DESIGN AND DEVELOPMENT OF A GAME BASED EYE TRAINING PROGRAM FOR CHILDREN WITH LOW VISION

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ABSTRACT

DESIGN AND DEVELOPMENT OF A GAME BASED EYE TRAINING PROGRAM FOR CHILDREN WITH LOW VISION

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This study explores the design principles of eye movement-based computer game applications as training material for children with low vision to enhance their vision skills. It aims to provide children with interactive materials to improve their vision. For the study, design-based research was employed in four phases, namely analysis, development, evaluation and testing, and documentation and reflection. In the analysis phase, a focus group meeting and interviews were conducted with experts from the field of low vision. Besides, interviews were conducted with special education teachers and an ophthalmologist to understand the current eye training applications for children with low vision. In the design phase, interviews were conducted with expert academicians from the field of low vision and instructional technology to gather expert opinion and to prepare storyboards for the eye training games. After that, two prototypes were developed by including formative evaluation supported with interviews with special education teachers, and interviews and focus group meeting with expert academicians. After these steps, the final product of the game-based eye training program for children with low vision was finalized, and design principles for developing eye gaze games were gathered. In the evaluation

and testing phase, the eye training program was tested with children with low vision, and the data were collected from their parents, ophthalmologists, and expert academicians as summative evaluation. In the documentation and reflection phase, the design principles were finalized for developing eye training programs for children with low vision.

This study revealed that eye-tracking technology can be used by people with low vision. The findings revealed design principles for designing and developing a game-based eye training program for children with low vision. By following these design principles, there is a need for developing more games with a variety of visual objects to help children with low vision to enhance their visual acuity and visual field through scanning and focusing on objects and controlling of eye movements as scanning and tracking by considering color discrimination, contrast sensitivity, and light sensitivity.

Keywords: Eye Gaze Games, Low Vision, Functional Vision, Eye Movements, Eye Tracking

ÖZ

AZ GÖREN ÇOCUKLAR İÇİN OYUN TABANLI GÖZ EGZERSİZ PROGRAMI TASARIMI VE GELİŞTİRİLMESİ

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Bu çalışma, az gören çocukların görme becerilerini iyileştirmek için egzersiz materyali olarak göz hareketleri takibi tabanlı bilgisayar oyunu uygulamalarının tasarım ilkelerini araştırmaktadır. Çocukların görme becerilerini geliştirmek için etkileşimli materyaller sağlamayı amaçlamaktadır. Bu çalışmada, analiz, geliştirme, değerlendirme ve test etme ile dokümantasyon ve tartışma olmak üzere tasarım temelli araştırma yöntemi dört aşama halinde uygulanmıştır. Analiz aşamasında, az görenler alandaki uzmanlarla odak grup toplantısı ve görüşmeler yapılmıştır. Ayrıca, az gören çocuklar için mevcut göz egzersiz uygulamalarını anlamak için özel eğitim öğretmenleri ve bir göz doktoru ile görüşmeler yapılmıştır. Tasarım aşamasında, uzman görüşü toplamak ve göz egzersiz oyunları için hikaye tahtaları hazırlamak amacıyla az görenler ve öğretim teknolojisi alanından uzmanlarla görüşmeler yapılmıştır. Bunun akabinde, özel eğitim öğretmenleriyle yapılan görüşmeler ve uzman akademisyenlerle yapılan odak grup toplantısı ve görüşmeler ile desteklenen süreç değerlendirmeleri ile iki prototip geliştirilmiştir. Bu adımlardan sonra az gören çocuklar için oyun tabanlı göz egzersiz programının nihai ürünleri tamamlanmış ve göz hareketleri tabanlı oyunlar geliştirmesi için tasarım ilkeleri elde edilmiştir.

Değerlendirme ve test etme aşamasında, göz egzersiz programı az gören çocuklar ile yapılan testler ve bu az gören çocukların ebeveynleri, göz doktorları ve uzmanlardan toplanan veriler ile birlikte değerlendirilmiştir. Dokümantasyon ve tartışma aşamasında, az gören çocuklar için göz egzersiz programları geliştirmek amacıyla oluşturulan tasarım ilkeleri tamamlanmıştır.

Bu çalışma, göz izleme teknolojisinin az gören kişiler tarafından kullanılabileceğini ortaya koymuştur. Bulgular doğrultusunda, az gören çocuklar için oyun tabanlı göz egzersiz programı tasarlanması ve geliştirmesi için kullanılabilecek tasarım ilkeleri ortaya çıkmıştır. Bu tasarım ilkeleri takip edilerek, az gören çocukların görme keskinliğini ve görme alanlarını geliştirmek için tarama ve nesnelere odaklanma ile tarama ve göz hareketlerini kontrol etme konularında; renk ayrımını, kontrast duyarlılığını ve ışık duyarlılığını dikkate alınarak çeşitli görsel nesneler içeren daha fazla oyun geliştirilmesine ihtiyaç vardır.

Anahtar Kelimeler: Gözle Takip Oyunları, Az Görme, İşlevsel Görme, Göz Hareketleri, Göz Hareketleri Takibi

To my family

who believed me and offered me unconditional love throughout my life

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ABBREVIATIONS

HCI	Human-Computer Interaction
IT	Instructional Technology
ICT	Information and Communication Technology
AT	Assistive Technology
WHO	World Health Organization
PC	Personal Computer
LCA	Leber's Congenital Amaurosis
CVI	Cerebral Visual Impairment
ROP	Retinopathy of Prematurity
UNESCO	The United Nations Educational, Scientific and Cultural Organization
OCR	Optical Character Recognition

CHAPTER 1

INTRODUCTION

This chapter provides introductory information for this study under seven headings. Firstly, the background of the study is pointed out. Then, the problem covered in this study is stated. After that, the purpose of the current study and its significance are presented. It continues with the research questions. It ends with the definitions of the related terminology and organization of this study.

1.1 Background of the Study

Most people with low vision can only recognize objects and their colors from a close distance. In other words, they are not blind, but they have difficulties to see clearly. Low vision has nothing to do with blindness because people with low vision still have some useful sight (World Health Organization, 1993). People with low vision can be trained to improve their visual functioning with the help of low vision services, materials, and devices in a planned program of visual experiences (World Health Organization, 2002; Yalo, Indoshi, & Agak, 2012). Although there are facilities that provide services to people with low vision with relevant technology and resources, people with low vision cannot always access such facilities, which would assist them in eliminating barriers in daily life. Considering improving vision promotes the growth and development of children with low vision (Goldie, Gormezano, & Raznik, 1986; Zammitt, O'Hare, Mason, & Elliott, 1999), it is essential to enhance vision functioning of such children to support their general development.

Accordingly, it affects the quality of life of people with low vision. Therefore, they need to enhance their functional vision to maintain their lives with higher quality. Doing practice with eye movements may provide improvement for the vision skills of people with low vision. Eye training for such people is essential for leading a productive and meaningful life (Strong, Jutai, Russell-Minda, & Evans, 2008a), because "visual impairment can be overcome with proper training and guidance" (Singh & Kumar, 2013, p.1). In this sense, eye training is essential for improving the visual functioning of people with low vision. The training programs for people with low vision might be more effective and efficient with the help of the use of technological tools. There are not many studies aiming at facilitating the improvement of eyesight capacity of people with low vision with the help of eye tracking-based eye training system. According to Tatsumi, Murai, Kawahara, Sekita, and Miyakawa (2010), eye tracking-based systems can be beneficial for low vision people to help them to see public signs clearer. However, their study is just related to helping low vision people maintain their lives. There is no eye training part of this application for vision improvement.

People with low vision can be trained to enhance their visual capabilities by obtaining help from relevant services, materials, and devices in a planned program of visual experiences. Although there are training services that assist people with low vision with low tech materials and devices, there is a lack of software and high-tech devices that can help them. Such help is especially crucial for young students because this problem significantly affects their education. Therefore, eye gaze games can provide significant assistance to improve the visual skills of students with low vision.

1.2 The Problem Statement of the Study

The need for technology usage in special education is increasing day by day. In the field of low vision, the current eye exercise-oriented applications are provided by experts in private rehabilitation centers (World Health Organization, 2002; Yalo et al., 2012). Usually, assessments or eye exercises are applied with the help of paper-

based materials according to the experts' subjective opinions. In the literature, it is reported that children with low vision have to make eye exercise to enhance their eyesight and increase their quality of life (Pasian, Corno, Signorile, & Farinetti, 2012; Strong et al., 2008a).

The first problem is the need for more research and development about the applicability of technology, especially eye-tracking technology, in the field of low vision. In the literature, there are several technological applications in special education, but it is limited in the field of low vision. However, technology usage in this field, especially for children with low vision, is a critical issue because of the urgent need for eye exercises at an early age. Moreover, the adaptation of eye-tracking technology is important to provide objective practice and assessment for children with low vision (Fikar, Güldenpfennig, & Ganhör, 2018; Simkin, Misra, Kasture, McGhee, & Dai, 2019). Therefore, there is a need for conducting more studies about technology usage, such as eye-tracking technology, in the field of low vision.

The second problem is that there is a lack of comprehensive, well-designed, and technology-embedded materials combined with the opinions of all stakeholders, namely special education teachers, expert academicians, ophthalmologists, and parents of children with low vision. There are studies in the field of ophthalmology, including clinical tests. Besides, there are educational and instructional studies that include teachers and academicians as well as parents. However, the field of low vision is an interdisciplinary field with diverse expertise. Therefore, there is a lack of studies integrating both the development process and opinions of all possible stakeholders into any eye training program.

The third problem is that there is a need for eye exercise solutions that can be used anywhere and anytime without expert supervision because children with low vision need to make continuous eye exercises to keep stable or improve their vision. In this context, there is a need for providing technology guided eye exercise to apply by

themselves at home, instead of doing limited eye exercise in rehabilitation centers under the supervision of an expert.

Thus, it is necessary to study the use of eye-tracking-based technology-enhanced eye training program for children with low vision by covering both theoretical and practical implications to generate design principles for further design and development.

1.3 Purpose of the Study

The purpose of the study is to propose design principles upon designing and developing eye movement-based game applications as an eye training program for children with low vision. This program can help children with low vision enhance their vision abilities while interacting with the computer.

This study is based on the design and development research and includes a detailed analysis to provide the best design for children with low vision. Therefore, a framework and design principles for design and development of an eye training program for children with low vision were proposed at the end of this study.

Since enhancing visual acuity and visual field of children with low vision is critical for quality of their lives and academic achievement, this study concentrated on strengthening such skills through scanning and focusing on objects, and control of eye movements as scanning and tracking by considering color discrimination, contrast sensitivity, and light sensitivity. For this purpose, the eye-tracking system was used to track eye movements of children and to offer an eye training program to enable such children to do eye exercises.

1.4 Significance of the Study

This study aims to propose design principles by designing and developing a game-based eye training program for children with low vision. It is well-known that such

children need to do eye exercise, especially at young ages. In other words, it is critical for children with low vision to apply relevant eye training for enhancing their eyesight and improving the quality of their lives (Strong et al., 2008a). Continuous eye practices can help improve their vision depending on their eyesight capacity (Singh & Kumar, 2013). Besides, the improvement in the eyesight of children with low vision is expected to result in the growth of their academic achievement. Hence, this study is expected to reveal an eye training program to enable them to do eye exercises with a computer with an eye-tracking device.

Besides, this study has significance with its use of technology while offering an eye exercise solution to such children. It is crucial to use technology in special education due to the difficulties in providing all kinds of actual objects during instruction (Mechling, Gast, & Barthold, 2003). It is also essential to provide eye exercise with different objects by keeping them active and their attention on track. They need eye exercise with objects in different colors, sizes, and shapes because of individual differences of children with low vision. Each child has his/her own needs to be able to do eye exercise. Therefore, this study provides a customizable eye exercise program in front of the computer by using a variety of visual objects in different shapes, colors, and sizes offered by the program.

In the current practices, there are place and time-dependent eye exercises accompanied by experts (Yalo et al., 2012). Then, the evaluation of vision is carried out by an expert based on his/her assessment. However, the eye training program developed as a result of this study provides a chance for children with low vision to do eye exercise on their own by using their computer at anytime and anywhere. Even, they can have objective results with their eye movement data gathered with eye-tracking devices.

Furthermore, this study is significant because it includes the opinions of special education teachers, expert academicians from both special education and instructional technology, ophthalmologists, and parents of children with low vision. It combines the expertise of different fields to build a framework and to document

design principles for an eye-tracking-based eye training program for children with low vision. The results are expected to support special education teachers, ophthalmologists, and low vision literature by providing significant benefits in technology usage in an educational setting of children with low vision. Moreover, this study is intended to provide design principles and new insights about designing and developing such training programs for children with low vision.

Overall, doing eye exercise, especially at younger ages, is very important for children with low vision. It is hard to keep them motivated during exercises because of their ages. Therefore, technology-supported environments are essential to keep children with low vision active while doing eye exercises and to provide customizable eye exercise experience for them. Besides, technology-enhanced environments can provide a relative independence thanks to its applicability at anywhere and anytime. In addition, the eye exercise process for scanning-focusing and scanning-tracking skills requires different perspectives by special education teachers, expert academicians and ophthalmologists, and parents of children with low vision. Therefore, it is certain that there is a need for such a study to design and develop an eye exercise program and to offer related experiences and design principles to support further developments.

1.5 Research Question

What are the design principles of designing eye movement-based game applications as a vision training program for children with low vision?

1.6 Definition of Terms

Low vision: It is the term used to describe significant visual impairment that cannot be corrected fully with glasses, contact lenses, medication, or eye surgery.

Eyesight: It is the term used to describe the ability to see.

Children with low vision: It refers to children who have low vision and eyesight generally less than 30 percent.

Eye training program: It is a software installed on a computer and includes eye training games, which can use eye movements via an eye-tracking device.

Eye-tracking device: It is a device that can be connected to the computer. It can follow the pupil of the user sitting in front of the computer and detect where the user is looking at the computer screen as x and y coordinates.

Focusing skills: It is the ability of children with low vision to fix their gaze on fixed objects.

Tracking skills: It is the ability of children with low vision to move their gaze intentionally with moving objects.

Special education: It is a type of education provided for students who have special educational needs because of their disabilities.

Formative evaluation: It is a method for evaluating the products during their design and development processes.

Summative evaluation: It is a method for evaluating the products as final products at the end of their design and development processes.

1.7 Organization of the Study

This study has five main chapters, namely, introduction, literature review, methodology, results, and discussion, and conclusion. In the first chapter, the introduction, the background, problem statement, purpose, and significance of the study were provided in detail. In addition, research question and definitions about the terms used in the study were presented.

In the second chapter, literature review and technology usage in special education, especially in the field of low vision, were presented. Besides, eye training practices

for children with low vision to enhance their eyesight were examined and reported under the theoretical framework of the study.

In the third chapter, methodology, there were headings to explain the overall design of the study, the process of development of eye training program, the participants of this study, data collection and analysis procedure.

In the fourth chapter, findings of the data, which were gathered from expert academicians, special education teachers, ophthalmologists, children with low vision, and their parents, were presented.

Lastly, in the fifth chapter, the study results were discussed, and suggestions and implications of this study were presented in detail.

CHAPTER 2

LITERATURE REVIEW

This chapter presents seven main headings to discuss the related literature with this study, namely technology usage in special education, children with low vision by touching upon the common causes of low vision, technology usage in the field of low vision, functional vision, improving functional vision skills by explaining eye training for effective use of vision, low vision devices and eye-tracking usage, the impact of eye training on the education of children with low vision, and overall summary for the literature.

2.1 Technology Usage in Special Education

Developments in the field of technology deploy several types of media and resources in education to facilitate learning and teaching. For instance, diverse technological devices, such as televisions, smart boards, tablet PCs, laptop computers, and smartphones, are used while lecturing. Especially mobile devices through which the instruction is provided have great potential in the learning process (Lan, Sung, & Chang, 2009; Roschelle et al., 2010; Sung, Chang, & Liu, 2016). In addition, there are several types of multimedia to support the instruction. For example, visual elements, such as illustrations, shapes, animations, graphics and images, videos, interactive materials, and simulations, can be counted as technological resources that facilitate education (Farkhadov, Vaskovsky, & Nadeinsky, 2017; Lin & Chen, 2014; Wang, Sun, & Li, 2019).

Although technology is extensively studied in the field of education, its reflection on the field of special education is limited and needs an expansion because technology

has great potential to offer benefits during instruction by considering the needs of special students. In special education, such technological enhancements are known as Assistive Technology (AT). AT is defined as the technology which is used to benefit from assistive technology device and service (Assistive Technology Act of 1998, 1998). Assistive technology device means any equipment, products, or systems that can be used to enhance the capabilities of disabled people, while assistive technology service means any services that can provide assistance for people with disabilities directly or help them use assistive technology devices (Assistive Technology Act of 2004, 2004). The usage of AT and information and communication technologies (ICT) for children with special needs has of great importance for facilitating their learning (Ouherrou, Elhammoumi, Benmarrakchi, & El Kafi, 2019). These technologies create new opportunities in the field of special education and improve the quality of life (Pasian et al., 2012; Strong et al., 2008a).

While technological devices are critical for special education, they need modifications or adaptations to provide an ultimate benefit. To do so, it is needed to go beyond existing applications since simple and traditional usage of technology is nothing anymore (Laursen, Jensen, Garde, & Jørgensen, 2002). At this point, alternative paths suggested by the AT should be provided for children in special education (Assistive Technology Act of 2004, 2004). For this purpose, alternative techniques should be introduced for interactions with devices, such as touch screen technology (Gybas, Kostolányová, & Klubal, 2017). According to Cabielles-Hernandez, Perez-Perez, Paule-Ruiz, and Fernandez-Fernandez (2017), mobile devices with touch screen technology are suitable for children with autism spectrum disorders to provide them better interaction during lessons, because touch screens offer opportunities for different gestures. These gestures can be classified as touching by taping, drag and drop, and voice control. Mobile devices provide portability and mobility for children with disabilities to keep the technology with them. It is also an effective and efficient way to teach skills for children with disabilities (Yucesoy-Ozkan, Gulboy, & Kaya, 2018). Technology-based interventions, such as computer game-based evaluations, and use of mobile technologies are easier to use and to offer

a relative comfort while teaching children with special needs (Chen, Wang, Zhang, Wang, & Liu, 2019). Besides, body parts can be used as input gestures in educational games for children with disabilities via game consoles, such as Nintendo's Wii and Microsoft's Xbox (Cagiltay, Cakir, Karasu, Islim, & Cicek, 2019). Computer games have a great impact on children, and it is suitable to use technology-based computer games for children with disabilities (Chen et al., 2019).

Moreover, it is obvious that ICT usage has much potential to support special education. It can provide equal opportunities in education for children with special needs (Aksal & Gazi, 2015). Besides, ICT integration into special education is essential to meet the needs for academic success (Heiman, Fichten, Olenik-Shemesh, Keshet, & Jorgensen, 2017), since children with special needs have differences in their learning processes, and each requires different interventions to foster their learning processes (Drigas & Ioannidou, 2013). Another important contribution of ICT usage is about its applicability to assessment procedures in special education (Mandula et al., 2016). It ensures a more objective and standardized assessment for children with special needs.

2.2 Children with Low Vision

Vision can be classified as normal vision and visual impairment (Keeffe, 1995). Those who can successfully perform all visual tasks from close or far distances are called individuals with normal vision, while those who have reduced vision because of any circumstances, like an accident or medical background, are called individuals with a visual impairment. People with a visual impairment sometimes cannot see the light, which is called total blindness. However, if they have some vision, they are called people with low vision. Low vision is defined as having visual acuity equal and higher than 5 percent (3/60) and lower than 33.33 percent (6/18) in the better eye of the person (World Health Organization, 2007, 2012).

According to World Health Organization (WHO) data, there were about 285 million people with visual impairments in the world in 2010, of whom approximately 246 million were people with low vision (World Health Organization, 2012). In addition, it was reported that around 19 million of 285 million people with visual impairments were children between the ages of 0-14. At the same time, approximately 18 million of them were children with low vision. In Turkey, there were about 8.4 million people with disabilities, and about 0.6 percent of them were with visual disabilities in 2002 (Turkish Statistical Institute, 2004).

In this context, low vision can mostly be improved with rehabilitation processes during childhood, so it is crucial to have early diagnosis among children with low vision (Ceyhan, Yaşar, & Çağlar, 2013). In Turkey, there is a vision research and low vision rehabilitation center within the department of ophthalmology of Ankara University Faculty of Medicine. It is the first vision therapy center in Turkey and provides vision rehabilitation for 5,500 children with low vision to date of 2019 (Altınbay & İdil, 2019). Besides, most of the causes of low vision are preventable and treatable (World Health Organization, 2007).

2.2.1 Common Causes of Low Vision

There are a variety of causes of low vision, depending on the social, economic, geographical, and cultural factors of the countries (Chiang, O'Connor, Le Mesurier, & Keeffe, 2011; World Health Organization, 2007, 2012). The common causes of low vision can be listed as albinism, amblyopia, cataract, cerebral visual impairment (CVI), cone dystrophy, cone-rod dystrophy, congenital retinoschisis, glaucoma, Leber's congenital amaurosis (LCA), macular dystrophy, optic atrophy, optic disc hypoplasia, retinitis pigmentosa, retinopathy of prematurity, retinoschisis and shortsightedness (myopia) (Boonstra et al., 2012; De Paula, Vasconcelos, Nehemy, & Granet, 2015; Keeffe, 1995; World Health Organization, 2007). They are explained below in detail.

Albinism: Albinism can cause nystagmus and poor vision with reduced visual acuity (Keeffe, 1995). Generally, people with albinism have better near vision than distance vision.

Amblyopia: It is known as a lazy eye, and it causes a decrease in one-sided or double-sided visual acuity (World Health Organization, 2007). The violation of neuronal interactions at the sensory retina and visual analyzer is the result of the amblyopia (Guzun, Boichuk, Chechin, Khramenko, & Konovalova, 2019).

Cataract: It is about the blurring on the lens of the eye, and generally causes reduced visual acuity and blurred vision (Keeffe, 1995). Both near and distance vision can be affected by the cataract. The light and its direction have much effect on the vision of people with low vision.

Cerebral Visual Impairment (CVI): It is about low vision caused by the damage between visual pathways and vision centers in the brain (Mazel, Bailin, Tietjen, & Palmer, 2019; Philip & Dutton, 2014). It is a common cause of low vision among children with cerebral palsy.

Cone Dystrophy: It is about functional abnormalities in the eye, and generally shows up during childhood (Simunovic & Moore, 1998). It causes reduced visual acuity and a lack of color vision.

Cone-rod Dystrophy: It is about genetic retinal degeneration, and it can result in color vision abnormalities and night blindness (Shaikh et al., 2015).

Congenital Retinoschisis: It is a genetic disorder that shows up by splitting of the retinal layers (Altay, Ugurlu, & Şengün, 2013).

Glaucoma: It is known as eye pressure. It is about the damage in the retina and the optic nerve because of the increased pressure in the eye (Keeffe, 1995).

Leber's Congenital Amaurosis (LCA): It is a type of retinal dystrophies (Fazzi et al., 2007). It is an innate visual impairment and causes loss of visual acuity.

Macular Dystrophy: It is a type of retinal disorder with dysfunction in vision centers, which causes loss of visual acuity (Rahman, Georgiou, Khan, & Michaelides, 2020). It is about the loss of visual acuity because of anomalies in the center of the retina, especially in the sensory retina (Rozet et al., 2005).

Optic Atrophy: It is about the degeneration of the optic nerves because of any reason such as eye injury, glaucoma, and innate defects (Keeffe, 1995). It results in a loss in visual acuity.

Optic Disc Hypoplasia: It causes getting thinner of the retinal nerve layer (Boonstra et al., 2012). It is about the dysfunction of optic nerves, and it is a non-progressive, unilateral, or bilateral eye disease.

Retinitis Pigmentosa: It is about the loss of visual acuity gradually over time (Keeffe, 1995). It generally emerges at a younger age, and visual acuity can be worse in time.

Retinopathy of Prematurity (ROP): It is neovascular retinal disorder among prematurely born children (Vural et al., 2019). It is a widespread childhood visual impairment.

Retinoschisis: It is about the separation of the neurosensory retina (Megan Alberts, Jennifer Sutter, & Kelli Payne, 2020). It can be unilateral or bilateral eye disease. It can affect peripheral or central vision.

Shortsightedness (Myopia): It is about having a too long eyeball (Keeffe, 1995). People having myopia cannot see in the distance clearly, but their ability to see nearby can be better.

2.3 Technology Usage in the Field of Low Vision

Information and communication technology (ICT) and assistive technology (AT) are tools for enhancing the abilities of children with visual impairments and increasing their quality of life (UNESCO, 2006). For instance, computers, smart devices, smart boards, and assistive software can be used as high-tech AT for children with special

needs (Aslan, 2018; Inico & Prabakaran, 2018). Especially computer-based AT tools improve visually impaired children's quality of life by offering them a chance to read and write emails and documents, surfing on the Internet, and engaging in digital activities (Rosner & Perlman, 2018). In addition, computers with specific software that enables children with visual impairments to reach digital environments are useful to provide them with educational opportunities (Ramos & de Andrade, 2016). In the circumstances where it is difficult to use computers, smart devices can be alternative thanks to their mobility.

Smart devices, such as mobile phones and tablet computers, have a positive effect on the education of children with visual impairments (Crossland et al., 2017). They can easily use these devices by zooming in the text while studying their course materials or have control over the device by using the voice control option offered by the device. Besides, scanners, readers, talking calculators, optical character recognition (OCR) software, and audio recordings are examples of AT, which can be offered for instructional purposes in the education of children with visual impairments (DePountis, Pogrund, Griffin-Shirley, & Lan, 2015). AT can provide visually impaired children with better adaptation to their schools by enabling them to access academic resources and communicate with their classmates more effectively (Ramos & de Andrade, 2016). Most of these AT are generally used by children who are totally blind, and they are adopted to the educational processes of children with low vision (Fichten, Asuncion, Barile, Ferraro, & Wolforth, 2009).

However, there are AT tools for improving the educational accessibility of children with low vision by utilizing their own eyesight. Software like magnification and zoom are some of the examples for AT for children with low vision (Fichten et al., 2009). They can use these tools to enlarge the objects on the screen to see by using their own visual acuity. For instance, they can zoom on visuals, texts, or buttons while searching on the web browser. Moreover, they can use software that can provide on-screen keyboards with larger keys, or large screen monitors to provide a wide area to detect and see stimuli on the screen (Fichten et al., 2009). User-centered designs are adopted to develop digital resources that are used by children with low

vision (Aziz, Mutalib, & Sarif, 2017). They should be information accessible, navigable, and enjoyable. Therefore, adopting and using ICT for the education of children with low vision will motivate them, as they can easily reach instructional content to maintain their education (Inico & Prabakaran, 2018; Lorenzini & Wittich, 2019). For this purpose, they need custom instructional materials to improve their learning process, like interactive materials that can meet their requirements (Aziz & Mutalib, 2019).

