

Effect of background music in a computer word processing task

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Abstract.

BACKGROUND: The relaxing effect of music has been shown to reduce stress induced subjective anxiety and improve the performance of stressful cognitive tasks.

OBJECTIVE: This experimental study evaluated the effect of music and induced mental load in a word processing task in terms of correct strokes and accuracy, typing force, variability of typing force and EMG (electromyography) of extensor digitorum muscle.

METHODS: Eight subjects participated in the study. A 2×2 repeated measure design was adopted, with or without background music, and with or without induced mental load. A computer algorithm detected the shift, drift and fidget patterns of finger and hand movements, which caused the variation of the typing force.

RESULTS: Although the overall typing productivity was compromised by music by 3.1%, the beneficial effect of music was the reduction of standard deviation of typing force by 23.2%, indicating a smoother or less erratic hand movement during typing.

CONCLUSIONS: The behavior change by music resulted in reduction in hand motions during typing may reduce the risk of musculoskeletal disorder related to typing task.

Keywords: Keyboard, force variability, EMG

1. Introduction

How music influences human behavior and performance is an elusive problem. Music has been employed as a means of easing the monotony of factory work, and simultaneously aiming to improve productivity levels [1]. With the prevalent use of personal-stereo headset, portable music player, and other mobile devices, study found that employees in the stereo condition exhibited significant improvements in performance, turnover intentions, organization satisfaction, mood states, and other responses, and employees in relatively simple jobs responded most positively to the stereos [2]. In a multi-attribute decision-making test [3], participants made decisions more accurately with the presentation of faster than slower tempo music, and faster tempo music was found to improve the accuracy of harder decision-making only, not that of easier decision-making. In an attention test, those who listened to music prior to testing obtained higher scores in attentiveness, whereas those who listened to music during the test showed extremely high level of variation in the test scoring [4]. Comparing to no music, background

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music has a positive impact on emotional reactions in reading comprehension tasks [5]. Computer programming is a mentally demanding task, and it requires both verbal and logical analysis. Lesiuk [6–8] collected data from information system developers working with preferred music, and results showed that state positive affect and quality-of-work were lowest, and time-on-task was longest without music, and narrative responses revealed the value of music listening for positive mood change and enhanced perception on design while working.

In terms of preferred music versus non-preferred music, the reading-comprehension test scores revealed that the participants scored significantly lower after they had been listening to the non-preferred music while reading, compared with reading in silence [9]. Compared to situations without background music, the likelihood of background music affecting test-taker attention performance is likely to increase with the degree to which the test-taker likes or dislikes the music [10].

The different content of music also has different effect. Music without lyrics is preferable because songs with lyrics are likely to reduce worker attention and performance [11]. During a verbal test study [12], overall performance for all participants was significantly better in silence, supporting the idea that lyrics interfere with the processing of verbal information in the task.

Using music to improve human performance, tasks are recommended to be performed in relatively quiet environmental settings, otherwise music might be overwhelmed by noise. Music may increase mental load because the brain has to process the information. Therefore, music may have a positive influence on human performance when the task itself causes relatively low mental load. A good effect of music is positive mood induction [6]. It relaxes mental tension and inspires us in the long term [13].

Nowadays, computer work is prevalent, and keyboard use is a common feature of everyday life. Keyboard use has been implicated as a potential risk factor for carpal tunnel syndrome and a variety of other musculoskeletal disorders (MSD), including epicondylitis [14]. According to Bureau of Labor Statistics and some other studies, upper extremity MSD associated with computer keyboard use is an important concern in occupational health [15,16] due to its high prevalence rate. Since computer keyboard use can be characterized by repetitive finger movements, these disorders may arise from cumulative effects of transient loads on the tissue through repetitive muscle activations.

Word processing tasks are a significant part of daily routine work, and require focus and concentration, which may lead to mental stress and mental fatigue. Since it is becoming common in offices to listen to music while at work [2,3], music may have some relaxing influence on human in reducing job related stress. Psychophysiological stress response has been known to increases muscle tension in repetitive manual tasks [17], and if music with its relaxing effect can reduce muscle tension it could potentially reduce MSD risk. At present, there is no research on direct physiological and psychological effect of music on computer word processing tasks. The objective of this study was to investigate the effect of music and mental load induction on typing productivity, typing force and EMG activity extensor digitorum muscles in word processing task.

2. Method

2.1. Participants

Eight male graduate students (average age 29) participated in the study. All participants were right-handed, in good physical health, no history of hand and forearm musculoskeletal symptoms, and were able to read and write English well.

