

CHAPTER V

DISCUSSION

This study examined the effects of cell phone conversation on driving performance and cognitive workload. Brake reaction time, lane maintenance, and crash avoidance ability were used to represent driving performance. Heart rate, skin temperature, and HRV were used to indicate cognitive workload level. Each participant was tested for all three phone conversation conditions (i.e. no phone conversation condition (NC), simple phone conversation condition (SC), and working memory conversation condition (WC)). The testing was scheduled one week apart and the order of phone conversation was random. The results showed that concurrently driving and talking on the phone leads to driving degradation and increased cognitive workload.

Driving performance

Brake reaction time

This study found that concurrently driving and talking on the phone results in delayed brake reaction time (BRT). We originally hypothesized that driving performance will be poorest in the WC condition, followed by the SC and NC condition, respectively. BRT results support this hypothesis. BRT was longest in the WC condition and shortest in the NC condition. When compared to the NC condition, there were 70 ms BRT delay for the WC condition, and 44 ms delay for the SC condition.

Results of this study were in accordance with previous works. Patten and colleagues (15) studied effects of complex and simple phone conversations while

driving on peripheral detection reaction time task. Reaction time was calculated from the time when the light stimulus was presented to the time when left index finger pressed on the bottom near of the steering wheel. The results showed that mean reaction time was 261 ms and 72 ms delayed for the complex and simple phone conversation compared to no phone conversation. Lesch and Hancock (34) found that mean brake reaction time during a cell phone distraction task of participants aged less than 60 years old was 100 ms delayed compared to that in no phone distraction.

BRT test is a measure of cognitive-psychomotor performance and attention deficit (35). Findings from several studies indicated that divided attention played a major role for delayed BRT (28, 29, and 34). Dual-task operation like concurrently driving and talking on the phone is a common cause for divided attention. In the present study, cell phone conversation may divide participant's attention from the primary driving task, resulting in a delay BRT. Moreover, results from the present study also suggested that a conversation that required working memory needed greater attention than a simple conversation about daily life, consequently led to a greater delay of BRT.

Lane maintenance and crash avoidance ability

Lane maintenance ability was presented by the number of lane crossing. Crash avoidance ability was showed by the number of object crashes. High amount of lane crosses and object crashes indicated poor driving performance. We hypothesized that lane maintenance and crash avoidance ability will be poorest in the WC condition, followed by the SC and NC condition, respectively. The results did not support this hypothesis. Although, there was no statistical significant difference in amount of lane

crosses and object crashes between the three testing conditions, there was a trend that the number of lane crosses and object crashes were greater for the WC and SC conditions compared to those in the NC condition. One possible explanation for the non significant difference of this result was the driving speed. In this study, all participants were asked to keep their driving speed at 65 ± 5 kilometers per hour. This driving speed may not be fast enough to affect the participant's ability in controlling the car in the driving simulation situation.

Another possible explanation for the non significant difference of lane maintenance and crash avoidance ability between the three testing conditions was a relatively low traffic driving scene in the present study. Lamble et al. (11) found that when the traffic was light, there was no significant difference of car lateral sway between the distraction and no distraction task. In contrast, the car lateral sway increased dramatically in busy traffic situation. In the present study, the majority of the driving time was in the light traffic (light traffic = 10 min, heavy traffic = 5 min). Thus, the relatively low driving speed together with light traffic environment in the present study may result in non significant difference in lane maintenance and crash avoidance ability.

Physiological changes

Heart rate and skin temperature were used to indicate cognitive workload level while HRV was used to indicate balance of the autonomic nervous system. We hypothesized that cognitive workload will be highest in the WC condition, followed by the SC and NC condition, respectively.

Previous work reported that cell phone conversation influenced cognitive workload and stress. Rakauskas and colleagues (29) studied effects of easy and difficult cell phone conversation types on subject's cognitive workload and driving ability. The rating scale of mental workload (RSME) was used to test the self-report perception of cognitive workload. The result revealed that there was a significant difference in cognitive workload level between the conversation task and no phone conversation task, but no significant difference between the 2 types of phone conversation.

To the author's knowledge, previous studies concerning cell phone and driving safety issue only used subjective self-report to test participant's cognitive workload. The present study was the first to use physiological parameters to indicate cognitive workload level. Changes of physiological parameters were interpreted in relation with the participant's cognitive workload.

