Serious Game of increase Cognitive Function for Elderly using Arduino based coordinated movement

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Abstract - Advanced in the development of medical technology, human life expectancy is increasing and old age related cognitive changes such as dementia and the interest in the improvement of cognitive function is increasing. Because of this, prevention of dementia and efforts to improve cognitive skills associated with dementia is actively walking in technical contents. And also the serious games to prevent dementia are introduced by improving cognitive functions. In this study, in order to compensate the defect of the existing functional game preventing dementia that their effectiveness of dementia is unproven, we have developed the functional game to improve elderly cognitive function based on the coordinate movement using Arduino that improves physical motor function and brain function at once. The effectiveness of this game was tested targeting 20 elderly people in Cheonan community center. In order to verify the effectiveness, the group was divided into the training group with game developed by using touch function of the tablet PC and the training group based on the coordinate movement using Arduino. The effectiveness of the cognitive function improvement, reaction velocity, and increase in the life satisfaction was verified and it was confirmed that the training group based on the coordinate movement using Arduino was more efficient.

Keywords: Elderly, Serious Game, Dementia, Cognitive Skills, Arduino, Motion Sensor

1 Introduction

As the human life expectancy increases, and the mortality rate decreases due to economic development and improvement of medical technology, population aging is underway. Interest in senile dementia associated with cognitive changes in old age is also increasing because of population aging. The dementia has emerged as a social problem in the modern society where the elderly population gradually increases.

According to the result of analyzing medical fees spent to dementia patients by National Health Insurance Corporation, the number of dementia patients was 105 thousands in 2006 and nearly three times increased to 312 thousands in 2011. It means that the number of patients who underwent dementia treatment increased by 24.4% annually in average.[1] In addition, the number of dementia patients in Korea is forecasted to exceed one million in 2025.[2]

In the past, the elderly with dementia were taken care of at home. However, due to social changes such as individualization and industrialization, as the number of the elderly with dementia who were taken care of at home decreases, and the elderly population continues to grow, the number of the elderly with dementia who need long-term care will rapidly rise as well as the number of the elderly with dementia will steadily increase. Moreover, family members who watch them experience great suffering because of the nature of dementia.[3, 4] Therefore, a dementia prevention program is required to prevent dementia by enhancing judgement, memory, ability to react instantly, and concentration, which are typical cognitive functions associated with dementia, and to improve quality of life of the elderly.[5]

Accordingly, functional dementia prevention games allowing the elderly to receive a dementia prevention training entertainingly and voluntarily by combining a fun element of games have appeared.[6] However, cognitive, physical, and emotional characteristics of human develop not independently but affecting one another, thus to prevent dementia more efficiently, improvement of body's motor skills and brain functions should be made together all the time.[7]

In this paper, a dementia prevention game for the elderly based on the coordination action utilizing Arduino was developed to complement shortcomings of existing dementia prevention functional games whose effectiveness is not verified properly and to improve body's motor skills and brain functions together. In order to verify the effectiveness of the developed game, 20 days of training was conducted targeting the elderly in a welfare center located in Cheonan. The effectiveness of 20 days of training on improvement of judgement, memory, ability to react instantly, and concentration was assessed by comparing the difference between when using Arduino to improve body's motor skills together and when using finger touch only considering enhancement of brain functions only. As a result, it was
found that the effectiveness was superior when using Arduino to improve body's motor skills and brain functions together.

2 Related Research

2.1 Dementia Prevention Game for the Elderly

Typical cognitive functions associated with senile dementia include judgement, memory, ability to react instantly, and concentration, thus improving these functions is very helpful to prevent dementia. Dementia prevention games for the elderly contain elements that can improve judgement, memory, ability to react instantly, and concentration. As presented in [figure 1], games should consist of judgement, memory, ability to react instantly, and concentration to assess user's brain functions, and through appropriate training and treatment, dementia should be prevented and improved. [8]

Figure 1: Typical cognitive skills about Dementia

Figure 2: Dementia Prevention Game for the Elderly “Rejuvenating Town”

2.2 Dementia Prevention Game for the Elderly “Rejuvenating Town”

The Rejuvenating Town is a dementia prevention game for the elderly containing a total of 9 cognitive games by dividing typical cognitive functions associated with dementia into memory, attention, and judgement. It is developed to train and enhance each element of cognitive functions through visual or auditory signal stimuli along with simple physical activity using touch interface and buttons. The game was developed by advice and thorough verification of medical staff at Asan Medical Center including Min-Ho Geon, division head of rehabilitation medicine, etc. and an expert group at Sungshin Women’s University including Kyoung-Chun Lim, professor at geriatric nursing, etc. From July 2012, a clinical trial was performed targeting 100 elderly for 5 months at Asan Medical Center.[9]

Figure 2: Dementia Prevention Game for the Elderly “Rejuvenating Town”

2.3 Dementia Prevention Game for the Elderly Utilizing Wearable Device

As cognitive, physical, and emotional characteristics of human are not independent but affecting one another, action-based type of games rather than mouse click or touch-based games are more efficiently helpful for dementia prevention.