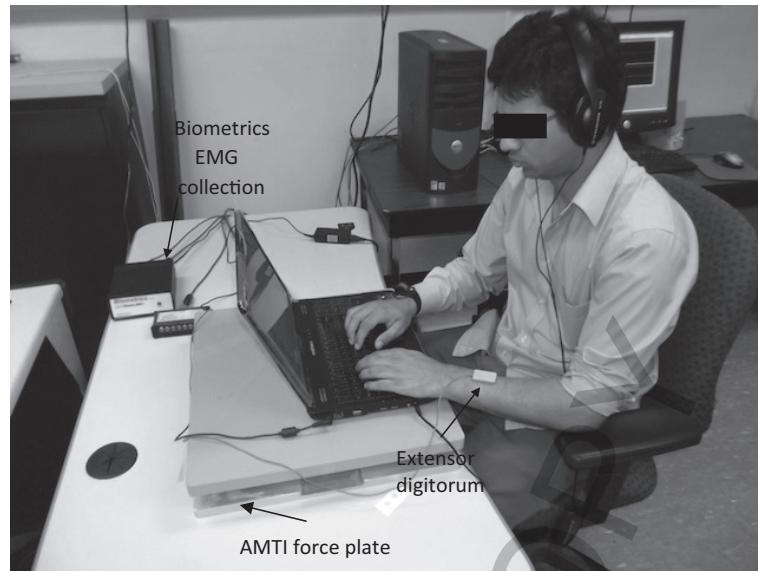


Fig. 1. Experimental configuration.

2.2. Instruments and materials

Figure 1 shows the experimental configuration. An AMTI force plate [18] was placed on a height adjustable table (59 cm–128 cm), and an Emachines E525 laptop computer was placed on the force plate. Vertical typing force was collected by AMTI's NetForce software with frequency of 50 samples/second and resolution of 0.7 N/bit for later analysis by AMTI's bioanalysis software, the forces in x and y axes were recorded, but not used in this study. Furthermore, we investigated the underlying cause for variability of typing force using a computer algorithm which determined the specific hand movement patterns in the force-time series. Details of the algorithm and the results have been presented in the result section to facilitate better understanding of the parameters being measured, and the related results.

EMG data was collected and analyzed by DataLINK PC software Version 2.00 (Biometrics Ltd.) through DataLINK Base Unit connected to an active bipolar EMG electrode with sampling rate of 1000 data/second and sensitivity of 300 mV. On cleaned and abraded skin surface of hand and finger extensor (extensor digitorum) muscle, electrolytic gel was applied and the EMG sensor (Biometrics type SX230) was adhered to the skin with double-faced adhesive tape. To elicit the potential muscle fatigue within a short time frame of the experimental trials, non-dominant hand was chosen. The sensor circuitry employs a differential amplifier with common mode rejection ratio of greater than 96 dB and very high input impedance of the order of 10^{15} ohms. The amplified data passes through a high pass filter to reduce motion artifacts and a low pass filter to remove unwanted frequencies above 450 Hz. The placement of the electrode followed recommendation by Basmajian and Blumenstein [19].

An adjustable office chair with armrest was used for the task to simulate an office workplace. The seat height of the chair were adjusted by the individual participants to their preference, then the table height was adjusted to obtain a relaxed but upright upper body posture and the participant felt comfortable using the laptop keyboard. The reading of force plate and EMG was reset to zero when participants put their hands away from keyboard relaxingly. Music was played by the same laptop computer, and output from a Sennheiser HD 202 headphone.

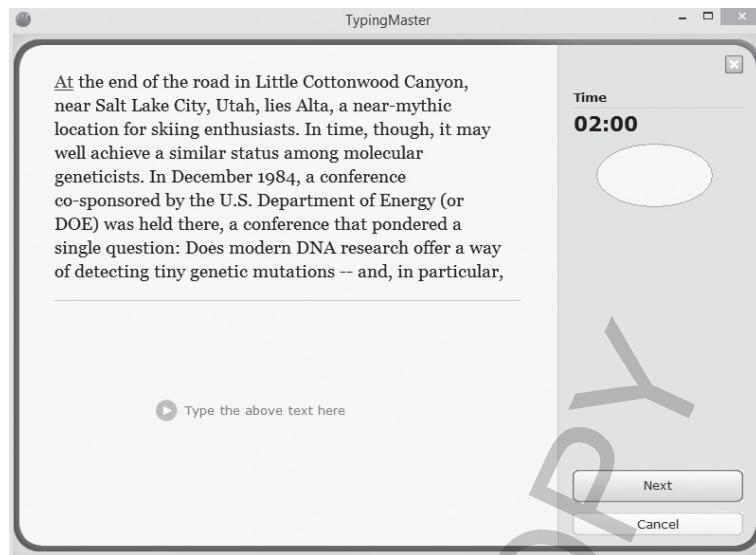


Fig. 2. Word processing task interface in TypingMaster Pro.

