Chairs

2.3.1 Description

Compared to the previous related works, exercise chairs are beneficial in that they are suitable for individual use at home, allowing the elderly to exercise while remaining independent. Exercise chairs are chairs equipped with features and functions that allow the user to engage in some form of exercise while sitting down. Many of these chairs are designed for the elderly, since sitting down gives them stability and relieves strain on the body while they exercise.

The first example is the ChairMaster, which comes with a bike and resistance bands for the user to train on cardio, strength, flexibility, and balance with fifty possible exercise movements (ChairMaster 2016). Another product is the Chair

Gym, which is a simpler version of the ChairMaster with just the resistance bands feature, but taking up less space. In the Japanese market, there is the morinone chair, which is a training chair designed specifically for the elderly using wood from Hinoki cypress trees in Wakayama prefecture (Nature Core Science Co., Ltd. 2010). These chairs are made of wood and use natural colored fabrics to depict a softer, safer image of exercise, which make it more attractive and appropriate for the elderly. There are four different chair designs, each with functions that target separate exercise movements. Two of them allow the user to exercise the lower limbs by doing leg extensions and leg curls. Another one focuses on back strength, and the other on the psoas major muscle, which joins the upper and lower body.

2.3.2 Discussion on Application to This Research

Although exercise chairs are suitable for individual use at home and allow the elderly to exercise whenever they desire, helping them remain independent, they lack some important aspects of an outdoor walk, and several points make them unfit for personal use. In addition to exercise from moving the body, outdoor walks provide a way for humans to collect and enjoy information of an external source through their senses. For example, the sound of the bustling city can make people feel lively and connected with the rest of society, whereas the sound of nature at a park can make them feel relaxed and calm. The scenery and sight during a walk can also be important, because they provide information of the outer world to people and make outdoor walks more interesting. In order to allow exercise chairs to provide the same or similar benefits as an outdoor walk, additional functions are required.

Additionally, even though exercise chairs are more appropriate for home and individual use compared to the other related works, they do not necessarily fit the needs of the elderly. For example, the ChairMaster takes up as much space as a recliner sofa, and is too heavy for most people to carry or even move around, making it inconvenient for the elderly. Other products that are smaller and have less functions like the Chair Gym is unstable and is not targeted for the elderly, making it unsafe for elder individuals to use. Exercise chairs that specifically target the seniors like the morinone chair appear to address the issues mentioned so far, but they are intended to be used by organizations, such as senior centers, medical institutions, and fitness centers. This is because the price of the chairs are relatively high, ranging from 80,000 yen to over 200,000 yen, which makes them less attractive to be bought for individual use (Nature Core Science Co., Ltd. 2010). Also, the manufacturer offers free trial for one month only to organizations, and not for individual homes. Another important point to note is that these chairs engage the user in repetitive movements with very little variation, which makes them less entertaining compared to the other related works.

2.4 Summary

Each of the three types of related works have their own set of goals and objectives for the user. Gym facilities aim to provide a safe environment where people can go to and exercise in pursuit of their personal health and fitness goals. It is also a resource of wellness and fitness, with the option to work with a personal trainer who prescribes, instructs, and measures exercise activity, and motivates clients by setting goals and providing feedback. Gym facilities provide variety to help decrease boredom, and a way to meet other people to help keep the users motivated. The objective of virtual and augmented assistive technologies is rehabilitation and physical therapy, which aim to facilitate the process of recovery from injury, illness, or disease to restore some or all of the patient's disabled physical, sensory, and mental capabilities. The treatment programs help patients cope with deficits that are difficult to reverse with medical care, and address the patients' specific physical, environmental, and psychological needs. Rehabilitation services are mainly provided in hospitals, clinics, nursing homes with specialized care, and health maintenance organizations. Finally, the aim of exercise chairs is to provide low-impact exercise and workouts to the user, which are easier on the body, especially the joints, and engage the user in exercise while reducing the risk of injury.

2.5 Contribution of This Research

There are various existing methods, each with their own set of objectives, for the elderly to participate in exercise activities that provide the benefits of walking outdoors while avoiding the associated challenges and dangers. The goals and objectives, however, do not effectively address the needs of the elderly in the context of this research, which is to allow the user to experience all three types of benefits of an outdoor walk while avoiding the associated challenges and dangers, and to help them remain independent, so that the costs for long-term care for the elderly to families and society can be further alleviated. This research will differ by providing the elderly users to engage in exercise activities at home that allow them to experience the physical, cognitive, and psychological benefits of an outdoor walk. It will also evaluate the proposed solution on the basis of the three types of benefits, which has not been completed prior to this research. The design and implementation process of the proposed solution will be introduced in the next chapter.

Chapter 3
Design

3.1 Preliminary Research

3.1.1 Fieldwork

In order to investigate what constitutes an outdoor walk for the elderly, fieldwork research was done by shadowing an elder person during her usual outdoor walk, and interviewing her for additional information. The fieldwork master was female, aged 82 years old living in Tokyo. She lives in her own house with her daughter, who takes care of her. She is still healthy overall, but has a slightly high blood pressure and realizes that her mental and physical abilities are declining. She likes to go for a walk outside, which she does with her daughter and by herself. When her daughter has time, they go for a walk together, usually lasting 30 to 40 minutes. When she has to stay home while her daughter is working, she goes for a short walk by herself, usually 5 to 10 minutes per walk, multiple times per day. During her walks, her pace is relatively slow and feels a slight pain in her knees while walking. Her personal profile and living conditions matched the target persona of the solution that will be proposed in this research, which will be discussed further on in this chapter. The focus points of the fieldwork were to investigate the pros and cons of going for a walk outside, and to note some of the common activities during a walk.

The walk during the fieldwork lasted for approximately 30 minutes, and the fieldwork master was asked to walk and behave as she usually does during her outdoor walk. During the walk, observations were noted, including the physical objects the master interacted with and the sensory triggers that influenced her behavior and actions. Figure 3.3 is a mental model that summarizes the activities that happened during the walk, broken down into the action trigger, and the fieldwork master's actions, thoughts, and feelings in response to those triggers.

Figure 3.1: Fieldwork during a 30-minute walk outside

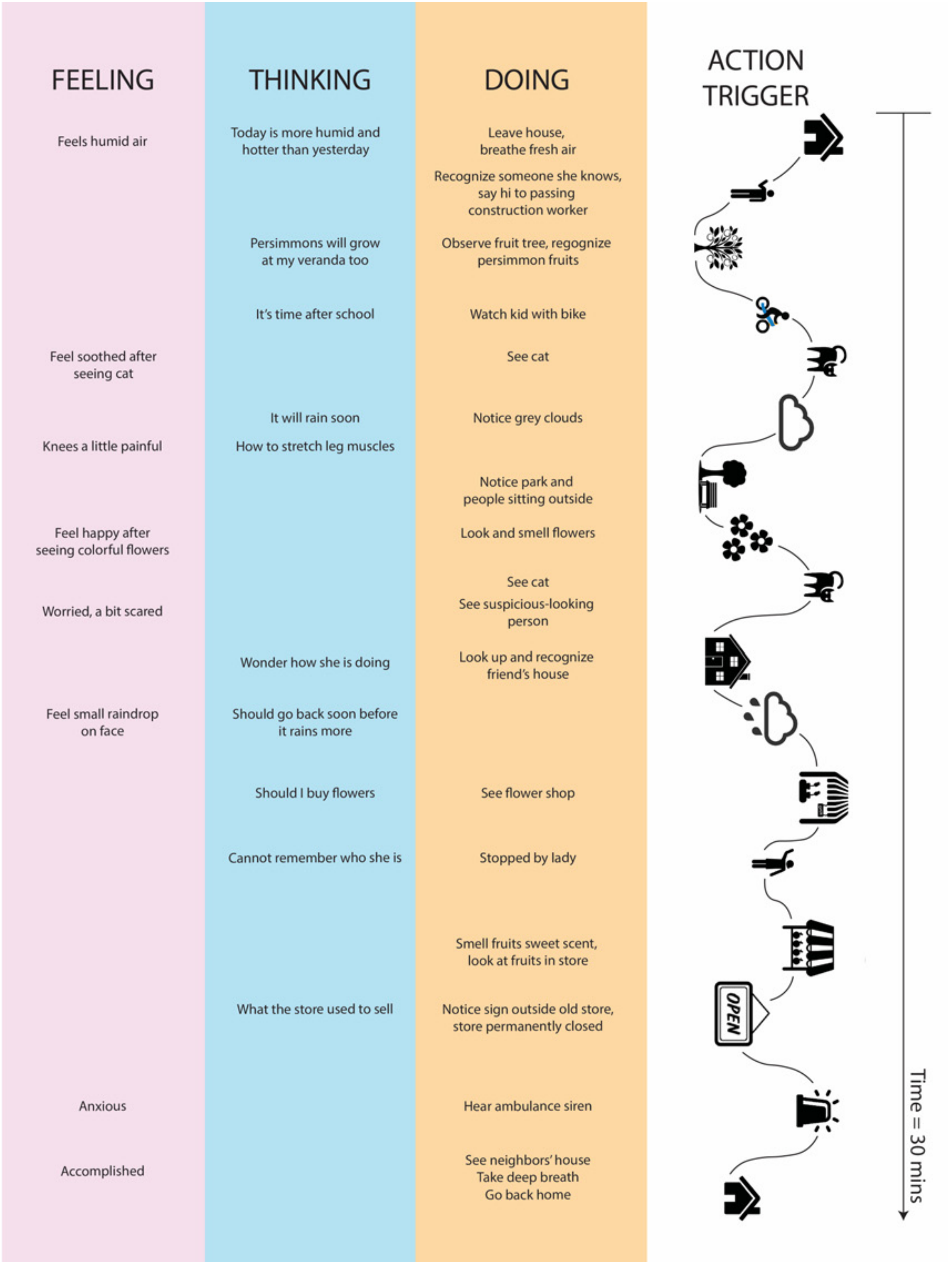

Figure 3.2: Mental model of a 30-minute walk

The activities were then examined, and identified and grouped into the type of benefit (physical, cognitive, and psychological) they each contribute to during an outdoor walk. Table 3.1 summarizes the activities in their appropriate benefit category.

Table 3.1: Activities during a walk grouped into their appropriate benefit category

Physical	**Cognitive**	**Psychological**
• Taking steps and increasing heart rate • Physically moving the body using muscles • Breathing air	• Recognition and identification of people, animals, fruits, items, etc. • Using visual and auditory information to predict future events • Recognition and association of common colors and sounds with what is happening at that time • Recognition and identification of familiar places, comparing past and present • Open mindset and ability to collect information about the surroundings through the senses	• Sense of accomplishment after finishing a walk • Flowers, animals, and children relax/soothe the mind • Making an effort to keep on walking • Boosting self-confidence after completing a nice walk outside

The next step was to develop a system that allows the user to engage in some of these activities in order to propose a solution that is effective in providing all three types of benefits, while avoiding the challenges and dangers associated with outdoor walks. The remainder of this chapter will describe the development flow of the solution proposed in this research. Each section represents an important component in the solution, and justification for its use is provided.

3.1.2 Pedal Exerciser

Justification for Selection

In Chapter 2, several related works were discussed, and among them, the exercise chair was identified to be most suitable for individual use at home. Since the chairs can be placed at home, elderly users do not have to leave the house and face the same challenges and risks of outdoor walking, and the elderly can exercise whenever they want to, all of which help them remain independent. The existing chairs, however, can be costly, dangerous, too large and inconvenient, which make them unfit for elderly use. Since the most important function of these chairs is that they allow the user to engage in light exercise indoors, devices that could substitute the exercise chairs were explored.

Since most households have chair furniture, the chair component of exercise chairs was not as significant. Also, since that component can make the device heavy and large, making it inconvenient for users to purchase one and place inside their homes, devices that could be used while users sat on their chairs at home were explored. Two appropriate devices were identified: the step machine (also known as steppers) and the pedal exerciser. The step machine is beneficial in that it allows the user to engage in their lower body muscles while exercising, just like climbing the stairs. However, when the device was tested with an elder person, the steps had too much pressure to step on, and it was difficult for individual use. The pedal exerciser, on the other hand, could be adjusted for low resistance, so that it was easy for the elder user to pedal, and exercise could be completed individually while sitting down. The biomechanical body movement during cycling is also ideal for the elderly, especially those with arthritis, because it is low-impact uses the largest muscle groups of the lower extremity (O'Brien 1991). There are pedal exercisers available for purchase with just the pedal component, and those with handles. Although the simpler devices are cheaper and smaller, the exerciser with a handle was selected for this research for additional safety and stability. The device is readily available both online and in-stores, and is approximately 4,500 yen (around 50 dollars), which is an affordable price for the general population. The pedal exerciser in Figure 3.3 was obtained for this research.

