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Cognitive dynamics of giftedness: Exploring brain dominance and overexcitability in high-achieving students

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ABSTRACT

This study aimed to examine differences in intellectual, emotional, and imaginative overexcitabilities based on brain dominance. It also explored the potential interaction effects between brain dominance, sex, and academic discipline among gifted university students. A cross-sectional design was used with a sample of 202 academically gifted students selected from a larger group of 1,280 students across public universities. Participants came from various academic fields, including medicine, science, engineering, social sciences, and humanities. Two self-report measures were used to assess overexcitabilities and brain dominance. Findings showed significant sex differences in emotional overexcitability with female students reporting higher levels. Students in engineering and science disciplines showed higher scores in intellectual and emotional overexcitabilities. However, no significant interaction effects were found between brain dominance and either sex or academic major.The study highlights the role of sex and academic field in shaping overexcitability patterns, while brain dominance alone showed limited influence. These results may help guide educational and psychological support strategies for gifted learners.

Contribution/Originality: This study explores the interaction between brain dominance and multiple types of overexcitability in gifted students considering sex and academic discipline. Unlike previous research, it combines cognitive style with emotional and intellectual traits, providing deeper insights into the cognitive and emotional profiles of gifted individuals across diverse educational contexts.

1. INTRODUCTION

Human nature is remarkably complex and shaped by varied experiences and daily interactions (Hebert, 2020). Each new situation and the lessons learnt contribute to the gradual development of mental abilities, emotional depth, and thinking skills. These skills not only improve our understanding of the world but also influence how we plan our lives and set goals for the future (Abdelrheem & Bendania, 2022).

It has been shown that gifted individuals contribute significantly to the development of society (Rinn, 2021). These gifted individuals can be distinguished by a variety of behavioral and cognitive factors. One of these factors is overexcitability, first proposed by Dabrowski in his theory of positive disintegration. In this theory, overexcitability is described as a heightened sensitivity to emotional, intellectual, sensory, imaginative, sensing, and psychomotor levels. Moreover, this sensitivity activates brain regions important for understanding how gifted people use the left and right hemispheres to process information (Al-Hroub & Krayem, 2020; Dai, 2020). Furthermore, many studies on giftedness (Allen Jr, 2020; Pfeiffer, 2021) suggested that a gifted individual's brain is activated in different brain areas (increased overexcitability) when over aroused to different kinds of environmental stimulation as well as their increased cognitive, emotional, sensory and creative abilities (Slade, 2021).

According to Dabrowski (1964), strong reactions improve perception and thought processes (Hill, 2020). This hypothesis states that this process is driven by an underlying psychological conflict that typically operates subconsciously, causing growth in both mental and emotional states (Collins, 2020; Laycraft, 2020). This enhances information processing and stimulates dominant brain regions resulting in reactions that are both innovative and flexible (Hebert, 2020; Rinn, 2021; Wiley, 2020). It appears that the tension caused by this gap is used to reconcile thoughts, emotions, and sensory experiences. By doing so, it helps balance decision-making, personality development, and well-being (Mohamed, Mourad, & Azzadin, 2024).

Dabrowski (1964) identified five types of over-excitabilities such as, intellectual, emotional, imaginative, sensual, and psychomotor. Intellectual overexcitability is a type of overexcitability that specifically concerns intense ways of thinking, learning, and using information (Wood & Laycraft, 2020). On the other hand, emotional overexcitability involves intense emotional experiences that can be shown as a strong desire to help others and a better ability to deal with negative emotions (Romanovicz & Martovska, 2020). Imaginative overexcitability occurs in abstract thinking and the creation of new, creative thoughts or patterns (Martowska, Matczak, & Jozwik, 2020). Finally, psychomotor overexcitability is characterized by excessive physical energy and the need to move to relieve stress (Collins, 2020; Laycraft, 2020; Zytka, 2020). These different types of overexcitability represent a distinctive feature that facilitates integration between ideas and plays an important role in the development of creativity and advanced cognitive functions (Guthrie, 2020). Moreover, they play a protective role in reducing cognitive distortions and preventing mental processing failures (Mohamed Abdelrheem, 2025).

