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Beyond Legality: Students' Moral Attitudes Toward Non-invasive Brain Stimulation for Cognitive Enhancement

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Abstract Cognitive enhancement involves using substances or technologies to improve mental performance in healthy individuals. While methods such as caffeine are widely accepted, others, including prescription stimulants and non-invasive brain stimulation (tDCS), evoke ethical concern. This study examined how university students evaluate three forms of cognitive enhancement (natural, pharmacological, brain stimulation) across five moral domains: academic fairness, free will, authenticity/naturalness, self-identity, and safety. We also tested how evaluations were shaped by framing (preservation vs. enhancement) and priming (self-affecting vs. non self-affecting). A total of 449 undergraduate psychology students (81.7% female)

from a single UK university were recruited via convenience sampling and completed an online experiment with a $2 \times 2 \times 3$ mixed design, rating enhancement acceptability after reading intervention-specific scenarios. Natural enhancers were judged most positively, followed by brain stimulation and then pharmacological agents. Safety concerns also differed across enhancement types, with pharmacological enhancement viewed as posing the greatest risk, followed by brain stimulation, while natural enhancement was perceived as the safest option. Importantly, although brain stimulation is legal and marketed as non-invasive, it was evaluated more like pharmacological enhancement than natural methods, indicating that legality alone does not determine moral acceptance. Framing effects showed that participants were more accepting of enhancement when it was described as preserving ability rather than augmenting it beyond baseline. Priming participants to consider how others' use might affect their own outcomes reduced moral acceptability, particularly for pharmacological and brain stimulation methods in the domain of academic fairness. Overall, students' attitudes were shaped by both perceived safety and broader moral concerns relating to fairness, authenticity, and competition. These findings highlight the importance of adopting pluralistic, context-sensitive approaches to policy and regulation that extend beyond considerations of legality alone.

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Introduction

Cognitive enhancement is the use of techniques or substances to improve cognitive performance in healthy individuals and has become a key focus in debates across neuroscience, bioethics, and education. With growing availability of both pharmacological and non-pharmacological tools aimed at improving cognitive abilities such as memory, attention, and executive functioning, individuals are increasingly presented with the option to modify cognition, not just in a clinical context, but in everyday life. These tools range from commonplace and widely accepted substances such as caffeine, to prescription-only pharmaceuticals like modafinil and methylphenidate (Ritalin), to newer, non-invasive brain stimulation technologies such as transcranial direct current stimulation (tDCS). While these methods vary in mechanism, accessibility, and risk, they all raise normative questions about what kinds of enhancement are acceptable, and under what conditions.

University students form a particularly relevant population for studying cognitive enhancement. As a group under consistent academic pressure and performance scrutiny, students may be both consumers of enhancement technologies and critical evaluators of their legitimacy. Existing data suggest increasing interest in the use of prescription stimulants such as modafinil among UK students without medical need (e.g., [1]). Yet despite rising use, student attitudes toward enhancement are complex and context-sensitive. While some enhancers are viewed as harmless or even necessary for coping with academic life [2], others are seen as morally questionable, potentially unfair, or indicative of an unhealthy culture of over-performance [3].

A growing body of literature has examined the factors that shape public judgments of cognitive enhancement. A key finding is that attitudes are not driven solely by considerations of efficacy or legality, but are influenced by underlying moral intuitions, particularly those related to fairness and authenticity [4–6]. For example, people are generally more accepting of enhancement when it is used to restore or preserve abilities, and more sceptical when it is used to push cognitive performance beyond the perceived baseline [7, 8]. This distinction between treatment and enhancement plays a powerful role in shaping moral reasoning, although the boundary between

treatment and enhancement is far from distinct [7]. It becomes even more opaque when considering temporary impairments commonly experienced by students and workers, such as stress or tiredness.

In addition to concerns about fairness and authenticity, cognitive enhancement also raises questions of identity. Scholars have argued that altering cognitive capacities can be seen as altering the self, threatening continuity of personal identity or undermining the authenticity of one's achievements [9, 10]. Relatedly, safety concerns often shape public debates, not only in terms of objective health risks but also in terms of perceived legitimacy: interventions judged unsafe are more easily construed as morally problematic [11]. Although caffeine is widely used despite recognised risks [12], newer technologies such as brain stimulation provoke unease precisely because their safety is relatively unknown amongst the general population [13]. Together, these themes suggest that judgments about enhancement reflect not just efficacy or legality, but also deeper intuitions about what it means to act authentically, preserve identity, and protect oneself and others from harm.

Social context also matters. Dinh et al. [14] demonstrate that attitudes toward pharmacological enhancement shift depending on who is using it and under what conditions. People tend to be more permissive when enhancement is used by themselves or by peers in low-stakes situations, but become more critical when it is used by others in competitive contexts. In such cases, the moral concern is less about the intrinsic nature of the enhancer and whether it is authentic/natural, legal, or medically safe and more about its perceived impact on fairness and merit. Specifically, enhancement is seen as ethically problematic when it is believed to give others an unfair advantage, disrupt equal opportunity, or undermine the legitimacy of performance outcomes. This suggests that moral evaluations are not only about the enhancer itself, but also about who benefits from it, and in what social context. This aligns with research suggesting that cognitive enhancement is evaluated through a relational lens, where judgments are sensitive to power dynamics, competitive settings, and concerns over social disruption [15, 16].