2.4 Functional Vision

Functional vision means purposefully usage of vision (Keeffe, 1995). Functional vision is generally grouped as distance visual acuity and near vision acuity (Keeffe, 1995). Distance visual acuity covers seeing and defining objects from a distance of approximately 3 meters, while near vision refers to the reading distance, which is about 40 centimeters (Colenbrander, 2001; Huurneman & Boonstra, 2016; Keeffe, 1995). Distance visual acuity of the children with low vision is assessed according to whether the child recognizes the face of people in a specific distance (Keeffe, 1995). Near vision is generally used for reading hard or soft copy of materials, so it is important to consider the size of letters and the distance from the material to read (Colenbrander, 2001). They should be configured according to the preferences of the children with low vision.

On the other hand, there are seven visual skills to assess the functional vision under the groups of distance visual acuity and near vision. These skills are focusing on objects, control of eye movements (scanning and tracking), visual acuity, visual field (central and peripheral vision), color discrimination, contrast sensitivity and light sensitivity (Aslan, 2015; Erin & Paul, 1996; Ganesh, Sethi, Srivastav, Chaudhary, & Arora, 2013; Keeffe, 1995; McCabe, Nason, Turco, Friedman, & Seddon, 2000; Palmer, 1997; Sugden & Reid, 2006). They are explained below in detail.

Focusing on Objects: It refers to the fixation of the eye gaze at an object or person for a certain time, like two or three seconds. Focusing skill is used to look at an object as long as enough to recognize and identify it (Keeffe, 1995). In addition, it is an indicator of the presence of visual acuity. It is crucial for students to have focusing skills because it is necessary to use it during the lessons to keep attention on board (Palmer, 1997). During the lessons, teachers can help children with low vision fixate their gaze by providing familiar objects in larger sizes. In order to increase the possibility of a proper focus, factors such as the size of the object, the distance in which the object was located, and the contrast of the object should be considered (Keeffe, 1995).

Control of Eye Movements (Scanning and Tracking): Scanning and tracking can be considered under both distance visual acuity and near vision. Tracking refers to the ability to track moving objects by using eye or head movements in the vertical, horizontal, cross, and circular directions (Keeffe, 1995; Poland & Doebler, 1980). Besides, tracking ability covers scanning ability, which refers to move eyes gaze from one object or person to another one (Keeffe, 1995). In order to move eye gaze to an object or person, a child with low vision should firstly be able to scan the environment to find the object, then he/she can track the object or person. Both tracking and scanning abilities are also necessary and used in the daily activities of children with low vision. These abilities are required to play games, act independently, search and find an object or person, match and identify objects, read and write from the board (Aslan & Çakmak, 2016). Therefore, they are essential for both the daily lives of children with low vision and their academic success. For instance, scanning and tracking abilities are critical to follow the class due to its requirements, such as copying the teacher's notes from the board to notebook (Palmer, 1997).

Visual Acuity: It refers to recognize and distinguish objects in detail (Keeffe, 1995). It is used as a measurement to define the extend of the visual acuity and identify the sight distance to objects (Colenbrander, 2001). Generally, it is tested by using

Snellen charts, which is based on showing letters from a distance and asking to read letters (Huurneman & Boonstra, 2016).

Visual Field (Central and Peripheral Vision): It refers to the whole area that can be seen while looking forward without moving the eyes, head, and body (Keeffe, 1995). The visual field of a person can be defined as 180 degrees angle, 90 degrees from the fixated point to the right, and 90 degrees to the left (Loschky, Szaffarczyk, Beugnet, Young, & Boucart, 2019). Besides, the visual field can be divided into two groups: central and peripheral visual fields (Altınbay & İdil, 2019; Palmer, 1997). Central vision means can be considered between 0 to 5 degrees from the fixation point, while peripheral vision means the rest of the 180 degrees (Loschky et al., 2019). To sum up, central vision enables children with low vision to see the objects just in front of them while peripheral vision allows them to see outside the center; the right side, left side, up and down.

Color Discrimination: It is about sensitivity to distinguish colors, such as red and green or blue and yellow (Hansen, Pracejus, & Gegenfurtner, 2009). It is essential to know the correct use of the colors (Ganesh et al., 2013; McCabe et al., 2000; Palmer, 1997; Tsai, Meng, Wu, Jang, & Su, 2013), and matching and sorting exercises can be done by using colorful objects to enhance color vision (Keeffe, 1995). Color vision of children with low vision can be assessed by using specially developed cards like City University Color Vision Test and Ishihara Color Test (Aslan, 2015).

Contrast Sensitivity: It is about lightness and darkness variations among objects (Keeffe, 1995). It is one of the most important environmental factors which affects the visibility of objects for children with low vision (Ganesh et al., 2013; McCabe et al., 2000; Palmer, 1997; Tsai et al., 2013). Therefore, it should be considered to increase the contrast of the objects to make them easier to be seen while developing eye training exercises for children with low vision (Colenbrander, 2001; Keeffe, 1995; Palmer, 1997). For example, rice placed in a dark-colored bowl creates a good contrast for children with low vision, while potatoes placed in a white bowl create poor contrast and make it difficult to recognize and identify (Keeffe, 1995).

Light Sensitivity: It is about the amount and direction of both natural and artificial light, which affects the visual functioning of children with low vision (Keeffe, 1995). The amount of light and environmental conditions should be regulated according to the preferences of children with low vision to provide better visual functioning for them. The position of the children in the environment can be arranged, or artificial light sources can be adjusted to meet such environmental conditions.

2.5 Improving Functional Vision Skills for Children with Low Vision

In Turkey, there are special education teaching programs in 38 universities, 30 of which are in the state universities and 8 in the private universities (Council of Higher Education, 2019). Although the number of programs can be enough for the field of low vision, there are not many schools for children with visual impairments. There are just 15 primary and secondary schools for visually impaired children in various provinces of Turkey (Ministry of National Education, 2010).

It is critical to perform early interventions to maintain and improve the functional vision skills of children with low vision (Gothwal, Lovie-Kitchin, & Nutheti, 2003). It can help them to maintain their daily activities and increase their quality of life (Keeffe, 1995; Pasian et al., 2012; Strong, Jutai, Russell-Minda, & Evans, 2008b). Besides, early visual rehabilitation to enhance functional vision skills of children with low vision can give them a chance to maintain their education with their peers with normal vision (Ganesh et al., 2013).

There are three important aspects to consider for improving the functional vision skills of children with low vision: eye training for effective use of vision, low vision devices, and eye-tracking usage.

2.5.1 Eye Training for Effective Use of Vision

The eye training program aims to provide an opportunity for children with low vision to use their vision better (Keeffe, 1995). Vision training should be adapted to daily life and should be organized as short sessions not to bore the child with low vision. There are three main techniques to help children with low vision use their vision effectively: visual environmental management, visual skills training, and visually dependent task training (Hall & Bailey, 1989; Lueck, Dornbusch, & Hart, 1999; Vervloed, Janssen, & Knoors, 2006).

Visual environmental management: It is essential to arrange an environment to provide better vision for children with low vision (Keeffe, 1995). Artificial lighting in an indoor environment can be adjusted for the preferences of children with low vision. In addition, they can take a relevant position according to the light source in an outdoor environment. Besides, it is crucial to provide an environment specifically designed to improve and use visual attention and examination, and to guide motor skills (Lueck et al., 1999).

Visual skills training: It is about doing eye training to control eye movements, such as scanning, focusing, and tracking (Lueck et al., 1999). Awareness and attention exercises can be used within visual skills training. It can be done by children with low vision using familiar objects like toys (Keeffe, 1995). Such children can be asked to keep their attention on the object while moving it. Then, the researcher can observe whether the child can notice the object (Poland & Doebler, 1980). For example, pencil push-ups treatment can be used for this purpose (see Figure 1). The child needs to hold the pencil in line with his/her nose and to focus on it. Then, the child moves the pencil 2 or 3 centimeters back and forward by maintaining his/her focus on it. This eye exercise can be repeated for 15 minutes.

Figure 1. Pencil push-ups activity as vision therapy (https://www.seevividly.com)

Moreover, eye training exercises for controlling eye movements by scanning the environment to detect the object can be used to enhance visual skills (Palmer, 1997). While doing these exercises, it is important to be able to move eyes from one object to another smoothly by keeping the eye movements among the direction between these objects (Keeffe, 1995). For instance, brock string can be used for children with low vision to enhance their visual skills (Taub, 2014). As seen in Figure 2, there are beads in different colors on the string. During the vision therapy, the child starts with fixating on the nearest bead and shifts the eye movements to the next bead one by one until the bead placed at the end of the string. After fixating on each bead, the child repeats the procedure.

Figure 2. Brock string activity as vision therapy (https://www.seevividly.com)

Besides, eye training exercises for controlling eye movements by tracking the moving objects or persons can be used to enhance visual skills. For instance, objects which are familiar to a child with low vision can be held in front of the child and moved slowly down and up (Keeffe, 1995). While doing this exercise, the eye movements of the child can be observed by the researcher to identify the consistency among the movements.

Such kinds of trainings are essential to maintain and enhance the vision of such children (Chacón-López et al., 2013). Besides, the response time of children with low vision can be shortened with the help of these trainings (Tsai et al., 2013). There are a variety of trainings including showing objects on the researcher's hands, providing visual therapy or offering computer-based visual objects whose sizes and durations on the screen and position are adjustable (Chacón-López et al., 2013; Coetzee & Pienaar, 2013; Werth & Seelos, 2005). Consequently, all of the trainings serve the same purpose to improve scanning, focusing, and tracking skills.

Visually dependent task training: It is about adapting and using the visual skills developed with trainings for other specific purposes (Lueck et al., 1999). It starts with the analysis of the dependent task and continues with the identification of necessary visual skills. Then, children with low vision can be asked and guided to complete the required training by using previously developed vision skills.

2.5.2 Low Vision Devices

There are optical, non-optical, and technological devices to enable children with low vision to see objects easier (Chiang et al., 2011; Keeffe, 1995; Palmer, 1997; Vervloed et al., 2006). Optical devices are used to assist children with low vision to get the ultimate benefit from their partial sight (Palmer, 1997). There are two types of optical devices to be used for distance and near vision. Telescopic lenses can be used for distance vision, while microscopic lenses, such as magnifiers, can be used for near vision. In addition, there are non-optical instruments to provide better environmental conditions to use partial vision effectively (Palmer, 1997). For instance, a reading stand can be listed as an example of non-optical devices for children with low vision (Keeffe, 1995). Besides, the amount and direction of a light source can be arranged to help children with low vision to see better. Moreover, there are technological reading devices, such as iPad and Kindle, to increase the reading speed of such children (Shah, Schwartz, Gartner, Scott, & Flynn, 2018).

2.5.3 Eye Tracking Usage

There are various types of eye training exercises for children with low vision, such as video-based solutions. For instance, Eyecanlearn (http://eyecanlearn.com) web site offers video-based materials in order to enhance focusing and tracking skills. In Figure 3, there is a video-based game for doing eye exercises to improve focusing skills. In the game, there is a fish at the center of the screen (see the left side of Figure 3), and the user needs to focus on the fish. Then, a shark comes to the scene suddenly

and eats the fish (see the right side of Figure 3). After that, the fish comes to the scene again to the same position, as seen on the left side of Figure 3.

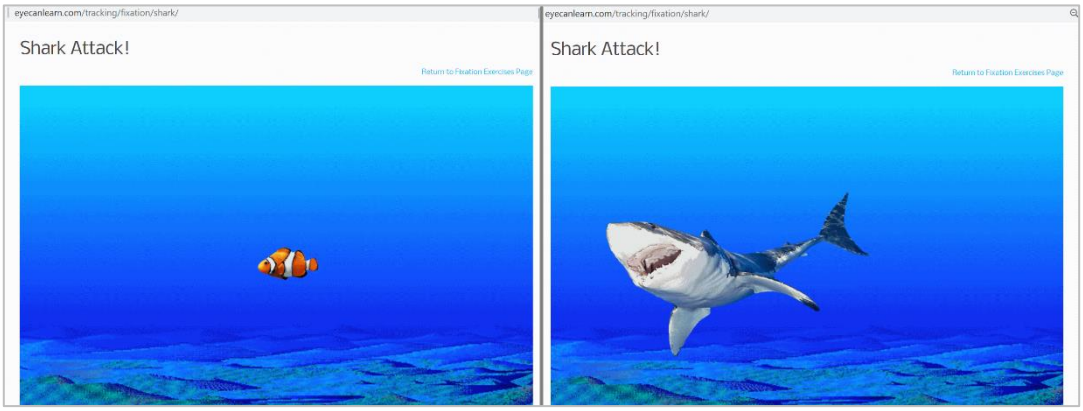


Figure 3. Video-based eye training for focusing skills (http://eyecanlearn.com)

Figure 4 presents a video used to improve tracking skills. A red bug on the screen walks through a horizontal direction on the screen. The user is asked to scan the environment to find the bug and to focus on and track it. The user has an option to increase and decrease the size of the object on the screen. However, the scanning, focusing, and tracking skills can be just assessed by using expert supervision or a user's self-report.

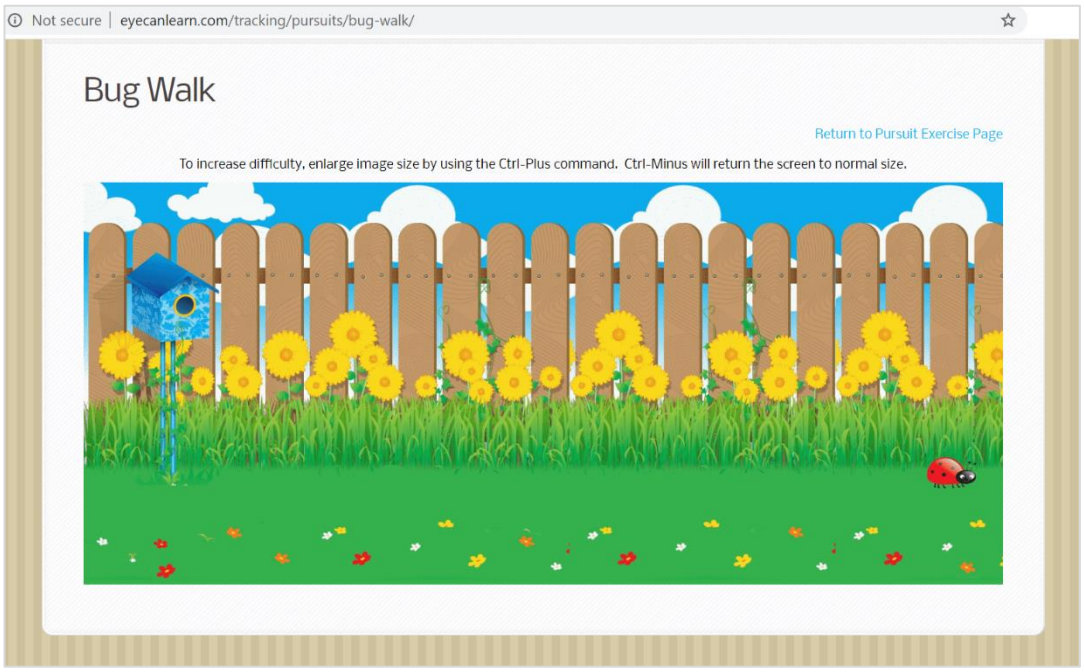


Figure 4. Video-based eye training for tracking skills (http://eyecanlearn.com)

The common problem is that such eye exercise programs are lack of motivating and attraction elements (Kasprowski, Dzierzega, Kruk, Harezlak, & Filipek, 2016). Computer-based technologies and computer games can be used to overcome such a problem and to help children with low vision improve their vision skills (Achtman, Green, & Bavelier, 2008). Besides, eye-tracking technology has an apparent potential, and it can be added to these kinds of game-based eye training systems (Donmez & Cagiltay, 2019; Fikar et al., 2018). For instance, Kasprowski et al. (2016) applied an eye-tracker-based vision training system for children with low vision, and they found that eye-tracking-based games can be used as vision therapies for such children. In addition, eye-tracking technology can be used as an assessment tool for the visual field of children with low vision (Simkin et al., 2019). Besides, eye-tracking technology can provide on-screen visual search activities for children with low vision by tracking their eye movements (Ivanov et al., 2018). The reason for using eye-tracking technology is that it can provide objective data about the eye movements of children with low vision. For example, Kooiker, Pel, Van der Steen-Kant, and Van der Steen (2016) found that eye-tracking technology could be used to

analyze the visual profile of children with visual impairments. Moreover, eye-tracking technology can provide reliable and stable data about the eye movements of children with visual impairments (Kooiker, van der Steen, & Pel, 2014). To sum up, eye-tracking technology has critical potential to provide eye training and assessment settings for children with low vision with objective, reliable and stable data about their eye movements.

2.6 Impact of Eye Training on Education of Children with Low Vision

Eye training exercise plays an important role for children with low vision thanks to its capacity to enhance vision skills (Vervloed et al., 2006). In parallel, enhancing vision skills have positive effects on maintaining daily activities and increasing the quality of life (Keeffe, 1995; Pasian et al., 2012; Strong et al., 2008b). Besides, visual training exercises can contribute to academic skills, such as reading, writing, spelling, and mathematical abilities (Helveston, 2005). Especially, reading skills are known to have an important impact on academic achievement (Lan et al., 2009) because reading is one of the most important problems for children with low vision (Vervloed et al., 2006). In other words, improving the reading ability can result in better academic achievements for children. It requires scanning, focusing, and tracking skills as well as the control of eye movements (Carney, Engbretson, Scammell, & Sheppard, 2003). Therefore, it is obvious that eye training with early visual rehabilitation has a positive impact on the academic success of children with low vision (Ganesh et al., 2013).

2.7 Summary

Although technology is extensively utilized for educational purposes, it has limited usage in special education; thus, it is needed to popularize the usage of ICT and AT in the special education field. ICT and AT can play an important role for children with visual impairments. Those children require extra tools or applications to reach

relevant resources like their peers. At this point, AT is a solution for their problem and can help them not to stay behind their peers while following the lesson or completing the course requirements. However, there is a need for conducting more research to understand their needs and to find a proper way to integrate ICT and AT into the field of low vision.

Moreover, the extensive research on the field of vision loss and enhancing particularly scrutinize the vision trainings with subjective evaluations of teachers or researchers in specific settings. However, technology-integrated vision trainings, namely ICT and AT, can be done independently of place and time with objective results by using eye-tracking devices. Therefore, there is a gap in the literature about the usage of eye training games through the data gathered from eye-tracking devices. In addition, eye training programs for improving the scanning, focusing, tracking, and controlling eye movement can be boosted with computer-based technologies, especially eye tracking-supported technologies, to include color discrimination, contrast sensitivity, and light sensitivity. Besides, enhancing the vision skills of children with low vision can result in better academic achievements. Therefore, it is vital to encourage them to do eye exercises to improve their functional vision skills instead of directing them to solutions generally applied to children who are totally blind. In this way, they can learn how to use their vision more effectively and efficiently to maintain their education.

CHAPTER 3

METHODOLOGY

This chapter presents the methodology of this study under six main headings: overall design of the study, development of the eye training program, participants, data collection, data analysis, and issues of trustworthiness.

3.1 Overall Design of the Study

The purpose of this study is to design and develop eye gaze game applications as a training program for children with low vision. During this study, design-based research was deployed as the main design of the study, which provides the potential to combine design, research, and practice (Wang & Hannafin, 2005). In addition, it includes systematicity among the instructional development that follows design, development and evaluation steps (Richey, Klein, & Nelson, 2004)

This study follows five fundamental characteristics of design-based research defined by Wang and Hannafin (2005): (a) pragmatic, (b) grounded, (c) interactive, iterative, (d) integrative, (e) contextual (Table 1). At first, this study is pragmatic because it is based on a theory and includes practice by applying developed eye training program to children with low vision. Secondly, it is grounded because it is based on gamification, and it is designed to use in a real-world setting as an extracurricular training program for children who need practice to improve and maintain their eyesight. Thirdly, it has interactivity by including designers, teachers, academicians, and ophthalmologists in the design processes. In addition, it is iterative because it consists of development cycles, such as pilot application, the first prototype, second prototype, and final product in detail. Fourthly, it is integrative because it utilizes

different methods in different phases. Finally, it is contextual because it provides design principles and guidance to apply them in the field of visually impaired student's education.

Table 1. Characteristics of design-based research (Wang & Hannafin, 2005)

Characteristics	Explanations
Pragmatic	• Design-based research refines both theory and practice. • The value of a theory is appraised by the extent to which principles inform and improve practice.
Grounded	• Design is theory-driven and grounded in relevant research, theory, and practice. • Design is conducted in real-world settings, and the design process is embedded in and studied through design-based research.
Interactive, iterative, and flexible	• Designers are involved in the design processes and work together with and flexible participants. • Processes are the iterative cycle of analysis, design, implementation, and redesign. • The initial plan is usually insufficiently detailed so that designers can make deliberate changes when necessary.
Integrative	• Mixed research methods are used to maximize the credibility of ongoing research. • Methods vary during different phases as new needs and issues emerge, and the focus of the research evolves. • Rigor is purposefully maintained, and discipline applied appropriately to the development phase.
Contextual	• The research process, research findings, and changes from the initial plan are documented. • Research results are connected with the design process and the setting. • The content and depth of generated design principles vary. • Guidance for applying generated principles is needed.

According to Reeves, Herrington, and Oliver (2004), design-based research includes four phases. The first phase is about the analysis of the problems from different perspectives. The second phase covers the technology-employed development process of solutions. The third phase is to test and revise the developed solutions by

following iterative cycles. The fourth and final phase is about preparing guidelines and design principles as documentation and reflection (see Figure 5).

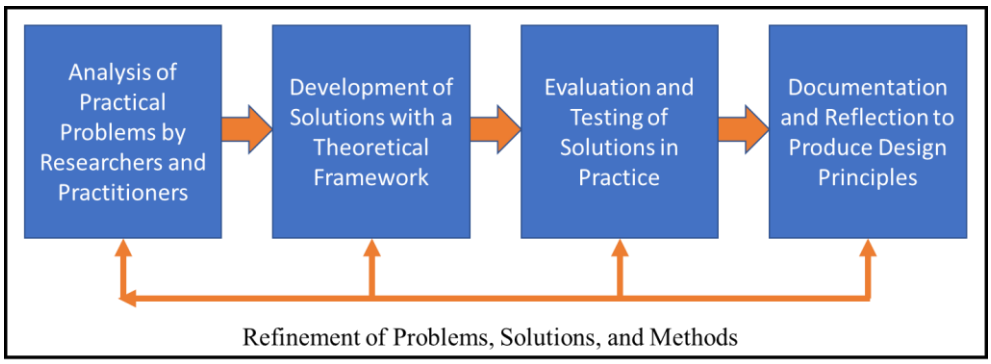


Figure 5. Design-Based Research Model by Reeves et al. (2004)

The current study followed the design-based research model of Reeves et al. (2004). The relevant steps were given in Figure 6.

The first phase of this study is about the analysis of the problem. First off, the needs analysis was initiated with the focus group meeting with three academicians from the department of visually impaired students' education. The purpose of the focus group meeting was to obtain their current solutions for providing eye movement exercises for children with low vision. Then, four teachers from a school for visually impaired students were interviewed to understand their current technology usage and their needs in the area of education of the children with low vision. After that, four academicians from the department of visually impaired students' education were interviewed to understand the educational needs of the students with low vision. Also, an interview was conducted with an ophthalmologist to have an idea about the general medical status of children with low vision. Lastly, students from the school for visually impaired students were recruited to a test for the pre-prototype version of the eye training program developed during this study.

<table>
<tr><th>Phase 1</th><th colspan="3">Phase 2</th><th>Phase 3</th><th>Phase 4</th></tr>
<tr><td>Analysis of Practical Problems by Researchers and Practitioners</td><td colspan="3">Development of Solutions with a Theoretical Framework</td><td>Evaluation and Testing of Solutions in Practice</td><td>Documentation and Reflection to Produce “Design Principles”</td></tr>
<tr><td>1.1. Needs Analysis</td><td>2.1. Identifying the Vision Skills to Develop</td><td>2.3. Development of the First Prototype</td><td rowspan="3">2.6. Formative Evaluation of Prototypes</td><td>3.1. Summative Evaluation of Eye Training Program</td><td>4.1. Refining Design Principles</td></tr>
<tr><td>1.2 Pre-prototype Tests (Review of Theoretical and Practical Applicability)</td><td>2.2. Preparing the Storyboards</td><td>2.4. Development of the Second Prototype</td></tr>
<tr><td></td><td></td><td>2.5. Development of the Final Product of the Eye Training</td></tr>
<tr><td></td><td></td><td colspan="2">2.7. Design Principles</td></tr>
</table>

Figure 6. Design of the study based on Design-Based Research (Reeves et al., 2004)

The second phase of this study is about the development of solutions with the preparation of the system flow diagram (see Figure 7). Firstly, an expert opinion was taken from an academician from the department of visually impaired students' education to identify the skills to be developed by students with low vision. Secondly, storyboards for the first prototype were prepared. During the preparation, the design of the eye training program was determined according to the revisions based on the feedback of two academicians, one from the field of visually impaired students' education, and one from the field of instructional technology. After that, the iterative and incremental development process was started, and the first prototype was developed. During the formative evaluation in the phase of development, a total of eight interviews were conducted, four with teachers from the school for visually impaired students and four with the academicians from the department of visually impaired students' education. Then, the development process of the second prototype was realized by assisting with formative evaluation. It was conducted by following a focus group meeting with three academicians from the department of visually impaired students' education was conducted to provide feedback to this phase. In addition, a pilot test was conducted in eight trials with a student from a school for visually impaired students. Then, the development of the final product was finalized. As a result, design principles were obtained at the end of this phase.

The third phase of this study is about the evaluation and testing of the generated solutions. It covers the summative evaluation of eye training program for students with low vision. Usability testing with logging actual use of participants and observations was applied during this phase. There were 36 children with low vision who played the eye movement games. During the usability testing, their eye movements, scores, playing eye games habits were recorded. Their medical diagnosis and demographic information were also collected to be used to interpret their eye movements. In addition, their parents were interviewed to understand views on the training program. In addition to four interviews with the academicians from the department of visually impaired students' education, another four interviews

were conducted with the ophthalmologists to gather their opinions about the eye training program offered for children with low vision.

