Impact Objectives

- Clarify the neural basis of unsafe driving in healthy older people
- Analyse the links between how a brain ages and high-risk driving actions

Driver behaviour linked with brain ageing

***Associate Professor Bun Yamagata** discusses his innovative medicine-engineering collaboration with **Associate Professor Motoki Shino**, **Assistant Professor Jinichi Hirano** and **Dr Yasuharu Yamamoto** combining brain image analysis technology with driving evaluation technology*

Associate Professor Bun Yamagata

Associate Professor Motoki Shino

Dr Yasuharu Yamamoto

Firstly, what inspired you to become involved in researching brain diseases?

I studied abroad at the Center for Interdisciplinary Brain Sciences Research (CIBSR) at Stanford University after obtaining my degree, and I was engaged in MRI research targeting genetic disorders such as Turner syndrome and Williams syndrome. After returning to Japan, I changed my research direction to highly heterogeneous psychiatric disorders such as depression and developmental disorders (autism and Attention Deficit Hyperactivity Disorder [ADHD]). I continued research to extract more disease specific brain function and structural abnormalities by combining brain imaging techniques such as MRI and NIRS with neuropsychological evaluation and using Artificial Intelligence (AI) technology (machine learning).

How did the inspiration for your latest project come about?

This project is a slight departure from my background. It began with an encounter with Professor Motoki Shino, an associate professor at The University of Tokyo's Faculty of Engineering. He specialises in ergonomics and mechanical engineering and was collecting and extracting data on highly unsafe driver behaviour and developing preventative safety systems based on his findings. In Japan, traffic accidents caused by elderly drivers have become a social problem, thus I thought that by combining my brain image analysis technology and Shino's driving evaluation technology, we will make a social impact.

What gaps in knowledge are you hoping to address?

In Japan, if you are diagnosed with dementia, you are obliged to return your driver's licence and you can no longer drive. It can also serve as a social message that healthy older people who have not been diagnosed with dementia can drive safely. Even in healthy older people without dementia and who are not obviously forgetful, the risk of unsafe driving increases as they age. We believe this does not mean all healthy older people can drive safely, but it is rather a social message that objective evaluation and intervention of driving skills are important.

How have you built on your previous learnings?

Age-related changes in the brain may be involved in the risk of unsafe driving in healthy older people. Brain volume shrinks with age, so even if cognitive function is age-appropriate, there must be healthy people whose brain atrophy is significant. This may contribute to unsafe driving. Our second research study investigated how brain structural abnormalities are involved in unsafe driving. We used neuropsychological tests and information on the volume of grey matter in the brain as an objective index. It became clear that age and the grey matter volume changes in the dorsolateral prefrontal cortex-parietal lobe region may help predict the risk of unsafe driving in healthy older people. Our results suggest that MRI images of the head can be a scientific index to predict the risk of unsafe driving and that abnormalities in the dorsal attention network may contribute to unsafe driving in healthy older people.

Can you talk a little about your collaboration with Asociate Professor Motoki Shino?

Shino collects and extracts data on highly unsafe behaviours based on actual driving behaviour. This study is an innovative medicine-engineering collaboration project in which his research team, who specialise in the quantification research on driving skills of the elderly and my own team, which focuses on prediction models using brain imaging research and AI technology, work together. This project would not be possible without this collaborative partnership between us. ▶

Screening for safer roads

*Researchers from the **Department of Neuropsychiatry, Keio University School of Medicine** and **The University of Tokyo** are combining engineering with neuropsychology techniques to link changes in ageing brains with inattention and an increased risk of unsafe driving*

Japan is known for the longevity of its citizens, with an average life expectancy of over 85 years. However, with increased life expectancy comes an increase in social and health problems associated with ageing populations. Where driving is concerned, for example, Japan has a significant social problem from accidents caused by elderly drivers. Drivers aged 75 and over are subject to cognitive function tests when renewing their driving licence. However, while this screens for dementia, it cannot account for healthy elderly people who have a greater risk of unsafe driving due to the natural ageing process.

Associate Professor Bun Yamagata, from the Department of Neuropsychiatry at Keio University School of Medicine, has been researching brain function and structural abnormalities within the brain using imaging techniques such as MRI and NIRS and combining these data with neuropsychological evaluations and AI technology. He has partnered with ergonomics and mechanical engineering specialist Associate Professor Motoki Shino, from The University of Tokyo, to conduct a new and innovative study combining engineering with neuropsychology techniques to gather data on driving behaviours and brain atrophy patterns. They seek to develop algorithms that predict the risk of dangerous driving behaviours in elderly drivers.

