BOLD Signal Change during Driving with Addition Task using fMRI

Ji-Hun Jo, Hyung-Sik Kim, Soon-Cheol Chung and Mi-Hyun Choi
Research Institute of Biomedical Engineering, Department of Biomedical Engineering, School of ICT Convergence, Engineering, College of Science & Technology, Konkuk University, 268 Chungwandae-ro, Chungju-si, South Korea

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Abstract: This paper uses a driving wheel and pedal (working as an accelerator, brake) equipped with an MR-compatible driving simulator at a speed of 80 km/h when driving and when driving while performing secondary tasks in order to observe differences in neuronal activation (BOLD signal change). The experiments consisted of three blocks, each block consisting of both a Control phase (1 min.) and a Driving phase (2 min.). During the Control phase, the drivers were instructed to look at the stop screen and not to perform driving tasks. During the Driving phase, the drivers either drove or drove while performing addition tasks at 80 km/h. The intensity of activated voxels increased in the addition task condition compared to the driving condition in insula.

1 INTRODUCTION

Quantitative observation of cerebral nerve activation using functional Magnetic Resonance Imaging (fMRI) is performed using two concurrent assessments: changes in the area of cerebral nerve activation (the number of activated voxel) based on Blood Oxygenation Level Dependent (BOLD) and changes in the size of cerebral nerve activation (the intensity of activated voxel). The changes in the area of cerebral nerve activation is an index assessing a specific region of the cerebral nerve activity or variation in the area of cerebral nerve activation, while the changes in the size of cerebral nerve activation is an index of the signal intensity of activated voxels within the same region. Therefore, either of the two methods can be selectively used for the studies with different primary purposes.

Many people nowadays frequently perform extra tasks (i.e. audio and navigation control, smartphone usage, eating, or carrying on a conversation) while driving. Recent neuroimaging studies have utilized fMRI to elucidate the neural activation under driving with extra task (Just et al., 2008; Uchiyama et al., 2012; Newman et al., 2007; Graydon et al., 2004). The subjects – while driving and performing an extra task simultaneously, in comparison with driving – exhibited reduced neural activation in the regions related to the spatial processing, visual spatial attention, movement planning and execution, action planning and motor control, but increased neural activity in the regions related to performing extra tasks (Just et al., 2008; Newman et al., 2007; Uchiyama et al., 2012). Nonetheless, these previous studies have primarily focused on observing the changes in the area or the region of cerebral activation. In order to more clearly understand the effects of performing simultaneous extra tasks on driving, not only the differences in the neural network activities but also the difference in the size of neural activity in the same region should be assessed via additional studies.

This study aims to observe the differences in the intensity of activated areas between driving and driving with a simultaneous additional task.

2 METHODS

In total, 10 adult male subjects in their 20's (mean age of 23.0±1.2) with mean driving experience of 2.6±1.8 years and without medical condition or history were selected for this study. Prior to the study participation, the subjects were provided with information regarding the purpose and the content of the study, and were controlled for other external factors that can affect either driving or cerebral nerve activation – including smoking, alcoholic

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drinks, and coffee. Practice driving runs were performed until the subject became familiar with the environment of driving simulator and could drive without an accident.

The developed MR-compatible driving simulator was composed of a driving wheel, an accelerator and a brake pedal (Figure 1). Driving environment was created using a software from Lightrock Entertainment. The subject used both hands to manipulate the driving wheel and right foot to press on the accelerator or brake pedal, and was asked to drive at a constant speed of 80km/h without making lane changes.

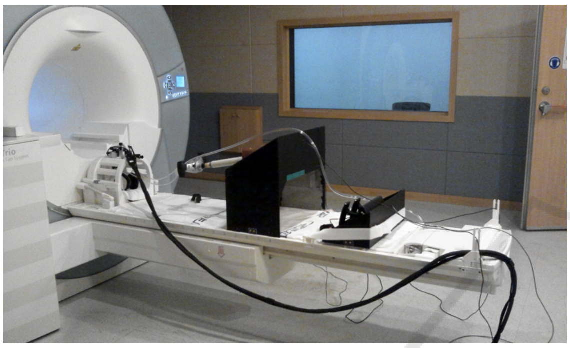

Figure 1: MR-compatible driving system.

The experimental design is composed of three blocks (Figure 2) – with one block consisting of the control phase (1 minute) and the driving phase (2 minutes). During the control phase, the subjects were asked to stare at a still frame without driving. During the driving phase, the subjects were either asked to focus on driving at 80km/h or perform both driving at 80km/h and an additional task at the same time. All subjects participated in the study under both conditions (driving, driving with an additional task). The speed of the vehicle was provided on the bottom left corner of the stimulator screen so that the subject could maintain the vehicle speed of 80km/h.

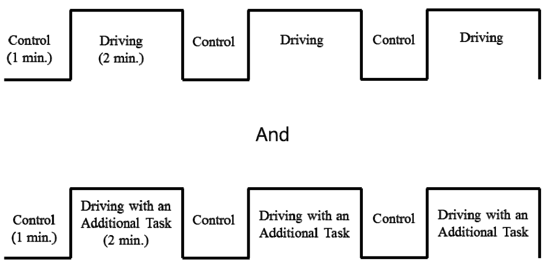

Figure 2: Experimental design.

The additional tasks were composed of mathematical calculations where the sum of the 2-digit numbers do not exceed 100 and the task requires carrying. There were 10 questions in each block, resulting in 30 questions of additional tasks in total. The investigator provided the additional task questions verbally via an audio system attached on the MR system, and the subject reported verbal responses to the questions.