2.3. Experimental procedure

Participants performed a word processing task for 10 minutes using TypingMaster Pro software in 2*2 trials, administered randomly: with or without background music, with or without mental load induction. Following a similar method used by Rietveld et al. [20], the mental load was induced by administering an IQ test [21] of 10 minute duration immediately before the word processing task. The participants were urged to do their best in the IQ test. Between each trial, participants were given a break of five minutes or more to relax, until they were ready for the next trial. In TypingMaster Pro (Fig. 2), participant could see the typing text in the upper part of the screen and time counting down in the right part of the screen. They typed in the lower part of the screen for 10 minutes in each trial. The software allowed participants to return and correct wrong letters in one word, but once SPACE key was pressed for that word, participants could not return and correct the word. If a word was wrong, it was counted as an error. The page turned automatically after it was completed. The text paragraphs were taken from GMAT reading comprehension test and were relatively in the same readability level. Several previous studies [6–8,22,23] found the beneficial effect of music, when participants chose their own preferred music. Accordingly, in our study, participants were informed to bring about ten pieces of music they want to listen while they would be doing a monotonous word processing task.

2.4. Data processing

TypingMaster Pro reported net typing speed in terms of correct number of words typed per minute, accuracy in terms of percentage of correct key strokes, and the productivity in terms of total correct key strokes typed within 10 min. Mean and standard deviation of typing force, root of mean square (RMS) of EMG were calculated from the data collected between 8 and 9 min, when these responses were expected to become fairly steady. Since the statistical analysis of variance employed in this study used a repeated measure design with participants as blocking factor, EMG values were not normalized.

Table 1

Overall average of typing performance, typing force, standard deviation of typing force and RMS EMG for each participant

Participant	Net speed (wpm)	Accuracy (%)	Correct strokes	Typing force (N)	SD of force (N)	EMG (mV)
1	44	96	2219	15.1	1.26	0.040
2	38	95	1932	15.7	2.39	0.038
3	29	96	1442	20.7	2.44	0.035
4	30	96	1512	17.2	3.33	0.040
5	39	92	1975	17.6	2.14	0.042
6	57	94	2849	30.9	1.68	0.041
7	65	94	3237	24.4	1.17	0.030
8	23	94	1143	0.6	0.71	0.032
Average	41	94	2038	17.8	1.89	0.037
Standard deviation	14.5	1.3	714.7	8.73	0.85	0.005

Table 2

Main effects of music and induction of mental load on typing accuracy, net strokes, standard deviation of typing force, typing force and EMG

	Without music				With music			
	Without mental load induction		With mental load induction		Without mental load induction		With mental load induction	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Accuracy	94.8%	2.1%	94.9%	1.3%	94.3%	2.1%	93.4%	2.6%
Correct strokes	2047.8	685.0	2094.0	707.0	2006.3	627.0	2005.6	660.0
Standard deviation of force	0.56	0.31	0.50	0.31	0.43	0.27	0.52	0.27
Typing force	4.20	2.26	4.12	1.99	3.78	2.12	3.87	2.09
EMG	0.0384	0.0073	0.0330	0.0063	0.0405	0.0059	0.0387	0.0042