The type of enhancement method also plays a role in shaping attitudes. While natural substances like caffeine are broadly accepted [2], pharmacological agents such as modafinil and methylphenidate are often met with ethical concern, particularly when

used *illegally* without prescription [17]. Meanwhile, brain stimulation techniques like tDCS are legal and marketed as non-invasive, yet remain unfamiliar to many and may evoke ambivalence or unease. However, research comparing ethical judgements of brain stimulation for cognitive enhancement with pharmacological or natural methods remains unexplored. Veit et al. [18] argue the importance of recognising the diversity of cognitive enhancement methods in relation to ethical concerns. Rather than adopting one-size-fits-all ethical frameworks, researchers and policymakers must consider how different tools interact with different values, contexts, and user intentions. Ethical analysis must move beyond blanket judgments and instead adopt a pluralistic, context-aware perspective.

The present study responds to this call by exploring how university students evaluate three forms of cognitive enhancement—natural substances (e.g., caffeine), pharmacological agents (e.g., modafinil, methylphenidate), and brain stimulation (e.g., tDCS)—across five moral domains: academic fairness, free will, self-identity, authenticity/naturalness, and safety. In addition to comparing these methods, we test how attitudes shift depending on framing (preservation vs. enhancement) and priming (self-affecting vs. non self-affecting scenarios). By incorporating these contextual dimensions, we aim to provide a more fine-grained understanding of how moral intuitions shape judgments about enhancement in real-world academic environments.

Method

Participants

Participants were recruited through convenience sampling from the undergraduate psychology participant pool at a single UK university (The University of Kent). Eligible participants were required to be enrolled psychology students with fluent English comprehension. To ensure data quality, individuals who failed one or more attention checks or failed to complete the study were removed. This resulted in the removal of 81 participants who failed to complete the entire questionnaire. None of the participants failed the attention check. The final sample comprised 449 participants, which exceeded the minimum sample size ($N=240$)

required to detect a small effect ($f=0.10$) with 90% power at $\alpha=0.05$, as determined using G*Power [19].

Design and Measures

This study employed a 2 (priming condition: self-affecting vs. non self-affecting) $\times$ 2 (framing: preservation vs. enhancement) $\times$ 3 (intervention type: pharmacological, brain stimulation, natural) mixed-factorial design. Priming condition and framing were between-subject variables, while intervention type was a within-subject variable. The primary dependent variable was attitude toward cognitive enhancement, operationalised through theme-specific mean scores across five moral domains: fairness in academia, autonomy and free will, self-identity, safety, and authenticity/naturalness.

Attitudes were measured using 20 items adapted from the Attitudes Toward Pharmacological Cognitive Enhancement Scale [20], which has previously demonstrated high internal consistency ($\alpha=0.80$). Each item was rated on a 7-point Likert scale ranging from -3 (“Strongly disagree”) to $+3$ (“Strongly agree”), with 0 indicating neutrality. Items were reverse-coded where necessary to ensure consistency in directionality, with higher scores indicating greater acceptability of enhancement.

Within the present study, the composite scales demonstrated acceptable internal consistency. Cronbach’s alpha ranged from 0.71 to 0.77 for the Academic Merit, Self-Identity, Free Will, and Safety domains across enhancement types. Reliability for the Naturalness domain was somewhat lower ($\alpha=0.63\text{--}0.71$), although still within an acceptable range for short item scales.

One item was excluded from the naturalness scale because it reduced the scale’s internal consistency. Results were substantively unchanged when the item was retained.

Procedure

Participants completed the study online via Qualtrics. After reading an information sheet and providing informed consent, participants generated an anonymous code to protect identity and enable withdrawal if requested. They first completed demographic questions and a brief set of items measuring prior awareness and use of cognitive enhancement techniques (see Supplementary 1).

Participants were then randomly assigned to one of two priming conditions (see Supplementary 1). In the self-affecting condition, the scenario stated that other students' grades could impact the participant's own academic outcomes. In the non self-affecting condition, the scenario suggested that others' performance had no impact on the participant's own results. Both primes were followed by a 15-s countdown and two attention check items.

Following priming, participants were randomly assigned to one of two framing conditions (see Supplementary 1), which described each intervention (natural enhancers, brain stimulation, and pharmaceuticals) as either "preserving" cognitive ability or "enhancing" it. Participants read three scenarios (one per intervention type) presented in randomised order. Each scenario was followed by 20 questions (four per theme), completed on the same Likert scale. The full survey took approximately 25 min to complete. Upon completion, participants were debriefed and awarded course credit as part of their undergraduate degree programme.

