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AN ERGONOMIC STUDY FOR DEVELOPING A DIGITAL MUSICAL INSTRUMENT FOR THE ELDERLY

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Abstract. *Aging is significant worldwide issue and supporting the elderly is important economic, political and academic concern. It is estimated approximately 22% of Korean seniors are suffering from mild cognitive impairment (MCI) in 2017. Cognitive training and music therapy are known helpful for seniors with MCI. Reminiscence music therapy is believed to enhance behavioral and cognitive functions of normal older adults. Neurologists, ergonomists, products designers, music therapists and electric product developers cooperate in the study to develop a digital music therapy system. They discussed and decided the type of music instrument and generate concept design of the music therapy system. A pilot study was conducted to understand preferences and behavioral characteristics of the elderly before developing the system. Eleven seniors played familiar songs with the digital keyboard mockup and their behaviors were recorded and analyzed. The dimension for the keyboard mockup was anthropometrically determined considering proximal finger breadths. We learned the colors of the keys are not enough for the elderly to differentiate keys when playing music and decided to print number on the keys additionally. The elder persons make more.*

Keywords: Aging, Mild cognitive impairment (MCI), Music therapy, Music instrument

1. **Introduction.** Aging is an inevitable and significant worldwide phenomenon. The global number of the persons aged 60 and over was 382 and 962 million in 1980 and 2017 respectively. The number of people aged 80 years or over was 137 million in 2017 and predicted to increase to 425 million by 2050. The elderly population is expected to reach 2.1 million in 2050 [1]. Aging is an extensively studied issue in the human-computer interaction discipline [2].

The aged people might have problems in their activities of daily living (ADLs) because of badly designed environment, products, systems, etc. Especially older adults with dementia or mild cognitive impairment (MCI) would suffer from daily products and activities.

We conducted an experiment to develop a music therapy system for the seniors with MCI. The system is composed with a specially designed keyboard, percussion and main control device. Music and reminiscence therapies are believed to enhance behavioral and cognitive functions of older persons [3,4].

Proper cognitive training could be more useful than pharmacological treatment for the seniors in early stage of dementia [5,6]. Non-pharmacological therapy is actively studied recently for its effectiveness [7]. Nonverbal nature of music is very useful for interacting with senior people and music easily elicit body movement stimulating perceptual and behavioral systems [8,9].

The number of Korean older people with MCI is estimated 1.5 million and approximately 22% of senior people MCI patients in 2017 [10]. There are 17 metropolitan dementia

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centers in Korea founded by Korean Dementia Management Act. 227 dementia counseling centers are established in the local health centers.

Digital device and serious game could be practical and helpful for the aged people to enhance their accurate movement and mental abilities [11]. In this study, we developed several digital music device concept design and conducted a pilot study to evaluate and improve the design. We developed a paper and acrylic keyboard prototype after conducting several professional workshops by neurologists, ergonomists, product designers, music therapists and electrics developers.

Older people participated in the experiment and they were observed how to play music with the paper prototype keyboard. The number of errors and response times in playing the keyboard were measured and analyzed. The perceived workload was assessed by Raw Task Load Index (RTLX), simplified NASA-Task Load Index (NASA-TLX) [12]. NASA-TLX was developed to measure subjective perceived workload by rating 6 factors such as mental demand (MD), physical demand (PD), temporal demand (TD), performance (OP), effort (EL) and frustration (FL).

2. Method.

2.1. Participants.

Eleven seniors (3 men and 8 women) participated in the study and received payment. The subjects ranged in age from 64 to 92 (M = 76.9, SD = 6.92). Five participants reported having experience in playing musical instruments.

2.2. Materials.

Several melody instrument designs were proposed for the project and the keyboard was selected (Figure 1). An anthropometric study was conducted and main specifications were decided.