Figure 3.3: Pedal exerciser with handle

Preliminary Tests

Although exercise using the pedal exerciser by itself already provides multiple benefits to the user, it is not sufficient as a solution that provides all three types of benefits of an outdoor walk, especially in engaging the user in some of the activities mentioned in Figure 3.1. In order to collect some inspiration to determine what kind of components and functions would be appropriate to add to the pedal exerciser, test users were asked to use the device by itself. This test was conducted for a duration of one week with three test users. The natural response of the users in their behavior and actions while they used the device was observed and noted. Table 3.2 summarizes the main observations, along with their implication and significance, which aided in developing the additional components and features further on in this research to supplement the pedal exerciser.

Table 3.2: Main findings of preliminary tests

Observation	Implication/Significance
Singing	Exercise goes well with music; music makes pedaling more fun
Counting in Japanese/English	Counting can encourage exercise; pedaling makes the brain more active
Watching television	Television (audiovisual content) makes exercise more entertaining; user wants to do something else at the same time

These findings were taken into consideration further on in the solution development process.

3.1.3 Tablet Computer

In order to make the proposed solution more comprehensive in providing the benefits of an outdoor walk, additional elements to the pedal exerciser were developed. The pedal exerciser itself already provides the physical benefits of outdoor walks by engaging the user in physical exercise; therefore, additional features to enable the solution to further provide cognitive and psychological benefits were explored. Since many of the activities during an outdoor walk that contributed to providing the cognitive and psychological benefits involved sight and hearing, as outlined in Table 3.1, devices that distribute visual and auditory information to the user were selected. In order to identify the appropriate device for the elderly, several devices were examined.

Electronic devices that are relatively common in households were explored, so that the elder users are accustomed to using them and can complete the steps to use the device by themselves. The first option was the television (TV). In the preliminary tests with the pedal exerciser, it was common for the test users to watch TV as they exercised. These appliances have a relatively large screen size, which can engage the user in the displayed contents. However, it can be difficult for the elderly to play original contents on TV, since they would have to use the remote control to select the correct option to display the contents. Another option was to use the computer or laptop. These devices provide easy access to the

Internet, through which the user can browse multiple types of contents. However, they are not ideal to be used with the pedal exerciser, since the computer would have to be placed on a table or another tool that would enable the screen height to be at eye level.

The next option was the smartphone, since they are much smaller and lightweight, and can be attached to the pedal exerciser. The problem was that the screen is too small for the elderly to clearly see the contents, and the controls on the screen are difficult for them to select. According to the Pew Research Center, in the US, although 77% of seniors aged 65 years and above own a cell phone, only 18% of them have adopted the use of smartphones, and their rate of smartphone adoption has not been increasing as much (Smith 2014). The adoption rate becomes even lower for individuals aged 75 years and above; 10% of 75 to 79 year olds, and 5% of those 80 years and above (Smith 2014). This left the option of using the tablet computer, since it provides a larger screen size than the smartphone but can still be attached to the pedal exerciser. Seniors are also more likely to adopt the use of tablets than smartphones, since 27% of older adults in the US own a tablet, an e-book reader, or both, compared to 18% for smartphones (Smith 2014).

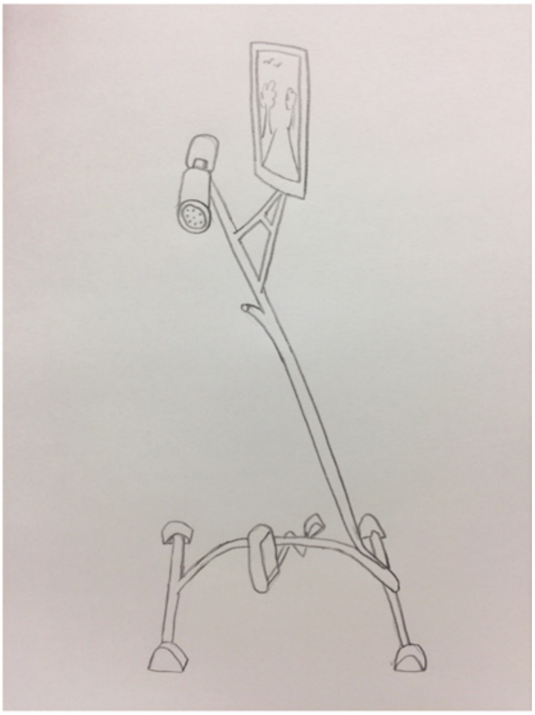

Figure 3.4: Sketch of tablet with pedal exerciser

Figure 3.4 is a sketch of how the device set-up for the proposed solution will look like. For the purpose of this research, the Amazon Fire HD 8 tablet was used. The actual set-up of the device will be discussed in the Implementation section.

3.2 Audiovisual Contents

This section describes the development process of the audiovisual contents that were to be played on the tablet computer. Audiovisual contents, combining visual contents with sound, were selected for this research for two main reasons. Firstly, as was previously mentioned, information collected from the visual and auditory receptors allow the user to experience the cognitive and psychological benefits during an outdoor walk. Secondly, during the preliminary tests with the pedal exerciser, the test users displayed behavior that involved visual contents and sound, such as television contents and music. The fact that these behaviors were natural responses to exercise with the pedal exerciser suggests that by stimulating the visual and auditory receptors, it is possible to engage the user in exercise activities. This means that in addition to providing cognitive and psychological benefits, audiovisual contents will support the pedal exerciser in providing the physical benefits, therefore enabling the proposed solution to provide all three benefit types.

In order to determine the appropriate type of audiovisual contents to develop for this research, attributes that positively influence the cognition and psychology of humans, particularly the elderly, were explored. The next two parts describe the attributes that aid in providing the cognitive and psychological benefits of an outdoor walk.

3.2.1 Attributes for Cognitive Benefits

The cognitive benefits of an outdoor walk contribute to improving cognitive functions and memory, thereby slowing mental decline. This part will describe how the activities that occur during an outdoor walk for the elderly stimulate different parts of the brain, as well as additional activities that have been recommended by research to provide the same effect, so that significant attributes can be identified for potential use in the audiovisual contents. It is important to include these specific attributes, because performing regular, targeted exercises for the brain helps protect brain tissue and can increase the brains cognitive reserve (Melone 2015).

During the fieldwork in the Preliminary Research, the activities that occurred during an outdoor walk that contributed to cognitive benefits were identified as follows:

- Recognition and identification of people, animals, fruits, items, etc.
- Using visual and auditory information to predict future events
- Recognition and association of common colors and sounds with what is happening at that time
- Recognition and identification of familiar places, comparing past and present
- Open mindset and ability to collect information about the surroundings through the senses

In order to explain what cognitive processes and which brain areas were involved during these activities, an image of the brain has been included in Figure 3.5.

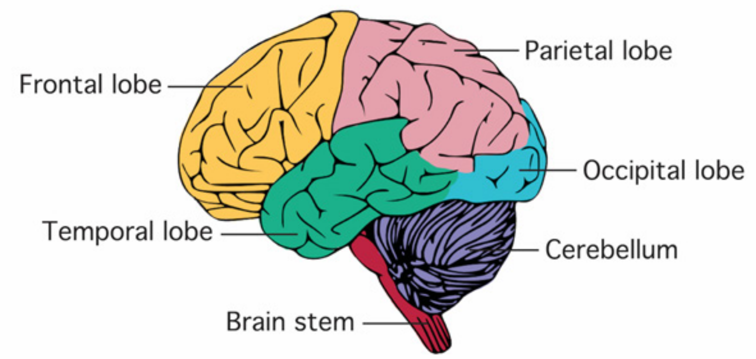

Figure 3.5: Parts of the brain

The process of recognition and identification of people, animals, fruits, items, etc. and recognition and association of common colors and sounds with what is happening at that time are important, because identifying objects that one sees involves the occipital lobes of the brain (Michelon 2008). When realizes the presence of something in an area that surrounds them, the brain has analyzed the spatial relationships between the objects that one sees, and this involves the occipital and parietal lobes (Michelon 2008). Recognition involves associating an event or physical object with one previously experienced or encountered, and it is a process of comparison of information with memory. Recalling memories to access past knowledge is a very important process to exercise the brain, and it involves the function of many different parts of the brain, including the frontal lobe and the cerebellum (Kapur et al. 1995). This process also took place during recognition and identification of familiar places, and when comparing the past with the present. Using visual and auditory information to predict future events, as well as collecting information about the surroundings through the senses involves sensory processing. By using multiple senses at once, it is possible to stimulate different lobes of the brain, such as the occipital lobe for sight and the temporal lobe for smell and sound (Marrelec et al. 2008).

In addition to these types of activities, there are other exercises and behaviors that are important in stimulating the brain. These include the following:

- Testing ones short-term memory, which involves the frontal and parietal lobes
- Staying focused and paying attention to detail to keep the brain active and not in the passive mode, since the latter can be detrimental to brain health (Melone 2015)
- Learning a new language by listening and hearing (Melone 2015)
- Singing songs
- Reading, which actively engages the mind and imagination, stimulating both brain hemispheres (Khalsa 2016)
- Brain exercise using numbers, reasoning, and spatial organization (Khalsa 2016)

The exercises described in this section helped develop audiovisual contents that can potentially benefit the users cognition, as will be discussed further on.

3.2.2 Attributes for Psychological Benefits

The psychological benefits of an outdoor walk contribute to an improved mood and a positive mental outlook, which can help the elderly stay healthy and independent. This part will describe the attributes based on fieldwork in the Preliminary Research that help provide a positive psychological effect, along with justification, so that significant attributes can be identified for potential use in the audiovisual contents.

During the fieldwork in the Preliminary Research, the activities that occurred during an outdoor walk that contributed to psychological benefits were identified as follows:

- Sense of accomplishment after finishing a walk
- Flowers, animals, and children relax/soothe the mind
- Making an effort to keep on walking
- Boosting self-confidence after completing a nice walk outside

These activities reflect some of the most important ways to improve ones mental health. For example, going for a walk outside, making an effort to keep on moving forward, and coming back home is an exercise goal, and setting realistic goals and accomplishing them boosts self-confidence and makes people feel good about themselves. The process of exercising also provides positive energy, since it means that one is taking good care of the body. Elements like flowers, animals, and children can relax and soothe the mind, since they are peaceful and provide a sense of comfort. They are visual cues that signal safety, which evokes a happy and positive emotional response. Being connected to nature and its elements calms the mind, and this type of effect is known as Ecotherapy (Bushak 2013).

The activities and elements described in this section helped develop audiovisual contents that can potentially benefit the users mental health and well-being, as will be discussed further on.

3.2.3 Content Development

This part will describe the types of audiovisual content that were developed for this research. The contents are divided into two main categories: virtual walk videos, which are videos from footage shot in the real world, and animations, which are original creations using the Adobe Systems software.

Virtual Walk Video: Neighborhood Streets

The first type of audiovisual content developed for this research was a virtual walk video through the neighborhood streets. The footage was shot throughout Japan in neighborhoods using the iPhone 6 and the DJI Osmo equipment for stability. Care was taken to keep the video as stable as possible, at an eye-level camera angle and walking speed that matches those of an average elderly person. Neighborhoods that are relatively safe for the elderly to walk in were selected, such as those that are not as crowded with few cars passing by. All footage was shot during the day for clarity of video contents. This video type was developed to replicate the view of an outdoor walk for the elderly, including elements that appear during a usual walk, such as people, both young and old, passing by, pets on a walk, and the sound of a local neighborhood. Two of the best footage were selected and edited in Adobe Premiere Pro to adjust the length and to add natural sound of the forest with singing birds and water flowing in one version, and upbeat music in another. Figure 3.6 is a sample still frame of this content category.

