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Original Article

Sustainable Design in Motion Sensing Game for Autistic Children

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Abstract: The population of autistic children is increasing rapidly in recent years, and it has become an urgent public health problem. The practice has proved that motion-sensing games can help autistic children solve their symptoms and help them grow healthily. However, there are still some defects in the operation of these games recently, e.g., fixed space and time, high cost, and public welfare institutions. Furthermore, no effective solution has been proposed in the academic field. To fulfill this research gap, this study focuses on value co-creation with autistic children in a motion-sensing game. The methods involve a double diamond design model and sustainable design approaches as the basis for the creative convergence motion sensing game. This study used the concept of sustainable design to develop a new game experience promoting the well-being of autistic children and stakeholders. To achieve sustainability in creative convergence motion sensing games for autistic children, it is necessary to fully consider the game design's technological innovation, social innovation, economic value, and diverse culture.

Keywords: Sustainable design; Motion sensing game; Autistic children; Double diamond design model.

1. Introduction

Autism Spectrum Disorder (ASD) is described as a serious neurodevelopmental disorder that involves delay in the development of many basic skills, including the ability to socialize and communicate (Clegg, 2006). as well as the ability to speak (Frutos et al., 2011). ASD is affecting 1 in 59 children in the USA (Maenner et al., 2020). According to Drake et al. (2012), in China, 0.9 in 100 children have diagnosed with ASDs. Autistic children will be disabled for life if they do not receive timely intervention. It has become an urgent public health problem. Few children can access efficacious interventions about cost and time due to the lack of public welfare institutions. Moreover, recent research suggests that the percentage of people who have autism has grown in recent decades (Ren & Bao, 2020). Therefore, new methods should be studied to develop various services for autistic children. Although autistic children's face-to-face communication is impaired and delayed, autistic individuals showed a propensity for computer technology (Zakari et al., 2014). This cognition led to a growing technology focusing on the education and therapy of diseased individuals (Wattanasoontorn et al., 2013).

Some studies insisted on creating touchless technology for the therapy of autistic children (Boucenna et al., 2014). Motion training, endurance, and learning interests of autistic children can be improved by using a

webcam motion sensor (Kun-Hsien et al., 2012). This study used a service design process and sustainable approach to the therapy of autistic children by providing a more efficient and engaging space for motor training, considering the context of mobile Internet popularization. Scratch is a no-cost game design software that can be used to design motion-sensing games by anyone who has installed it on their computer. The study describes the design and preliminary assessment of motion sensing game as "catching fruit with face". This game collects fruit and gets feedback through immersive design and facial movements of autistic children, including head, eyes, ears, nose and other parts. Empirical data from this study indicate that children with autism have improved play autonomy and performance, improved motor ability, and beneficial effects on social skills.

2. Materials and Methods

Designing and creating tailored, adaptable assistive technology games for unique populations is difficult. In order to facilitate physical accessibility, cognitive accessibility, and sensory accessibility, the design requirements must adhere to the universal and adaptive design principles (Cañete et al., 2021). Our team must thoroughly understand the characteristics of the kids for whom their games are designed. As designers, we must also understand the potential and limitations of motion-sensing games for autistic children. Therefore, a specific design framework is defined for developing a creative motion-sensing game. This study combines the service design process and a sustainable design approach to design. According to the double diamond design model, it has been around since it was officially invented by the British Design Council (2005). The service design process can be divided into discovery, define, development, and delivery. This well-organized method leads the reader from the beginning of the process to its conclusion, where a finished game is generated. Therefore, our game was designed to follow these four processes (Figure 1).

Meanwhile, the sustainable domain provides a toolbox that includes technology, social, economic, and cultural components to find sustainable solutions (Miranda et al., 2018). The technologies that will be created will aim to use resources, energy, and manufacturing processes more effectively to have a smaller negative impact on the environment. The social component concerns how a product affects people's quality of life, considering factors like housing, health, education, culture, and housing at the level of an employee, a consumer, and a community. The economic factors include productivity, the creation of affordable goods, the beginning of businesses, the creation of jobs, and profitability, among others. The explanation of each stage of the process is given in brief (Figure 1).