FIGURE 1. Proposed melody musical instruments

Critical dimension for the keyboard is the length and width of the keys. The size of piano white key is 2.3cm × 15cm and black key is 1cm × 9.8cm. Proximal index, middle and ring finger breadths are related to the key width (Figure 2). The elderly users would play the keyboard with their index, middle, ring finger or combination of the fingers because of their inaccurate finger movement and weak finger muscle strength. The age range of the keyboard users was expected from 60 to 75 and the sum of 95^{th} percentiles of the users' index, middle and ring finger breadth was 5.3cm. Therefore, the specification of the key was decided as 5.3cm × 15cm. A paper mockup was produced for the experiment.

2.3. Experimental design.

The experiment was completely randomized two-factor within subject factorial design with unbalanced replication. The tempo of songs and number of strokes were independent variables. Time gap, the number of errors, and the perceived workload were dependent variables.

Time gap was defined as the absolute value of time difference in second between the accurate key pressing time and actual key pressing time. Sum of time gaps was divided

FIGURE 2. Proximal index finger breadth

FIGURE 3. Snapshot of the experiment

by the correct number of key presses to calculate mean time gap. Time gap was measured for evaluating the speed of the play.

When the participants pressed the wrong key or missed key press it was assessed as error. Total number of wrong key presses was divided by the expected total number of key presses and defined as error ratio.

2.4. **Procedure.** Purpose, procedures, risks and benefits of the experiments were briefly explained to the participants and informed consent was obtained. The participants played the trial songs and repeated the trial procedure until they felt adapted to the environment and the keyboard. The participants were instructed how to play the music.

The participants played two different (slow and fast) songs with two different numbers of strokes and repeated the procedure one more time after a short break (Figure 3). They evaluated the perceived workload for each situation in the second experiment procedure. A researcher guided which keyboard should be played by indicating the lyrics and key

numbers with a stick pointer. The seniors were supposed to press the proper key when the corresponding lyric was pointed. The experiment was recorded for the analysis with the participants' consent.

3. **Results.** It took approximately 30 minutes for each participant to complete the experiment. The mean number of errors is given in Table 1. Participants made more errors on songs with faster tempo and more strokes. Table 1 shows error ratios for the different rhythm and number of strokes.

TABLE 1. Error ratios due to the tempo and the number of key strokes

Slow & Few	Slow & More	Fast & Few	Fast & More
0.32 ± 0.73	1.16 ± 1.3	1.72 ± 2.01	3.28 ± 3.03

The Friedman test showed the error medians were significantly different for the comparisons ($p < .001$). Wilcoxon test was conducted to evaluate comparisons between pairs of medians and all pairs showed significant differences except Slow & More and Fast & Few at $\alpha = .02$ (Figure 4).

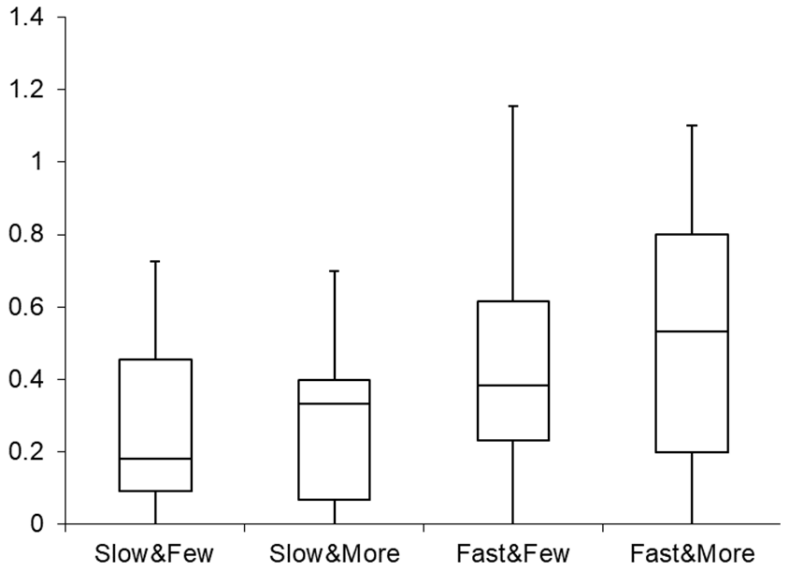

FIGURE 4. Mean number of errors

The participants were instructed to press correctly numbered color keys when the mark was presented and pointed on the screen. The time difference between the correct key press time and actual key press time was defined as time gap. Mean time gaps are presented in Table 2.