2.4 Arduino

However, the existing wearable device was not made considering elderly users, and therefore, an inclusive design type of wearable device should be produced for dementia prevention games for the elderly.[10] Arduino is AVR-based single board microcontroller, the most suitable open source to make as a type of this inclusive design. In addition, it is providing the integrated development environment (IDE) for software development. Arduino can make a product interacting with the environment by accepting a value from the switch or sensor and controlling external electronic devices such as LED or monitor. Moreover, it can be

Figure 3: Configuring Arduino basic board
used by interlocking with software such as flash, processing, visual programming, Unity3D, etc.[11]

3 Dementia Prevention Game for the Elderly Developed in this Study

3.1 Game Design Elements for Dementia Prevention

In this paper, a coordination action based dementia prevention game was suggested as a treatment method for senile dementia prevention. In [Table 1], four brain function elements including concentration, judgment, memory, and ability to react instantly were presented. Additionally, an exercise effect due to muscle use of the elderly can be seen together by playing the dementia prevention game based on the coordination action using Arduino.

Table 1: Four Kind of Brain Skill elements for Dementia

<table>
<thead>
<tr>
<th>Brain Function</th>
<th>Competence Test</th>
<th>Daily Training</th>
</tr>
</thead>
<tbody>
<tr>
<td>Concentration</td>
<td>Concentration Test</td>
<td>Dugg’y Hide-and-Seek</td>
</tr>
<tr>
<td>Judgment</td>
<td>Judgment Test</td>
<td>Nyang’s Separate</td>
</tr>
<tr>
<td>Memory</td>
<td>Memory Test</td>
<td>Guri’s Twinkle Twinkle</td>
</tr>
<tr>
<td>React</td>
<td>React Test</td>
<td>Grandpa Pile Tower</td>
</tr>
</tbody>
</table>

3.2 Arduino Hardware Design Part

To make an action recognition ring and bracelet using Arduino, as shown in [figure 4], for the bracelet, mpu-6050 acceleration sensor and bluetooth FB155BC were installed in Arduino pro mini board, and for the ring, mpu-6050 acceleration sensor was installed in Arduino beetle.

Figure 4: Arduino Bracelet and Anklet

3.3 Arduino Software Design Part

As shown in [figure 5], Arduino can do code work to make a desirable program using the exclusive compiler of Arduino. In this study, codes for a ring worn on the finger and a bracelet worn on the wrist were written respectively. For the bracelet, codes for actions including left and right rotation below the wrist, left and right rotation of the wrist, and up/down action of the wrist were written.

Figure 5: Arduino Gesture Recognition Code

3.4 Interlinking between Arduino and Unity

The dementia prevention game suggested in this paper was created based on Unity3D. To make the action recognition device, Arduino, recognized in the game, it receives communication information that is sent from...
3.5 Dementia Prevention Game for the Elderly, “Youth over Flowers”

A dementia prevention game for the elderly, named Youth over Flowers, was developed combining four elements to prevent dementia. The [figure 7] displays the overall structure of Youth over Flowers in diagram form.

The game Youth over Flowers is divided into proficiency testing phase and everyday training phase. In the proficiency testing phase, the user's levels of concentration, judgment, memory, and ability to react instantly are evaluated, while in the everyday training phase, the user continues to play for 20 days to improve concentration, judgment, memory, and ability to react instantly. The [figure 8] shows the main screening of Youth over Flowers, the functional game for elderly cognitive function improvement.

As shown in [figure 9], the judgment test game is finding the same color and the same picture with the three pictures coming out on the top and designed to measure judgment not only putting drawings but also having background color.

In the memory test game, a picture is divided into four pieces, and one piece is shown at a time. The user finds the same picture with the whole picture in such that all pieces are together, and it is designed to measure memory.

The test for the ability to react instantly is a game shooting a slingshot when the passing target is located in the center and is designed to measure the ability to react instantly.

In the concentration test game, moles randomly come up from 9 holes, and the user hits the moles, which is designed to measure concentration.