Figure 3.6: Sample still frame of video through neighborhood streets

Virtual Walk Video: Park

The second type of audiovisual content developed for this research was a virtual walk video through the park. The footage for this category was shot throughout Japan as well, in parks with green areas and trees using the iPhone 6 and the DJI Osmo equipment for stability. Care was taken to keep the video as stable as possible, at an eye-level camera angle and walking speed that matches those of an average elderly person. Parks with many trees and green areas where people gather, and of a size that allows visitors to enjoy walks were selected. All footage was shot during the day for clarity of video contents. This video type was developed to evaluate the effects of Ecotherapy while maintaining the authenticity of the view of an outdoor walk through a park for the elderly, including elements that are characteristic of a park, such as abundant green color and calm environmental sounds. Two of the best footage were selected and edited in Adobe Premiere Pro to adjust the length and to add natural sound of the forest with singing birds and water flowing in one version, and upbeat music in another. Figure 3.7 is a sample still frame of this content category.

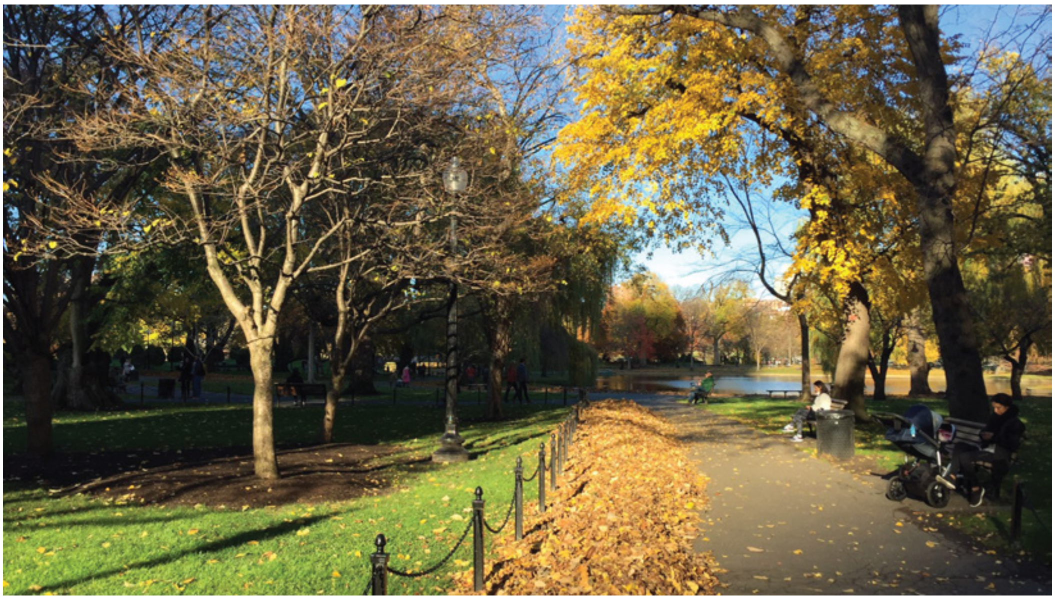

Figure 3.7: Sample still frame of video through park

Animation: Walk Through Park

The second main category of audiovisual contents is animation, which was developed and used in this research because it allows flexible original content creation and manipulation. The “Walk Through Park” animation is similar to the previous content type, but was created from scratch using the Adobe Systems software. First, all the elements of the video, such as the sky, trees, and animals, were created originally and individually using Adobe Illustrator. Specific elements like animals were included because they played an important role in the actual outdoor walks for the elderly. Care was taken to add the appropriate amount of green color, and calm colors overall so that the effect of Ecotherapy could be measured through the animation as well. The elements were then added onto Adobe After Effects in one project, and the movement of each element was transformed by adjusting the position and scale over time. The trees were transformed in a way that allows the viewer to feel as if he or she is moving forward on a path through the forest. Clouds in the sky move sideways, and forest animals appear at random. The end result was exported, and then edited further using Adobe Premiere Pro to add transitions and audio. In one video version, natural sound of the forest with singing birds and water flowing was added, and in another version, upbeat sound was added. Figure 3.8 is a sample still frame of this animation content.

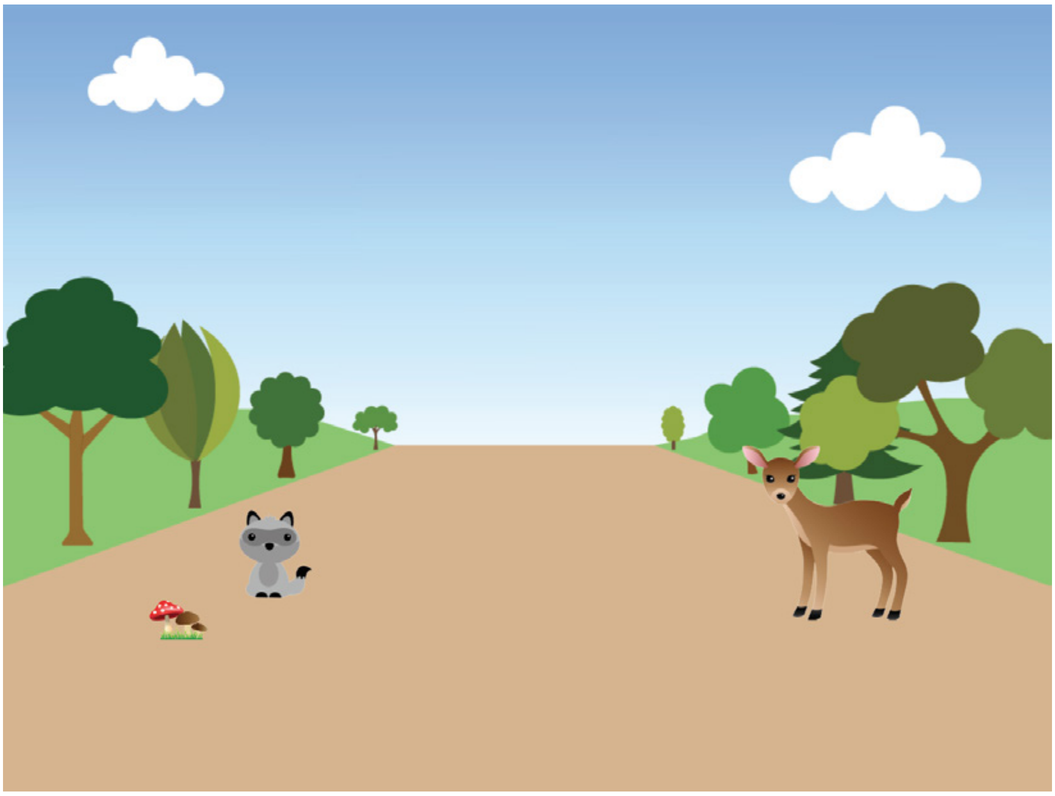

Figure 3.8: Sample still frame of "Walk Through Park" animation

Animation: Count to 20 in English

The "Count to 20 in English" animation was developed mainly to incorporate elements that provide the cognitive benefits, particularly those of learning a new language by listening and hearing, singing songs, and reading. This animation was also created from scratch using the Adobe Systems software. The forward-moving animation through a forest path in the background used in this animation is the same as that used in the previous animation, so that there is a connection between the animation content and the pedaling movement. All the elements of the video, such as the words, numbers, trees, and animals, were created originally and individually using Adobe Illustrator. Care was taken to use colors and text size that could be clearly seen on the screen by the elderly users. The elements were then added onto Adobe Premiere Pro in one project, and edited so that the progress of the animation would match the counting song. In one video version, the counting song was slowed down, and in another version, the same song with a faster tempo was used. Figure 3.9 is an image of the workspace in creating the animation, and Figure 3.10 is a sample still frame of this animation content.

In this animation, the user is asked to count together with the singer up to 20 in English. The limit was set to 20, because in the Preliminary Test with the pedal exerciser, the test users counted out loud in English up to 10, and 20 was thought to be the appropriate number to engage the user in a new type of task. If a number higher than 20 was used, the task may become too difficult and tiring. The song counts to 20 multiple times, and does so in three different speeds. The instructions throughout the video encourage the viewer to make an effort to continue pedaling, and then praise the user for doing a great job. The instructions were written in Japanese since the users invited to the experiment tests were all Japanese.

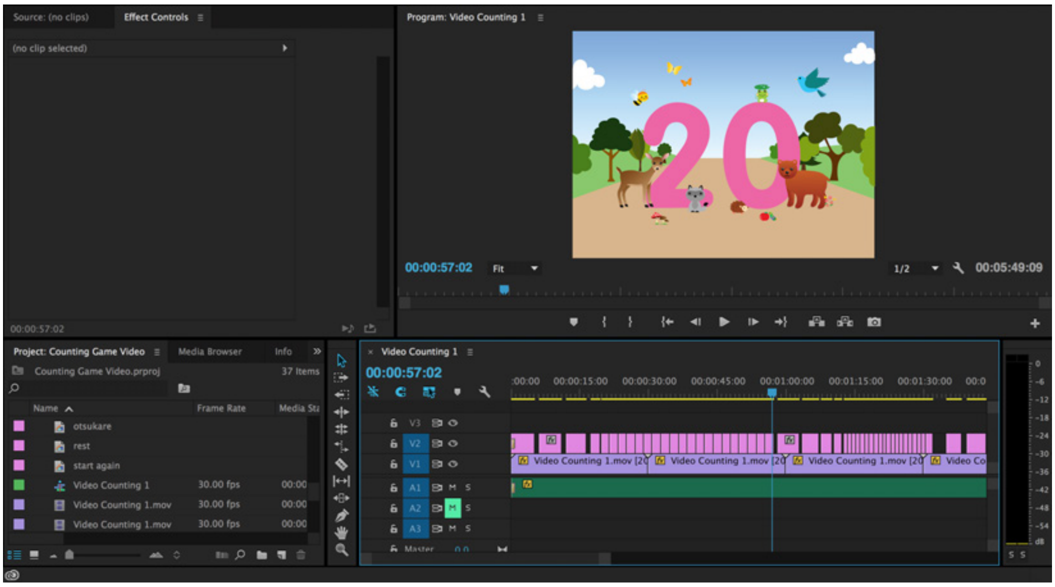

Figure 3.9: Workspace of “Count to 20 in English” animation

Figure 3.10: Sample still frame of "Count to 20 in English" animation

Animation: Walking Quiz Game

The "Walking Quiz Game" animation was developed mainly for brain exercise using numbers, reasoning, and spatial organization to keep the brain active while the user engaged in pedaling exercise. It helps exercise the brain by testing the users' short-term memory, encouraging them to stay focused and pay attention to detail, and inviting them to read and participate in the animation. This animation was also created from scratch using the Adobe Systems software. The forward-moving animation through a forest path in the background used in this animation is the same as that used in the previous two animations, so that there is a connection between the animation content and the pedaling movement. All the elements of the video, such as the words, numbers, trees, flowers, fruits, and animals, were created originally and individually using Adobe Illustrator. Care was taken to use colors and text size that could be clearly seen on the screen by the elderly users. Some of the elements were then added onto Adobe After Effects in one project, and the movement of the elements was transformed by adjusting the position and scale over time. Animals moved across the screen on the ground or in the sky, and fruits rolled down the path. The end result was exported, and then edited further with the remaining elements using Adobe Premiere Pro to add transitions and audio. In one video version, natural sound of the forest with singing birds and water flowing was added, and in another version, upbeat sound was added. Figure 3.11 is an image of the workspace in creating the animation, and Figure 3.12 is a sample still frame of this animation content.

In this animation, the user is asked to answer five questions on counting the animals, fruits, and flowers that appear on the screen as they pedal. The first two questions include fruits and flowers that are stationary on the screen, and the remaining three questions include animals that move across the screen. The difficulty of the questions increases as the animation progresses to keep the quiz interesting and engaging. There are instructions throughout this video as well to encourage the viewer to make an effort to answer the questions and to continue pedaling, and then to praise the user for doing a great job. The instructions were written in Japanese since the users invited to the experiment tests were all Japanese.

