Anterior cingulate activation during cognitive control relates to academic performance in medical students

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Abstract

Academic performance is in part determined by cognitive control, the skill of flexibly guiding behavior. The lateral and medial prefrontal cortex, including anterior cingulate cortex, are involved during tasks of cognitive control. Little is known about the relation between brain mechanisms underlying cognitive control and academic performance in a real-world educational environment. In the current fMRI study, Freshman students from Medical College performed a Go/NoGo task and a Stroop task. A positive correlation was observed between average course grades and activation of the dorsal anterior cingulate cortex during cognitive inhibition on the Stroop task. No significant correlation was found between grades and activation in rostral anterior cingulate cortex during emotional inhibition. Grades were not associated with prefrontal activation during motor inhibition or performance monitoring on the Go/NoGo task. These findings suggest that engagement of dorsal anterior cingulate cortex for cognitive control can be linked to individual differences in academic achievement.
Introduction

Cognitive control, the ability to direct behavior and override impulses, has been related to positive life outcomes in diverse clinical and societal contexts (Miyake & Friedman, 2012). Individual differences in this ability are associated with academic performance across childhood (Best, Miller, & Jones, 2009). In college students, cognitive control, as measured by questionnaires, predicts self-regulated learning (Garner, 2009) and grades (Tangney, Baumeister, & Boone, 2004). The skill of adapting one’s behavior to reach a desired goal is needed to get through college successfully. Obtaining a degree involves planning, avoiding distractions and focusing on exams. These cognitive control skills engage lateral and medial prefrontal brain regions, including the anterior cingulate cortex (Brass, Derrfuss, Forstmann, & von Cramon, 2005; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). Particularly, the anterior cingulate cortex plays a role in conflict and outcome monitoring (Botvinick, 2007). A link might be expected between functioning of these prefrontal areas and academic success. This is important to investigate because it could provide more insight into neural correlates of performance in a real-world educational setting. Individual differences in academic performance might be partly due to variation in underlying brain mechanisms. For students of similar age from the same college, behavioral tests of cognitive control are probably not sensitive enough to predict achievement. Nonetheless, differences between good and average students in a homogeneous group could be observable at the neural level.

Cognitive control is often assessed using the Go/NoGo task (Garavan, Ross, & Stein, 1999) or the Stroop task (MacLeod & MacDonald, 2000). These tasks focus on response inhibition, the suppression of a prepotent response. During the Go/NoGo paradigm, a visual stream of letters is presented and the participant is instructed to press a button each time a letter appears on the screen, but to withhold a response for one particular letter (e.g., X). The ability to suppress a tendency to press the button on these infrequent NoGo trials is a measure of motor inhibition. During the Stroop paradigm, color words are presented and the participant has to indicate the color of the ink in which the words are written. On incongruent trials, the written word interferes with the ink of the word (e.g., the word blue printed in
Color labeling requires cognitive inhibition of the more salient tendency to read the word.

A meta-analysis on neuroimaging research including various response inhibition tasks has demonstrated common activation in the dorsolateral prefrontal cortex, inferior frontal gyrus, anterior cingulate cortex and inferior parietal cortex (Nee, Wager, & Jonides, 2007). For the Go/NoGo task, the largest cluster was found in right dorsolateral prefrontal cortex extending into right inferior frontal gyrus and insula. Most activation during the Stroop task was observed in left dorsolateral prefrontal cortex, extending into insula, and in the anterior cingulate cortex.

Functioning of the anterior cingulate cortex has been linked to academic results in college students (Hirsh & Inzlitch, 2010). In this Event-Related Potential (ERP) study, participants carried out a Stroop paradigm while the Error-Related Negativity (ERN), generated from the anterior cingulate cortex, was measured. The ERN following errors correlated positively with grades, indicating that the error detection mechanism works better in students who perform well in college. ERP research in school-aged children showed that the P3 component during a Go/NoGo task, recorded over the parietal cortex, was a predictor of reading and arithmetic achievement (Hillman et al., 2012). These findings suggest that neural correlates of cognitive control can be indicators of academic success, although up till now, this has not been studied with functional Magnetic Resonance Imaging (fMRI). More knowledge is needed about cortical regions that can be associated with individual performance differences in higher education.

