

ARTICLE



Would you be willing to zap your child's brain? Public perspectives on parental responsibilities and the ethics of enhancing children with transcranial direct current stimulation

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ABSTRACT

Background: Transcranial direct current stimulation (tDCS) is an experimental brain stimulation technology that may one day be used to enhance the cognitive capacities of children. Discussion about the ethical issues that this would raise has rarely moved beyond expert circles. However, the opinions of the wider public can lead to more democratic policy decisions and broaden academic discussion of this issue. **Methods:** We performed a quantitative survey of members of the U.S. public. A between-subjects design was employed, where conditions varied based on the trait respondents considered for enhancement. **Results:** There were 227 responses included for analysis. Our key finding was that the majority were unwilling to enhance their child with tDCS. Respondents were most reluctant to enhance traits considered fundamental to the self (such as motivation and empathy). However, many respondents may give in to implicit coercion to enhance their child in spite of an initial reluctance. A ban on tDCS was not supported if it were to be used safely for the enhancement of mood or mathematical ability. Opposition to such a ban may be related to the belief that tDCS use would not represent cheating or violate authenticity (as it relates to achievements rather than identity). **Conclusions:** The wider public appears to think that crossing the line from treatment to enhancement with tDCS would not be in a child's best interests. However, an important alternative interpretation of our results is that lay people may be willing to use enhancers that matched their preference for "natural" enhancers. A ban on the safe use of tDCS for enhancing nonfundamental traits would be unlikely to garner public support. Nonetheless, it could become important to regulate tDCS in order to prevent misuse on children, because individuals reluctant to enhance may be likely to give in to implicit coercion to enhance their child.

KEYWORDS

transcranial direct current stimulation; enhancement; ethics; surveys and questionnaires; noninvasive brain stimulation

Transcranial direct current stimulation (tDCS), the direct application of a weak, constant electric current to the scalp via two electrodes, is a biomedical technology that may be capable of producing enhancement effects (Moreno Duarte 2014). The outcomes of numerous studies suggest that cognition (Cohen Kadosh et al. 2010; Fregni et al. 2005; Hsu et al. 2011; Iyer et al. 2005; Weiss and Lavidor 2012), and perhaps even mood (Marshall et al. 2004) and moral behavior (Wang et al. 2014), can be enhanced temporarily by tDCS.

tDCS devices are available for purchase online. Alternatively, individuals can inexpensively assemble their own if they follow the instructions available on do-it-yourself (DIY) websites (Yamada 2014). These highly portable devices, once purchased or built, can be used by anyone to target almost any area of the cerebral cortex (Cohen Kadosh et al. 2012).

It is possible that well-meaning parents would consider the technology for their children, for example, to try to

improve academic performance (Krause et al. 2014; Maslen et al. 2013). Currently, however, tDCS use would possibly expose a child to a risk of significant harm. There is scarce knowledge regarding the effects of tDCS on children, in the long term, and outside of research settings (Davis 2014; Maslen et al. 2013). Moreover, there may be significant limitations on attempts to cognitively enhance with tDCS. According to net zero-sum theory, neural "gains" will always be matched by neural "losses"¹ (Brem et al. 2014; Iuculano and Cohen Kadosh 2013).

But what if further research showed tDCS to be a safe and effective enhancer of children? Various ethical consequences would emerge from pediatric enhancement with tDCS, and these should be researched in the early stages of the technology's adoption. Some of these have been explored in debates about other enhancers (e.g., pharmaceuticals), including the concern about the impact of

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¹The evidence for tDCS enhancing within the framework of net zero-sum model is limited. Many reports suggest that tDCS enhancements result not from resource reallocation but from an addition of actual resources available to the brain (Luber 2014).

enhancement on authenticity. The essentialist conception of authenticity claims that there is a way someone truly is, and that this is his or her fundamental self. To be authentic means to identify one's pre-given self through a journey of self-discovery, and to live accordingly² (Bublitz and Merkel 2009). On the matter of enhancers, Carl Elliott (2004) claims that if a man were to take Prozac to improve his personality, it would no longer be his own personality. It follows that achievements resulting from enhanced traits would therefore not really be an individual's own doing. Existentialist, or "self-creation," conceptions of authenticity, in contrast, allow for individuals to change themselves, even quite radically, if these changes align with how they want to be (Degrazia 2000).

tDCS also raises moral concerns that are distinct from pharmaceuticals. A survey of tDCS researchers found that many were concerned about the safety of using tDCS as an enhancer, while a minority suspected that there is a low risk–benefit ratio when attempting to improve functions in the "normal" brain (Riggall et al. 2015). Consequently, 71% of researchers believed that tDCS should not be available to the public. Despite expert fears, a study on the DIY tDCS community demonstrated that most were using tDCS with the aim of enhancing normal cognitive function, rather than for the treatment of a medical condition (Jwa 2015).