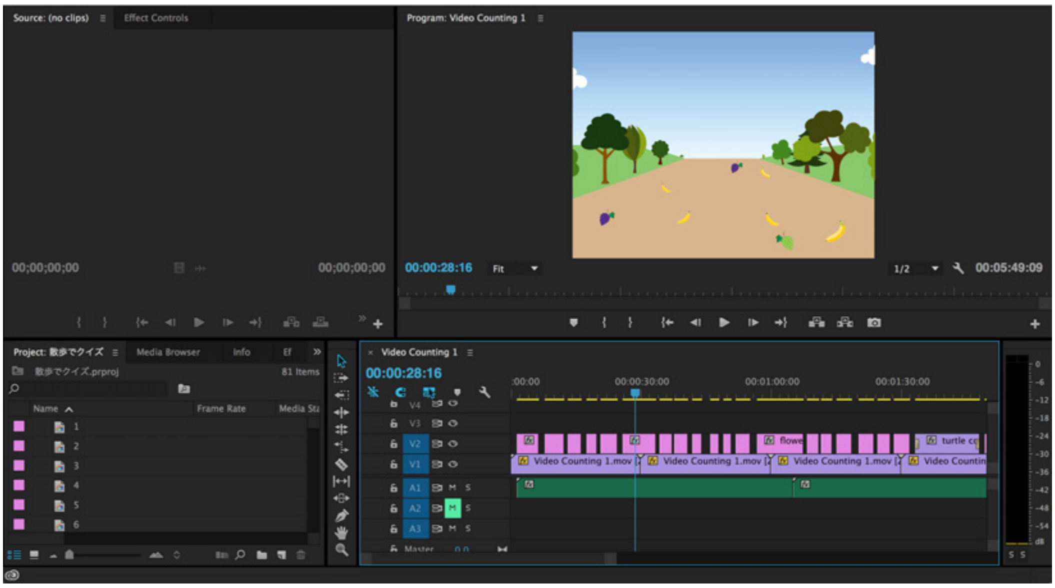

Figure 3.11: Workspace of "Walking Quiz Game" animation

Figure 3.12: Sample still frame of “Walking Quiz Game” animation

3.3 Implementation

This part describes how the different components of the system described so far, including the pedal exerciser, tablet computer, and audiovisual contents, come together as the proposed solution that allows the user to experience the three types of benefits of an outdoor walk while avoiding the associated challenges and dangers.

Figure 3.13 shows the accessories that were added onto the pedal exerciser, including the tablet computer and the tablet stand. They are attached to the pedal exerciser as shown in Figure 3.14, and the height, direction, and orientation of the tablet stand can be changed as desired. One of each type of audiovisual content was added onto one folder in a micro SD card, which was then inserted into the tablet. The contents can be viewed on the tablet screen in one folder, and can be selected easily to be played.

Figure 3.13: Accessories to supplement pedal exerciser

Figure 3.14: System set-up of proposed solution (side view, front view)

The types of audiovisual contents developed and added onto the tablet computer were the following 10 contents:

- Virtual walk neighborhood streets, natural sound
- Virtual walk neighborhood streets, upbeat music
- Virtual walk park, natural sound
- Virtual walk park, upbeat music
- Animation "Walk Through Park", natural sound
- Animation "Walk Through Park", upbeat music
- Animation "Count to 20 in English", slow tempo
- Animation "Count to 20 in English", fast tempo
- Animation "Walking Quiz Game", natural sound
- Animation "Walking Quiz Game", upbeat music

All the videos were set to play for a duration of 5 minutes, since it was an appropriate length for the elderly to continuously exercise for one set/session. It has also been proven in past research that exercise can improve cardiovascular health and body composition when done in as little as 5 minute bouts for a total of 30 minutes per day (Coleman et al. 1999). Therefore, in the ideal case, the user would use the pedal exerciser with the audiovisual contents for 5 minutes per session, and enough times per day along with other exercise to meet the 30-minute goal. The minimum bout time was used so that the solution can be used by as many elderly people as possible.

3.4 Target Persona

The target persona of the proposed solution in this research is an 80-year old individual (in this example, female) who is still in good health and lives in her house with her husband in an urban city. Although still in good health overall, she realizes that her mental and physical abilities are declining, and sometimes finds it difficult to complete her daily tasks such as cleaning the house and taking good care of herself and her husband. Many of her friends live in a retirement home or go to senior centers everyday, but she prefers not to and wants to stay independent. She is well-aware of the fact that exercise is key to a long, healthy life, and likes to go for a walk outside everyday. However, she faces barriers to outdoor walks from time to time, such as when it is too cold outside in the winter or too hot and humid in the summer, or when she feels discomfort in her knees and is afraid to go outside. Her daughter comes to see her every weekend, and is also concerned about her safety when she walks outside, since there is a risk of traffic accidents or other danger.

It is at this point when the proposed solution comes into good use. When she is faced with these barriers, she can place the pedal exerciser with the tablet stand in front of her chair, and set the tablet in its place. She sits down and selects the audiovisual content of her choice on the screen, and pedals as the content plays. When the content finishes, she plays another content if she wants to continue exercising, or takes a break and continues later on during the day. Even when she cannot go outside to exercise for at least 30 minutes every day, she can rely on the pedal exerciser with the audiovisual contents to keep her physical, cognitive, and psychological state healthy, so that she can continue to live independently and take good care of herself.

3.5 Hypothesis

In order to determine whether or not the proposed solution provides the desired effect of the physical, cognitive, and psychological benefits of an outdoor walk while avoiding the associated challenges and dangers, the following hypothesis was devised:

> "Audiovisual contents with the pedal exerciser support the elderly's exercise activities at home by helping provide the physical, cognitive, and psychological benefits of going for a walk outside."

In order to test the hypothesis, user tests were conducted with the proposed solution as will be explained in the next chapter.

Chapter 4
Evaluation

4.1 Experiment Setting

In order to evaluate the degree to which audiovisual contents can support exercise activities using the pedal exerciser by helping provide the three types of benefits for the elderly, user tests were conducted with the pedal exerciser and the ten audiovisual content types using the set-up shown in Figure 3.14, along with control experiments. The subjects of the study were 5 elderly individuals living in Tokyo. Three of them participated in the experiment using the audiovisual contents with the pedal exerciser, and the remaining two participated in the control experiment using only the pedal exerciser. The subject selection criteria were as follows: over 65 years old, living in own house, healthy status with minor health problems, and no disease that could affect performance during the experiment. All the subjects understood the purpose of this study, and were asked to behave as they would normally do if they were to use the system at home. The experiment was conducted over a 20-day period, at the homes of three test users. One test trial was equivalent to one exercise session using one audiovisual content, which lasted five minutes, and using no contents for up to five minutes for the control tests. The number of test trials done per day varied for each test user, with a minimum of two trials and a maximum of three trials per day to ensure that the participants had enough rest in between the trials. For the control experiments, the participants were asked to use the pedal exerciser two to three times per day everyday. The participants were asked to behave and spend the remainder of their days as they would normally do.

There were 11 types of test trials as follows:

- Virtual walk neighborhood streets, natural sound
- Virtual walk neighborhood streets, upbeat music
- Virtual walk park, natural sound

- Virtual walk park, upbeat music
- Animation “Walk Through Park”, natural sound
- Animation “Walk Through Park”, upbeat music
- Animation “Count to 20 in English”, slow tempo
- Animation “Count to 20 in English”, fast tempo
- Animation “Walking Quiz Game”, natural sound
- Animation “Walking Quiz Game”, upbeat music
- No content

The last item, “No content,” was used for the control experiment to serve as the basis of comparison for the experiment results using the audiovisual contents. It was used for both the test users with the audiovisual contents and the test users for the control experiment with only the pedal exerciser. Each type of test trial with the audiovisual contents was only done once on each test user, so that the contents could remain fresh every time and the user’s reaction would be as authentic and natural as possible.

Each test trial was recorded on video so that the test user’s behavior and reaction could be analyzed afterwards. Observations were noted during the test trials, and in-depth interviews were conducted after one exercise session. Figure 4.1 shows an example of a test trial taking place.

Since the physical, cognitive, and psychological benefits of an outdoor walk all differ, it was necessary to evaluate the degree to which the audiovisual contents and pedal exerciser together can provide each of the three types of benefits separately using different evaluation methods. Therefore, the remainder of this chapter is divided into three sections, one for each type of benefit. In each section, the evaluation method used and a discussion of findings has been provided.

Figure 4.1: User test with audiovisual contents and pedal exerciser

4.2 Evaluation of Physical Benefits

4.2.1 Method

A combination of quantitative and qualitative research methods was used to evaluate the physical benefits that the audiovisual contents help provide during exercise with the pedal exerciser. The method was devised upon examination of the physical benefits that an outdoor walk provides, as well as the activities that contribute to those benefits during a walk for the elderly, because the aim of this research is to propose a solution that provides the physical benefits of an outdoor walk. Three quantitative measurements, or variables, were used, including total pedal count, total pedal time, and count stability, along with qualitative research methods by observation and in-depth interviews with the test users to calculate the physical score.

Total Pedal Count

The total pedal count is the total number of times (strokes) the test user pedals in one test trial, or exercise session. One pedal is equivalent to one stroke, which is one 360 degree motion on one pedal using one foot. For the experiments with the audiovisual contents, each test trial was recorded on video and the total pedal count was determined by counting the motion on video for each test trial on the three test individuals. This produced three values for each content type, and the average was calculated to determine the final total pedal count. For the control experiments, three of the recordings of the test trials were selected randomly and used to determine the total pedal count, so that three values would be produced, and the average was calculated to determine the final total pedal count for the control experiments as a whole.

The total pedal count is significant because it is a measure of the amount of exercise activity done in one exercise session. The pedaling motion is synonymous to the steps taken during a walk, and the higher the total pedal count, the greater the amount of physical movement, and the greater the degree of physical benefits one exercise session can provide. Therefore, a higher total pedal count value corresponds to a greater effectiveness in providing the physical benefits of an outdoor walk.

Total Pedal Time

The total pedal time is the total number of seconds during which the test user continues to pedal in his or her own will in one exercise session. Since the duration of one exercise session is five minutes, the maximum total pedal time is 300 seconds. For the experiments with the audiovisual contents, the total pedal time was determined by counting the exercise duration in the video recordings for each test trial on the three test individuals. This produced three values for each content type, and the average was calculated to determine the final total pedal time. For the control experiments, the same three recordings of the test trials selected to determine the total pedal count value were used to determine the total pedal time, so that three values would be produced, and the average was calculated to determine the final total pedal time for the control experiments as a whole.

The total pedal time is significant because it is a measure of the duration of exercise activity done in one exercise session. Since various health organizations and research state that at least 30 minutes of exercise per day is needed for the exercise benefits to take into effect, the longer the total pedal time, the more significant the exercise session becomes since it contributes more to and brings the user closer to achieving this minimum requirement (Haskell et al. 2007). Therefore, a higher total pedal count time corresponds to a greater effectiveness in providing the physical benefits of an outdoor walk.

Count Variability

The count variability refers to the pedal count degree of variability, which is a measure of how unstable (or stable) the pedal count was over the course of one exercise session. The value was determined by first counting the total pedal count at every minute in the video recordings for each test trial on the three test individuals for the experiments with the audiovisual contents, and for the control experiments, in the same three recordings of the test trials selected to determine the total pedal count and time. This means counting the number of strokes between the following times: 0 to 1 minute, 1 to 2 minutes, 2 to 3 minutes, 3 to 4 minutes, and 4 to 5 minutes. The average stroke count of each trial test type was then calculated, and were all plotted together on a graph of pedal count versus minute. The slope of a linear fit through the graph points was determined, and the absolute value of the slope is equivalent to the count variability.

The count variability is significant because it is a measure of how stable the pedaling rate was over the course of one exercise session. It is important to consider this value in the evaluation, because even if both the total pedal count and total pedal time were high, the user may have pedaled very fast in the beginning and very slowly near the end of the exercise session. It is preferable to maintain a stable pedaling pace over the entire exercise session, because it helps the user exercise for a longer time and does not put additional pressure on the body, which is important for the elderly. Therefore, a lower value of count variability corresponds to a greater effectiveness in providing the physical benefits of an outdoor walk.

Physical Score

The physical score is a measurement device intended to assess the test users' experience related to some of the activities, tasks, behaviors, and conditions that are signs of improved physical strength and overall health. The items to be assessed were selected based on the types of physical benefits an outdoor walk provides, since the aim of this research is to propose a solution that provides some of those benefits. The selected items were as follows:

- More active throughout the day
- Decreased knee pain
- Decreased muscular pain and stiffness
- Improved balance
- Easier to carry out daily tasks
- Improved overall health (e.g. lower blood pressure, other medical measures of health if applicable)

These items were assessed by scoring them through the qualitative research methods of observation and in-depth interviews at the end of all test trials. The items that were not applicable or irrelevant to the test user were removed from the assessment. The scoring scale used is shown in Table 4.1.

