Accuracy of reaching a target key by trained pianists.

Chie Ohsawa,[*1] Takeshi Hirano,[*] Satoshi Obata, [*] Taro Ito, [#] Hiroshi Kinoshita[*]

[*]*Graduate School of Medicine, Osaka University, Japan*

[#]*School of Health and Sports Sciences, Mukogawa Women's University, Japan*

[1]c-ohsawa@moted.hss.osaka-u.ac.jp

ABSTRACT

Background

Findings of recent neuro-physiological studies have repeatedly shown that any tools after an extended period of practice form tool-use specific neural network in the user's brain (eg., Maravita and Iriki 2004, Johnsson-Fry 2004). The tool thus can be represented in the brain as a part of the user's body. Musical instruments including the piano can be viewed as tools for musicians. To be an established pianist, he/she has to spend hours of deliberate practice striking the keys of the piano daily for more than a decade (Ericsson et al. 1993). It is thus quite possible to assume that a keyboard of the piano is represented in the brain of highly trained pianists. We hypothesized that pianists with years of training would possess fairly accurate spatial memory of a keyboard, and thus able to target any key position without viewing a keyboard.

Spatial accuracy of locating fingers on a musical instrument has been reported by several researchers of string instruments. Chen, et al. (2008) demonstrated that while trained cellists located the left finger on a target intonation without viewing the fingerboard, additional fine tuning of the intonation was commonly made by sound feedback. The findings indicated that cellists were always making re-calibration and updating of the spatial map during their performance.

Aims

The aim of the present study was to investigate accuracy of key position memory in highly trained pianists.

Methods

Ten active right-handed pianists (6 females, 4 males, age = 26.5 + 5.8 yrs.) with at least 15 years (22.1 + 5.2 yr) of formal piano training participated in the present study.

The experimental set-up consisted of Qualisys 3D motion capture system with four Oqus300 cameras mounted on 2-m tripods, two PCs, a pair of speakers, a table-top type score stand, a cardboard covered by a full scale copy of piano keyboard, a experimental table and front panel boards all covered by a plain black cloth, and a height-adjustable piano chair (Figure 1).

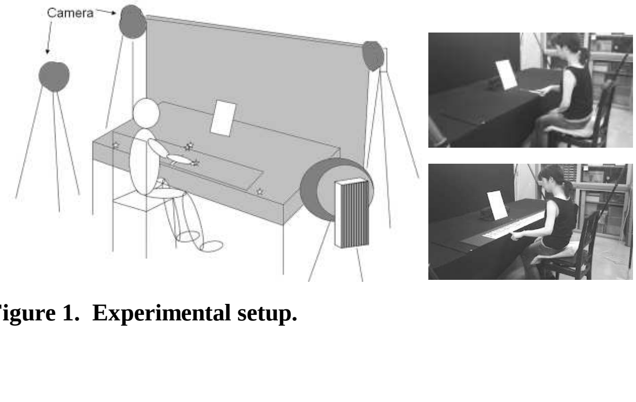

Figure 1. Experimental setup.

The participants seated on the chair viewed a sheet of the score showing task tones to be played. Then they waited to hear pairs of premade midi tones informing the two keys to be hit by their right or left index finger. The initial tone of the pairs was always C4 as a reference tone while the second tone was one of the followings; C2, C3, E3, A4, C5, C6, and in addition, A1, F2 for the left hand, G5, E6 for the right hand. Each tone was generated for 3 sec, which was followed by a 3-sec rest period. The participants moved their finger to hit the key or assumed key position simply by following the tones presented visually and auditory. Each participant performed these tasks with (keyboard condition) and without (no-keyboard condition) the keyboard sheet. For the no-keyboard condition, only a copy of the C4 key was present. The order of the presentation of the paired tones was randomized for each participant, and 10 trial data were collected for each pair.

In the beginning of experiment, the participant practiced all experimental tasks until they felt comfortable to perform. Then, the experiments for the no-keyboard condition followed by the keyboard condition were performed by each hand. The hand order was counterbalanced for each participant.

Kinematics of the fingertip was recorded by motion capture system sampling at 60 Hz. All 3D fingertip position data stored were recalibrated off-line so that the midpoint of the near edge of the reference key was the origin of the 3D space in the subsequent kinematics computation. The fingertip-key contact point was determined by the mean horizontal displacement data for 500-ms period of the steady state position in the later half of the 3-sec finger-target-key contact period. Three parameters of movement variability were computed for the data of each trial. These were the constant and absolute errors. The first parameter was individual mean of the differences in horizontal distance between the finger position and the center of the target key, the second was the individual mean of absolute values of the differences and last was the individual SD of the differences.

Two-way repeated measures ANOVA was performed for each of the experimental conditions using each of the error data as dependent variable. The independent variables examined were hand (right or left), and key distance (6 degree, 1 octave and 5 degree, or 2 octave and 3 degree; E3/A4, F2/G5, or A1/E6 for right/left hand) from reference key (C4).

Results and Discussion

The keyboard condition

The mean values of absolute, constant, and variable errors for the keyboard condition were all less than 3 mm. ANOVA revealed no hand and distance effect in the absolute and variable errors. There was a significant distance effect on the constant error ($F_{(2,18)}$=10.82, p=0.001). However, the difference in the mean values in any distance was less than 2 mm. These results of the small errors were expected because the participants moved their testing arm and finger to a target key at a free chosen speed. In addition, the task was much easier than their daily practice of the piano.