Previous research has shown that the human brain has specific functions (Abdelrheem, 2021,Tarik, 2018) and is divided into two different hemispheres connected by the corpus callosum (Kocevar et al., 2019; Popescu et al., 2019) which helps transfer different types of information from the right to left hemispheres. In 1982, Herrmann proposed brain dominance theory, which states that the brain can be divided into four fundamental sections (Gorovitz, 1982). These sections are presented in the right limbic mode (RLM), left limbic mode (LLM), right cerebral mode (RCM), and left cerebral mode (LCM) (Herrmann, 1991; Schilling, 1999), all of which are in the right and left brain. Research has shown that the right brain correlates with holistic, intuitive, and integrative thinking (De Boer, Bothma, & du Toit, 2011; Herrmann, 1991) that often results in productive outputs, synthesis skills, and systems thinking concepts. However, logical and analytical reasoning are related to the left cerebral hemisphere, which enhances mathematical, computational, and problem-solving skills through a more conventional, fact-based approach (Wilson, 2007). It appears that each hemisphere has unique characteristics. For instance, the left hemisphere is related to linear processing to break information into single units that can be logically arranged in sequence to derive conclusions (Corballis, 2020). In addition, the left hemisphere is linked to symbolic processing, which involves symbol decoding or solving mathematical expressions (Yazgan & Sahin, 2018). In contrast, the right hemisphere is known to be able to perceive analysis with a focus on holistic understanding (Herrmann, 1991). Moreover, the right hemisphere prefers learning tangible-observed elements (Aubry, Gonthier, & Bourdin, 2021; Bahar & Ozturk, 2018).

Prior studies have observed several differences between the right and left brain. The left brain is connected to linear processing, and divides information into segments and connects them logically through a sequence of conclusions (Corballis, 2020). While the right hemisphere is characterized by holistic processing, which processes information as a whole or as one unit (Herrmann, 1991).

The second difference is sequential processing, such as left brain dominance. They keep events and data on neat lists and scrutinize them to reach evidence-based conclusions (Bahar & Ozturk, 2018). In contrast, people with the right brain as the leading hemisphere differ in their processing style by using random processing and constantly jumping from one idea to another based on a strong internal desire to come to a solution, resulting in a non-conventional way of processing information related to a task (Norris, 1985).

The third characteristic is symbolic processing performed by the left hemisphere, which is evident in its ability to decode symbols, such as solving mathematical equations (Yazgan & Sahin, 2018). On the other hand, concrete processing associated with the right hemisphere relies on tangible and observable elements, as individuals with this style prefer to see and learn words rather than just hear them (Aubry et al., 2021; Bahar & Ozturk, 2018).

The fourth characteristic is logical processing, which distinguishes left-brain-dominant individuals. They understand the relationships between different pieces of information before processing them and tend to discard information that cannot be related to other data (Tall, 2019). In contrast, individuals with right-brain dominance prefer intuitive processing, relying on both conscious and subconscious guessing; for instance, knowing the correct answer without understanding the steps that led to it (Tall, 2019).

The fifth characteristic is verbal processing, where individuals with right-brain dominance prefer to express themselves using clear words and phrases (Takeuchi et al., 2018). Meanwhile, those with left-brain dominance favor nonverbal processing using various methods to understand and absorb information (Takeuchi et al., 2018).

The sixth characteristic is reality-based processing, typical of left-brain-dominant individuals who deal with information and objects as they are, adapt to changing variables, and tend to learn and follow established rules (Norris, 1985). In contrast, individuals with right-brain dominance prefer fantasy-oriented processing, relying on imagination and their own rules when processing information and performing tasks.

Considering the characteristics of the two brain hemispheres, there was an overlap between them and patterns of overexcitability. This overlap indicates a relationship between overexcitability and activity in both hemispheres. For example, imaginative and sensual overexcitability are mainly observed in the right hemisphere, whereas the left hemisphere is primarily responsible for emotional overexcitability (Norris, 1985). These interactions highlight the role of each hemisphere and the dominance of one over the other, depending on the nature of the stimuli, which supports Jackson's concept of the leader hemisphere. This idea is further supported by the fact that right-handed individuals typically exhibit left-hemisphere dominance and vice versa. Torrance explains that brain dominance reflects an individual's preference to rely on one hemisphere over the other for cognitive and information processing. Despite the evidence that both intellectual and emotional overexcitabilities boost brain activity, no study has directly examined their association with brain dominance. This gap was the focus of this study.

