Trends in Neuroscience and Education 15 (2019) 10–17

Contents lists available at ScienceDirect

Trends in Neuroscience and Education

journal homepage: www.elsevier.com/locate/tine

Research paper

The neural correlates of academic self-concept in adolescence and the relation to making future-oriented academic choices

L.P.E. van der Aar*, S. Peters, R. van der Cruijsen, E.A. Crone

Department of Developmental Psychology, Leiden University, the Netherlands

ARTICLE INFO

Keywords:
Academic self-concept
Adolescence
Future orientation
Motivation
fMRI
Precuneus

ABSTRACT

This study examined the role of brain regions involved in academic self-evaluation in relation to problems with study orientation. For this purpose, 48 participants between ages 14–20 years evaluated themselves on academic traits sentences in an fMRI session. In addition, participants completed an orientation to study choice questionnaire, evaluated the importance of academic traits, and completed a reading and shortened IQ test as an index of cognitive performance. Behavioral results showed that academic self-evaluations were a more important predictor for problems with study orientation compared to subjective academic importance or academic performance. On a neural level, we found that individual differences in the positivity of academic self-evaluations were reflected in increased precuneus activity. Moreover, precuneus activity mediated the relation between academic self positivity and problems with study orientation. Together, these findings support the importance of studying academic self-concept and its neural correlates in the educational decision-making process.

1. Introduction

1.1. Academic choices in adolescence

An important challenge for adolescents is to make future-oriented academic choices that fit with their identity, such as deciding about what courses to take in high school or choosing a study in higher education. Here, the final years of high school are especially an important time for adolescents, as they have to start to think beyond the borders of high school and puzzle over what future academic and/or vocational career they want to pursue after graduation [1]. This marks the start of an extensive period of planning, exploration and complex career decision- making. Orientation to a future study choice has been found to be one of the most important tasks in the total career decision-making process [2], as this includes the students' first awareness of the need to make this future-oriented decision and engage in relevant actions that contribute to a deliberate outcome.

To date, studies investigating orientation to a future study choice have focused on the role of various demographic variables, such that being older, being female and having a higher socio-economic background have been associated with more readiness and capacity to engage in the process of future career decision-making [3]. Also specific personality traits have been linked to career orientation and exploration, where higher levels of conscientiousness, extraversion and agreeableness have been shown to relate to more career planning and exploration [4,5].

However, a topic that has been relatively understudied in relation to future orientation is how one sees and evaluates themselves and more specifically their competences in an academic or learning context, also known as academic self-concept [6]. Academic self-concept has been related to many educational outcome variables, such as students' school engagement and interests [7], motivation [8], emotions [9], academic adjustment or wellbeing [10], and school achievement or performance [11]. However, much less is known about how academic self-concept is connected to making future-oriented academic decisions. It is important to examine the role of academic self-concept in the orientation to future academic choices, as the beliefs individuals have about their traits and competencies in the academic domain could significantly influence their awareness and motivation to engage in the career decision-making process.

1.2. A neuroscientific approach to the academic self

Recent studies in the field of neuroscience have shown that neural measures can provide unique additional variance in academic outcomes, over behavioral measures alone. For example, neural activity

* Corresponding author at: Institute of Psychology; Brain and Development Research Center, Leiden University, Wassenaarseweg 52; 2333 AK Leiden; the Netherlands.

E-mail addresses: l.p.e.van.der.aar@fsw.leidenuniv.nl (L.P.E. van der Aar), s.peters@fsw.leidenuniv.nl (S. Peters), l.w.p.van.der.cruijsen@fsw.leidenuniv.nl (R. van der Cruijsen), ecrone@fsw.leidenuniv.nl (E.A. Crone).

https://doi.org/10.1016/j.tine.2019.02.003
Received 28 February 2018; Received in revised form 22 February 2019; Accepted 27 February 2019
Available online 27 February 2019

during a working memory task has shown to predict measures of school performance such as reading and mathematics two years later [12,13]. To this end, understanding more about the neural underpinnings of academic self-concept could possibly also benefit our knowledge about the relation between academic self-concept and orientation to making future academic choices. To date, research on the neurological correlates of self-concept has mostly focused on brain areas related to general self-evaluations. These studies have consistently found that cortical midline structures such as the medial prefrontal cortex (mPFC) are involved in thinking about the self, compared to thinking about traits of others or baseline activation (for reviews, see [14–16]). Moreover, more specific parts of this brain region have been linked to differences in valence and self-relevance of traits, such that stronger activation in the ventral part of the mPFC (vmPFC) has been related to more positive as well as more self-relevant self-descriptions [17,18].

Although the neural correlates of general self-evaluations have been well studied, much less is known about what brain areas are involved in self-descriptions specific to different domains, even though it is well established that self-descriptions become increasingly differentiated upon domain [19,20]. A few studies that have investigated domain-specific self-concept have shown that a broader network of brain regions is activated according to different domains of self-concept, including posterior cingulate cortex (PCC) related to more external, physical traits; and medial prefrontal cortex (mPFC) associated with more internal, character or competence traits [21,22]. For the domain of academic self-concept specifically, a study of van der Cruijsen et al. [18] found in an adult sample more activation in the precuneus and vmPFC when thinking about academic traits and competencies related to self, relative to evaluating own physical or prosocial traits. These results indicate that the precuneus and vmPFC could play an important role in the domain specificity of academic self-concept.

1.3. *The current study*

The main goal of this study was to examine the relation between behavioral and neural indices of academic self-concept, and orientation to future academic choice. For this purpose, we included a subsample of 48 adolescents that participated in the Leiden Self-Concept study [23] and who reported they were in the final years of high school. In addition to academic self-concept measures, we also tested whether other academic variables, such as academic performance (measured by IQ and a reading fluency test) and the subjective importance of academic traits, would relate in a similar or different way to orientation to future academic choice. This way, we aimed to investigate to what extent academic self-concept could be unique in its relation with future career decision-making.

