Can Functional Brain Imaging Prompt Innovations in Next-generation Automobiles?

Ryuta Kawashima
Department of Advanced Neuroscience, IDAC, Tohoku University, Sendai 982-8575 Japan
ryuta@idac.tohoku.ac.jp

ABSTRACT

Information about cognitive processing that occurs when an automobile is being driven can be obtained using neuroimaging techniques. Such information will certainly be advantageous in the near future for automobile design, given that automobiles are more than mere tools for transportation; they're a man-machine interface. Therefore, it would be in the best interest of engineers to invest in some knowledge of recent neuroimaging techniques from cognitive neuroscientists, and to at least comprehend the advantages and disadvantages of those techniques. In this symposium, I will discuss the possibility of applying neuroimaging techniques to the R&D of next-generation automobiles.

1. Introduction

Recent advancements in neuroimaging techniques enable us to visualize brain activity during various kinds of cognitive activities. We believe the utilization of information from human cognitive activity is certain to directly contribute to innovations made for the next-generation automobile. Recent automobiles and, of course, those of the future are emphatically acting as a man-machine interface, directly connecting one's intention to move with the mechanical systems of the automobile.

Functional magnetic resonance imaging (fMRI) is one of such techniques which is able to measure changes in brain activity. One of the significant advantages of the fMRI technique is that it can make visualization with relatively high spatial resolution of whole brain networks involved in specific cognitive function(s), and even access those structures located in deeper parts of the brain. However, a few restrictions apply to fMRI experiments. One is that fMRI experiments must be done in a MRI scanner room and the subjects must be put inside a MRI scanner. The MRI system is very large and heavy. Another restriction is that, since the MRI system uses string magnetic power, metals with electrically conductive parts cannot be used within or near the MRI scanner.

Near infrared spectroscopy (NIRS) is another neuroimaging technique. It records activity at the surface of the cerebral cortex by measuring related changes in the concentration of oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb). The advantage of NIRS is that it can be used in daily life situations. For example, it can measure the temporal course of cortical activity while a person actually drives a car. Nevertheless NIRS only can measure the activity of the brain's surface and nothing can be known about what is happening in deeper structures. In addition, its spatial resolution is very low- only several centimeters.

2. An example of an fMRI experiment

As mentioned, one cannot bring metals and electric parts close to the MRI scanner. Nevertheless, one can present any visual and auditory stimuli inside of the MRI scanner through a projector and a pair of MRI compatible headphones. The subject's head must be fixed on a head rest, but he/she is free to move his/her hands and feet during the MRI scans, as long as those movements do not cause any movement of the head.

We previously ran an experiment to measure brain activity when detecting hazardous situations while driving. In this experiment, we placed an accelerator and a brake pedal at the end of the MRI scanner bed and, through the projector, presented several video clips of different driving situations (Fig. 1). Subjects were asked to imagine they were driving their own car and to step on the brake when they came upon a hazardous situation. We then calculated brain activation at the time subjects moved their right foot from the accelerator. In addition, the activity of the activated areas was compared with the subject's score for individual sensitivity to hazard detection, which was measured by psychophysical tests on a different day.

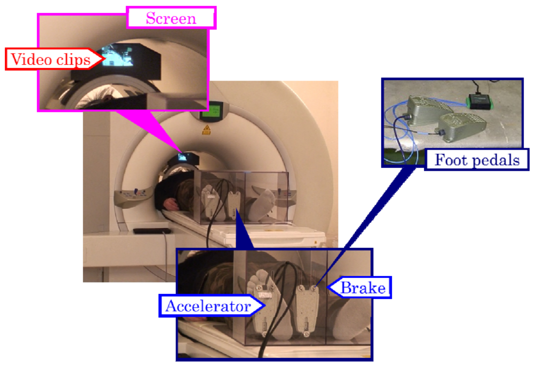

Fig. 1 An example of the experimental set-up for fMRI

The results indicate that a brain network consisting of the premotor cortex of the left hemisphere, the posterior parietal, and the occipital cortices of the bilateral hemispheres are involved in hazard detection. The activity of the left premotor cortex was shown to be related to the sensitivity of one's hazard detection abilities (Fig. 2).