Ethical Considerations

This study was reviewed and approved by the University of Kent Research Ethics Committee [Ref: 202417314953719401]. All procedures conformed to the British Psychological Society's Code of Ethics and Conduct. Participants were fully informed of their rights and could withdraw at any point. No deception was involved, and although the study posed no physical risks, some items referred to potentially sensitive topics such as the use of controlled substances or perceived academic pressure. To minimise discomfort, responses were anonymous and non-identifiable, and contact details for the research team and ethics committee were provided in case of concerns. All data were stored securely on password-protected university servers, with access restricted to the research team. In accordance with the General Data Protection Regulation (GDPR), only minimal personally identifiable information was collected.

Statistical Analysis

Data were analysed using JASP (Version 0.19.3) [21]. For each of the five moral themes, a 2 (Priming) $\times$ 2 (Framing) $\times$ 3 (Enhancement Type) mixed repeated

measures ANOVA was conducted to assess main effects and interactions. To determine whether brain stimulation was perceived as more similar to natural or pharmacological enhancement, absolute difference scores were calculated between attitudes towards brain stimulation and each of the other enhancement types. These difference scores were then compared using paired-samples *t*-tests. When appropriate, post hoc pairwise comparisons with Holm-Bonferroni correction were used to examine differences between enhancement types. Greenhouse–Geisser corrections were made when assumptions of sphericity were violated.

Results

Demographics

The final sample consisted of 449 participants. After exclusions, the groups were slightly imbalanced: Self-affecting/Preservation ($N=106$), Self-affecting/Enhancement ($N=107$), Non self-affecting/Preservation ($N=119$), and Non self-affecting/Enhancement ($N=117$). The average age was 19.90 years ($SD=3.85$; range=18–54 years). The majority identified as female (81.7%), with 15.6% identifying as male, 2.2% as third gender or non-binary, and 0.4% preferring not to disclose. In terms of ethnicity, 64.0% identified as White, 15.1% as Black/African/Caribbean/Black British, 12.1% as Asian/Asian British, 4.0% as Mixed or multiple ethnic groups, and 3.3% as Other, while 1.1% preferred not to say.

92% of participants were aware of natural cognitive enhancers, 83.3% were aware of pharmacological cognitive enhancers, and 39.0% were aware of brain stimulation as a cognitive enhancement tool. Ten participants decided not to disclose their use of cognitive enhancers. Of the remainder ($N=439$), 298 (67.88%) reported using natural substances, 28 (6.38%) reported using brain stimulation, and 40 (9.11%) reported using illegal pharmacological methods to enhance cognitive functioning.

All mean attitude scores for each cognitive enhancement method across each moral theme are presented in Table 1.

Academic Fairness

The main effects of Enhancement Type, $F(1.74, 773.71)=463.61$, $p<0.001$, $\eta_p^2=0.51$, Framing,

Table 1 Attitudes towards natural, brain stimulation, and pharmacological enhancers across the moral themes of academic fairness, free will, authenticity/naturalness, self-identity, and safety

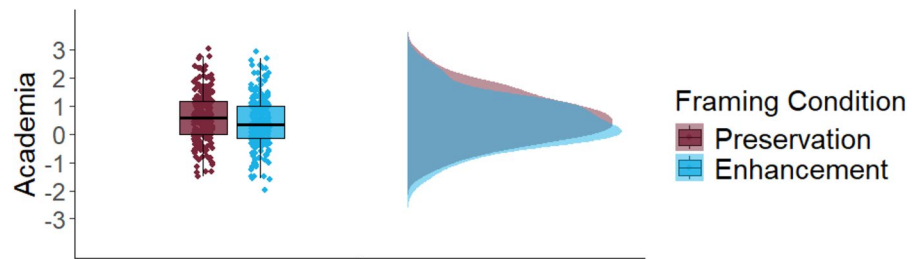
	Natural Mean (SD)	Brain Stimulation Mean (SD)	Pharmacological Mean (SD)
Academia			
<i>Self-affecting</i>			
Preservation	1.54 (1.12)	0.11 (1.08)	−0.13 (1.16)
Enhancement	1.44 (1.10)	−0.11 (1.25)	−0.47 (1.18)
<i>Non self-affecting</i>			
Preservation	1.57 (1.04)	0.28 (1.13)	0.12 (1.22)
Enhancement	1.44 (1.02)	0.22 (1.10)	−0.06 (1.15)
Free will			
<i>Self-affecting</i>			
Preservation	1.36 (0.96)	0.62 (0.95)	0.44 (1.12)
Enhancement	0.95 (0.94)	0.41 (1.00)	0.19 (1.01)
<i>Non self-affecting</i>			
Preservation	1.02 (1.12)	0.52 (1.15)	0.33 (1.18)
Enhancement	1.13 (1.09)	0.67 (1.11)	0.39 (1.16)
Authenticity/Naturalness			
<i>Self-affecting</i>			
Preservation	0.93 (0.93)	0.14 (0.90)	0.01 (0.90)
Enhancement	0.81 (0.96)	−0.10 (0.91)	−0.22 (0.86)
<i>Non self-affecting</i>			
Preservation	0.84 (0.88)	0.06 (0.92)	−0.05 (0.96)
Enhancement	0.87 (0.99)	0.10 (0.98)	−0.11 (0.97)
Self-Identity			
<i>Self-affecting</i>			
Preservation	1.51 (1.03)	0.74 (1.00)	0.38 (1.09)
Enhancement	1.40 (1.09)	0.53 (1.02)	0.23 (1.02)
<i>Non self-affecting</i>			
Preservation	1.47 (1.00)	0.70 (1.13)	0.44 (1.13)
Enhancement	1.47 (1.02)	0.73 (1.09)	0.40 (1.07)
Safety			
<i>Self-affecting</i>			
Preservation	−0.54 (1.28)	0.39 (1.06)	0.92 (0.96)
Enhancement	−0.54 (1.06)	0.32 (1.05)	0.88 (0.87)
<i>Non self-affecting</i>			
Preservation	−0.68 (1.08)	0.09 (1.10)	0.78 (0.95)
Enhancement	−0.53 (1.22)	0.34 (1.07)	0.98 (0.92)