Behaviorally, we expected that a more positive academic self-concept would be related to having fewer problems with orientation to future academic choice, indicating early awareness and motivation to start the career decision-making process. This hypothesis was based on earlier established relations between academic self-concept and general motivation in school [8,24], but no prior study has linked this to orientation to future academic choice. On a neural level, we expected more activation in vmPFC and precuneus for evaluating academic traits compared to a control task (see also van der Cruijsen et al. [23] for a report in the larger sample). We finally expected that brain activity related to evaluating academic traits could be informative for predicting orientation to future academic choice. We hypothesized that activity in these brain regions would be more pronounced for participants who evaluated themselves more positively on academic traits, and we examined whether these relations would be associated with orientation to future academic choice.

2. Method

2.1. *Participants*

The present study was part of a larger study (the Leiden Self-Concept study) with 150 participating adolescents in the age range 11–21 years. The subsample used in the current study comprised 48 participants in the age range 14–20 years (M_{age} = 16.62; SD = 1.33; 22 males; 26 females) who indicated to be in one of the final years of secondary education (grade 10, 11 or 12). Only these participants completed questionnaires related to study orientation, as this topic is not relevant yet for adolescents who are still in the first few grades of high school or for the ones who already continued with post-secondary education (college or vocational education). Participants were enrolled in different levels of educational programs: Pre-vocational education or “VMBO”, 17%; Higher general continued education or "HAVO”, 19%; or Pre-university education or "VWO”, 63%. As the duration of secondary education in the Netherlands is dependent upon the type of program, the final years of high school are differently defined for the different educational tracks. For the VMBO and HAVO program, the final years comprise the final two years (students aged 14–17 years), whereas for the VWO program these consist of the final three years of high school (students aged 15–18 years). All participants completed two subtests of the WISC-III or WAIS-III (Similarities and Block Design) in order to obtain an estimation of IQ. Estimated IQ scores fell between 82.5 and 137.5 (M = 109.58, SD = 9.64), and IQ did not correlate with age ($r(48) = 0.05$, $p = .758$). IQ did differ between school levels ($F(2,44) = 8.73$, $p = .001$) with lower IQ scores for participants following the VMBO program compared to participants following the HAVO program ($p = .006$) and VWO program ($p < .001$). Written informed consents were provided by the participants themselves or by a parent as well in the case of minors. All participants were screened for MRI contra indications, had normal (or corrected to normal) vision, were fluent in Dutch, and had no neurological or psychiatric impairments. The University Medical Ethics Committee approved the study and its procedures.

2.2. *Experimental task*

Self-concept was measured with an fMRI task in which participants were presented with short sentences that described positively or negatively valenced traits or competencies in the domains of academics, prosocial skills and physical appearance (for more information and validation of the traits, see [23]. For the current study, we focused on the academic domain specifically. In the self-condition, participants were asked to indicate for each trait sentence to what extent the trait applied to them, using a Likert-type 4-point rating scale (1 = not at all, to 4 = completely). Each domain consisted of 20 stimuli, half with positive valence and half with a negative valence, making a total of 60 trait sentences (e.g. ‘I am smart’ or ‘I think school is hard’). For the control-condition, participants were asked to categorize other traits relating to the same three domains (e.g. ‘having a good memory’) into one of four categories: [1] school, [2] social, [3] physical appearance, or [4] I don't know. This condition contained 20 traits in total, again equally divided in positive and negative valence.

The stimuli were presented in an optimized pseudorandomized order using Optseq [25] and were separated with a jittered black screen that varied between 0 and 4400 ms. Each trial started with a 400 ms fixation cross, after which the stimulus was presented for 4600 ms, consisting of the trait sentence and response options [1–4] (see Fig. 1). Participants could respond to the sentence within this timeframe by pressing buttons with the index to little finger of their right hand where after the number of their choice turned from white to yellow for the remaining stimulus time. If the participant failed to respond within the 4600 ms, they were shown the phrase ‘Too late!’ for 1000 ms. These trials were modeled separately and were not included in the analysis,

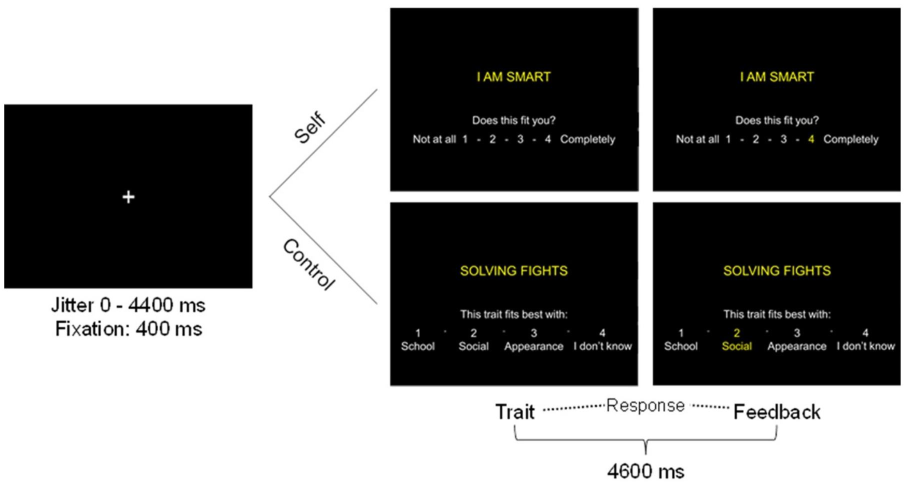

Fig. 1. Example of a trial in the Self and the Control condition. Each trial started with a black screen with a jittered duration between 0 and 4400 ms. Subsequently, a fixation cross was shown for 400 ms after which the stimulus was presented. In the self-condition, participants rated on a scale of 1 to 4 to what extent the traits fit themselves. In the control-condition, participants categorized the trait sentences into one of four options. The stimulus was shown for 4600 ms. If participants responded within this time-frame, the number of their choice would turn yellow. If participants failed to respond within this timeframe, a screen with the phrase 'Too Late!' was shown for an additional 100 ms after which the next trial would start.

and occurred on less than 0.7% of the trials in the self-condition and on less than 0.4% in the control-condition.