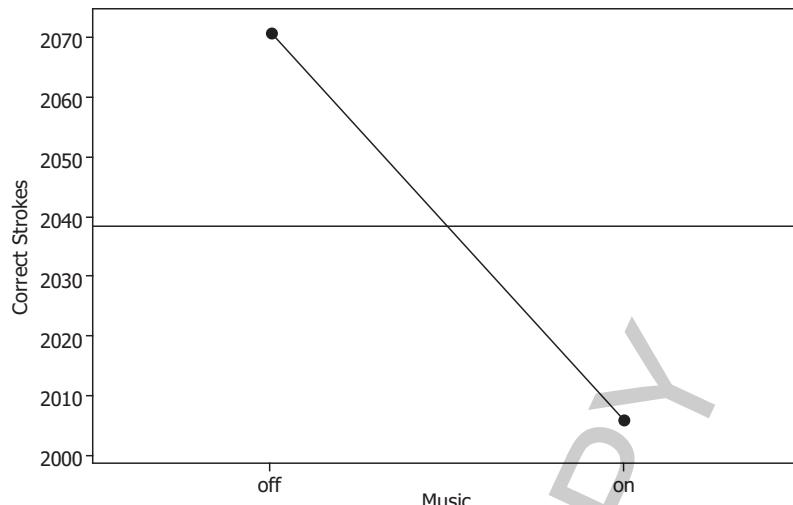
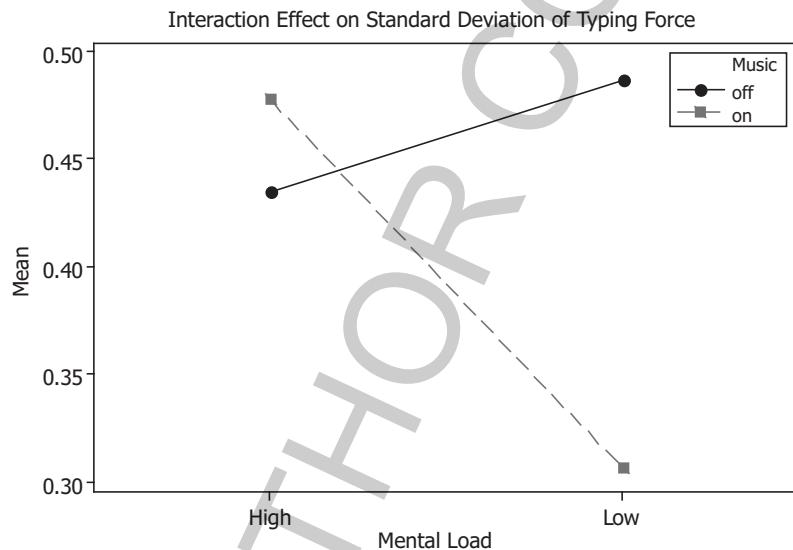
3. Results

3.1. Overall means

The mean values of analyzed responses over 4 trials for each participant are presented in Table 1. The overall average typing speed and accuracy of the participants reached 41 wpm and 94%, respectively. Although typing proficiency varied widely between participants, 23 to 65 wpm, accuracy scores were close, between 92–96%. Average typing force of participant 8 was much lower compared to the other participant. This was because he used typical finger typing rather than touch typing. He did not rest his wrist on the keyboard when typing. In analysis related to typing force, his data were excluded. For participants with high productivity, standard deviation of typing force seemed lower than participants with low productivity excepting participant 8. The RMS EMG between participants ranged between 0.030 mV to 0.043 mV.

3.2. Statistical analysis

ANOVA test was conducted with a repeated measure design with participant as a blocking factor using Minitab15. The main effects of music and mental load induction on typing productivity, typing accuracy, typing force, standard deviation of typing force, and RMS EMG of extensor digitorum muscle are presented in Table 2. The statistical significance level was set at 10%. Music significantly reduced productivity in terms of correct strokes ($p = 0.046$) (Fig. 3). Overall, music decreased correct strokes from 2070.9 to 2005.9, by 3.1%, from 2094.0 to 2005.6 by 4.2% with mental load induction, and from

Fig. 3. Effect of music on correct strokes ($p = 0.046$).Fig. 4. Interaction effect of music and mental load induction on standard deviation of typing force. Standard deviation of typing force significantly decreased ($p = 0.051$).

2047.8 to 2006.3 by 2.0% without mental load induction. Induced mental load had no significant effect on productivity.

Music or induced mental load had no effect on typing accuracy or typing force. The interaction effect of music and mental load induction had statistically significant effect ($p = 0.051$) on the standard deviation of typing force (Fig. 4). Music decreased standard deviation of force by 23.2% without mental load induction, and increased it by 4% after mental load induction.

Both music ($p = 0.035$) and mental load induction ($p = 0.023$) had significant influence on RMS EMG (Fig. 5). Music increased RMS EMG by 10.9%, and mental load induction decreased it by 9.1%.

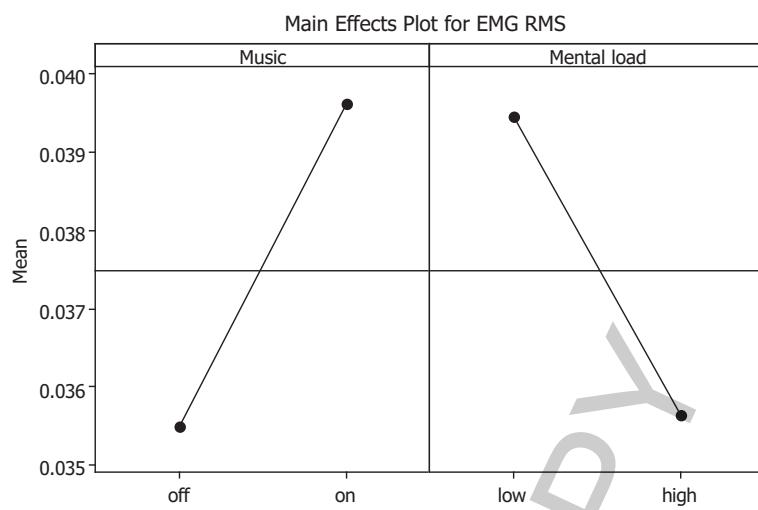


Fig. 5. Main effects of music ($p = 0.035$) and mental load induction ($p = 0.023$) on EMG RMS.