All themes were scored from −3 (negative) to +3 (positive)

$F(1, 445)=4.29$, $p=0.04$ (see Fig. 1), $\eta_p^2=0.01$, and Priming, $F(1, 445)=5.71$, $p=0.02$, $\eta_p^2=0.01$, were significant. A post hoc pairwise comparison using Holm correction showed that natural methods were rated significantly higher than brain stimulation, $t(445)=23.81$, $p<0.001$, $d=1.21$ and pharmacological agents, $t(445)=28.34$, $p<0.001$, $d=1.45$. Brain Stimulation was rated significantly higher than pharmacological agents, $t(445)=4.53$, $p<0.001$, $d=0.23$.

To determine whether brain stimulation was perceived as more similar to natural or pharmacological enhancement, absolute difference scores were compared using a paired-samples t -test. The absolute difference between brain stimulation and pharmacological enhancement ($M=0.70$, $SD=0.73$) was significantly smaller than the absolute difference between brain stimulation and natural enhancement ($M=1.47$, $SD=1.12$), $t(448)=12.19$,

Fig. 1 Academic fairness attitudes towards cognitive enhancers were more positive in the preservation scenario across all enhancement types and priming conditions



$p < 0.001$, $d = 0.58$, indicating that participants perceived brain stimulation as more similar to pharmacological than to natural enhancement. (see Fig. 2).

A priming $\times$ enhancement type interaction was also identified, $F(1.74, 773.71) = 3.90$, $p = 0.03$, $\eta^2_p = 0.01$. Post hoc t -tests showed a significant effect of priming for pharmacological enhancement, $t(447) = 2.97$, $p = 0.003$, $d = 0.28$, and brain stimulation, $t(447) = 2.31$, $p = 0.02$, $d = 0.22$, but not natural, $t(447) = 0.21$, $p = 0.84$, $d = 0.02$.

Free Will

The main effect of Enhancement Type, $F(1.82, 811.23) = 183.83$, $p < 0.001$, $\eta^2_p = 0.29$ was significant.

Natural methods were rated significantly higher than brain stimulation, $t(445) = 13.40$, $p < 0.001$, $d = 0.52$ and pharmacological agents, $t(445) = 18.58$, $p < 0.001$, $d = 0.72$. Brain stimulation was also rated significantly higher than pharmacological agents, $t(445) = 5.18$, $p < 0.001$, $d = 0.20$; see Fig. 3.

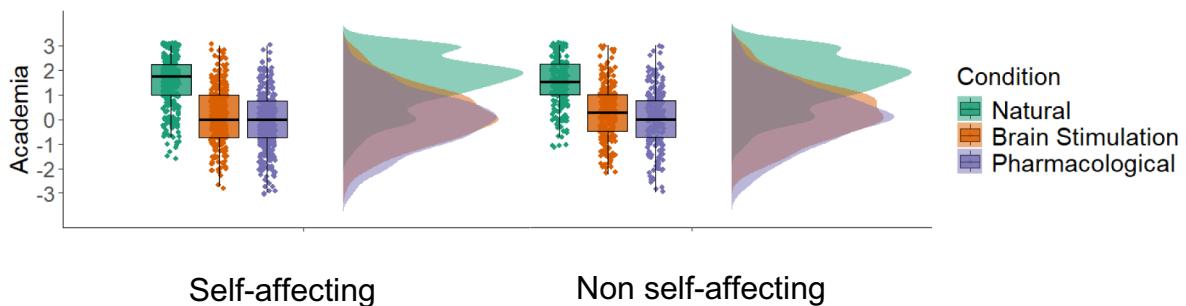


Fig. 2 Academic fairness attitudes showed a similar pattern across self-affecting priming conditions for natural enhancers but attitudes were not as positive for brain stimulation and

pharmacological enhancers when other students' use of cognitive enhancement could affect participants' grades

