Effect of Music and Induced Mental Load in Word Processing Task

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***Abstract*—An experimental study was conducted to determine the effect of music and induced mental load in a word processing task. Eight subjects participated in the study. A 2x2 repeated measure design was implemented, with or without background music and with or without induced mental load. Applied typing force, typing productivity, and electromyography (EMG) of the left hand extensor digitorum muscle were measured. A computer algorithm detected the patterns of typing force, which were the cause of variability of typing force. Although overall typing productivity was compromised by music, the beneficial effect of music appeared to be a reduction of wrong finger touch during typing. The behavior change by music resulted in an increased extensor digitorum muscle activity for lifting and controlling fingers. This study contributes to the field of utilizing music to influence human performance in the workplace.**

Keywords-word processing, music, typing force, productivity

I. INTRODUCTION

Music is a gem of human culture. What music provides to the human spirit by an ordered succession of sounds, varying in pitch and loudness, will always remain a marvel. How music influences human performance is still an elusive problem. First emerging in academia early in the twentieth century, psychological interest in the industrial use of music grew into a subject of public interest and government research by the 1940s. During the Second World War, analysis of how music could be employed as an effective soundtrack in factories became a prominent area of psychological research [1]. Music was employed as a way of easing the monotony of factory work while simultaneously aiming to raise productivity levels [2]. Employees had a highly favorable attitude toward music and thought they could accomplish more work with it [3]. Athletic activities, which do not require significant intellectual involvement, can be performed better with background music. Studies found that music can improve athlete performance [4-7]. Driving with music is a common phenomenon. Dalton and Behm conducted a thorough and systemic review on driving-related tasks, and concluded that music seems to reduce driver stress and mild aggression while at times facilitating performance, but the distracting nature may impede vigilance performance, such as maneuvering to avoid another vehicle or pedestrian [8]. Different characteristics of sound, such as loudness, type, and tempo, influence human performance differently. It is still unclear which aspect, music or noise, affects task performance to a greater degree. There are several different kinds of cognitive tasks have been tested, since music is more likely to affect them. Reading comprehension is a task that requires verbal coding, abstraction and memorizing. Performance during a reading comprehension task was significantly worse with music than that in silence. Music and noise are considered just as distracting during a comprehension task [9]. Programming is a cognitively demanding task, and it requires both verbal and logical analysis. In the workplace, Lesiuk [10] 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 in programming tasks. For a word processing task, background music significantly disrupted writing fluency, even though no response to the music was required [11]. Those who listened to music prior to the attention testing obtained higher scores in attentiveness, whereas those who listened to music during the test showed extremely high level of variation in attention test scoring [12].

To achieve performance improvement from the use of music, tasks should be performed in a relatively quiet environmental setting. Music may increase cognitive load because the brain has to handle the additional information. Therefore, music may have a positive effect on human performance when the task itself causes relatively low cognitive demands. Another positive effect of music is a positive mood-induction [10]. It relaxes mental stress and inspires us in a long-term basis.

Nowadays, computer work has become widespread, and the word processing task is extremely monotonous. It requires attention and concentration, and it can cause mental fatigue and stress. Additionally, keyboard use has been implicated as a risk factor for carpal tunnel syndrome and other musculoskeletal disorders, including epicondylitis [13]. Upper extremity musculoskeletal disorder associated with computer keyboard use is a serious issue in occupational health [14]. Since computer keyboard use is characterized by recurrent finger movements as defined by a keystroke, these disorders may arise from cumulative effects of transient loads on the tissue through repeated muscle activations.

The objective of this study was to investigate the effect of music and mental load induction on typing productivity, applied typing force and muscle activity in terms of electromyography (EMG) of the left hand extensor digitorum in a word processing task.

