Large-Scale Functional Brain Network Changes in Taxi Drivers: Evidence From Resting-State fMRI

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Abstract: Driving a car in the environment is a complex behavior that involves cognitive processing of visual information to generate the proper motor outputs and action controls. Previous neuroimaging studies have used virtual simulation to identify the brain areas that are associated with various driving-related tasks. Few studies, however, have focused on the specific patterns of functional organization in the driver's brain. The aim of this study was to assess differences in the resting-state networks (RSNs) of the brains of drivers and nondrivers. Forty healthy subjects (20 licensed taxi drivers, 20 nondrivers) underwent an 8-min resting-state functional MRI acquisition. Using independent component analysis, three sensory (primary and extrastriate visual, sensorimotor) RSNs and four cognitive (anterior and posterior default mode, left and right frontoparietal) RSNs were retrieved from the data. We then examined the group differences in the intrinsic brain activity of each RSN and in the functional network connectivity (FNC) between the RSNs. We found that the drivers had reduced intrinsic brain activity in the visual RSNs and reduced FNC between the sensory RSNs compared with the nondrivers. The major finding of this study, however, was that the FNC between the cognitive and sensory RSNs became more positively or less negatively correlated in the drivers relative to that in the nondrivers. Notably, the strength of the FNC between the left frontoparietal and primary visual RSNs was positively correlated with the number of taxi-driving years. Our findings may provide new insight into how the brain supports driving behavior. *Hum Brain Mapp* 36:862–871, 2015. © 2014 Wiley Periodicals, Inc.

Key words: driving; functional network; independent component analysis; resting state

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INTRODUCTION

Driving a car is the primary means of transportation for many people. It is a complex behavior that relies on cognitive processing of visual information to generate the proper motor outputs and action controls. Michon [1985] proposed that the architecture of driving behavior can be modeled into the following three interacting hierarchical levels: the strategic level (trip planning and route finding), the tactical level (planning of relevant actions based on the current driving context), and the operational level (action execution and perception). During driving, fatal accidents can occur because of a lack of cognitive and psychomotor abilities resulting from aging, neurological disorders, or alcohol. Therefore, understanding the neural mechanisms underlying driving behavior is important for traffic safety.

Previous neuroimaging studies have used virtual simulation to examine brain activity evoked during various driving-related tasks [Calhoun et al., 2002; Callan et al., 2009; Horikawa et al., 2005; Spiers and Maguire, 2007; Uchiyama et al., 2003; Walter et al., 2001] and its response to alcohol [Meda et al., 2009] and other drugs, such as antihistamines [Tashiro et al., 2008]. These studies found that the act of driving recruits multiple brain areas that support perception, motor control, attention, working memory, and decision-making functions. Additionally, the activity in specific brain areas was found to be positively or negatively correlated with task performances, such as average driving speed [Calhoun et al., 2002; Horikawa et al., 2005], number of crashes [Horikawa et al., 2005], and the ability to maintain a safe driving distance [Uchiyama et al., 2003]. Given that simulated driving in a scanner differs from actual driving in a real environment, these studies do not completely reveal the neural mechanisms underlying driving behavior. Indeed, Jeong et al. [2006] suggested that while simulated and actual driving can show similar patterns of brain activation for the perceptive and visuomotor components, there should be significant differences between them for higher-order components, such as attention and autonomic responses. There are strong links between specialized skills and specific brain functions, which can be attributed to either the innate predisposition or neural plasticity [Musacchia et al., 2007; Wan et al., 2011]. Therefore, comparing the functional organization in the brains of drivers and nondrivers may provide new insight into how the brain supports driving behavior.

Resting-state functional MRI (rs-fMRI) is a powerful tool for investigating the large-scale intrinsic functional organization of the brain. Previous resting-state functional connectivity studies have demonstrated that there are highly correlated spontaneous low-frequency (< 0.1 Hz) blood oxygen level-dependent fluctuations in spatially distinct but functionally related brain regions, namely the resting-state networks (RSNs) of the human brain [Biswal et al., 1995; Fox and Raichle, 2007]. These networks recapitulate the architecture of the known functional systems related to

TABLE I. Characteristics of the participants in this study

Variable	Drivers	Nondrivers	<i>P</i> value
Sample size	20	20	
Age (years)	39.8±5.5	41.1±5.0	0.42 ^a
Sex (male/female)	19/1	18/2	0.55 ^b
Education (years)	9.3±1.6	9.0±1.4	0.54 ^a
Years of taxi driving	4.6±3.5		
Years of total driving	11.6±4.9		

^aTwo-sample *t* test.