2.3. Materials

Importance: After the scanning session, participants were asked to rate the same 60 trait sentences on importance of possessing these traits. They could indicate importance on a scale of 1 (It is very important to me to **not** have this trait) to 5 (It is very important to me to have this trait). Scores for the negative traits were recoded and merged with the positive traits, so that a higher combined score indicated a general positivity score for importance.

Orientation to study choice: We used the subscale 'orientation to choice' of the Study Choice Task Inventory (SCTI; [26]. This 12-item questionnaire measures the extent to which adolescents are aware of the need to make a decision for a study in higher education and their motivation to do so. An example of an item is "I seldom think about what I will study". Answers were given on a 9-point Likert scale ranging from 1 ("does not describe me at all") to 9 ("describes me very well"). The scale was reliable according to a Cronbach's alpha of 0.89. Counter indicative items were recoded so that higher scores indicated more problems with orientation to study choice.

Reading: Reading skills were measured with a reading fluency task, called the "Three-Minute-Test" [27]. In this task, participants received a list of Dutch words and were instructed to read the words aloud as clearly and quickly as possible in 1 min. The total score is defined as the number of correct words read minus the number of incorrect words. The Three-Minute-Test has good validity and reliability with a Cronbach's alpha of 0.96.

2.4. Procedure

Participants were given an extensive explanation and practice session in a mock scanner to familiarize them with the procedure of an MRI scan. Before scanning, participants received instructions about the self-concept tasks and performed 9 practice trials for each condition. Anonymity was emphasized and participants were encouraged to honestly describe how they thought about themselves and ask questions if they did not understand the meaning of a trait adjective.

2.5. MRI data acquisition

MRI scans were acquired on a Philips 3T MRI scanner, using a standard whole-head coil.

Functional scans were collected in two runs with T2*-weighted echo-planar imaging (EPI)

The first two volumes were discarded to allow for equilibration of T1 saturation effect. Volumes covered the whole brain (TR = 2200 ms, TE = 30 ms, sequential acquisition, 37 slices of 2.75 mm, FOV = 220 × 220 × 111.65 mm). After the functional scans, a high-resolution 3D T1 scan was obtained as anatomical reference (TR = shortest msec, TE = 4.6 ms, 140 slices, voxel size = 0.875 mm, FOV = 224 × 178.5 × 168 mm). Sentences were projected on a screen behind the scanner and could be viewed through a mirror attached to the head coil. Head movement was restricted by placing foam inserts inside the coil.

2.6. MRI data analyses

MRI data were preprocessed and analyzed with SPM8 (Wellcome Department of Cognitive Neurology, London). Images were corrected for slice-timing acquisition and differences in rigid body motion. The normalization algorithm used a 12-parameter affine transformation together with a nonlinear transformation involving cosine basis functions and resampled the volumes to 3 mm cubic voxels. Templates were based on the MNI305 stereotaxic space [28]. Functional volumes were spatially smoothed using a 6 mm FWHM isotropic Gaussian kernel.

Individual participants' data were analyzed using the general linear model in SPM8. The fMRI time series were modeled as a series of zero duration events convolved with the hemodynamic response function (HRF). Modeled events of interest for the self-task were: "Academic-Positive" and "Academic-Negative". For the control-task, we used one event of interest ("Control") that was collapsed across domains and valences. Trials on which participants failed to respond were modeled as covariate of no interest and were excluded from further analyses. The events were used as covariates in a general linear model, along with a basic set of cosine functions that high-pass filtered the data. Six motion regressors were added to the model. The resulting contrast images, computed on a subject-by-subject basis, were submitted to group analyses.

At the group level, we compared academic trials (collapsed across valences) to the control trials using a one sample *t*-test for the contrast Academic-Self > Control. For all analyses, we applied FDR cluster level correction ($p < .05$) at an initial uncorrected threshold of $p < .001$, as implemented in SPM8. The general contrast Academic-Self > Control was also reported in van der Cruijsen et al. [23] in the larger sample of the Self-Concept Study ($N = 150$). In addition, whole-brain regression analyses were performed to investigate whether stimulus-related activation in the academic trials was correlated with the individual responses in the task. Here, we recoded responses on the negative traits and merged them with the positive traits, such that higher average scores indicated more positive evaluations of the academic self. (academic self positivity). These regression analyses were also FDR cluster corrected at $p < .05$, at an initial uncorrected threshold of $p < .001$. In order to further examine the neural correlates of academic self-concept and the relation to orientation to study choice, functional ROIs were defined with the use of the MarsBar toolbox in SPM8 [29]. Outlier scores (z-value < −3.29 or >3.29) were winsorized [30].

3. Results

3.1. Behavioral measures

Table 1 shows the correlation between "self positivity scores of academic traits" (M = 2.83, SD = 0.44), "positivity scores on academic importance" (M = 3.90, SD = 0.48), and "problems with orientation to study choice" (M = 3.56, SD = 1.70). In addition, we report correlations with IQ (M = 109.58, SD = 9.64) and reading performance (M = 98.19, SD = 12.60) as indices of performance outcomes. Age was not significantly correlated with any of these key variables, therefore we did not include age in any further analyses.