In the current study, the relation between brain activation during cognitive control and academic achievement was investigated in Freshman students from Medical College. All students were 18 or 19 years old and completed six core courses of the medical curriculum. Average grades during the first academic year were used as an objective measure of performance. A modified Go/NoGo task (Evers et al., 2006) as well as a combined cognitive and emotional Stroop task (Evers, Van der Veen, Jolles, Deutz, & Schmitt, 2006) were conducted in the fMRI scanner. On the Go/NoGo paradigm, feedback in the form of a green (correct) or red (incorrect) square was added to measure performance monitoring, in addition to motor inhibition. Performance monitoring is an aspect of cognitive control, involving the anterior cingulate cortex, that is assumed to play a role in academic
success. On the Stroop task, negative emotional trials were included (e.g., the word death printed in red), next to incongruent trials. Negative emotional words automatically draw attention and therefore cause interference with color labeling (Frings, Englert, Wentura, & Bermeitinger, 2010; McKenna & Sharma, 1995). Cognitive control is needed to suppress interfering emotions, which might also be important to maintain focus on academic work. This is particularly relevant for Freshmen, since many social changes take place during the transition from high school to college. In a period of personal development and emerging relationships, it is crucial to control emotions. Thus, two different processes were measured with the Stroop task, which will be referred to as cognitive inhibition and emotional inhibition.

Prior research employing the same Go/NoGo task demonstrated involvement of the right dorsolateral prefrontal cortex, dorsomedial prefrontal cortex, left insula, right inferior parietal cortex, left inferior parietal cortex, and right middle temporal gyrus in motor inhibition while the dorsal anterior cingulate cortex was activated during performance monitoring (Evers, Van der Veen, Van Deursen, et al., 2006). For the Stroop task, previous results indicated that the left dorsolateral prefrontal cortex and dorsal anterior cingulate cortex are particularly important for cognitive inhibition while the postcentral gyrus plays a role during emotional inhibition (Evers, Van der Veen, Jolles, et al., 2006). Others have also found engagement of the anterior cingulate cortex, in a more rostral subdivision, during the emotional Stroop task (Mohanti et al., 2007; Whalen et al., 1998). For the present study, it was hypothesized that activation of regions in the prefrontal cortex and anterior cingulate cortex would correlate with grades. A homogeneous sample of students from Medical College aged 18 and 19 was recruited to explore whether good students could be distinguished from average students. It is particularly relevant to determine markers of success in Medical College because of the difficult curriculum and strict selection procedure. Behavioral measures and self-report questionnaires have limited predictive validity (Ferguson, James & Madeley, 2002), therefore neuroimaging methods are employed here. Students with high grades and students with sufficient grades were expected to show differential brain activation during cognitive control, in the context of similar task performance.
Methods

Participants

Twenty-six Freshman students (13 male, 13 female, mean age = 18.79 years, SD age = 0.32 years, age range = 18.36 – 19.37 years) from Medical College at VU University Amsterdam participated in this study. At the start of the academic year 2010 – 2011, all Freshman students aged 18 or 19 received a letter with information about the research and a request to participate in exchange for monetary compensation. Volunteers had no history of neurological or psychiatric disorders and no contraindications for MRI. This research was approved by the Medical Ethics Committee of VU Medical Centre. Participants gave written informed consent and permission to obtain grades from the official student information systems. The current participants were part of a larger sample in a study aimed at investigating age- and sex-related differences in brain activation on the Stroop (Veroude, Jolles, Croiset & Krabbendam, 2013) and Go/NoGo task (Knežević, Veroude, Jolles & Krabbendam, manuscript in preparation). Those results are described elsewhere. Here, we report for the first time the relation between brain activation and student grades.

For each student, the average grade on six core courses was calculated at the end of the academic year. The grades were based on the first attempts at exams of compulsory preclinical courses, consisting of multiple choice questions. Assessments for professional competence and practical work were not included. In the Dutch educational system, grades can vary between 1 and 10 with 1 considered ‘very poor’ and 10 considered ‘excellent’. A grade of 5.5 or higher indicates ‘pass’. One female student was excluded from further analyses because she did not pass the first academic year (average grade = 4.67). The analyses of the Stroop task involved the remaining 25 participants (mean grade = 7.09, SD grade = 0.70, grade range = 5.50 – 8.50). One female student did not complete the Go/NoGo task and one male student had too many errors (> 2 SD), so 23 participants were included in the analyses of the Go/NoGo task (mean grade = 7.09, SD grade = 0.73, grade range = 5.50 – 8.50).
Procedure

The tasks were practiced in a behavioral session that took place one or two days before the fMRI session. During the fMRI session, participants performed a combined cognitive and emotional Stroop task (Evers, Van der Veen, Jolles, et al., 2006) and a Go/NoGo task (Evers, Van der Veen, Van Deursen, et al., 2006). Both tasks, programmed in E-Prime 2.0 (http://www.pstnet.com/eprime.cfm), consisted of two runs lasting about 5 minutes starting with an instruction screen presented for 6 seconds. The runs of each task were counterbalanced across participants.