This study aimed to investigate the relationship between brain dominance and overexcitability in academically gifted students. It seeks to determine how different patterns of brain dominance relate to various forms of overexcitability, specifically intellectual and emotional overexcitability. The study also examined gender differences in overexcitability among gifted students, which may inform tailored educational strategies. Additionally, it explores how academic majors interact with brain dominance and sex to influence overexcitability patterns. Ultimately, these findings may help educators to design programs and interventions that support the positive development of overexcitability in gifted students.

2. METHOD AND PROCEDURES

Participants: This study complied with the American Psychological Association (APA) ethical guidelines for studying human beings. To guarantee that the participants were completely aware of the purpose of the study and their rights as volunteers, they gave their informed consent before beginning the study. Data were collected from 202 academically gifted students (including 104 female students), selected based on their academic performance, with cumulative grades ranging from 90% to 98.6%, representing the top 15.6% of the study population. Participants came from six public Saudi universities, with an average of 22.4 years (SD = 1.6). The participants were recruited during the winter semester of 2022–2023.

Research Method: This study employed a cross-sectional research approach, which collected data from participants at a certain time. Using Dabrowski's theory of positive disintegration and brain dominance, this design was chosen to examine variations in intellectual, emotional, and imaginative overexcitabilities among college students who are excellent academically.

2.1. Instruments

Overexcitability Scale: The second version of the Emotional and Intellectual Overexcitability Scale developed by Falk, Lind, Miller, Piechowski, and Silverman (1999) was used in this study after an Arabic back-translation process. Originally, this scale focused on five types of overexcitability: intellectual, emotional, imaginative, sensual, and psychomotor overexcitability. For the current study, the scale was modified to focus on three types, i.e., intellectual, emotional, and imaginative overexcitability. The final version of the scale contained 30 items rated on a five-point Likert scale. Psychometric properties were evaluated using Cronbach's alpha and split-half reliability coefficients, which were 0.864 and 0.804 for intellectual, 0.710 and 0.775 for emotional, and 0.842 and 0.882 for imaginative overexcitability, respectively, indicating acceptable reliability. Principal component analysis revealed three factors that explained 54.28% of the total variance. Specifically, 10 items loaded on the intellectual factor, 10 on the imaginative factor, and 9 on the emotional factor; one item (item 13) did not load on any factor and was, therefore, excluded. This resulted in a final scale of 29 items that measured overexcitability across the three dimensions. A confirmatory factor analysis (CFA) was conducted to validate the proposed three-factor scale structure. The goodness-of-fit indices indicated acceptable model fit: $\chi^2 = 104.762$, $p < 0.001$; CMIN/DF = 1.656, NFI = 0.904, CFI = 0.916, IFI = 0.824, and RMSEA = 0.05. These findings highlight the psychometric validity of the Arabic version of the overexcitability scale. The results supported a three-factor structure, with 10 items for intellectual, 10 for imagination, and 9 for emotional overexcitability.

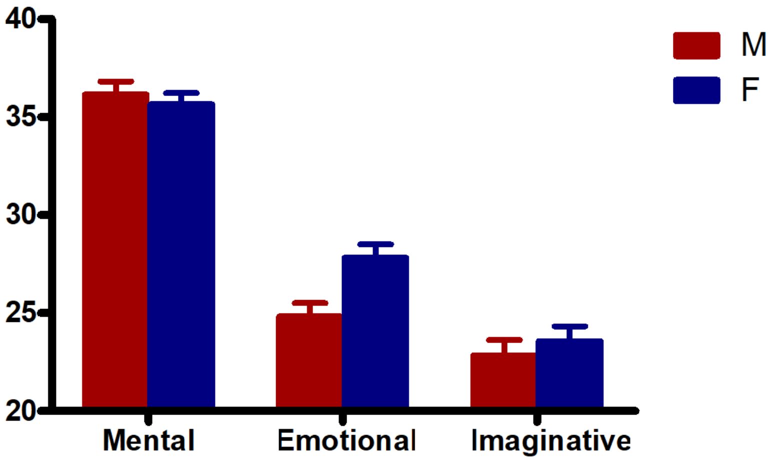
Brain Dominance Scale: MacCrone (2010) developed a modern scale to measure brain dominance based on neuroimaging studies that examine differences in brain activity across regions. Although this instrument has been infrequently used in the Arab context, it offers valuable insights into brain function. The scale consists of 16 items, each of which provides two options for the respondents to choose. The overall score determined the pattern of brain dominance (right, left, or integrated). The reliability of the scale was assessed using the Kuder-Richardson formula, yielding coefficients of 0.86 for the right hemisphere and 0.84 for the left hemisphere. In addition, the validity was evaluated using the point biserial correlation coefficient by comparing the McCrone Brain Dominance Scale with the Torrance Brain Dominance Scale, with correlation coefficients ranging from 0.63 to 0.88, all significant at the 0.01 level.