II. METHOD

Eight graduate students of the New Jersey Institute of Technology participated in the study. All participants were right-handed, in proper physical condition, able to read and write English well and had no history of hand and forearm musculoskeletal problems. A force plate (Advanced Mechanical Technology Inc.) was put on an adjustable table (59cm-128cm), and a laptop (Emachines E525) was put on the force plate [15]. Vertical typing force was recorded by AMTI's NetForce software with a frequency of 50 datasets/second and a resolution of 0.157 lbf/bit. The raw data were subsequently analyzed by AMTI's bioanalysis software. EMG data were recorded and analyzed by DataLINK PC software Version 2.00 (Biometrics Ltd) through a DataLINK Base Unit connected to an active EMG electrode with a sampling rate of 1000 data/second and sensitivity of 300mV. On a cleaned and abraded skin surface on the finger extensor (extensor digitorum) muscle of the non-dominant arm, electrolytic gel was applied and the electrode was adhered to the skin with double-faced adhesive tape. Participants with EMG electrodes attached sat on an adjustable chair with an armrest. Before typing, participants were asked to adjust the table and chair until they felt comfortable, and the reading of the force plate and EMG was reset to zero when participants relaxed their hands away from the keyboard. Music was played in the same laptop, and output by a headphone (Sony MDR-NC6).

Word processing task was performed on software TypingMaster Pro® in 2*2 trials randomly: with or without background music, with or without mental load induction. Between each trial, participants were allowed 10 minutes break. In TypingMaster Pro®, 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 the space key was pressed for that word, participants could not return and correct the word. The page was turned automatically after it was completed. The texts were taken from GMAT reading comprehension section, to establish similar readability level. Participants were informed to bring about ten pieces of music they like and want to listen while they were doing monotonous task. The music selection was up to the individual choice, because that is what happens in real workplace [10]. Previous researchers have used an intelligence/skill task to induce stress before typing task [16]. In this experiment, mental load was induced by an IQ test on paper for 10 minutes in which participants were encouraged to do their best [17].

III. RESULTS

TypingMaster Pro® reports correct key strokes, net speed in terms of the correct number of words per min (wpm), and accuracy in terms of percentage of correct key strokes. The overall productivity was indicated by correct strokes. Root of mean square (RMS) of EMG was computed by using Triangle/Bartlett moving window of 4 mS. Mean and standard deviation of typing force, RMS of EMG was calculated from the data recorded between 8 and 9 min, when the effect of music on the participants would be more pronounced. All means of analyzed responses for each participant over 4 trails were presented in Table I.

TABLE I. TYPING PERFORMANCE, FORCE AND EMG FOR EACH PARTICIPANT

Participant	Net speed (wpm)	Accuracy (%)	Correct Strokes	Average Force (lb)	SD of Force (lb)	RMS EMG (mV)
1	44.0	95.8	2218.8	3.383	0.2831	0.0403
2	38.2	94.8	1932.3	3.527	0.5356	0.0383
3	28.5	95.5	1441.8	4.641	0.5461	0.0346
4	29.8	95.5	1511.5	3.850	0.7472	0.0403
5	39.0	91.8	1974.8	3.946	0.4810	0.0422
6	56.5	93.8	2849.0	6.925	0.3761	0.0407
7	65.2	94.0	3236.5	5.482	0.2631	0.0300
8	22.8	93.5	1142.8	0.124	0.1599	0.0315

Although the typing proficiency varied widely between participants, 23 to 65 wpm, the accuracy score was close between participants, 92 to 96%. Correct key strokes were essentially equaled to wpm times 50, since there are on an average five letters in English words and 10 minutes duration of typing. Average typing force of participant #8 was much lower than others, because he used typical finger typing instead of touch typing. He also did not rest his wrist on the keyboard when typing. Due to this atypical result, in the 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. The RMS EMG between participants seemed close to each other, and they ranged between 0.030mV to 0.043mV. ANOVA test was conducted with participant as a blocking factor using Minitab® 15. The data, which were partly missed in few trials due to instrumentation problem, were excluded from the analysis.

Music significantly reduced productivity in terms of correct strokes ($p=0.046$). None of the factors was found significant for accuracy and mean typing force. The interaction effect of mental load induction and music was significant at 10% level ($p=0.051$) for the standard deviation of typing force. Both music ($p=0.035$) and mental load induction ($p=0.023$) had a significant effect on RMS EMG.

The percentages of increased or reduced responses by a significant factor or interaction were calculated from fitted mean. Music decreased correct key strokes from 2070.88 to 2005.94, by 3.1% on average. Music reduced correct key strokes from 2094 to 2005.63, by 4.2% with mental load induction, but from 2047.75 to 2006.25 by 2.0% without mental load induction. Music decreased standard deviation of force by 38.1% without mental load induction, and increased it by 15.5% with mental load induction. Music increased RMS EMG by 10.0%, and mental load induction decreased it by 10.8%.