As can be seen in Table 1, academic self positivity was significantly correlated with academic importance and problems with future orientation, but not with IQ and reading. In addition, academic importance was correlated with IQ and reading. IQ and reading were also inter-correlated. These findings suggest that there are partly overlapping, and partly separable relations between these measures of academic self-concept, performance and problems with future orientation to study choice. Next, we performed a multiple regression analysis including all academic variables as predictors and future orientation to study choice as dependent variable to test whether academic self-concept could be viewed as a more important predictor in this relationship. Results showed that only academic self-concept significantly predicted problems with future orientation (β = −0.33, p = .042) thereby indicating that academic self-concept could be a more important predictor for future orientation to study choice compared to academic importance or performance.

To further examine these distinct relations, we checked whether the 5 academic variables could be encompassed by different factors using a Principal Component Analysis (PCA). Assumptions check for the PCA showed a Kaiser-Meyer-Olkin (KMO) value of 0.70, which indicated adequate sampling, and a significant Barlett's test of sphericity (χ^2 = 28.427, df = 10, p = .002), which indicated suitability of the data for PCA. To extract the suitable number of factors, an initial PCA analysis with varimax rotation was conducted. The parallel analysis indicated that two factors should be retained. The two factors together explained 61.68% of the total variance. The variables IQ, reading, and academic importance together loaded high on one factor, whereas academic self positivity and problems with orientation to study choice loaded on another factor. This suggests two separate academic constructs; one related more to academic performance and the other embodying academic self-concept and motivation. The specific factor loadings can be found in Table 2.

Table 1
Intercorrelations between academic variables.

	Academic importance	IQ	Reading	Problems with orientation
Academic self positivity	**.38****	0.27	0.27	**−0.35***
Academic importance		**.32***	**.31***	−0.15
IQ			**.37***	−0.09
Reading				−0.18

* p < .05.
** p < .01.

Table 2
Factor loadings for the Principal Component Analysis.

	Factor 1	Factor 2
IQ	0.794	
Reading	0.714	
Academic importance	0.658	
Problems with orientation		−0.893
Academic Self Positivity		0.677

Only factor loadings > 0.40 are printed in this table.

3.2. fMRI results

3.2.1. Whole brain contrasts and regressions

To test for the neural correlates of academic self-concept, we first tested at the whole brain level whether we could find similar results compared to the previous findings within the larger sample (N = 150; van der Cruijsen et al. [23] in the current subsample (whole brain contrast), and whether there were relations with academic self-concept ratings and problems with orientation to study choice (whole brain regression).

First, we examined the brain regions that were involved in evaluating academic traits. Consistent with results reported in van der Cruijsen et al. [23], in the current subsample of adolescents (N = 48), the contrast Academic-Self > Control resulted in increased activity in mPFC (see Fig. 2A and Table 3). Next, we tested for additional relations with academic self positivity in the contrast Academic-Self > Control, by means of a whole brain regression analysis. This resulted in positive correlations between academic self positivity and Academic-Self > Control in the precuneus (see Fig. 2B) and right temporal lobe (see Table 3). As shown in Fig. 2B, adolescents who rated their academic self-concept more positively showed greater activation in a posterior subsection of the precuneus. We conducted a similar whole brain regression analysis with problems with orientation to study choice as regressor variable, but this did not result in significant clusters of activation.

3.2.2. Post hoc ROI analyses

To further explore how brain regions involved in academic self-concept were related to having problems with making future-oriented study choices, we extracted two ROIs of the mPFC and precuneus and related activity in these ROIs to the behavioral measures (see Table 4). To test whether any of these effects were valance specific, all correlation analyses were also performed for positive and negative academic items separately. The correlation between activity for positive and negative traits was .75 in mPFC and .82 in precuneus.

Next, we examined whether neural activity for academic self-concept could possibly mediate the relation between academic self positivity and problems with orientation to study choice, using the methods developed by Hayes [31]. As mPFC activity did not correlate with any of the behavioral measures, we only used precuneus activity for these mediation analyses.

We tested three mediation models with precuneus activity from the contrast Academic-Self (positive and negative together) > Control, as well as with the positive and negative traits separately as possible mediators between academic self positivity (X) and the outcome variable problems with orientation to study choice (Y). Based on 10.000 bootstrap resamples, the indirect path of academic self positivity to problems with orientation was only significant for precuneus activity within the negative traits (B = −0.44, 95% CI = [−1.22 - −0.05]). Moreover, with the inclusion of precuneus activity in the model, the direct path from academic self positivity to problems with orientation was no longer significant (see Fig. 3). Thus, a more positive academic self-concept was associated with more precuneus activity for the

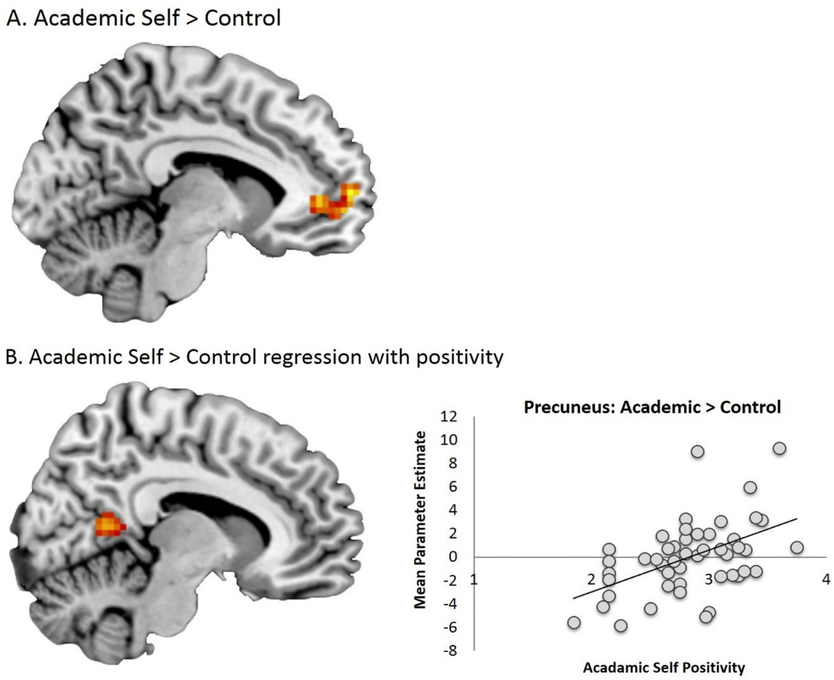

Fig. 2. (A) Main contrast Academic-Self > Control resulted in increased activity in mPFC, and (B) relation with academic self positivity (regression analysis Academic-Self > Control, positive relation with academic self positivity) shows stronger posterior precuneus activity for higher academic self positivity.