Advances in enhancement technologies will affect lay people, and their perspectives can provide context for policy decisions that must be justifiable to the public. Enhancers can be subject to criticism due to the view that their use is unfair; however, a survey by Sabini and Monterosso (2005) found that providing the bottom 10% of performers with access to enhancers was seen as less unfair than if they affected everyone. Also, a survey by Riis et al. (2008) exploring lay people's understandings of authenticity found that the majority subscribed to the essentialist definition of authenticity. Previous studies have identified that certain personality traits vary in their importance to authenticity, and that fundamental traits (such as mood and empathy) are the least attractive for enhancement (Cabrera et al. 2014; Riis et al. 2008).

Only one study has explored parents' views on cognitively enhancing their children after birth. This collected qualitative data through interviews with 12 parents of dependent children. It was found that 25% of participants were open to any form of safe and effective cognitive enhancement (including medication, surgery, natural products, and removable devices). The majority of parents were opposed to enhancement (Ball and Wolbring 2014).

Despite the pressing ethical concerns created by the increasing availability of tDCS devices, there has been no research exploring lay people's beliefs about enhancing children with

tDCS. Our study was therefore the first to investigate public perceptions of this issue.

Methods

A between-subjects online quantitative survey was performed, followed by ethical analysis. Participants were recruited online via Amazon Mechanical Turk and reimbursed \$1.00 for completing the questionnaire. Respondents were excluded from analyses if they did not complete the questionnaire in its entirety or failed an attention check. Refer to Appendix A for the full version of the questionnaire, which was designed on Survey Monkey.

Each respondent was allocated to one of five possible conditions. Conditions varied based on the trait under consideration for enhancement. These traits included math ability, motivation, mood, and empathy. There were two definitions of motivation allocated to two separate conditions. Motivation defined as task enjoyment (henceforth known as motivation (E)) is endurance toward a goal because one derives pleasure from the work required to achieve the goal. Motivation defined as perseverance (henceforth known as motivation (P)) is perseverance toward a goal irrespective of whether one enjoys the work required to achieve the goal. We refer to each of the five conditions as the relevant trait under investigation, namely, Math, Motivation (E), Motivation (P), Empathy, and Mood.

The introduction of the questionnaire provided respondents with the hypothetical scenario in which they would be making enhancement decisions (Figure 1).

The first part of the survey contained questions specific to the trait being examined. Three categorical questions asked respondents about their willingness to enhance with tDCS if their child's baseline capacity for the trait under consideration were below average, average, and above average. Respondents' attitudes to enhancing their own child with tDCS and to other parents enhancing their children were investigated with several normative statements, with agreement or disagreement indicated on a 7-point Likert scale.

Questions in the second part of the survey were the same in all conditions. We asked respondents about their willingness to enhance their child with tDCS in a version of the net zero-sum scenario, where long-term memory of facts could be enhanced at the cost of a slight reduction in working memory. Respondents were then asked to indicate their general attitudes to tDCS and enhancement on a 7-point Likert scale. We also collected data on respondent demographic characteristics and applied two validated personality scales (Need for Cognition [Cacioppo and Petty 1982] and Social and Economic Conservatism [Everett 2013]).

Data organization and analysis were performed using IBM SPSS Statistics version 22.0 for Mac software. Based on previous research (Sabini and Monterosso 2005), we calculated that a sample size of 170 would have a power of 80% to detect an 8% shift from willingness to enhance to reluctance to enhance ($p = .05$). Statistical analyses included descriptive statistics, Pearson's chi-squared tests, McNemar–Bowker tests to compare responses within conditions, one-way analyses of variance

²However, it is important to note that this understanding of authenticity is problematic when applied to children. One's personality traits develop through interaction with the environment in which one grows up. If the essentialist conception of authenticity is taken to be correct, at what age does the self become fixed and ready to be discovered by an individual? Very young children and infants may not yet have a fundamental self that can be interfered with by enhancement.