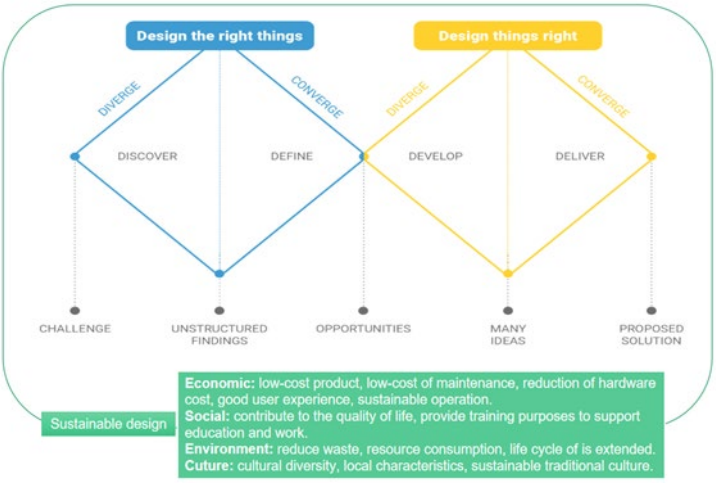


Figure 1. Creative convergence game design methodology.

2.1. Discover Phase

The discovery stage mainly includes questioning the demand for the research object, choosing the research direction, and launching the research. In the service design (motion sensing) games for autistic children, the discovery stage usually includes understanding the service background, stakeholders in the existing therapeutic game services, and problems in the existing service process.

2.2. Define Phase: Synthesis

The original research data obtained in the discovery stage is analyzed and sorted out in the define stage. The design objectives are defined, including the following steps: summarize and study the original data, cluster analysis, design insight, and redefine the design requirements. In this step, the original needs of autistic children's games are redefined, and the foundation is laid for the subsequent divergence and output of design concepts.

2.3. Development Phase: Ideation

The deliver stage is the most familiar process for designers to put forward design concepts through creative divergence, which includes constant polishing and improvement of concepts. The main steps include creative divergence-concept evaluation (iterative process)-design scheme. It should be noted that the design concept output of service design should consider service users and service providers. The core is how to create a sound service process to give all stakeholders a better experience. In the stage of design concept divergence, we should position the designer as the organizer and enabler and bring all stakeholders into the creative design process by organizing collaborative design workshops, which will make all stakeholders produce multiple harvests.

2.4. Deliver Phase: Implementation

This stage is the final project output, including prototyping-test analysis-solution iteration. After the service design scheme is produced, the service prototype can be quickly created to test and improve the scheme. Establishing a service prototype can save the cost of trial and error, and the problems can be found and improved early. After completing the game plan, it also needs continuous testing and iteration to improve.

3. Results

Following the design model of the creative convergence game design methodology (Figure 1), this section analyzes the design problem, the definition of needs and functions, the conceptual and detailed design, the implementation of the creative games, and design verification.

3.1. Design Problem Analysis

Because of the lack of public welfare institutions, few children can access efficacious interventions about cost and time. Moreover, recent research suggests that the percentage of people who have autism has grown in recent decades. There is a need to develop effective and creative motion games adaptable to any user and context of use (therapy, family, didactic environment). Therefore, the project focused on the following design objectives:

- **First:** Develop a motion-sensing game that integrates sensory, motor, and cognitive activities in the same device. It should be entertaining, safe, age-appropriate, and attractive while enhancing and honing various skills of kids with autism. Target market and user group: ASD children aged 3 to 12 with possible playmates (parents, guardians, therapists, teachers, or youngsters typically developing).
- **Second:** Develop an interactive motion-sensing game that allows for interplay (imitation, competition, sharing) between the game, autistic children, and playmates.
- **Third:** Develop a cooperative game to enhance the cognitive, motor, and sensory abilities of autistic children and to promote social connection.
- **Four:** Develop an activity game that can be used indoors and outdoors.
- **Five:** Develop motion-sensing games that can be easily recreated according to personal preferences.

3.2. Needs and Functions Definition

The motion-sensing game aims to help autistic children develop cognitive, motor, social, and innovation skills. Therefore, our objectives are primarily categorized under the cognitive, motor, and social dimensions.

- ***Cognitive Skills:*** All sorts of play games include using cognitive skills. We aim to encourage body consciousness and abstraction capacity because autistic children have low cognitive power. The game "catching fruit with the face" can help autistic children perceive various fruits, such as watermelons, bananas, apples, grapes, etc.
- ***Motor Skills:*** Providing visual stimuli connected with each movement promotes different motor skills such as body awareness, movement regulation and coordination (Facial recognition game). The game of "catching fruit with the face" allows autistic children to control the game by using eight body parts, including the head, eyes, nose and ears.
- ***Social Skills:*** Social interaction must be supported "by design" through competitions, sharing, game re-creation, promoting and leveraging social skills such as communication, strategic planning, and cooperation.
- ***Innovation Skills:*** Innovation is the generation, acceptance and implementation of new ideas, processes, products, or services. We encourage autistic children or playmates to work together to make any changes to the "Catching fruit with face" game during the re-creation process.