Table 3
Regions activated during the target contrasts.

Region		*BA*	*Coordinates*			*Cluster size*	*T*
(A) Academic > Control							
Frontal cortex	L Superior Medial Frontal (mPFC)	10	−9	59	7	121	4.68
(B) Academic > Control with academic self positivity as positive regressor							
Temporal cortex	R Middle Temporal	40	48	−28	22	156	4.87
	R Middle Temporal Gyrus	37	51	−55	10		4.22
Parietal cortex	R Supramarginal Gyrus	40	60	−25	19		4.09
	R Calcarine Gyrus / R Precuneus	23	9	−55	10	92	4.32
	L Precuneus	23	−3	−55	16		3.62

Names were based on the Automatic Anatomical Labeling (AAL) atlas.

Table 4
Intercorrelations between academic self-concept, performance, orientation and involved brain activity.

	Academic Self Positivity	Academic importance	IQ	Reading	Problems with orientation
mPFC Acposneg > control	−0.07	0.09	0.15	0.16	−0.01
mPFC Acpos > control	−0.03	0.08	0.14	0.17	0.01
mPFC Acneg > control	−0.12	0.08	0.14	0.13	−0.03
Precuneus Acposneg > control	–	**.28***	0.25	0.09	**−.29***
Precuneus Acpos > control	–	**.32***	0.28	0.06	−0.20
Precuneus Acneg > control	–	0.22	0.21	0.13	**−.35***

** $p < .01$.
* $p < .05$.

negative traits only, and more precuneus activity was in turn associated with fewer problems with future orientation. No significant mediation effects were found for precuneus activity for the positive traits ($B = -0.09$, 95% CI = [−0.53–0.50]) or for the positive and negative traits combined ($B = -0.30$, 95% CI = [−0.95–0.16]).

4. Discussion

In this study, we combined behavioral indices and neural correlates of academic self-concept and related these outcomes to the awareness and motivation of adolescents to start engaging in the educational decision-making process. Results revealed three main findings. First, academic self-concept was a better predictor for orientation to future academic choice compared to subjective academic importance or performance. Specifically, this relation indicated that a more positive academic self-concept was associated with fewer problems with future orientation. Second, similar to prior research of van der Cruijsen et al. [23] we showed increased activation in the mPFC for evaluating academic self-traits compared to a baseline task, in a smaller subsample. In addition, we found posterior precuneus activity in relation with more

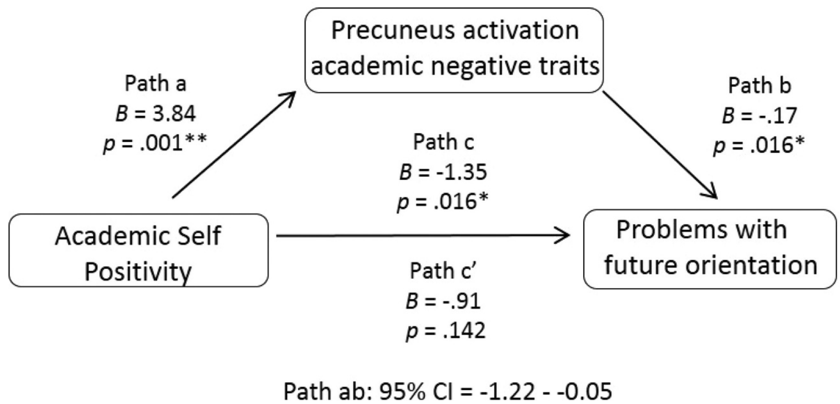

Fig. 3. Mediation analyses for the relation between Academic Self Positivity, Problems with future orientation, and precuneus activity for negative trials separately (academic negative traits).

positive self-ratings. Third, precuneus activity specifically mediated the relation between academic self-concept and problems with orientation to future academic choice. The discussion is organized alongside the line of these findings.

4.1. The relation between academic predictors and future orientation

The choice of a postsecondary study can be described as a major educational decision with far- reaching consequences and implications for students' future careers [32]. Many individual factors have been found to play an important role in the complex decision-making process, leading to this final choice. Here we tested the contribution of self-evaluations in the academic domain to problems adolescents can experience with the start of the orientation process, and how this contribution might differ from other academic and self-concept measures, such as academic performance and the subjective importance given to academic traits. Results showed that academic self-concept and academic performance can be viewed as two different, independent constructs with possible distinct relations with study orientation. As future orientation marks the start of the awareness and motivation of adolescents towards orienting themselves towards options after high school, this could also be viewed as a form of 'academic motivation for the future' or motivation based on the expectation of long-term rewards [33]. Research on academic motivation has shown relations with academic self-concept as well as academic performance [6,8,34]. However, most studies investigated these relationships separately, focusing on academic performance as outcome variable. The few studies that focused on academic self-concept and motivation found the two to be strongly related, where motivation served as a mediator between academic self-concept and performance [34]. In addition, studies investigating differences between academic self-concept and a related construct of self-beliefs, self-efficacy (the confidence in one's own abilities to perform a certain task successfully), showed that academic self-concept was a better predictor for motivation, whereas self-efficacy was a better predictor for academic performance [24,35]. Our results fit with this line of research, showing that academic self-concept was a more important predictor for problems with study orientation than academic performance. In other words, the way adolescents evaluate their academic traits and skills in the past and the present is related to how they feel about engaging in orientation for a career in the future. However, to make definite conclusions regarding the sequential nature of self-evaluations involved in the process of orienting towards a study in higher education, longitudinal research is needed.

