Schizotypy, Manual Dexterity, and Cognitive Ability Distinguish STEM and non-STEM students

Pavida Nithananon
Faculty of Psychology
Chulalongkorn University
Bangkok, Thailand
Email: 6338047038@student.chula.ac.th

Valrin Intharasombat
Faculty of Psychology
Chulalongkorn University
Bangkok, Thailand
Email: 6338055038@student.chula.ac.th

Gunjeera Chinpeerasatian
Faculty of Psychology
Chulalongkorn University
Bangkok, Thailand
Email: 6338002738@student.chula.ac.th

Graham Pluck
Faculty of Psychology
Chulalongkorn University
Bangkok, Thailand
ORCID: 0000-0002-0368-0051

***Abstract*—The neuroscience of education is an approach to the scholarship of learning and teaching that draws on cognitive and brain sciences. It holds potential for enhancing pedagogical understanding, such as the variation between students in terms of ability. One such example is schizotypy, a personality trait that is linked to neurodevelopmental disorders, cognitive weaknesses, and relatively low academic performance. Schizotypy has been reported to be lower in STEM students compared, to other groups, particularly arts students. But less is known about cognitive ability variations between students in different majors. We compared three groups of university students, studying STEM, arts, or social science. All were evaluated with a self-report measure of schizotypy, and a battery of tests focused on cognitive, social cognition, and motor skill. The results confirmed that the study groups did indeed vary on schizotypy and task performance. Contrary to expectations, STEM students were found to be relatively high on positive aspects of schizotypy, scoring higher on the cognitive-perceptual subscale than non-STEM students, and they also scored below non-STEM students on a perceptual task. We also observed associations between schizotypy and performance measures across the full sample. Specifically, students with more negative schizotypy, scoring relatively high on the interpersonal subscale, had significantly better executive function (switching) and significantly worse manual dexterity. We conclude that schizotypy (as a form of neurodiversity), cognitive ability, and motor dexterity, may be important factors linked to selection of study major among university students, which has implications for their educational achievements.**

Keywords—STEM, educational neuroscience, personality, schizotypy, executive function, cognitive function, motor control, manual dexterity, neurodiversity, pedagogy

I. INTRODUCTION

Educational neuroscience is an approach to pedagogy that draws on academic and clinical knowledge from the cognitive and brain sciences. In this study we used such an approach, addressing the issue of how students studying for STEM or non-STEM degrees differ from each other in terms of basic temperaments and abilities. This could have implications for how to foster better learning, and also early recognition of potential problems.

It is true that various cognitive abilities, and even neurobehavioral traits, such as handedness, do influence some aspects of student achievement, even in higher education [1-3]. And there is in fact a popular approach to understanding such variation in terms of learning styles, which suggests that individual students have individual cognitive styles that mean that they will only learn optimally if taught in a way appropriate to their learning style. Furthermore, students in particular degree programs, such as mathematics, or engineering are argued to have particular patterns of these learning styles [4]. Hence, it has been argued, that educators should adjust their teaching styles to maximize learning by their students, depending on the subject matter of the classes.

The problem is that the established cognitive and neurosciences do not support learning-styles theory [5]. As much research effort has gone into this now debunked approach, there has been a lack of research using established science. This is a pity as evidence suggests that individual variation between students is the most important factor predicting academic achievement.

By analyzing an extremely large corpus of research studies, known as a mega-analysis, it was estimated that only about 20-25% of the variation in grade point average in higher education is due to factors related to the educators (e.g., their teaching methods, knowledge, or experience). A much larger proportion, about 50%, could be attributed to the students' qualities (e.g., their motivation, personality, cognitive skills, or neurobehavioral traits) [6]. Although intelligence or IQ tests have traditionally been used to estimate that student factor, unfortunately, they actually predict little about student achievement in higher education [2]. This is probably because many other factors, such as attitude, motivation, openness to new ideas etc., are more important. In addition, it is likely that although some neurocognitive factors, such as behavioral inhibition are important in general for success in higher education [3], there are also likely specific factors that are associated with academic achievement, dependent on the field being studied [1, 7].

One useful way forward, is to examine traits identified in clinical neurosciences that have been associated with specific careers. These are interesting from an educational perspective because they also have implications for strengths and weaknesses of individuals. One example of this is the autistic spectrum. This was for a long time considered purely in terms of pathology. However, it has been noted that mathematicians and scientists score much higher than the general public on these traits [8]. This suggests that some level of autistic profile is beneficial in technical and analytical fields.