The regions of cerebral nerve activation under each condition (driving, driving with an additional task) were calculated in comparison to the control phase. Using a voxel exhibiting the greatest statistical significance for activation as the standard, a 5x5x5 region was selected. In this selected region, the mean value of BOLD signal according to each condition and each phase was calculated. In order to analyze the variations in the cerebral nerve activation during the stimulation phase in comparison with the resting phase under each condition, BOLD % change was calculated using the following equations:

$BOLD\ \%\ change$ = {(Driving phase – Control phase) / Control phase} x 100(%)

In order to assess the difference in BOLD % change at the selected regions under each condition, Independent t-test (PASW 18) was performed.

3 RESULTS

The 8 regions that were commonly activated under both condition included inferior frontal gyrus, inferior parietal lobule, inferior temporal gyrus, insula, lingual gyrus, precentral gyrus, precuneus, and superior temporal gyrus. In comparison to driving condition, only the one region –insula ($p<0.01$)– exhibited significantly larger BOLD % change when the subject was driving and performing additional tasks simultaneously (Figure 3).

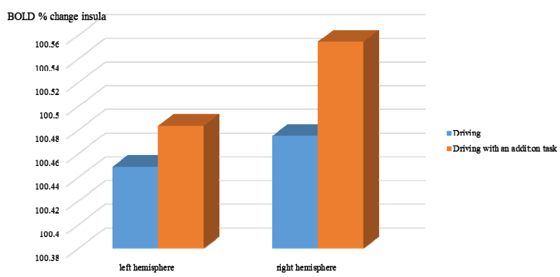

Figure 3: BOLD % change of insula.

4 CONCLUSIONS

The outcomes of this study were in agreement with the previous studies, with cerebral nerve activation in the similar regions. More specifically, BOLD signals were increased in the inferior parietal lobule, precuneus and inferior frontal gyrus regions associated with recognition (Andersen, 2011), as well as the precentral gyrus region associated with arm and eye movements (Graydon et al., 2004; Spiers, 2007). These regions are responsible for processing visual information related to the driving and auditory information related to the additional tasks which involve listening to the questions and providing answers. Furthermore, BOLD signals were increased in the insula, the region associated with error monitoring and controlling unnecessary behaviors (Anderson et al., 1994).

Previous studies that focused on the regions and the changes in the area of cerebral nerve activation reported that performing extra tasks while driving – in comparison with driving – reduces the area of cerebral nerve activation associated with driving but increases the area associated with performing extra tasks (Just et al., 2008; Uchiyama et al., 2012).

With increasing demand to supplement (or overcome) this, there is an increased activity in the sub-lobular regions which are associated with error monitoring and controlling unnecessary behaviors (Graydon et al., 2004). In this study, BOLD signal difference in the regions commonly activated under both conditions was compared. In other words, instead of observing the change in the area of activation based on the condition, the intensity of activity in the same activated region was observed. The outcomes of this study suggest that when driving and performing extra task simultaneously – in comparison with driving – BOLD signal was greater in the inferior and superior temporal gyri, which are associated with extra tasks. Furthermore, BOLD signal was also greater in the insula region associated with error monitoring and controlling unnecessary behavior. Nonetheless, the differences in BOLD signal were not observed in other regions directly or indirectly associated with driving. These findings further confirmed the outcomes of previous studies that have utilized BOLD signal intensity, which is another important measurement index of the changes in cerebral nerve activation. However, at the same time, these findings also raise the need for additional studies.

In conclusion, comprehensive analysis of the outcomes from the previous studies – that focused on the region and the change in the area of cerebral nerve activation – and this study – which focused on the change in the size of activation – suggests that while driving and performing addition tasks simultaneously, in comparison with driving, both the area and the size of neural activation increased in the regions associated with performing addition tasks and controlling unnecessary behaviors. However, other regions deeply related to driving (i.e. region associated with spatial recognition) did not exhibit change in the size of neural activation in this study, despite the previous study outcomes that demonstrated decreased area of neural activation. Additional studies are required to explain this deviation, and potential reasons include: the difference in the sensitivity of the two indices; differences in the characteristics of neural activation; or experimental design.

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REFERENCES

Just, M. A., Keller, T. A., Cynkar, J., 2008. A decrease in brain activation associated with driving when listening to someone speak. *Brain Research.* 1205: 70-80.

Uchiyama, Y., Toyoda, H., Sakai, H., Shin, D., Ebe, K., Sadato, N., 2012. Suppression of brain activity related to a car-following task with an auditory task: an fMRI study. *Transportation Research Part F: Traffic Psychology and Behaviour*. 15: 25-37.

Newman, S. D., Keller, T. A., Just, M. A., 2007. Volitional control of attention and brain activation in dual task performance. *Human Brain Mapping.* 28: 109-117.

Graydon, F. X., Young, R., Benton, M. D., Genik, Ⅱ R. J., 2004. Posse S, Hsieh L, Green C. Visual event detection during simulated driving: identifying the neural correlates with functional neuroimaging. *Transportation Research Part F: Traffic Psychology and Behaviour*. 7: 271-286.

Andersen, R. A., 2011. Inferior parietal lobule function in spatial perception and visuomotor integration. *Comprehensive Physiology* 1: 483–518.

Spiers, H. J., Maguire, E. A., 2007. Neural substrates of

driving behaviour. *NeuroImage* 36: 245–255.
Mechelli, A., Humphreys, G. W., Mayall, K., Olson, A., Price, C. J., 2000. Differential effects of word length and visual contrast in the fusiform and lingual gyri during reading. *Proceedings of the Royal Society B: Biological Sciences*. 267: 1909-1913.
Anderson, T. J., Jenkins, I. H., Brooks, D. J., Hawken, M. B., Frackowiak, R. S. J., Kennard, C., 1994. Cortical control of saccades and fixation in man A PET study. *Brain* 117: 1073-1084.