Interestingly, the subjective importance given to academic traits was not correlated to future orientation. This is surprising, as the extent to which a trait or self-view is considered to be important has been related to personal goals and motivation [36]. In this light, one would expect that giving more emphasis to traits such as doing well in school, would also result in more motivation to start the orientation process for a suitable major in higher education. More research is needed in order to understand the relation between importance and future orientation. Possibly, academic importance ratings are less important than expected, or the current sample was too small to reveal this relation.

Together, these behavioral results emphasize academic self-concept as a key component with a unique contribution to the awareness and motivation to start the orientation process for a future study.

4.2. The relation between behavioral and neural correlates of academic self-concept

A second aim of this study was to examine the neural correlates of academic self-concept and relate these outcomes to individual differences in behavioral self-concept measures. We found mPFC involvement during the evaluations of academic traits compared to a control task. This is consistent with prior studies investigating internal, character or competence traits [21,22], and a study investigating academic self-concept in adults [18]. This effect was previously reported in van der Cruijsen et al. [23] in a larger sample with a wide age range that included the current sample. These results add to the existing literature by showing the mPFC is a robust area for supporting judgments about the self in the academic domain as well.

Different from results of van der Cruijsen et al. [18,23], we did not find precuneus involvement for evaluating academic traits on the whole brain level, possibly because our sample was smaller. However, posterior precuneus activity was observed when we related neural responses to individual differences in academic self-concept positivity. Specifically, we found that this section of the precuneus was more active when adolescents rated themselves more positively on academic traits and competences. This is interesting, as we did not find this dependency for the mPFC. Other studies that have examined general self-concept have mostly found ventral mPFC to be sensitive to signaling personal significance, showing increased activation when stimuli are more self-relevant [37]. VMPFC responses have also been linked to positive valuation processes, which could be related to the idea that positive self-descriptions are often also simultaneously viewed as more self-relevant [17,38,23]. This study suggests that for self-evaluations specific to the academic domain, posterior precuneus serves as an indicator for individual differences in the positivity with which adolescents describe their academic traits.

The precuneus has been found to be involved in the social brain network and activated during social cognitive processes, such as when one thinks about others and selves in social contexts [39]. Interestingly, a study focusing on the neural correlates of social comparison as one of the most omnipresent mechanism of social cognition, found that precuneus in particular was highly involved when adult participants compared their intelligence to other individuals [40]. In adolescence, the academic domain could be profoundly sensitive to social comparison, as the classroom is a highly evaluative environment where comparison of performance and grades with classmates is often emphasized [41]. In previous studies, the exact location of precuneus activity differed between reports. In the current study, the precuneus region falls within the posterior part of the precuneus atlas, bordering but distinct from the lingual gyrus. An important direction for future research will be to examine the contribution of these different sections of the precuneus to individual differences in self-concept.

4.3. The role of neural correlates of academic self-concept in future orientation

An important goal of this study was to test the contribution of behavioral and neural correlates of academic self-concept to whether adolescents are aware and motivated to start the orientation process for a study in higher education. These analyses resulted in two important findings. First, we found a positive relation between activity in the posterior precuneus when participants were evaluating their academic traits and the problems they encounter with future orientation. Specifically, adolescents who reported to have fewer problems with future orientation showed more precuneus activation when evaluating their academic traits. Moreover, this relation was present for the evaluation of negative academic traits and the combination of positive and negative traits, but not for solely positive academic traits. Possibly, variance in precuneus activity is largest for academic traits with a negative valence, such as "I am dumb" or "I receive low grades". These self-evaluations may be more salient for individuals who are more focused on study orientation.

Second, precuneus activity during these evaluations of negative academic traits specifically, mediated the relation between behavioral outcomes of academic self-concept and problems with orientation to future academic choice. That is, adolescents who evaluated negative academic traits as less applicable to themselves indicated they experienced fewer problems with future orientation, and this relation was mediated by stronger precuneus activity. These findings suggest that the precuneus may be an important brain region that processes how adolescents evaluate negative academic traits, and subsequently influences how adolescents think about their future academic self through study orientation. It will be necessary to extent these findings using future longitudinal designs, but the findings fit with the presumed role of the precuneus in comparing self to others [40,42] and may in the current context also reflect the process of comparing current to future self.

4.4. Limitations and future directions

This study has several strengths, among them the inclusion of a diverse set of behavioral academic factors and neural measures of academic self-concept. However, there are some limitations that should be addressed in future studies. First, our measures of academic performance consisted of an estimation of IQ and scores on a reading fluency test, whereas academic performance is generally measured by specific school grades or GPA. Although IQ and GPA have been found to be moderately correlated, academic performance measured by GPA is influenced by many more variables than IQ alone [43]. In future studies, it should be considered to include both measures of IQ and school grades to give a more accurate estimate of academic performance.

Although beyond the scope of this paper, it should be noted that the Dutch school system stands out by distinguishing between multiple types or tracks of secondary education. These types differ in duration of the track as well as the academic level. Therefore, it is more difficult to compare grades into one GPA score, as a grade at a lower level does not evenly compare to a similar grade in a higher level. Moreover, because the duration of secondary education is dependent upon the type of program, students graduate at different ages. In this study, we did not select participants based on the educational track and therefore our sample was too small to include the type of educational program in the analyses. However, it would be an interesting direction for future research to incorporate the variety of scholastic tracks into the study design, thereby investigating the possible influences of these differences on the educational decision-making process.

A final limitation of this study concerns the cross-sectional design. Although this study contributes to the understanding of the relation between the behavioral and neural indices of academic self-concept and the motivation to make future oriented academic choices, we cannot firmly conclude that measures of academic self-concept play an antecedent role in this motivation for future orientation. Future research would benefit by testing these relations using longitudinal designs.

