Psychopharmacology (2011) 217:595–603
DOI 10.1007/s00213-011-2318-0

ORIGINAL INVESTIGATION

Characterization of the acute effects of alcohol on asymmetry of inferior frontal cortex activity during a Go/No-Go task using functional near-infrared spectroscopy

Takeo Tsujii · Kaoru Sakatani · Emi Nakashima · Takahiro Igarashi · Yoichi Katayama

Received: 2 February 2011 / Accepted: 15 April 2011 / Published online: 3 May 2011

Abstract
Rationale Successful response inhibition is associated with right-lateralized inferior frontal cortex (IFC) activity, and alcohol impairs this inhibitory control, thereby enhancing false-alarm responses in the Go/No-Go task. However, the neural correlates of effect of alcohol on response inhibition remain unclear.
Objective This study characterized the acute effects of alcohol on IFC activity during Go/No-Go tasks using near-infrared spectroscopy (NIRS).
Methods Thirty-two subjects visited our laboratory twice: once for alcohol intake and once for placebo intake. On each visit, subjects performed Go/No-Go tasks immediately before and 10 min after intake of the alcohol or placebo. NIRS was used to evaluate IFC activity measured during Go/No-Go tasks.
Results Alcohol significantly enhanced false-alarm responses in No-Go trials. NIRS analysis showed that IFC activity was greater in the right hemisphere than in the left hemisphere prior to alcohol or placebo intake. This right hemispheric superiority was eliminated in response to alcohol but not in response to placebo. Correlation analysis showed that subjects with right-lateralized IFC activity made fewer false-alarm responses in No-Go trials and that alcohol-induced inhibition of hemispheric IFC asymmetry resulted in higher false-alarm rates.
Conclusion These findings suggest that the right IFC may mediate the acute effects of alcohol on inhibitory control. When the alcohol impairs the right IFC activity, subjects cannot inhibit the pre-potent responses for No-Go trials, resulting in enhanced false-alarm responses. Thus, this study successfully demonstrated the neural correlates of the alcohol effect in the right IFC activity during inhibitory control processes.

Keywords Alcohol · Response inhibition · Inferior frontal cortex · Near-infrared spectroscopy · Go/No-Go task · Hemispheric asymmetry reduction

T. Tsujii (✉) · K. Sakatani
Department of Neurological Surgery, Division of Optical Brain Engineering, Nihon University School of Medicine,
30-1 Oyaguchi-Kamicho, Itabashi-ku,
Tokyo 173-8610, Japan
e-mail: tsujiitakeo@gmail.com

T. Igarashi · Y. Katayama
Department of Neurological Surgery, Division of Neurosurgery, Nihon University School of Medicine,
30-1 Oyaguchi-Kamicho, Itabashi-ku,
Tokyo 173-8610, Japan

E. Nakashima
Department of Pharmaceutical Sciences, Faculty of Pharmacy, Keio University,
Tokyo, Japan

Alcohol impairs inhibitory control of behavioral responses that underlie various impulsive behaviors, including aggression, suicide, risky driving, and other socially inappropriate behaviors (Barkataki et al. 2005; Dougherty et al. 2008; Fillmore et al. 2008, 2009). Experimental assessments of response inhibition are often conducted using the Go/No-Go task, in which subjects are required to perform timed responses for Go trials (e.g., pressing a button in response to the letter A) and to inhibit responses for No-Go trials (e.g., refraining from pressing a button in response to the letter B). During a testing session, No-Go trials are typically given less frequency than Go trials in order to enhance the pre-potent response tendency during the task. Previous behavioral studies demonstrated that alcohol administration enhanced false-alarm responses to No-Go trials (Field et al. 2010; Fillmore et al. 2009; Ostling and Fillmore 2010).

Neuroimaging studies of response inhibition have suggested that the activity of right-lateralized inferior frontal cortex (IFC) is critical for the inhibitory functions (Aron et al. 2004; Bunge and Wright 2007; Rubia et al.

2001). For example, successful response inhibition was associated with right IFC activity in the Go/No-Go task (Chikazoe et al. 2007; Herrmann et al. 2005), and right IFC activation was also enhanced by the task-set switching paradigm in which subjects were instructed to change from one task to another (Cools et al. 2002; Xue et al. 2008). Further, right IFC activity was associated with successful performance of belief-bias reasoning tasks in which subjects must inhibit automatic heuristic thinking (Tsujii et al. 2010a, b; Tsujii and Watanabe 2009, 2010).