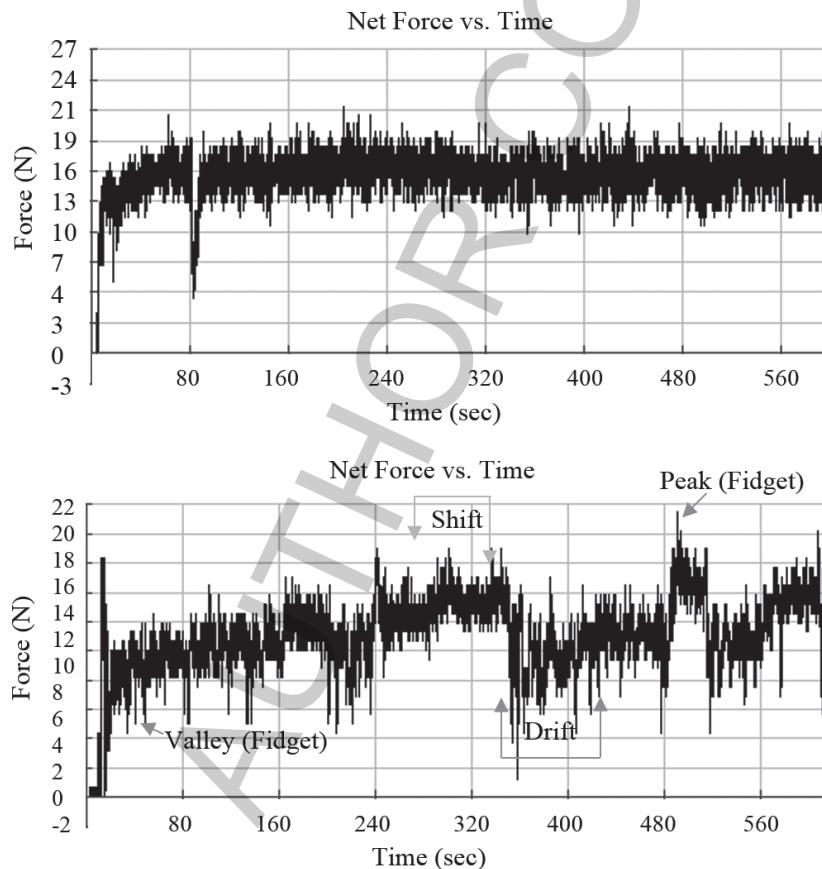


Fig. 6. Typical samples of vertical force plot between typist with high productivity and typist with low productivity.

3.3. Analysis of variability of typing force

The force recorded by the AMTI force plate at 50 Hz, that not only captured change in typing force arising from key pressing and releasing, but also it captured the inertial forces from gross hand movement over the keyboard. Since music decreased standard deviation or variability of typing force significantly (23.2%, $p = 0.051$) in the absence of mental load induction, we decided to further investigate the underlying cause for this reduction in variability. We used a computer algorithm proposed by Duarte et al. [24] to determine three specific patterns, fidget, shift and drift in the force-time series. Figure 6 shows two time series plots of typing force with low and high variability and explains these patterns. Fidget was defined as the fast and pulse-like displacements, noted as peaks and valleys, followed by a return of the force to approximately the same level. The fidget pattern corresponds to change in typing force from fast up and down motion of finger to press and release the individual keys. Shift was defined as a step-like displacement of the average force from one level to another, and drift was defined as a slow continuous ramp-like displacement of the average force. Comparatively slower hand repositioning over the keyboard, that would be required to reach to a specific key, or moving the hand from one row of keys to other or changing the contact point of the base of the wrist should be associated with shift and drift patterns of typing force variability.

The following algorithm was implemented by Matlab to determine the number, length and position of these patterns.