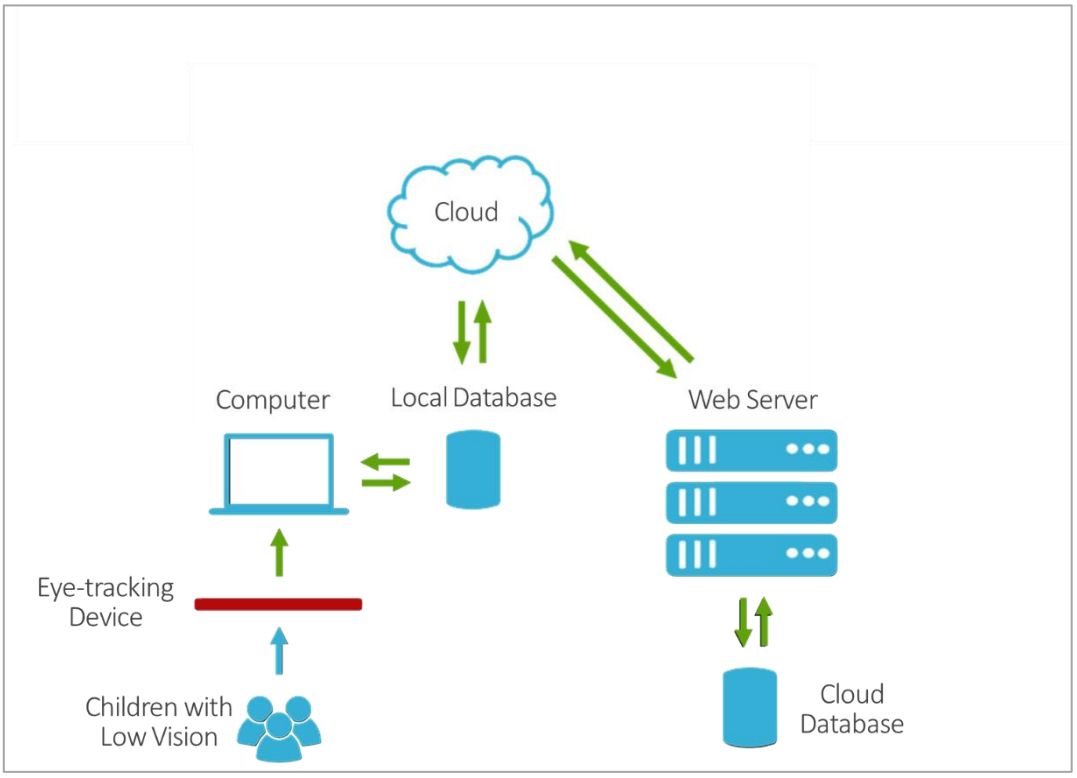


Figure 7. System flow diagram

The fourth phase of this study is about documentation and reflection to produce design principles. In this phase, design principles were finalized and documented according to the analysis results of the data collected during the evaluation and testing phase.

In summary, this study is about the design and development of a game-based eye training program for students with low vision, and overall phases of this study were provided in detail.

3.2 Development of Eye Training Program

A game-based eye training system was designed and developed iteratively during this study to enhance the vision of children with low vision. During the analysis phase, the pre-prototype version of the system was developed and tested with children with low vision. The system consists of two games to enhance visual acuity and visual field of children with low vision, and these games are based on scanning and focusing on objects and controlling eye movements to scan and track the objects by considering color discrimination, contrast sensitivity, and light sensitivity. As shown in Figure 8, there are the same number of different colored and randomly positioned circles in each region. This game aims to enhance scanning and focusing on objects. Children can select a color at the beginning of the game and try to scan the environment and focus on the selected colored circle for a certain time to make it disappear from the screen.

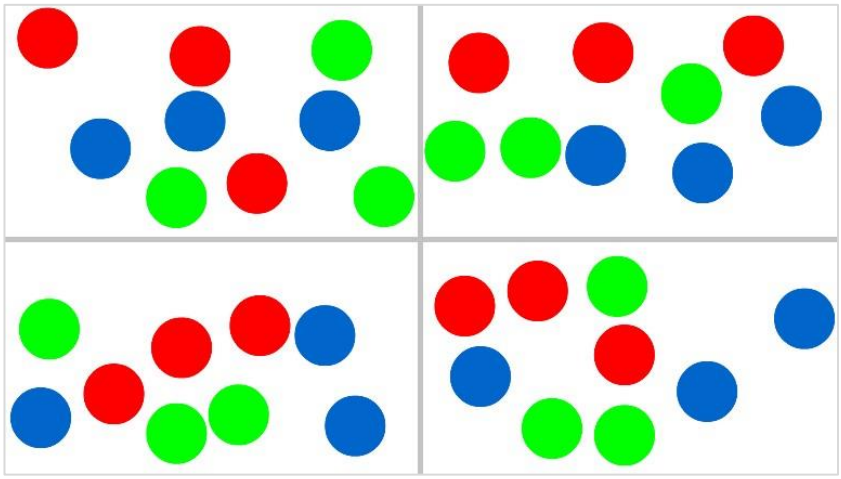


Figure 8. Pre-prototype game for scanning and focusing skills

The second game, which was developed for controlling eye movements as scanning and tracking skills, as shown in Figure 9, has four different path options: horizontal, vertical, right diagonal, and left diagonal.

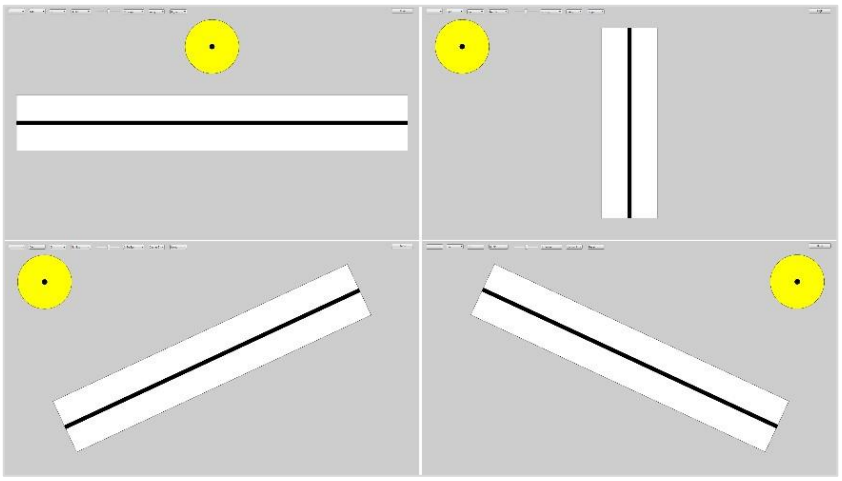


Figure 9. Pre-prototype game for scanning and tracking skills

The circular object is matched to the eye movements of the user and can be moved with the eye movements. To make eye movement exercise with this game, children have to move the circular object through the selected path by using their eye movements.

After testing the pre-prototype eye training program, including two games in the analysis phase, the first prototype of an eye training program was developed in the development phase. It includes two games similar to pre-prototype and aims to enhance scanning and focusing on objects and controlling eye movements to scan and track the objects. The first one (see Figure 10) has colored balloons, and children can blow them up by scanning and focusing on them for a certain time. This game also can provide information about their field of vision.

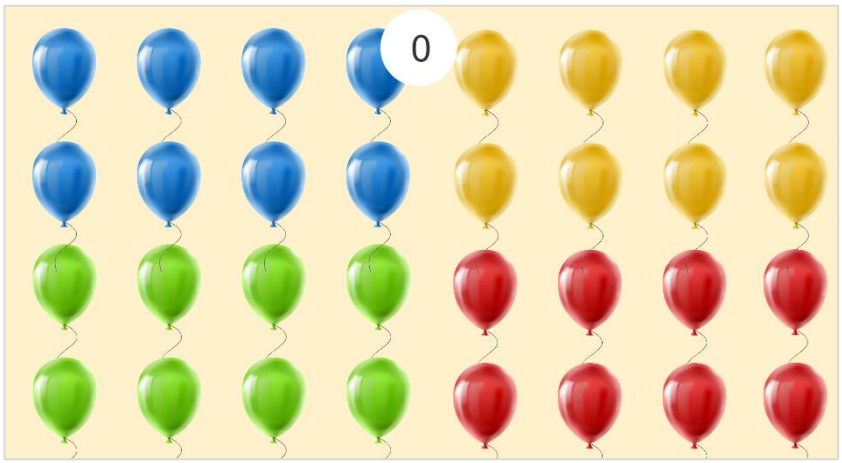


Figure 10. First prototype game for scanning and focusing skills

The second one (see Figure 11) is to enhance children's scanning and tracking skills. Children need to focus on each ball in turn and to take each to the pot by using their eye movements.

Figure 11. First prototype game for scanning and tracking skills

Storyboards of the games were taken into consideration during the development phase of the first prototype. Then, the interviews with the academicians and teachers were used in the formative evaluation process before developing the second prototype. After that, the second prototype of the eye training program was developed. Then, a focus group meeting was held with three academicians, and a

pilot test was conducted with a student from school for visually impaired students. The pilot test was conducted in eight trials, and each trial was performed on consecutive days. During the pilot study, a classroom environment was used, as seen in Figure 12. The child was asked to sit in front of the participant's screen with a fixed eye-tracking device.

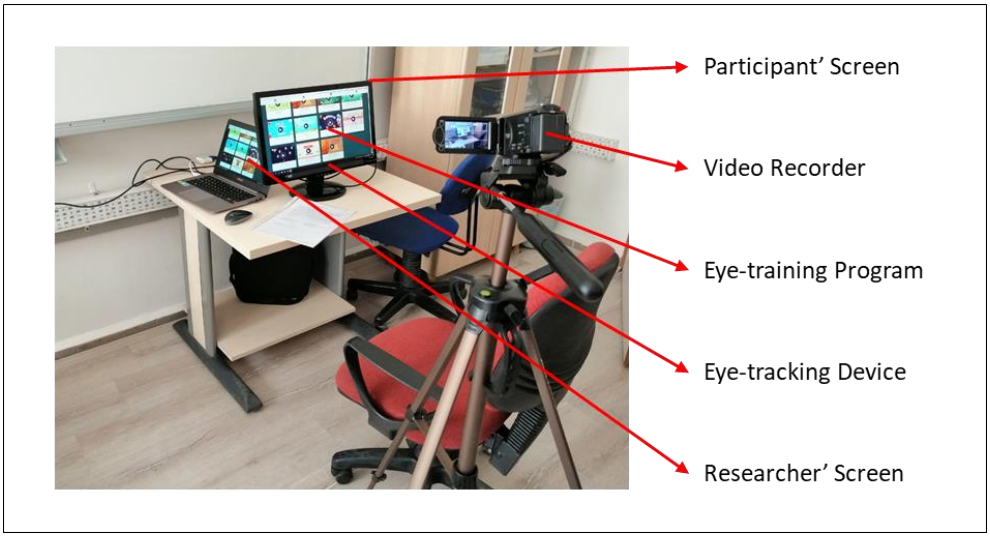


Figure 12. Data Collection Setting for a pilot study

The researcher controlled the games from the duplicated screen, and the experience of the child was recorded with a video camera while doing exercise with the eye training program. After the pilot test, eye training games were finalized to be implemented in the evaluation and testing phase. The final product has four games to be applied to children with low vision. Two of them are to enhance scanning and focusing skills, and the other two are for scanning and tracking skills. The scanning and focusing games for enhancing visual acuity and visual field of children with low vision are balloon popping and basketball (focusing) games, as seen in Figure 13. Both games require the user to focus on the objects. At the beginning of the games, the user can select the difficulty level for the game, size of the objects, and duration to focus.

Then, the user can start the game and play as long as he/she wants. In the first game, there are colored balloons on the screen, and the user has to look at them for a certain time to blow them up one by one. When the user completed the time to focus on the balloon, it disappears. Then, the user can move on to the next balloon. The user can decide any balloon to shoot by any order. He/she is free to select and play the game. In the second game, there is a ball on the screen to shoot. The user needs to look at the ball for a certain time to make a score. When the user completes the shooting, the ball disappears for a moment and comes back in a new position. For this game, there are four positions the ball can follow in turn: middle left, middle top, middle right, and middle bottom. If the user cannot focus on the ball in a minute, the ball moves to its next position.

Figure 13. Scanning and focusing games in the final product

The other two games, which are related to enhancing visual acuity and visual field of children with low vision with the help of scanning and tracking activities, are themed as food collecting and basketball (tracking), as seen in Figure 14. The difference between scanning-focusing and scanning-tracking games is that focusing games require just a constant look on objects while tracking games requires a look and then intentional eye movements. The food collecting game requires the user to identify the object seen at the center and then to find the same one among the objects on the screen. Then, the user needs to scan and focus on the same object for a certain time and to move it to the center with his/her eye movements. After completing the task, the new object comes to the center, and again the user tries to identify, match, and pair the objects. The basketball game played with scanning and tracking

activities requires the user to look on one of the balls for a certain time, and then to move it to the pot by his/her using eye movements. The user can start from any ball to play, and the balls have a fixed position, as seen in Figure 14. Besides, the balls on the screen are refreshed each minute.

Therefore, four games were developed under two categories - scanning-focusing and scanning-tracking - within the eye training program for children with low vision at the end of the development phase. These games were played by children with low vision for five minutes, each under the supervision of the researcher at the evaluation and testing phase.

Figure 14. Scanning and tracking games in the final product

3.3 Participants

This study is based on design-based research and consists of four phases. In each phase, there are several participants. The participants were selected using convenience and purposeful sampling methods because it was crucial to use it to understand the problem to be solved (Creswell & Creswell, 2018). At the analysis phase of the study, there were four academicians from the department of visually impaired students' education, four teachers from a school for visually impaired students, and an ophthalmologist to conduct the needs analysis and to test the pre-prototype of the eye training system (see Table 2).

Table 2. Demographic information about academicians and teachers

No	Occupation	Age	Field of Expertise	Education Level	Work Place	Exp.
ACA1	Academician	30	Visually Impaired Students' Education	M.Sc.	Public University	7
ACA2	Academician	29	Visually Impaired Students' Education	M.Sc.	Public University	6
ACA3	Academician	29	Visually Impaired Students' Education	M.Sc.	Public University	5
ACA4	Academician	38	Visually Impaired Students' Education	Ph.D.	Public University	16
ACA5	Academician	49	Visually Impaired Students' Education	Ph.D.	Public University	27
IT1	Academician	57	Instructional Technology	Ph.D.	Public University	31
TE1	Teacher	35	Special Education	B.Sc.	Guidance Research Center	12
TE2	Teacher	31	Special Education	B.Sc.	Public School	7
TE3	Teacher	26	Special Education	B.Sc.	Public School	4
TE4	Teacher	39	Special Education	B.Sc.	Private School	3

The analysis phase started with a focus group meeting with three academicians from the field of visually impaired students' education, namely ACA1, ACA2, and ACA3, as seen in Table 2. Then, four special education teachers from the low vision field were interviewed. They are coded as TE1, TE2, TE3, and TE4 (Table 2). After that, academicians from the field of visually impaired students' education were interviewed and coded as ACA1, ACA2, ACA3, and ACA4. They have at least five years of experience in the field, and can be regarded as experts. In addition, an interview with an ophthalmologist, coded as OPH1 in Table 3, was conducted to understand the medical condition of children with low vision.

Table 3. Demographic information about ophthalmologists

No	Occupation	Graduation	Work Place	Exp.
OPH1	Ophthalmologist	Hacettepe University	Private Clinic	32
OPH2	Ophthalmologist	Hacettepe University	Public Hospital	4
OPH3	Ophthalmologist	Ankara University	Public Hospital	9
OPH4	Ophthalmologist	Ankara University	Public Hospital	7
OPH5	Ophthalmologist	Ankara University	Public Hospital	42

In the development phase of the study, there were three steps to complete: the first prototype, second prototype, and final product. Firstly, getting an expert opinion session was conducted with an academician (ACA4 in Table 2) from the field of visually impaired students' education before preparing the storyboards of the eye training program. Then, the storyboards were prepared according to the interview with two academicians, one from the special education field (ACA4 in Table 2) and one from the instructional technology field (IT1 in Table 2). Accordingly, the development of the first prototype was carried out. After that, a formative evaluation was conducted with interviews with academicians and teachers. There were interviews with four academicians from the department of visually impaired students' education (ACA1, ACA2, ACA4, and ACA5 in Table 2). In addition, there were interviews with four teachers from a school for visually impaired students (TE1, TE2, TE3, and TE4 in Table 2). Then, the second prototype of the eye training program was developed. After the development of the second prototype, the formative evaluation was applied with a focus group meeting and pilot testing. The focus group meeting was conducted with three academicians from the field of visually impaired students' education (ACA1, ACA4, and ACA5 in Table 2). The aim of gathering these data was to complete the design and development of the eye training system and to prepare design principles. Besides, a pilot test was performed with an 8^{th}-grade child with low vision was for eight days as one session a day. Finally, the games in the eye training program were revised as final products, which led the design principles for eye training program.

In the evaluation and testing phase of the study, usability testing with logging actual use of participants and observations were applied. Convenience and purposeful sampling methods were employed to select the participants. Children who were admitted to Vision Research and Low Vision Rehabilitation Unit of Department of Ophthalmology at Ankara University for eight weeks were invited to participate in this study. Thirty-six of these children accepted to participate, and each tested the eye training program developed during this study for 20 minutes (see Table 4).

Table 4. Demographic information about children

No	Gender	Age	Residency	Eye Exercise at Home	Diagnosis	Right Eye Visual Acuity (%)	Left Eye Visual Acuity (%)
CH01	Female	12	Ankara	Yes	Hereditary macular dystrophy	16	20
CH02	Male	10	Ankara	No	Cone-rod dystrophy	60	60
CH03	Male	7	Gaziantep	Yes	Albinism	10	16
CH04	Male	18	Ankara	No	Congenital retinoschisis	5	5
CH05	Male	11	Bitlis	Yes	Cone dystrophy	10	16
CH06	Female	14	Ankara	No	Congenital retinoschisis	5	4
CH07	Male	9	Kocaeli	Yes	Cortical visual impairment	0.1	2
CH08	Male	2	Ankara	Yes	Ocular Albinism	10	10
CH09	Female	13	Kütahya	No	Stargardt macular dystrophy	5	5
CH10	Male	9	Burdur	No	Congenital cataract	16	10
CH11	Female	8	Ankara	Yes	Glaucoma	5	5
CH12	Male	12	Bursa	No	Stargardt macular dystrophy	5	5

Table 4. (continued)

No	Gender	Age	Residency	Eye Exercise at Home	Diagnosis	Right Eye Visual Acuity (%)	Left Eye Visual Acuity (%)
CH13	Male	10	İstanbul	No	Leber congenital amaurosis	5	5
CH14	Male	12	Kocaeli	No	Congenital cataract retinoschisis	10	10
CH15	Female	13	Zonguldak	Yes	Albinism	10	10
CH16	Female	14	Ankara	No	Macular dystrophy	5	5
CH17	Male	18	Kayseri	No	Degenerative Myopia	5	5
CH18	Male	8	Ankara	No	Leber congenital amaurosis	1	1
CH19	Male	10	Ankara	Yes	Hereditary macular dystrophy	16	16
CH20	Male	6	Balıkesir	No	Disc Hypoplasia	1	20
CH21	Female	6	Ankara	Yes	Hereditary macular dystrophy	5	5
CH22	Female	17	Ankara	No	Retinitis pigmentosa	5	5
CH23	Female	15	Ankara	No	Retinitis pigmentosa	10	5
CH24	Male	6	Ankara	No	Retinitis pigmentosa	5	5
CH25	Female	10	Yozgat	No	Retinoschisis	30	30
CH26	Female	16	Ankara	No	Amblyopia	16	40
CH27	Male	11	Antalya	Yes	Retinopathy of prematurity	5	5
CH28	Female	18	Ankara	No	Albinism	20	20
CH29	Female	12	Ankara	Yes	Cerebral Visual Impairment	60	60

Table 4. (continued)

No	Gender	Age	Residency	Eye Exercise at Home	Diagnosis	Right Eye Visual Acuity (%)	Left Eye Visual Acuity (%)
CH30	Male	10	Diyarbakır	Yes	Ocular Albinism	16	16
CH31	Male	11	İstanbul	Yes	Hereditary macular dystrophy	10	10
CH32	Female	11	Ankara	No	Amblyopia	30	30
CH33	Female	5	İstanbul	No	Hereditary macular dystrophy	10	10
CH34	Male	17	İstanbul	No	Cerebral Visual Impairment	60	20
CH35	Female	8	Kocaeli	No	Optic atrophy - Didmoad syndrome	-60	50
CH36	Female	14	Kocaeli	No	Optic atrophy - Didmoad syndrome	-20	30

Then, the participants' parents were interviewed to obtain information about their child's experience and their views on the eye training system (see Table 5).

Table 5. Demographic information about parents

No	Age	Occupation	Residency	Educational Attainment
PR01	32	Tailor	Ankara	High school
PR02	43	Housewife	Ankara	Primary school
PR03	32	Construction worker	Gaziantep	High School (Abandoned)
PR04	36	Housewife	Ankara	High school
PR05	34	Farmer	Bitlis	Primary school
PR06	36	Housewife	Ankara	High school
PR07	36	Housewife	Kocaeli	Primary school
PR08	21	Housewife	Ankara	High School (Abandoned)
PR09	35	Housewife	Kütahya	Primary school

Table 5. (continued)

No	Age	Occupation	Residency	Educational Attainment
PR10	48	Retired	Burdur	Associate Degree
PR11	34	Worker	Ankara	Secondary School
PR12	33	Student	Bursa	Undergraduate
PR13	38	Construction worker	İstanbul	Primary school
PR14	38	Housewife	Kocaeli	High school
PR15	41	Miner	Zonguldak	Secondary School
PR16	66	Housewife	Ankara	Primary school
PR17	43	Housewife	Kayseri	Primary school
PR18	35	Electrician	Ankara	High school
PR19	38	Engineer	Ankara	Undergraduate
PR20	29	Repairman	Balıkesir	Secondary School
PR21	35	Security Guard	Ankara	Associate Degree
PR22	36	Housewife	Ankara	Primary school
PR23	36	Housewife	Ankara	Primary school
PR24	36	Housewife	Ankara	Primary school
PR25	34	Housewife	Yozgat	Primary school
PR26	41	Housewife	Ankara	Primary school
PR27	46	Forester	Antalya	Primary school
PR28	43	Officer	Ankara	Undergraduate
PR29	32	Housewife	Ankara	Secondary School
PR30	29	Housewife	Diyarbakır	Primary school
PR31	33	Housewife	İstanbul	Secondary School
PR32	42	Housewife	Ankara	High school
PR33	33	Housewife	İstanbul	Secondary School
PR34	53	Teacher	İstanbul	Undergraduate
PR35	37	Housewife	Kocaeli	Primary school
PR36	37	Housewife	Kocaeli	Primary school

After that, interviews were conducted with four ophthalmologists from a public hospital, coded as OPH2, OPH3, OPH4, and OPH5 in Table 3. Accordingly, four academicians from the department of visually impaired students' education (ACA1, ACA2, ACA4, and ACA5 in Table 2) were interviewed.

At the documentation and reflection phase, design principles were refined and finalized by using the data collected from the participants through the study.

3.4 Data Collection

At the beginning of this study, the relevant approval was obtained from the METU Human Subjects Ethics Committee and provided in Appendix G. Then, a permission letter was obtained from the Ministry of Education before collecting data from schools (Appendix H). Prior to data collection, the aim of this study was explained to all participants, and all of the participants signed an informed consent form (Appendix I) for voluntary participation in this study. In addition, parents signed a parental approval form (Appendix J) to permit their children to participate in this study. At the end of the data collection process, a debriefing form (Appendix K) to follow this study was provided with contact information for further communication.

In this study, there were several instruments used during the data collection at different phases (see Table 6). The main data collection instruments were interviews, focus group meetings, video recordings of gameplays on the eye training program, and observations. The instruments used and the process followed while collecting the data were explained below.

Table 6. The data collection process of this study

Phase	Participants	Data Collection Instruments	Data Analysis
Analysis	Academicians	Focus group meeting	Content analysis
	Teachers	Interviews	Qualitative analysis
	Academicians	Interviews	Qualitative analysis
	Ophthalmologist	Interviews	Qualitative analysis
Development	Academician	Expert opinion	Content analysis
	Academicians	Expert opinion	Content analysis
	Teachers	Interview	Qualitative analysis
	Academicians	Interview	Qualitative analysis
	Academicians	Focus group meeting	Content analysis
	Child	Observation	Descriptive statistics
	Child	Logging actual use	Descriptive statistics
Evaluation	Children	Logging actual use	Descriptive statistics
and Testing	Children	Observation	Descriptive statistics
	Parents	Interview	Qualitative analysis
	Ophthalmologists	Interview	Qualitative analysis
	Academicians	Interview	Qualitative analysis

3.4.1 Data Collection Instruments

According to Fraenkel, Wallen, and Hyun (2011), qualitative data can be collected through interviews, observations, and focus groups. As it is important to use multiple sources of data, this study covers all of these techniques, namely interviews, focus group meetings and observations, and also the usability testing by logging actual use as the main data collection instruments (Creswell & Creswell, 2018). All the instruments used in the study are explained according to the phases below.

Focus group meetings in analysis and development phases: They can be explained as conducting interviews with more than one participant, generally up to eight participants, by gathering responses to the relevant questions from the participants (Fraenkel et al., 2011). In addition, during a focus group meeting, all of the participants should come together and discuss each other's responses by asking

unstructured questions (Creswell & Creswell, 2018). In the analysis and development phases of this study, unstructured focus group meetings were conducted with academicians from the field of low vision to gather information about how to design the eye training system and what should be considered while designing it. At the beginning of the focus group meeting, the purpose of the study and the expectations from the participants were explained by following a script generated for the "academician focus group meeting" in the analysis and development phase (see Appendix A). Then, a demonstration was shown to the participants about eye-tracking technology for children with low vision to trigger them for brainstorming. Lastly, their opinions were collected and recorded in each session lasting approximately 40 minutes.

Interviews in analysis, development, and evaluation and testing phases: They can be explained as conducting meetings with a selected participant by eliciting his/her responses to the relevant questions (Fraenkel et al., 2011). Interviewing is one of the key instruments to collect in-dept data (Creswell & Creswell, 2018). In data analysis, development, evaluation, and testing phases of this study, interviews were conducted with several participants who have diverse expertise.