What is unknown is how alcohol could influence the right-lateralized IFC activities associated with response inhibition. The present study thus examined the acute alcohol effect on the IFC activities during the Go/No-Go task using near-infrared spectroscopy (NIRS). NIRS is a relatively new imaging technique for investigating cortical hemodynamic responses by measuring changes in the attenuation of near-infrared light passing through tissue. Since oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) have different absorption spectra in the infrared range, changes in oxy-Hb and deoxy-Hb can be calculated by detecting infrared light at different wavelengths on the skull. In general, enhanced oxy-Hb and reduced deoxy-Hb are associated with regional cortical activation (Obrig et al. 2002). NIRS is noninvasive, is robust against body movement, and has been validated as a suitable technique for investigating neural mechanisms in psychological experiments.

In the present study, we hypothesized that alcohol would reduce the right-lateralized IFC activities, enhancing the false-alarm responses to No-Go trials. Reduced right-lateralized IFC activity is associated with impaired behavioral performance of inhibitory control (Rubia et al. 1999, 2001, 2005, 2007), and alcohol reduces the hemispheric asymmetry in cortical responses, thereby impairing behavioral performance in several cognitive tasks (Soderlund et al. 2007; Wendt and Risberg 1994, 2001; Wendt et al. 1994). These observations encouraged us to predict that alcohol would reduce the hemispheric asymmetry in IFC activation, impairing response inhibition performance in the Go/No-Go task.

Methods

Subjects

Subjects were 32 healthy Japanese volunteers (17 female, 15 male) ranging in age from 21 to 38 years (age [mean ± standard deviation], 28.19 ± 5.05 years). The Edinburgh Handedness Inventory (Oldfield 1971) indicated that 29 of the subjects were right-handed. All subjects had normal or corrected-to-normal vision. Subjects completed questionnaires that provided demographic information, drug use history, and physical and mental health status. All subjects were fasted for 3 h prior to the session and abstained from alcohol for 24 h prior to the session. The study was conducted in accordance with the principles of the Declaration of Helsinki, and all protocols were approved by the Ethics Committee of Nihon University School of Medicine. Written informed consent was obtained from all subjects prior to enrolment in the study.

General procedure and alcohol administration

The experiment was run individually. All subjects visited our laboratory twice: once for alcohol intake and once for placebo intake. On each visit, subjects performed Go/No-Go tasks immediately before and 10 min after intake of the alcohol or placebo. Alcohol was administered at a dose of 0.5 g/kg of body weight, mixed with orange juice (total amount = 400 ml). Vodka (37.5% alcohol) was chosen because of its purity compared with other alcohol-containing beverages (Leake and Silverman 1971). The placebo drink was the same total volume of orange juice (400 ml), so that the visual appearance was quite similar between alcohol and placebo drinks. Total administration time was 7 min for both sessions. Subjects drank 200 ml in the first 3 min, took a 1-min break, and then drank the second 200 ml in the remaining 3 min.

An interval of at least 3 days was given between visits. The order of alcohol and placebo sessions was randomized to control for any task-learning effect or temporal variances in the NIRS measurement. Upon arrival to the laboratory, all subjects were first tested with a breath analyzer (SC-302, Central Automobile Products Ltd., Osaka, Japan) and found to be sober. Subjects then performed the Go/No-Go task for approximately 18 min, followed by alcohol or placebo administration over the next 7 min. Breath alcohol concentration (BrAC) was tested again 10 min after administration of alcohol or placebo (mean BrAC, 0.24 ± 0.06 mg/L after alcohol intake), and the Go/No-Go task was performed again over approximately 18 min. During the Go/No-Go tasks, the activity of IFC was measured using NIRS.

Go/No-Go task

For each visit, subjects performed the Go/No-Go task twice: once immediately before the administration session and once 10 min after the administration session. Completion of the Go/No-Go task required approximately 18 min. The task was operated using E-Prime 2.0 software (Psychology Software Tools, USA). In the Go/No-Go task, 10 test blocks were sandwiched between 11 baseline blocks. Each test block contained 10 Go trials (occurrence probability = 62.5%) and six No-Go trials (occurrence probability = 37.5%), while each

baseline block contained 16 Go trials but did not contain No-Go trials. In the test block, the Go and No-Go trials were presented in randomly intermixed order. Each block required approximately 45 s to complete. At the beginning of each block, a cue was presented for 5 s to indicate whether the coming block was test or baseline.

The beginning of each trial was signaled by the fixation cross that appeared in the center of the computer screen for 500 or 1,500 ms. In the Go trials, the letter "A" was presented immediately after the fixation cross, and the subjects were required to press a response button as fast and as accurately as possible. By contrast, a "B" followed the fixation cross in the No-Go trials. Subjects were told to inhibit their prepared response in the No-Go trials. Both stimuli were presented until subjects made a response or until 500 ms passed. The inter-stimulus interval was 1,500 ms. A practice session was given for each visit to familiarize the subjects with the task.