In a moving window ($w = 20$ sec), any peak or valley typing force (x_F) satisfying Eq. (1) was classified as a fidget. When the amplitude of the difference of x_F from the mean typing force (\bar{x}_w) over the window in terms of the standard deviation of force (SD_w) exceeded a cutoff value ($f_{fidget} = 3$), it was counted as a fidget.

$$\left| \frac{x_F - \bar{x}_w}{SD_w} \right| \geq f_{fidget} \quad (1)$$

For any two consecutive non-overlapping moving windows ($w_1 = 5$ sec and $w_2 = 5$ sec), if the amplitude of the difference in the mean typing forces in terms of joint standard deviation, exceeded a cutoff value ($f_{shift} = 2$) satisfying Eq. (2), it was classified as a shift.

$$\left| \frac{\bar{x}_{w1} - \bar{x}_{w2}}{\sqrt{SD_{w1}^2 + SD_{w2}^2}} \right| \geq f_{shift} \quad (2)$$

If the absolute difference between the amplitudes of two consecutive local maximum (x_{max}) and minimum (x_{min}) in a moving window ($w = 20$ sec), in terms of SD_w exceeded a cutoff value ($f_{drift} = 1$), the displacements between the consecutive maximum and minimum were classified as a drift (Eq. (3)).

$$\left| \frac{x_{max} - x_{min}}{SD_w} \right| \geq f_{drift} \quad (3)$$

The windows moved 1% of the length of a base window until covering all data, so the unit time added to a detected pattern was 1% of the length of a base window if the detected pattern continued for a while. The Matlab program counted the number and duration of fidget, shift and drift patterns between the 8th and 9th minute of the typing force data.

These additional three dependent variables were analyzed using the same ANOVA statistical model, the effect of the interaction of music and mental load was significant for number ($p = 0.010$) and time duration ($p = 0.040$) of shift patterns. Music decreased number of shifts (37%) and duration of shift (58%) patterns when mental load was absent. The changes in the number and duration of fidget and drift were not significant.

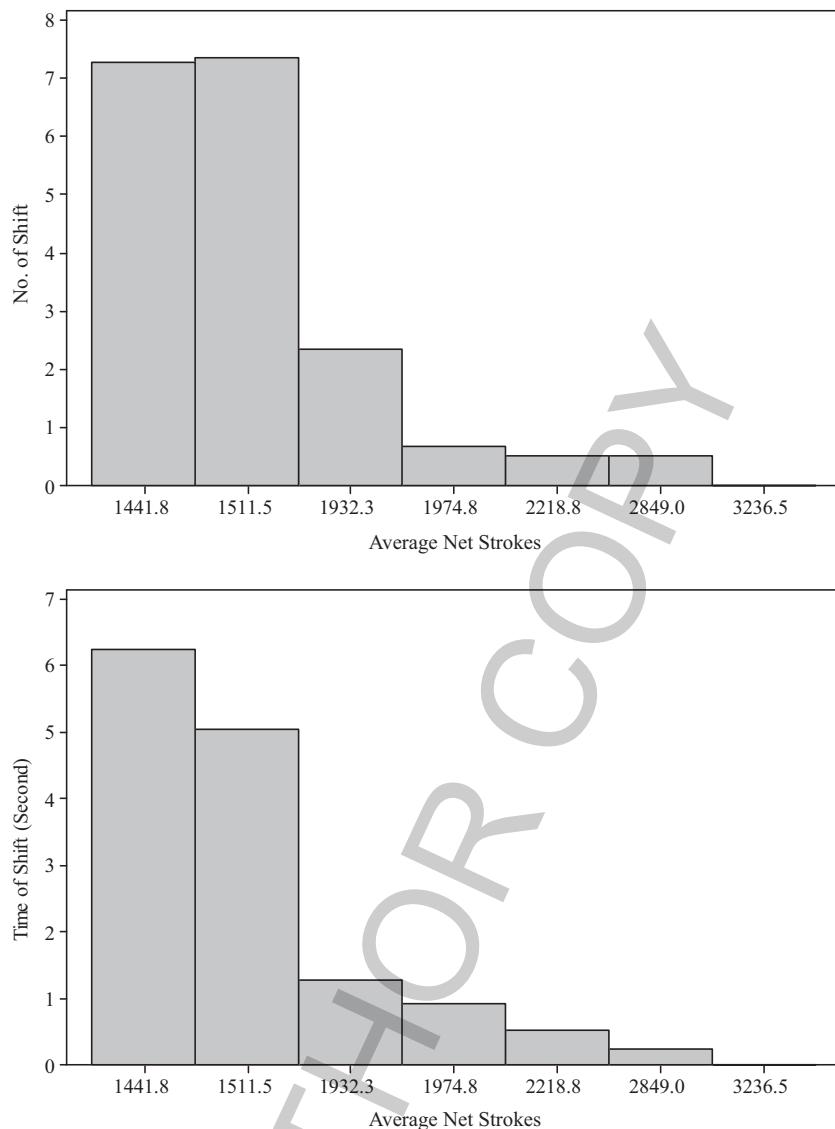


Fig. 7. Correct strokes vs. shift for each participant.