First of all, teachers, academicians, and an ophthalmologist from the field of low vision were interviewed in the analysis phase (see Appendix B). The purpose of these interviews was to collect data about their demographics: occupation, working place, experience in years, age, and educational attainment. In addition, it was to collect data about their current applications in the field of low vision, their technology usage in this field, and their first impression about using eye-tracking technology for children with low vision.

Secondly, teachers and academicians from the field of low vision were interviewed in the development phase (see Appendix C). Again, the primary purpose of these interviews was to collect data about their demographics. In addition, it was to collect data about the general design of the eye training program to be developed during this study, anticipating problems to be solved, their opinions about scanning-focusing

and scanning-tracking games, and their suggestions to finalize the eye training system.

Lastly, in the evaluation and testing phase, interviews were conducted with parents of children with low vision (see Appendix D). The purpose of these interviews was to collect data about their demographics: occupation, educational attainment, and age. In addition, it was to collect data about eye exercises the children do at home, including their types, examples, and application processes. Moreover, their opinions were elicited about eye-tracking technology for providing eye exercise for children with low vision and its applicability at home. Besides, academicians and ophthalmologists from the field of low vision were interviewed (see Appendix E). The purpose of these interviews was to collect data about their demographics. In addition, it was to collect data about the visual design of the eye training program, general suggestions about its design, the suitability of scanning-focusing and scanning-tracking games for children with low vision and revision suggestions for them, and their general advice for the design of the games.

Expert opinion in the development phase: According to Fraenkel et al. (2011), expert opinion is one of the ways of knowing. During the development phase of this study, expert opinion was obtained from the academicians in the field of low vision and instructional technology to design and develop the first prototype of the eye training program. It started with a demonstration of the drafts and continued with getting feedback from them for the possible improvements.

Usability testing with observations and logging actual use in development, and evaluation and testing phases: While designing and developing applications to run on computers, it is essential to consider the design as user-friendly (Nielsen, 1993). According to Nielsen (1993), there are five main attributes of providing usability: learnability, efficiency, memorability, errors, and satisfaction. Firstly, learnability is about providing an easy-to-use system to ensure a quick adaptation. Secondly, efficiency is about providing efficiency and productivity after learning how to use the system. Thirdly, memorability is about the sustainability of the knowledge to use

the system after a while. Fourthly, errors are about providing a tested system with a low error rate. Lastly, satisfaction is about presenting a system that offers pleasant use with user satisfaction. There are several usability assessment methods, and observations and logging actual use of participants were used to collect data in the current study.

To begin with, observations are about observing participants and recording what they do, generally using an observation form (Fraenkel et al., 2011). Observation is the key instrument to understand the personal experiences of participants (Creswell & Creswell, 2018). Therefore, observations were done by the researcher during the eye training program trials in the development phase and evaluation and testing phase of this study. It is a non-participant observation in which the researcher sits and observes the participant's experience instead of involving in the activity as a participant (Fraenkel et al., 2011).

Observations were done by using an observation checklist, which includes several tasks for all of the four scanning-focusing and scanning-tracking games for enhancing visual acuity and visual field of children with low vision by considering color discrimination, contrast sensitivity, and light sensitivity (see Appendix F). For the balloon popping game, one of the scanning-focusing games, there were five tasks to be recorded. They were related to whether the game could be played, the balloons on the upper left area were popped up, the balloons on the upper right area were popped up, the balloons on the bottom left area were popped up, and the balloons on the bottom right area were popped up.

For the basketball (focusing) game, the other scanning-focusing game, there were five tasks to be recorded. They were whether the game could be played, participant scored a basket with the ball on the left, participant scored a basket with the ball on the top, participant scored a basket with the ball on the right, and participant scored a basket with the ball on the bottom.

For the scanning and tracking games, namely, food collecting and basketball (tracking) games, there were five tasks to be recorded. They were listed below:

- The game could be played.
- The objects on the upper left corner were taken and brought to the center.
- The objects on the upper right corner were taken and brought to the center.
- The objects on the bottom left corner were taken and brought to the center.
- The objects on the bottom right corner were taken and brought to the center.

Finally, logging actual use of participants is about collecting statistics and user experience duration in detail while participants using the actual system (Nielsen, 1993). During this study, users' experiences were recorded with an external video camera, and their statistics were recorded in the eye training program developed during this study. For this purpose, the game scores of the participants were recorded within the given time for doing eye exercise with each eye training game.

3.4.2 Data Collection Process

In the analysis phase, a focus group meeting was conducted with three academicians from the field of low vision to understand better the needs of children with low vision. Before the meeting, the purpose of this study was explained to academicians. It started with a demonstration of the eye-tracking technology and continued with eliciting their suggestions. It was recorded with a tape recorder at an office at the university, and it took about 18 minutes. After that, interviews were conducted with teachers. There were four teachers from a school for visually impaired children. The interviews were recorded in the teachers' room in their schools. The interviews were recorded with a tape recorder, and they took 5 minutes on average. After completing interviews with teachers, four academicians from the field of low vision were interviewed in their offices at the university. Interviews were recorded with a tape recorder, and they took 13 minutes on average. Lastly, an ophthalmologist was interviewed in her private clinic by using a tape recorder to record the interview. It took about 7 minutes.

In the development phase, expert opinion was obtained from an academician from the field of low vision to identify the vision skills to be covered in the eye training program. It was conducted as a meeting at the office of the academician, and highlights of the interview were noted. The meeting to make decisions about the storyboards of the first prototype took about 30 minutes. Then, storyboards for eye training program were prepared as a result of a meeting. This meeting was carried out to obtain expert opinions from two academicians, one from the field of low vision and one from the field of instructional technology. The meeting was conducted at the office of one of the academicians at the university, and the draft storyboards of the eye training program were reviewed by the academicians. Their feedbacks were noted down, and this meeting took about 20 minutes. Hence, the development process of the first prototype was completed. Then, interviews were conducted with teachers to gather data from them about the first prototype. Interviews were carried out at the teachers' room in their schools by using a tape recorder. In addition, interviews were conducted with academicians to gather data from them about the first prototype. Interviews were carried out at their offices at the university by using a tape recorder. The interviews with teachers took 5 minutes on average while the ones with academicians took about 6 minutes. Then, the second prototype of the eye training program was developed by considering the data collected. After that, a focus group meeting was conducted with academicians again. It started with a demonstration of the eye training program and continued with obtaining their suggestions. It was recorded with a tape recorder at an office at the university, and it took about 25 minutes. Next, the eye training program was applied to a child with low vision in eight trials, and each trial was conducted in consecutive days to collect the data about its usability. Before the usability testing, parental approval was obtained from his parents. During the test, the data were collected using observation and logging actual use of the participant. While testing the program, the researcher used the observation checklist and eye training program's recording feature to log the experience of the child. Each trial included playing four games, and each trial took 20 minutes, 5 minutes for each game. During the trials, the gameplays were

recorded using a video camera. After the pilot test, the games were revised and finalized as final products of the eye training program. Lastly, design principles emerged for the eye training program for children with low vision.

In the evaluation and testing phase, the final product of the eye training program was applied to 36 children with low vision during their visit for follow-up examination in the hospital. Before collecting data, parental approval was obtained from their parents. Then, usability testing was launched with logging actual use of children and observation in an available laboratory room in the hospital. Each child used the eye training program, and each trial took 20 minutes, 5 minutes for each game except for children who could not play the first game. If children could not play the first game after trying for 5 minutes, the data collection process with this child was terminated. While testing the program, the researcher used the observation checklist and eye training program's recording feature to log the experience of the child. During the trials, gameplays were also recorded with a video camera. After collecting usability data from children, their parents asked to join an interview pertinent to their children's experience. Interviews were conducted in the same room where the usability testing was done. Interviews took 2 minutes on average. Subsequently, interviews were conducted with four ophthalmologists employed in the hospital, where usability data were collected. The interviews were recorded with a tape recorder, and they took 4 minutes on average. Finally, interviews were carried out with four academicians from the field of low vision in their offices at the university. Interviews were recorded with a tape recorder, and they took 4 minutes on average.

3.5 Data Analysis

This study used several data collection instruments, such as focus group meetings, interviews, observations, expert opinions, and logs of actual uses. Each instrument requires using appropriate analysis techniques. Therefore, three techniques were deemed to be appropriate to analyze the data: content analysis, qualitative data analysis, and descriptive statistics (see Table 6).

Firstly, content analysis was used to analyze the data collected from focus group meetings and expert opinions. Content analysis is a technique to investigate human behaviors through indirect ways, such as documentation or written transcriptions (Fraenkel et al., 2011). In this study, meeting recordings were transcribed after each focus group meeting, and the transcribed texts were analyzed using the content analysis technique to provide input for the next phase of the study. During the analysis, the pre-determined categories were used to extract themes and subthemes from the data. Then, themes were formulated, organized, and grouped to present the findings. Finally, the themes and sub-themes were reported as findings of this study.

Secondly, qualitative data analysis, which is the main analysis technique used in this study, was used to analyze data gathered from interviews. Qualitative data analysis is a technique used to code the data collected mostly from interviews (Fraenkel et al., 2011). It is used to gather meaningful data from raw transcriptions of the interviews. According to Fraenkel et al. (2011), there are two types of qualitative coding: selective coding and open coding. In this study, open coding was used the analyze interview data. The transcriptions of the interviews were read sentence by sentence by the researcher to extract the underlying idea behind them. Then, they were labeled with appropriate codes and sub-codes. It was an iterative process so that sub-codes were often refined. After that, the findings gathered from the interviews were organized and reported.

Lastly, descriptive statistics were used to make the data meaningful. Descriptive statistics can be used to translate and summarize the raw data into meaningful data to make inferences (Creswell & Creswell, 2018; Fraenkel et al., 2011). In this study, descriptive statistics were used to summarize the data collected with the observation checklist. On the observation checklist, there were four main headings related to each game of the eye training program. By using descriptive statistics, the data collected from each child with observation were paired with their demographics and summarized with meaningful tables and graphics. In addition, the data collected with logging the actual use technique during the usability testing were combined with the data about children’s demographics and medical backgrounds. Then, the combined

raw data were summarized and reported by using descriptive statistics. The derived graphics and tables were used to present the findings.

3.6 Issues of Trustworthiness

The validity of the data in a study can be ensured by cross-checking the sources in which the data collected, and this can be performed with triangulation (Fraenkel et al., 2011). Therefore, data triangulation and investigator triangulation were used to provide the validity of the study. Different sources can be used to obtain data to provide data triangulation (Turner & Turner, 2009). For this purpose, interviews, focus group meetings, observations, expert opinions, and logging actual uses were used as the data collection instruments of this study. The advantage of conducting the interviews, expert opinion sessions, and focus group meetings was to expand the responses of participants instead of limiting even if they took longer in duration. Observation forms were used to save the data of certain behaviors of participants during the usability tests, which brought an advantage because of conducting the tests individually. In other words, during the usability tests, each participant was asked to use the eye training program, which facilitated filling out the observation forms for one participant at a time. In addition to observation forms, logs of actual uses were recorded to confirm and verify the data obtained from observation forms.

Moreover, there were several sources of data in terms of participants, namely, special education teachers, expert academicians, ophthalmologists, children with low vision, and their parents.

Besides, it is necessary to use confirmatory coding by another researcher in addition to the actual researcher to provide investigator triangulation, especially during the qualitative data analysis (Turner & Turner, 2009). In this study, some data coding and content analysis activities were repeated by another researcher. The codes and sub-codes were compared with each other to provide investigator triangulation. In addition, the themes extracted from the data were examined by two researchers in detail to have a mutual understanding.

CHAPTER 4

RESULTS

This chapter presents the results of this study under two main headings, including the four phases of this study: analysis, development, evaluation and testing, and documentation and reflection phases. The first heading of this chapter is about the research question. The question is about the design principles of designing eye movement-based game applications as a vision training program for children with low vision. The second heading is about the documentation and reflection for the design principles.

4.1 Research Question

RQ1. What are the design principles of designing eye movement-based game applications as a vision training program for children with low vision?

This research question was answered based on the findings of the analysis, development, and evaluation and testing phases.

4.1.1 Analysis Phase

In the analysis phase, the needs analysis was conducted with four academicians, four teachers, and an ophthalmologist. Also, pre-prototype tests were performed with visually impaired children to understand their needs to enhance their vision skills.

4.1.1.1 Needs Analysis

The needs analysis started with the focus group meeting with three academicians from the field of low vision to get knowledgeable about their experience in the field of low vision and obtain their ideas about the development of a vision training program for children with low vision.

Besides, interviews were conducted with four teachers from the school for visually impaired children and four academicians from the department of visually impaired children's education. In addition, an interview was carried out with an ophthalmologist who is employed in a private clinic for low vision. The purpose of the interviews was to understand the participants' opinions about utilizing eye-tracking technology within a vision training program for children with low vision. As a result, four themes emerged as to responses to current methods used while giving the instruction, technology usage, and point of view about the usage of eye-tracking technology, and listed below:

- Low vision
- Design suggestions
- Technology usage
- Implementation considerations

These themes are explained below in detail.

Low vision: One of the teachers mentioned the importance of having background information and the diagnosis of the child with low vision before providing any vision training. The teacher stated that it was crucial to know the visual field, visual acuity, eye movement skills, and preferences of the child in advance. For instance, the teacher said:

> *To do this for focusing and tracking skills, their focus and visual perceptions, visual acuities, peripheral vision, central vision, and vision loss must be determined to know how far from a person can see objects and people and identify his/her near and far vision. The vision loss in which part of the eye needs to be determined. (TE1)*

Odaklanma ve izleme becerilerine yönelik bunu yapabilmek için önce onların odaklanma ve görsel algılarının, görme keskinliklerinin, çevresel görüşlerinin, merkezi görmelerinin, görme kayıplarının belirlenmesi gerekiyor ki kişi ne kadar mesafeden nesneleri ve kişileri görebiliyor. Uzak görmesi nasıl, yakın görmesi nasıl. Görme kaybı gözün hangi bölümünde var bunların tespit edilmesi gerekiyor. (TE1)

Design Principle: The findings revealed the following design principle: The eye training games should be designed based on the eye exercise needs of the target group, such as focusing on objects, controlling eye movements (scanning and tracking), visual acuity, visual field (central and peripheral vision), color discrimination, contrast sensitivity, and light sensitivity.

In addition, four academicians mentioned that they preferred to provide eye training for children with low near vision to improve their eye movements in terms of focusing and tracking. For instance, one of them said:

For example, eye trainings are done for near vision in these sessions. The first one is related to focusing skills, and the second one is about the tracking skills. In addition, vision skills, such as light sensitivity, visual field, contrast sensitivity, and reading and writing for academic purposes should be examined, and all of these are related to the near vision. (ACA4)

Tabi bu oturumlarda daha çok mesela yakın görme üzerine çalışmalar yapılır. Bunlardan ilki odaklanmadır. İkincisi izlemedir. Daha sonra ışık duyarlılığı, görme alanı, kontrast duyarlılığı ve akademik beceriler başlığı altında okuması yazması gibi konulara bakılır, bunlar yakın görmeyi ilgilendirir. (ACA4)

Besides, three teachers had an explanation about the visual skills they practiced during their lessons. They stated that they emphasized focusing and tracking skills to improve children's reading and writing skills. For instance, one of them said:

There are generally eye exercises for mathematics, reading, and writing skills. We usually emphasize reading and writing skills. (TE2)

Okuma yazma kapsamında egzersizler var genelde. Matematik, okuma yazma. Okuma yazma üzerinde genelde gidiyoruz. (TE2)

In parallel, the ophthalmologist stated that it was important to enhance the functional vision of children with low vision. For this purpose, it is crucial to provide vision training applications, such as reading and writing exercises.

Design Principle: Based on the findings, the following design principle emerged: The games should be categorized in the eye training program in terms of their improvements on vision skills such as scanning-focusing games, and scanning-tracking games.

Moreover, four academicians stated that they were using real objects and asking children with low vision to focus on and follow these objects as vision training exercises. They stated that these trainings were done with a specialist and could be applied in various types of objects. For instance, one of them said:

> *For providing eye training, the creativity of the practitioner is very important; that is, various kinds of activities can be applied. As we just said, stringing beads on the rope for focusing skills, or putting two buckets in front of the child and asking him/her to put the beads on them, putting the yellow beads in one of the buckets and putting the reds in the other bucket, by separating them according to the color or separating the balls. These are examples of enhancing both focusing and tracking skills. (ACA1)*

> *Bunun için aslında kişinin yaratıcılığı çok önemli yani her türlü etkinlik yapılabilir. Az önce de söylediğimiz gibi bir ipe boncuk dizme mesela odaklanma için bir ipe boncuk dizme, işte önüne iki kova koyup boncukları koyup işte sarıları buraya atma kırmızıları buraya atma rengine göre ayırma veya işte topları şey atma bir şeyin içerisine atma. Bunlar aslında hem izleme hem de odaklanma için. (ACA1)*

Three teachers stated that they were doing vision training exercises with children with low vision in their classrooms. They explained that they were using real objects and asking the students to focus on and follow the objects by using verbal clues. For instance, a teacher said:

> *For example, finding the ball or something on the table by scanning the environment with eye movements. We do eye trainings by tracking the objects, the light, or the ball. (TE3)*

Topla ya da mesela masanın üstündeki nesneyi bulma, gözle tarayıp bulma. İzleme, ışık izleme ya da topla izleme çalışmaları yapıyoruz. (TE3)

Lastly, two academicians mentioned the importance of both central and peripheral visual fields while developing the games. They stated that the objects on the game have to spread on the screen instead of using just center or corners. For instance, an academician said:

The object should start from the center and move through all over the screen to have the opportunity to do eye exercises at each part of the screen. I think the balls should be located both in the center and corners in the games (ACA1)

Ortadan başlayıp ve de her bir bölge için ayrı ayrı yapmalı bence bu uygulama hem ortada hem kenarlarda toplar olmalı. (ACA1)

Another academician stated:

In the game, the ball should appear both in the center and the corners, namely upper right, upper left, bottom right, and bottom left areas. (ACA2)

Ekranda hem merkezde top belirse sağ üst sol üst sağ alt sol altta belirse. (ACA2)

Design suggestions: Three academicians stated that leveling should be considered both within the game and inter-games. They stated that the games would have to include in-game levels, such as easy, medium, and hard. In addition, games have to be categorized according to their difficulty levels, such as beginner, intermediate, and advanced to prepare children for further levels. For instance, an academician explained:

The difficulty levels of the games could range from simple to difficult. The levels could be easy, medium, and hard. In addition, the games could be divided into stages both to increase the number and diversity of the games and to provide that children are accustomed to levels of the games. (ACA2)

Yani basitten zora doğru gidebilir. Kolay, orta, karmaşık düzey gibi belki. Biz şey düşünüyoruz, üçlü yani basit, orta ve karmaşık. Bir de o

etkinlikleri de mesela 3 aşamaya bölersiniz hem etkinliğiniz çoğalır hem de basit orta karmaşık diye çocuklar alışmış olur. (ACA2)

Design Principle: Based on the findings, the following design principle emerged: Each eye training game should include difficulty levels, such as easy, medium, and hard by considering visual acuity.

Design Principle: In parallel to the design principle above, the following design principle also emerged: The eye training games should be designed according to the flow theory to provide challenge and immersive experience to users and encourage them to use their eye movements more.

Design Principle: In parallel to the design principles above, the following design principle also emerged: In the eye training program, the games should be listed for the user in terms of their difficulty levels, from easy to hard by considering their visual impairments and visual acuity.

In addition, one of the academicians mentioned that it was crucial to keep it simple while designing games for children with low vision. The academician stated that the screen design should include just essential objects and exclude all distracting objects and said:

The game design should be simplified. The game design seems to have been developed by using various visual objects to make it better, but this can distract the child while playing the game. (ACA2)

Bu ekrandaki alanı sadeleştirin. Siz burada daha bir görselleştirip oyun güzel olsun diye hani düşünerek yapmışsınız ama çocuk buna bakarken bu dikkatini de dağıtabilir yani. (ACA2)

Design Principle: Based on the findings, the following design principle emerged: The eye training games should have a very simple design without any distracting objects by keeping the objects to be fixated with eye movements in the foreground.

Besides, one of the academicians mentioned the importance of using contrast colors on background and foreground to allow children with low vision to see the objects better:

It could be useful to prefer colors allowing the child to distinguish the objects better. This also makes it easier to see. (ACA3)

Şimdi çocuğun ayırt etmesini de kolaylaştıracak renkler kullanmak da işinize yarayabilir. Çünkü çocuğun görmesini kolaylaştırır bu yani. (ACA3)

Technology usage: Four teachers stated that they were using optical or technological/electronic magnifiers as tools to allow children to see the objects easier or printers to provide texts in larger fonts. For instance, one of the teachers said:

We use the smartboard for children with low vision. We use the programs on the smartboard for our students to enhance their visual tracking skills and functional vision skills. We use an electronic magnifier. We get printouts that allow some of those with low vision to see with larger font sizes. (TE4)

Az görenlerle ilgili akıllı tahta kullanıyoruz. Akıllı tahtadaki programları, öğrencilerimizin görsel takip ve işlevsel görmesinde kullanıyoruz. Elektronik büyüteç kullanıyoruz. Az görenlerin bazısının daha büyük puntoyla görebilmesini sağlayan çıktılar alıyoruz. (TE4)

In parallel, four academicians explained that they were using computer-based magnifiers to enlarge the texts and objects on the screen to make children with low vision see the objects better. For instance, one of them said:

There are devices, such as computers, magnifiers, etc., that are used by children with low vision. Children with low vision could follow the lecture with audio programs or screen magnification programs. (ACA4)

Az gören çocukların kendi kullandıkları bilgisayarlar, büyüteçler vb. şeyler var. Onlar sesli programlar veya ekran büyütme programlarıyla ders süreçlerini takip edebiliyorlar. (ACA4)

Besides, two teachers mentioned the usage of smart boards with their magnifier features, while one of them mentioned the usage of mobile devices for this purpose. They also stated that smart boards, tablet computers, voice-controlled/recognition software, and telescopic glasses were among the examples of technology used in the education of children with low vision.

In addition to their current applications, three teachers agreed that technology usage was inevitable for providing vision training for children with low vision. For instance, one of them said:

> *Since we are not from the field of software development, we could not develop eye exercise software for children with low vision. However, we could do eye exercises together with children if we are provided with such software that is compatible with smart boards or working on a computer. (TE3)*

> *Gayet mantıklı geliyor, yani biz alanımız gereği hadi söyle bir program yapalım söyle çalışalım diyemiyoruz ama bize böyle programlar getirilirse çokta güzel çalışırız diye düşünüyorum çocuklarla. Gerek akıllı tahtalara uyarlanmış programlarla gerek bilgisayar üzerinden. (TE3)*

In parallel, four academicians emphasized the importance of using technology for eye training purposes among children with low vision upon considering the recent technological innovations. In addition, they stated that computer-based applications would motivate children with low vision to do eye exercises. For instance, one of them said:

> *Of course, there are technology-based eye-tracking systems and websites developed by some technology companies. There are lots of exercises for focusing and tracking skills. We also see their positive contributions. (ACA4)*

> *Tabii son zamanlarda teknoloji boyutunda göz takip sistemleri olsun işte bir takım teknoloji şirketlerinin geliştirdiği web siteleri olsun, oralarda izleme ve odaklanma ağırlıklı anlamda baya bir egzersiz var. Bunların da olumlu yönde katkılarını da görüyoruz. (ACA4)*

Following teachers and academicians, the ophthalmologist stated that there were several technological applications to be used according to the needs of children with low vision. The ophthalmologist also expressed positive opinions about technology usage for vision training:

> *I think technology should be integrated into vision training. I already use technology for the rehabilitation of children with low vision. (OPH1)*

Bence teknoloji olması gerekiyor, ben de zaten az görenler için teknoloji kullanıyorum. (OPH1)

Moreover, three teachers uttered their positive opinions about the usage of eye-tracking technology in vision training for children with low vision. They also mentioned that such technology could be configured to the needs of children with low vision. For instance, one of them stated:

It is very useful. It could improve the focusing skills of children with low vision, and of course, the student needs to be suitable for it. The eyes of the student should not flicker more. Even so, I believe that even the students with eye flickering could use the eye training program too with appropriate development methods and, maybe, with some configurations. (TE4)

Muhakkak çok yararlı. Odaklanmasını arttıracaktır ve tabii öğrencinin buna hazır olması lazım. İşte göz titrememesi gerekiyor. Ama ben inanıyorum ki biraz zorlamayla gözü titreyen öğrenciler bile belki programdaki bazı ayarlamalarla, onlar da yapabilir diye düşünüyorum. (TE4)

In parallel, four academicians stated that eye-tracking technology had to be used during eye training among children with low vision by considering their visual acuity and their medical diagnosis. They also pointed out that this technology could provide objective results for the evaluation of the trainings used for children with low vision. For instance, one of them said:

If it is appropriate to use eye-tracking technology for enhancing the vision skills of children with low vision, the usage of this technology could give us much more definite evidence about where the children's eyes focus on and much more clear information about what they would exercise to improve their vision. (ACA3)

Göz hareketleri takip teknolojisi de az gören kişilerle eğer uygunsa yani göz hareketleri takip teknolojisine uygun bir görme becerisi varsa kullanılması özellikle nerelerde odaklandığını çok daha net bir şekilde bize bilgi verebilir ve hangi alanlarda egzersiz yapmamız gerektiği hakkında çok daha net bilgi verebilir. (ACA3)

In addition, the ophthalmologist mentioned the importance of eye tracking usage for enhancing eyesight of children with low vision by saying:

I think it is convenient to use the eye tracking systems for children with low vision. In other words, it is necessary to learn how to use the residual seeing best, and it should be used in this field. (OPH1)

Bence uygun. Yani kişinin kalıntı görmesini en iyi nasıl kullanacağını öğrenmesi için gerekli ve uygulanması gerekiyor. (OPH1)

However, one of the teachers remained undecided due to not seeing the demonstration of the vision training program for children with low vision. The teacher stated that they were using verbal clues and real objects while providing eye training for children with low vision, and it was hard to imagine without examining an example for such technology to be used for this purpose. The teacher said:

I could not make a comment since I do not know how to do technology-enhanced eye trainings on computers. I need to see an example. (TE1)

Şimdi göz egzersizin teknoloji üzerinde bilgisayar üzerinde nasıl bir çalışma yapıldığını bilmediğim için yorum yapamıyorum açıkçası. Bir örnek görmem gerekiyor. (TE1)

Implementation considerations: Four academicians stated that the implementation duration could be adjusted based on the preferences and eyesight condition of children with low vision, but they agreed that it could be applied in sessions between 20 and 30 minutes.