^bPearson Chi-square test.

visual, motor, attention, memory, and other brain functions [Beckmann et al., 2005; Biswal et al., 1995; Damoiseaux et al., 2006; Greicius et al., 2003], and show a striking spatial correspondence to task-induced coactivation patterns [Smith et al., 2009]. Importantly, it has been suggested that the RSNs play a role in human behaviors. For example, previous studies show that the resting-state functional connectivity between specific processing areas can predict individual variability in task performance [Hampson et al., 2006; Kelly et al., 2008; Seeley et al., 2007]. Moreover, it has been shown that the functional connectivity patterns at rest can be altered by extensive training and recent experiences [Albert et al., 2009; Duan et al., 2012; Jolles et al., 2013; Lewis et al., 2009; Stevens et al., 2010]. These findings raise the interesting possibility that the brain's intrinsic functional organization may serve to stabilize brain ensembles, aid in the memory consolidation of recent experiences, and prepare the individual for its moment-to-moment responses to environment demands [Buckner and Vincent, 2007; Raichle, 2010].

In this study, we hypothesized that the RSNs were likely to encode or support the encoding of people's driving skill. We acquired rs-fMRI data from 20 licensed taxi drivers and 20 nondrivers. Taxi drivers were chosen to ensure that the individuals in this group had a consistent level of driving in the environment. Group independent component analysis (ICA) was used to decompose the rs-fMRI data into distinct RSNs. By comparing the intrinsic brain activity of each RSN in the drivers and nondrivers, we expected to acquire evidence for specific patterns of functional organization in the driver's brain. Recent studies suggest that spontaneous brain activity is not only organized into separated patterns but is also engaged in a whole-brain level of functional cooperation and communication [Achard et al., 2006; Jafri et al., 2008; Liao et al., 2010]. Therefore, we also evaluated the driving-related differences in the temporal correlation between the time courses of the RSNs, which is referred to as functional network connectivity (FNC) [Jafri et al., 2008]. Finally, we examined whether the driving-related changes in resting-state functional connectivity were associated with the number of driving years.

MATERIALS AND METHODS

Subjects and Data Acquisition

The subjects included 20 licensed taxi drivers and 20 nondrivers. The two groups were matched for age, sex, and education level (Table I). All of the subjects were recruited in Chongqing, China, where the traffic is relatively crowded. Because this city is located in a mountainous region, its road situation is complicated, and there is almost no east-west or north-south oriented road. The mean time that the drivers had possessed an ordinary driving license was 11.6 years (range 6–23 years), and the mean time for them being licensed Chongqing taxi drivers was 4.6 years (range 1–14 years). The taxi drivers worked approximately 8 h a day. The nondrivers did not know how to drive at all. The transportation modes of the nondrivers included by foot and by bus. They chose to not use other vehicles (e.g., bicycle) as their transportation mode because the roads in Chongqing spiral upward. All of the subjects were right-handed. None of the participants had experienced major head trauma, had a history of alcohol or drug dependence, or had any neurological disorder. Written informed consent was obtained from each subject. This study was approved by the Institutional Review Board of the Southwest University.

During the resting-state scan, the subjects were instructed to keep still with their eyes closed, remain awake, and not think of anything in particular. All of the subjects reported that they remained awake for the duration of the experiment. Images were collected using a SIEMENS TRIO 3-T MRI scanner in the Key Laboratory of Cognition and Personality (Southwest University), Ministry of Education, China. The imaging parameters were as follows: 32 axial slices, TR = 2,000 ms, TE = 30 ms, slice thickness = 3.0 mm, flip angle = 90°, FOV = 200 × 200 mm², and in-plane resolution = 64 × 64. Each resting-state scan lasted 8 min, and 240 volumes were obtained.