3. RESULTS

To test the first hypothesis which states that "there are significant differences in the mean scores of overexcitability among academically gifted students based on gender (male versus female)." To test this hypothesis, an independent samples t-test was used to compare overexcitability patterns between male and female students. The results show differences between male and female students in emotional overexcitability $t(200) = 3.116$, with academically gifted female students scoring higher than their male counterparts (Mdiff = -3.01). The average score for female students was 27.83 compared to 24.82 for male students, indicating that overexcitability varies by gender. However, no significant sex differences were found in intellectual or imaginative overexcitability as shown in Table 1 and Figure 1.

Table 1. T-test results examining differences in overexcitability between academically gifted male and female students.

Variables	Sex	Mean	SD	T-test	Significant
MOs	M	36.163	6.6499	0.581	0.562
	F	35.654	5.7938		
EOs	M	24.827	6.7869	-3.116	0.002
	F	27.837	6.9298		
IOs	M	22.847	7.8417	-0.681	0.497
	F	23.587	7.6038		



Figures 1. Differences between males and females in overexcitabilities.

To test the second hypothesis, there are differences in the mean scores of overexcitability among academically gifted students based on brain dominance—a one-way ANOVA was performed on the three overexcitability types among students with right, left, and integrated brain dominance. The results indicated no significant differences in emotional, intellectual, or imaginative overexcitability based on brain dominance (see Table 2).

Table 2. One-way ANOVA results for the overexcitability scores of academically gifted students, which is attributed to the brain dominance factor.

Variables	Groups	Sum of sq	Mean sq	F-test	Significant
MOs	Between	125.660	62.830	1.638	0.197
	Within	7634.360	38.364		
EOs	Between	133.848	66.924	1.368	0.257
	Within	9737.558	48.932		
IOs	Between	46.045	23.023	0.385	0.681
	Within	11901.479	59.806		

To evaluate the third hypothesis, which asserts that there are differences in mean overexcitability scores among academically gifted students based on academic major (Medical, Engineering & Science, and Humanities & Social Sciences), a one-way ANOVA was performed on the three overexcitability types among students from these fields. The results showed that there were no differences between the different types of over-excitabilities, as shown in Table 3.

Table 3. The one-way ANOVA results for the overexcitability scores of academically gifted students are attributed to the academic major factor.

Variables	Groups	Sum of sq	Mean sq	F-test	Significant
MOs	Between	56.447	28.223	0.729	0.484
	Within	7703.573	38.711		
EOs	Between	48.842	24.421	0.495	0.610
	Within	9822.564	49.360		
IOs	Between	7.313	23.656	0.061	0.941
	Within	11940.212	60.001		

To test the fourth hypothesis—which states that "there is a statistically significant effect of brain dominance patterns (right or left or both), academic specialization, or their interaction on the overexcitability patterns of academically gifted students"—the study sample was divided into three groups: students with right-brain control (n = 68) and those with left-brain control (n = 89), and those with both (n= 45) across the three academic disciplines (Medical, Engineering & Science, and Humanities & Social Sciences). A multivariate linear test was conducted after confirming that the assumptions were met and that they were appropriate for the study sample.

The results revealed that the main effect of brain dominance patterns was not statistically significant, F (6, 384) = 0.822, p = 0.553, indicating that there was no significant difference in overexcitability scores between students with different types of brain dominance (see Figure 2). Similarly, the results revealed that the main effect of academic majors was not statistically significant, F (6, 384) = 0.237, p = 0.950 indicating that there was no significant difference in the overexcitability scores between students with different majors. Furthermore, the results revealed that the interactions between major and brain dominance were not significant, F (12, 579) = 0.934, p = 0.518 (see Figure 2).