The sessions should not exceed 40 minutes. Students with low vision should be given short breaks, perhaps at 20-minute intervals, as they use their visual skills extensively in focusing and tracking. (ACA3)

Çoğunlukla 40 dakikayı geçmemeli. Özellikle az gören öğrencilerde odaklama ve izlemede de görme becerilerini yoğun olarak kullandıkları için hatta belki 20 dakika kısa aralıklarla kısa kısa molalar verilmeli. (ACA3)

In addition, one of the academicians explained that it could be beneficial to set a time limit while applying the games. The academician suggested using each game for at least 5 minutes to enable children with low vision to get familiar with the game:

I think the child needs to play games at least 5 minutes for each so that he/she could concentrate on it. (ACA1)

Bence en az bir 5dk bir oyuna vermek lazım ki çocuk burada buna odaklansın. (ACA1)

Besides, four teachers expressed their opinions about the duration of eye training for children with low vision. Two of them stated that it depended on children with low vision. For instance, one of them said:

It varies from person to person. There are also children who spend hours on the computer. But, there are also students who look on it for 1 or 2 minutes and are tired of its light. (TE1)

Yine kişiden kişiye değişiyor. Ekran başında saatlerce kalan az görenler de var. Ama daha az 1-2 dakika bakıp gözü yorulan ışıktan dolayı, öğrenciler de olabiliyor. (TE1)

Two of the teachers also expressed their experience about the implementation duration and suggested limiting the implementation session as 20 minutes of a 40-minute lesson. For instance, one of them said:

We allow such students to do eye training for 20 minutes in a class hour, and we can spare only one hour per day. (TE3)

Bir ders süresinde 20dk kadar yapıyoruz, günde de sadece bir ders ayırabiliyoruz. (TE3)

In addition to considerations about the implementation duration, four academicians commented on the implementation environment of eye training for children with low vision and expressed that the sessions could include one-to-one applications under an expert supervision to make it more efficient. For instance, one of them said:

I think that a teacher or a practitioner could have difficulties in the classroom. However, if we organize individual-oriented eye exercise sessions, the student will, of course, make progress. (ACA1)

Sınıf içerisinde bir öğretmenin veya çalışacak kişinin zorlanacağını düşünüyorum. Ancak bu işi bireysel yaptığımız takdirde, öğrenci tabi ki ilerleme kaydedecektir. (ACA1)

As a result of the needs analysis, it could be stated that teachers, academicians, and ophthalmologists were capable of using the technology provided for them. Besides, they were willing to use any useful, effective, and efficient technology. Besides, they

were aware of the needs of children with low vision with whom they do exercise, and they were open to use computer-based technologies during eye trainings. In addition, they indicated the specifications of an eye-tracking-based training program for children with low vision. Moreover, they emphasized the need for an application to be used individually by children with low vision to improve their functional vision. It is also necessary for their academic achievement because enhancing functional vision can result in improvements in reading and writing skills, which are the most used activities during the courses. Lastly, they stated that an eye training program for children with low vision had to be configurable according to their preferences, visual acuity, visual field, color discrimination, contrast sensitivity, and light sensitivity.

4.1.1.2 Pre-prototype Tests

Pre-prototype tests were conducted to be knowledgeable about children with low vision in general. During the tests, four students from the school for visually impaired children tried to use the pre-prototype version of the eye training program. Each child was asked to sit in front of the computer with an eye-tracking device and observed while playing the pre-prototypes of vision training program. According to the observation notes, the eye movements of children with low vision could be captured by the eye training program. Using the data coming from their eye movements, it was recorded that they could focus on and track the objects on the computer screen. In addition, the important points to be considered were noted to capture the eye movements of children with low vision better. It is essential to:

- Arrange the sitting position of children with low vision in front of the computer.
- Manage light coming from the window or any artificial sources.
- Use a stable chair for seating instead of a chair with wheels.
- Keep the child's head stable while using the training program.
- Consider that their eyes could move fast and jump immediately from one point to another.

- Consider that the data rate coming from their eye movements could be lower.

Design Principle: Based on the findings of the eye movements of children with low vision, the following design principle emerged: The eye training games should have an indicator, like a magnifier, to show eye movements of users.

- Show children with low vision their scores in the game to increase their motivation to play games.

Design Principle: Based on the finding of showing the scores, the following design principle emerged: In the eye training games, users should be able to see their scores.

- Remember the last preferences in the previous game to use eye training program with the same preferences.

Design Principle: Based on the finding of saving the preferences in the previous game, the following design principle emerged: The eye training games should save the eye preferences of users and apply previous preferences automatically to next plays.

4.1.2 Development Phase

The research question was answered by following several steps. Firstly, the vision skills to develop by using the vision training program were identified. Accordingly, the storyboards were prepared for designing and developing the eye training program for children with low vision. Then, the first prototype of the eye training program was developed by using data gathered during the formative evaluation. Next, the second prototype of the eye training program was developed with the help of the data from formative evaluation. After that, the eye training program was finalized as a final product by utilizing formative evaluation. Lastly, the data collected from these steps were combined with emerging design principles for designing and developing an eye-tracking-based vision training program for children with low vision.

4.1.2.1 Identifying the Vision Skills to Develop Training

An interview was conducted with an academician from the field of low vision to identify the vision skills to focus on while developing the vision training program for children with low vision. During the interview, it was decided to focus on eye movement exercises, especially scanning and focusing, and scanning and tracking skills. It was considered to cover these skills in the eye training program for children with low vision. During the interview, it was decided to use the whole screen to configure visual objects, as seen in Figure 15.

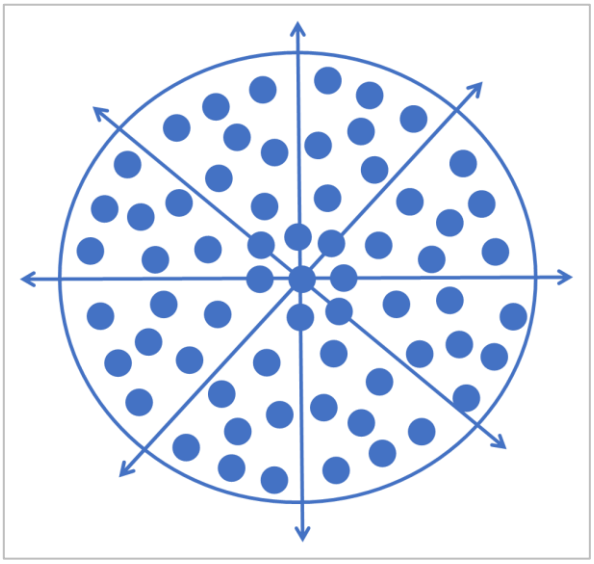


Figure 15. The visual field for scanning and focusing

Moreover, it was decided to use each direction and the center of the screen to provide eye movement exercises for scanning and tracking skills, as seen in Figure 16.

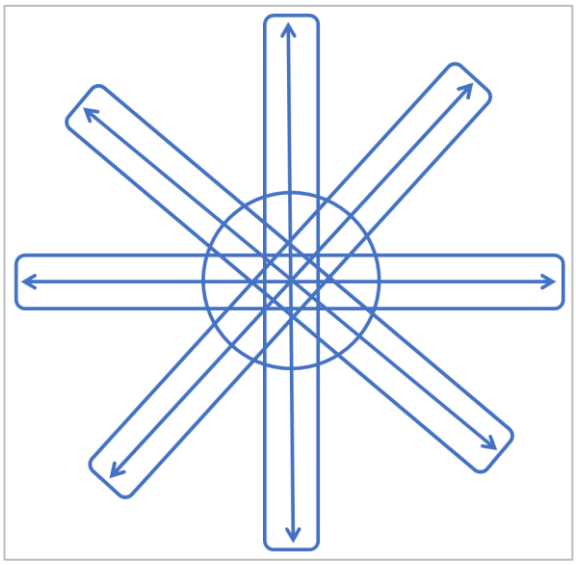


Figure 16. The visual field for scanning and tracking

In addition, the training program used objects both in the center and the corners of the screen as spread across the screen to enable users to practice for their visual field skills, such as central and peripheral vision. Besides, color discrimination is one of the most critical visual skills for children with low vision, and it was decided to use contrast colors in the program. As a result of the interviews, it was decided to design the eye training program as to cover two categories of the skills: scanning-focusing and scanning-tracking skills.

4.1.2.2 Preparing the Storyboard

The data gathered during the analysis phase, the needs analysis and pre-prototype tests, were considered while preparing the storyboards. In addition, the vision skills identified to focus on during the design and development of eye training program were taken into consideration.

During the storyboard preparation, an interview was carried out with two academicians to apply their (expert) opinions. One of the academicians was from the

field of low vision, while the other one was from the field of instructional technology. The main points of this interview are listed below:

- The games should be categorized. The eye training program should be divided into two categories: scanning-focusing games, and scanning-tracking games.
- The balloon popping and basketball (tracking) games should be developed as the first prototype. Then, these two games should be revised during the development of the second prototype. In addition, the other two games, basketball (focusing) and food collecting games, should be developed within the second prototype.
- On the screen, there should be an identifier to show users' eye movements.
- The balloon popping game should be developed first because this game can provide an idea about whether children with low vision can use the eye training program developed during this study.

Based on the interview results, the storyboards were prepared, and its final version is presented below (see Table 7).

Table 7. Storyboards for eye training games

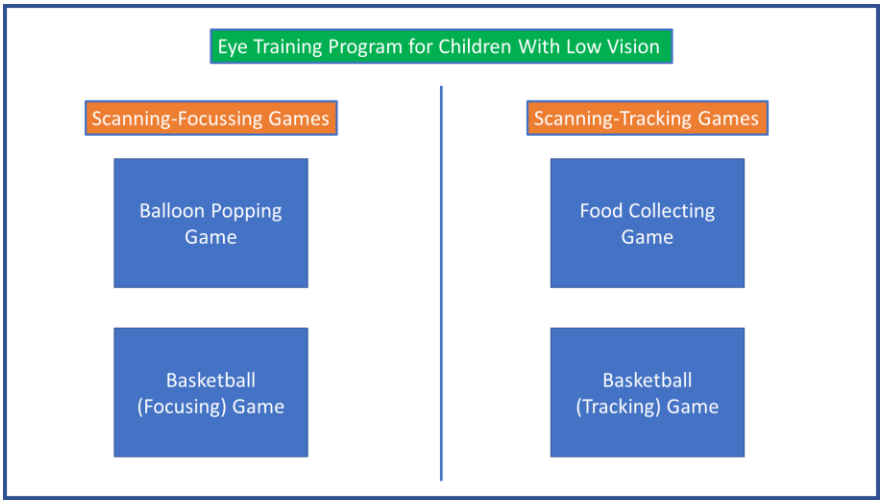
Scene 1: Home Screen	
Scene	
Scenario	The buttons to navigate each game are shown on the screen. The user can navigate each game by clicking on the related button. The games on the screen are categorized and shown under their categories.
Animation and Sound	The headers for the eye training program and its categories are stable on the screen. The button to navigate the games has “hover” and “click” states. When the user comes over the game icon, its opacity is decreased to indicate the hover status. After that, the border color of the icon of each game changes to indicate click status if the user clicks on it. In addition, there is a sound effect for both hover and click status to provide a clue for the states.

Table 7. (continued)

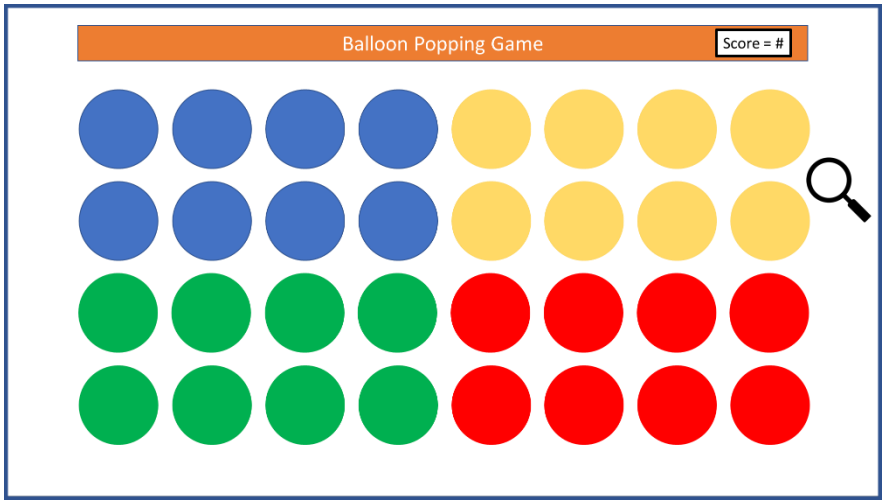
Scene 2: Balloon Popping Game	
Scene	
Scenario	At the top of the screen, there is a header to indicate the name of the game. It disappears 10 seconds after starting the game, but the scoreboard remains on the screen. On the screen, there are eight balloons with 4 different colors. They are stable on the screen, and there is the same amount of space among them. The user can control the magnifier on the screen with his/her eye movements. The magnifier moves wherever the user looks. After looking at any of the balloons for 1 second, the balloon disappears. When the user blows up all balloons on the screen by focusing each, the balloons re-appear on the screen. Then, the user tries to focus on balloons again by using his/her eye movements.
Animation and Sound	On the screen, there is a magnifier to indicate the eye movements of the user. When magnifier comes on any balloon, the balloon highlights itself with a different border color. When the user focuses on the balloon for a certain time, it disappears with a clap sound. The score point starts with 0 in the beginning. After popping each balloon, the points on the scoreboard increase by 1 point.

Table 7. (continued)

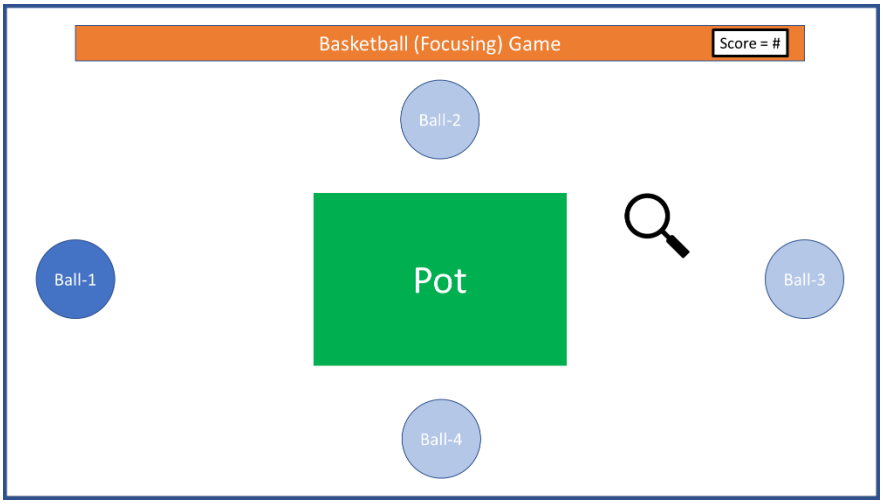
Scene 3: Basketball (Focusing) Game	
Scene	
Scenario	At the top of the screen, there is a header to indicate the name of the game. It disappears 10 seconds after starting the game, but the scoreboard remains on the screen. On the screen, there are four positions to move and indicated with Ball-1, Ball-2, Ball-3, and Ball-4. The ball appears on the screen in pre-determined positions respectively, and remains stable. The user can control the magnifier on the screen with his/her eye movements. The magnifier moves wherever the user looks. After looking on a ball for 1 second, the ball disappears and moves its next position. Then, the user focuses on the ball on the new position and so on. If the user cannot focus on the related ball in one minute, the ball moves to a new position.
Animation and Sound	On the screen, there is a magnifier to indicate the eye movements of the user. When magnifier comes on the ball, the ball highlights itself with a different border color. When the user focuses on the ball for a certain time, it disappears with clap sound. The score point starts with 0 in the beginning. After focusing on any ball and taking it to the center successfully, the points on the scoreboard increase by 1 point.

Table 7. (continued)

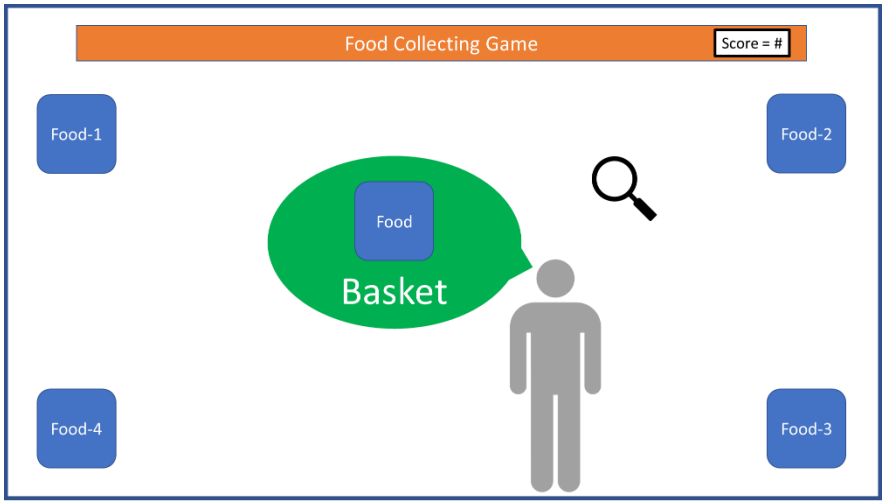
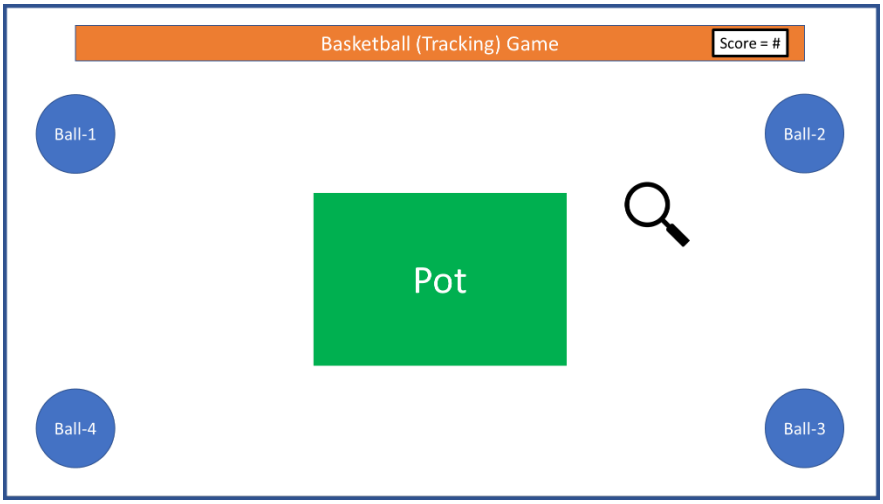
Scene 4: Food Collecting Game	
Scene	
Scenario	At the top of the screen, there is a header to indicate the name of the game. It disappears 10 seconds after starting the game, but the scoreboard remains on the screen. On the screen, there are four positions to show foods. The character imagines a food, and it appears in the basket at the center of the screen. Then, the user scans the environment to identify the matching food from the options, namely Food-1, Food-2, Food-3, and Food-4. After finding the same food from the options by scanning, the user needs to focus on the related food. After focusing on the food for 1 second, the food can be moved by using eye movements. Then, the user needs to take the food to the basket at the center of the screen with his/her eye movement. Then, the foods on the basket disappear, and another food request comes in the basket. If the user cannot take the related food to the center in one minute, another food request comes in the basket.
Animation and Sound	On the screen, there is a magnifier to indicate the eye movements of the user. When magnifier comes on food, the food highlights itself with a different border color. When the user focuses on the food for a certain time, it can be moved with eye movements. When the user takes it to the center by using eye movements, it disappears with a clap sound. The score point starts with 0 in the beginning. After moving each food to the center successfully, the points on the scoreboard increase by 1 point.

Table 7. (continued)

Scene 5: Basketball (Tracking) Game	
Scene	
Scenario	At the top of the screen, there is a header to indicate the name of the game. It disappears 10 seconds after starting the game, but the scoreboard remains on the screen. On the screen, there are four positions to show the ball. Then, the user scans the environment to choose a ball from the options, namely Ball-1, Ball-2, Ball-3, and Ball-4. After choosing a ball from the options, the user needs to focus on the ball. After focusing on the ball for 1 second, the ball can be moved by using eye movements. Then, the user needs to take the ball to the pot at the center of the screen with his/her eye movements. Then, the ball disappears, and the user can focus on another ball. After taking all four balls to the center, they re-appear on the screen. After that, the user repeats the tasks. If the user cannot take all of four balls to the center in one minute, the balls on the screen are refreshed.
Animation and Sound	On the screen, there is a magnifier to indicate the eye movements of the user. When magnifier comes on any of the balls on the screen, the ball highlights itself with a different border color. When the user focuses on the ball for a certain time, it can be moved with eye movements. When the user takes it to the center by using his/her eye movements, it disappears with clap sound. The score point starts with 0 in the beginning. After taking each ball to the center with success, the points on the scoreboard increase by 1 point.

4.1.2.3 Development of the First Prototype

Based on the storyboards, two games were developed for enhancing the scanning and focusing skills, and scanning and tracking skills of children with low vision. The first one was about scanning the screen to select the balloon and, and then focusing on it for a certain time to blow it up (see Figure 17).

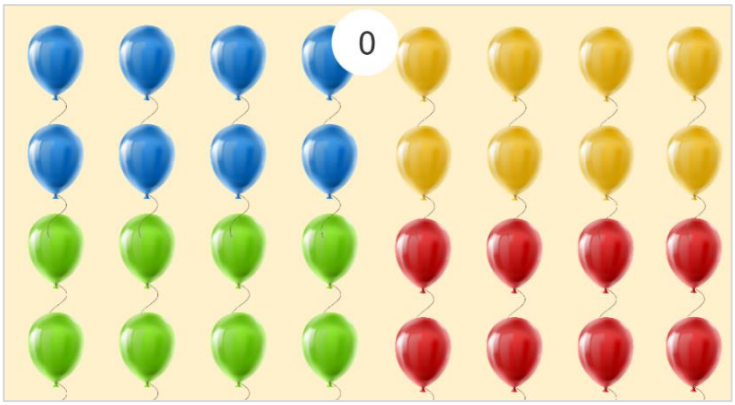


Figure 17. Screenshot of first prototype game for scanning-focusing skills

The second one was about playing basketball to make a score. It requires scanning the screen to select one of the balls, and then moving it with eye movements to the pot (see Figure 18).

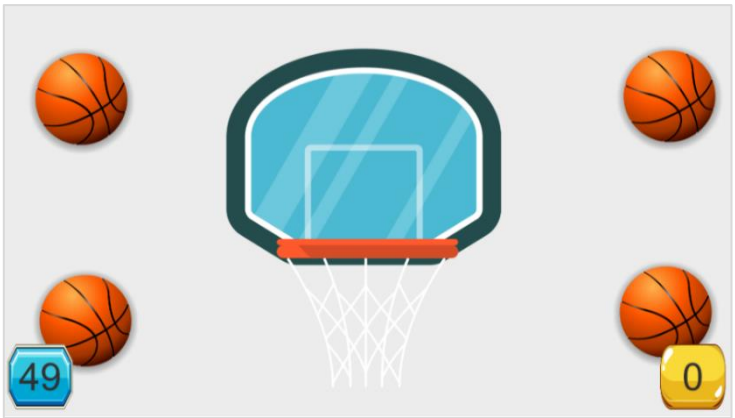


Figure 18. Screenshot of first prototype game for scanning-tracking skills

4.1.2.4 Formative Evaluation of the First Prototype

The formative evaluation was conducted with four teachers and four academicians after developing the first prototype. The teachers were from the school for visually impaired children, while academicians were from the department of visually impaired children's education. These interviews were conducted to get their ideas about the general design of the games, the problems to be considered in revising, and alternatives to improve the eye training program. Eight themes emerged from interviews of teachers and academicians. These themes are listed below:

- Visual Skills
- Opinions about General Design
- Opinions about Scanning and Focusing Game
- Opinions about Scanning and Tracking Game
- Number of Games
- Suggestions for Data Collection

These themes were explained below in detail.

Visual Skills: Two teachers and two academicians mentioned the appropriateness of the eye training program in terms of the target group and functional vision skills. They stated that it could be used for preschool kids and first and second graders with low vision to enhance their focusing and tracking skills. For instance, one of the teachers said:

> *I liked the eye training program. These games will improve focusing and tracking skills, and I think it could work especially well in preschool, 1st-grade, and 2nd-grade children. (TE1)*
>
> *Beğendim. Bu uygulamalar odaklanma ve izleme becerilerini geliştirir ve özellikle okul öncesinde, 1 ve 2. sınıftaki çocuklarda bence gayet işe yarayacaktır. (TE1)*

In addition, one of the academicians stated that eye training program could help children with low vision to improve their functional vision skills by saying:

I think the design of the games contains contents suitable for visual skills related to low vision. (ACA5)

Tasarımda az görme ile ilgili görsel becerilere uygun içerikler yer aldığını düşünüyorum. (ACA5)

Opinions about General Design: Four teachers and four academicians stated that the general design of the eye training program was appropriate for applying them to children with low vision.

I did not see any design-related problems. (ACA4)

Tasarımsal anlamda herhangi bir problem görmedim ben. (ACA4)

In addition, three teachers and one academician especially mentioned that the contrast, color selection, and simple design were the most important design considerations while developing a vision training program for children with low vision, and stated that the program complied with such considerations. For instance, one of the academicians said:

When I checked the overall design, the appropriateness of color contrast, activities, and game scenarios, I realized that the harmony of colors or simplicity and complexity in the games could appeal to the students with low vision. (ACA1)

Genel tasarımına baktığımız zaman, renk kontrast uyumu, etkinlik ve oyun bağlamında baktığımız zaman, onların içerisindeki renk uyumu veya basitlik karmaşıklık uyumunun bence yerinde olduğunu yani az gören öğrencilere hitap edeceğini düşünüyorum. (ACA1)

Besides, two of the academicians emphasized that highlighting the objects with different border colors while looking at them can provide a clue for children with low vision to understand the position of their eye movements. For instance, one of the academicians said:

The focused object gives you a signal with a different color as if you clicked an icon on it. Therefore, this also confirms with a visual stimulus that the person is focusing on the object. Pretty good. (ACA4)

Odaklanılan nesne farklı bir renk tonuyla böyle bir hani ikona basmışsınız gibi size bir sinyal veriyor. Dolayısıyla kişinin

odaklandığı nesneye odaklandığını aynı zamanda görsel bir uyaranla da ip ucuyla da onaylamış oluyor. Gayet güzel. (ACA4)

Design Principle: Based on the findings of visual feedback, the following design principle emerged: The eye training games should provide feedback with visual effects by engaging the eye fixations.