Transcranial electrical stimulation (tES) is a new technology. During tES, a weak electric current is applied with small pads that are placed on the outside of the person's head. The amount of current delivered by the stimulation is typically less than that required to power a single LED indicator. Different abilities can be improved with tES, depending on where the pads are placed, and what the person is doing during the procedure. It is safe, painless and does not have any side effects.

Imagine you are the parent of a 10-year-old child. Imagine you could use tES to improve your child's math ability. The procedure would take 20 minutes. During this time, your child would work through some mathematics problems. The improvement would last 6 months.

Figure 1. Introduction of survey for Math. The text in blue highlights the key information that changed between conditions: the trait under consideration for enhancement, and the training the child would undertake during the tDCS procedure. The term tES rather than tDCS was chosen as it was thought to be more easily understood by lay people. The meanings of Motivation (E) and Motivation (P) were provided in the introduction for respondents allocated to Motivation (E) and Motivation (P), respectively. Respondents in Empathy were informed that enhancement would improve their child's "ability to understand and respond to the emotions of others." Those allocated to Mood were told that enhancing their child would make him or her "feel happier more often, and be more positive about life."

(ANOVAs), and predictive statistics (multinomial logistic regression).

This project received ethics approval from the University of Oxford Central University Research Ethics Committee and the Monash University Human Research Ethics Committee.

Results

Respondent characteristics

Data from 227 respondents met the inclusion criteria. The age range of respondents was 18 years and above, with the majority aged 21–39 years (69%). There was a predominance of males in this sample (55%). Table 1 provides a detailed breakdown of respondent demographic characteristics.

Willingness to enhance

The majority of respondents would not enhance with tDCS (Figure 2). However, more respondents were willing to enhance when their child's capacity was below average (45%), compared to when it was average (25%) or above average (19%). The lowest proportion would enhance within the net zero-sum scenario (7%). The majority of respondents would wish their child could have a better capacity if the baseline was below average or average, but would not give tDCS (51% and 62%, respectively). Just

under half gave the same response when the baseline was above average.

In order to examine the effect of altering the baseline level of capacity, McNemar–Bowker tests were performed to compare responses within conditions. These determined that a significant proportion of respondents willing to enhance a capacity from a below average baseline became unwilling once faced with the prospect of a side effect (85%, $p \leq .001$), or enhancing from an average or above average baseline (46% and 60% respectively, $p \leq .001$).

Effect of condition on willingness to enhance

There were significant differences between conditions in the willingness to enhance from any baseline, particularly from an average one ($\chi^2(8, n = 227) = 36.38, p \leq .001$). The majority of respondents would be willing to enhance their child's mood if it were below average (58%). However, if their child's capacity was average or above average, respondents in Math were more likely to enhance with tDCS than those in Mood (39% compared to 31%, and 31% compared to 20%, respectively). Figure 3 demonstrates respondent's willingness to enhance in Math. For all three levels of capacity, respondents were least likely to enhance empathy. Intriguingly, the majority of respondents in Empathy would not even wish their child to have a better than

Table 1. Respondent characteristics.

		Overall (%)	Math (%)	Motivation (E) (%)	Motivation (P) (%)	Empathy (%)	Mood (%)
Age (years)	18–20	4	5	4	0	8	2
	21–29	38	46	38	41	41	31
	30–39	30	23	29	36	24	35
	40–49	14	13	11	12	16	19
	50–59	10	5	16	9	11	8
	60 and older	4	8	2	2	0	5
Gender	Male	55	67	49	55	46	58
	Female	45	33	51	45	54	42
Parental status	Nonparent	62	72	53	66	51	64
	Parent	38	28	47	34	49	36
Religious	Yes	53	54	56	48	54	52
	No	48	46	45	53	46	48
Religion practiced	Christianity	83	85	77	92	74	82
	Non-Christian	6	6	7	4	5	8
	Other	11	9	16	4	21	10