4. Discussion

In our study, music significantly decreased productivity, which was due to the distracting effect of lyrical music, from verbal coding perception interference described by Wickens and Hollands' [25] well known multiple-resource theory. Martin et al. [26] found no interference between instrumental music and reading comprehension, but did find that comprehension suffered when lyrics were added. However, in our experiments, all participants selected pop music with lyrics, and the compromised productivity by music was expected from multiple resource theory, since the verbal coding perception overlapped in the word processing task while listening to music with lyrics.

The relaxing function of music is often utilized in bars, stores, supermarket, banks, and hospitals [27–

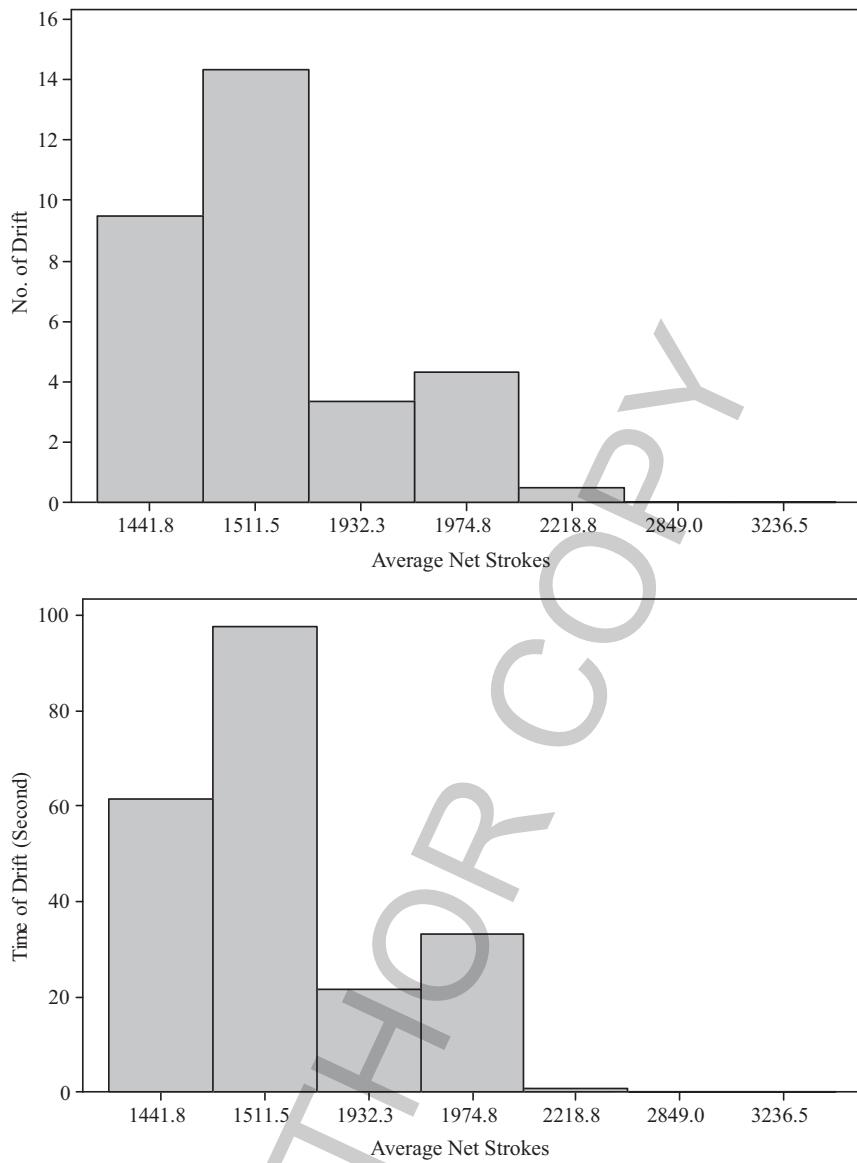


Fig. 8. Correct strokes vs. drift for each participant.