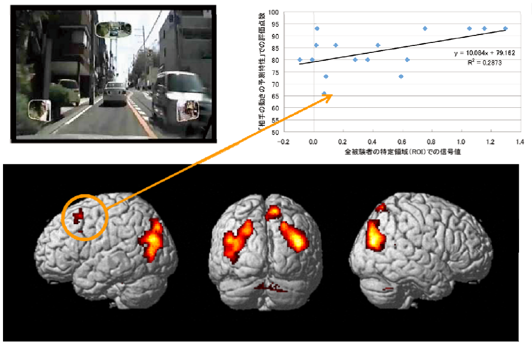

Fig. 2 Brain areas involved in hazard detection

This study gives us the following idea for developments in future automobiles. If we could continuously monitor the brain activity of the left premotor cortex using some device while one is actually driving, we can estimate one's ability to detect hazards as they occur, and then use that information to control the driving system of the automobile.

3. An example of NIRS experiment

We measured the activity of the dorsolateral prefrontal cortex (DLPFC) while cars were being driven using a prototype of the wearable optical topography (WOT) system (Hitachi Ltd., Tokyo, Japan) based on NIRS (Fig. 3). The DLPFC is known to play a key role in cognitive functions directly related to safe driving, such as attention, inhibition, decision making, etc.

A probe unit of the WOT system can be adjusted to fit on the head of a subject, and a processing unit can be strapped to the subject's body. Therefore, we can monitor changes in cortical activities while subjects are driving cars, or even riding motorcycles, in daily life situations.

Fig. 3 A prototype of the wearable optical topography (WOT) system

In our previous preliminary experiments, the activity of the DLPFC in healthy adults was measured while the adults drove cars in a closed driving course using the WOT. While driving cars with manual transmission, only the right DLPFC showed high activation. While driving cars with automatic transmission, the DLPFC of both hemispheres did not show any activation. It is interesting to note that driving a kart activated the bilateral DLPFC.

The left DLPFC showed activation only while a kart was being driven. Activation of the left DLPFC is often related to verbal tasks requiring executive processing. The drivers probably used a logical and/or verbal approach when considering how to handle the kart. In contrast, it has been argued that executive demand increases activity in the right DLPFC for spatial working memory processing. Thus there may be a greater requirement for spatial working memory when driving cars with manual transmission and karts. Cognitive load was relatively low when driving a car with manual transmission.

In general, the rate of age-related decline in measures of cognitive functioning will be less pronounced for people who are more mentally active, or, equivalently, the cognitive differences among people who vary in level of mental activity will be greater with increased age. When we design specific cars for our elderly population, we may have to consider designing cars that lend a hand to those with lower mental activity.

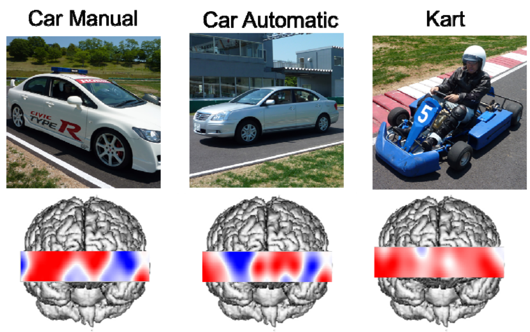

Fig. 4 Typical patterns of cortical activity when driving cars

4. Concluding remarks

We believe that applying what is known about cognitive functions through neuroimaging techniques to the R&D of next-generation automobiles can bring forth a new perspective. Creating a platform for discussion between cognitive neuroscientists and car engineers would surely be fruitful for innovation.