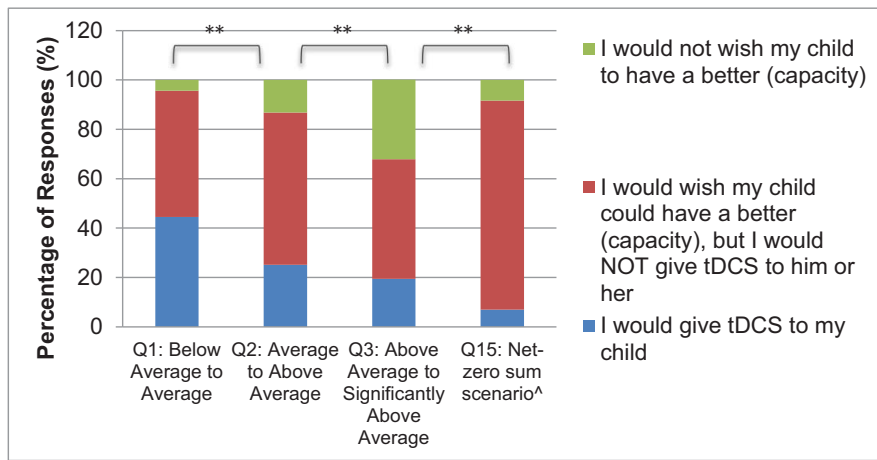


Figure 2. Willingness to enhance by level of capacity ($n = 227$). Labels on the y-axis refer to the baseline and the enhanced levels of capacity stated in each question. For example, Question 1 asked: “Would you be willing to enhance your child if he or she had a *below average* (trait) and would become *average*?” ^ Answer options (b) “I would wish my child my child could have a better long-term memory, but I would NOT give tDCS to him or her if there were any reduction in working memory” and (c) “I would wish my child could have better long-term memory, but I would NOT give tDCS to him or her *regardless* of the effect on working memory” were combined to permit comparison to Questions 1–3. Double asterisk indicates significant at $p < .001$

above average capacity (65%), compared to less than 31% in the other conditions.

Due to the differences in demographic characteristics between conditions, multinomial logistic analyses were performed to control for possible confounders, including age, parental status, gender, and religiosity. Condition remained a significant predictor for willingness to enhance after these analyses.

Within conditions, McNemar–Bowker tests illustrated that a significant proportion of respondents willing to enhance a lower level of capacity became unwilling when the capacity baseline was increased. Among those willing to enhance a below average mood, for example, 71% were unwilling to enhance an above average mood ($p \leq .001$).

Attitudes to enhancement

In order to elicit participant’s enhancement attitudes, several normative statements about enhancement with tDCS were provided and responses were indicated on a 7-point Likert scale.

Trait-specific attitudes to enhancing one’s own child

There were significant differences between conditions as determined by one-way ANOVA for question 5, “This would fundamentally change who my child is” ($F(4, 222) = 4.21, p = .003$). Condition remained a significant predictor of responses after controlling for potential confounders with linear regression. When the mean responses to question 5 are used to order the five traits from least fundamental to most fundamental to self, it can be shown that these rankings precisely match willingness to enhance an average capacity in order from least reluctant to most reluctant (Table 2).

Respondents were more likely to disagree than to agree that tDCS “would give my child an unfair advantage over others” (mean -1.0 , 95% CI -1.2 to -0.8). There was also a slight trend toward agreement with the statement “the level of my child’s (capacity) (below average, average, above average) is not relevant. I would give tDCS to my child only if I determined it would improve his or her wellbeing” (mean 0.2 , 95% CI 0.0 to 0.5). Conversely, respondents were more likely to use tDCS “if other parents were using it for their children, and as a result my child could be disadvantaged without it” (mean 0.8 , 95% CI 0.6 to 1.1). There were no significant differences between conditions for any of these questions.

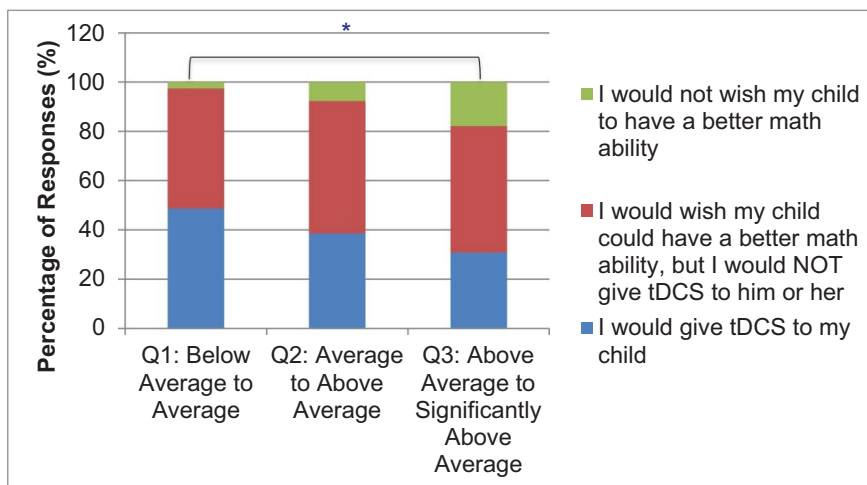


Figure 3. Willingness to enhance **math ability** by level of capacity ($n = 39$). Asterisk indicates significant at $p < .05$.