32] to influence customers' behavior such as drink/waiting time, customers' satisfaction and anxiety. In the UK, based on a survey conducted on nearly three hundred office employees, employees listened to self-selected music for a third of their working week, reported listening to a wide variety of music styles and artists, and music helped them to both engage in and escape from work, and they often used music to seal themselves off from the office environment [22]. In the workplace, Lesiuk [6] collected data for five weeks from 56 information system developers. The results indicated that state-positive affect and quality-of-work were lowest with no music, and time-on-task was longest when music was removed. Narrative responses revealed that the music listening enhanced positive mood change and perception on design while working. Similar positive effects of music were not noticed in terms of increase in

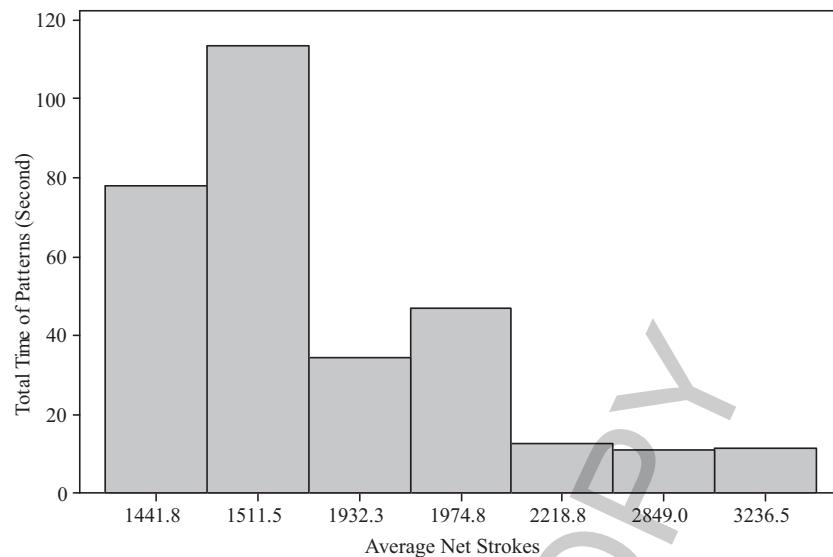


Fig. 9. Correct strokes vs. total pattern time for each participant.

productivity or reduction in error rate in the present experiment probably because of the short duration of the experimental task.

There was also no significant effect of induced mental load through IQ test on typing productivity. The possible reason was that the mental load induced by IQ test was not strong enough compared to the mental load caused by word processing task itself. Furthermore, during the 10 minute IQ test, the extensor digitorum muscle of the participants received extra rest than other trials, and started the induced mental load trials with more rested (or less fatigued) state of muscle, which might explain reduction in EMG with IQ test.

Music significantly ($p = 0.051$) decreased the standard deviation (23.2%) of typing force in the absence of induced mental load. The analysis of variance additionally revealed that music significantly decreased number of shift (37%) and duration of shift (58%) patterns in the absence of mental load. Without mental load induction, music made the participants type more smoothly with more standard finger touch and lower amplitude of hand position change, which caused more constant typing force applied on keyboard. The absence of this effect in the presence of mental load indicated that the soothing effect of music was overpowered by induced mental stress.

It was expected that more standard touch-typing participants achieved, the less variable the force typing force would be. This notion was also confirmed by the fact that there was a negative correlation between correct strokes and standard deviation of typing force, since the hand position change on the keyboard may slow down the typing speed. The standard deviation of force can be recognized as an indicator of the amplitude of hand position change. Visual checks on typing force plots revealed a distinct difference in variability between participants with high productivity and low productivity (Fig. 6). Pearson correlation coefficient between standard deviation of typing force and correct strokes was significant ($p = 0.000$) and negative (-0.678), which also supports that persons with high productivity produced low variation in typing force.

Although hand position change can decrease productivity, merely reduction of hand position change by music did not result in higher overall productivity. The distracting effect of music overwhelmed the beneficial effect of music in our study regarding productivity.

Gerard et al. [33] found extensor digitorum muscle's function is to hold wrist and fingers extended. In our study, music increased EMG of extensor digitorum, which means the extensor digitorum muscle group lifted and controlled the fingers more under music. Increase in extensor muscle EMG indirectly supported the finding of reduction of variability of typing force with music.

Muscles involved with flexion, adduction or abduction motions of hand were not monitored in this study. Since there was a significant reduction of hand movement in terms of shift patterns in typing force, it may be possible that muscles responsible for those movement would have reduced, had those been measured. Reduction of variability of force induced by music should reduce MSD risk from the reduction of hand motions during typing.

5. Conclusions

This research investigated the effect of music and induced mental load in word processing task. Productivity was compromised by music because participants were mentally distracted due to verbal coding perception overlapped between the task and music with lyrics. The beneficial effect of music, which was presented without mental load induction, was to reduce variability of typing force on keyboard. Hand position change gave rise to shift or drift patterns of typing force, increased variability of force and reduced productivity. However, merely less hand position change did not result in higher overall productivity. The behavior change by music resulted in reduction of variability of typing force from smoother hand motions during typing, which may reduce the risk of musculoskeletal disorder related to typing task. The background music and its effectiveness in stress reduction indicate a positive report of music in reducing work stress for computer workers.

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