4.5. Conclusions

We investigated the role a diverse set of academic factors, including measures of academic performance and behavioral- and neural correlates of academic self-concept, in relation with problems adolescents can experience with starting the orientation process for a future study. In summary, we observed that self-ratings on academic traits were related to future study orientation. Moreover, neural activity during academic self-evaluations were observed in medial PFC and posterior precuneus, but only precuneus activity was correlated to rating the self positively on academic traits. Most importantly, precuneus activity mediated the relation between self-ratings and problems with study orientation, possibly reflecting a role of present and future self-comparison [42]. These findings have several important implications for future research on study orientation. First, academic self-evaluations were a more important predictor for study orientation than cognitive performance, showing the importance of a broader definition of factors influencing future orientation [1,3]. Second, an important question for future research will be to test the role of the precuneus in a longitudinal design to examine whether precuneus activity can predict future study orientation problems, and to test whether precuneus activity can be trained using self-concept training studies [44]. Taken together, these results demonstrate the importance of studying academic self-concept and its neural correlates in the educational decision-making process.

Acknowledgments

We thank all participants for their collaboration and everyone involved with data collection for the Leiden Self-Concept project. This work was supported by a grant from The Netherlands Organization for Scientific Research (NWO-VICI 453-14-001 E.A.C.)

References

[1] ME Rogers, PA Creed, A longitudinal examination of adolescent career planning and exploration using a social cognitive career theory framework, J. Adolesc. 34 (1) (2011) 163–172. Available from http://dx.doi.org/10.1016/j.adolescence.2009.12.010.

[2] V Germeijs, K. Verschueren, High school students' career decision-making process: development and validation of the study choice task inventory, J. Career Assess. 14 (4) (2006) 449–471. Available from http://jca.sagepub.com/cgi/doi/10.1177/1069072706286510.

[3] PA Creed, W Patton, LA Prideaux, Predicting change over time in career planning and career exploration for high school students, J. Adolesc. 30 (3) (2007) 377–392.

[4] TA Klimstra, K Luyckx, V Germeijs, WHJ Meeus, L Goossens, Personality traits and educational identity formation in late adolescents: longitudinal associations and academic progress, J. Youth Adolesc. 41 (3) (2012) 346–361.

[5] ME Rogers, PA Creed, A Ian Glendon, The role of personality in adolescent career planning and exploration: a social cognitive perspective, J. Vocat. Behav. 73 (1) (2008) 132–142.

[6] M Bong, EM. Skaalvik, Academic self-concept and self-efficacy: how different are they really? Educ. Psychol. Rev. 15 (1) (2003) 1–40.

[7] HW Marsh, AJ Martin, Academic self-concept and academic achievement: relations and causal ordering, Br. J. Educ. Psychol. 81 (2011 Mar) 59–77. Available from