The game utilizing Arduino based on the coordination action is designed to select an object that the user wants. In case of the bracelet, using actions moving left and right, an object that the user wants can be selected, while in case of anklet, actions moving into eight directions are used.

As presented in [figure 10], to enhance cognitive functions more efficiently by connecting cognitive, physical, and emotional characteristics in the process of changing touch-based game into coordination-action based game, the graphic design was newly constructed to match the emotion of the elderly.
If four tests, judgement, memory, ability to react instantly, and concentration, are completed, as shown in [figure 11] left, comprehensive information about the test is displayed, and based on the data in database, the information about whether it is lower or higher than the average can be checked. Moreover, after determining which part should be focused on in training based on the test result, it constructs a training game as shown in the [figure 11] right.

In this paper, the efficacy of Youth over Flowers, a dementia prevention game, implemented in this study, was verified. For this, 3-month experiment was conducted targeting 20 senior citizens in a welfare center located in Cheonan.

For the dementia prevention game, four kinds of cognitive function test games and four training games to improve cognitive functions were arranged. In this experiment, for group 1, 20 days of training was conducted using tablet PC touch only, and for group 2, it was conducted based on the coordination action interlocking with Arduino.[figure 13]

### 4 Experiment and Result

<table>
<thead>
<tr>
<th>Period</th>
<th>June to August 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>Place</td>
<td>Welfare center in Cheonan</td>
</tr>
<tr>
<td>Target</td>
<td>Welfare center 65-year-old or older(20 people)</td>
</tr>
<tr>
<td>Age</td>
<td>Male</td>
</tr>
<tr>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>60</td>
<td>5</td>
</tr>
<tr>
<td>70</td>
<td>7</td>
</tr>
<tr>
<td>Total</td>
<td>12</td>
</tr>
<tr>
<td>Substance</td>
<td>Efficacy verified of Dementia Prevention Game for the Elderly</td>
</tr>
<tr>
<td>Experimentation</td>
<td>Improvement of Cognitive Functions, Measurement of Response Time and Accuracy, Emotional Depression of the Elderly</td>
</tr>
<tr>
<td>Method</td>
<td>Group 1: Touch-based</td>
</tr>
<tr>
<td></td>
<td>Group 2: Arduino-based</td>
</tr>
</tbody>
</table>

Figure 12: Experiments overview

#### 4.1 Difference in Improvement of Cognitive Functions between Touch-based and Action Recognition-based Game

The differences in cognitive functions between the initial test game and after completion of 20 days of training were compared between the group 1, which used touch-based small muscles only, and the group 2, which received a training based on the coordination action using Arduino.

Figure 14: Improvement of cognitive functions between group 1 and 2
4.2 Measurement of Response Time and Accuracy

The differences in response time and accuracy between the initial test game and after completion of 20 days of training were compared between the group 1, which used touch-based small muscles only, and the group 2, which received a training based on the coordination action using Arduino.

![Figure 15: Measurement of Response Time and Accuracy between group 1 and 2](image)

4.3 Impact on Emotional Depression of the Elderly

To investigate the difference in the change of life satisfaction between using touch-based small muscles and conducting the training based on the coordination action utilizing Arduino, the degree of depression was tested for group 1 and group 2 at initial test game and after completion of 20 days of training.

![Figure 16: Emotional Depression of the Elderly between group 1 and 2](image)

5 Conclusions

In this study, a dementia prevention game for the elderly was developed combining four kinds of cognitive function improvement factors with a fun factor of the game in order to prevent dementia by enhancing typical cognitive functions associated with dementia, judgment, memory, ability to react instantly, and concentration, and by improving quality of life of the elderly. Additionally, a wearable device utilizing Arduino, as a method improving brain functions and body's motor skills at the same time, was made and incorporated into the game because cognitive, physical, and emotional characteristics of human develop not independently but affecting one another.

To verify the effectiveness of the game developed, 20 days of training was conducted targeting 20 senior citizens at a welfare center located in Choenan, dividing into group 1 using tablet PC touch function only and group 2 receiving a training based on the coordination action interlocking with Arduino. Through this experiment, it was confirmed that the degree of improvement of judgment, memory, ability to react instantly, and concentration was greater when the coordination action based training was given using Arduino than when small muscles were used by simple touch. As a result of measuring the degree of depression at initiation of the training and after completion of 20 days of training, it was found that the quality of life increased more when using Arduino.

In the future, further study will be performed to additionally develop a game that can improve cognitive functions and to make it more helpful in preventing dementia and keeping physical health by adding more efficient actions for the physical exercise effect through studies of actions of the elderly.
6 References


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