Heart rate and skin temperature

Results of heart rate partially supported the hypothesis. Heart rate was significantly greater in the WC and SC conditions compared to that in the NC condition. When compared to the NC condition, heart rate increased 8.68% and 5.33% in the WC and SC conditions, respectively. There was no significant difference between mean heart rate in the WC and SC conditions. The result indicated that heart rate was affected by cell phone talking but not by different conversation types. Johnsen and colleagues (36) used the high and low mental anxiety tasks to test the effects of different tasks on heart rate changes. In agreement with the present study,

the result indicated a significant increase of mean heart rate for both high and low mental anxiety tasks compared to baseline.

Similar to heart rate, results of skin temperature partially supported the hypothesis. Skin temperature was significantly greater in the WC and SC conditions compared to that in the NC condition. There was no significant difference between WC and SC conditions. These results indicated effect of cell phone conversation on skin temperature. However, there was no significant difference in skin temperature between the two conversation conditions.

Previous studies revealed the association between skin temperature and sympathetic activity. Svedberg and colleagues (37) suggested that the low skin temperature was associated with an increase of parasympathetic activity. Decrease of the cortical and subcortical inhibitory affects vasomotor neurons by increasing vasoconstriction and restriction of cutaneous blood flow. On the other hand, high skin temperature could be explained by the opposite mechanism. Increase of skin temperature indicated sympathetic activity. In the present study, a significant greater skin temperature in the WC and SC condition (compared to the NC condition) suggested an increased activation of the sympathetic nervous system during phone conversation.

Non significant differences of heart rate and skin temperature between the WC and SC conditions may be due to the demand of our working memory task. It has been reported that working memory of a healthy individual has a capacity to hold 7 ± 2 digits (38). In the present study, we asked participants to memorize 5 digits. Given that the participants were relatively young (mean age = 28.3 ± 4.3 yr) and educated (mean education was Bachelor degree), this working memory task may not

demanding for them. Thus, the cognitive effort required to perform the WC condition was not significantly different from that in the SC condition. Consequently, when the cognitive effort was low, the sympathetic activation was not prominent.

Heart rate Variability (HRV)

Time domain analysis

Two parameters of time domain analysis were included in this study (i.e. SDNN and RMSSD). It was not surprised that a repeated measure ANOVA revealed no significant difference between the three testing conditions for SDNN. According to Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (26), SDNN is calculated on the standard deviation of the beat to beat interval of heart rate. Total variance of heart rate increases with the length of analyzed recording. It has been recommended that SDNN should be calculated over a 24-hour period. Fifteen minutes of testing time in the present study was not long enough to reveal the changes of SDNN.

Another analysis of time domain parameter was the square root of the mean squared differences of successive NN intervals (RMSSD). RMSSD was significantly lower in the WC and SC conditions compared to that in the NC condition. There was no significant difference between WC and SC conditions.

RMSSD was the secondary data from mathematics calculation of SDNN. It was mostly used to indicate the state of stress, anxiety and cognitive workload level (25, 26). Buchholz and the colleagues (39) studied effect of mental stress on RMSSD.

The stress was induced by salt injection. Result revealed that RMSSD was significantly reduced in stress condition. Johnsen et al. (36) examined effects of

anxiety and cognitive workload situation on changes of RMSSD. The result presented significant reduction of RMSSD when subjects performed a cognitive workload task.

The reduction of RMSSD in the present study indicated an increased cognitive workload and stress level while performing both phone conversations related task. The possible explanation for non difference of RMSSD between WC and SC condition was the similar effect of both conditions. Hansen and colleagues (17) studied different effects on RMSSD between working memory task and sustained attention task. The result showed that RMSSD decreased significantly in both tasks. This indicated that working memory and sustained attention questions had similar effects on RMSSD. The SC condition in this study required participants to sustain their attention to the on going conversation while the WC condition required participants to memorize a series of digits and report back to the experimenter on the phone. In agreement with previous work (17), our results showed that these two conversation conditions had similar effects on RMSSD.

Frequency domain analysis

Three frequency domain analyses of HRV were included in this study (i.e. LFnu, HFnu, LF/HF ratio). LF and HF were expressed in normalized unit for equal comparisons. LF/HF ratio was an indicator of LF and HF balance.