Data Preprocessing

Prior to preprocessing, the first 10 volumes were discarded for magnetic saturation effect. The rs-fMRI data were preprocessed using the statistical parametric mapping software package (SPM8, <http://www.fil.ion.ucl.ac.uk/spm>). The images were corrected for within-scan acquisition time differences between slices and realigned to the first volume to correct for interscan head motions. All of the subjects in this study had less than 2 mm of translation and 2° of rotation in any of the *x*, *y*, and *z* axes. Then, the images were normalized to the standard EPI template in the Montreal Neurological Institute (MNI) space and resliced to 3 × 3 × 3 mm³. The resulting images were spatially smoothed with a Gaussian filter of 8 mm full-width half-maximum kernel.

Analysis of Intrinsic Brain Activity Within the RSNs

After these preprocessing steps, group spatial ICA was conducted using the GIFT software (<http://icatb.sourceforge.net/>) [Calhoun et al., 2001; Calhoun et al., 2009]. First, the data for each individual subject were dimension-reduced temporally using PCA. All the subjects were then concatenated into one group and passed through another dimension reduction step. The grouped data were decomposed into 30 aggregate components (with time courses and spatial maps) using the Infomax approach [Bell and Sejnowski, 1995]. Finally, a GICA back reconstruction step was performed to calculate the individual subject components from the aggregate components of ICA and the reducing matrices determined by PCA, which effectively capture intersubject variability [Allen et al., 2012]. It involved estimating a mixing matrix which had partitions that were unique to each subject and contained the time courses for each of the 30 components. Once the mixing matrix was estimated, the spatial maps for each subject were computed by projecting the individual subject data onto the inverse of the partition of the mixing matrix that corresponding to that subject. In the end this provided subject-specific spatial maps and time courses which were further used to make group-level random-effects inferences.

The individual subjects' spatial maps for each selected RSN were converted to *Z* values. Therefore, the intensities of each spatial map indicate the relative contribution of the voxels to the distributed and coherent brain activity within that RSN. For each selected RSN, a voxel-wise one-sample *t* test was first conducted across all of the subjects' spatial maps. The statistically thresholded *t*-value map was used to define the brain regions that belong to the RSN. The driving-related differences in the intrinsic brain activity in all of the regions of each RSN were then examined using a voxel-wise two-sample *t* test.

Analysis of Functional Network Connectivity Between the RSNs

Group ICA in GIFT also produced time courses for each RSN and for each subject, which corresponded to the waveform of a specific pattern of intrinsic brain activity. The time courses for the selected RSNs were temporally band-pass filtered (0.01–0.1 Hz), followed by linear detrending to remove any residual drift. Nine nuisance signals were then removed from the time courses via linear regression, including the signals averaged from white matter, cerebrospinal fluid and the whole brain, and six parameters obtained by head motion correction. This regression procedure was performed to reduce the spurious variance that unlikely reflects neuronal activity. The temporal relationship between the RSN time courses was evaluated using the Pearson's correlation coefficient. Fisher's *z*-transform was applied to the correlation values to

Figure 1.

Sagittal, coronal, and axial views of spatial maps for each RSN. **A–G:** show the anterior DMN, posterior DMN, left FPN, right FPN, primary VN, extrastriate VN, and SMN, respectively. Each RSN map was obtained using a one-sample t test across all of the individual IC patterns ($P < 0.05$, FDR corrected). The right side of the image corresponds to the left hemisphere of the brain. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

ensure normality. For each pair of RSNs, we compared the correlation values in the drivers and nondrivers to study the possible driving-related differences in the functional connectivity between the RSNs.

RESULTS

RSN Maps

Figure 1 shows the spatial maps of the seven selected RSNs obtained from the rs-fMRI data of all the subjects by Group ICA. These RSNs are located in the cortex and maximally overlap with the previously reported default mode, frontoparietal, visual and sensorimotor networks (SMN) [Beckmann et al., 2005; Damoiseaux et al., 2006, 2008; Smith et al., 2009]. Among these RSNs, the posterior default mode network (DMN), anterior DMN, left frontoparietal network (FPN) and right FPN are related to higher-order cognitive functions, and the primary visual

network (VN), extrastriate VN, and SMN are associated with lower-level sensory processing.

An interesting aspect of the RSN maps is that we identified two components resembling the DMN (posterior DMN and anterior DMN). A similar decomposition of the DMN has been previously reported [Damoiseaux et al., 2006, 2008; Li et al., 2013]. Recent studies have also shown that the anterior and posterior regions of the DMN have different anticorrelated networks [Uddin et al., 2009] and exhibit different patterns of task-evoked activity during specific tasks [Sestieri et al., 2011]. These results suggest that the DMN is not a functionally homogenous system and can be divided into subnetworks.