NIRS recordings

During the Go/No-Go task, relative changes in oxy- and deoxy-Hb concentration values were measured in the bilateral IFC regions using a two-channel portable-type NIRS system (PNIRS-10, Hamamatsu Photonics K.K., Hamamatsu, Japan). This device uses near-infrared light at three wavelengths, ranging around 735±15, 810±18, and 850±20 nm. The oxy-Hb and deoxy-Hb values were estimated from the detected changes of the near-infrared light using Modified Beer–Lambert Law (Delpy et al. 1988). Because the individual optical path length is unknown, the hemoglobin concentration value is not an absolute but a relative value; this value is expressed as a change from baseline concentration (a.u., arbitrary units). The sampling frequency was 10.2 Hz (97.8 ms/data). Moving average methods were used to cut the high-frequency noise. The moving average window was 31 data points, which corresponds to approximately 3,032 ms.

The flexible NIRS probe (P-Probe-1 M, Hamamatsu Photonics K.K., Hamamatsu, Japan) consisted of a LED emitter and a detector, separated by a distance of 30 mm. The detectors were always placed more laterally relative to the emitters on the subject's forehead (see Fig. 2). The detectors were placed at the F7 position for left IFC measurements and at the F8 position for the right IFC measurements (international 10–20 system). The F7 and F8 roughly correspond to the inferior frontal gyrus (Homan et al. 1987; Okamoto et al. 2004; Jurcak et al. 2005, 2007). For some subjects, detectors could not be placed precisely at the F7 or F8 position because the subject's hair interrupted precise measurements. In those cases, the detector position was moved more medially. Mean movement distances were 9.25 mm (SD=9.56 mm) for the left IFC and 9.38 mm (SD=9.24 mm) for the right IFC.

Data analysis

For behavioral performance, the reaction time (RT) for Go trials and the false-alarm rates for No-Go trials in the test block were analyzed. Trials in which the RTs were not within the time range of the mean ±3 SD were excluded from the RT analysis. Data were compared by two-way analysis of variance (ANOVA), with within-subject factors of drink type (alcohol, placebo) and test period (before, after).

For NIRS response, the mean oxy- and deoxy-Hb concentration change (Δoxy-Hb and Δdeoxy-Hb) were analyzed during the time window from 0 s (trigger-point: start time of the test block) to 45 s. Baseline epochs were set for a pre-trigger of 20 s in the baseline block. The baseline corrected oxy- and deoxy-Hb waveforms were averaged over the 10 test blocks. For statistical analysis, mean Δoxy-Hb and Δdeoxy-Hb values were tested by three-way ANOVA, with within-subject factors of drink type (alcohol, placebo), test period (before, after), and hemisphere (LH, RH). Because the second-order interactions were significant both for Δoxy-Hb ($F(1, 31)=4.19$, $p<.05$) and for Δdeoxy-Hb ($F(1, 31)=4.75$, $p < .05$), separate two-way ANOVAs were performed for each condition.

Finally, correlation analysis was performed between the right/left IFC activation and behavioral performance (false-alarm rates for No-Go trials and RTs for Go trials). The laterality index (LI) was used to represent the degree of hemispheric asymmetry of IFC activation and was calculated using the formula:

$$(R - L)/(R + L)$$

where R and L indicated Δoxy-Hb concentration values at the right and left IFC, respectively. Thus, high LI indicates strong right-lateralization of IFC activation. Furthermore, the effect of alcohol on the correlation between NIRS response and behavioral performance was assessed by subtracting values obtained after drinking placebo from those obtained after drinking alcohol.

Results

Behavioral performance

Figure 1a summarizes mean RTs for Go trials of each drink type. Two-way ANOVA revealed a significant drink type × test period interaction ($F(1, 31)=11.43$, $p<.01$), suggesting that alcohol significantly delayed responses when compared with placebo ($F(1, 62)=15.27$, $p<.01$). However, there was no significant different in response times between those same groups of volunteers before administration of alcohol or placebo ($F(1, 62)=.06$, $p=.27$).

Figure 1b summarizes mean false-alarm rates for No-Go trials of each drink condition. Two-way ANOVA revealed a significant drink type × test period interaction ($F(1, 31)=9.16$, $p<.01$), suggesting that alcohol significantly enhanced false-alarm rates when compared with placebo ($F(1, 62)=16.83$, $p<.01$). However, there was no significant difference in false-alarm rates between those same groups of volunteers before administration of alcohol and placebo ($F(1, 62)=.06$, $p=.81$).