Moreover, one of the academicians stated that using sounds as feedback is essential to keep the attention of children with low vision on the game and to motivate them:

Using sound notifications is something that the student could like and keep his/her attention on the games. (ACA5)

Sesin olması öğrencinin hoşuna gidecek ve orada kalmasını sağlayacak şeyler. (ACA5)

Design Principle: Based on the findings of feedback with sound notifications, the following design principle emerged: The eye training games should provide feedback with sound notifications to urge users to scan objects on the screen.

Lastly, two teachers mentioned that it is important to provide customizable preferences for children with low vision while using the eye training program. They suggested that it could be useful to provide an option to select the source of eye movements at the beginning, like right eye, left eye, or both eyes. For instance, one of the teachers said:

I think individual preferences, like eye selection, should be added. (TE3)

Göz seçme özelliği yani kişiye özel şeylerin eklenebilmesi gerektiğini düşünüyorum. (TE3)

This feature is already included in the software of the eye-tracking device.

Design Principle: Based on the findings of customizable preferences, the following design principle emerged: The eye training games should provide a relative flexibility for users to select the best options based on their visual impairments.

Design Principle: In parallel to the design principle above, the following design principle also emerged: The eye training games should have configurable designs according to the preferences of users based on their visual impairments.

Opinions about Scanning and Focusing Game: Four teachers and four academicians emphasized that the scanning and focusing game was appropriate and useful for children with low vision to improve their vision skills. For instance, one of the academicians stated that this game would serve as a useful tool to enhance focusing skills of such children:

> *I like the games. It seems that you have developed games that could help improve children's focusing skills. I don't have any other suggestions for the development right now. (ACA1)*
>
> *Ben beğendim yani. Gerçekten baktığınız zaman odaklanmaya hizmet edecek uygulamalar geliştirilmiş. Bir değişiklik önerisi şu an gözükmüyor. (ACA1)*

In addition, one of the teachers mentioned that this game was also important in terms of helping children with low vision to use their head movements as well:

> *I think the games are appropriate for a child with low vision. The child can also learn how to use his/her head movements by using his/her visual field. (TE1)*
>
> *Uygun olduğunu düşünüyorum. Çocuk görme alanını kullanarak bu şekilde baş hareketlerini de kullanmayı öğrenebilir. (TE1)*

Opinions about Scanning and Tracking Game: Four teachers and four academicians mentioned that the scanning and tracking game was appropriate and useful for children with low vision to improve their vision skills. For instance, one teacher stated that this game would serve as a successful tool to enhance the tracking skills of such children:

> *I think the games are appropriate. I don't think of any change suggestions. I think the eye training program is sufficient for enhancing tracking skills. (TE1)*
>
> *Başarılı buldum. Değişiklik önerisi aklıma gelmiyor. İzleme becerileri için yeterli olacağını düşünüyorum. (TE1)*

Number of Games: Two teachers and two academicians especially emphasized that these games were useful to improve the functional vision of children with low vision, and they provided new scenario ideas for the development of further games. In addition, one of the teachers suggested that straight game scenarios could be applied to an eye training program for adults with low vision:

> *These games, for example, are generally for younger age groups. They can also be adapted for adults. (TE2)*
>
> *Oyunlar mesela genelde küçük yaş grubu için olmuş. Büyük yaşlar için odaklanma ve izleme olarak oyunlar da tasarlanabilir. (TE2)*

Suggestions for Data Collection: One of the teachers and two academicians expressed suggestions for this eye training program. They are listed below:

- There can be a need for environmental arrangements according to the preferences of children with low vision. These arrangements could be related to lighting of the room, sitting position in front of the computer, seating position in the room, and adjustment of the screen brightness.
- Using a larger screen may be an advantage for expanding the area of implementation and for children with low vision to see the objects better.

4.1.2.5 Development of the Second Prototype

There were storyboards for four games to develop the eye training program. Two of them, balloon popping and basketball (tracking) games, were developed as the first prototype of the eye training program. During the formative evaluation, they were found appropriate to be used in the vision training program. In addition, the result of the formative evaluation showed that it was necessary to develop more games for children with low vision. In parallel, the other two games, basketball (focusing) and food collecting games, were developed as the second prototype of the eye training program. Therefore, these four games were developed as the second prototype for enhancing scanning, focusing, and tracking skills of children with low vision. Two of them were about blowing up the balloons and making a score with the ball on the

screen by scanning the screen to select one of the balloons or balls, and then focusing on it for a certain time to blow up or make a score (see Figure 19).

Figure 19. Screenshots of the second prototype games for scanning-focusing skills

The other two games were about food collecting and playing basketball. The child needs to find the intended food by scanning the screen and then to move it to the center with his/her eye movements. In the basketball game, the child needs to scan the screen to select the ball and then to move it to the center with his/her eye movements to make a score (see Figure 20).

Figure 20. Screenshots of the second prototype games for scanning-tracking skills

4.1.2.6 Formative Evaluation of the Second Prototype

After developing the second prototype, another focus group meeting was conducted with three academicians from the field of low vision to obtain their ideas and suggestions about the developed games as the vision training program. In addition

to the focus group meeting, a pilot test was carried out with a child with low vision to test the games. The preliminary design suggestions and ideas emerged from the focus group meeting are listed below:

- The general design of the eye training program was approved by the academicians, and they stated it was appropriate to apply to children with low vision to improve their vision skills.
- The designs of the games were simple, and there were no distracting objects on the screen.
- The scenarios of the games were appropriate for children with low vision. The scenarios should be kept simple to follow easily.

Design Principle: Based on the finding of the game scenarios, the following design principle emerged: The eye training games should be easy to follow instead of containing complex scenarios to make it easier to fixate on objects and shorten the time to fixate on objects instead of creating a cognitive load.

- Scanning and focusing games were appropriate for children with low vision.
- Scanning and tracking games were appropriate for children with low vision.
- The focus duration on objects on the screen should be adjustable at the beginning of the games.

Design Principle: Based on the finding of the focus duration on objects, the following design principle emerged: The eye training games should have options to select the focusing duration on objects to complete focusing and tracking tasks.

- The size of an object on the screen should be configurable at the beginning of the games.

Design Principle: Based on the finding of the size of objects on the screen, the following design principle emerged: The eye training games should have options to change the size of the objects on the screen.

- The color of the background should be configurable at the beginning of the games.

Design Principle: Based on the finding of the background color, the following design principle emerged: The eye training games should include an option to change the color of the background from black to white.

Moreover, a pilot test was conducted in eight trials with a student from a school for visually impaired students. The trials were observed, and the actual usage of the participant was logged. The participant played each game for 5 minutes. The observations revealed that eye movements of the child with low vision had instantaneous jumps on the screen. In addition, the eyes of the child were moving and flickering more. Therefore, the magnifier moving with the eye movements could difficultly be fixated on the objects on the screen.

The findings from the observation checklist also showed that the child had difficulty in focusing on the right side of the screen and mostly focused on the bottom in the first five trials, while he/she was able to focus on all over the screen in the last three trials. Accordingly, it can be inferred that the focusing performance of the child showed a relative progress during the trials. In addition, the findings showed that the child started to move objects by using eye movements faster throughout the trials.

Besides, actual usage logs of the participant in the pilot test were presented in Table 8. The pilot test was performed in eight trials, and each trial lasted in 20 minutes, 5 minutes for each of four games. Findings showed that the maximum score in the balloon popping game was 26 while the minimum score was 13. In addition, the maximum score in the basketball (focusing) game was 54 while the minimum score was 15. Besides, the maximum score in the food collecting game was 25, while the minimum score was 11. Lastly, the maximum score in the basketball (tracking) game was 34, while the minimum score was 12.

Table 8. Game scores during the pilot test

# of Trial	The score in Balloon Popping Game in 5 mins	The score in Basketball (Focusing) Game in 5 mins	The score in Food Collecting Game in 5 mins	The score in Basketball (Tracking) Game in 5 mins
1st Trial	13	22	15	12
2nd Trial	22	15	20	20
3rd Trial	17	21	19	15
4th Trial	25	36	25	24
5th Trial	19	28	11	22
6th Trial	24	20	15	24
7th Trial	26	54	22	34
8th Trial	22	17	11	14

Based on the pilot test data, two design suggestions were uttered for the games in the vision training program. The first suggestion was about the magnifier, which moves with eye movements. The sensitivity of the magnifier should be reduced to make it move slower on the screen because it is necessary to soften the jumps of instantaneous eye movements of children with low vision. The second suggestion was about the area of the object on the screen. There was a need for enlarging the area of the object to be detected easily by the user using the magnifier.

To sum up, the findings showed that the scores of the participant showed a relative incremental pattern in all the games. In addition, the duration and order of the games were appropriate for children with low vision. Therefore, the implementation environment and procedures used in the pilot test were confirmed for children with low vision

4.1.2.7 Development of the Final Product of the Eye Training Program

The necessary revisions were made to reach the final product of the vision training program for children with low vision. There were four suggestions obtained during the formative evaluation of the second prototype and applied to all finalized games.

- The duration of focusing to make the objects disappeared or moved on the screen should be configurable at the beginning of games (see Figure 21). Therefore, it was set to between zero and three seconds. Zero second means that the user actualizes the task with immediate eye fixation on the object. At the same time, three seconds means that the user actualizes the task 3 seconds after keeping eye movements on the object.

Figure 21. Sample screenshot of focusing duration configuration

- The configuration option should be added for the size of the objects (see Figure 22). Therefore, the objects were set to be configurable to three sizes, namely, size-one, size-two, and size-three in all the games. These sizes were decided according to the screen size. In parallel, the number of objects on the screen were reduced in just the balloon popping game.

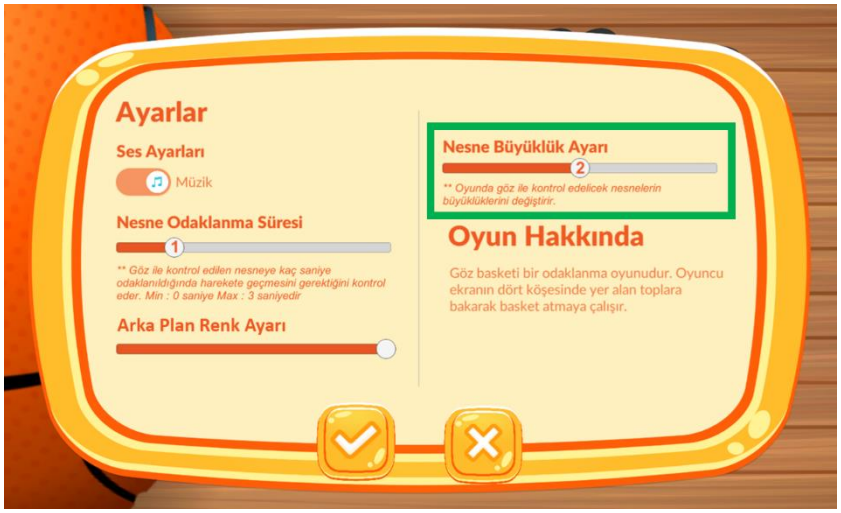


Figure 22. Sample screenshot of object size configuration

- The color of the background should be configurable at the beginning of the games (see Figure 23). Accordingly, the setting was configured to change background color from black to white to provide better eyesight for children with low vision according to their preferences.

Figure 23. Sample screenshot of background color darkness configuration

- The sensitivity of the magnifier should be reduced to soften the jumps of instantaneous eye movements of children with low vision. Hence, it was

configured to cache recent eye movement data and to average eye movements. Then, the magnifier on the screen was configured to move according to this average eye movement data.

- The area of the object scanned by the magnifier was increased by using an invisible frame, which is 25 percent larger than the objects, and this frame was taken into consideration while focusing and tracking them.

4.1.2.8 Design Principles

The design principles for designing and developing the eye training program for children with low vision were listed based on the findings. In addition, the finalized, refined, and categorized version of these design principles were presented under the documentation and reflection phase of this study. The design principles that emerged to the end of the development phase were given following the related findings, and they were listed below.

- The eye training games should provide a relative flexibility for users to select the best options based on their visual impairments.
- The eye training games should have configurable designs according to the preferences of users based on their visual impairments.
- The eye training games should be designed based on the eye exercise needs of the target group, such as focusing on objects, controlling eye movements (scanning and tracking), visual acuity, visual field (central and peripheral vision), color discrimination, contrast sensitivity, and light sensitivity.
- The games should be categorized in the eye training program in terms of their improvements on vision skills such as scanning-focusing games, and scanning-tracking games.
- In the eye training program, the games should be listed for the user in terms of their difficulty levels, from easy to hard by considering their visual impairments and visual acuity.

- The eye training games should be easy to follow instead of containing complex scenarios to make it easier to fixate on objects and shorten the time to fixate on objects instead of creating a cognitive load.
- The eye training games should have a very simple design without any distracting objects by keeping the objects to be fixated with eye movements in the foreground.
- Each eye training game should include difficulty levels, such as easy, medium, and hard by considering visual acuity.
- The eye training games should be designed according to the flow theory to provide challenge and immersive experience to users and encourage them to use their eye movements more.
- The eye training games should include an option to change the color of the background from black to white.
- The eye training games should have options to select the focusing duration on objects to complete focusing and tracking tasks.
- The eye training games should have options to change the size of the objects on the screen.
- The eye training games should have an indicator, like a magnifier, to show eye movements of users.
- The eye training games should provide feedback with visual effects by engaging the eye fixations.
- The eye training games should provide feedback with sound notifications to urge users to scan objects on the screen.
- In the eye training games, users should be able to see their scores.
- The eye training games should save the eye preferences of users and apply previous preferences automatically to next plays.

4.1.3 Evaluation and Testing Phase

The summative evaluation was conducted with children with low vision, their parents, ophthalmologists, and academicians to finalize design principles emerging at the end of the development phase.

4.1.3.1 Summative Evaluation of Eye Training Program with Children with Low Vision

There were 36 children with low vision during the summative evaluation of the vision training program. Usage logs of children with low vision and observation checklist were used to collect the data. Firstly, the usage of children was logged during the data collection. Each participant played each game for five minutes, and their scores were noted. The scores of the participants in the games were shown in Table 9. 9 of 36 children with low vision could not complete the all the four games while 27 of 36 children could complete all of four games.

Table 9. Actual usage logs of children with low vision

No	Visual Acuity of the Better Eye (%)	Completed All of The Games	The score in Balloon Popping Game	The score in Basketball (Focusing) Game	The score in Food Collecting Game	The score in Basketball (Tracking) Game
CH01	20	Yes	169	92	29	66
CH02	60	Yes	156	55	31	75
CH03	16	Yes	39	35	6	10
CH04	5	Yes	32	16	6	1
CH05	16	Yes	57	27	11	5
CH06	5	Yes	10	1	5	3
CH07	2	No	5	-	-	-
CH08	10	No	2	-	-	-
CH09	5	Yes	30	54	8	19
CH10	16	Yes	36	40	4	13
CH11	5	No	2	-	-	-

Table 9. (continued)

No	Visual Acuity of the Better Eye (%)	Completed All of The Games	The score in Balloon Popping Game	The score in Basketball (Focusing) Game	The score in Food Collecting Game	The score in Basketball (Tracking) Game
CH12	5	Yes	21	0	1	0
CH13	5	Yes	23	4	0	1
CH14	10	Yes	124	68	29	58
CH15	10	Yes	12	9	5	3
CH16	5	Yes	81	59	30	68
CH17	5	No	4	-	-	-
CH18	1	No	0	-	-	-
CH19	16	Yes	144	90	26	24
CH20	20	No	2	-	-	-
CH21	5	No	0	-	-	-
CH22	5	Yes	51	38	11	18
CH23	10	Yes	108	41	15	22
CH24	5	Yes	108	65	19	32
CH25	30	Yes	34	57	20	26
CH26	40	Yes	85	64	26	32
CH27	5	No	2	-	-	-
CH28	20	Yes	24	63	20	36
CH29	60	No	8	2	-	-
CH30	16	Yes	6	45	8	4
CH31	10	Yes	42	62	25	18
CH32	30	Yes	19	38	8	7
CH33	10	Yes	21	22	0	4
CH34	60	Yes	101	64	16	12
CH35	60	Yes	45	77	7	24
CH36	30	Yes	138	66	17	35

According to Table 9, two children with low vision who had visual acuity smaller than 5 percent in the better eye could not complete all the games while 8 of 12 children with 5 percent visual acuity could play the games. In addition, 10 of 11

children with visual acuity higher and equal to 10 percent and smaller than 20 percent could play the games, and 9 of 11 children with visual acuity higher and equal to 20 percent could play the games. Therefore, it was concluded that children with low vision with visual acuity between 5 and 10 percent required to try to use eye-tracker-based eye training program while children with visual acuity higher than 10 percent were high possibly to complete eye-tracker-based eye training program.

Based on the actual usage logs of children with low vision, it was obvious that their scores in the games were parallel to each other, as seen in Figure 24. In other words, the participants' scores in balloon popping game had a similar pattern with other game scores. These findings showed that the game achievement rates of participants were consistent; even the difficulty levels were different among the games.

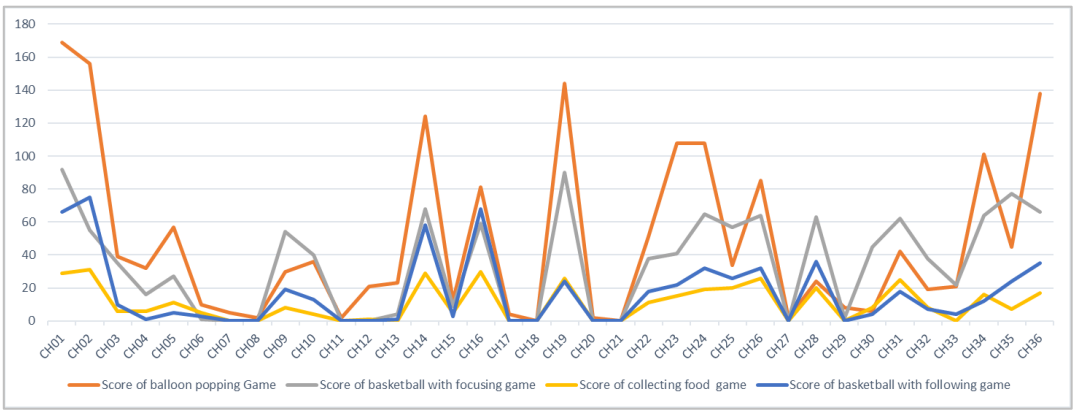


Figure 24. The game scores of children with low vision

Moreover, the observation method was used to collect data while children with low vision using the vision training program. Accordingly, the observation form created for this study (see Appendix F) was used to identify their eye movements. This observation form consists of four main sections related to each game in the final product of the eye training program. These sections are used to check whether each task is completed. The list of the tasks was presented below (see Table 10).

Table 10. Observation checklist for the games

Eye Game	Tasks
Balloon Popping Game	1. The participant could play the balloon popping game. 2. The participant could pop up balloons in the upper left area. 3. The participant could pop up balloons in the upper right area. 4. The participant could pop up balloons at the bottom left area. 5. The participant could pop up balloons at the bottom right area.
Basketball (Focusing) Game	1. The participant could play the basketball (focusing) game. 2. The participant could score a basket with the ball on the left. 3. The participant could score a basket with the ball on the top. 4. The participant could score a basket with the ball on the right. 5. The participant could score a basket with the ball on the bottom.
Food Collecting Game	1. The participant could play the food collecting game. 2. The participant could move foods from the upper left to the center. 3. The participant could move foods from the upper right to the center. 4. The participant could move foods from the bottom left to the center. 5. The participant could move foods from the bottom right to the center.
Basketball (Tracking) Game	1. The participant could play the basketball (tracking) game. 2. The participant could move the ball from the upper left to the center. 3. The participant could move the ball from the upper right to the center. 4. The participant could move the ball from the bottom left to the center. 5. The participant could move the ball from the bottom right to the center.

During the data collection, the tasks listed on the observation form were filled for 36 children. Seventy-five percent (27 of 36) of children with low vision could play the

balloon popping game and continued with the other three games. The findings of the balloon popping game were presented in Table 11. Seventy-two percent of children could pop up the balloons at the upper area (both upper left and upper right areas) of the screen. In addition, 69 percent of children could pop up the balloons at the bottom left area while 67 percent of children could pop up the balloons at the bottom left area.

Table 11. Observation checklist for the balloon popping game

Tasks	# of Children (%)
1. The participant could play the balloon popping game.	75%
2. The participant could pop up balloons in the upper left area.	72%
3. The participant could pop up balloons in the upper right area.	72%
4. The participant could pop up balloons at the bottom left area.	69%
5. The participant could pop up balloons at the bottom right area.	67%

The findings of the basketball (focusing) game were presented in Table 12. Seventy-two percent of children could play the game and score a basket with the ball on the left of the screen. In addition, sixty-nine percent of children could pop up the balloons at the bottom left area while sixty-seven percent of children could score a basket with the ball on the top, right, and bottom of the screen.

Table 12. Observation checklist for the basketball (focusing) game

Tasks	# of Children (%)
1. The participant could play the basketball (focusing) game.	72%
2. The participant could score a basket with the ball on the left.	72%
3. The participant could score a basket with the ball on the top.	69%
4. The participant could score a basket with the ball on the right.	69%
5. The participant could score a basket with the ball on the bottom.	69%

Table 13 presents the findings of the food collecting game. Sixty-nine percent of children could play the game. Fifty-three percent of children could move foods from the upper left to the center, while sixty-one percent of children could move foods from the upper right to the center. Besides, fifty-six percent of children could move foods from bottom left to the center, while sixty-seven percent of children could move foods from bottom right to the center.

Table 13. Observation checklist for the food collecting game

Tasks	# of Children (%)
1. The participant could play the food collecting game.	69%
2. The participant could move foods from the upper left to the center.	53%
3. The participant could move foods from the upper right to the center.	61%
4. The participant could move foods from the bottom left to the center.	56%
5. The participant could move foods from the bottom right to the center.	67%

Table 14 shows the findings of the basketball (tracking) game. Seventy-two percent of children could play the game. Sixty-four percent of children could move the ball

from left (both upper and bottom) to the center while fifty-eight percent of children could move the ball from right (both upper and bottom) to the center.

Table 14. Observation checklist for the basketball (tracking) game

Tasks	# of Children (%)
1. The participant could play the basketball (tracking) game.	72%
2. The participant could move the ball from the upper left to the center.	64%
3. The participant could move the ball from the upper right to the center.	58%
4. The participant could move the ball from the bottom left to the center.	64%
5. The participant could move the ball from the bottom right to the center.	58%

The observation notes highlighted that the participating children had similar completion rates for movement directions or focusing on corners in the games. Therefore, it showed that children with low vision could use different directions in the eye training games. Besides, there were several suggestions to the games as future enhancements. These suggestions are listed below:

- The eye training games can be developed as to enhance color discrimination skills.

Design Principle: Based on this suggestion, the design principle on the categorization of the games in terms of vision skills was revised as following: The games should be categorized in the eye training program in terms of target vision skills, such as scanning-focusing games, scanning-tracking games, and color discrimination games.

- There can be an option in the games to select the eye to do eye exercises.

Design Principle: Based on the suggestion, the following design principle emerged: Each eye training game should have an option to choose the relevant eye to do exercises, such as the left eye, right eye, or both eyes, at the beginning.

- There can be more options to change the color of the background.

Design Principle: Based on this finding, the design principle about the background color was revised as follows: The eye training games should include an option to change the color of the background from a color palette and its darkness to ensure color contrast and make color discrimination easier by considering the visual impairments of users.

- There can be an option to select colors of foreground objects.

Design Principle: Based on the findings, the following design principle emerged: The eye training games should include an option to change the color of the objects to be fixated, such as primary colors to create contrast based on their visual impairments.

Design Principle: In parallel with the design principles about color selection above, the following design principle also emerged: The eye training games should offer appropriate color contrast between foreground and background colors to increase the visibility of the objects.

- There can be an option to change and limit the game duration.

Design Principle: Based on the suggestion, the following design principle emerged: The eye training games should have options to select the game duration from 5 minutes to 10 minutes in specific intervals to determine optimum rehabilitation duration by considering the visual impairments of users.

- There can be an option to change the sensitivity of the eye movement shown on the screen.

Design Principle: Based on the suggestion, the following design principle emerged: The eye training games should have options to select the sensitivity of the eye movements shown on the screen, such as soft, normal, and hard.

- There can be verbal explanations at the beginning of each game.

Design Principle: Based on the suggestion, the following design principle emerged: The eye training games should have verbal explanations at the beginning for children about required eye movements to complete the games.

- There can be an option to change the indicator, which shows the eye movements of users.

Design Principle: Based on this suggestion, the design principle about the indicator to track eye movements on the screen was revised as follows: The eye training games should have options to select an indicator which shows eye movements of users, like a magnifier.

- There can be an option to create a collection of games that are prescribed to the child.

Design Principle: Based on the suggestion, the following design principle emerged: The eye training games should have an option to create a collection of games that are prescribed to the child with low vision.

- There can be an option to create a user account in the eye training games to save users' data, such as their game scores.

Design Principle: Based on this suggestion, the design principle about showing scores on the screen was revised as follows: The eye training games should inform the users about their scores to increase their motivation to keep them active in the training program and save these scores with a timestamp to follow their rehabilitation processes.

Design Principle: In parallel with the design principle above, the following design principle also emerged: The eye training program should have an option to customize

preferences by enabling users to create an account to track their rehabilitation processes.

Design Principle: Based on these design principles about creating user accounts, the design principle about applying previous preferences was revised as follows: The eye training games should apply previous preferences, such as preferred eye/s or color selection, automatically from account history to resume the rehabilitation.

Design Principle: In parallel with the design principle above, the following design principle also emerged: The eye training games should save the eye preferences of users, such as the left, right, and both eyes, in their accounts.

4.1.3.2 Summative Evaluation of Eye Training Program with Parents

After collecting data from the children with low vision, their parents were interviewed to get data about their experience. The mean age of the parents was 38. 23 of them were female, while 13 of them were male. 22 of 23 mothers were white-collar employees, and one of 23 mothers was a blue-collar employee. In addition, 9 of 13 fathers were blue-collar employees, 3 of them were white-collar employees, and one of 13 fathers was retired. Besides, 16 of 36 parents were primary school graduates, 8 of them were secondary school graduates, 6 were high school graduates, 2 held an associate degree, and 4 held an undergraduate degree.

