

Riding a Motorcycle Affects Cognitive Functions of Healthy Adults

- A Preliminary Controlled Study -

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ABSTRACT: We investigated whether riding a motorcycle in daily life has beneficial effects on the cognitive functions of healthy subjects. Twenty-two healthy right-handed men, who had a significant break from riding, participated in this study. They were randomly assigned to either the intervention or control group. The intervention group was asked to ride a motorcycle in their daily life for two months. The intervention group showed improvement of their visuospatial cognition compared with the control group. Results of this study indicate that riding a motorcycle in daily life could have beneficial effects in returning riders.

KEY WORDS: Human Engineering, Driving Act, Central Nervous System / Returning Riders, Daily Intervention, Controlled Study, Cognitive Functions, Beneficial Effects [C2]

1. Introduction

In general, motorcyclists represent an important concern from the road safety perspective, since riding a motorcycle is associated with a higher risk of fatality than driving a car⁽¹⁻⁴⁾. Therefore, most of the previous investigations on the behavior and psychological characteristics of motorcyclists focused on issues associated with the risks of motorcycles. A previous psychological study⁽⁵⁾ showed that motorcyclists are not significantly different from non-motorcycling car drivers in driving behaviors or safety when driving their cars, and that motorcyclists and non-motorcycling car drivers do not significantly differ on more general characteristics and attitudes, such as sensation seeking and social motives. However, it is interesting to note that the ability to detect hazardous situations is significantly higher in motorcyclists than non-motorcycling car drivers. In fact, motorcyclists carry out more saccades and rapidly capture information from their rearview mirrors and on the road in front of them⁽⁶⁾. Those observations led to hypotheses that riding a motor cycle requires rapid and careful hazard detection and decision making in order to avoid hazardous situations, because motorcyclists always recognize that riding a motorcycle is a risky event, and pay closer attention to their own safety while driving, and therefore riding a motor cycle could affect cognitive functions, which are directly related to rapid and careful hazard detection and decision making.

According to general knowledge of cognitive neuroscience, careful detection and decision making assume several cognitive functions; such as processing speed, visuo-spatial attention, visuo-spatial cognition, working memory, and executive function. Therefore, in this preliminary study, we addressed the question of

whether riding a motorcycle in daily life has beneficial effects on these cognitive functions of healthy subjects.

2. Methods

2.1. Subjects

Twenty-two healthy right-handed men aged 42 to 56 (mean age, 48.1) participated in this study. All the subjects have a motorcycle driver's license, had ridden a mid-sized motorcycle while they were young, and have had a significant break of 10 years or more from riding a motorcycle. Mean (SD) of duration for riding motorcycle prior to the break was 13.8 (5.8) years.

This study was approved by the Ethics Committee of the Tohoku University Graduate School of Medicine, and written informed consent was obtained from each participant. The participants were then assigned randomly by lot into two groups, the intervention and control groups.

2.2. Intervention methods

Eleven participants (aged 43 to 52; mean age, 47.9) assigned to the intervention group were asked to ride a motorcycle in their daily life for two months. All of them used a mid-sized motorcycle (225 cc - 600 cc) for both leisure and travel to work. The mean frequency of usage of motorcycle for travel to work was 5.2 days a week (S.D., 1.1), and the mean duration for that was 112.3 min (S.D., 30.3). Another eleven participants (aged 42 to 56; mean age, 48.3), assigned to the control group were instructed to maintain their current lifestyles. All of them did not ride motorcycles during the experimental period.

Mean (SD) of duration for riding motorcycle prior to their break was 11.5 (4.1) and 16.1 (6.5) years for intervention and control groups, respectively, with statistically significant differences ($p = 0.07$, student t-test).

The participants in the intervention group performed the following cognitive tests prior to the start of the intervention (Pre) and two months after the intervention (Post). The characteristics of the control group were measured at the same time as those of the intervention group.

2.3. Outcome measures

In this preliminary study, we assessed the cognitive functions that are related to driving safety (Table 1).