Visual check on typing force plots revealed a distinct difference between participants with high productivity and low productivity concerning variability (Figure 1). Pearson

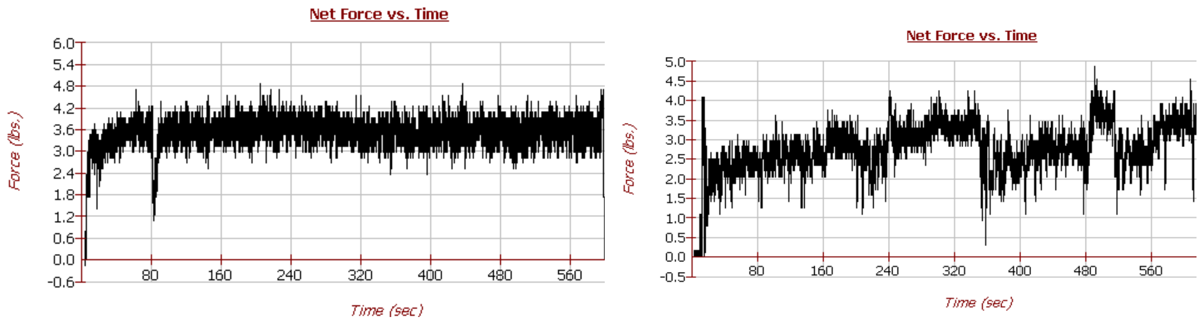

Figure 1. Typical Samples of Vertical Force Plot Between Typist with High Productivity (left) and Typist with Low Productivity (right)

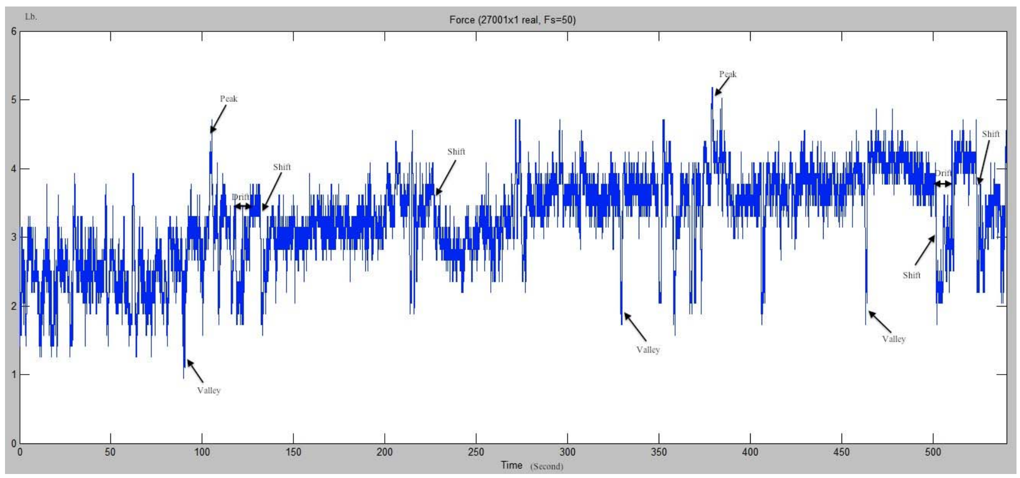

Figure 2. Sample of Patterns in a Trail between 0.5 min and 9.5min (Partly Labeled)

correlation coefficient between standard deviation of typing force and correct strokes was significant (p=0.000) and negative (-0.678). In order to find out what variability of force can indicate physically and practically, a computer algorithm based on moving windows analysis was adopted from Duarte et al. [18] to identify patterns of typing force that were the cause of variability of typing force. Three patterns including shift, fidget and drift, were identified in the force time-series (Figure 2). Shift was a fast and step-like displacement of the average force from one level to another. Fidget is a fast, large and pulse-like displacement followed by a return of the force to approximately the same level, and drift is a slow and ramp-like continuous displacement of the average force. This algorithm was implemented by Matlab, to record numbers, length and positions of these patterns. Any two consecutive non-overlapping moving windows (W1 and W2) satisfying equation (1) was classified as a shift:

$$\left| \frac{\bar{x}_{w1} - \bar{x}_{w2}}{\sqrt{SD_{w1}^2 + SD_{w2}^2}} \right| \geq f_{shift} \qquad (1)$$

In a moving window (W), any peak or valley (F) satisfying equation (2) was classified as a fidget:

$$\left| \frac{x_F - \bar{x}_w}{SD_w} \right| \geq f_{fidget} \qquad (2)$$

If the difference between the amplitudes of two consecutive local maximum and minimum in a moving window satisfied the equation (3), the displacements between the consecutive maximum and minimum were classified as a drift.