During the interviews, 13 of 36 parents stated that their children were doing eye training exercises. In contrast, 23 of them indicated that their children did not do any eye training exercises. 6 of 13 parents who participated in vision training stated that they were showing objects and asking their children to focus on and track them. Moreover, 3 of them explained that their children were using low vision devices, such as telescopic lenses, to watch objects and eyeball sphere to read something. In addition, one of the parents stated that they were doing painting and playing football. Besides, the other three of them explained that they were doing various kinds of focusing, finding, and tracking exercises. Lastly, 8 of 13 parents whose children were

doing eye training exercises stated that they used to accompany their children during exercises while 2 of them explained that their children were doing eye training exercises at school. 2 of them also stated that their children were doing eye exercise on their own while one of them stated that they sometimes accompanied the child during the eye training.

During the interviews, parents were asked to share their opinions about the eye-tracking technology as a tool for providing children with low vision to improve their vision skills. 15 of 36 parents stated that this eye training program could be helpful for enhancing the functional vision skills of their children. The other 15 expressed that it seemed a nice application to use as an eye training tool for their children, while 6 of them explained that they remained undecided about the usage of this eye training program before trying at home. Lastly, parents were asked whether this eye training program was useful to apply at home. 32 of 36 parents stated that they could easily use this program at home to provide eye training to their children, while one of them indicated that they could not apply for this program at home. The last three of them were neutral about whether they could use it at home.

To sum up, the findings showed that most of the parents did not use to apply any kind of eye training exercises for their children to improve their vision skills, but they were willing to use technology-enhanced eye training exercises for their children at home. In addition, they found the eye tracking-based eye training program helpful for their children to do eye exercise for enhancing their vision skills.

4.1.3.3 Summative Evaluation of Eye Training Program with Ophthalmologists and Academicians

Interviews were conducted with four ophthalmologists and four academicians to understand their evaluations about the usage of eye-tracking technology as a vision training program for children with low vision. Three themes emerged from their evaluations:

- General Opinions about the Eye Training Program
- Opinions about the Games
- Design Suggestions

These themes were explained below in detail.

General Opinions about Eye Training Program: All four ophthalmologists stated that the eye training program to be applied to children with low vision was appropriate for them to improve their vision. For instance, one of them said:

> *I liked the games. I mean, I think that they could be useful for children. (OPH2)*
>
> *Beğendim. Yani çocuklar için faydalı olabileceğini düşünüyorum. (OPH2)*

In addition, all four academicians explained that this eye training program could be useful and effective for children with low vision to enhance their functional vision skills, such as scanning, focusing, and tracking.

> *The general designs and scenarios of the games are appropriate for the students with low vision to enhance focusing and tracking skills. I really like them. (ACA4)*
>
> *Genel tasarımı az gören öğrencilerin odaklanma ve izleme becerilerine yönelik bir tasarım, kurgu olmuş. Gayet de hoşuma gitti. (ACA4)*

Opinions about the Games: All four ophthalmologists and all four academicians emphasized their positive opinions about the appropriateness of all games. For instance, one of the academicians said:

> *The games are appropriate for focusing and tracking skills. (ACA4)*
>
> *Uygundur. Evet, odaklanma ve izlemeyi kapsamaktadır. (ACA4)*

Design Suggestions: All four ophthalmologists and all four academicians did not utter any suggestions as improvements for the final version of the eye training program.

In addition, two of four ophthalmologists and the academicians emphasized that the number of eye training games should be increased, and their scenarios should be diversified.

Besides, one of four ophthalmologists suggested that eye training program should also be oriented to improve eye tremors.

As a result, the ophthalmologists and academicians agreed that the eye training program developed for children with low vision was appropriate to enhance their functional vision skills, especially scanning, focusing, and tracking skills. In addition, most of the ophthalmologists and academicians suggested that more games with various kinds of scenarios should be developed within the eye training program.

4.2 Documentation and Reflection Phase

Documentation and reflections were presented at this phase of the study. Design principles were refined and finalized using the data collected during the evaluation and testing phase.

4.2.1 Refining Design Principles

The design principles that emerged during the iterations of the development phase were revised and finalized according to the data collected during analysis, development, and evaluation and testing phases. After that, these design principles were categorized under related themes, namely design principles for eye training games in special education, visual design principles for eye-tracking-based training in special education, and content design principles for eye-tracking-based training in special education. These design principles are presented below.

4.2.1.1 Design Principles for Eye Training Games in Special Education

- The eye training games should have verbal explanations at the beginning for children about required eye movements to complete the games.
- The eye training games should provide feedback with visual effects by engaging the eye fixations.
- The eye training games should provide feedback with sound notifications to urge users to scan objects on the screen.
- The eye training games should be designed according to the flow theory to provide challenge and immersive experience to users and encourage them to use their eye movements more.
- The eye training games should inform the users about their scores to increase their motivation to keep them active in the training program and save these scores with a timestamp to follow their rehabilitation processes.
- The eye training program should have an option to customize preferences by enabling users to create an account to track their rehabilitation processes.
- The eye training games should save the eye preferences of users, such as the left, right, and both eyes, in their accounts.
- The eye training games should apply previous preferences, such as preferred eye/s or color selection, automatically from account history to resume the rehabilitation.

4.2.1.2 Visual Design Principles for Eye-tracking-based Training in Special Education

- The eye training games should have a very simple design without any distracting objects by keeping the objects to be fixated with eye movements in the foreground.
- The eye training games should have configurable designs according to the preferences of users based on their visual impairments.

- The eye training games should be designed based on the eye exercise needs of the target group, such as focusing on objects, controlling eye movements (scanning and tracking), visual acuity, visual field (central and peripheral vision), color discrimination, contrast sensitivity, and light sensitivity.
- In the eye training program, the games should be listed for the user in terms of their difficulty levels, from easy to hard by considering their visual impairments and visual acuity.
- The eye training games should offer appropriate color contrast between foreground and background colors to increase the visibility of the objects.
- The eye training games should include an option to change the color of the background from a color palette and its darkness to ensure color contrast and make color discrimination easier by considering the visual impairments of users.
- The eye training games should include an option to change the color of the objects to be fixated, such as primary colors to create contrast based on their visual impairments.

4.2.1.3 Content Design Principles for Eye-tracking-based Training in Special Education

- The eye training games should provide a relative flexibility for users to select the best options based on their visual impairments.
- Each eye training game should include difficulty levels, such as easy, medium, and hard by considering visual acuity.
- The eye training games should have an option to create a collection of games that are prescribed to the child with low vision.
- The eye training games should be easy to follow instead of containing complex scenarios to make it easier to fixate on objects and shorten the time to fixate on objects instead of creating a cognitive load.

- The eye training games should have options to select the game duration from 5 minutes to 10 minutes in specific intervals to determine optimum rehabilitation duration by considering the visual impairments of users.
- The games should be categorized in the eye training program in terms of target vision skills, such as scanning-focusing games, scanning-tracking games, and color discrimination games.
- Each eye training game should have an option to choose the relevant eye to do exercises, such as the left eye, right eye, or both eyes, at the beginning.
- The eye training games should have options to select the focusing duration on objects to complete focusing and tracking tasks.
- The eye training games should have options to select the sensitivity of the eye movements shown on the screen, such as soft, normal, and hard.
- The eye training games should have options to select an indicator which shows eye movements of users, like a magnifier.

CHAPTER 5

DISCUSSION AND CONCLUSION

This chapter presents the discussion and conclusion of this study under six main headings: design principles for eye training games, practical implications for instructional designers, practical implications for special education teachers and practitioners, conclusion, recommendations for future research, and limitations of the study.

5.1 Design Principles for Eye Training Games

There are several design principles to follow while developing games for children. However, the game design in the field of special education requires various considerations, such as individual differences, characteristics, and needs of children. Therefore, it can be required to follow situation-specific design principles to design and develop appropriate games for children's levels, especially in the field of vision. While designing computer-based games for children with visual impairments, deciding and choosing design principles to follow become more important because of their reduced vision. Thus, the design principles emerging during this study are discussed based on the themes of design principles for eye training games in special education, visual design principles for eye-tracking-based training in special education, and content design principles for eye-tracking-based training in special education. Such a categorization is to present emerged design principles from general game design principles to specific eye-tracking interaction principles.

5.1.1 Design Principles for Eye Training Games in Special Education

The designs for eye training games are somehow different than usual game designs because of their target group, which is children with visual impairments, especially with vision loss. Therefore, it is important to provide a chance for such children with games as eye training. In the study, eight game design principles emerged, and they are listed below:

The first design principle of eye training games in special education is: *The eye training games should have verbal explanations at the beginning for children about required eye movements to complete the games.* Games generally include written or verbal explanations at the beginning to inform users about the gameplay. For eye training games, it is important to provide verbal explanations instead of written explanations because of the limited eyesight of the target group. Even they have little vision to be able to recognize objects or people, some of them can have better eyesight than just recognizing. Still, it can be hard for them to understand and follow written warnings and information messages. In the literature, it is suggested to provide verbal explanations auditorily instead of merely showing the texts, which creates better learning (Ioannou, Rodiou, & Iliou, 2017; Moreno & Mayer, 1999). Therefore, clear and easy to understand verbal guidance should be provided for children with low vision instead of only on-screen texts.

The second design principle is: *The eye training games should provide feedback with visual effects by engaging the eye fixations.* The visual effects are already a common feedback type in game designs. Besides, the purpose of using visual feedback is quite different for eye training games. It is to enable users to do eye exercises by scanning the screen to see the visual feedback and focus on it. This principle is essential as it is capable of practicing eye training while even using visual feedback. Therefore, this principle is to improve the vision of children with low vision without confusing them with complex visual feedbacks by considering the variance in the visual acuity of their better eye as seen in Table 9. Similar to this design principle, Mihelj et al.

(2012) state that it is important to use simple to follow visual feedbacks without distracting users in rehabilitation games.

The third design principle is: *The eye training games should provide feedback with sound notifications to urge users to scan objects on the screen.* The sound notifications are also a common type of feedback in game designs. Using sounds to notify users about their progress in the games, such as their success in focusing, in addition to visual effects as feedback can provide a clue and trigger for the children to scan the screen for visual feedback. Therefore, using sounds to notify children with visual impairments can increase the effect of the feedback positively (Muhammad, Thoo, & Masra, 2012). In parallel to this principle, Neto, Fontoura, Bordini, Otsuka, and Beder (2019) point out that providing sound feedback is necessary for educational games for children with visual impairments.

The fourth design principle is: *The eye training games should be designed according to the flow theory to provide challenge and immersive experience to users and encourage them to use their eye movements more.* The flow theory is about keeping the user in the game by offering them a challenge that is appropriate for them with optimal experience (Inal & Cagiltay, 2007; Kiili, 2005; Wang & Chen, 2010). According to flow theory, the game design should be as easy as to keep the users in the game and hard enough to bring them to achievement. For eye training games, the situation is somehow different, because it is important to keep the users in the game for regular and continuous eye exercises without an interruption. Therefore, it is vital to consider this design principle while offering challenge and immersive experience for children with low vision to allow them to do successful eye training. Similar to this design principle, Seitamaa-Hakkarainen, Laamanen, Viitala, and Mäkelä (2013) state that using a flow in the educational material design provides peak experience by involving users in the challenge. In addition, Ke and Abras (2013) suggest that it is important to apply appropriate challenges to maintain the engagement of users with special learning needs. Besides, Torres-Carazo, Rodriguez-Fortiz, and Hurtado (2016) state that games for children with visual impairments should include a challenge in addition to rehabilitation and educational purposes.

The fifth design principle is: *The eye training games should inform the users about their scores to increase their motivation to keep them active in the training program and save these scores with a timestamp to follow their rehabilitation processes.* The scoreboard is one of the most necessary components of a game design to see the achievements. Biehle and Jeffres (2018) suggest using scores as a part of gamification while assessing the games for children. In addition, the applying a scoring system increases children's engagement in the games (Mohd Syah, Hamzaid, Murphy, & Lim, 2016; Schwartz & Bayliss, 2011). For eye training games, it is also important to track the rehabilitation process of children with low vision. The inferences about the enhancements in their vision and the progress of the rehabilitation can be made by using the data on the scoreboard in eye training games. Thus, this principle is deemed to be essential in eye training games to understand children's improvements in terms of vision skills. In parallel to this principle, Janarthanan, Assad-Uz-Zaman, Rahman, McGonigle, and Wang (2020) designed and developed rehabilitation games for disabled users, displayed the scores in the game during the rehabilitation, and recorded them for further access by therapists.

The sixth design principle is: *The eye training program should have an option to customize preferences by enabling users to create an account to track their rehabilitation processes.* Similar to general game design principles for children to track their progress (De La Guía, Lozano, & Penichet, 2015), it is vital to provide an option to create an account for each user to keep their data, such as demographics and game scores, during their experience in the eye training games. It is necessary to monitor the development of children with low vision and to evaluate their progresses over time. Unlike the user accounts in usual games, the purpose of creating an account in eye training games is to ensure a data flow to their ophthalmologists or practitioners rather than the users themselves. Based on these data, the rehabilitation process can be directed by experts to enhance the vision of children with low vision.

The seventh design principle is: *The eye training games should save the eye preferences of users, such as the left, right, and both eyes, in their accounts.* In addition to demographics and game scores of the users, the preferences and habits of

the users are able to save during their experience in eye training games (Manero, Torrente, Fernandez-Vara, & Fernandez-Manjon, 2017). The purpose of keeping these preferences, compared to general game designs, is that they can allow inferences about both their current vision and progress in their vision. Therefore, this principle is vital to understand the eyesight and the best eye preferences for children with low vision.

The eighth design principle is: *The eye training games should apply previous preferences, such as preferred eye/s or color selection, automatically from account history to resume the rehabilitation.* In general game designs, it is essential to offer appropriate preferences to provide a better game experience (Wang & Chen, 2010). In addition, it is necessary to enable users to resume the game from the point at their previous gameplay. It can be adapted to eye training games as applying previous preferences because the preferences, such as eye preference or color selection, should be considered and kept until the users' progress in the game and change the preferences intentionally. Therefore, this principle is important to ease the usage of eye training games for children with low vision.

5.1.2 Visual Design Principles for Eye-tracking-based Training in Special Education

The visual design principles for eye training games are quite different than of usual game design because of its target field, namely special education. Therefore, it is important to consider the special needs of users as possible. In the study, seven visual design principles emerged for eye-tracking-based training in special education for children with low vision, and they are listed below:

The first design principle of visual design principles for eye-tracking-based training in special education is: *The eye training games should have a very simple design without any distracting objects by keeping the objects to be fixated with eye movements in the foreground.* While designing and developing games in the scope

of special education, it can be essential to keep the game environment as simple as possible to keep the attention of the children within the purpose of the game. For eye training games, it is also important to use simple design not to direct the focus of children with low vision to the visual design on the background. Instead, it is necessary to direct their eye movements to the core object on the screen. Therefore, this principle is as important as to be considered while designing eye training games for children with low vision. Similar to this design principle, Ke and Abras (2013) state that it is important to keep the design of the games simple to increase the engagement of children with special learning needs.

The second design principle is: *The eye training games should have configurable designs according to the preferences of users based on their visual impairments*. Individual differences, such as medical diagnosis, left and right eye visual acuity (as seen in Table 4), can be important to consider during design and development of games in special education. Similar to this principle, Ward and McCormick (1981) state that individualized designs for students with low vision offer more flexibility; thus, they are essential to maintain their attention into the activity.

In parallel to the design principle above, the third design principle is: *The eye training games should be designed based on the eye exercise needs of the target group, such as focusing on objects, controlling eye movements (scanning and tracking), visual acuity, visual field (central and peripheral vision), color discrimination, contrast sensitivity, and light sensitivity*. It can be essential to consider the needs of the target group during the design and development of the games. Similar to these design principles, Matas, Santos, Hernández-del-Olmo, and Gaudioso (2017) point out the importance of adaptable designs, which can be set according to the characteristics of a child with visual impairments.

The fourth design principle is: *In the eye training program, the games should be listed for the user in terms of their difficulty levels, from easy to hard by considering their visual impairments and visual acuity.* According to the flow theory, it seems similar to the design principle about the preferences of users while beginning a new

task with a low set of skills (Sharek & Wiebe, 2011). In addition, the difficulty level should be manageable by users to increase their success in the game. Therefore, this principle should also be taken into consideration because of its importance to motivate children with special needs.

The fifth design principle is: *The eye training games should offer appropriate color contrast between foreground and background colors to increase the visibility of the objects.* The color contrast is essential for users with visual impairments to increase the visibility of objects (Ganesh et al., 2013; McCabe et al., 2000; Palmer, 1997; Tsai et al., 2013). Therefore, this principle is important to increase the color contrast between the objects on which users will focus by using their eye movements and the background of the screen.

In parallel to the design principle above, the sixth design principle is: *The eye training games should include an option to change the color of the background from a color palette and its darkness to ensure color contrast and make color discrimination easier by considering the visual impairments of users.* Based on the special needs of children, games can be designed as to offer as many preferences as possible. Therefore, it can be important to leave the decision about the background color to the users. Similar to this design principle, Tolentino, Savvides, and Birchfield (2010) point out the importance of applying a design principle about individual customization in special education, like changing background color of the game.

In parallel to the design principle above, the seventh design principle is: *The eye training games should include an option to change the color of the objects to be fixated, such as primary colors to create contrast based on their visual impairments.* Following the background color preferences, users can change the foreground color. Especially in the field of low vision, this principle is deemed to be important to apply for the game design because children with low vision can have color preferences based on their medical histories, such as reduced visual acuity and lack of color vision. Similar to these design principles, Dickinson, Trillo, and Gridley (2017)

indicate that low vision applications for users with low vision should offer color selection to allow a contrast between foreground and background.

5.1.3 Content Design Principles for Eye-tracking-based Training in Special Education

The content design principles for eye-tracking-based training games bear some considerations because of its target field, namely special education. It is important to consider both the special needs of users and the capability of eye-tracking technology while deciding on the content. Accordingly, in the study, seven visual design principles emerged for eye-tracking-based training in special education for children with low vision, and they are listed below:

The first design principle of content design principles for eye-tracking-based training in special education is: *The eye training games should provide a relative flexibility for users to select the best options based on their visual impairments*. It is vital to use flexible designs for the games for children with special needs. The options to manage the game flow can be provided for users as a solution for their individual differences, such as their medical diagnosis, left and right eye visual acuity as seen in Table 4. Similar to this design principle, Matas et al. (2017) state that the tasks in the games should be adaptable for each child to provide optimum motivation. Therefore, this principle is to offer a smooth gameplay experience for the children.

The second design principle is: *Each eye training game should include difficulty levels, such as easy, medium, and hard by considering visual acuity.* Leveling the activities is common in special education. They generally start with an easy task, then continue with the medium through hard ones. Children with special education needs are generally used to play games following this leveling. Therefore, it can be beneficial to apply this design principle to design and development processes of the games for children with visual impairments. In the literature, Chang et al. (2016)

designed a pedestrian safety game for children with disabilities and used similar difficulty levels in the game, as entry, medium, and advanced.

In parallel to the design principle above, the third design principle is: *The eye training games should have an option to create a collection of games that are prescribed to the child with low vision.* This design principle aims to offer users a list of games to be played in company with practitioners/experts by considering the difficulties of the games to ensure the higher motivation and engagement of the children during the gameplay. Similar to this design principle, Lueck (1997) stated the importance of the help of rehabilitation specialists to create a training program for users with low vision based on their needs. With the help of this design principle, easy to apply gameplay experience can be provided for children with special needs within a predetermined rehabilitation program.

The fourth design principle is: *The eye training games should be easy to follow instead of containing complex scenarios to make it easier to fixate on objects and shorten the time to fixate on objects instead of creating a cognitive load.* The purpose of eye training games is to provide eye exercises for children with low vision. Therefore, there can be a need to avoid complex game scenarios and contents for these children with special needs (Ke & Abras, 2013). However, it should not be too easy to increase engagement (Sharek & Wiebe, 2011). Therefore, it is important to implement this principle to game design in special education as it can keep the engagement high without increasing the cognitive load of users.

The fifth design principle is: *The eye training games should have options to select the game duration from 5 minutes to 10 minutes in specific intervals to determine optimum rehabilitation duration by considering the visual impairments of users.* According to Biehle and Jeffres (2018), it is important to set the duration of the game while playing with children. It can be helpful for users to make their own decisions on the game duration during their rehabilitation process. Therefore, this design principle is essential to limit the game playtime for children with visual impairments.

The sixth design principle is: *The games should be categorized in the eye training program in terms of target vision skills, such as scanning-focusing games, scanning-tracking games, and color discrimination games.* The main purpose of eye training is to improve functional vision, and there are several visual skills to assess functional vision (Keeffe, 1995). Therefore, it can be necessary to categorize the eye training games in terms of these skills, such as scanning, focusing, tracking, and color discrimination. It is also important for children with low vision to choose the game purposefully. In parallel to this principle, it is important to assess the functional vision under parallel categories of visual skills: visual acuity, visual field, contrast sensitivity, color vision, and light sensitivity. Hence, it is important to divide the eye exercises into categories to have optimum benefit.

The seventh design principle is: *Each eye training game should have an option to choose the relevant eye to do exercises, such as the left eye, right eye, or both eyes, at the beginning.* Eye-tracking-based applications based on eye-tracking can use the gaze point estimation with the data coming from the left and right eyes of the users (Mooney et al., 2018). The eye training games for children with low vision sometimes require applying for the left eye, right eye, or both of the eyes (Lodato & Ribino, 2018). The reason can be about too poor eyesight in one of the eyes (as seen in Table 4), or eye exercise can be needed for the eyes one by one. Therefore, this principle is deemed to be essential to offer an option for the users to select the relevant eye or eyes before doing eye exercises.

The eighth design principle is: *The eye training games should have options to select the focusing duration on objects to complete focusing and tracking tasks.* In eye training, the duration of fixations is an important parameter to consider for focusing and tracking skills, since children with low vision are generally expected to improve their fixation stability by doing eye exercises (Legge & Chung, 2016). Therefore, it is important to provide an option to set a fixation duration limit while completing the tasks in the games. Users can change this duration according to their visual performance. In parallel with this design principle, Kooiker et al. (2016) state that

the duration of fixating the eye movements could vary depending on the visual impairment of the children.

The ninth design principle is: *The eye training games should have options to select the sensitivity of the eye movements shown on the screen, such as soft, normal, and hard.* The eye movements of the user can have frequent eye tremors or rapid eye splashes due to their medical diagnoses (Table 4). Consequently, the detected position of the eyes may be misdirected on the screen. There can be filters to correct the eye movement data gathered via eye-tracking devices. As Gavas et al. (2018) mention, it can be necessary to use filters to handle the errors in the eye movement data collected via eye-tracking devices while designing and developing rehabilitation applications. Therefore, this design principle is important to offer to improve the user experience in the games. In line with this principle, the sensitivity of the eye movements can be adjusted by users to decrease the adverse effects of such undesirable eye movements.

The tenth design principle is: *The eye training games should have options to select an indicator which shows eye movements of users, like a magnifier.* For eye training games, it is essential to track the eye movements of users. For this purpose, an indicator that moves in parallel with the eye movements can be placed on the screen. Therefore, both users and practitioners can follow eye movements on the screen. In parallel to this principle, Wiecek, Lashkari, Dakin, and Bex (2014) used a pointer in the form of a target symbol during the usage of the eye-tracking-based application for users with visual impairments to see their eye movements on the screen.

5.2 Practical Implications for Instructional Designers

The findings of this study suggest that instructional designers can design and develop games to be used as vision training materials for children with low vision. Design principles that emerged during this study may guide the design and development processes of eye training games.

Besides, this study includes the opinions and experience of several participants with diverse expertise in addition to children with low vision, such as special education teachers, expert academicians, ophthalmologists, and parents. It is vital to understand the needs of children with low vision from various points of view. Therefore, instructional designers can review the findings gathered from these participants and design their own solutions to the issue in light of emerged design principles.

5.3 Practical Implications for Special Education Teachers/Practitioners

Special education teachers and practitioners can take advantage of the findings of this study while adapting technology to provide vision training for children with low vision. The findings of this study indicated that it could be helpful to provide eye training for such children with objective results in addition to the activities and assessments applied by experts. Therefore, location free and time-independent eye exercise can be supportive for them.

In addition, the results of this study contained the opinions of several participants, namely, special education teachers, expert academicians, ophthalmologists, and parents. While applying eye training for children with low vision, special education teachers and practitioners can benefit from such expert opinions.

During this study, usability testing was done with children with low vision and presented in detail. Special education teachers and practitioners can follow the procedure while applying similar eye training program for children with low vision. Moreover, they can benefit from design principles and suggestions while applying for an eye training program.

Thus, the findings of this study, the procedure followed, and design principles emerged can be useful for special education teachers and practitioners, such as vision therapists and ophthalmologists, to have an in-depth comprehension while practicing eye training with children with low vision.

5.4 Conclusion

The game-based eye training program can be considered as an alternative eye exercise opportunity for children with low vision in terms of various aspects. It can provide objective results about the experience of the children with low vision and offer them to do eye exercise anywhere and anytime they want. In addition, both experts and practitioners are open to use technology for the rehabilitation of such children. Thus, it can be concluded that eye-tracking technology is a useful technology to be used in the field of low vision to help such children to improve their vision skills.

The main goal of this study was to design and develop an eye training program for children with low vision to enhance their visual skills in terms of scanning, focusing, and tracking. The program was developed with the contributions of special education teachers, experts from both special education and instructional technology, ophthalmologists, children with low vision, and their parents. Hence, the expertise of contributors was combined and reflected in the design and development of the eye training program. It can be concluded that it was important to include such expert contributors to the design and development process of the eye training program to increase the effectiveness and usefulness of it. In addition, it can be concluded that the contributions provided during the development phase and the suggestions collected during the iterations of the prototype were essential to reach the final version of the eye training program.

As a result of this study, several design principles emerged and were categorized under related themes, namely design principles for eye training games in special education, visual design principles for eye-tracking-based training in special education, and content design principles for eye-tracking-based training in special education. These design principles can be applied to the design and development processes of further eye training programs for children with low vision. Even, many more design principles can be found in the literature; it is possible to design and develop better eye training games for children with low vision to enhance their

functional vision skills by following the design principles that emerged from this study.