NIRS response

Figure 2a

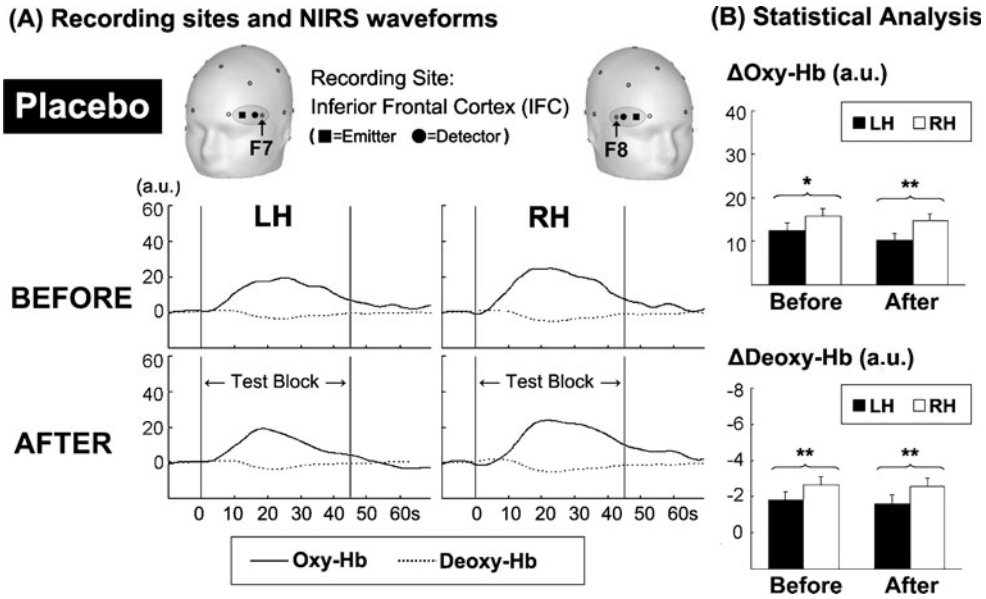

Fig. 3 **a** Oxy- and deoxy-waveforms in the IFC region in the LH and RH during the Go/No-Go task before and after placebo administration. **b** The bar graphs represent the mean oxy- and deoxy-Hb values during the test blocks. The *error bars* represent the standard errors of oxy- and deoxy-Hb values. The *Y*-axis of the bar graph in reversed on Δdeoxy-Hb, because reduced deoxy-Hb concentration values are generally associated with regional cortical activation. Significant comparisons are shown: *$p<.05$, **$p<.01$

significant for either Δoxy-Hb ($F(1, 31)=14.65$, $p<.01$) or Δdeoxy-Hb ($F(1, 32)=.06$, $p=.80$).

Correlation analysis

The relationships between behavioral performance and hemispheric IFC activity in the Go/No-Go task were analyzed. The correlation between the RTs for Go trials and the LI of IFC activities ($r=-.18$, $p=.31$) was not significant (Fig. 4a). By contrast, there was a significant negative correlation between the false-alarm rates for No-Go trials and LI of IFC activities ($r=-.37$, $p<.05$; Fig. 4b). Since high LI means that IFC activity is more right-lateralized, these findings indicate that subjects with right-lateralized IFC activity made fewer false-alarm responses for No-Go trials.

The relationship between alcohol effect, behavioral performance, and hemispheric IFC activity were assessed by subtracting values obtained after drinking placebo from those obtained after drinking alcohol. The correlation between RTs for Go trials and LI of IFC activities was not significant ($r=-.17$, $p=.35$; Fig. 5a), but there was a significant negative correlation between the false-alarm rates for No-Go trials and the LI of IFC activities ($r=-.45$, $p<.01$; Fig. 5b). This means that subjects with alcohol-induced disruption of right lateralization of IFC activity had higher false-alarm rates for No-Go trials. By contrast, subjects in whom right lateralization remained high were able to maintain low false-alarm rates even after drinking alcohol.

Discussions

The present study used NIRS to examine the effect of alcohol on hemispheric IFC activity during the Go/No-Go task. Subjects visited our laboratory twice: once for alcohol intake and once for placebo intake. On each visit, subjects