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

The following criterion values were chosen in this study for classifying the data as shift, fidget or drift patterns, respectively: f_{shift}=2, a base window of 5 s; f_{fidget}=3, and a base window of 20 s; f_{drift}=1, and a base window of 20 s. The windows moved 1% of the length of a base window until covered all data, so the unit time added to a detected pattern was 1% of the length of a base window if the detected pattern lasted for a while.

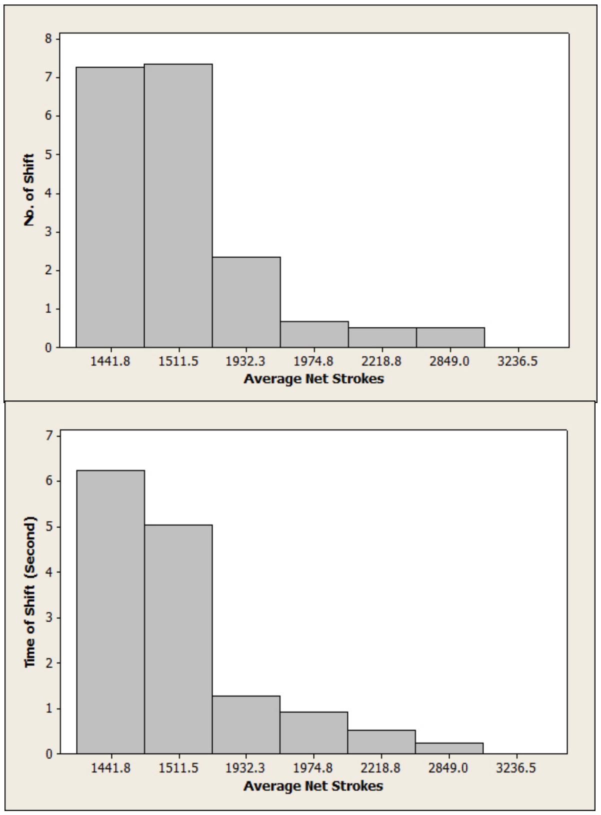

Figure 3. Correlation Between Correct Strokes of Each Participant and Shift

Correlations between correct strokes and pattern parameters were checked. The total number (p=0.001) and time (p=0.001) of shift, the total number (p=0.008) and time (p=0.005) of drift, the total time of all patterns (p=0.004), the total number (p=0.004) and time (p=0.002) of shift plus drift were significant, and all the correlations were negative. Figure 3 graphically shows the correlation between correct stroke and shift, in terms of number and time. There was no significant correlation between number or time of fidget and productivity.

IV. DISCUSSION

Music significantly decreased productivity, which was due to distracting influence of music. Although subjective rating was not recorded officially, most of the participants reported that they felt distracted by music. Wickens and Hollands [19] described multiple-resource theory that predicts relative independence between the perception of music, which is more associated with spatial and analog processing, and involvement with tasks that are manual or verbal. This prediction seems to be consistent with the results of a study by Tayyari and Smith [20], who found no interference between "light orchestral" music listening and data processing task. Similarly, Martin et al. [21] found no interference between instrumental music and reading comprehension, but did note that comprehension suffered when lyrics were added. In the experimental programming study, Lesiuk [22] selected some classical music for listening, and found significant decreased anxiety level and increased score by music, which also avoided perceptional overlap. However, in this experiment, all participants chose pop music with lyrics in their most familiar language. The compromised productivity by music can be explained by multiple-resource theory, since the verbal coding perception overlapped in the word processing task while listening to music with lyrics.

To influence customers' behavior, customers' satisfaction and anxiety, the relaxing role of music is often utilized in bars, stores, supermarket, banks, and hospitals [23-28]. Similar positive mood-change and enhanced perception on design while working on a programming task were not noticed in the present study. This was probably because of the short duration of the experimental task. There was no significant effect of the IQ test on typing productivity. The likely reason was that, the mental load induced by the IQ test was not strong enough compared to the mental load caused by the word processing task itself.