Driving-Related Differences in the Intrinsic Brain Activity of the RSNs

For each RSN, we used a voxel-wise two-sample t test to examine the intrinsic brain activity differences between the

Figure 2.

Driving-related decreases in the intrinsic brain activity of (A) the primary VN and (B) the extrastriate VN. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

Figure 3.

Driving-related differences in the functional network connectivity between the RSNs. Relative increases of connectivity strength in the driver group compared with the nondriver group are displayed by the red line, and decreases are displayed by the blue line. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com.]

TABLE II. Comparison of the strength of FNC for the drivers and nondrivers

FNC				
RSN1	RSN2	Driver (mean ± sem)	Nondriver (mean ± SEM)	P value
Driver > nondriver				
posterior DMN	primary VN	0.297 ± 0.050	0.120 ± 0.047	0.014
anterior DMN	SMN	-0.025 ± 0.044	-0.221 ± 0.039	0.002
left FPN	primary VN	-0.087 ± 0.042	-0.257 ± 0.043	0.008
right FPN	SMN	-0.078 ± 0.037	-0.231 ± 0.059	0.034
right FPN	primary VN	-0.126 ± 0.059	-0.313 ± 0.059	0.031
right FPN	extrastriate VN	-0.051 ± 0.043	-0.257 ± 0.047	0.003
Nondriver > driver				
primary VN	extrastriate VN	0.687 ± 0.051	0.827 ± 0.041	0.037
SMN	extrastriate VN	-0.112 ± 0.059	0.064 ± 0.058	0.039

drivers and nondrivers. The significance level was set at $P < 0.001$ uncorrected. Multiple comparisons were corrected at the cluster level ($P < 0.05$, false discovery rate). Compared with the nondrivers, the drivers showed reduced brain activity in the right calcarine (MNI: 6, -75, 15; BA 17) of the primary VN (Fig. 2A) and reduced brain activity in the right lingual gyrus (MNI: 9, -90, -6; BA 18) of the extrastriate VN (Fig. 2B). Using the same significance level, no driving-related intrinsic brain activity differences were observed in the other RSNs.

Driving-Related Differences in the Functional Connectivity Between the RSNs

Significant driving-related differences in the functional connectivity between the RSNs are summarized in Figure 3

Figure 4.

The average connectivity strength among the higher-order cognitive networks (E_H), lower-level sensory networks (E_L), and cognitive to sensory networks (E_{HL}) in the driver and nondriver groups. The error bars represent the standard error of mean (SEM).

and Table II. We found that a set of FNCs were more positively correlated or less negatively correlated in the drivers than in the nondrivers. These FNCs included the connectivity between the posterior DMN and primary VN ($t = 2.58$; $P = 0.014$), the connectivity between the anterior DMN and SMN ($t = 3.34$; $P = 0.002$), the connectivity between the left FPN and primary VN ($t = 2.81$; $P = 0.008$), the connectivity between the right FPN and SMN ($t = 2.20$; $P = 0.034$), the connectivity between the right FPN and primary VN ($t = 2.24$; $P = 0.031$), and the connectivity between the right FPN and extrastriate VN ($t = 3.22$; $P = 0.003$). However, the drivers had a less positive correlation in the FNC between the primary VN and extrastriate VN ($t = 2.16$; $P = 0.037$), and a more negative correlation in the FNC between the SMN and extrastriate VN ($t = 2.13$; $P = 0.039$) when compared with the nondrivers.

Figure 5.

Scatter plots and regression line for the number of taxi-driving years against the strength of the functional connectivity between the left FPN and primary VN.

Each RSN can be classified as either a higher-order cognitive network or a lower-level sensory network. For a better understanding of the driving-related differences in the RSN interactions, we also compared the average connectivity strengths among the higher-order cognitive networks, the lower-level sensory networks, and the cognitive to sensory networks in the drivers and nondrivers (Fig. 4). We found that the higher-order cognitive networks were more interconnected with the lower-level sensory networks in the drivers than in the nondrivers ($t = 3.19$; $P = 0.003$). In contrast, the lower-level sensory networks were less intraconnected in the drivers than in the nondrivers ($t = 2.80$; $P = 0.008$). The two groups did not show significant difference in the intraconnectivity between the higher-order cognitive networks ($t = 0.015$; $P = 0.988$).