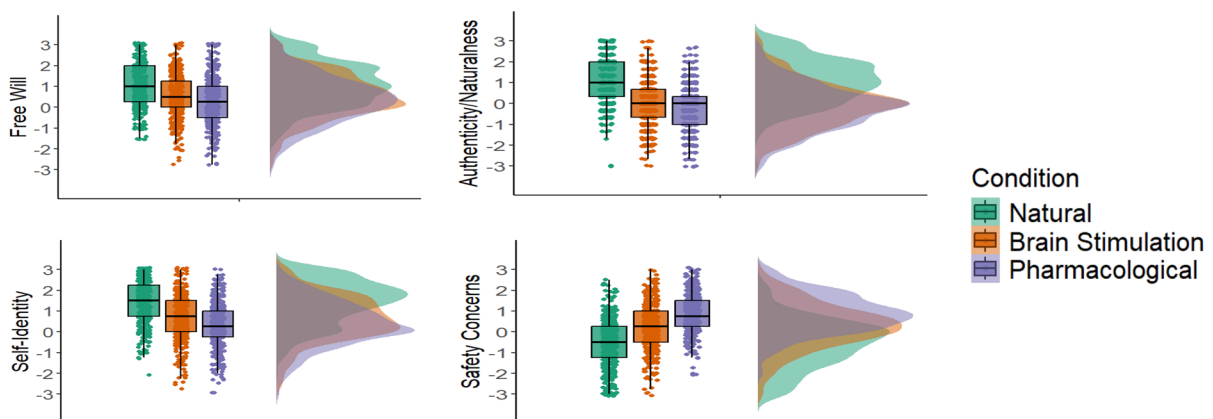


Fig. 3 Student attitudes towards free will, authenticity/naturalness, self-identity, and the safety of pharmacological, brain stimulation, or natural enhancers. *Note.* All enhancement conditions differed significantly from one another

A paired-samples *t*-test comparing the absolute difference scores indicated that brain stimulation was perceived as significantly more similar to pharmacological than to natural enhancement, $t(448)=4.24$, $p<0.001$, $d=0.20$. The mean absolute difference between brain stimulation and pharmacological enhancement ($M=0.56$, $SD=0.57$) was smaller than the mean absolute difference between brain stimulation and natural enhancement ($M=0.74$, $SD=0.71$). The main effects of Framing, $F(1, 445)=1.09$, $p=0.30$, $\eta^2_p=0.002$, and Priming, $F(1, 445)=0.03$, $p=0.86$, $\eta^2_p<0.001$, were both non-significant. However, the Priming $\times$ Framing interaction was significant, $F(1, 445)=4.95$, $p=0.03$, $\eta^2_p=0.01$. Follow-up Holm-corrected comparisons did not identify any reliable simple effects. Within each priming condition (self-affecting vs. non self-affecting), responses did not differ significantly between preservation and enhancement framing. Likewise, within each framing condition, the two priming groups did not differ significantly from one another (all $ps>0.14$).

The interaction effects between Enhancement Type and Framing condition, $F(1.82, 811.23)=1.06$, $p=0.34$, $\eta^2_p=0.002$ or Priming condition, $F(1.82, 811.23)=2.17$, $p=0.12$, $\eta^2_p=0.005$ were non-significant. Additionally, the three-way interaction was non-significant, $F(1.82, 811.23)=0.96$, $p=0.38$, $\eta^2_p=0.002$.

Authenticity/Naturalness

The main effect of Enhancement Type, $F(1.74, 774.02)=341.86$, $p<0.001$, $\eta^2_p=0.43$, was significant, suggesting that attitudes differed significantly across methods. However, the main effects of Framing, $F(1, 445)=2.93$, $p=0.09$, $\eta^2_p=0.01$, and Priming, $F(1, 445)=0.34$, $p=0.56$, $\eta^2_p<0.001$, were non-significant.

A post hoc pairwise comparison using Holm-Bonferroni correction showed that natural methods were rated significantly higher than brain stimulation, $t(445)=20.11$, $p<0.001$, $d=1.06$, and pharmacological agents, $t(445)=21.20$, $p<0.001$, $d=1.23$. Brain stimulation was rated significantly higher than pharmacological agents, $t(445)=4.17$, $p<0.001$, $d=0.17$ (see Fig. 3).

A paired-samples *t*-test comparing the absolute difference scores indicated that brain stimulation was perceived as significantly more similar

to pharmacological than to natural enhancement, $t(448)=10.36$, $p<0.001$, $d=0.49$. The mean absolute difference between brain stimulation and pharmacological enhancement ($M=0.68$, $SD=0.65$) was smaller than the mean absolute difference between brain stimulation and natural enhancement ($M=1.27$, $SD=1.06$). The interaction effects between Enhancement Type and Framing condition, $F(1.74, 774.02)=0.50$, $p=0.58$, $\eta^2_p=0.001$ or Priming condition, $F(1.74, 774.02)=0.31$, $p=0.70$, $\eta^2_p=0.001$, were non-significant. Additionally, the three-way interaction was non-significant, $F(1.74, 774.02)=0.25$, $p=0.75$, $\eta^2_p=0.001$, suggesting that the relationship between Priming, Framing and Enhancement Types did not significantly interact to influence attitudes of authenticity/naturalness.

Self-identity

There was a significant main effect of Enhancement Type, $F(1.81, 807.02)=256.94$, $p<0.001$, $\eta^2_p=0.366$, indicating that attitudes differed depending on the type of cognitive enhancement. Pairwise comparisons showed that natural methods were rated more positively than brain stimulation, $t(445)=15.77$, $p<0.001$, $d=0.74$ and pharmacological agents, $t(445)=21.99$, $p<0.001$, $d=1.04$. Brain stimulation was rated more positively than pharmacological agents, $t(445)=6.22$, $p<0.001$, $d=0.29$ (see Fig. 3).