A similar revelation is occurring in how neuroscientists conceptualize Attention Deficit Hyperactivity Disorder (ADHD). For a long time this has been seen as a disorder that

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requires treatment, often with psychopharmacological interventions. While it may be true that many people with ADHD can benefit from medication, this has created the image that ADHD is a pathology. However, a very recent study has shown that the typical rapid attentional shifts shown by people with ADHD have likely evolved in humans precisely because they convey an advantage that helps people to discover new resources [9].

In the current research we have similarly used a concept from clinical neuroscience that may help to understand differences between people, specifically, between STEM and non-STEM students. Schizotypy is a normal personality trait that conveys a risk for development of schizophrenia and related psychotic illness, as well as schizotypal personality disorder [10-11]. Importantly, healthy people who score high on schizotypy show similar (though less impaired) cognitive function profiles to individuals with the clinical disease states [10-12]. From an educational perspective, this is important because students who express high levels of this trait tend to achieve lower grade point average [1, 13].

Of interest is that schizotypy appears to be associated with certain careers. For example, professional comedians tend to score highly on schizotypy questionnaires, compared to others in related professions, such as actors [14]. This suggests that their unusual cognitive style conveys a creative advantage. Indeed this seems to be supported by studies of university students. Engineering students tend to score lower on schizotypy than social sciences students [15]. Arts students appear to score particularly highly on schizotypy [16]. This may be important for understanding achievement of students in higher education, as other research suggests that traits associated with high grade point average vary by discipline [7]. Scores on schizotypy appear to predict performance in social sciences, but not engineering. Scores for general intelligence show the opposite pattern [1].

In the current research we explored how schizotypy may help to understand differences between students studying for STEM or non-STEM degrees. We measured three different aspects of schizotypy as a psychometric construct using a self-report questionnaire (cognitive-perceptual, interpersonal, and disorganized aspects). We included as a sample of STEM students, undergraduates studying on a biotechnology program. As a non-STEM comparison group, because schizotypy has been reported to be particularly associated with arts majors, we included a group of students studying fine arts or design. We also included a group social scientists, studying psychology degrees, as a group that we would anticipate may be half way between the STEM and non-STEM student groups.

As schizotypy has been associated with a particular profile of abnormalities in visual perception, social cognition, executive function, and fine motor control [10-12] we also measured those abilities with performance tasks.

Our three hypotheses were:

i. Students on the different degree programs will vary regarding levels of schizotypy.

ii. The students in the different programs will also differ regarding the performance measures.

iii. The performance measures will be associated with schizotypy over the full sample of students.

II. Methods

A. Reserach Design

A quasi-experimental design was employed using three different groups of university students. These were compared on a self-report measure of schizotypy, and a battery of performance tests measuring cognitive and motor control issues associated with schizotypy. In addition, the associations between schizotypy scores and task performance were estimated in the combined group using correlational methods.

B. Participants

A total sample of 42 student participants were recruited, all were students studying for majors taught in English at Chulalongkorn University, Thailand. A group 15 STEM students was recruited from a biotechnology program, a group of 15 social studies students was recruited from a psychology program, and 12 humanities students were recruited from either a program in fine and applied arts, or design and architecture.

The mean ages of the three groups were: STEM = 21.2 (SD = 0.9), social science = 21.5 (SD = 1.0) and arts = 22.2 (SD = 1.3). The differences in ages were not statistically significant, $F(2,39) = 3.17$, $p = .071$. For gender identification, the STEM group were 3/15 (20%) male, the social science group were 7/15 (47%) male, and the arts group were 5/12 (33%) male. All other participants identified as female. The differences in gender balance between groups was not significant , $X^2 = 2.58$, $p = .275$.

C. Assessment Tools

As all participants were fluent in English and pursuing degree programs taught entirely in English, we used English-language versions of assessment tools. To assess schizotypy as a psychometric construct we used the 32-item Schizotypy Personality Questionnaire -Brief [17]. This provides a total score for schizotypy, as well as three main components of schizotypy: i. cognitive-perceptual problems, ii. interpersonal problems, and iii. disorganization. The first two of these correspond to positive and negative aspects of psychotic disorders, respectively.

To assess fine motor coordination we used the Grooved Pegboard Test [18]. This is an apparatus that contains a metal plate with 25 randomly positioned slots in its surface. There is a well containing 25 metal pegs. The participant's task is to pick up the pegs one by one and fill the slots. The dominant hand (usually the right) is tested first, then the non-dominant hand. The time taken to complete the task is recorded. As such, shorter times indicate better performance. As an overall measure of manual dexterity, we took the sum of both hands performance as the main measure.