Correlations With Driving Years

The correlation between the time spent as a taxi driver and the extent of changes in the functional connectivity was evaluated using the Pearson's correlation coefficient. We found that there was no correlation between the number of taxi-driving years and the intrinsic brain activity in the regions that exhibited significant driving-related differences ($P > 0.2$). Correlation analysis was also performed between the time spent as a taxi driver and the FNCs that exhibited significant driving-related differences. We found that the connectivity between the left FPN and primary VN showed a positive correlation with the number of taxi-driving years ($r = 0.634$, $P = 0.003$; Fig. 5). The remaining FNCs, however, did not show any significant correlation with the number of taxi-driving years ($P > 0.13$).

We also examined the correlation between the altered functional connectivity and the number of total-driving years. We found, however, that there was no significant correlation between the number of total-driving years and the changes in intrinsic brain activity ($P > 0.10$) or FNC ($P > 0.20$) in the driver group.

DISCUSSION

In this study, we examined driving-related differences in the intrinsic brain activity of the RSNs and in the FNC between the RSNs. We found that the drivers exhibited reduced intrinsic brain activity in the VNs when compared with the nondrivers. For the FNC, the drivers exhibited stronger correlations between the higher-order cognitive networks and lower-level sensory networks, whereas weaker correlations between the lower-level sensory networks. Notably, the strength of the FNC between the left FPN and primary VN was positively correlated with the number of taxi-driving years. To the best of our knowledge, this is the first study to probe the specific patterns of functional organization in the driver's brain and may pro-

vide new insight into how the brain supports driving behavior.

In this study, we show that the resting-state functional connectivity between the higher-order cognitive networks and lower-level sensory networks is more positively correlated or less negatively correlated in drivers than in nondrivers. Interestingly, a recent EEG study has also found that training on a multitasking car race game can enhance the theta coherence between the frontal and posterior brain regions [Anguera et al., 2013]. While the neural mechanism underlying the negative functional connectivity remains to be elucidated, a defensible generalization seems to be that the negative correlation in spontaneous brain activity is related to active decoupling of different functional systems, which may prevent them from effectively interacting with each other under task conditions [Deco et al., 2009; Lewis et al., 2009]. Moreover, the findings from another study suggest that negative functional connectivity may be the result of phase accumulation along the shortest path in brain functional networks [Chen et al., 2011]. Based on these findings, we propose that drivers may have an enhanced ability to rapidly integrate the cognitive and sensory functions to make the moment-to-moment responses to the external environment during the act of driving.

More specifically, the brain areas encompassed in the FPN have been repeatedly found to be active during external attention tasks [Corbetta and Shulman, 2002; Dosenbach et al., 2008]. The stronger functional connectivity between the FPN and primary VN may enhance the driver's ability to rapidly process visual information to meet varying environmental demands. Moreover, the stronger functional connectivity between the posterior DMN and primary VN may facilitate the monitoring of internal and external environment during actively driving without any attention-demanding cognitive tasks [Gusnard and Raichle, 2001]. Communication between the right FPN and extrastriate VN bears a strong resemblance to the dorsal visual stream and may play a role in transforming visual information into the required coordinates for prepared motor actions [Rizzolatti and Matelli, 2003]. It has been suggested that the anterior DMN is involved in internally oriented thoughts and can protect the execution of long-term mental plans from immediate environmental demands [Burgess et al., 2007; Gusnard and Raichle, 2001; Koechlin and Hyafil, 2007]. Reaching a destination is usually the main goal of driving, especially for taxi drivers. To achieve this goal, drivers need to maintain the internally oriented thoughts of trip planning and route finding. Complex road environments also require that drivers place their ongoing internally oriented thoughts into a pending state and select the most relevant behavior for the current situation and traffic conditions. Both the anterior DMN and right FPN exhibited stronger functional interactions with the SMN in the drivers, which may give them the ability to pursue their long-term driving plan and to respond to the demands of the immediate driving context at the same time.