Stroop task

Each run of the Stroop task contained 40 congruent color words (e.g., the word red printed in red ink), 40 incongruent color words (e.g., the word blue printed in red), 24 positive emotional words (e.g., friend), 24 negative emotional words (e.g., death) and 24 neutral words (e.g., house). Cognitive inhibition was assessed with the incongruent color words (condition Incongruent) and emotional inhibition was assessed with the negative emotional words (condition Negative). The neutral words (condition Neutral) formed a baseline while the congruent color words and positive emotional words were of no interest for the current study. Four different colors were used and participants indicated the color by button press using the left middle finger for blue, left index finger for red, the right index finger for green and right middle finger for yellow. A word was shown on a black background every 2 seconds until a response was given. A blank black screen was shown until the next word appeared. The participants were instructed to respond accurate and as fast as possible to the color of the ink and to remember the stimulus-response correspondence. In case they forgot, the order of colors was written in white letters on the bottom of the screen.

Go/NoGo task

During each run of the Go/NoGo task, 500 yellow letters were presented on a black background. Participants were instructed to respond by button press on alternating
presentations of X and Y, thus an X preceded by Y or a Y preceded by X (Go trials). They had to withhold a response for repetitions of X and Y (NoGo trials). No response was required on other letters (filler trials). Each run contained 75 Go trials and 12 NoGo trials. Letters were presented for 500 milliseconds and were occasionally followed by feedback in the form of a green square (correct) or a red square (incorrect). A green square was presented after correct Go and correct NoGo trials. No feedback was given after correctly omitted filler trials. A red square was shown after a response to a NoGo trial, a response to a filler letter and no response to a Go trial.

**fMRI data acquisition**

Participants were scanned on a General Electric 3 Tesla head-only MRI scanner. Functional images were collected using a T2*-weighted echo planar imaging (EPI) sequence (time to repetition (TR) = 2000 ms, time to echo (TE) = 35 ms, flip angle (FA) = 80°, field of view (FOV) = 22 x 22 cm, number of slices = 35, voxel size = 3.5 x 3.5 x 3 mm). To aid with spatial normalisation, a T1-weighted anatomical scan was acquired (TR = 7.876 ms, TE = 3.06 ms, FA = 12°, FOV = 22 x 22 cm, number of slices = 166, voxel size = 1 x 1 x 1 mm).

**Behavioral data analysis**

Reaction times and response errors on both tasks were recorded. Performance measures were correlated with grades. Kendall’s tau is reported because of the non-normality of the behavioral data and small sample size. Results are thresholded at $p < 0.01$, corrected for multiple correlations.

**Stroop task**

To assess cognitive inhibition time for each participant, the average reaction time during the condition Incongruent minus the average reaction time during the baseline condition Neutral was calculated. The difference between the average reaction times on the conditions Negative and Neutral constituted the emotional
inhibition time. Cognitive inhibition error rate was defined as the error percentage during the condition Incongruent minus the error percentage during the condition Neutral. Likewise, emotional inhibition error rate was calculated by subtracting the error percentage of the condition Neutral from the error percentage of the condition Negative. Cognitive inhibition time as well as emotional inhibition time was correlated with grades. In addition, the correlation between grades and cognitive inhibition error rate as well as emotional inhibition error rate was calculated.

Go/NoGo task

Responses on NoGo trials constitute errors of commission, which is a measure of motor inhibition. The error rates on NoGo trials were correlated with grades. When no responses are given on Go trials, these are errors of omission, a measure of attention. The correlation between grades and error rates on Go trials as well as average reaction times on Go trials was also calculated.

fMRI data analysis

Statistical Parametric Mapping (SPM8, www.fil.ion.ucl.ac.uk/spm) was used for analyzing the fMRI data. Preprocessing steps were similar for both tasks. First, the functional images were realigned with a six-parameter rigid body transformation to correct for head movement. Then, functional images were coregistered to the anatomical image and subsequently normalized to the MNI template. The images were spatially smoothed with a 7-mm FWHM isotropic Gaussian kernel.