Frequency domain analysis of HRV indicated balance of autonomic nervous system (25, 26). Low frequency (LF) has been used as the sympathetic detection. An increase of the LF component has been generally considered to be a consequence of sympathetic activity. High frequency (HF) of HRV has been generally defined as a marker of vagal modulation (25). Normalized LF and HF represent the relative value

of each power component in proportion of the total power minus the very low frequency (VLF) component.

LF and HF in normalized unit emphasized the controlled and balanced behaviors of the two branches of the autonomic nervous system. The LF/HF ratio reflected the global sympatho-vagal balance and could be used as a measure of this balance (25).

Previous study reported that human information processing had an association with heart rate variability. Mulder and Mulder (40) studied changes of HRV power spectrum analysis during an increase of cognitive workload. Choice reaction time task was used as a cognitive workload task. Result revealed dominance of low frequency spectrum while performing the reaction time task.

In the present study, LFnu, HFnu and LF/HF ratio were used to examine effect of cell phone conversation on participant's cognitive workload. All frequency domain analyses of this study were significant different between the three testing conditions. LFnu and LF/HF were highest in the SC condition and lowest in the NC condition. In contrast, HFnu was lowest in the SC condition and highest in the NC condition. These results suggested that the SC condition induced the greatest activation of sympathetic activation and greatest depression of parasympathetic. We hypothesized that the WC condition would present the most dominance of LF and the greatest depression of HF. Thus, this hypothesis was not supported.

The highest sympathetic activity and depression of parasympathetic activity in the SC condition may be due to the speaking frequency. Previous studies found relationship between talking, breathing frequency, and changes of HRV. Bernadi and colleagues (41) studied effect of talking and reading on HRV. HRV was used to

compare the spontaneous breathing; reading text silent, reading text aloud, free talking, mental stress without talking, and control breathing. The power spectrum analysis revealed that LFnu and LF/HF ratio were highest in the free talking task. HFnu was lowest in the control breathing task. Importantly, respiratory rate were slowing in the free talking and mental stress aloud task.

During the same type of task, the changes of respiratory rate caused by verbalization also markedly affect the variation of beat-to-beat heart rate. There was a large decrease in breathing frequency, which was shifted total power spectrum of HRV into the LF band (41). The SC condition in the preset study assigned participants to continue talking through almost 15 minutes of the testing time. The constant speech frequency in the SC condition may shift frequency power into LF section and consequently, resulted in an increase of LF, decrease of HF, and then, increase of LF/HF ratio.

CONCLUSION

Results of the present study suggested that simultaneously driving and talking on the phone leads to driving degradation and increased cognitive workload. All dependent variables measured in this study were significantly different when compared between the phone conversations conditions (SC and WC) and driving alone condition (NC), except for the number of lane crosses and object crashes. Thus, number of lane crosses and object crashes may not be as sensitive as other variables used in the present study. The longest brake reaction time was presented in the WC condition followed by the SC condition, and shortest in the NC condition, suggesting that working memory task requires greater attention than a simple talking task.

The effects of different phone conversation types on cognitive workload level were inconclusive. Results from heart rate, skin temperature, and RMSSD did not show significant differences between the SC and WC conditions. It was possible that the two conversation conditions had similar effects on these variables. An alternative explanation was that the working memory task used in the present study was not demanding enough. Thus, the cognitive effort required to perform simple conversation and working memory conversation was not different. On the contrary, results from LFnu, HFnu, and LF/HF ratio indicated the significant greater sympathetic activation and depression of parasympathetic activation in the SC condition compared to the WC condition. We speculated that continued talking required in the SC condition may account for this finding. The constant talking which resulted in decreased respiratory rate may shift frequency power into LF section and

consequently, resulted in an increase of LF, decrease of HF, and then, increase of LF/HF ratio. Nevertheless, further study needs to verify these issues.



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FUTURE STUDY

The present study revealed negative effects of cell phone use while driving. However, the effects of different conversation types were inconclusive. To minimize the effects of respiration as a consequence of talking duration on HRV, future studies should control for breathing frequency.

Several questions related to cell phone use while driving are to be investigated in future studies. For example, it is not known about the optimal duration that one can talk on the phone without compromising for driving safety. Furthermore, effects of cell phone talking while driving should also be conducted in elderly population.