Table 2. Mean responses to question 5, “This would fundamentally change who my child is,” compared to willingness to enhance an average capacity.

Trait	Fundamental change (95% CI)	Willing to enhance an average capacity (%)
Math ability	−0.5 (−1.0 to 0.1)	39
Mood	0.1 (−0.3 to 0.6)	31
Motivation (E)	0.2 (−0.3 to 0.7)	27
Motivation (P)	0.5 (−0.1 to 1.0)	21
Empathy	1.2 (0.6 to 1.8)	5

Note. Possible responses ranged from −3 to +3. Negative responses indicated disagreement, positive responses indicated agreement, and 0 indicated neutrality.

Trait-specific attitudes to others enhancing their child with tDCS

One-way ANOVA demonstrated significant differences between conditions for question 13, “This technology should not be used in this way and it should be banned” ($F(4, 222) = 2.67, p = .033$) (Figure 4). Respondents were significantly more opposed to bans on mood and math ability enhancement, whereas a ban on empathy enhancement was more likely to receive support. These findings remained

significant after controlling for numerous possible confounders.

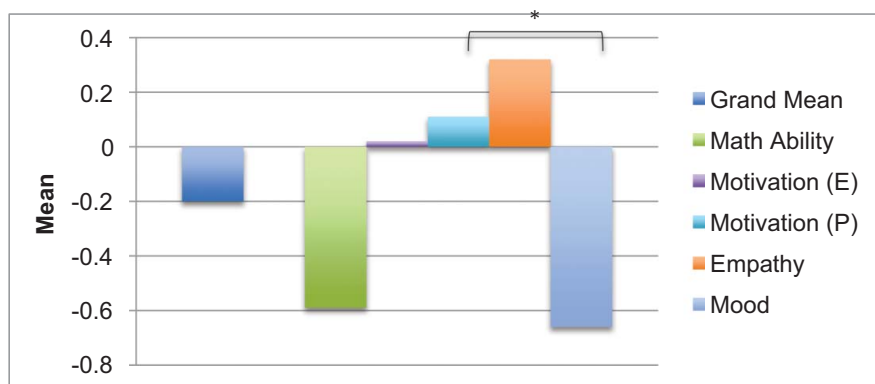
The mean response to question 14, “Using tDCS this way would be cheating”, was -0.50 (95% CI -0.73 to -0.27). There were no significant differences between conditions.

General attitudes to tDCS and enhancement

The mean responses to the questions designed to elicit participants’ general attitudes to tDCS and enhancement are outlined in Table 3. These questions were the same in all conditions. Respondents’ attitudes to enhancement with tDCS were associated with concerns about the procedure and its unnaturalness. There was a trend toward agreement that enhancement would interfere with a child’s development of good character, yet respondents were more likely to disagree that tDCS would impair authenticity as it relates to achievement.

Parental status

Respondents’ demographic characteristics and their responses were analyzed to investigate whether there was any significant

**Figure 4.** Question 13: “This technology should not be used in this way and it should be banned” ($n = 227$). Asterisk indicates significant at $p < .05$. Possible responses ranged from −3 to +3. Negative responses indicated disagreement, positive responses indicated agreement, and 0 indicated neutrality.**Table 3.** Questions 16–20 and 22–25, $n = 227$.