To measure executive cognitive function we used the Color Trails Test, which was validated in Thailand [19]. This involves two subtasks, on the first the participant is presented with an A4 page and asked to join a series of numbered circles in sequence. Time to completion is recorded. In the second task, the participant is asked to do the same as before, but this time to alternate joining pink and yellow colored circles. The extra switching between colors introduces an executive control component. As in the previous task, time to completion is recorded. To extract an index of executive control the ratio of performance times on the two tasks is computed [20], such that higher scores indicate better cognitive performance.

To measure visual perceptual skill we used the Size Judgement Task [21]. This involves participants viewing pairs of abstract designs which are of the same form, but one is slightly larger than the other (range of area differences = 12 – 16%). The task is to decide which is the larger of the two. These were shown on a laptop screen in a PowerPoint File.

To measure declarative memory we used the Test of Visual Episodic Incidental Learning [22-23]. This involves presenting the same 27 stimuli as used in the Size Judgment Task (described above). However, in each display one of the original shapes in shown, along with a completely novel shape. The task is decide which one of the pair they recognize. The Size Judgment Task is administered about 40 minutes before the Test of Visual Episodic Incidental Learning, and no warning is given that there will be a later memory test. This memory assessment is designed to be used with high-ability participants, such as university students. Higher scores indicate better declarative memory.

To measure social cognition we used the Reading the Mind in the Eyes Test [24]. This involves theory of mind skill, i.e., the ability to recognize mental states in other people. In each of 36 trials, a black and white photographic image is shown of the eye region of a person's face. On each trial there are four possible choices of the mental state of the person in the photograph. The participant must choose the correct one in each trial. These were displayed in a PowerPoint file on a laptop computer screen. Higher scores indicate better mentalizing ability.

D. Procedure

All participants were recruited using a snowballing method around Chulalongkorn University campus. Once recruited, each participant was interviewed individually in a quiet room. Each participant had the procedure explained to them and provided informed written consent to participate. Background demographic information was recorded first, then the performance tests, starting with the Size Judgement Task, and finishing with the memory test. Next, the Schizotypy Personality Questionnaire-Brief was completed in a Google form. The participant was thanked for participation and debriefed about the research. The whole assessment took approximately one hour per participant. No payment or inducement was given for participation.

E. Statistical Analysis Methods

All score distributions were Winsorized at three standard deviations to prevent extreme scores overly influencing the results. The data distributions were assessed for normality using standard procedures based on skew and kurtosis. Where data distributions were not normally distributed they were Rankit transformed to allow parametric analysis. For between group analyses ANOVA was employed, with the three student groups as the between-subjects factor.

Three planned contrasts were run to compare i. STEM versus arts, ii. STEM versus social sciences, and iii. STEM versus arts and social sciences combined. Contrast analyses were performed two-tailed. Effect sizes for ANOVA are given as eta squared (η^2) and for contrasts as Cohen's *d*. Correlation analysis used Spearman's formula to calculate *r* values, with *p* values calculated two-tailed.

The significance threshold for all tests was .05 and all analyses were performed with SPSS v. 29.

III. Results

TABLE I. COMPARISON OF THE THREE STUDENT GROUPS FOR SCHIZOTYPY, COGNITIVE, AND MOTOR CONTROL ASSESSMENTS SHOWING MEAN SCORES (+ STANDARD DEVIATIONS)

Assessment		Student Group		
		STEM	***Social Science***	***Arts***
Schizotpy	Total score	111.5 (9.8)	100.6 (16.0)	102.9 (13.4)
	Cognitive-perceptual*	53.1 (7.1)	45.2 (9.0)	50.7 (9.0)
	Interpersonal	31.8 (4.3)	27.2 (7.0)	26.8 (8.0)
	Disorganized	26.5 (4.7)	28.2 (6.0)	25.4 (5.0)
Cognitive	Perceptual size judgement*	24.6 (2.5)	26.2 (1.3)	25.8 (1.4)
	Social cognition	21.9 (5.6)	24.1 (3.8)	25.2 (3.2)
	Memory	13.4 (3.4)	13.7 (1.8)	14.2 (2.9)
	Executive skill	0.51 (0.15)	0.57 (0.18)	0.49 (0.15)
Motor	Manual dexterity*	139.2 (18.3)	138.6 (15.7)	120.5 (13.1)

* Indicates a statistically significant between-group difference in scores. For cognitive variables, higher scores indicate better performance. For Schizotypy higher scores indicate greater symptomology, for manual dexterity, higher times indicate slower, less-efficient performance.