Stroop task

At the first level, a General Linear Model (GLM) was specified with the onsets of congruent color words, incongruent color words, positive emotional words, negative emotional words and neutral words. The events were convolved with a canonical hemodynamic response function. Low-frequency noise was removed using a high-pass filter and motion parameters were included as regressors of no
interest. The conditions Incongruent and Negative were contrasted with the baseline condition Neutral for each participant and individual contrast images were entered into second-level analyses.

To investigate the relation between grades and brain activation during cognitive inhibition, a multiple regression design was constructed including the contrast images Incongruent versus Neutral and grades as a regressor. For emotional inhibition, a multiple regression design was defined including the contrast images Negative versus Neutral and grades. ROIs were chosen based on results obtained with the same Stroop task (Evers et al., 2006). In this study, the left dorsolateral prefrontal cortex (MNI = -40 24 26) and dorsal anterior cingulate cortex (MNI = 0 36 22) were found to be particularly important for labeling incongruent color words. The postcentral gyrus (MNI = -44 -32 46) was involved when labeling negative emotional words. An additional ROI was derived from other research reporting activation of the rostral anterior cingulate cortex (MNI = -2 44 20) during emotional inhibition (Bishop, Duncan, Brett & Lawrence, 2004; Bush, Luu & Posner, 2000). Ten-mm spheres were built around the center coordinates to construct the ROIs in MarsBaR (http://marsbar.sourceforge.net). For the cognitive inhibition model, data was extracted from the prefrontal and dorsal anterior cingulate ROIs and the effect of the regressor grades was determined. Data was extracted from the postcentral and rostral anterior cingulate ROIs to examine the effect of grades during emotional inhibition. A threshold of $p < 0.01$, corrected for multiple ROIs was used. Mean parameter estimates were imported into Excel to calculate correlations with grades.

**Go/NoGo task**

For each participant, a General Linear Model (GLM) was specified with the onsets of correct Go trials, correct NoGo trials and errors, convolved with a canonical hemodynamic response function. A high-pass filter was applied to remove low-frequency noise and motion parameters were included as regressors of no interest. Correct NoGo trials were contrasted with correct Go trials to assess motor inhibition and errors were contrasted with correct trials (Go and NoGo) to assess
performance monitoring. Individual contrast images were entered into group analyses.

To investigate the relation between grades and brain activation during motor inhibition, a multiple regression design was constructed including the contrast images NoGo versus Go and grades as a regressor. A multiple regression design was defined including the contrast images Errors versus Correct and grades to examine the effect of grades during performance monitoring. Regions of Interest (ROIs) were chosen based on results obtained with the same Go/NoGo paradigm (Evers et al., 2006). These included right dorsolateral prefrontal cortex (MNI = 48 34 22), dorsomedial prefrontal cortex (MNI = 2 26 42) and left insula (MNI = -30 26 -6) for motor inhibition and the dorsal anterior cingulate cortex (MNI = 6 26 40) for performance monitoring. Using MarsBaR, ROIs were defined by 10-mm spheres around the center coordinates. Results were thresholded at \( p < 0.01 \), corrected for multiple ROIs. Correlations between grades and activation of these ROIs were calculated by importing the mean parameter estimates into Excel.

**Results**

**Behavioral results**

**Stroop task**

The mean reaction times and error rates of the conditions Incongruent, Negative and Neutral are presented in Table 1. As predicted, there was no relation between academic performance and behavioral inhibition measures. Grades did not correlate significantly with cognitive inhibition time (\( \tau = 0.06, p = 0.71 \)) or emotional inhibition time (\( \tau = 0.28, p = 0.05 \)). There was also no correlation between cognitive inhibition error rate (\( \tau = -0.10, p = 0.49 \)) or emotional inhibition error rate (\( \tau = 0.16, p = 0.30 \)).
Table 1. Mean reaction times (ms) and error rates (%) on the Stroop task and the Go/NoGo task, including the standard deviations in parentheses.