By contrast, there were no significant main effects of Priming, $F(1, 445)=0.70$, $p=0.40$, $\eta^2_p=0.002$, or Framing, $F(1, 445)=0.92$, $p=0.338$, $\eta^2_p=0.002$. Likewise, none of the interactions were significant: Enhancement $\times$ Priming, $F(1.81, 807.02)=0.51$, $p=0.584$, $\eta^2_p=0.001$; Enhancement $\times$ Framing, $F(1.81, 807.02)=0.11$, $p=0.882$, $\eta^2_p<0.001$; Priming $\times$ Framing, $F(1, 445)=0.90$, $p=0.343$, $\eta^2_p=0.002$; or Enhancement $\times$ Priming $\times$ Framing, $F(1.81, 807.02)=0.31$, $p=0.715$, $\eta^2_p<0.001$.

A paired-samples *t*-test comparing the absolute difference scores indicated that brain stimulation was perceived as significantly more similar to pharmacological than to natural enhancement, $t(448)=7.04$, $p<0.001$, $d=0.33$. The mean absolute difference between brain stimulation and pharmacological enhancement ($M=0.64$, $SD=0.66$) was smaller than

the mean absolute difference between brain stimulation and natural enhancement ($M=0.99$, $SD=0.92$). The interaction effects between Enhancement type and Framing condition, $F(1.83, 972.80)=0.50$, $p=0.590$, $\eta^2_p<0.01$, or Priming condition, $F(1.83, 972.80)=0.36$, $p=0.678$, $\eta^2_p<0.01$ were non-significant. Additionally, the three-way interaction was non-significant, $F(1.83, 972.80)=0.67$, $p=0.498$, $\eta^2_p<0.01$, suggesting the relationship between Priming, Framing and Enhancement Types did not significantly interact to influence attitudes pertaining to the self.

Safety

The main effect of Enhancement Type was significant, $F(1.92, 853.89)=299.13$, $p<0.001$, $\eta^2_p=0.40$. However, the main effects of Framing, $F(1, 445)=1.21$, $p=0.27$, $\eta^2_p=0.002$, and Priming, $F(1, 445)=1.06$, $p=0.30$, $\eta^2_p=0.002$ were non-significant.

Post hoc comparisons with Holm correction showed that natural methods were rated with fewer safety concerns than brain stimulation, $t(445)=-14.03$, $p<0.001$, $d=-0.81$ and pharmacological agents, $t(445)=-22.62$, $p<0.001$, $d=-1.39$. Brain stimulation was also rated with fewer concerns than pharmacological agents, $t(445)=-11.19$, $p<0.001$, $d=-0.57$.

A paired-samples t -test comparing the absolute difference scores indicated that brain stimulation was perceived as significantly more similar to pharmacological than to natural enhancement, $t(448)=3.54$, $p<0.001$, $d=0.17$. The mean absolute difference between brain stimulation and pharmacological enhancement ($M=0.92$, $SD=0.91$) was smaller than the mean absolute difference between brain stimulation and natural enhancement ($M=1.15$, $SD=1.04$).

The interaction effects between Enhancement Type and Framing condition, $F(1.92, 853.89)=0.007$, $p=0.99$, $\eta^2_p<0.001$, or Priming condition, $F(1.92, 853.89)=0.46$, $p=0.62$, $\eta^2_p=0.001$ were non-significant. Additionally, the three-way interaction was non-significant, $F(1.92, 853.89)=0.30$, $p=0.73$, $\eta^2_p=0.001$, suggesting the relationship between Priming, Framing and Enhancement Types did not significantly interact to influence student attitudes concerning safety.

Discussion

We assessed student attitudes to cognitive enhancers under varying contextual conditions. Our study contributes to a growing body of research exploring the social and moral psychology of cognitive enhancement [22], offering new insights into how students evaluate different enhancement methods under varying contextual conditions. One of our central findings is that brain stimulation, although legal and non-invasive, was judged more similarly to pharmacological enhancement than to natural methods such as caffeine. This indicates that legal status alone does not guarantee moral acceptance, similar to previous findings [23, 24]. Instead, participants appeared to rely on deeper, intuitive judgments about the authenticity/naturalness or familiarity of different enhancement types. This is consistent with prior work suggesting that people evaluate brain stimulation with caution due to its perceived artificiality or invasiveness [25], even in the absence of clinical risk [26].

An important feature of our findings is that, although participants consistently distinguished between enhancement methods, apart from safety concerns over pharmacological cognitive enhancement, their evaluations were generally close to the neutral point of the scale rather than strongly negative. This suggests that students did not regard cognitive enhancement, including non-invasive brain stimulation, as inherently immoral or unacceptable. Instead, their responses reflected a more nuanced form of moral ambivalence, in which enhancement was viewed as raising ethical concerns without eliciting outright condemnation. This pattern may indicate that contemporary students perceive cognitive enhancement as an increasingly familiar aspect of academic life, recognising both its potential benefits and its ethical challenges. Accordingly, the primary distinction observed in the present study was not between moral acceptance and rejection, but between comparatively greater acceptance of natural enhancement and greater moral caution toward pharmacological and brain stimulation methods.