Table 1 Summary of cognitive function measures

Cognitive function	Task
Processing speed	Digit-symbol
Working memory	Digit-span
Executive function	Dual attention
Visuo-spatial attention	Reaction time
Visuo-spatial cognition	Mental rotation

Processing speed was assessed by a digit-symbol test, a subtest of WAIS-III⁽⁷⁾. The participants were shown a series of symbols that are paired with numbers. Using a pencil with a 60 s time limit, participants drew each symbol under its corresponding number. The primary measure of this test was the number of correct answers.

Working memory was assessed by a digit span backwards test, which is also a subtest of WAIS-III⁽⁷⁾. The participants were asked to memorize a number and then repeat the number in the inverse order. The primary measures of this test were raw scores that reflected the number of correctly repeated sequences until the discontinue criterion (that is, failure to reproduce two sequences of equal length) was met⁽⁷⁾.

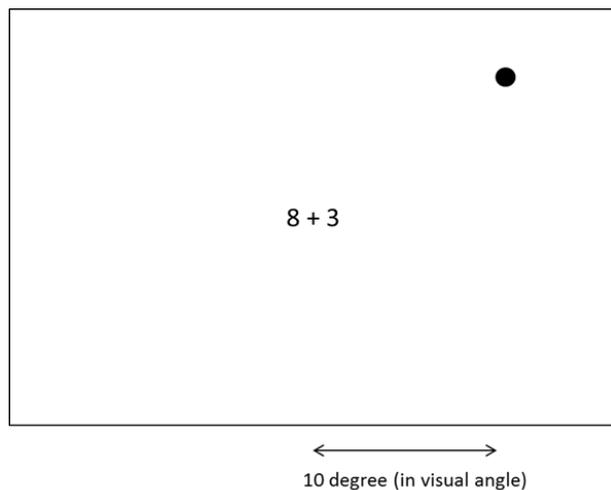


Fig 1. Example of dual attention task. Participants were asked to solve one-digit addition problems presented at the center of the screen and simultaneously respond by pressing the key when a target appeared on the screen.

Executive function was measured by a dual attention task (Fig. 1). In this task, problems of one-digit addition (e.g. $3 + 5$) were presented at the center of a display in turn 1 s for each problem, and the participants were asked to solve each problem and answer verbally. In addition, a target stimulus (yellow square) was presented at the peripheral area of the display randomly for 200 ms, and the participants were asked to press a key when they detected the presentation of the target stimulus. The distance between the center of the equation (plus mark) and the target was between 10 to 15 degrees in the visual field. We measured reaction time between target presentation and key press. The primary measure for the executive function was an index obtained from the reaction time in the dual attention task divided by the reaction time in the subsequent visuo-spatial attention task. This operation was necessary in order to compensate for individual differences in simple reaction time.

Visuo-spatial attention was measured by a reaction time task. In this task, the task settings were almost the same as those of the dual attention task, but without the presentation of problems. The participants were asked to gaze on a fixation point displayed at the center of the screen, and to press a key when they detected the presentation of the target stimulus.

Visuo-spatial cognition was measured by a mental rotation task⁽⁸⁾. In this mental rotation task (Fig. 2), pairs of Japanese “Hiragana” syllables were printed on a paper. In each pair, the same characters were printed. The left side character was always printed normally; however, the right side character was always rotated to some degree. In addition, in one-half of the pairs, the right-side character was mirrored. Using a pencil with a 60 s time limit, participants were asked to judge whether two objects presented with angular disparity were identical or mirror versions of each other. The primary measure of this test was the number of correct answers.



Fig. 2. Examples of mental rotation task. Participants were asked to judge whether two objects presented with an angular disparity are identical or mirror versions of each other.

As for the statistical analysis, we calculated the change score (Post score minus Pre score) in all cognitive function measures. Then, we conducted an ANCOVA for the change scores in each cognitive test. The change scores were the dependent variable.