<table>
<thead>
<tr>
<th></th>
<th>Reaction times</th>
<th>Error rates</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>STROOP TASK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incongruent</td>
<td>758.30 (165.83)</td>
<td>11.80 (8.24)</td>
</tr>
<tr>
<td>Negative</td>
<td>689.95 (131.14)</td>
<td>12.33 (6.07)</td>
</tr>
<tr>
<td>Neutral</td>
<td>658.87 (125.33)</td>
<td>5.50 (5.48)</td>
</tr>
<tr>
<td>Cognitive inhibition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Incongruent – Neutral)</td>
<td>99.43 (59.01)</td>
<td>6.30 (8.47)</td>
</tr>
<tr>
<td>Emotional inhibition</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Negative – Neutral)</td>
<td>31.08 (31.89)</td>
<td>6.83 (6.46)</td>
</tr>
<tr>
<td><strong>GO/NOGO TASK</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NoGo</td>
<td>-</td>
<td>23.37 (19.73)</td>
</tr>
<tr>
<td>Go</td>
<td>389.29 (17.07)</td>
<td>9.42 (4.80)</td>
</tr>
</tbody>
</table>

Go/NoGo task

Error rates on NoGo trials, Go trials and mean reaction time on Go trials are shown in Table 1. No correlation was found between grades and commission error rate ($\tau = -0.06, p = 0.69$), a behavioral measure of motor inhibition. There was also no significant correlation with the omission error rate ($\tau = -0.32, p = 0.04$) or reaction times on Go trials ($\tau = 0.09, p = 0.58$).

Figure 1. (A) The region of interest in the dorsal anterior cingulate cortex (MNI = 0 36 22). (B) Correlation between average grade and activation of the dorsal anterior cingulate cortex during cognitive inhibition on the Stroop task.
fMRI results

Stroop task

There was a significant positive association between grades and activation in the dorsal anterior cingulate cortex during cognitive inhibition (\( t = 3.58, p < 0.001 \)). Students with higher grades activated this region to a larger extent when labeling incongruent color words (see Figure 1). There was no correlation between grades and activation in the left dorsolateral prefrontal cortex (\( t = 0.19, p = 0.42 \)). For emotional inhibition, no correlation was present between grades and activation in the postcentral gyrus (\( t = -0.88, p = 0.81 \)). The association between grades and activation of rostral anterior cingulate cortex was not significant (\( t = 1.56, p = 0.07 \)). The correlations between grades and mean parameter estimates of all ROIs are presented in Table 2.

Table 2. Correlations between grades and activation in the regions of interest (ROIs) for the Stroop task. Center coordinates of the ROIs in MNI space are provided. The correlation in dorsal anterior cingulate cortex was significant.

<table>
<thead>
<tr>
<th>Region</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitive inhibition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left dorsolateral prefrontal cortex</td>
<td>-40</td>
<td>24</td>
<td>26</td>
<td>0.04</td>
</tr>
<tr>
<td>Dorsal anterior cingulate cortex</td>
<td>0</td>
<td>36</td>
<td>22</td>
<td>0.60*</td>
</tr>
<tr>
<td>Emotional inhibition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postcentral gyrus</td>
<td>-44</td>
<td>-32</td>
<td>46</td>
<td>-0.18</td>
</tr>
<tr>
<td>Rostral anterior cingulate cortex</td>
<td>-2</td>
<td>44</td>
<td>20</td>
<td>0.31</td>
</tr>
</tbody>
</table>

* \( p < 0.001 \)

Table 3. Correlations between grades and activation in the regions of interest for the Go/NoGo task, with center coordinates in MNI space. None of the correlations reached significance.

<table>
<thead>
<tr>
<th>Region</th>
<th>x</th>
<th>y</th>
<th>z</th>
<th>r</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor inhibition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right dorsolateral prefrontal cortex</td>
<td>48</td>
<td>34</td>
<td>22</td>
<td>-0.38</td>
</tr>
<tr>
<td>Dorsomedial prefrontal cortex</td>
<td>2</td>
<td>26</td>
<td>42</td>
<td>-0.01</td>
</tr>
<tr>
<td>Left insula</td>
<td>-30</td>
<td>26</td>
<td>-6</td>
<td>-0.14</td>
</tr>
<tr>
<td>Performance monitoring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsal anterior cingulate cortex</td>
<td>6</td>
<td>26</td>
<td>40</td>
<td>0.33</td>
</tr>
</tbody>
</table>
Go/NoGo task

Correlations between grades and mean parameter estimates of the ROIs from the Go/NoGo task are shown in Table 3. During motor inhibition, there was no association between grades and activation in the right dorsolateral prefrontal cortex ($t = -1.85$, $p = 0.04$), dorsomedial prefrontal cortex ($t = -0.07$, $p = 0.47$) and left insula ($t = -0.67$, $p = 0.26$). The correlation with activation in the dorsal anterior cingulate cortex during performance monitoring did not reach significance ($t = 1.61$, $p = 0.06$).