A. Between-Group Comparisons

To test the first hypothesis that students on different majors vary on schizotypy, we compared all three groups on the total and subscale schizotypy scores. Mean scores are shown in Table I. The STEM students appeared to score more highly than either the arts of social science students for the total score, but that was not a significant difference ($p = .077$). There was a significant between-groups difference on only one of the measures, the Cognitive-perceptual subscale, $F(2,39) = 3.501$, $p = .040$, $\eta^2 = .152$. Planned contrasts confirmed that the STEM students scored more highly than the other students, $p = .029$, $d = 1.46$, particularly the social science students, $p = .031$, $d = 0.82$. The contrast with arts students was not significant.

To test the second hypothesis that the student groups would differ on the various performance measures we examined scores on the motor coordination and cognitive tests. The means are also summarized in Table I. The three-group ANOVA revealed that there were indeed group differences on two of the tasks. Perceptual size judgment and manual dexterity.

Size judgment scores were higher in the social science group, and lowest in the STEM group, $F(2,39) = 3.703$, $p = .034$, $\eta^2 = .160$, a significant and qualitatively large effect. The contrasts here confirmed that the STEM group scored below the level of the other groups, $p = .022$, $d = 1.64$, which was qualitatively a large difference in performance. The STEM group also scored significantly worse than the social science students, $p = .011$, $d = 0.87$.

Regarding manual dexterity, the arts students appeared to perform much better than the STEM students or the social science students, $F(2,39) = 5.678$, $p = .007$, $\eta^2 = .226$, a significant and qualitatively large effect. The arts students, on average, completed the manual dexterity task about 18 seconds faster than the other student groups.

TABLE II. CORRELATION COEFFICIENT VALUES FOR THE ASSOCATIONS BETWEEN SCHIZOTYPY SUBSCALE SCORES AND COGNITIVE AND MOTOR PERFORMANCE MEASURES

Performance Measure	**Schizotypy Subscale**		
	Cognitive-perceptual	***Interpersonal***	***Disorganized***
Size judgement	-.18	-.08	.09
Social cognition	-.10	.01	-.15
Memory	-.11	.15	.17
Executive skill	-.18	.34*	-.08
Manual dexterity	.07	.31*	.26

*Indicates a statistically significant correlation ($p < .05$, two-tailed)

The contrasts, which are focused on the STEM group, confirmed that the arts students performed significantly better that the STEM students, $p = .004$, $d = 1.147$, a large effect. There were no other differences in task performance between the groups that were statistically significant.

B. Associations Between Schizotypy and Task Performance

In these analyses the three student groups were combined to make a full sample of N = 42 participants, and the strengths and directions or correlation statistics between schizotypy scores and task performance (cognitive and motor) were examined.

These analyses were used to test the third hypothesis, that schizotypy among students is associated with variations in cognitive and motor abilities. The correlation *r* values are shown in Table II. While there was a consistent pattern of poor cognitive performance associated with cognitive-perceptual features of schizotypy, none of the associations were statistically significant. However, for the Interpersonal scale, there were some significant associations. Firstly, students who reported high levels of interpersonal aspects of schizotypy took longer on the manual dexterity task (indicating worse performance), with a large correlation effect. In contrast, there was also an association between that trait and better switching ability on the executive function task, also a qualitatively large effect. Thus, students high on the negative symptoms factor (interpersonal problems) tended to have worse manual dexterity, but better executive switching.

The executive switching index that we used was a ratio of performance on routine and switching trials, a method thought to be the best indicator executive function [20]. Examination of the raw task completion times suggested that the observed correlation is driven by people who scored high on the interpersonal trait performing relatively slowly on the routine trial, but relatively quickly on the switching trial. The association between the executive switching index score and interpersonal schizotypy scores is shown in Fig. 1.