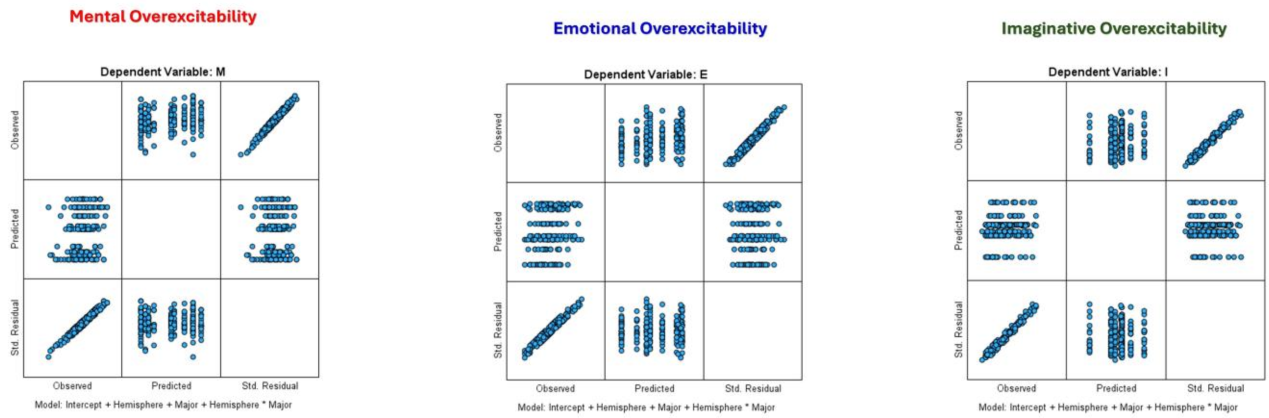


Figure 2. Multivariate analysis for overexcitability (mental, emotional, and imaginative) across different majors.

To test the fifth hypothesis, brain dominance patterns (three levels) and gender, or their interaction have a statistically significant effect on the overexcitability patterns of academically gifted students, a general linear model was constructed using a 2×2 factorial design. In this model, brain dominance (BD) with three levels and sex (coded as 0 = male and 1 = female) were used as between-subjects factors, and three dependent variables (mental, emotional, and imaginative overexcitability) were analyzed. Prior to the analysis, assumptions of normality and homogeneity of variance were verified.

The main effect of brain dominance [BD] was not significant for mental (intellectual) overexcitability (F (2, 196) = 1.94, p =0.147, partial η^2 =0.019). Similarly, the main effect of sex (F (1, 196) = 0.06, p =0.804) and the interaction between BD and sex (F (2, 196) = 1.31, p =0.274) were not significant (see figure 3a).

For the emotional overexcitability measure, although the main effect of BD did not reach significance (F (2, 196) = 0.81, p =0.448), a significant main effect of sex was found (F (1, 196) = 7.74, p =0.006, partial η^2 =0.038). No significant interaction was observed between BD and sex (F (2, 196) = 2.16, p =0.118). In addition, post hoc pairwise comparisons (Wwith Bonferroni adjustment) within the male subgroup revealed a significant difference between BD groups 1 and 2 (mean difference = -2.82, p = 0.006), suggesting that emotional overexcitability varied by BD among male students (see Figure 3b).

There were no significant effects for the imaginative overexcitability measure: the main effect of BD, *F* (2, 196) = 0.23, *p* = 0.797; the main effect of sex, *F* (1, 196) = 0.07, p = 0.798 and their interaction, F (2, 196) = 0.90, p = 0.407.

Overall, these findings indicate that sex significantly influenced emotional overexcitability whereas neither mental nor imaginative overexcitability showed significant effects related to brain dominance or sex and no significant interactions were found between the two factors (figure 3c). Post-hoc analyses using Scheffé's test did not reveal any further significant pairwise differences among the BD groups, except for the difference in emotional overexcitability observed among male students (see Figure 3).