Yamagata has conducted a series of studies exploring the relationship between the structural connectivity of white matter in the brain and the driving ability of healthy older people. He found that changes in the white matter within the dorsal attention network may contribute to a higher risk of unsafe driving behaviours in healthy elderly people. 'We found that the white matter structure of the superior longitudinal fascicle connecting the dorsolateral prefrontal cortex and the parietal lobe was significantly impaired in the unsafe driving group,' he describes.

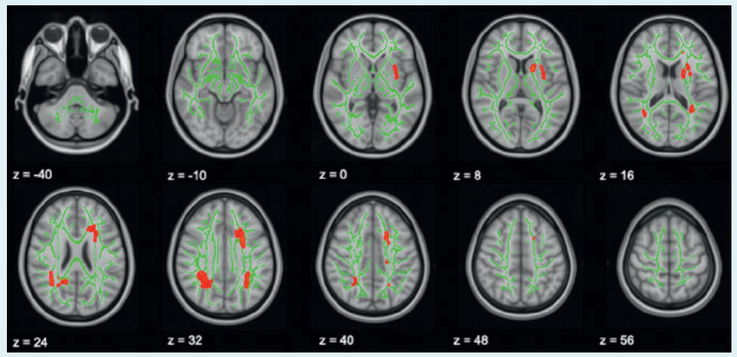
REAL-WORLD DATA COLLECTION

Gathering real information on the driving behaviour of older drivers was a critical aspect of this study. Using a car equipped with a global positioning system (GPS), a video camera and a drive recorder, the team collected the data required to build a new driving skill index. This work enabled them to quantitatively analyse the driving behaviours of their subjects. 'Using machine learning, we established a model that predicts the risk of unsafe driving in healthy older people with high accuracy from neuropsychological tests and practical visual acuity,' outlines Yamagata.

The researchers performed LASSO (least absolute shrinkage and selection operator) and LOOCV (leave-one-out cross validation) analyses on the data gathered based on the Akaike Information Criterion (AIC). This enabled them to select specific features for their prediction model. Using LOOCV also enabled the team to optimise the training sample and avoid a split bias situation that could have arisen due to their small sample size. Yamagata used a linear support vector machine (SVM) to create the prediction model used in the study as well as utilising Optuna in the development of the linear SVM algorithm. Data was validated using the LOOCV analysis, but he notes that the difficulty in validating the data without an independent data set is a limitation of this study. 'Strictly speaking, we believe that it cannot be put into practical use unless we verify whether the algorithm obtained in this research can discriminate safe/unsafe driving with high accuracy using a completely independent data set,' he points out.

CHALLENGES AND RESULTS

From Yamagata's perspective, one of the important factors for the success of research is acquiring high-quality data sets. 'This has proven the most difficult area to implement as the subjects were required to take part in many different experiments over several days, which may have dissuaded potential participants from taking part,' he comments. Each subject was required to undergo a driving skill evaluation in a real vehicle at a driving school, followed by a neuropsychological examination at Yamagata's facility. They were also given an MRI scan.



Voxels showing significant higher axial diffusivity (AD) values in unsafe drivers compared with safe drivers. An AD increase in unsafe drivers relative to safe drivers is shown in red. The whole-brain skeleton is shown in green.

> *"Using machine learning, we established a model that predicts the risk of unsafe driving in healthy older people with high accuracy from neuropsychological tests and practical visual acuity"*