Groups (Intervention and Control) were the independent variable. Pre score and age were the covariates to exclude the possibility that any pre-existing difference of measure between groups affected the result of each measure and to adjust for background characteristics. The level of significance was set at $p < 0.05$. To conduct ANCOVA, homogeneity of regression slopes as well as homogeneity of variance between two groups were tested for regression slopes of Pre and Post score for each cognitive task.

In addition, as post hoc, paired t-tests were applied for each group for each outcome measure to test whether changes between Post and Pre were significant.

3. Results

The group comparison (two-sample t-test) of the pre-training scores demonstrated that there were no significant differences in any measures of cognitive functions between the intervention group and the control group (Table 2). The homogeneity of regression slopes were not statistically significant for digit-symbol ($p = 0.529$), digit-span ($p = 0.758$), dual attention ($p = 0.960$), and mental rotation ($p = 0.422$) tasks. However, that for reaction time task was statistically significant ($p = 0.03$). The homogeneity of regression variances were not statistically significant for all tasks; digit-symbol ($p = 0.399$), digit-span ($p = 0.426$), dual attention ($p = 0.203$), reaction time (0.078), and mental rotation tasks (0.124). We, therefore, applied ANOVA instead of ANCOVA for analysis of reaction time task.

Table 2 Mean (SD) of Pre and Post scores of cognitive function measures

Task	Intervention	Control	ANCOVA p-value
Digit-symbol			
pre	43.64 (6.38)	40.73 (4.78)	
post	46.64 (6.62)*	44.00 (4.88)*	0.873
Digit-span			
pre	1.36 (0.67)	1.54 (0.52)	
post	1.81 (0.75)	1.27 (0.79)	0.093
Dual attention			
pre	1.60 (0.25)	1.54 (0.14)	
post	1.42 (0.16)*	1.53 (0.17)	0.089
Reaction time +			
pre (sec)	0.29 (0.02)	0.30 (0.04)	
post (sec)	0.28 (0.02)	0.29 (0.02)	0.484
Mental rotation			
pre	43.09 (4.39)	39.72 (10.53)	
post	52.09 (4.65)*	42.82 (9.35)	0.012

* means a statistically significant improvement at Post compared with Pre (post hoc analysis; paired t-test). + ANOVA was used for statistical analysis.

The results of ANCOVA for the change scores showed that the intervention group statistically significantly improved mental rotation task ($F(1, 21) = 7.89, p = 0.012$) compared with the control group. Changes of individual scores of the cognitive measure is shown in Figures 3. Changes of digit-span task ($F(1, 21) = 3.15, p = 0.093$), dual attention task ($F(1, 21) = 3.24, p = 0.089$), digit-symbol task scores ($F(1, 21) = 0.26, p = 0.87$), and reaction time task scores ($F(2, 22) = 0.739, p = 0.74$) were not statistically significant.

Post hoc analysis showed that scores in the digit-symbol task were statistically significantly improved in both the intervention and control groups at Post compared with Pre ($p < 0.001$ for both groups). In the intervention group, scores in the dual attention and

mental rotation tasks also showed statistically significant improvement at Post compared with Pre ($p < 0.001$ for both tasks).