Both direct observation and pattern analysis revealed that the variability of force applied on the keyboard was largely increased by wrong finger touch, which is, a key is touched by a finger that is not supposed to be used in standard touch typing. The more standard touch typing participants achieved, the less was the variability of the force. It was also confirmed by the fact that there was a negative correlation between correct strokes and standard deviation of typing force, since when the wrong finger was used to touch a specific key comparing with the standard touch typing, the typing speed slowed down. Furthermore, because there was no correlation between correct strokes and accuracy (p=0.814), productivity was not affected by the accuracy (i.e., right or wrong finger touched the wrong key) but the wrong finger touch. Standard hand posture and finger touch can result in high productivity, and low variability of force applied on keyboard. To sum up, the standard deviation of force can be recognized as an indicator of the amplitude of wrong finger touch. Music decreased it without mental load induction and increased it after mental load induction. Without mental load induction, music made the participants type more smoothly with more standard finger touch and lower amplitude of wrong finger touch, which caused more constant typing fore applied on keyboard. For decades, music therapy has been practiced for reducing movement and sensory impairments from Parkinson's disease. In this study, music's rhythmic nature may have facilitated coordination of muscular movements. However, although wrong finger touch can decrease productivity, merely less wrong finger touch did not result in higher overall productivity. The distracting effect of music overwhelmed the beneficial effect of music in this study regarding productivity.

Patterns determined the variability of force. While the standard deviation of force indicated the gross level of smoothness when typing, patterns indicated the numbers and time of finger touch that reduced the smoothness. In these patterns, shift and drift were negatively correlated to the productivity. They were caused by hand position change away from standard hand position, which was also due to wrong finger touch on keyboard. From observations of computer keyboard users, it has been identified that they adopt one of two key-striking patterns during computer keyboard use. They either ‘‘plant’’ their wrist/forearms in one place by resting their wrists on the desktop or a wrist rest and reaching for the keys with primarily finger motions, or they ‘‘float’’ over the keys, continuously repositioning their hand/wrist units to reposition their fingers for key strike [29]. The shift and drift patterns complied with the “float” patterns. Fidgets were caused by hard finger touch or release, and they were not correlated with productivity. According to Baker et al. [29], the planted pattern, which resulted in more constant force applied on the keyboard, would often be associated with increased ulnar and radial deviation angles when reaching for the keys at the extreme right and left of the keyboard. For the floating pattern, the wrist, hand and fingers essentially act like a single unit. Since musculoskeletal disorders of the upper extremities are often associated with repetitive use of the joints, individuals who ‘‘plant’’ may have increased stress on joints and tendons during computer use due to the increased angles at the wrist. However, “float” may require more muscle activities of arms and hands.

Typing can cause both dynamic (finger flexor and extensor) and static (trapezius and deltoid) muscle fatigue. Gerard et al. [30] found the finger extensor was used to hold fingers extended to avoid accidental key presses. Dennerlein et al. [31] suggested that the role of extrinsic finger flexors during a keystroke is to overcome the activation force of the key switch, while the role of extrinsic extensors is to perform the upswing rather than stop the downswing. In this study, music increased RMS EMG of extensor, which means extensor digitorum muscle group lifted and controlled the fingers more under music. Although EMG of finger flexor was not measured in this study, muscle activity of finger flexor could be less with music, based on the fact that keystrokes were less with music. Music can influence human behavior, and then effects different muscle activity indirectly. Mental load induction decreased RMS EMG, which may be explained by the fact that participants had more time to rest during mental load induction (10 min) than without. During rest time, the muscle recovered from fatigue.

V. CONCLUSION

This research investigated the effect of music and induced mental load in a 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 good effect of music, which only presented without mental load induction, was to reduce wrong finger touch. Wrong finger touch caused hand position change on the keyboard, which in turn gave rise to shift or drift patterns of typing force, increased variability of force and reduced productivity. However, merely less wrong finger touch did not result in an increased overall productivity. The behavior change by music resulted in an increased extensor digitorum muscle activity, which was required to lift and control fingers. Further research should investigate the long-term effect of music such as positive mood-induction, and measure mental load to evaluate the mental effect of music directly.

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