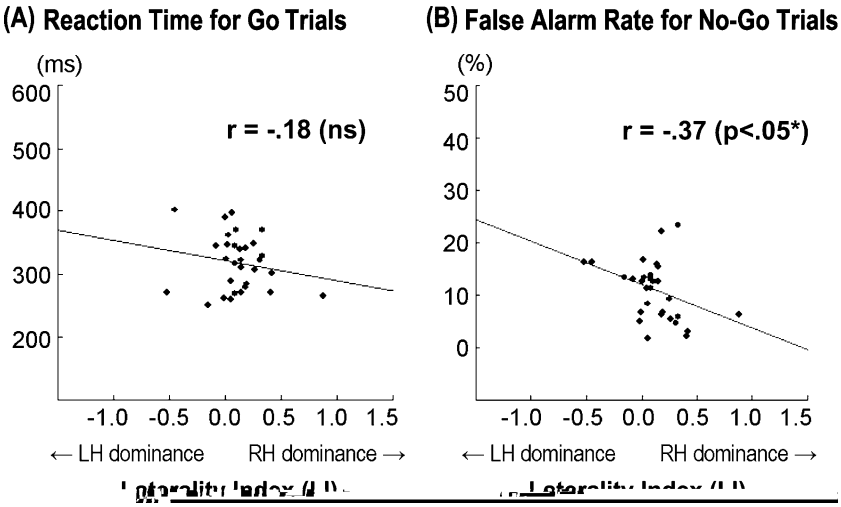

Fig. 4 Relationships between behavioral performance and hemispheric lateralization of IFC activity in the Go/No-Go task. High laterality index indicates strong right lateralization of IFC activation. The laterality index was significantly correlated with false-alarm rates for No-Go trials (**b**) but not with reaction times for Go trials (**a**). Thus, subjects with right-lateralized IFC activity made fewer false-alarm responses in No-Go trials

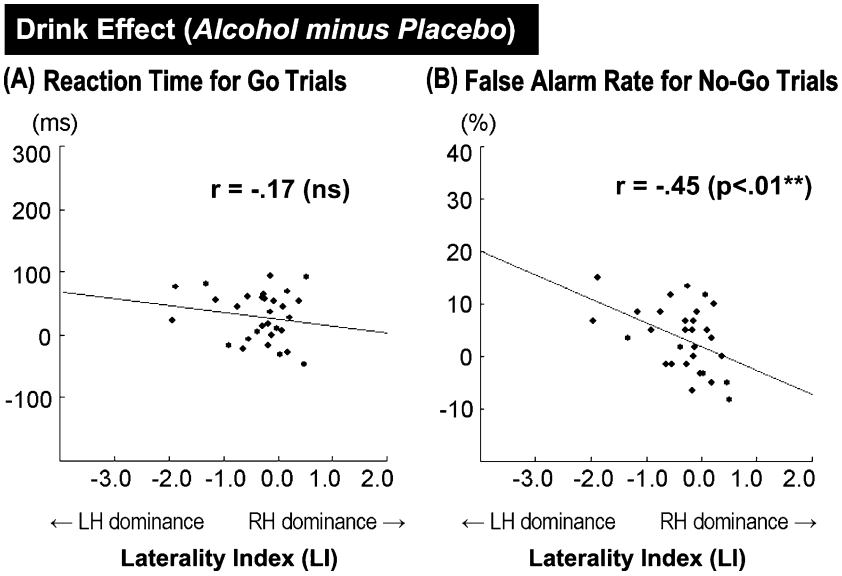

Fig. 5 Relationship of the effect of alcohol on behavioral performance and hemispheric lateralization of IFC activity was analyzed by subtracting values obtained after placebo intake from those obtained after alcohol intake. The laterality index was significantly correlated with false-alarm rates for No-Go trials (**b**) but not with reaction times for Go trials (**a**). Thus, subjects whose right-lateralization of IFC activity was disrupted by alcohol had higher false-alarm response rates, while subjects whose right lateralization remained high could maintain low false-alarm response rates

performed Go/No-Go tasks immediately before and 10 min after intake of the alcohol or placebo. We measured the hemispheric IFC activity during Go/No-Go tasks using NIRS. Here, we discuss the present findings in the following subsections: neural correlates of alcohol effect on response inhibition, hemispheric asymmetry reduction by alcohol consumption, and the limitations of this study.

Neural correlates of the effect of alcohol on response inhibition

The aim of this study was to examine the neural correlates of the effect of alcohol on response inhibition processes in the Go/No-Go task. Behavioral analysis found that alcohol administration enhanced the false-alarm responses for No-Go trials (Fig. 1), confirming previous behavioral findings (Fillmore et al. 2009). NIRS analysis showed that the alcohol consumption impaired right IFC activity without affecting left IFC activity (Fig. 2). Before drinking alcohol, IFC activity was higher in the right hemisphere than in the left hemisphere, but this difference was eliminated after drinking alcohol. These findings could not be attributed to the simple learning effect because drinking orange juice (placebo) did not affect hemispheric asymmetry in IFC activation (Fig. 3). Correlation analysis showed that subjects with right-lateralized IFC activity made fewer false-alarm responses in No-Go trials (Fig. 4), while subjects in whom alcohol reversed right hemispheric IFC superiority had higher false-alarm rates in No-Go trials (Fig. 5). Reaction times for Go trials did not significantly correlate with hemispheric asymmetry in IFC activation. In combination, these findings suggest that the right-lateralized IFC activity may mediate the acute effect of alcohol on response inhibition.