3.3. Conceptual and Detail Design

We insist that the design concept output of service design should consider the service user and the service provider. The main concern is creating an effective service procedure that will improve the experience for all stakeholders involved. In the stage of design concept convergence, we should position the designer as the organizer and enabler and bring all stakeholders into the creative convergence design process, which will give all stakeholders a good experience. In the "Catching Fruit with Face" game, different motion sensing methods are designed to meet the needs of autistic children and playmates to play and learn. Our team brainstormed the game's design details (Table 1).

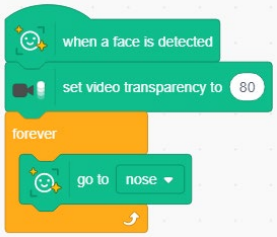
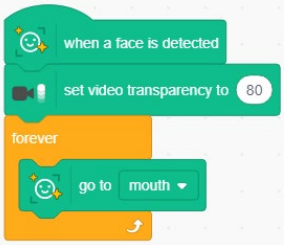
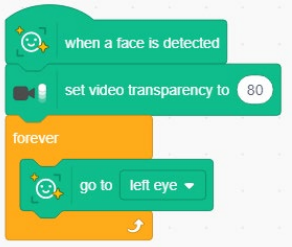
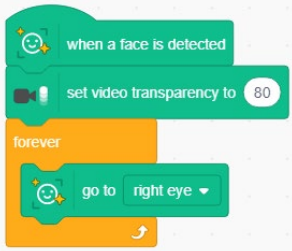
Table 1. Detail of Functional Requirements for Motion Sensing Game.

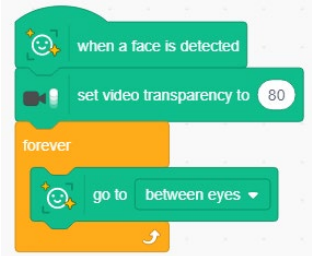
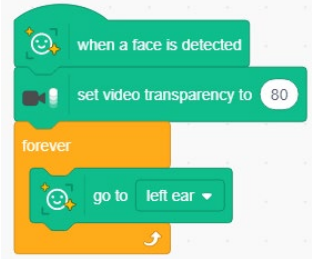
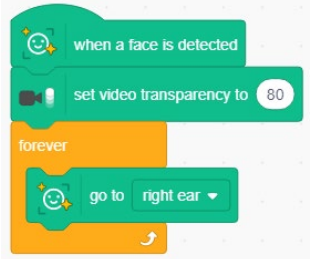
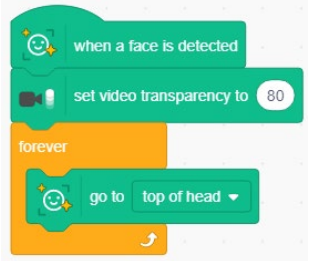
General Requirements		Specific Requirements
Cognitive accessibility		Recognize various fruits in life. Automatic collection of relevant data from the game experience. Adaptation to different people (autism children or their playmates).
Sensory accessibility		Play the game through multisensory, including the head, eyes, nose and ears. Comfortable, safe stimulation adapted to autistic children. Improve attention processes through motion tasks (handphone or computer with mirror).
Social interaction accessibility		Can experience a game competition at any time. The game can be shared instantly. The game allows for re-creation. Participation of various stakeholders.
Innovation accessibility		Gameplay innovation. Innovation of game service model. The innovation of games serving the community and society.
Sustainable design	Economic feasibility	Low-cost product, Low-cost of maintenance, Reduction of hardware cost, Good user experience, Sustainable operation.
	Social feasibility	Contribute to the quality of life,

General Requirements	Specific Requirements
	provide training purposes to support education and work, and contribute to the community and society.
Environment feasibility	Reduce waste and resource consumption. The life cycle is extended.
Culture feasibility	Cultural diversity, Local characteristics, Sustainable traditional culture.

Finally, the game "Catching Fruit with Face" is an interactive motion-sensing game that allows for an autonomous interaction between autistic children and the game. To implement the functions related to the motion, the game integrates sensors that capture the child's actions and the information from the game. The interactive design is the main priority of "Catching fruit with the face." The game modes are described below (Table 2) according to the functional requirements for motion-sensing games.