Discussion

The current study demonstrates a link between neural correlates of cognitive control and academic performance. A correlation between grades and brain activation on a Stroop task was observed in Freshmen from Medical College. Students with high grades recruited the anterior cingulate cortex more during cognitive inhibition compared to students with average grades. An association with achievement was only found in the dorsal anterior cingulate cortex, indicating that involvement of this region can potentially predict differences in educational success. No correlation was present in the left dorsolateral prefrontal cortex during cognitive inhibition or in the postcentral gyrus and rostral anterior cingulate cortex during emotional inhibition.

Both the dorsolateral prefrontal cortex and the anterior cingulate cortex are often activated on the Stroop task (Laird et al., 2005). However, not all studies show involvement of the anterior cingulate cortex during cognitive and emotional inhibition (Compton et al., 2003; Mincic, 2010). In previous research with 74 students from Medical College, including the current sample, we used the same Stroop task reported here (Veroude et al., 2013). No activation of the anterior cingulate cortex was observed on the group-level when all students were included, independent of academic performance. Our present results provide a clear indication that there are individual differences in the engagement of this area, since we demonstrated variation of anterior cingulate recruitment related to grades.
It has been suggested that the anterior cingulate cortex plays a role in detection of conflict while the dorsolateral prefrontal cortex is involved in the implementation of control (Carter & Van Veen, 2007). More generally, the function of the anterior cingulate cortex can be defined as a monitoring mechanism related to decision making (Botvinick, 2007). Students from our sample with relatively low grades demonstrated less activation of the anterior cingulate cortex during incongruent words compared to neutral words. It appears that these students failed to selectively engage this region when cognitive control is needed.

Our finding of more anterior cingulate activation on the Stroop task in Freshmen who perform better is in line with the ERP study of Hirsh and Inzlicht (2010). They reported a larger ERN, resulting from the anterior cingulate cortex, for undergraduates with higher grades. We showed that a correlation with academic success was present in the dorsal subdivision of this area during cognitive inhibition, but not in the rostral subdivision during emotional inhibition. Together, these results support the notion that stronger engagement of a neural monitoring mechanism is related to increased achievement in a real-world college environment.

No correlation with grades was found during motor inhibition and performance monitoring on the Go/NoGo task. The different patterns of findings on the Go/NoGo task and the Stroop task might be related to differences in the paradigms. Although both paradigms measure cognitive control, the Go/NoGo task is aimed at the more elementary process of motor inhibition while the Stroop task involves word reading and has a stronger cognitive component. This could explain why a link with college performance was observed on the latter task only.

This study is correlational in nature and therefore no conclusions can be drawn about the directionality of effects. The fMRI sessions took place before the end of the first academic year and each student was scanned in a different period. The grades were collected after the end of the academic year and were based on exams conducted over that entire year. Possibly, good students are better in cognitive control at the onset of college, evident by stronger anterior cingulate activation, and consequently obtain higher grades. Alternatively, students who obtain high grades have studied more and thereby trained their cognitive control skills, resulting in more brain activation. Future research could investigate whether
neural patterns can predict grades, by testing upcoming freshmen in an fMRI session before the start of school.

Our participants were 18 and 19 year old students in Medical College. This is a homogeneous sample consisting of highly motivated and intelligent young people. Only students who passed the first academic year were investigated, in order to distinguish between good and sufficient performance. Even in this highly selected group, neural correlates of academic success could be identified. It must be noted that these results cannot be easily generalized to older students, since the brain is not yet fully mature at the age of 18 or 19 (Bennett & Baird, 2006; Giedd & Rapoport, 2010; Tamnes et al., 2010).

No behavioral differences between students with good and sufficient grades were observed on the Stroop task or the Go/NoGo task. Clearly, investigating neural mechanisms provides additional insights into individual differences in academic achievement. The current fMRI results contribute to behavioral research on factors associated with success in Medical College (Kusurkar, Ten Cate, Vos, Westers & Croiset, 2013; Urlings-Strop, Stijnen, Themmen & Splinter, 2009). Our findings emphasize that cognitive control is a vital skill for students to pass a difficult curriculum. This implies that educational interventions aimed at strengthening this ability could have a positive impact on students’ learning outcomes.

References