It is interesting to note that the drivers also had specific patterns of decreased intrinsic brain activity and FNC. For example, the extrastriate VN and SMN were independent in the nondrivers but were negatively correlated in the drivers. As we previously discussed, negative functional connectivity can be interpreted as an efficient computational state that prevents two systems from directly communicating with each other under task conditions and may facilitate independent task recruitment and switching [Deco et al., 2009; Lewis et al., 2009]. During driving, people need to either attend to visual information or to self-generated motor actions. In this context, the negative correlation between the VN and SMN may operate to prevent the perceptual and motor systems from interfering with each other during driving. After repeated experiences from driving in the same city, drivers acquire information concerning what is possible or probable in the forthcoming environment. A series of neuroimaging studies have shown that this type of foreknowledge is associated with facilitated visual perception and a reduction in neural activity in the visual areas [Marois et al., 2000; Summerfield and Egnér, 2009]. Therefore, long-term driving in the same environment may result in reduced intrinsic brain activity within the VNs.

Currently, there is no definitive conclusion on whether the modulation of resting-state functional connectivity is a passive consequence of previous task performance [Hasson et al., 2009; Waites et al., 2005], or is directly related to training and learning [Albert et al., 2009; Duan et al., 2012; Lewis et al., 2009]. In this study, we found that the strength of the FNC between the left FPN and primary VN was positively correlated the number of taxi-driving years. The other driving-related functional connectivity differences, however, did not show a significant correlation with the number of taxi-driving years. On one hand, the amount of taxi-driving time for each subject in the driver group was greater than 1 year. It is possible that once the driving skill has been learned, the repeated performance of familiar driving tasks with the same intensity will not alter the intrinsic functional organization of the brain. Conversely, driving can be very dangerous, especially when trying to avoid potential collisions. However, the occurrence of these types of driving events, such as controlling a car in a swerve or acting to avoid a collision, is rare in the driver's experience, and is thought to be related to the number of driving years. Previous studies have shown that the frontal and parietal regions are more active in the left than the right hemisphere when performing complex motor sequences [Haaland et al., 2004; Wymbs et al., 2012]. The linear effect of taxi-driving years on the FNC between the left FPN and primary VN suggests that sophisticated drivers are better at rapidly performing a series of unprepared motor actions in response to an emergency. Based on our results, we speculate that stable changes in resting-state functional connectivity can only be induced by novel patterns of brain coactivation, possibly through the development of myelinated fibers that connect neurons in different cortical regions [Hagmann et al., 2008].

It should also be mentioned that we found no significant correlation between the number of total-driving years and the driving-related changes in resting-state functional connectivity. A possible explanation for this result is that the number of total-driving years does not represent the actual amount of time that one performs driving behaviors because people do not typically spend the same amount of time driving every day. The working hours of the taxi drivers, however, were approximately the same. Therefore, it is reasonable to assume that the number of taxi-driving years is proportional to the amount of time that our subjects spent consistently performing driving behaviors and may be associated with specific functional connectivity changes.

There were several potential limitations in this study. First, the sample size was relatively small, which limits the statistical power for detecting group differences. Second, we only used functional connectivity to measure the temporal synchronization of rs-fMRI time series, which does not provide any information on the causality relationships between the RSNs. Recently, some studies have begun to examine the directional connectivity patterns of the RSNs [Jafri et al., 2008; Lewis et al., 2009; Liao et al., 2010]. However, because of the low EPI sampling and various noises, the estimation of directionality from rs-fMRI data is still under debate [Smith et al., 2011]. Recent advances in data acquisition methods, such as ultrahigh speed and ultrahigh field fMRI [Feinberg and Yacoub, 2012], may provide more accurate directionality estimations. Finally, we were not able to quantitatively evaluate the participants' driving competence in this study. Therefore, we could not directly explore the brain-behavior relationships. Moreover, the taxi drivers in this study had a daily driving time of approximately 8 h and can be considered professional drivers. Therefore, our results on the driving-related functional connectivity differences would be somewhat special cases. Additional studies comparing taxi drivers, ordinary drivers and nondrivers and evaluating driving skills should be conducted to draw more definitive general conclusions.

CONCLUSION

In conclusion, this study investigated the specific patterns of RSN organization in the brains of taxi drivers. We found that the taxi drivers had significantly stronger functional connectivity between the cognitive RSNs and sensory RSNs compared with the nondrivers, which may provide efficient neural pathways for the successful performance of driving behavior. These findings may be potentially useful in judging a person's fitness to drive.

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