http://www.ncbi.nlm.nih.gov/pubmed/21391964.
[8] JC Valentine, DL Dubois, H Cooper, The relation between self-beliefs and academic achievement : a meta-analytic review, Educ. Psychol. 39 (July 2015) (2004) 111–133.
[9] T Goetz, H Cronjaeger, AC Frenzel, O Ludtke, NC Hall, Academic self-concept and emotion relations: domain specificity and age effects, Contemp. Educ. Psychol. 35 (1) (2010) 44–58. Available from http://dx.doi.org/10.1016/j.cedpsych.2009.10.001.
[10] S Wouters, V Germeijs, H Colpin, K Verschueren, Academic self-concept in high school: predictors and effects on adjustment in higher education, Scand. J. Psychol. 52 (6) (2011) 586–594.
[11] C Huang, Self-concept and academic achievement : a meta-analysis of longitudinal relations, J. Sch. Psychol. 49 (5) (2011) 505–528. Available from http://dx.doi.org/10.1016/j.jsp.2011.07.001.
[12] S Peters, M Van der Meulen, K Zanolie, EA Crone, Predicting reading and mathematics from neural activity for feedback learning, Dev. Psychol. 53 (1) (2017) 149–159. Available from http://doi.apa.org/getdoi.cfm?doi=10.1037/dev0000234%5Cnhttp://www.ncbi.nlm.nih.gov/pubmed/28026194.
[13] I Dumontheil, T Klingberg, Brain activity during a visuospatial working memory task predicts arithmetical performance 2 years later, Cereb. Cortex 22 (5) (2012) 1078–1085.
[14] Kober Denny, O Wager, A meta-analysis of functional neuroimaging studies of self and other judgments reveals a spatial gradient for mentalizing in medial prefrontal cortex, J. Cogn. Neurosci. 24 (8) (2012) 1742–1752.
[15] C Sebastian, S Burnett, SJ Blakemore, Development of the self-concept during adolescence, Trends Cogn. Sci. 12 (11) (2008) 441–446.
[16] RJ Murray, M Schaer, M Debbané, Degrees of separation: a quantitative neuroimaging meta-analysis investigating self-specificity and shared neural activation between self- and other-reflection, Neurosci. Biobehav. Rev. 36 (3) (2012 Mar) 1043–1059 cited 2017 Dec 5 Available from http://www.ncbi.nlm.nih.gov/pubmed/22230705.
[17] JM Moran, CN Macrae, TF Heatherton, CL Wyland, WM Kelley, Neuroanatomical evidence for distinct cognitive and affective components of self, J. Cogn. Neurosci. 18 (9) (2006) 1586–1594. Available from http://www.ncbi.nlm.nih.gov/pubmed/16989558.
[18] R van der Cruijsen, S Peters, EA Crone, Neural correlates of evaluating self and close-other in physical, academic and prosocial domains, Brain Cogn. 118 (2017) 45–53.
[19] HW Marsh, V Ayotte, Do multiple dimensions of self-concept become more differentiated with age? The differential distinctiveness hypothesis, J. Educ. Psychol. 95 (4) (2003) 687–706.
[20] LPE van der Aar, S Peters, EA Crone, The development of self-views across adolescence: investigating self-descriptions with and without social comparison using a novel experimental paradigm, Cogn. Dev. 48 (2018) 256–270. Available from https://doi.org/10.1016/j.cogdev.2018.10.001.
[21] JM Moran, SM Lee, JDE Gabrieli, Dissociable neural systems supporting knowledge about human character and appearance in ourselves and others, J. Cogn. Neurosci. 23 (9) (2011) 2222–2230.
[22] N Ma, S Wang, Q Yang, T Feng, F Van Overwalle, The neural representation of competence traits: an fMRI study, Sci. Rep. 6 (November) (2016) 1–10. Available from http://dx.doi.org/10.1038/srep39609.
[23] R van der Cruijsen, S Peters, LPE van der Aar, EA Crone, The neural signature of self-concept development in adolescence: the role of domain and valence distinctions, Dev. Cogn. Neurosci. 30 (2018) 1–12.
[24] BE Fenning, LN. May, “Where there is a will, there is an A”: examining the roles of self-efficacy and self-concept in college students’ current educational attainment and career planning, Soc. Psychol. Educ. 16 (4) (2013) 635–650.
[25] AM Dale, Optimal experimental design for event-related fMRI, Hum. Brain Mapp. 8 (2–3) (1999) 109–114 cited 2017 Nov 6Available from http://doi.wiley.com/10.1002/%2528SICI%25291097-0193%25281999%25298%253A2/3%253C109%253A%253AAID-HBM7%253E3.0.CO%253B2-W.
[26] V. Germeijs, High school students’ career decision-making process: development and validation of the study choice task inventory, J. Career Assess 14 (4) (2006) 449–471. Available from http://jca.sagepub.com/cgi/doi/10.1177/1069072706286510.
[27] R. Krom, I. Jongen, N. Verhelst, F. Kamphuis, F Kleintjes, DMT en AVI: Wetenschappelijke Verantwoording [DMT and AVI: Scientific Basis], CITO Institute for Test Development, 2010.
[28] C Cocosco, V Kollokian, RK Kwan, GB Pike, AC Evans, BrainWeb : online interface to a 3D MRI simulated brain database, 3rd Int Conf Funct Mapp Hum Brain, 5 1997, p. S425.
[29] M Brett, JL Anton, R Valabregue, JB Poline, Region of interest analysis using an SPM toolbox, Neuroimage 16 (2002) 497.
[30] BG Tabachnick, LS Fidell, Using Multivariate Statistics, Pearson Education, Boston, 2013.
[31] A Hayes, Introduction to Mediation, Moderation, and Conditional Process Analysis, NY Guilford, New York, 2013, pp. 3–4.
[32] M Pinxten, B De Fraine, J Van Damme, E D'Haenens, Student achievement and academic self-concept among secondary students in Flanders: gender and changes over time, Irish Educ. Stud. 32 (April 2013) (2013) 157–178.
[33] MM Wong, M Csikszentmihalyi, Motivation and academic achievement: the effects of personality traits and the quality of experience, J. Pers. 59 (3) (1991) 539–574.
[34] F Guay, CF Ratelle, A Roy, D Litalien, Academic self-concept, autonomous academic motivation, and academic achievement: mediating and additive effects, Learn. Individ. Differ. 20 (6) (2010) 644–653. Available from http://dx.doi.org/10.1016/j.lindif.2010.08.001.
[35] J Ferla, M Valcke, Y Cai, Academic self-efficacy and academic self-concept: reconsidering structural relationships, Learn. Individ. Differ. 19 (4) (2009) 499–505.
[36] A D'Argembeau, H Jedidi, E Balteau, M Bahri, C Phillips, E Salmon, Valuing one's self: medial prefrontal involvement in epistemic and emotive investments in self-views, Cereb. Cortex 22 (3) (2012) 659–667.
[37] A D'Argembeau, On the role of the ventromedial prefrontal cortex in self-processing: the valuation hypothesis, Front. Hum. Neurosci. 7 (2013) 372. Available from http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3707083&tool=pmcentrez&rendertype=abstract.
[38] J Peters, C Büchel, Neural representations of subjective reward value, Behav. Brain Res. 213 (2010) 135–141.
[39] AE Cavanna, The precuneus: a review of its functional anatomy and behavioural correlates, Brain 129 (3) (2006) 564–583. Available from http://www.brain.oxfordjournals.org/cgi/doi/10.1093/brain/awl004%5Cnpapers2://publication/doi/10.1093/brain/awl004.
[40] G Kedia, M Lindner, T Mussweiler, N Ihssen, DEJ Linden, Brain networks of social comparison, Neuroreport 24 (5) (2013) 259–264.
[41] MJPW Wehrens, AP Buunk, MJ Lubbers, P Dijkstra, H Kuyper, GPC van der Werf, The relationship between affective response to social comparison and academic performance in high school, Contemp. Educ. Psychol. 35 (3) (2010) 203–214. Available from http://dx.doi.org/10.1016/j.cedpsych.2010.01.001.
[42] JK Swencionis, ST Fiske, How social neuroscience can inform theories of social comparison, Neuropsychologia 56 (1) (2014) 140–146. Available from http://dx.doi.org/10.1016/j.neuropsychologia.2014.01.009.
[43] AL Duckworth, MEP Seligman, Self-discipline outdoes IQ in predicting academic performance of adolescents, Psychol. Sci. 16 (12) (2005) 939–944.
[44] A O'Mara, H Marsh, R Craven, R Debus, Do self-concept interventions make a difference? A synergistic blend of construct validation and meta-analysis, Educ. Psychol. 41 (3) (2006) 181–206.