These findings are largely consistent with previous findings that the right IFC is critical for response inhibition (Aron et al. 2004; Bunge and Wright 2007). Functional neuroimaging studies have consistently indicated that the right IFC was activated in a wide variety of inhibitory control tasks that involved Go/No-Go tasks (Bunge et al. 2002; Chikazoe et al. 2007; Herrmann et al. 2005), stop signal tasks (Boecker et al. 2007; Rubia et al. 2003), and belief-bias reasoning tasks (Tsujii and Watanabe 2009, 2010; Tsujii et al. 2010a, b). The right IFC was also shown to be crucial in neuropsychological studies of patients with unilateral right prefrontal damage (Aron et al. 2003; Clark et al. 2007). These studies demonstrated that the extent of damage to the right IFC correlated significantly with the degree of impaired performance in response inhibition tasks. Further, other studies have suggested that the right IFC deficit may underlie the impaired response inhibition in patients with attention-deficit hyperactivity disorder (Durston et al. 2006; Rubia et al. 1999, 2005, 2010).

This is the first study to demonstrate that right-lateralized IFC activation is critical for the alcohol-induced modulation of response inhibition. One previous functional magnetic resonance imaging (fMRI) has examined the neural correlates of the effect of alcohol on cognitive control processes using a Go/No-Go task (Anderson et al. 2011). However, that study addressed the error monitoring process with particular attention to the anterior cingulate cortex rather than addressing the response inhibition process in the lateral IFC region. Those investigators demonstrated that alcohol significantly reduced anterior cingulate cortex activity during false-alarm responses for No-Go trials (Anderson et al. 2011). Thus, this previous study does not contradict findings from the present study; rather, these

studies elucidate different aspects of the effect of alcohol on cognitive control processes.

Reduction of hemispheric asymmetry by alcohol

The present study showed that alcohol eliminated the RH superiority in IFC activity during inhibitory processes. In accordance with this finding, several neuroimaging studies previously reported that hemispheric asymmetry was reduced or eliminated by alcohol consumption (Soderlund et al. 2007; Wendt et al. 1994; Wendt and Risberg 2001). For example, Wendt et al. (1994) found that a visuo-spatial task activated the right-lateralized occipito-parietal cortex and that alcohol eliminated this hemispheric asymmetry. Other studies have shown that alcohol reduced left-lateralized prefrontal cortex activity during a verbal fluency task (Wendt and Risberg 2001).

Further, the present study showed that patients in whom right lateralization of IFC activity was disrupted by alcohol had higher false-alarm rates for No-Go trials, while subjects in whom alcohol did not reduce right lateralization could maintain low false-alarm rates (Fig. 5). Consistent with this finding, Wendt and Risberg (1994) found a significant positive correlation between scores on the visuo-spatial task and RH superiority in the occipito-parietal cortex. In their study, alcohol consumption disrupted the task performance, eliminating the RH superiority in the occipito-parietal cortex (Wendt et al. 1994). In addition, another study reported that left-lateralized IFC activity was reduced by alcohol only when the recognition memory performance was impaired (Soderlund et al. 2007). These findings suggest that alcohol produces a deleterious effect on cognitive performance via reduction of hemispheric asymmetry.

Limitations of this study

This study possesses several limitations. First, this study used a relatively low amount of alcohol (0.5 g/kg). By contrast,

Acknowledgements This work was supported by the fund for Grant-in-Aid for Young Scientists (B) from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT) of Japan. In addition, manuscript preparation was partly supported by the fund of Pfizer Health Research Foundation and Japan Science and Technology Agency (JST), under Strategic Promotion of Innovative Research and Development Program. There was no conflict of interest in this study.

References

Anderson BM, Stevens MC, Meda SA, Jordan K, Calhoun VD, Pearlson GD (2011) Functional imaging of cognitive control during acute alcohol intoxication. Alcohol Clin Exp Res 35:156–165

Aron AR, Fletcher PC, Bullmore ET, Sahakian BJ, Robbins TW (2003) Stop-signal inhibition disrupted by damage to right inferior frontal gyrus in humans. Nat Neurosci 6:115–116

Aron AR, Robbins TW, Poldrack RA (2004) Inhibition and the right inferior frontal cortex. Trends Cogn Sci 8:170–177

Barkataki I, Kumari V, Das M, Hill M, Morris R, O'Connell P, Taylor P, Sharma T (2005) A neuropsychological investigation into violence and mental illness. Schizophr Res 74:1–13

Boecker M, Buecheler MM, Schroeter ML, Gauggel S (2007) Prefrontal brain activation during stop-signal response inhibition: an event-related functional near-infrared spectroscopy study. Behav Brain Res 176:259–266