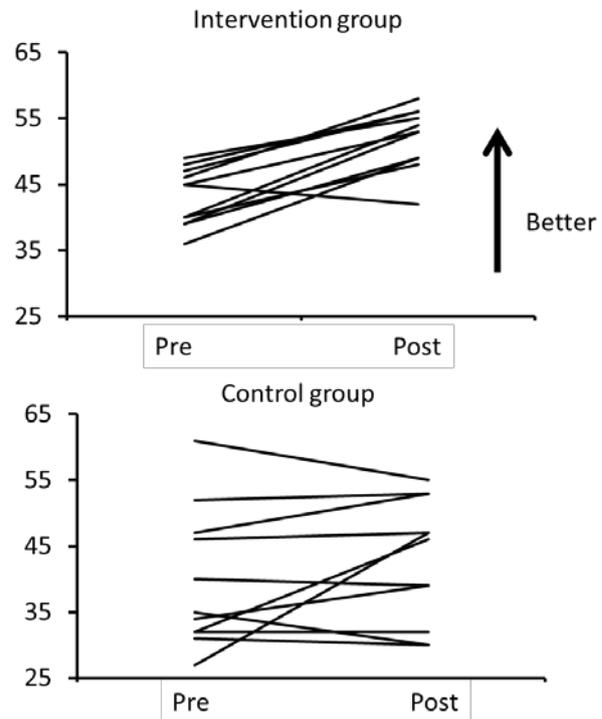


Fig. 3. Changes of individual scores for the mental rotation task

4. Discussion

Results of this preliminary report indicate that riding a motorcycle in daily life could have beneficial effects to improve visuo-spatial cognition in returning riders. Subthreshold improvement was found in working memory ($p = 0.093$) and executive function ($p = 0.089$) of the intervention group compared with the control group.

We previously demonstrated that some cognitive training could induce the improvement of non-trained cognitive functions (transfer effect) of young^(9, 10) and elderly healthy subjects⁽¹¹⁾. It has been hypothesized that the transfer effect could be induced if the cognitive processes during both the training and transfer tasks overlap⁽¹²⁻¹⁴⁾. As mentioned in the introduction, rapid and careful hazard detection and decision making in order to avoid hazardous situations are essential for road safety for motorcyclists, and those behaviors assume several cognitive functions; such as processing speed, visuo-spatial attention, visuo-spatial cognition, working memory, and executive function. Therefore, the results of this study which shows the transfer effect from riding a motorcycle to visuospatial cognition is in line with the results of our previous studies.

In this study, the subjects were randomly assigned into intervention and control groups, but duration of subject's previous experience of riding motor cycle was different between two groups. Although all of them are return riders who have had a significant break for more than ten years, those differences may have affected the results of this study.

Without any doubt, riding a motorcycle is a risk-taking behavior, which should induce emotional and physical stress. Emotional and physical stress has been known to increase the nerve growth factor level in the blood^(15, 16), which is important for the growth, maintenance, and survival of sympathetic and

sensory neurons, for protection against various psychiatric diseases⁽¹⁷⁾, and for improvement of cognitive functions⁽¹⁸⁾. Although, most of the previous investigations were conducted using animals, the biological and psychological mechanisms related to mental and physical stress can also support our results.

It is interesting to note that the average age of motorcyclists is greater than those in previous years, indicating that nowadays motorcycling is not solely a youth-oriented mode of transportation like in former days^(19,20), as that the majority of returning riders are middle-aged and elderly motorcyclists⁽²¹⁾. Why do these older motorcyclists who often have a high income and belong to a high social-economic class favor such a risky mobility? Previous psychological studies related to the motivation for riding addressed the following motivational emotional aspects of motorcyclists⁽²⁰⁾. 1. Positive experiences as motives, such as joy, fun and pleasure. It includes self-discovery and being in a good mood. 2. Dynamic aspects of riding; when riding the experiences of acceleration, speed, maneuverability, and cornering are related to the physics of motorbikes. 3. Performance aspects; testing the performance limits of oneself and the machine. This is similarly experienced in sports and competitive behavior. This study may add another interpretation that acquiring self-confidence caused by improvement of important cognitive functions enhances the motivation to ride.

There exist a few limitations in this study. (1) The relatively weak statistical power due to the small sample size. The results need replication in large samples in the future. In addition, long-term effects must be addressed in the future as well. (2) The lifestyle changes of the subjects after the intervention were not recorded. Riding a motor cycle in daily life may have led to changes in the subject's lifestyles, e.g. increase activity. We think changes in lifestyle can be regarded as another beneficial effects of riding. However, in terms of scientific research, it could affect the results to some degree. In our future study, we will obtain a larger sample of data, therefore allowing us to statistical analysis and estimate the negative effects of our current study.

5. Conclusion

Results of this preliminary report indicate that riding a motorcycle in daily life could have beneficial effects to improve visuo-spatial cognition in returning riders, that is, those who return to motorcycling after a significant break from riding.

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