TABLE 2. Mean time gap due to the tempo and number of key strokes

Slow & Few	Slow & More	Fast & Few	Fast & More
0.24 ± 0.24	0.26 ± 0.21	0.46 ± 0.34	0.53 ± 0.39

The Friedman test showed the time gaps were significantly different due to the tempo and the number of strokes ($p < .001$). Wilcoxon test was conducted for follow-up test and detected all pairs were significantly different except Slow & Few - Slow & More and Fast & Few - Fast & More ($\alpha = .005$).

The results of NASA-TLX measurements for the different tempo and the number of strokes were presented in Figure 5.

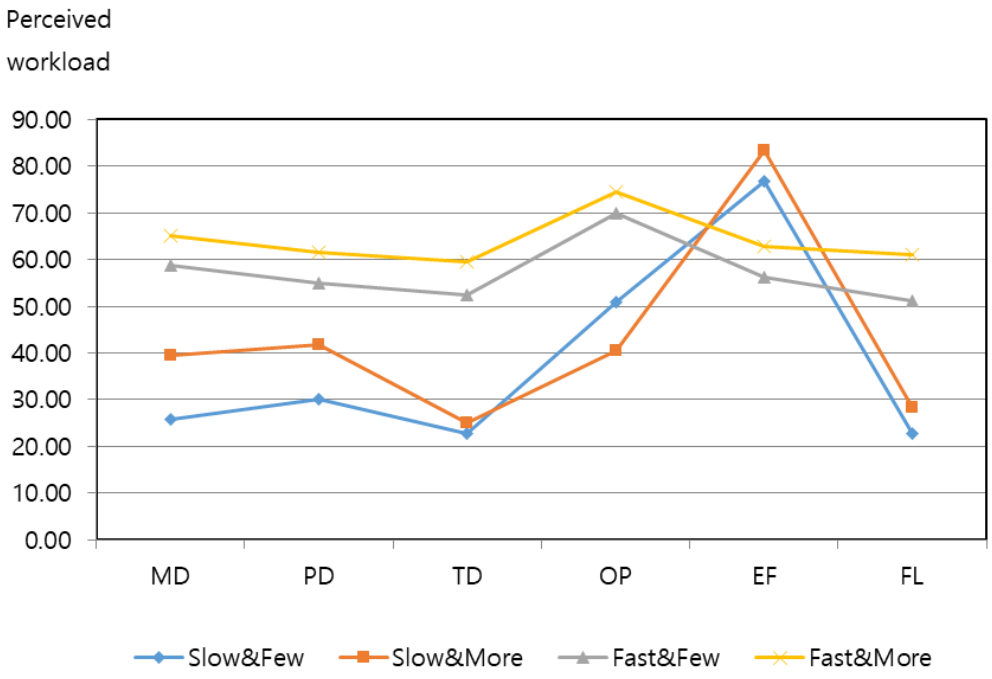

FIGURE 5. Perceived workload measured by NASA-TLX

The participants felt the number of key strokes is more significant than the tempo of songs for assessing the workload of players.

4. **Conclusions.** Music and reminiscence therapy is effective for the aged people and especially older adults with MCI. To develop a digital music instrument for the elderly an ergonomic empirical study was conducted to decide the conceptual design and specification of the keyboard.

We found training could enhance the playing skill of seniors and they can perfectly play easy songs after repetition. Anthropometrically designed key board dimensions were assessed as acceptable and satisfactory.

The older adults make more errors when the tempo of song is fast and more key presses are required. When the song is fast music therapist can adjust the difficulty by decreasing the number of key presses and vice versa.

Proper feedback is very required for giving effective treatment to the older players and judging system is essential for the digital music system. If users' key stroke is later than .26 and .53 seconds for slow and fast song respectively, it can be evaluated as wrong play.

The perceived workload is also affected by the tempo and number of key presses. In the future study, the relationship between play score and workload would be studied further. A pilot study was conducted for developing a digital music system in the study. Some characteristics of the elderly were analyzed and the results can be applied to developing the system.

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