Table 4.1: Scoring scale used to determine Physical Score

Score	**Detail**
1	Very rarely or never
2	Rarely
3	Sometimes
4	Often
5	Very often or always

One physical score was determined for the experiments using the audiovisual contents as a whole, and another score for the control experiments without the contents. Separate physical scores were not obtained for each audiovisual content type, because the activity of one test trial may influence the assessment of the test trials done afterwards. This produced five assessment scores for each item, three for the experiments with the contents, and two for the control experiments. All the scores of all items were averaged for each experiment set to evaluate the physical benefits of the audiovisual contents. The assessment was developed so that a high physical score corresponds to a greater effectiveness in providing the physical benefits of an outdoor walk.

4.2.2 Discussion of Findings

Figure 4.2 shows a graph of the pedal count at every minute during the duration of one trial test for each trial test type. The lines connecting the pedal counts show how the pedal count varied at every minute. The steeper the slope, the greater the variation. The linear fit was included to determine its slope, and the absolute value was used as the count variability, which is summarized in Table 4.2. Individual pedal count values for each test user can be found in Appendix Part A.

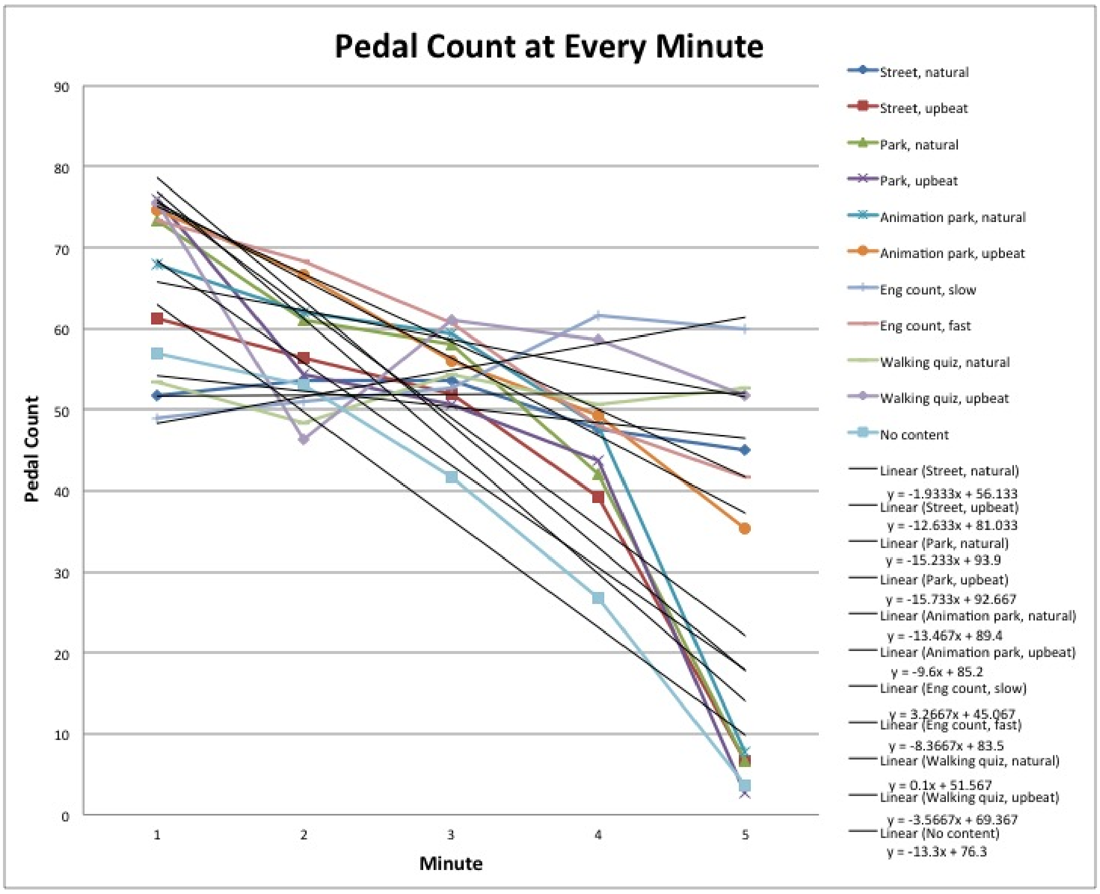

Figure 4.2: Graph showing average pedal count at every minute with a linear fit through the graph points for each trial type

Some significant findings from the graph will be explained along with possible explanations based on observation and in-depth interviews. For the test trial types with a downwards slope, the test users pedaled very quickly in the beginning, and became tired so they gradually pedaled more slowly. This was particularly the case with contents with upbeat music, since the test users matched their pedal pace with the music tempo. For the other test trial types, such as the one with no content, there was nothing to encourage the test users to continue pedaling and make an effort, so the pedaling count decreased at every minute. For some of the test trial types, the lines decrease and then increases afterwards. This was the case with the Walking Quiz animation, both with natural music and upbeat music, because the test users could not concentrate and see the details of the contents properly if they pedaled quickly for some of the questions in the quiz.

Table 4.2 is a summary of the average values of total pedal count, total pedal time, and count variability for each test trial type. Individual values for each test user can be found in Appendix Part A.

Table 4.2: Average variable values for evaluating physical benefits of each content type

Content Type	**Total Pedal Count (strokes)**	**Total Pedal Time (sec)**	**Count Variability**
Street, natural	252	290	1.93
Street, upbeat	216	255	12.63
Park, natural	241	257	15.23
Park, upbeat	227	250	15.73
Animation park, natural	245	252	13.47
Animation park, upbeat	282	287	9.60
English count, slow	274	300	3.27
English count, fast	292	268	8.37
Walking quiz, natural	259	300	0.10
Walking quiz, upbeat	293	300	3.57
No content	182	248	13.30

Some significant findings from the table will be explained along with possible explanations based on observation and in-depth interviews. A total pedal time value that is less than the maximum value of 300 seconds indicates a few possibilities. In some cases, the contents did not encourage the test user to continue pedaling for the duration of the entire exercise session, such as the virtual walk of both the neighborhood streets and the park with natural music, as well as the animation of a walk through the park with natural music. In other cases, the contents encouraged the test user to pedal too quickly in the beginning, so that the user became too tired to continue pedaling for the duration of the entire exercise session. This was the case with the same contents as previously stated but with upbeat music. In terms of providing the physical benefits of an outdoor walk, the contents with the maximum total pedal time were most effective, which include the animation of counting to 20 in English, and the animation of the Walking Quiz, both with natural and upbeat music. It is important to encourage the user to pedal for the entire duration of the exercise session, because that helps them attain the 30 minute daily minimum requirement for exercise.

The total pedal count value, though less significant a factor than the total pedal time in the evaluation, is important to ensure that the test user was pedaling enough times during the exercise session. It is possible for the total pedal time to be high and the count variability to be low, but the total pedal count to be low as well, which would not make the test trial type effective in providing the physical benefits because the user would not be pedaling enough to make the exercise session beneficial for their physical health.

Table 4.3 is a comparison of the average physical benefit score with the audiovisual contents and without the contents (control experiment). The score without audiovisual contents is relatively high already, which proves that the pedal exerciser itself provides the physical benefits of an outdoor walk for the elderly users. The score with the audiovisual contents is even higher, with an increase of around one full score, which proves that audiovisual contents support the elderly's exercise activities by further providing the physical benefits of an outdoor walk. Individual values for each physical score item for each test user can be found in Appendix Part A.

Table 4.3: Comparison of average physical benefit score with and without audiovisual contents

Experiment Type	**Average Physical Score**
With audiovisual contents	4.61
Without audiovisual contents (control)	3.67

Based on the results of the experiments, the three most effective content types in providing the physical benefits of an outdoor walk were the following: animation of the Walking Quiz with natural music, animation of counting to 20 in English with slow speed music, and animation of the Walking Quiz with upbeat music. In this selection, all three variables in evaluating the content types were considered, with the most emphasis on the total pedal time and count variability. The total pedal count was considered afterwards, and the content types were identified to be effective even though the total pedal count was not the highest as long as it was not significantly low. In terms of the count variability, although the value for the virtual walk of the streets with natural music was relatively low, it was not selected as being effective since the pedal count was low near the end of the exercise session.

4.3 Evaluation of Cognitive Benefits

4.3.1 Method

A combination of quantitative and qualitative research methods was used to evaluate the cognitive benefits that the audiovisual contents help provide during exercise with the pedal exerciser. The method was devised upon examination of the cognitive benefits that an outdoor walk provides, as well as the activities that contribute to those benefits during a walk for the elderly, because the aim of this research is to propose a solution that provides the cognitive benefits of an outdoor walk. One quantitative measurement, or variable, was used, which was the engagement rate, along with qualitative research methods by observation and in-depth interviews with the test users to calculate the cognitive score. The same evaluation methods could not be applied to the control experiments for the cognitive benefits, because they were dependent on the audiovisual contents, which were not used for the control. The evaluation methods were to be considered significant as long as there was positive feedback with the experiments using the audiovisual contents.

Engagement Rate

The engagement rate is the total time the user looks at the contents of the tablet screen over the total content duration, expressed as a percentage. The video recordings of each test trial was used to monitor and measure the total time (in seconds) the test users spent looking at the contents of the screen. The value of the total time over the total content duration, which was 300 seconds, was then calculated and converted into a percentage. This produced three percentage values for each content type, and the average was calculated to determine the final engagement rate.

The engagement rate is significant because it is a measure of how engaged the user is in the audiovisual contents, and the contents should engage the user's attention to be considered effective in improving cognition (Khalsa 2016). During the fieldwork in the preliminary research, the information that the user collected through his or her visual and auditory senses contributed to the cognitive benefits of an outdoor walk, and since the audiovisual contents play the role of triggering those senses, user engagement is significant to provide the cognitive benefits. If the user is more engaged, he or she is more likely to experience the cognitive benefits by keeping the brain active for a longer time. Therefore, a higher engagement rate corresponds to a greater effectiveness in providing the cognitive benefits of an outdoor walk.

Cognitive Score

The cognitive score is a measurement device intended to assess the test users' experience related to some of the activities, tasks, behaviors, and conditions that help improve cognitive functions and memory. The items to be assessed were selected based on the types of cognitive benefits an outdoor walk provides, since the aim of this research is to propose a solution that provides some of those benefits. The selected items were as follows:

- Overall response rate to contents
- Recognition and identification of elements in content (e.g. people, animals, fruits, items, etc.)
- Does it encourage user to keep an open mindset to collect information about the surroundings through the senses
- Does the user understand current circumstances by connecting visual and auditory cues with what is happening
- Does the user use visual and auditory information to predict future events
- Does it test short term memory
- Does it engage the user to do new tasks, such as brain exercise using numbers, reasoning, and spatial organization
- Does it engage the user to sing
- Does it engage the user to read

These items were assessed by scoring them through the qualitative research methods of observation and in-depth interviews at the end of each test trial. The items that were not applicable or irrelevant to the test user were removed from the assessment. The scoring scale used is shown in Table 4.4.

Table 4.4: Scoring scale used to determine Cognitive Score

Score	Detail
1	Very rarely or never (low)
2	Rarely
3	Sometimes (medium)
4	Often
5	Very often or always (high)

Three score values were produced for each item, one from each test user, and the average score was calculated. Then, the average score of all individual scores for each item was calculated as the final cognitive score for each content type. The assessment was developed so that a high cognitive score corresponds to a greater effectiveness in providing the cognitive benefits of an outdoor walk.

4.3.2 Discussion of Findings

Table 4.5 is a summary of the average values of engagement rate and cognitive score for each content type. Individual values for each test user can be found in Appendix Part B.