Our results align closely with Dinh et al. [14], who found that moral concern about cognitive enhancement often arises not from objective characteristics of the enhancer itself, but from its implications for fairness and social comparison. In our study, students perceived

brain stimulation as occupying a middle ground between natural and pharmacological enhancers, but importantly, with closer alignment to pharmacological enhancers, despite its legal and commercially available status. This suggests that students are forming categories not based on legality or availability, but on perceived moral distance from socially accepted practices.

Self-identity concerns also emerged as a central dimension of students' moral judgments. Whereas natural enhancers were largely seen as compatible with a stable sense of self, both pharmacological and brain stimulation methods were more likely to evoke unease about authenticity and continuity of identity. These findings align with the idea that enhancement is not evaluated solely in terms of individual choice but in relation to implicit concerns about social equity and moral status. Francis Fukuyama's [27] notion of "Factor X," a core human essence grounding dignity, offers a useful lens: when cognitive capacities are seen as modifiable through artificial means, this may be perceived as undermining the shared basis of moral equality. In competitive academic contexts, threats to selfhood are not only experienced individually but also carry relational implications: if some students are perceived to enhance in ways that compromise authenticity, this can destabilise the sense of equal moral standing that underpins fair competition. In this way, identity-related discomfort intersects with fairness concerns, reinforcing unease about legitimacy and equity in academic achievement. The prominence of these concerns may also reflect the characteristics of the sample, which consisted of undergraduate psychology students from a single UK university. As university students operating within competitive academic environments, participants are routinely exposed to systems in which achievement, merit, and fair evaluation are highly valued. Consequently, questions surrounding authenticity and undeserved advantage may be particularly salient for this population, making student perspectives especially important for understanding the ethical implications of cognitive enhancement in educational settings.

These findings reinforce Veit et al.'s [18] call to recognise the diversity of cognitive enhancement in ethical discussions. Rather than treating enhancement as a monolithic category, our data show that students distinguish between methods in nuanced ways, with attitudes shaped by perceived invasiveness, familiarity, and social meaning. Brain stimulation, despite

being new and legally available, does not benefit from the same moral leniency as natural enhancers, and instead inherits the ethical burden often placed on pharmacological agents. A pluralistic, context-sensitive ethical framework, one that evaluates each form of enhancement on its own terms, is therefore essential for capturing how these technologies are understood and morally negotiated.

Another key finding relates to the effect of framing. Across all enhancement types, participants expressed more favourable attitudes when the enhancer was described as preserving or restoring cognitive function, rather than improving it beyond baseline. This finding supports the well-established treatment–enhancement distinction in moral psychology [7, 8]. Notably, our scenarios involved only minor and non-clinical deficits, such as tiredness or lack of focus, yet the preservation framing still shifted responses. This indicates that the treatment framing may serve as a moral justification mechanism, making enhancement feel less like an unfair advantage and more like a form of responsible self-care. These results also align with Dinh et al. [14], who found that people tend to accept enhancement more readily when it is framed as addressing a need rather than augmenting ability.

Our priming manipulation, which varied whether enhancement was framed as self-relevant, also significantly shaped moral judgments. When participants were asked to consider how others' use of enhancement could affect their own academic outcomes, they evaluated enhancement more negatively, particularly for pharmacological and brain stimulation methods. In contrast, judgments of natural enhancers remained relatively stable. The effect was especially pronounced in themes related to fairness and identity, suggesting that enhancement is not merely a personal choice but a socially consequential one. This pattern may be particularly relevant in student populations, where academic outcomes are closely tied to future opportunities and where performance comparisons are a routine feature of everyday life. As a result, students may be especially sensitive to enhancement practices that appear to alter the conditions of academic competition, highlighting the value of examining attitudes within this group. These findings are consistent with research showing that enhancement in zero-sum environments (for example, competitive academic contexts) is judged more harshly, as it may threaten perceptions of merit and equity [5, 6].

Our results extend this by showing that even mild priming, which highlights how others' actions might impact one's own standing, can activate fairness-related moral concerns, but primarily in relation to pharmacological and neural interventions. One possible explanation is that these methods are seen as more artificial and more capable of producing substantial performance gains, which heightens concerns about undeserved advantage, authenticity, and social comparison. Natural enhancers, by contrast, may be perceived as part of everyday academic life and therefore less threatening to fairness or identity.