Table 2. Game Detail and Mode Description

Mode	Objectives	
Mode 1: Catching fruit with nose		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit with their noses.
Mode 2: Catching fruit with mouth		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit with their mouths.
Mode 3: Catching fruit with left eye		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit with the left eye.
Mode 4: Catching fruit with right eye		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit with the right eye.

Mode	Objectives	
Mode 5: Catching fruit with between eyes		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit between eyes.
Mode 6: Catching fruit with left ear		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit with the left ear.
Mode 7: Catching fruit with right ear		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit with the right ear.
Mode 8: Catching fruit with top of head		Autism children or playmates (parents, guardians, therapists, teachers, or youngsters who are typically developing) can catch fruit on top of their head.

3.4. Implementation of the Creative Convergence Game and Design Verification

According to the game of characteristics and functionalities, “Catching Fruit with Face” can be considered an interactive creative convergence game. It is more than a game of entertainment and learning; it is more of a community that can integrate stakeholders to help them gain more benefits and progress.

Table 3. Characteristics of the Creative Convergence Game

	Product-oriented stage	Service-oriented stage	Social-oriented stage
Characteristics	Motion sensing is the main activity of autistic children or their playmates. It contains components such as Technology, Entertainment, Learning, and Training.	An integrated product, service, stakeholder support network, and infrastructure system. Reduce the use of materials and waste, reduce energy consumption, and reduce cost investment.	Contribute to the quality of life, community, and society. Provide training purposes to support education and work and achieve sustainable development.

In this way, the creative convergence games are created according to the different developmental stages of autistic children. "Catching fruit with the face" as an integrated product, service, stakeholder support network, and infrastructure system and reducing material resources and energy dependence by providing

high-quality services to minimize the use of materials and waste, reducing energy consumption and cost investment, and ultimately achieving sustainable development. The game "Catching Fruit with Face" development process was used to verify the design concept. According to the creative convergence game design methodology, the prototype was integrated into the following scopes (see Table 3). The game "Catching Fruit with Face" is developed with an open-source " Scratch " electronic platform. It is a no-cost, easy-to-use software and easy to recreate (Figure 2). Most importantly, it allows for the interaction between autistic children and their playmates, creating spaces for collaborative play. The structural design of the product makes the result adaptable to different contexts of use at any time, whether in indoor (therapy room, home, or school) or outdoor environments.

Figure 2. Immersive "Catching Fruit with Face" in Different Contexts of Use.

4. Discussion

The game "Catching fruit with face" is developed for autistic children. Meanwhile, it is adaptable to any time, any user and any context of use (therapy, home, school) that helps autistic children to develop those skills (Cognitive Skills, Motor Skills, Social Skills, Innovation Skills) in which they have difficulties and need improvement. "Catching fruit with face" is not just a game for autistic children. It is a collaborative product and a system for social service innovation. Not only can it improve cognitive, motor, and sensory skills in autistic children with special needs, but it can also promote social interaction. It should be more of a system for social service innovation. Firstly, future developments in this project will focus on transforming the motion sensing game into social media platforms. In order to provide all interested people with the opportunity to participate anytime, anywhere, as long as your phone or iPad has a camera, you can play our motion-sensing games, follow, like, comment, share, and recreate.

In social media, that would allow for medical monitoring and personalization. Because the game is used in the context of social media platforms, data can be collected automatically and analyzed, so we can quickly update games and create more effective games for autistic children. Secondly, future work will focus on developing appropriate motion-sensing games for children with autism according to their severity (mild, moderate, or severe). Finally, in human development and social sustainability, the games also improve the availability and accessibility of products and services. In the future, our team will focus on developing a framework for the social service innovation mode with assistive technology for autistic children.

5. Conclusions

This study is a motion-sensing game based on the Scratch platform, mainly designed for autistic children. Using the service design process (e.g., discover, define, development, delivery), this paper introduces the design of games to contribute to the challenges. It needs to enable more inclusive innovation and innovative social transformation. Introducing new emerging technologies (motion sensing technology to create interactive games) into everyday products is of great interest to autistic children and stakeholders. "Catching fruit with face" is also designed to promote a more inclusive approach to the technology healing industry for autistic children. These solutions can improve the health and social well-being of currently underprivileged groups, helping technology advance the development of social service innovation. We maintain that the most important thing is to expand its platform and design creative convergence solutions to meet the needs of autistic children and stakeholders, which will better promote the sustainable development of social service innovation.

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