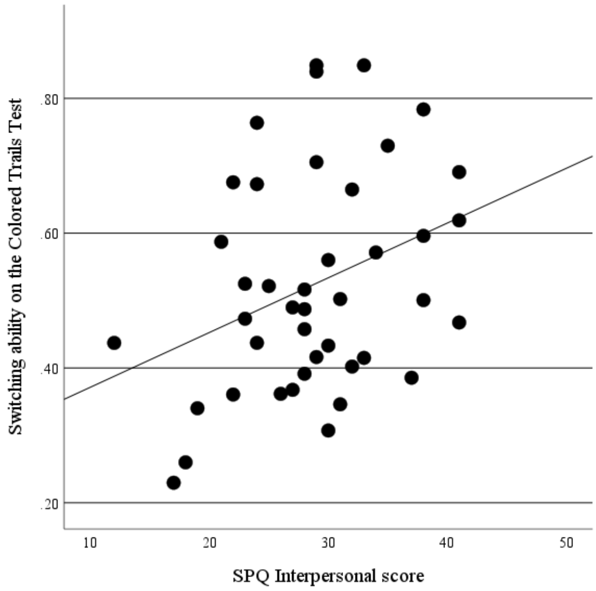

Fig. 1. Scatterplot (with regression line) showing the correlation between Interpersonal factor schizotypy scores and scores on the Color Trails Test

IV. DISCUSSION

The overall aim of this research was to use an educational neuroscience perspective to assess individual differences between STEM and non-STEM university students. In particular, we examined schizotypy, a personality dimension, which although existing on a spectrum in the non-clinical population, does indicate increased risk of major neurodevelopmental disorder, cognitive impairments, and likely also drop-out from educational programs [10-12]. It also predicts relatively low grade point average [1,13]

In addition, we examined, as individual differences between STEM and non-STEM students, cognitive and motor abilities that have previously been noted to be worse in high schizotypy individuals.

The first hypothesis was partially supported. This was that the student groups would vary on levels of schizotypy. However, the result differs from that reported by other researchers. The usual observed pattern is that people working or studying in STEM tend to score below the levels of people working in or studying arts [16]. In our data, we actually found that the STEM group scored more highly on one aspect of schizotypy, when compared to the other students (arts or social science). That association was with the Cognitive-perceptual subscale, which measures aspects of schizotypy that resemble the positive symptoms of schizophrenia. When course types were compared directly, the STEM students scored significantly higher on this trait than the social science students. This contrasts with a previous study that found that social science students scored at an equivalent levels to STEM students on that trait [1]. However, it should be noted that that study compared educational psychologists to engineers. It is quite possible that our samples (psychologists and biotechnologists) are not equivalent.

It should also be noted that the schizotypy difference found in the current students was for the Cognitive-perceptual subscale. This measures positive features of cognitive disorder linked to schizophrenia, such as magical thinking, proneness to sensory distraction, and superstitious or conspiratorial beliefs. Raised levels of this trait have been previously associated with problems with high-level cognitive ability [10-12] and lower grade-point average of university students [1, 13].

Following on from this, our second hypothesis, was also that there would be individual differences between the student groups, this time focused on performance measures. This hypothesis was also confirmed. There were significant differences between the groups on two separate tasks.

One of these was a perceptual task involving judgement of size. The STEM group actually performed substantially less well than the other groups of students. This is consistent with some previous studies that have suggested lower perceptual ability in STEM students. In one study, using the same task as used here, psychology students were found to perform less well than engineering students, although the difference was slight [1]. Furthermore, there is growing evidence that aphantasia, the absence of visual imagery ability is common among scientists [25], suggesting a switch away from visuospatial awareness to more abstract representations for cognitive processing. On the other hand, some STEM groups (i.e., general science or chemistry) have been shown to have better visuospatial skill than students with little scientific training [26]. Also, it should be added that better ability in visuospatial tasks by STEM students is usually associated with higher grade point average [21,27] and in addition, training of visuospatial skills appears to have a causative influencing on improving STEM grades [28]. Thus, evidence of the links between perceptual ability and achievement therefore have real-life implications for education.

We also found a strong link between fine motor control and student group status. The test of manual dexterity used here indicates how well the brain is able to perform complex motor tasks. Nevertheless, as much of the brain is involved with motor control, and movement seems to be coded in almost all neurons [29], impairments of dexterity are indicative of a wide-range of problems, including acquired neurological illness and neurodevelopmental abnormalities. This is why impaired performance on pegboard tests is associated with risk of psychiatric disorders such as schizophrenia [11], and also with sub-clinical schizotypy [12], as investigated in this study. Despite this, we found that our arts student sample performed well above the levels of either our STEM or social sciences samples.