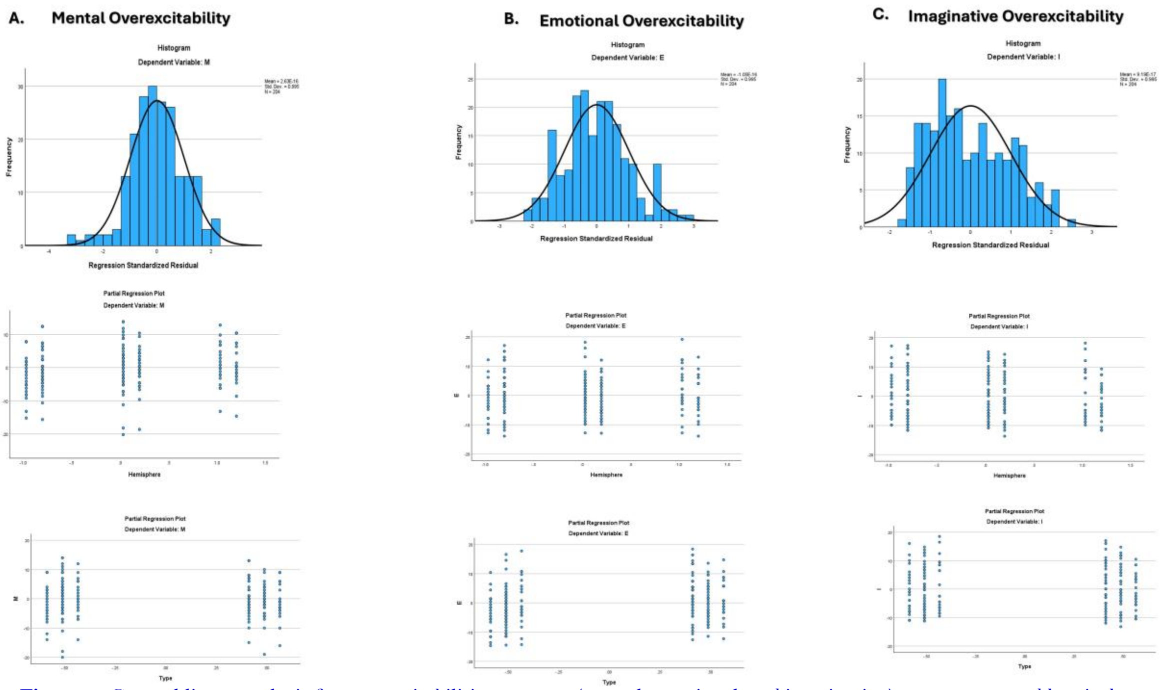


Figure 3. General linear analysis for overexcitabilities patterns (mental, emotional, and imaginative) across sexes and hemispheres.

4. DISCUSSION

The current study examined key indicators of academically gifted students by investigating the relationship between brain dominance and three patterns of overexcitability. The study was conducted among Saudi university students from six governmental universities representing various majors (medical, engineering and science, and humanities and social sciences). A total of 202 academically gifted students were selected from a pool of 1,280 students based on their academic achievement levels, with cumulative grades ranging from 90% to 98.6%, representing the top 15.6% of the study population. Several research hypotheses were tested using appropriate statistical methods.

The first hypothesis revealed differences in emotional overexcitability between gifted male and female students, with female students exhibiting higher levels of emotional overexcitability (see Table 1). This finding can be explained by the Saudi cultural environment and its longstanding traditions, which require adherence to specific social norms regarding emotional expression. Although recent initiatives under Saudi Arabia's Vision 2030 have empowered women, some constraints still limit their emotional expression. Consequently, these students tend to channel or transfer their emotions in ways that align with their societal expectations. In contrast, no significant differences in intellectual (mental) or imaginative overexcitability were found between male and female students. This may be because these forms of overexcitability, which are part of cognitive processing and creative imagination, operate independently of cultural-, ethical-, and value-based conflicts. These findings align with those of Wood and Laycraft (2020) who concluded that highly profoundly gifted children display heightened sensitivity, intensity, awareness, and advanced cognitive development compared with their age-matched peers. Additionally, the characteristics and behaviors of gifted children closely align with a combination of multiple and higher-level overexcitabilities, which differ from individual overexcitabilities.

The second hypothesis examined the differences in overexcitability patterns based on brain dominance (right, left, or both). The findings revealed no significant differences among individuals with right, left, or integrated brain dominance in any of the measures of overexcitability (see Table 2). This may be related to the functional characteristics of the brain hemisphere. The left hemisphere typically processes information linearly, sequentially, symbolically, logically, nonverbally, or realistically whereas the right hemisphere is associated with holistic, random, focused, intuitive, verbal, and imaginative processing. Since overexcitability appears to be driven by internal conflicts that stimulate both hemispheres in parallel, neither hemisphere plays a dominant role in producing differences in intellectual, emotional, or imaginative overexcitability. These findings contradict those of Chang and Kuo (2013) who identified distinct brain regions associated with different forms of overexcitability, such as linking emotional overexcitability with the posterior parietal gyrus (BA2), sensory overexcitability with the left superior temporal gyrus, intellectual overexcitability with the left inferior parietal lobule (BA40), and imaginative overexcitability with the right parietal lobe. It is important to note that Chang and Kuo (2013) used functional magnetic resonance imaging (fMRI) to examine blood oxygenation levels in response to overexcitability, which differs from the traditional assessment of brain dominance used in the current study.