Bunge SA, Wright SB (2007) Neurodevelopmental changes in working memory and cognitive control. Curr Opin Neurobiol 17:243–250

Bunge SA, Dudukovic NM, Thomason ME, Vaidya CJ, Gabrieli JD (2002) Immature frontal lobe contributions to cognitive control in children: evidence from fMRI. Neuron 33:301–311

Chikazoe J, Konishi S, Asari T, Jimura K, Miyashita Y (2007) Activation of right inferior frontal gyrus during response inhibition across response modalities. J Cogn Neurosci 19:69–80

Clark L, Blackwell AD, Aron AR, Turner DC, Dowson J, Robbins TW, Sahakian BJ (2007) Association between response inhibition and working memory in adult ADHD: a link to right frontal cortex pathology? Biol Psychiatry 61:1395–1401

Cools R, Clark L, Owen AM, Robbins TW (2002) Defining the neural mechanisms of probabilistic reversal learning using event-related functional magnetic resonance imaging. J Neurosci 22:4563–4567

Delpy DT, Cope M, van der Zee P, Arridge S, Wray S, Wyatt J (1988) Estimation of optical pathlength through tissue from direct time of flight measurement. Phys Med Biol 33:1433–1442

Dougherty DM, Marsh-Richard DM, Hatzis ES, Nouvion SO, Mathias CW (2008) A test of alcohol dose effects on multiple behavioral measures of impulsivity. Drug Alcohol Depend 96:111–120

Durston S, Mulder M, Casey BJ, Ziermans T, van Engeland H (2006) Activation in ventral prefrontal cortex is sensitive to genetic vulnerability for attention-deficit hyperactivity disorder. Biol Psychiatry 60:1062–1070

Field M, Wiers RW, Christiansen P, Fillmore MT, Verster JC (2010) Acute alcohol effects on inhibitory control and implicit cognition: implications for loss of control over drinking. Alcohol Clin Exp Res 34:1346–1352

Fillmore MT, Blackburn JS, Harrison EL (2008) Acute disinhibiting effects of alcohol as a factor in risky driving behavior. Drug Alcohol Depend 95:97–106

Fillmore MT, Ostling EW, Martin CA, Kelly TH (2009) Acute effects of alcohol on inhibitory control and information processing in high and low sensation-seekers. Drug Alcohol Depend 100:91–99

Herrmann MJ, Plichta MM, Ehlis AC, Fallgatter AJ (2005) Optical topography during a Go-NoGo task assessed with multi-channel near-infrared spectroscopy. Behav Brain Res 160:135–140

Homan RW, Herman J, Purdy P (1987) Cerebral location of international 10–20 system electrode placement. Electroencephalogr Clin Neurophysiol 66:376–382

Jurcak V, Okamoto M, Singh A, Dan I (2005) Virtual 10–20 measurement on MR images for inter-modal linking of transcranial and tomographic neuroimaging methods. Neuroimage 26:1184–1192

Jurcak V, Tsuzuki D, Dan I (2007) 10/20, 10/10 and 10/5 systems revisited: their validity as relative head-surface-based positioning systems. Neuroimage 34:1600–1611

Leake CD, Silverman M (1971) The chemistry of alcoholic beverages. In: Kissin B, Begleiter H (eds) The biology of alcoholism, vol 1, Biochemistry. Plenum, New York, pp 575–612

Loeber S, Duka T (2009) Acute alcohol decreases performance of an instrumental response to avoid aversive consequences in social drinkers. Psychopharmacology 205:577–587

Obata A, Morimoto K, Sato H, Maki A, Koizumi H (2003) Acute effects of alcohol on hemodynamic changes during visual stimulation assessed using 24-channel near-infrared spectroscopy. Psychiatry Res 123:145–152

Obata A, Morimoto K, Sato H, Takeshita T, Kawaguchi H, Koizumi H, Maki A (2005) Effects of alcohol on hemodynamic and cardiovascular reaction in different genotypes. Psychiatry Res 139:65–72

Obrig H, Israel H, Kohl-Bareis M, Uludag K, Wenzel R, Muller B, Arnold G, Villringer A (2002) Habituation of the visually evoked potential and its vascular response: implications for neurovascular coupling in the healthy adult. Neuroimage 17:1–18

Okamoto M, Dan H, Sakamoto K, Takeo K, Shimizu K, Kohno S, Oda I, Isobe S, Suzuki T, Kohyama K, Dan I (2004) Three-dimensional probabilistic anatomical cranio-cerebral correlation via the international 10–20 system oriented for transcranial functional brain mapping. Neuroimage 21:99–111

Oldfield RC (1971) The assessment and analysis of handedness: the Edinburph Inventory. Neuropsychologia 9:97–113