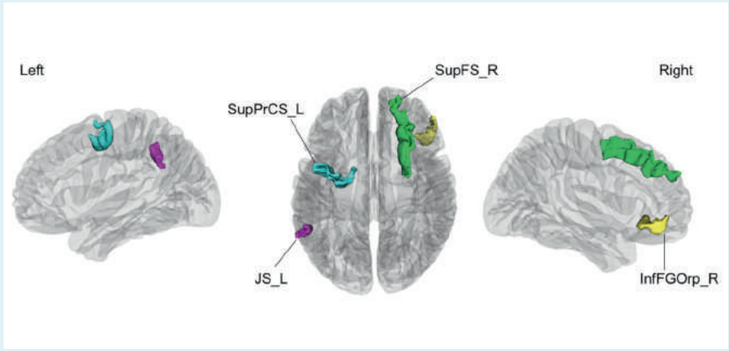
Some surprising results were garnered by the team. They found that the results of the immediate recall neuropsychological test highlighted the risk of unsafe driving. 'That is, the high-risk driving behaviours were not linked with forgetfulness, which is characteristic of dementia and early Alzheimer's disease, but related to the changes in attention that appeared to impair driving behaviour in the elderly,' describes Yamagata. While data is not available on driving patterns in dementia patients as it is not considered ethical to conduct such research, these findings raise the possibility that early-stage dementia does not necessarily equate to poor driving. 'In addition, results from the MRI scans consistently showed that subjects demonstrating unsafe driving behaviours were more likely to also demonstrate changes in the brain structure within the dorsal attention network,' he adds.

TACKLING A SOCIAL PROBLEM

This is important research that can help address a growing social problem, make roads safer and allow at-risk elders to identify how the way in which their brains are ageing can affect their behaviours. 'Using AI technology, we created a model that predicts unsafe driving behaviour at stop intersections with the highest accuracy from various neuropsychological tests,' explains Yamagata. Their findings show the risk of unsafe driving strongly correlated with age and attention dysfunction as determined by the score on the first immediate recall in the Rey Auditory Verbal Learning Test. Drivers over 75 in Japan are screened for dementia when renewing their licences. However, Yamagata has shown that healthy elderly people who also have a higher risk of road accidents could also be screened using MRI screening to highlight atrophy in parts of the brain. 'We clarified that attentional dysfunction in the elderly is involved in unsafe driving risks,' he states.

Yamagata believes that his work may help in reducing the risk of serious traffic accidents by identifying healthy older drivers who are more likely to demonstrate poor driving behaviours. By using brain imaging techniques in conjunction with AI, he is confident that this group of drivers can be readily identified and interventions such as additional driving lessons can be offered. This would not only keep costs low, by targeting these resources only to those most at risk, but also benefit individuals and society in general by reducing the likelihood of serious road accidents.

One of his plans for future research aims to target implementation of large-scale screening of elderly drivers. However, these results must be verified on a large scale, in a multi-centre trial, before being carried out. 'I am also seeking to conduct similar research focused on ADHD, which is linked with a high risk of unsafe driving,' Yamagata says. This disorder is characterised by impulsive behaviour, hyperactivity and inattention, and may be a useful model to investigate the impact of inattention on unsafe driving.



The four cortical regions identified as consistent classification inputs were located within the cortical regions involved in cognitive functions essential for driving, such as voluntary orienting of attention, decision-making and working memory.

Road accidents involving elderly drivers have become a widespread global problem, and it is important steps are taken to tackle this issue. However, a balance between budget and impact must be struck to achieve a viable solution for all. This ground-breaking work by Yamagata and Shino could result in a cost-effective method for identifying high-risk drivers, enabling them to receive targeted assistance in improving their driving behaviours, making the roads safer for all. ●

Project Insights

FUNDING
The General Insurance Association of Japan and JSPS, KAKENHI Grant Numbers 20H03607 and JP16H03130

COLLABORATORS
Associate Professor Motoki Shino, Department of Human and Engineered Environmental Studies, The University of Tokyo, Japan

TEAM MEMBERS
Assistant Professor Jinichi Hirano and Dr Yasuharu Yamamoto, Department of Neuropsychiatry, Keio University School of Medicine

CONTACT
Associate Professor Bun Yamagata
Project Coordinator

T: +81 3 5363 3971
E: yamagata@a6.keio.jp

BIO
Associate Professor Bun Yamagata is based at the Department of Neuropsychiatry, Keio University School of Medicine. His research focuses on elucidating disease-specific neurobiological evidence in psychiatric disorders such as depression and developmental disorders.

Associate Professor Motoki Shino is based at The University of Tokyo. His research has covered Wellbeing Science and Assistive Technology that leads to the improvement of QOL. Shino is looking to the establishment of technology and study to provide a safe and comfortable life through a mixture of human adaptability, interface and robotics for the persons with disabilities and the elderly.

Keio University 1858 CALAMVS GLADIO FORTIOR

科研費 KAKENHI