Table 4.5: Average variable values for evaluating cognitive benefits of each content type

Content Type	Engagement Rate (%)	Cognitive Score
Street, natural	76	3.70
Street, upbeat	61	2.78
Park, natural	73	3.07
Park, upbeat	62	2.41
Animation park, natural	85	2.15
Animation park, upbeat	83	1.93
English count, slow	98	4.89
English count, fast	93	4.59
Walking quiz, natural	96	4.70
Walking quiz, upbeat	98	4.63

Some significant findings from the table will be explained along with possible explanations based on observation and in-depth interviews. A low engagement rate means that the test users spent relatively less time looking at the contents of the tablet screen as they exercised. This was particularly the case for the virtual walk through the streets and the park, both with upbeat music, mainly because the contents were not interesting enough to engage the users and hold their attention, and because the upbeat music encouraged the users to pedal faster. When the users pedaled fast, they often looked down on their feet to watch the pedal movement, and this is also a sign that they were making an effort to pedal fast. The engagement rate for the virtual walk through the streets and the park, both with natural sound, was still relatively low, which further supports the fact that the contents were not engaging enough. This makes those contents less effective in providing the cognitive benefits of an outdoor walk, because the users experience those benefits by engaging in and paying attention to the contents, which stimulates their brain.

The engagement rate of the animation of a walk through the park was higher than that of the virtual walks, since the test users were more interested in animation contents. The cognitive score, however, was the lowest of all content types, because the animation was repetitive, and did not provide many tasks and activities to stimulate the brain. The cognitive score of the virtual walks was higher, because the contents are similar to what the elderly see and hear during a usual outdoor walk.

The engagement rate of the animation of counting to 20 in English and walking quiz was highest of all content types, mainly because the words and instructions kept the users fully engaged. The animations gave specific tasks for the users to do, and the users demonstrated positive behavior and reaction to those tasks. In the animations, there were words that applauded and cheered the users for making an effort, which further kept them engaged. The cognitive score of those animations was also high, mainly because they were made by taking care to include specific tasks and activities that stimulate the brain. Since the users were engaged in those tasks and activities, the animation contents were able to provide the appropriate cognitive benefits.

Although the evaluation methods could not be used for the control experiments in this case, the positive results of the engagement rate and cognitive score of the audiovisual contents overall make the evaluation significant in assessing the contribution of the contents in providing the cognitive benefits of an outdoor walk.

The results prove that audiovisual contents support the elderly's exercise activities by providing the cognitive benefits of an outdoor walk, which would otherwise be lacking with only the pedal exerciser.

Based on the results of the experiments, the three most effective content types in providing the cognitive benefits of an outdoor walk were the following: animation of counting to 20 in English with slow speed music, animation of Walking Quiz with natural sound, and animation of Walking Quiz with upbeat music. In this selection, both variables in evaluating the content types were considered, with slightly greater emphasis on the cognitive score since it measures the extent to which the contents stimulate the brain. This is why the animation of counting to 20 in English and the Walking Quiz with natural sound were identified as being more effective in providing the cognitive benefits with a higher cognitive score, even though the engagement score of the Walking Quiz animation with upbeat music was the highest of all content types.

4.4 Evaluation of Psychological Benefits

4.4.1 Method

Qualitative research methods were used to evaluate the psychological benefits that the audiovisual contents help provide during exercise with the pedal exerciser. The method was devised upon examination of the psychological benefits that an outdoor walk provides, as well as the activities that contribute to those benefits during a walk for the elderly, because the aim of this research is to propose a solution that provides the psychological benefits of an outdoor walk. Qualitative research methods by observation and in-depth interviews with the test users were done to calculate values of the Emotional Wellness Scale and the psychological score. The evaluation was done on both the experiments with the audiovisual contents and without the contents (control experiment).

Emotional Wellness Scale

The Emotional Wellness Scale (EWS) is a measure of emotional well-being developed by positive psychology researchers Ed Diener and Robert Biswas-Diener (Diener and Biswas-Diener 2008). It is an evaluation of the pleasant and unpleasant feelings that the participants experienced in the activities and experiences they were engaged in during a past defined period, using a numbered scale. The items evaluated in the assessment are as follows (the item number is written in parentheses):

- Positive (1)
- Negative (2)
- Good (3)
- Bad (4)
- Pleasant (5)
- Contented (6)
- Interested (7)
- Stressed (8)
- Unpleasant (9)
- Happy (10)
- Sad (11)
- Angry (12)
- Afraid (13)
- Loving (14)
- Depressed (15)
- Joyful (16)

The numbered scale used to score the items is shown in Table 4.6.

Table 4.6: Number scale used for scoring items

Score	**Detail**
1	Very rarely or never
2	Rarely
3	Sometimes
4	Often
5	Very often or always

This assessment method was used to evaluate the pleasant and unpleasant feelings that the test users experienced during each test trial, and the scores were determined through in-depth interviews. This produced three scores for each content type in the experiments with the audiovisual contents, and an additional three scores for the control experiments from the same three test trials that were video recorded for evaluation of physical and cognitive benefits. The three scores were averaged for each set of test trials (or for each content type). Using the average scores for each item, the overall pleasant and unpleasant feelings scores and the happiness balance score were calculated. The overall pleasant feelings score can be calculated by adding up the scores on items 1, 3, 5, 6, 7, 10, 14, and 16 (8 items), and the overall unpleasant feelings score can be calculated by adding up the scores on items 2, 4, 8, 9, 11, 12, 13, and 15 (8 items). The happiness balance score is the relation between the overall pleasant and unpleasant scores, and it is calculated by subtracting the overall unpleasant feelings score from the overall pleasant feelings score. Tables 4.7, 4.8, and 4.9 below provide an interpretation of each of these three calculated scores.

Table 4.7: Score interpretation for pleasant feelings

Score Range	Detail
8 ∼ 13	Extremely low pleasant feelings
14 ∼ 18	Very low
19 ∼ 23	Low
24 ∼ 27	Moderate
28 ∼ 30	High
31 ∼ 35	Very high
36 ∼ 40	Extremely high pleasant feelings

Table 4.8: Score interpretation for unpleasant feelings

Score Range	Detail
8 ∼ 11	Extremely low unpleasant feelings
12 ∼ 16	Very low
17 ∼ 20	Low
21 ∼ 25	Moderate
26 ∼ 28	High
29 ∼ 31	Very high
32 ∼ 40	Extremely high unpleasant feelings

Table 4.9: Score interpretation for happiness balance

Score Range	Detail
24 ∼ 32	Very happy
16 ∼ 23	Happy
5 ∼ 15	Slightly happy
4 ∼ -3	Neutral, mixed
-4 ∼ -12	Somewhat unhappy
-13 ∼ -23	Very unhappy
-24 ∼ -32	Extremely unhappy

Psychological Score

The psychological score is a measurement device intended to assess the test users' experience related to some of the activities, tasks, behaviors, and conditions that contribute to and are signs of an improved mood and a positive mental outlook. The items to be assessed were selected based on the types of psychological benefits an outdoor walk provides, since the aim of this research is to propose a solution that provides some of those benefits. The selected items were as follows:

- Signs of enjoyment (e.g. smiling, laughing)
- Positive facial expression
- Improved mood
- Less stress, more calm
- Boost in self-confidence (do users feel better about themselves)
- User is making an effort
- User is competent and capable of doing tasks and activities
- User is engaged and interested in the tasks and activities
- User feels a sense of accomplishment after completion of exercise and contents
- Better sleep at night

These items were assessed by scoring them through the qualitative research methods of observation and in-depth interviews at the end of each test trial. The scoring scale used is the same as that shown in Table 4.6.

Three score values were produced for each item for the experiments with the audiovisual contents, one from each test user, and an additional three scores were produced for each item for the control experiments from the same three test trials that were video recorded for evaluation of physical and cognitive benefits. The three scores were averaged for each item, and those scores were averaged again to calculate one final psychological score for each content type. The assessment was developed so that a high psychological score corresponds to a greater effectiveness in providing the psychological benefits of an outdoor walk.

4.4.2 Discussion of Findings

Table 4.10 is a summary of the average values of the Emotional Wellness Scale, divided into the three values of pleasant feelings, unpleasant feelings, and happiness balance, and the psychological score for each content type. Individual values for each test user can be found in Appendix Part C.

Table 4.10: Average variable values for evaluating psychological benefits of each content type

Content Type	**Emotional Wellness Scale**	**Psychological Score**
Street, natural	25.66 / 9.65 / 16.01	3.20
Street, upbeat	28.68 / 8.00 / 20.68	3.50
Park, natural	26.00 / 9.65 / 16.35	3.23
Park, upbeat	28.34 / 8.00 / 20.34	3.50
Animation park, natural	28.01 / 8.33 / 19.68	3.47
Animation park, upbeat	29.01 / 8.00 / 21.01	3.73
English count, slow	37.01 / 8.00 / 29.01	4.67
English count, fast	35.00 / 8.33 / 26.67	4.50
Walking quiz, natural	34.99 / 8.00 / 26.99	4.63
Walking quiz, upbeat	36.00 / 8.66 / 27.34	4.67
No content	20.34 / 12.34 / 8.00	3.33

**Notes: There are three values or scores for the Emotional Wellness Scale. They are listed in the following order: Pleasant Feelings (PF) / Unpleasant Feelings (UF) / Happiness Balance (HB).*

Some significant findings from the table will be explained along with possible explanations based on observation and in-depth interviews. The pleasant feelings score of all test trials with audiovisual contents fell within the range of moderate to extremely high pleasant feelings, with the highest scores from the animations of counting to 20 in English and of the Walking Quiz. This is mainly due to the fact that the test users enjoyed the contents of these animations, which is in line with the high engagement rate of those contents. The users especially enjoyed the tasks that were given in the animations, which contributed to a positive emotional health. The unpleasant feelings score of all test trials with the contents fell within the extremely low unpleasant feelings range, which is significant because this suggests that none of the contents led to unpleasant feelings, and the addition of the contents in exercise activities can only contribute positively to the users' psychological health. The happiness balance score of all the contents fell within the range of happy to very happy, which is valid because all the contents produced favorable pleasant feelings and no unpleasant feelings.

The psychological score was highest for the same contents with the best EWS scores, which were the animations of counting to 20 in English and of the Walking Quiz. This is mainly because the contents were made by taking care to include details, and task categories and difficulties that were appropriate for elderly users. Since the users reacted favorably to the contents, these animations were able to provide the desired psychological benefits.

The scores of the EWS were the lowest and the psychological score was one of the lowest for the test trials of the control experiments without the audiovisual contents, and all the scores of the experiments with the contents demonstrated greater effectiveness in providing the psychological benefits of an outdoor walk, which proves that the contents support the elderly's exercise activities by providing the psychological benefits of an outdoor walk. The pleasant feelings score of the control tests fell within the low pleasant feelings range, mainly because there were no additional features such as contents that could contribute to a positive experience. Nevertheless, the unpleasant feelings score fell within the very low range, which suggests that exercise using the pedal exerciser is not an unpleasant experience, which supports the effectiveness of the proposed solution. The happiness balance score fell within the slightly happy range, which is valid because even though the pleasant feelings score was not as high, there were very little unpleasant feelings from the experience. The psychological score of the control tests was relatively low, because there were no additional features that could provide the psychological benefits of an outdoor walk.

Based on the results of the experiments, the three most effective content types in providing the psychological benefits of an outdoor walk were the following: animation of counting to 20 in English with slow speed music, animation of Walking Quiz with upbeat music, and animation of Walking Quiz with natural sound. In this selection, all variables in evaluating the content types were considered, with slightly greater emphasis on the happiness balance score of the EWS, since it balances out both the pleasant and unpleasant feelings score, and the psychological score, since it measures the extent to which the contents contribute to positive psychology. In this evaluation, the top three contents with the highest happiness balance score were equivalent to the top three contents with the highest psychological score, which simplified the selection process.

Chapter 5
Conclusion

5.1 Conclusion

The aim of this research is to allow the elderly to engage in exercise activities that provide the physical, cognitive, and psychological benefits of an outdoor walk, with the goal to help the users remain independent so that the costs for long-term care for the elderly to families and society can be alleviated. Walking is one of the best forms of exercise for the elderly, but there are various barriers to participation; this research provides a solution to those barriers by removing the associated challenges and dangers. The proposed solution involves the pedal exerciser with a tablet computer with which the user can engage in audiovisual contents while they exercise at home. The hypothesis tested in this research was as follows: “Audiovisual contents support the elderly’s exercise activities at home by helping provide the physical, cognitive, and psychological benefits of going for a walk outside.” In response to this hypothesis, the proposed solution was evaluated to answer the following research question: “What kind of audiovisual contents are most effective in supporting exercise activities at home for the elderly in the context of providing the physical, cognitive, and psychological benefits of walking outdoors?”