Ostling EW, Fillmore MT (2010) Tolerance to the impairing effects of alcohol on the inhibition and activation of behavior. Psychopharmacology 212:465–473

Rubia K, Overmeyer S, Taylor E, Brammer M, Williams SC, Simmons A, Bullmore ET (1999) Hypofrontality in attention deficit hyperactivity disorder during higher-order motor control: a study with functional MRI. Am J Psychiatry 156:891–896

Rubia K, Russell T, Overmeyer S, Brammer MJ, Bullmore ET, Sharma T et al (2001) Mapping motor inhibition: conjunctive brain activations across different versions of go/no-go and stop tasks. Neuroimage 13:250–261

Rubia K, Smith AB, Brammer MJ, Taylor E (2003) Right inferior prefrontal cortex mediates response inhibition while mesial prefrontal cortex is responsible for error detection. Neuroimage 20:351–358

Rubia K, Smith AB, Brammer MJ, Toone B, Taylor E (2005) Abnormal brain activation during inhibition and error detection in medication-naive adolescents with ADHD. Am J Psychiatry 162:1067–1075

Rubia K, Smith AB, Taylor E, Brammer M (2007) Linear age-correlated functional development of right inferior fronto-striato-cerebellar networks during response inhibition and anterior cingulate during error-related processes. Hum Brain Mapp 28:1163–1177

Rubia K, Halari R, Cubillo A, Mohammad AM, Scott S, Brammer M (2010) Disorder-specific inferior prefrontal hypofunction in boys with pure attention-deficit/hyperactivity disorder compared to boys with pure conduct disorder during cognitive flexibility. Hum Brain Mapp 31:1823–1833

Soderlund H, Grady CL, Easdon C, Tulving E (2007) Acute effects of alcohol on neural correlates of episodic memory encoding. Neuroimage 35:928–939

Tsujii T, Watanabe S (2009) Neural correlates of dual-task effect on belief-bias syllogistic reasoning: a near-infrared spectroscopy study. Brain Res 1287:118–125

Tsujii T, Watanabe S (2010) Neural correlates of belief-bias reasoning under time pressure: a near-infrared spectroscopy study. Neuroimage 50:1320–1326

Tsujii T, Yamamoto E, Ohira T, Saito N, Watanabe S (2007) Effects of sedative and non-sedative H1 antagonists on cognitive tasks: behavioral and near-infrared spectroscopy (NIRS) examinations. Psychopharmacology 194:83–91

Tsujii T, Masuda S, Yamamoto E, Ohira T, Akiyama T, Takahashi T, Watanabe S (2009a) Effects of sedative and nonsedative antihistamines on prefrontal activity during verbal fluency task in young children: a near-infrared spectroscopy (NIRS) study. Psychopharmacology 207:127–132

Tsujii T, Yamamoto E, Masuda S, Watanabe S (2009b) Longitudinal study of spatial working memory development in young children. Neuroreport 20:759–763

Tsujii T, Masuda S, Akiyama T, Watanabe S (2010a) The role of inferior frontal cortex in belief-bias reasoning: an rTMS study. Neuropsychologia 48:2005–2008

Tsujii T, Okada M, Watanabe S (2010b) Effects of aging on hemispheric asymmetry in inferior frontal cortex activity during belief-bias syllogistic reasoning: a near-infrared spectroscopy study. Behav Brain Res 210:178–183

Tsujii T, Yamamoto E, Ohira T, Takahashi T, Watanabe S (2010c) Antihistamine effects on prefrontal cortex activity during working memory process in preschool children: a near-infrared spectroscopy (NIRS) study. Neurosci Res 67:80–85

Wall TL, Ehlers CL (1995) Acute effects of alcohol on P300 in Asians with different ALDH2 genotypes. Alcohol Clin Exp Res 19:617–622

Wall TL, Gallen CC, Ehlers CL (1993) Effects of alcohol on the EEG in Asian men with genetic variations of ALDH2. Biol Psychiatry 34:91–99

Wendt PE, Risberg J (1994) Cortical activation during visual spatial processing: relation between hemispheric asymmetry of blood flow and performance. Brain Cogn 24:87–103

Wendt PE, Risberg J (2001) Ethanol reduces rCFB activation of left dorsolateral prefrontal cortex during a verbal fluency task. Brain Lang 77:197–215

Wendt PE, Risberg J, Stenberg G, Rosen I, Ingvar DH (1994) Ethanol reduces asymmetry of visual rCBF responses. J Cereb Blood Flow Metab 14:963–973

Xue G, Ghahremani DG, Poldrack RA (2008) Neural substrates for reversing stimulus-outcome and stimulus-response associations. J Neurosci 28:11196–11204