Although this study can be used as a guide to develop an eye training program for children with low vision to improve their vision skills, there is a need for more research in the field of low vision about the integration of technology, especially eye-tracking technology, since technology can provide objective data about the eye movements of children with low vision. It is expected that the findings of this study help instructional designers, special education teachers, and practitioners in the field of low vision rehabilitation.

5.5 Suggestions for Future Research

This study revealed a comprehensive design and development process for an eye training program for children with low vision. At the end of this study, design principles for designing and developing eye training games emerged to be used in the eye training program to improve the vision of children with visual impairments. While conducting this study, the data were gathered from several participants, such as expert academicians, special education teachers, ophthalmologists, children with low vision, and their parents for designing, developing, and applying for the eye training program. Although this study employed a broad perspective, future research would need to focus on the following areas:

- The eye training games developed during this study could be applied for more children with several types of visual impairments to increase the individual adaptability of the eye training program.
- By using the design principles emerged from this study, the number of games and the diversity of their scenarios could be increased to offer more options for children with low vision.
- Longitudinal studies could be carried with children with low vision by gathering their medical test results from their ophthalmologists periodically, such as visual

acuity and visual field, to compare the effectiveness of eye training program in the long run.

- In-depth studies could be conducted with a limited number of children who have similar causes for low vision to evaluate the effectiveness of the eye training program on specific visual impairments.
- The usability testing of eye training program could be performed in the home environment of children with low vision.
- In-depth studies could be carried out with younger children under three years old with low vision.

5.6 Limitations of the Study

There were limitations of this study, and they were listed below:

- The number of the participants' trials of the games constitutes a limitation for this study. Even if there were 36 children with low vision who used the eye training program developed during this study, each child experienced the eye training program once.
- This study was limited in terms of participant diversity. Children who were admitted to Vision Research and Low Vision Rehabilitation Unit of the Department of Ophthalmology at Ankara University for eight weeks were included in this study.
- During this study, the researcher was the only person who collected the data, observed the participants, transcribed the interviews and focus group meetings, analyzed the data, and interpreted them.

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APPENDICES

A. Academician Focus Group Meeting Script for Analysis and Development Phase

Merhaba. Ben Araştırma Görevlisi Mehmet Dönmez. Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü'nde doktora tez öğrencisiyim. Doktora tezim kapsamında araştırma konum az gören özel eğitim öğrencilerine yönelik göz hareketleri takibi tabanlı göz egzersiz sistemi tasarımı ve geliştirilmesidir. Sizinle bu odak toplantılarını gerçekleştirecek olmamın sebebi de özel eğitim alanındaki akademisyenler olarak göz hareketleri takibi tabanlı göz egzersiz sistemi tasarımı ve geliştirilmesi sürecine sizi aktif olarak dahil etmektir. Özel eğitim alanından akademisyenler olarak sizin görüşlerinizin çalışmamda yer alması son derece önemlidir.

Öncelikle sizlere göz hareketleri takibinden bahsetmek istiyorum. Bir göz hareketleri takip cihazı yardımı ile kişilerin bilgisayar ekranında baktıkları yerler tespit edilebilmektedir. Bu teknolojiden yola çıkarak az gören kişiler için objektif değerlendirme yapabilen ve çocuklara kendi başlarına egzersiz yapabilmeleri için imkan sunan bir göz egzersiz sistemi ortaya konulması hedeflenmektedir. Bugünkü ilk toplantıda göz hareketleri takibi tabanlı bir uygulamanın sizlere demosunu göstereceğim.

Odak toplantılarımızda her bir akademisyenin görüşlerini ve kişisel deneyimlerini paylaşması önemli görülmektedir. Bu fikirler ve aktif katılım göz egzersiz sisteminin tasarlanması ve örnek bir model yaratılmasında büyük önem arz etmektedir. Her bir odak görüşmesinin yaklaşık 1 saat sürmesi planlanmaktadır. Ayrıca görüşmeler video kamerayla kayıt altına alınacak, görüşleriniz isimsiz olmak kaydıyla sadece akademik amaçlı yayınlarda kullanılacaktır.

Özveriniz, katılımınız ve iş birliğiniz için şimdiden teşekkür ederim.

B. Teacher, Academician and Ophthalmologist Interview Questions for Analysis Phase

Demografik Sorular

İlk olarak sizi ve konumunuzu daha iyi tanımlayabilmek adına bazı giriş sorularıyla başlamak istiyorum.

1. Mesleğiniz nedir?

2. Nerede görev yapıyorsunuz?

3. Kaç yıldır görev yapıyorsunuz?

4. Yaşınızı sorabilir miyim?

5. Hangi üniversiteden mezun oldunuz?

İçerik ve Süreç ile İlgili Sorular

1. Halihazırda az görenler alanında teknoloji kullanma düzeyiniz nedir? Ne tür teknolojiler kullanıyorsunuz?

2. Bu teknolojileri hangi ortamlarda (konularda) kullanıyorsunuz?

3. Bu teknolojileri hangi amaçlar için kullanıyorsunuz?

4. Göz egzersizi için kullandığınız klasik yöntemler nelerdir?

5. Bu yöntemleri nasıl uyguluyorsunuz?

5. Göz egzersizi için teknoloji kullanımı hakkında ne düşünüyorsunuz?

6. Göz hareketleri takibi teknolojisinin az gören kişiler için kullanılması konusunda ne düşünüyorsunuz?

C. Teacher and Academician Interview Questions for Development Phase

Demografik Sorular

İlk olarak sizi ve konumunuzu daha iyi tanımlayabilmek adına bazı giriş sorularıyla başlamak istiyorum.

1. Mesleğiniz nedir?

2. Nerede görev yapıyorsunuz?

3. Kaç yıldır görev yapıyorsunuz?

4. Yaşınızı sorabilir miyim?

5. Hangi üniversiteden mezun oldunuz?

İçerik ve Süreç ile İlgili Sorular

1. Geliştirilmekte olan göz egzersiz sisteminin genel tasarımı hakkında ne düşünüyorsunuz?

2. Prototip sistemin tasarımsal problemleri nelerdir?

3. Göz kaslarının geliştirilmesi için odaklanma uygulaması uygun mudur? Değişiklik önerileriniz varsa nelerdir?

4. Göz kaslarının geliştirilmesi için takip etme uygulaması uygun mudur? Değişiklik önerileriniz varsa nelerdir?

5. Tasarıma ilişkin problemlerin düzeltilmesi için neler önerirsiniz?

D. Parent Interview Questions for Evaluation and Testing Phase

Demografik Sorular:

1. Mesleğiniz nedir?
2. Eğitim durumunuz nedir?
3. Yaşınızı sorabilir miyim?

İçerik ve Süreç ile İlgili Sorular

1. Halihazırda evde göz egzersizi yapıyor musunuz?
    a. Ne tür egzersizler yapıyorsunuz?
    b. Örnek verebilir misiniz?
    c. Egzersiz esnasında çocuğunuzun yanında oluyor musunuz?
2. Göz hareketleri takibi teknolojisinin az gören kişiler için kullanılması konusunda ne düşünüyorsunuz?
3. Yapmış olduğumuz bu bilgisayar tabanlı egzersiz uygulamasını evde kendi başınıza uygulayabilir misiniz?

E. Ophthalmologist and Academician Interview Questions for Evaluation and Testing Phase

Demografik Sorular:

1. Mesleğiniz nedir?
2. Yaşınız nedir?
3. Hangi üniversiteden mezun oldunuz?
4. Nerede görev yapıyorsunuz? Kaç yıldır görev yapıyorsunuz?

İçerik ve Süreç ile İlgili Sorular

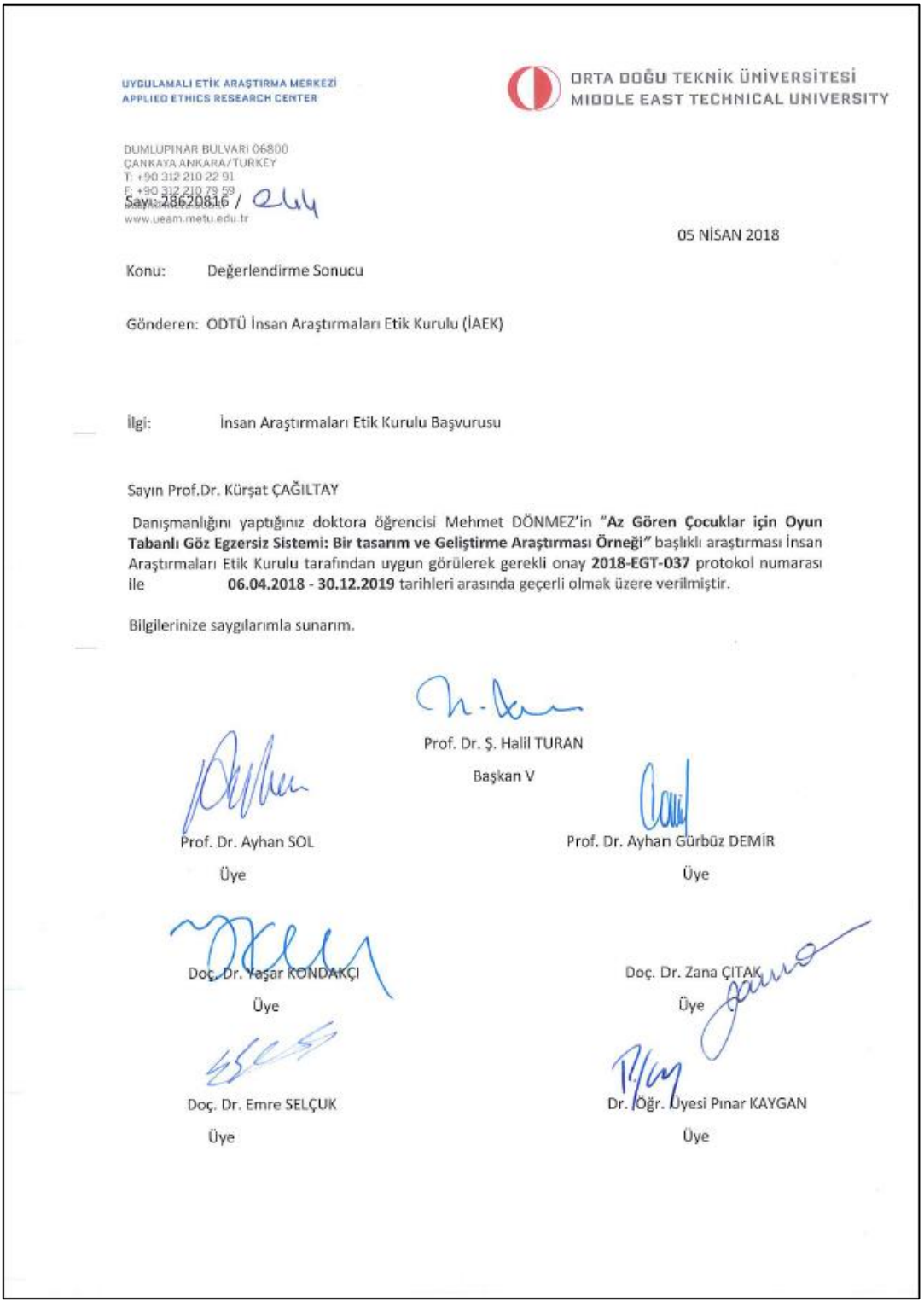
1. Geliştirilen göz egzersiz sisteminin genel tasarımı hakkında ne düşünüyorsunuz?
2. Sistemin tasarımsal problemleri nelerdir?
3. Göz kaslarının geliştirilmesi için odaklanma uygulaması uygun mudur? Değişiklik önerileriniz varsa nelerdir?
4. Göz kaslarının geliştirilmesi için takip etme uygulaması uygun mudur? Değişiklik önerileriniz varsa nelerdir?
5. Tasarıma ilişkin problemlerin düzeltilmesi için neler önerirsiniz?

F. Observation Checklist for Children with Low Vision for Evaluation and Testing Phase

Görevler	Yaptı	Yapamadı	Yorumlar
1. Balon Patlatma oyununu oynadı.			
2. Balon Patlatma oyununda sol üst bölgedeki balonları patlattı.			
3. Balon Patlatma oyununda sağ üst bölgedeki balonları patlattı.			
4. Balon Patlatma oyununda sol alt bölgedeki balonları patlattı.			
5. Balon Patlatma oyununda sağ alt bölgedeki balonları patlattı.			
6. Odaklanarak Basket Atma oyununu oynadı.			
7. Odaklanarak Basket Atma oyununda soldaki top ile basket attı.			
8. Odaklanarak Basket Atma oyununda üstteki top ile basket attı.			
9. Odaklanarak Basket Atma oyununda sağdaki top ile basket attı.			
10. Odaklanarak Basket Atma oyununda alttaki top ile basket attı.			
11. Meyve Toplama oyununu oynadı.			
12. Meyve Toplama oyununda sol üst bölgedeki meyveleri alıp ortaya getirdi.			
13. Meyve Toplama oyununda sağ üst bölgedeki meyveleri alıp ortaya getirdi.			
14. Meyve Toplama oyununda sol alt bölgedeki meyveleri alıp ortaya getirdi.			
15. Meyve Toplama oyununda sağ alt bölgedeki meyveleri alıp ortaya getirdi.			
16. Takip Ederek Basket Atma oyununu oynadı.			

17. Takip Ederek Basket Atma oyununda sol üst bölgedeki topları alıp ortadaki potaya getirerek basket attı.			
18. Takip Ederek Basket Atma oyununda sağ üst bölgedeki topları alıp ortadaki potaya getirerek basket attı.			
19. Takip Ederek Basket Atma oyununda sol alt bölgedeki topları alıp ortadaki potaya getirerek basket attı.			
20. Takip Ederek Basket Atma oyununda sağ alt bölgedeki topları alıp ortadaki potaya getirerek basket attı.			

G. Permission Letter from Ethics Committee



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05 NİSAN 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Kürşat ÇAĞILTAY

Danışmanlığını yaptığınız doktora öğrencisi Mehmet DÖNMEZ'in **"Az Gören Çocuklar için Oyun Tabanlı Göz Egzersiz Sistemi: Bir tasarım ve Geliştirme Araştırması Örneği"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-EGT-037** protokol numarası ile **06.04.2018 - 30.12.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
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Doç. Dr. Yaşar KONDAKÇI
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Doç. Dr. Zana ÇITAK
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Doç. Dr. Emre SELÇUK
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Dr. Öğr. Üyesi Pınar KAYGAN
Üye

H. Permission Letter from Ministry of Education

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T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.2845863 08.02.2019
Konu : Araştırma izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) 30/01/2019 tarihli ve 86 sayılı yazınız.

Üniversiteniz Doktora Öğrencisi Mehmet DÖNMEZ' in "**Az gören çocuklar için oyun tabanlı göz egzersiz sistemi: Bir tasarım ve geliştirme araştırması örneği"** konulu çalışması kapsamında uygulama yapma talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Uygulama formunun (6 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Güvenli Elektronik İmzalı
Asli İle Aynıdır.
08/02/2019

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Bu evrak güvenli elektronik imza ile imzalanmıştır. https://evraksorgu.meb.gov.tr adresinden 7124-5661-308e-8cb2-38e0 kodu ile teyit edilebilir.

I. Informed Consent Form

Bu çalışma, Arş. Gör. Mehmet Dönmez'in doktora tez çalışması olup, danışmanlığını Prof. Dr. Kürşat Çağıltay yapmaktadır. Bu çalışmanın amacı az gören özel eğitim öğrencilerine yönelik göz hareketleri takibi tabanlı göz egzersiz sistemi tasarımı ve geliştirilmesidir. Çalışma kapsamında az gören çocukların kolaylıkla göz egzersizi yapabilecekleri bilgisayar tabanlı bir sistem geliştirilecektir. Çalışma süreci; analiz, tasarım, geliştirme, değerlendirme olmak üzere dört bölümden oluşacaktır. Süreçler içerisinde özel eğitim öğretmenleri, göz doktorları ve akademisyenler ile görüşmeler ve az gören öğrenciler ile uygulamalar yapılacaktır. Çalışmaya katılım tamamıyla gönüllülük temelinde olmalıdır. Belirli kimlik bilgileri dışında sizden özel bilgiler istenmeyecektir. Öğrencilerin ad, yaş, cinsiyet gibi bilgileri de sadece akademik amaçlı yayınlar için kullanılacaktır. Cevaplarınız tamamıyla gizli tutulacak ve sadece araştırmacılar tarafından değerlendirilecektir; elde edilecek bilgiler bilimsel yayınlarda kullanılacaktır. Bu çalışmaya katıldığınız için şimdiden teşekkür ederiz. Çalışma hakkında daha fazla bilgi almak için Orta Doğu Teknik Üniversitesi Bilgisayar ve Öğretim Teknolojileri Eğitimi Bölümü Araştırma Görevlisi Mehmet Dönmez (Oda: EFC-07; Tel: 210 7525; E-posta: mdonmez@metu.edu.tr) ya da öğretim üyesi Prof. Dr. Kürşat Çağıltay (Oda: EFC-14; Tel: 210 3683; E-posta: kursat@metu.edu.tr) ile iletişim kurabilirsiniz.

Bu projeye tamamen gönüllü olarak katılıyorum ve istediğim zaman yarıda kesip çıkabileceğimi biliyorum. Verdiğim bilgilerin bilimsel amaçlı yayımlarda kullanılmasını kabul ediyorum. (Formu doldurup imzaladıktan sonra uygulayıcıya geri veriniz).

Adı Soyadı Tarih İmza

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J. Parental Approval Form

Sayın Veli,
09.03.2018

Orta Doğu Teknik Üniversitesi, Bilgisayar ve Öğretim teknolojileri Eğitimi Bölümü'nde araştırma görevlisi olarak çalışmaktayım. Prof. Dr. Kürşat Çağıltay hocamın danışmanlığında doktora tezim kapsamında az gören çocuklara yönelik az gören çocuklar için oyun tabanlı göz egzersiz sistemi adlı bir çalışma yürütmekteyim. Çalışma sürecinde göz hareketleri takibine dayalı bilgisayar tabanlı göz egzersiz sistemi tasarlanacak ve geliştirilecektir. Bu mektubun yollanış amacı, çocuklarınızın çalışma kapsamına dahil edilebilmesinde sizden gerekli iznin alınabilmesidir.

Çalışmaya istinaden çocuğunuzun belirli kimlik bilgileri dışında (ad, yaş, cinsiyet) herhangi özel kimlik bilgisi saklanmayacaktır. Belirli kimlik bilgileri de araştırma sonunda oluşturulacak yayınlarda kullanılacaktır. Akademik amacın dışında bu bilgiler hiç kimse ve hiçbir kurumla paylaşılmayacaktır.

Çalışmaya katılımda çocuğunuzun gönüllü olması ilk ve en önemli aşamadır. Çocuğunuzun çalışmaya katılmaya istekli olması şartı sağlandıktan sonra sizden bu mektuba yanıt vermeniz beklenmektedir. Bununla birlikte projeye katılım tamamen gönüllülük çerçevesinde gerçekleşeceğinden ötürü, herhangi bir yaptırıma maruz kalmadan siz ya da çocuğunuz katılımdan vazgeçme hakkına sahip olduğunuzu özellikle belirtmek isteriz.

Araştırmayla ilgili sorularınızı aşağıdaki e-posta adresini veya telefon numarasını kullanarak bize yöneltebilirsiniz.

Saygılarımızla,

Arş. Gör. Mehmet Dönmez
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Yukarıda açıklamasını okuduğum çalışmaya, oğlum/kızım _____'nin katılımına izin veriyorum. Ebeveynin:

Adı, soyadı: _____ İmzası: _____Tarih:_____

K. Debriefing Form

Bu çalışma daha önce de belirtildiği gibi ODTÜ Bilgisayar ve Öğretim Teknolojileri Bölümü doktora öğrencisi Mehmet Dönmez tarafından doktora tezi kapsamında yürütülen bir çalışmadır. Bu çalışmanın amacı az gören özel eğitim öğrencilerine yönelik göz hareketleri takibi tabanlı göz egzersiz sistemi tasarımı ve geliştirilmesidir. Çalışma sürecinde az gören çocukların odaklanma ve izleme becerilerini geliştirmeye yönelik bilgisayar tabanlı göz egzersiz sistemi geliştirilecektir.

Bu çalışma sürecinde elde edilecek verilerin Aralık 2018 sonunda analiz edilmesi amaçlanmaktadır. Elde edilen bilgiler sadece bilimsel araştırma ve yazılarda kullanılacaktır. Çalışmanın sonuçlarını öğrenmek ya da bu araştırma hakkında daha fazla bilgi almak için aşağıdaki isimlere başvurabilirsiniz. Bu araştırmaya katıldığınız için tekrar çok teşekkür ederiz.

Arş. Gör. Mehmet Dönmez (Oda: EFC-07; Tel: 210 7525; mdonmez@metu.edu.tr)

Prof. Dr. Kürşat Çağıltay (Oda: EFC-14; Tel: 210 3683; E-posta: kursat@metu.edu.tr)

CURRICULUM VITAE

PERSONAL INFORMATION

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EDUCATION

Degree	Institution	Year of Graduation
MS	METU Information Systems	2015
BS	METU Computer Education and Instructional Technology	2012
High School	Lüleburgaz Anatolian Vocational High School, Kırklareli	2007

WORK EXPERIENCE

Year	Place	Enrollment
2020-Present	METU Registrar's Office	Instructor
2012-2020	METU Computer Education and Instructional Technology	Research Assistant

FOREIGN LANGUAGES

Advanced English, Intermediate Spanish, Beginner Portuguese

PUBLICATIONS

<u>International Book Chapters</u>

1. Donmez M., Cagiltay K., Alkan S., Bolukbas F. and Kaplan G. "Use of Large Multi-Touch Interfaces: A Research on Usability and Design Aspects", Optimizing Human-Computer Interaction with Emerging Technologies, (2017)

International Journal Papers

1. Donmez M. and Cagiltay K. “Development of Eye Movement Games for Students with Low Vision: Single-subject Design Research”, Education and Information Technologies, (2019)

International Conference Papers

1. Kaplan G., Sevim N., Duman M. and Donmez M. “An Insight to the Design and Development of an Early Childhood Education E-book for both iOS and Android Platforms”, Sixth International Computer &Instructional Technologies Symposium, (2012)

2. Donmez M. and Cagiltay K. “Az Görenler İçin Göz Hareketleri Takibi Teknolojisi Kullanılarak Oyunlaştırılmış Göz Egzersiz Eğitimi Sistemi Geliştirilmesi ve Kullanılabilirliği”, Eighth International Computer &Instructional Technologies Symposium, (2014)

3. Cagiltay K., Donmez M. and Cicek F. “Eye Tracker Based Eye Training System for Children with Low Vision Effectiveness and Usability”, AERA Annual Meeting, (2015)

4. Donmez M., Cagiltay K., Alkan S., Bolukbas F. and Kaplan G. “Use of Large Multi Touch Interfaces: A Research on Usability and Design Aspects”, Fifth International Conference on Software and Emerging Technologies for Education, Culture,Entertainment, And Commerce (SETECEC), (2016)

5. Dogan S., Donmez M., Islim O. F. and Sevim N. “BÖTE Öğrencilerinin Bölümlerine Yönelik Algısı Ankara Örneği”, Tenth International Computer & Instructional Technologies Symposium, (2016)

6. Donmez M. and Cagiltay K. “Göz Hareketleri ile Bilgisayar Kullanma Sistemi”, Tenth International Computer & Instructional Technologies Symposium, (2016)

7. Donmez M. and Cagiltay K. “A Review and Categorization of Instructional Design Models”, E-Learn: World Conference On E-Learning in Corporate, Government, Healthcare, And Higher Education, (2016)

8. Cagiltay K. and Donmez M. “Engelleri Aşmak için Göz Hareketleri Takibi Teknolojisi”, Engelsiz İş Dünyası Kongresi, (2017)

9. Dogan S., Aslan O., Donmez M. and Yildirim S. “Sözde Kod Oluştururken Öğrencilerin Zihinsel Süreçlerindeki Farklılıklar: Bilişsel Etnografi Çalışması”, 11th International Computer & Instructional Technologies Symposium, (2017)

10. Donmez M., Dogan S. and Baran E. “Sinyal İlkesinin Öğrenme Üzerindeki Etkileri: Bir Göz Hareketleri İzleme Çalışması”, 12th International Computer & Instructional Technologies Symposium, (2018)

11. Aslan O., Dogan S., Donmez M. and Yildirim S. “Öğretim Teknolojileri Alanında Temel Araştırma Alanları ve Araştırma Yöntemleri Problemleri İçin Bir Çözüm Önerisi: Bilişsel Etnografya”, 12th International Computer & Instructional Technologies Symposium, (2018)

12. Esen O., Esfer S., Cevizci Karatas E., Donmez M. and Cagiltay K. “Examining in-class technology use with Eye Tracking: E-Teach Project”, 12th International Computer & Instructional Technologies Symposium, (2018)

13. Cevizci Karatas E., Cagiltay K., Esen O., Donmez M. and Esfer S. “Insights of E-Teach Project: ETEC Usage for Expert and Novice Teachers”, 13th International Computer & Instructional Technologies Symposium, (2019)

National Journal Papers

1. Donmez M., Dogan S. and Baran E. “How Signaling Principle Affects Learning: An Eye Tracking Study”, Mersin University Journal of the Faculty of Education, (2018)

2. Dogan S., Aslan O., Donmez M. and Yildirim S. “Investigation of Students’ Cognitive Processes in Computer Programming: A Cognitive Ethnography Study”, Turkish Online Journal of Qualitative Inquiry, (2019)

3. Aslan O., Donmez M., Dogan S. and Yildirim S. “Bilişsel Etnografya: Kuramsal Çerçeveler, Yöntemler ve Süreçler”, Eğitim Teknolojisi Kuram ve Uygulama, (2019)

National Conference Papers

1. Donmez M., and Cagiltay K. “Göz Hareketleri Takibi Teknolojisi Kullanılarak Oyunlaştırılmış Göz Egzersiz Eğitimi Sistemi Geliştirilmesi ve Kullanılabilirliği”, 26. Ulusal Özel Eğitim Kongresi, (2016)

2. Donmez M., and Cagiltay K. “Fiziksel Engelliler için Göz Hareketlerini İzleme Yöntemi ile Bilgisayar Kullanma Sistemi”, Eğitimde FATİH Projesi Eğitim Teknolojileri Zirvesi, (2016)

3. Cagiltay K., Donmez M., and Imre S. “Göz Hareketleri Takip Teknolojisi ile Geliştirilen Yenilikçi Teknolojik Çözümler”, Engellilerde ve Yaşlılarda Dijital Dönüşüm Sempozyumu, (2019)