Ten types of audiovisual contents were developed using video and animation content along with natural sound and upbeat music. In the evaluation process, user tests were conducted with the pedal exerciser and the audiovisual contents, along with control experiments without any contents. Both quantitative and qualitative methods were used to evaluate the contents based on the specific physical, cognitive, and psychological benefits of an outdoor walk that they could provide. Based on the results, the three most effective types of contents in these three benefit categories are listed in Tables 5.1 to 5.3.

Table 5.1: The 3 most effective content types for physical benefits

Content Type	Total Pedal Count	Total Pedal Time	Count Variability
Walking quiz, natural	259	300	0.10
English count, slow	274	300	3.27
Walking quiz, upbeat	293	300	3.57

Table 5.2: The 3 most effective content types for cognitive benefits

Content Type	Engagement Rate	Cognitive Score
English count, slow	98	4.89
Walking quiz, natural	96	4.70
Waking quiz, upbeat	98	4.63

Table 5.3: The 3 most effective content types for psychological benefits

Content Type	Emotional Wellness Scale PF / UF / HB	Psychological Score
English count, slow	37.01 / 8.00 / 29.01	4.67
Walking quiz, upbeat	36.00 / 8.66 / 27.34	4.67
Walking quiz, natural	34.99 / 8.00 / 26.99	4.63

The values and scores of the audiovisual contents determined in the evaluation were all favorable and demonstrated higher effectiveness in providing the benefits compared to the control experiments with only the pedal exerciser. This supports the hypothesis and proves that audiovisual contents support the elderly's exercise activities at home by helping provide the physical, cognitive, and psychological benefits of an outdoor walk, which would otherwise be lacking or minimal.

The single most effective type of content in providing all three types of benefits overall was the animation of counting to 20 in English with slow paced music. The animation engaged the users, encouraging them to continue pedaling while exercising their brain as they listened and counted out loud in English. The users enjoyed the contents, which made them feel accomplished and confident about themselves. By providing all three types of benefits, the pedal exercise with the animation can help the elderly take care of themselves and remain independent, which is the main goal of this research.

5.2 Limitation

The results of this research were favorable and supported the hypothesis, yet there are limitations to the research study that should be taken into account. Firstly, there was a limit in the number and variety of the types of contents developed and tested, and a greater variety of contents can lead to a greater variety of results, which can help increase the depth and scope of this research. Nevertheless, the consistency of the positive results across all audiovisual content types makes the findings of this research reliable. Also, the results of the control experiments proved that using the pedal exerciser by itself is already beneficial enough to the users, and the addition of audiovisual contents can only make the experience better.

Another limitation is in the number of test users involved in this research. Three test users participated in the experiments with the audiovisual contents, and two test users participated in the control experiments, which can limit the accuracy of the results. Since there was minimal variability in the results for each type of experiment, and each test user displayed similar behavior and results for the same test trial, the sample size should not have a large impact on the overall findings and conclusions of the study.

There were limitations in the qualitative research methods used for the evaluation due to potential sources of bias in recorded observations and self-reported data. For example, since the test trials with the different audiovisual contents were conducted over several consecutive days, the experience and activity of one test trial may have affected those of the test trials conducted afterwards. Also, when the reaction and behavior of the test users to different contents were similar, it was sometimes difficult to compare and differentiate the recorded observations. The presence of the researcher during data gathering and the experiment setting may have affected the test users' responses, particularly for one test user who felt slightly afraid and uncomfortable with the test setting.

There are also limitations with the Emotional Wellness Scale, because to a certain extent, the test users' levels of pleasant and unpleasant feelings can be influenced by their inborn temperaments. To some individuals, it may be easier to develop pleasant feelings and they may have pleasant feelings more often, while others may have lower levels of pleasant feelings and still be happy. Nevertheless, these limitations should not impact the reliability of the score data collected, since all the test users demonstrated high levels of pleasant feelings and very little unpleasant feelings.

5.3 Future Works

There are various ways this research can be improved by addressing the limitations mentioned previously, and extended for future research and practical applications. Firstly, a greater variety of audiovisual contents can be developed, particularly using animation techniques, because in this research they were the most effective in providing the three types of benefits and in engaging the user. In the contents, various combinations of visual and auditory elements can be included to provide further benefits for the user. Additional functions can be added to the solution as well, for example, by syncing the user's pedaling speed and direction on the exerciser with the speed and direction of movement in the video content. This can help make exercise more fun and improve user engagement by allowing the users to feel like they are really moving forward and exercising outdoors even in an indoor environment.

As a recommendation for compiling and presenting the contents, a website or tablet application that is easy to use for the elderly can be developed. The platform can present the contents in a clear, simple way, so that the elderly can start the program and use it by themselves without assistance, which would help them remain independent. It would also be beneficial to increase the sample size by testing the contents with more users within the target group. Since the contents in this research were tested with Japanese elderly users, the contents can be developed for a global audience so that the proposed solution can be enjoyed by a larger population and be introduced into the international market.

Since the focus of this research was to develop and evaluate audiovisual contents that provide the three types of benefits, further research can be done to make the contents effective and engaging for an extended period of time. Methods to maintain the users' motivation and to encourage them to continue using the pedal exerciser would be beneficial by adding functions such as tracking activities and setting goals to accomplish with the system. Activity data can also be synced with other existing devices and applications that track the users' health and fitness. Future improvements in technology can also take this research a step further with additional functions and methods to engage the user while allowing the elderly to adopt and benefit from new technology.

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Appendix

A Physical Benefits

Total Pedal Count and Total Pedal Time

Value Description	*0-1 min*	*1-2 mins*	*2-3 mins*	*3-4 mins*	*4-5 mins*	*Total Pedal Count*	*Total Pedal Time*
Content type: Street, natural							
Test user #1	48	56	58	54	49	265	300
Test user #2	52	48	55	43	36	234	280
Test user #3	55	57	48	46	50	256	290
Average	51.67	53.67	53.67	47.67	45	251.67	290
Content type: Street, upbeat							
Test user #1	61	55	57	38	7	218	250
Test user #2	58	55	48	41	5	207	255
Test user #3	65	59	51	39	8	222	260
Average	61.33	56.33	52	39.33	6.67	215.67	255
Content type: Park, natural							
Test user #1	74	64	70	47	5	260	250
Test user #2	68	62	55	40	12	237	270
Test user #3	78	57	49	39	3	226	250
Average	73.33	61	58	42	6.67	241	256.67
Content type: Park, upbeat							
Test user #1	78	56	54	44	0	232	240
Test user #2	70	52	48	38	3	211	250
Test user #3	80	55	50	49	5	239	260
Average	76	54.33	50.67	43.67	2.67	227.33	250
Content type: Animation park, natural							
Test user #1	69	62	68	50	12	261	260
Test user #2	65	60	58	45	3	231	245
Test user #3	70	64	52	49	8	243	250
Average	68	62	59.33	48	7.67	245	251.67

Figure A.1: Values of three test users and average for pedal count at every minute, total pedal count, and total pedal time for each content type (Part 1).

Value Description	*0-1 min*	*1-2 mins*	*2-3 mins*	*3-4 mins*	*4-5 mins*	*Total Pedal Count*	*Total Pedal Time*
Content type: Animation park, upbeat							
Test user #1	75	68	55	49	38	285	280
Test user #2	70	62	51	48	27	258	280
Test user #3	79	70	62	51	41	303	300
Average	74.67	66.67	56	49.33	35.33	282	286.67
Content type: English count, slow							
Test user #1	50	50	55	70	74	299	300
Test user #2	45	48	45	50	48	236	300
Test user #3	52	55	58	65	58	288	300
Average	49	51	52.67	61.67	60	274.33	300
Content type: English count, fast							
Test user #1	70	65	57	48	42	282	270
Test user #2	72	68	60	49	38	287	265
Test user #3	78	72	65	47	45	307	270
Average	73.33	68.33	60.67	48	41.67	292	268.33
Content type: Walking Quiz, natural							
Test user #1	52	42	50	51	48	243	300
Test user #2	49	53	55	47	50	254	300
Test user #3	59	50	58	54	60	281	300
Average	53.33	48.33	54.33	50.67	52.67	259.33	300
Content type: Walking Quiz, upbeat							
Test user #1	78	40	62	61	52	293	300
Test user #2	70	49	58	55	48	280	300
Test user #3	79	50	63	60	55	307	300
Average	75.67	46.33	61	58.67	51.67	293.33	300
Content type: No content							
Test user #1	58	52	36	28	0	174	235
Test user #2	52	48	41	20	8	169	260
Test user #3	61	59	48	32	3	203	250
Average	57	53	41.67	26.67	3.67	182	248.33

Figure A.2: Values of three test users and average for pedal count at every minute, total pedal count, and total pedal time for each content type (Part 2).

Physical Score

Test user #	1	2	3	4 (control)	5 (control)
More active throughout the day	5	5	5	4	4
Decreased knee pain	5	4	4	4	3
Decreased muscular pain and stiffness	5	5	4	3	4
Improved balance	4	4	5	3	4
Easier to carry out daily tasks	5	5	4	4	4
Improved overall health (e.g. lower blood pressure, other medical measures of health if applicable)	5	4	5	4	3
Average			4.61		3.67

Figure A.3: Values of three test users for experiments with contents, and of two test users for control experiments for each item, and calculated average score value for each experiment type.

B Cognitive Benefits

Engagement Rate

Engagement Rate = time looking at screen/total video time				
	Time on screen	*Total video time*	*Engagement rate*	*%*
Content type: Street, natural				
Test user #1	227	300	0.7567	75.67
Test user #2	215	300	0.7167	71.67
Test user #3	238	300	0.7933	79.33
		Average	0.7556	75.67
Content type: Street, upbeat				
Test user #1	180	300	0.6000	60.00
Test user #2	192	300	0.6400	64.00
Test user #3	177	300	0.5900	59.00
		Average	0.6100	61.00
Content type: Park, natural				
Test user #1	214	300	0.7133	71.33
Test user #2	232	300	0.7733	77.33
Test user #3	210	300	0.7000	70.00
		Average	0.7289	72.89
Content type: Park, upbeat				
Test user #1	179	300	0.5967	59.67
Test user #2	199	300	0.6633	66.33
Test user #3	180	300	0.6000	60.00
		Average	0.6200	62.00
Content type: Animation park, natural				
Test user #1	253	300	0.8433	84.33
Test user #2	268	300	0.8933	89.33
Test user #3	244	300	0.8133	81.33
		Average	0.8500	85.00

Figure B.1: Values of three test users of total time on screen, total video time (always 300), engagement rate in absolute value and percentage, and average value of engagement rate in absolute value and percentage for each content type (Part 1).

Engagement Rate = time looking at screen/total video time				
	Time on screen	*Total video time*	*Engagement rate*	*%*
Content type: Animation park, upbeat				
Test user #1	233	300	0.7767	77.67
Test user #2	257	300	0.8567	85.67
Test user #3	260	300	0.8667	86.67
		Average	0.8333	83.33
Content type: English count, slow				
Test user #1	295	300	0.9833	98.33
Test user #2	289	300	0.9633	96.33
Test user #3	298	300	0.9933	99.33
		Average	0.9800	98.00
Content type: English count, fast				
Test user #1	283	300	0.9433	94.33
Test user #2	274	300	0.9133	91.33
Test user #3	281	300	0.9367	93.67
		Average	0.9311	93.11
Content type: Walking Quiz, natural				
Test user #1	289	300	0.9633	96.33
Test user #2	283	300	0.9433	94.33
Test user #3	290	300	0.9667	96.67
		Average	0.9578	95.78
Content type: Walking Quiz, upbeat				
Test user #1	298	300	0.9933	99.33
Test user #2	292	300	0.9733	97.33
Test user #3	295	300	0.9833	98.33
		Average	0.9833	98.33

Figure B.2: Values of three test users of total time on screen, total video time (always 300), engagement rate in absolute value and percentage, and average value of engagement rate in absolute value and percentage for each content type (Part 2).