It is unclear why there should be such a sharp difference in manual dexterity between groups of students, based on the topics studied. One could perhaps argue that the arts student sample require motor dexterity to aid artistic and design expression. Perhaps those with good manual dexterity are attracted to arts because they have an affinity for it, or that practice of arts hones manual dexterity. However, one could almost as easily argue that our STEM sample, students of biotechnology, would need to use laboratory tools requiring precision dexterity, such as pipettes. Nevertheless, such between-group differences of dexterity should be taken seriously, as they may have an impact on academic achievement, and even health, due to their association with neurological and psychiatric disorders.

Despite not being able to offer clear explanations why there should be between-group task performance differences, for either perceptual ability or manual dexterity, the point is made that students in different course vary systematically in their neurocognitive abilities.

The third hypothesis tested in this research was also at least partly confirmed: that task performance of university students is linked to schizotypy. Many previous studies have linked the constructs studied here to variation in schizotypy, i.e., higher levels of schizotypy being linked to worse perceptual, social cognition (theory of mind), declarative memory, executive function and motor control [12]. We found that two out of the five skills assessed were linked to schizotypy.

Firstly, we found a large, significant correlation between interpersonal aspects of schizotypy and executive function (see Fig. 1). However, our association is the opposite direction to those usually reported: students with high scores on the negative aspects of schizotypy, as measured by the Interpersonal scale, tended to have better executive function, as indexed by cognitive switching. Although this is contrary to the general reported trend of poor task performance associated with raised schizotypy, it should be noted that not all executive functions show this association, and in fact, schizotypy is sometimes associated with better than normal performance [10, 30]. It may be that the method we used here, is one such example.

Alternatively, the reason for opposite results may lie in the social situation in which research is conducted. The trait in question, interpersonal skill, is seen as a sub-clinical marker of negative symptoms of schizotypy. One particular component of interpersonal of schizotypy is social anxiety. This may be an important factor in determining task performance. Consider the Yerkes-Dodson Law, an aspect of this theory is that skill can be either facilitated or hindered by increased arousal [31]. Given that people who are high on schizotypy traits tend to have high social anxiety, this would usually lead to reduced task ability, due to the high arousal level. However, if arousal were low already, then the extra arousal due to performance in a social situation would bring performance closer to the optimal state.

Although this is merely hypothesized as a mechanism, the Yerkes-Dodson law is well established, and so provides a very plausible explanation for why socially anxious individuals (such as people high on the interpersonal trait of schizotypy) could either show better, or worse performance on cognitive tests, such as our Color Trails Test (which we used). This may be one reason why contradictory results have been reported, such as a negative correlation in some studies [e.g., 30], and a positive correlation in the current study.

Secondly, we found that the same measure of schizotypy, negative features (i.e., Interpersonal scores) were associated with worse manual dexterity. This is more consistent with past research that has reported similar associations. Our findings replicate such past research. This also adds weight to the positive association we described between executive function and schizotypy, as this was evident despite some impairment in more basic task performance.

There are several implications stemming from the overall findings of this study. The most obvious finding is that students vary in their abilities with implications for their academic achievement [21-23]. The current results extend this by showing that variation can vary systematically, such that students studying for particular degrees may tend to have particular patterns of strengths and weaknesses. This is understandable, and relates well to organizational psychology. The person-environment fit approach suggests that people actively seek out careers that fit with their abilities [32]. It seems natural that students with a different skill set would be attracted to studying biotechnology than would be attracted to studying arts. This will also have implications for their educational achievements. It is known that interpersonal-emotional factors, including schizotypy, likely impact performance more in some study majors than others, and likewise high cognitive ability is more important in some than subjects than others [1,7].

On a more general view, the observed differences highlight the fact that strengths and weaknesses are dependent on the environment that they are enacted within. Whereas, high personality factors (such as schizotypy) may convey benefit in some areas of study (e.g., arts) [8], it may be a hinderance in other fields such as STEM or social sciences [1,7].This analysis overall supports the idea that although people vary in their abilities, it is equally important to consider the environment and their goals [33]. It is becoming increasingly common to view such diversity in abilities, linked to cognitive and neurological processes, under the concept of neurodiversity. Indeed, detailed analyses reveal that many cognitive and brain traits that were once considered to be pathological can now be seen as conveying disadvantage, or advantage, dependent on the context [8,9,33]. However, neurodiversity, although well recognized, is generally not handled well with higher education, as the specific requirements of students are often not recognized [34].

The current results partly address this gap in the educational literature, specifically, on how neurocognitive diversity associates with study choices. The results also partly support, in general, the neurodiversity approach to understanding individual differences.

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