Safety emerged as an important dimension in students' evaluations of cognitive enhancement. Participants perceived pharmacological enhancement as posing the greatest safety concerns, followed by brain stimulation, whereas natural enhancement was consistently viewed as the safest option. This pattern is consistent with previous research suggesting that perceptions of risk vary according to the type of enhancement method rather than enhancement per se [11, 17]. Although pharmacological enhancers such as methylphenidate and modafinil have demonstrated cognitive benefits, their non-medical use remains associated with concerns about adverse effects, misuse, and dependence [17]. By contrast, brain stimulation techniques such as transcranial direct current stimulation (tDCS) are generally regarded as safe when administered under controlled research or clinical conditions, but uncertainty surrounding unsupervised and commercial use may contribute to more cautious evaluations [26]. Natural enhancers, such as caffeine, are widely embedded in everyday academic practice and may therefore be perceived as comparatively familiar and acceptable despite carrying recognised health risks of their own [2]. Together, these findings suggest that students' safety judgments are shaped not only by objective evidence of risk but also by familiarity, perceived controllability, and the social normalisation of different enhancement methods. Our findings also have implications for debates surrounding the regulation of cognitive enhancement technologies. Direct-to-consumer brain stimulation devices, for instance, are marketed as legal and non-invasive yet were received with moral ambivalence by students. This suggests that public acceptance cannot be assumed on the basis of legality or safety alone. Rather, our findings indicate that concerns about fairness, authenticity, and identity shape how these technologies are perceived

and may therefore influence their social legitimacy. These findings should not be interpreted as implying that regulation ought to directly reflect public moral intuitions. Decisions about law and policy necessarily require consideration of additional factors, including evidence of harm, safety, coercion, informed consent, inequality, commercial practices, vulnerability, and the broader institutional context. Instead, our results highlight dimensions of public concern that may otherwise be overlooked if regulatory debates focus exclusively on legal status or technical risk. While much of the regulatory debate surrounding direct-to-consumer brain stimulation has centred on the United States [28], similar issues are emerging in the UK and EU, where consumer neurotechnology often falls between medical device and consumer product frameworks. This regulatory uncertainty reflects a broader ethical tension between precautionary and proactionary approaches to emerging technologies [29]: whether regulation should restrict enhancement in anticipation of potential risks or permit innovation unless concrete harms are demonstrated. Our findings suggest that students' attitudes align more closely with precautionary ethical intuitions, emphasising fairness, authenticity, and identity alongside considerations of legality and safety. These attitudes do not, by themselves, determine appropriate regulatory policy, but they may help identify issues that policymakers should consider when developing governance frameworks that are both ethically informed and publicly legitimate.

An important consideration when interpreting these findings is the demographic composition of the sample. Participants were predominantly psychology students, a group for whom issues of academic performance, fairness, and personal achievement are particularly relevant. Their educational background may also provide greater familiarity with psychological and ethical concepts, making them a valuable population for exploring attitudes toward cognitive enhancement and emerging neurotechnologies. The prominence of concerns relating to fairness, authenticity, and social consequences may therefore reflect both broader moral intuitions and the particular perspectives of students navigating competitive educational environments.

Several limitations should be considered when interpreting these findings. Although undergraduate psychology students represent an important population for understanding attitudes toward cognitive

enhancement in educational settings, the use of a convenience sample from a single UK university, comprising predominantly female participants, limits the generalisability of the findings. Attitudes may differ across institutions, academic disciplines, demographic groups, and cultural contexts. The study relied on self-report questionnaires, which may be influenced by social desirability and may not fully capture real-world behaviour or willingness to use enhancement technologies. The scenarios used to describe enhancement methods, while designed to be clear and balanced, cannot reflect the full complexity of lived decision-making. The cross-sectional design also prevents conclusions about how attitudes may shift over time or in response to direct experience with enhancement. Finally, the study examined three categories of enhancers and five moral domains, which provides an informative but incomplete picture of the broader ethical terrain. Although multiple comparisons were conducted within each analysis, we did not correct across analyses and therefore small effects should be treated with caution and require replication.

Future research should address these limitations by recruiting more diverse and cross-cultural samples, including groups such as clinicians, policymakers, and working professionals who are directly involved in debates about enhancement. Longitudinal and experimental approaches could clarify how moral judgments change as technologies like brain stimulation become more familiar or as individuals acquire direct experience with them. Further work could also investigate how individual moral foundations, such as fairness, harm, and purity, predict differences in moral evaluation, and whether targeted interventions or public engagement can reshape perceptions. For the field of neuroethics, a particularly valuable direction will be to integrate empirical findings with normative analysis, examining not only how people evaluate enhancement but also whether and how those intuitions should guide ethical and regulatory frameworks. In this way, future work can help bridge descriptive accounts of moral psychology with prescriptive debates about the legitimate role of enhancement in education, healthcare, and society.

In summary, this study shows that attitudes toward cognitive enhancement are shaped not only by the type of method but also by how it is framed and situated within a social context. Brain stimulation, despite being legal and non-invasive, was judged

more like pharmacological enhancement than natural methods, highlighting that moral evaluations are not reducible to risk or legality. Framing enhancement as preservation increased acceptability, while priming participants to consider competitive consequences reduced it, particularly for artificial methods. Together, these findings underscore the importance of integrating empirical insights into moral psychology with normative analysis in order to inform ethical debate and policy. Understanding how people evaluate enhancement in everyday academic life provides a crucial foundation for broader neuroethical discussions about fairness, authenticity, and the limits of self-improvement.

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Declarations

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