Cognitive Score

Content type:	1	2	3	4	5	6	7	8	9	10
Overall response rate to contents	4, 3, 4; 3.67	2, 1, 2; 1.67	2, 2, 3; 2.33	1, 2, 2; 1.67	1, 2, 1; 1.33	2, 1, 2; 1.67	5, 5, 5; 5	5, 4, 5; 4.67	5, 5, 5; 5	5, 5, 5; 5
Recognition and identification of elements in content (e.g. people, animals, fruits, items, etc.)	4, 4, 4; 4	4, 3, 3; 3.33	4, 5, 4; 4.33	4, 3, 4; 3.67	4, 4, 3; 3.67	3, 3, 2; 2.67	5, 5, 5; 5	5, 4, 5; 4.67	5, 5, 5; 5,	5, 5, 5; 5
Does it encourage user to keep an open mindset to collect information about the surroundings through the senses	4, 3, 4; 3.67	3, 2, 3; 2.67	4, 4, 3; 3.67	2, 3, 3; 2.67	2, 2, 3; 2.33	3, 2, 3; 2.67	5, 5, 5; 5	5, 5, 4; 4.67	5, 5, 5; 5,	4, 5, 5; 4.67
Does the user understand current circumstances by connecting visual and auditory cues with what is happening	4, 5, 4; 4.33	3, 4, 4; 3.67	4, 5, 4; 4.33	3, 3, 4; 3.33	3, 3, 3; 3	3, 3, 3; 3	5, 4, 5; 4.67	5, 4, 4; 4.33	5, 5, 5; 5	5, 5, 4; 4.67
Does the user use visual and auditory information to predict future events	4, 3, 4; 3.67	3, 2, 2; 2.33	2, 2, 3; 2.33	2, 2, 1; 1.67	1, 2, 2; 1.67	1, 1, 2; 1.33	5, 5, 5; 5	4, 4, 5; 4.33	5, 5, 5; 5	5, 4, 5; 4.67
Does it test short term memory	4, 4, 4; 4	4, 3, 3; 3.33	4, 4, 4; 4	3, 3, 4; 3.33	1, 2, 1; 1.33	1, 1, 2; 1.33	4, 4, 5; 4.33	4, 4, 4; 4	5, 5, 5; 5	5, 5, 5; 5
Does it engage the user to do new tasks, such as brain exercise using numbers, reasoning, and spatial organization	3, 3, 4; 3.33	3, 3, 2; 2.67	3, 2, 3; 2.67	2, 2, 3; 2.33	2, 2, 1; 1.67	1, 2, 1; 1.33	5, 5, 5; 5	5, 5, 4; 4.67	5, 5, 5; 5	5, 5, 5; 5
Does it engage the user to sing	3, 3, 4; 3.33	2, 3, 2; 2.33	2, 3, 3; 2.67	2, 2, 2; 2	3, 3, 4; 3.33	2, 2, 3; 2.33	5, 5, 5; 5	5, 5, 5; 5	3, 2, 2; 2.33	3, 3, 2; 2.67
Does it engage the user to read	3, 4, 3; 3.33	3, 3, 3; 3	1, 2, 1; 1.33	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5
Average	3.70	2.78	3.07	2.41	2.15	1.93	4.89	4.59	4.70	4.63

Figure B.3: Values of three test users and average for each item, and calculated overall average cognitive score for each content type.

*Notes:

- First row in blue lists the content types, which are numbered as follows:

- 1: Street, natural
- 2: Street, upbeat
- 3: Park, natural
- 4: Park, upbeat
- 5: Animation park, natural
- 6: Animation park, upbeat
- 7: English count, slow
- 8: English count, fast
- 9: Walking quiz, natural
- 10: Walking quiz, upbeat

- In each white table box, the scores are listed in the following order:
  test user #1, test user #2, test user #3; average

C Psychological Benefits

Emotional Wellness Scale

Content type:	1	2	3	4	5	6	7	8	9	10	11
1 positive	3, 4, 3; 3.33	3, 4, 4; 3.67	3, 4, 3; 3.33	4, 4, 3; 3.67	3, 4, 4; 3.67	4, 4, 4; 4	4, 5, 5; 4.67	4, 4, 5; 4.33	4, 5, 4; 4.33	4, 5, 4; 4.33	3, 4, 3; 3.33
2 negative	1, 1, 2; 1.33	1, 1, 1; 1	1, 2, 1; 1.33	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	2, 2, 2; 2
3 good	3, 3, 4; 3.33	4, 4, 4; 4	4, 3, 4; 3.67	4, 4, 4; 4	3, 4, 4; 3.67	4, 4, 4; 4	4, 5, 5; 4.67	4, 5, 4; 4.33	4, 4, 5; 4.33	4, 5, 5; 4.67	4, 4, 3; 3.67
4 bad	2, 1, 1; 1.33	1, 1, 1; 1	2, 1, 1; 1.33	1, 1, 1; 1	1, 1, 2; 1.33	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	2, 2, 1; 1.67
5 pleasant	3, 3, 3; 3	3, 4, 3; 3.33	3, 3, 3; 3	3, 3, 4; 3.33	3, 3, 4; 3.33	3, 4, 4; 3.67	4, 4, 5; 4.33	4, 4, 4; 4	4, 4, 5; 4.33	4, 5, 4; 4.33	3, 3, 3; 3
6 contented	3, 2, 3; 2.67	4, 3, 4; 3.67	2, 3, 3; 2.67	3, 4, 4; 3.67	4, 3, 3; 3.33	4, 4, 3; 3.67	5, 5, 5; 5	5, 4, 5; 4.67	4, 4, 5; 4.33	5, 5, 4; 4.67	2, 2, 2; 2
7 interested	4, 4, 4; 4	4, 4, 3; 3.67	4, 3, 4; 3.67	4, 3, 3; 3.33	3, 3, 3; 3	3, 2, 3; 2.67	5, 5, 5; 5	5, 5, 4; 4.67	5, 5, 5; 5	5, 5, 5; 5	2, 2, 2; 2
8 stressed	2, 1, 1; 1.33	1, 1, 1; 1	1, 2, 1; 1.33	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 2, 1, 1.33	1, 1, 1; 1	2, 1, 1; 1.33	2, 2, 2; 2
9 unpleasant	2, 1, 1; 1.33	1, 1, 1; 1	1, 2, 1; 1.33	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	3, 2, 2; 2.67
10 happy	4, 3, 3; 3.33	4, 3, 4; 3.67	3, 3, 4; 3.33	3, 4, 4; 3.67	4, 3, 4; 3.67	4, 4, 4; 4	4, 5, 5; 4.67	5, 4, 5; 4.67	4, 4, 5; 4.33	4, 5, 5; 4.67	3, 3, 3; 3
11 sad	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1
12 angry	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1
13 afraid	2, 1, 1; 1.33	1, 1, 1; 1	1, 1, 2; 1.33	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 2; 1.33	1, 1, 1; 1
14 loving	3, 3, 2; 2.67	3, 3, 3; 3	3, 3, 3; 3	3, 3, 3; 3	3, 4, 4; 3.67	3, 3, 4; 3.33	3, 4, 4; 3.67	3, 4, 3; 3.33	4, 3, 4; 3.67	3, 3, 4; 3.33	2, 2, 1; 1.67
15 depressed	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1	1, 1, 1; 1
16 joyful	4, 3, 3; 3.33	4, 4, 3; 3.67	3, 3, 4; 3.33	4, 3, 4; 3.67	3, 4, 4; 3.67	4, 4, 3; 3.67	5, 5, 5; 5	5, 5, 5; 5	4, 5, 5; 4.67	5, 5, 5; 5	2, 2, 1; 1.67
PF	25.66	28.68	26.00	28.34	28.01	29.01	37.01	35.00	34.99	36.00	20.34
UF	9.65	8.00	9.65	8.00	8.33	8.00	8.00	8.33	8.00	8.66	12.34
HB	16.01	20.68	16.35	20.34	19.68	21.01	29.01	26.67	26.99	27.34	8.00

Figure C.1: Score values of three test users and average for each item in Emotional Wellness Scale, and calculated pleasant feelings (PF), unpleasant feelings (UF), and happiness balance (HB) score from average score values for each content type.

*Notes:
- First row in blue lists the content types, which are numbered as follows:

- 1: Street, natural
- 2: Street, upbeat
- 3: Park, natural
- 4: Park, upbeat
- 5: Animation park, natural
- 6: Animation park, upbeat
- 7: English count, slow
- 8: English count, fast
- 9: Walking quiz, natural
- 10: Walking quiz, upbeat
- 11: No content

- In each white table box, the scores are listed in the following order:
  test user #1, test user #2, test user #3; average

Psychological Score

Content type:	1	2	3	4	5	6	7	8	9	10	11
Signs of enjoyment (e.g. smiling, laughing)	2, 2, 2; 2	2, 3, 2; 2.33	2, 2, 2; 2	2, 3, 2; 2.33	3, 3, 3; 3	3, 4, 3; 3.33	5, 5, 5; 5	5, 4, 5; 4.67	5, 5, 4; 4.67	5, 5, 4; 4.67	2, 2, 2; 2
Positive facial expression	1, 2, 2; 1.67	2, 2, 2; 2	1, 2, 2; 1.67	2, 2, 2; 2	2, 3, 2; 2.33	2, 3, 3; 2.67	4, 5, 4; 4.33	4, 5, 5; 4.67	4, 4, 5; 4.33	4, 5, 4; 4.33	2, 1, 2; 1.67
Improved mood	3, 4, 4; 3.67	4, 4, 4; 4	4, 4, 4; 4	4, 5, 4; 4.33	4, 4, 4; 4	4, 5, 4; 4.33	5, 5, 5; 5	5, 5, 4; 4.67	5, 4, 5; 4.67	5, 5, 5; 5	4, 4, 3; 3.67
Less stress, more calm	5, 4, 4; 4.33	4, 5, 4; 4.33	4, 4, 5; 4.33	4, 4, 3; 4.33	4, 4, 4; 4	4, 4, 3; 4.33	4, 4, 4; 4	3, 3, 4; 3.33	4, 4, 3; 3.67	4, 3, 4; 3.67	5, 5, 5; 5
Boost in self-confidence (do users feel better about themselves)	5, 4, 4; 4.33	5, 5, 4; 4.67	4, 5, 4; 4.33	5, 5, 4; 4.67	5, 4, 4; 4.33	5, 5, 4; 4.67	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	5, 5, 4; 4.67
User is making an effort	4, 4, 4; 4	4, 4, 5; 4.33	4, 4, 4; 4	4, 4, 5; 4.33	4, 4, 4; 4	4, 4, 5; 4.33	5, 5, 5; 5	5, 5, 4; 4.67	5, 5, 5; 5	5, 5, 5; 5	4, 4, 5; 4.33
User is competent and capable of doing tasks and activities	4, 4, 4; 4	4, 5, 4; 4.33	4, 4, 4; 4	4, 4, 5; 4.33	4, 4, 4; 4	4, 3, 4; 3.67	5, 4, 4; 4.33	4, 4, 4; 4	5, 5, 5; 5	5, 5, 5; 5	4, 4, 5; 4.33
User is engaged and interested in the tasks and activities	2, 1, 2; 1.67	2, 2, 2; 2	2, 2, 1; 1.67	2, 2, 2; 2	2, 2, 2; 2	2, 3, 2; 2.33	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	2, 3, 2; 2.33
User feels a sense of accomplishment after completion of exercise and contents	4, 4, 4; 4	4, 4, 5; 4.33	4, 4, 4; 4	4, 4, 4; 4	4, 4, 5; 4.33	4, 5, 5; 4.67	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	5, 5, 5; 5	4, 4, 4; 4
Better sleep at night	2, 2, 3; 2.33	2, 3, 3; 2.67	2, 3, 2; 2.33	3, 3, 2; 2.67	3, 3, 2; 2.67	3, 3, 3; 3	4, 4, 4; 4	4, 4, 4; 4	4, 4, 4; 4	4, 4, 4; 4	2, 1, 1; 1.33
Average	3.20	3.50	3.23	3.50	3.47	3.73	4.67	4.50	4.63	4.67	3.33

Figure C.2: Values of three test users and average for each item in both experiments with contents and control experiments, and calculated overall average psychological score for each content type.

*Notes:
- First row in blue lists the content types, which are numbered as follows:

- 1: Street, natural
- 2: Street, upbeat
- 3: Park, natural
- 4: Park, upbeat
- 5: Animation park, natural
- 6: Animation park, upbeat
- 7: English count, slow
- 8: English count, fast
- 9: Walking quiz, natural
- 10: Walking quiz, upbeat
- 11: No content

- In each white table box, the scores are listed in the following order:
  test user #1, test user #2, test user #3; average