The no-keyboard condition

The mean values of the absolute error for the no-keyboard condition showed a larger error for a more remote key, and greater errors for the left hand than the right hand (Figure 2). ANOVA revealed significant main effect of distance ($F_{(2,18)}$=9.28, p=0.027), and hand ($F_{(1,9)}$=12.09, p=0.007). The hand × distance interaction was non-significant. The greater error with distance should be due to the effect of tradeoff between accuracy and distance of reaching. The hand x distance effect was because the distance effect was greater for the left hand than the right hand. The hand effect can be due to the effect of right-left asymmetry in their spatial memory of the keyboard, and/or handedness.

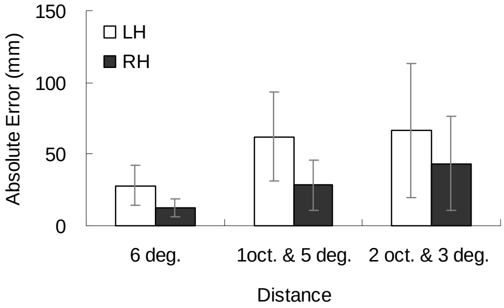

Figure 2. Absolute errors in the no-keyboard condition

The constant error provides information on the direction of the error; overshooting or undershooting. As shown in Figure 3, the mean values of all constant errors at all three distances and both hands had positive value. The participants were thus commonly targeted their believed key position to be at more remote position than the actual position. ANOVA revealed significant main effect of distance ($F_{(2,18)}$=4.59, p=0.024) and hand ($F_{(1,9)}$=11.30, p=0.008). The distance x hand interaction effect was non-significant. The result that the overshooting was greater at more remote keys suggested that the keyboard in their memory could be expanding with distance. The hand effect indicated that the overshooting was less for the right hand. The findings suggested that the left side of the keyboard could be represented larger than the right side. This may also be related to asymmetry in keyboard's spatial memory.

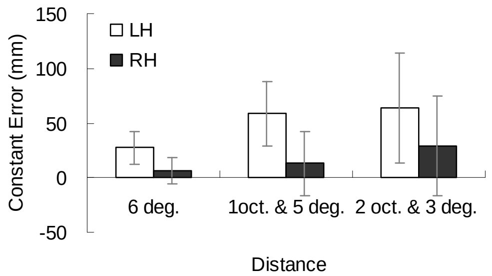

Figure 3. Constant errors in the no-keyboard condition

The variable error indicates the stability of targeting the finger on the key (Figure 4). ANOVA revealed a significant main effect of hand ($F_{(1,9)}$,=13.56, p=0.005), and distance ($F_{(2,18)}$=12.12, p=0.000), and their interaction ($F_{(2,18)}$=11.01, p=0.001). The interaction was resulted because a larger error at the middle distance and smaller error at remote distance were present for the left hand compared to the other distance and hand conditions. The interaction was resulted because the error for the right hand increased with distance whereas it did not for the left hand. The reason for this interaction was, however, unknown. The decreased consistency of estimating the key by the left hand, and at greater distance was due most likely to less accurate spatial memory of the left side and more remote keys, which supported the findings of the absolute error.

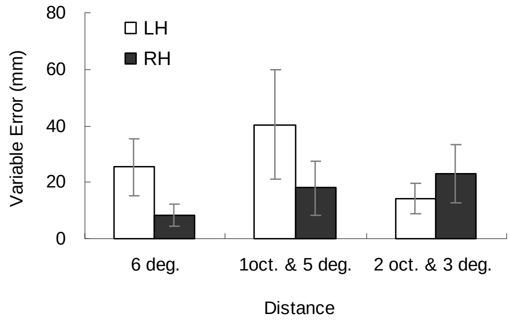

Figure 4. Variable errors in the no-keyboard condition

Conclusions

The spatial memory of the piano keyboard in highly trained pianists was less accurate than expected. The piano may be represented as a tool in their neural network, but because of its large size, the keyboard representation seems to be not precise as those for small handheld tools. It is also possible to note that since pianists are always able to view the keyboard, and rarely train blind key touch, refined spatial memory of the keyboard may not be developed.

The spatial memory of the piano keyboard had right-left asymmetry. The lower errors of the right side indicate higher accuracy of its spatial memory of the keys. This seems to reflect a demand of a higher accuracy for playing melodies by the right hand.

A comparative study of beginners of the piano is needed to compare with the current results in order to find the effect of extensive piano training on spatial memory of the keyboard. More detailed examination of the hand and laterality effects on spatial memory of the keyboard is also needed in the future work.

Keywords

piano, keyboard, spatial representation, spatial error, laterality

REFERENCES

Chen, J., Woollacott, M. H., Pologe, S., & Moore, G. P. (2008). Pitch and space maps of skilled cellists: accuracy, variability, and error correction. *Experimental brain research. 188*(4), 493-503.

Ericsson, K. A., Krampe, R. T., Tesch-romer, C., Ashworth, C., Carey, G., Grassia, J., Hastie, R., et al. (1993). The Role of Deliberate Practice in the Acquisition of Expert Performance, *100*(3), 363-406.

Johnson-Frey, S. H. (2004). The neural bases of complex tool use in humans. *Trends in cognitive sciences*, *8*(2), 71-78.

Maravita, A., & Iriki, A. (2004). Tools for the body (schema). *Trends in cognitive sciences*, *8*(2), 79-86.