The third hypothesis revealed that there were no statistically significant variations in overexcitability scores across different academic majors (see Table 3). This suggests that a student's chosen field of study does not influence their levels of overexcitability. The lack of variation implies that overexcitability could be an inherent characteristic of gifted individuals, independent of their academic discipline. As noted by Alias, Rahman, Abd Majid, and Yassin (2013) , overexcitability levels remain consistent across various fields, programs designed to identify and support gifted students should focus on these fundamental traits rather than tailoring interventions to specific disciplines. This underscores the importance of a holistic approach to understanding and nurturing gifted individuals. Although academic majors did not account for differences in overexcitability scores, other factors such as cultural background, teaching methods, and personal characteristics might play a more significant role.

The fourth hypothesis showed that neither brain dominance nor academic specialization significantly influenced the overexcitability scores of academically gifted students. This suggests that whether an individual is in the right or left hemisphere or utilizes both brain hemispheres, along with their academic field, does not impact their level of overexcitability. These findings imply that overexcitability is an inherent characteristic of giftedness that remains constant irrespective of the type of brain dominance or academic discipline. Additionally, the absence of significant interaction effects indicates that the influence of academic specialization on overexcitability is not affected by brain dominance type.

The fifth hypothesis explored how brain dominance and sex influence three types of overexcitability—mental, emotional, and imaginative using factorial design. For the mental (intellectual) overexcitability measure, neither brain dominance ($F\ (2,\ 196) = 1.94$, $p = 0.147$, partial $\eta^2 = 0.019$) nor sex ($F\ (1,\ 196) = 0.06$, $p = 0.804$) nor their interaction, $F\ (2,\ 196) = 1.31$, $p = 0.274$) had a significant impact. This suggests that intellectual overexcitability in gifted students does not vary based on either brain dominance patterns or sex, indicating that intellectual overexcitability is a stable characteristic of giftedness.

In contrast, the analysis revealed a significant main effect of sex on emotional overexcitability, $F\ (1,\ 196) = 7.74$, $p = 0.006$, partial $\eta^2 = 0.038$), indicating that male and female students differed in their emotional responses. However, brain dominance did not have a significant main effect on emotional overexcitability, and no significant interaction was found between brain dominance and sex ($F\ (2,\ 196) = 2.16$, $p = 0.118$). Notably, post-hoc comparisons within the male subgroup showed a significant difference between the two brain dominance groups, suggesting that among male students, emotional overexcitability may vary by brain dominance.

For the imaginative overexcitability measure, no significant effects were found for brain dominance ($F(2,\ 196) = 0.23$, $p = 0.797$), sex ($F(1,\ 196) = 0.07$, $p = 0.798$), or their interaction ($F(2,\ 196) = 0.90$, $p = 0.407$), indicating that imaginative overexcitability is a stable trait across both sexes and different brain dominance patterns.

Overall, these findings suggest that while sex significantly influences emotional overexcitability, it does not appear to affect mental or imaginative overexcitability. Moreover, the impact of brain dominance on overexcitability was minimal, with a noticeable effect only on the emotional aspect among female students. These findings highlight the necessity of considering sex when evaluating emotional reactions in gifted students and suggest that additional research should investigate other elements that might influence mental and imaginative overexcitability.

In summary, overexcitability appears to be a fundamental characteristic of academically gifted students unaffected by their majors or brain dominance. Emotional overexcitability differs by sex, with female students generally exhibiting higher levels and some variations among males depending on brain dominance. Conversely, intellectual and imaginative overexcitability remains consistent across sexes and brain dominance types. These results suggest that support and intervention programs for gifted students should address their overall overexcitability traits rather than focus on specific academic disciplines or brain profiles.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Data Availability Statement: The supporting data for this study will be made available upon reasonable request.
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