Question	Mean (95% CI)	SD
Q16: “tDCS should not be given until my child is old enough to make his or her own decision, even if there is less improvement from the procedure at an older age.”	0.7 (0.5 to 1.0)	1.69
Q17: “Even if I were assured that the procedure is safe, I would worry that this might affect my child in unexpected ways.”	1.6 (1.4 to 1.8)	1.44
Q18: “I would not like the idea of having a procedure performed on my child.”	1.1 (0.9 to 1.3)	1.75
Q19: “I dislike the unnaturalness of this procedure.”	0.8 (0.5 to 1.0)	1.91
Q20: “tDCS involves the use of medical technology. A medical professional, such as a doctor, should make the final decision as to whether a child should have this procedure.”	0.0 (−0.2 to 0.3)	1.92
Q22: “After using tDCS, my child’s achievements would no longer be his or her own doing.”	−0.3 (−0.6 to −0.1)	1.84
Q23: “My child is a gift. He or she will have different talents and flaws, as all people do. I should be accepting of my child, rather than intervening and trying to change him or her.”	1.2 (1.0 to 1.4)	1.62
Q24: “Struggle is necessary for developing good character. This would remove effort and make things too easy for my child.”	0.4 (0.1 to 0.6)	1.77
Q25: “If my child could gain the same improvements by taking a pill with no side effects, I would be more likely to give them the pill than tES.”	−0.3 (−0.5 to −0.0)	1.83

Note. Possible responses ranged from −3 to +3. Negative responses indicated disagreement, positive responses indicated agreement, and 0 indicated neutrality.

relationship. We found that parents were less willing to enhance any level of capacity compared to nonparents. After controlling for possible confounders, these differences were statistically significant only when considering enhancement of a below average capacity, with only 29% of parents willing, compared to 54% of nonparents ($p < .001$)

Parents also had more negative attitudes toward enhancement compared to nonparents. For instance, parents were more likely to agree that giving tDCS would “communicate to my child that I do not accept him or her, and create feelings of inadequacy and rejection” (parents: mean 0.7, 95% CI 0.3 to 1.1, nonparents: mean -0.1, 95% CI -0.5 to 0.2). Parents also appeared to have a greater degree of concern regarding the unnaturalness of tDCS (parents: mean 1.5, 95% CI 1.2 to 1.8, nonparents: mean 0.4, 95% CI 0.0 to 0.7). After controlling for possible confounders, including condition, parental status remained a significant predictor of attitudes to enhancement

Although parents had more negative enhancement attitudes than nonparents in all conditions, two-way ANOVA demonstrated a statistically significant interaction between parental status and condition in only Motivation (E) ($F(1, 43) = 7.351$, $p = .01$), and Empathy ($F(1, 35) = 4.651$, $p = .038$). Graphical analysis to interpret this interaction revealed that in conditions Motivation (P) and Motivation (E), the difference between parents’ and nonparents’ enhancement attitudes was much greater than in the other three conditions. Parents were much less pro-enhancement in Motivation (P) and Motivation (E). However, there was still a trend toward parents being less pro-enhancement than nonparents in the other three conditions.

Personality scales

There was no significant relationship between need for cognition and willingness to enhance, or conservatism and willingness to enhance.

Discussion

Willingness to enhance

The majority of respondents would not enhance their healthy child with tDCS, regardless of his level of capacity. This could reflect a belief that the treatment/enhancement distinction is morally relevant, which would indicate agreement with the ethicists Kass (2003) and Sandel (2009). The percentage of respondents willing to enhance an average capacity in our survey (25%) replicated the proportion willing to enhance an average or “normal” ability if doing so were safe and effective in the study by Ball and Wolbring (2014).

The majority of our respondents would wish their child could have a better capacity if the baseline was below average or average, but would not give tDCS. This finding can be interpreted in light of the study by Ball and Wolbring (2014), in which parents wanted their children to improve, but the majority preferred methods other than enhancement (such as hiring a tutor). The desire for their children to be better was necessary but not sufficient to make the decision to enhance. On the other hand, our results may indicate that lay people would be willing to enhance with interventions other than tDCS. Given the modest dislike for the

unnaturalness of tDCS demonstrated by our study, acceptable enhancers may be those seen as natural.

Factors associated with willingness to enhance

Level of capacity

Respondents were less reluctant to enhance traits from a lower compared to a higher baseline. In fact, a sizeable minority appears to believe that crossing the line from treatment to enhancement with tDCS would not be impermissible. Those willing to enhance a below-average capacity may view enhancement with tDCS as acceptable if it were to help their child overcome academic, social, or emotional struggles, even if she didn’t suffer from a diagnosed medical condition. Our respondents were slightly more inclined to agree that they would enhance their child with tDCS only if they determined it would improve her well-being. Respondents who did agree may subscribe to Levy and Savulescu’s view that what is important about tDCS is not whether it will treat disease, but whether it will improve well-being (Levy and Savulescu 2014).

Alternatively, our respondents may have been less reluctant to enhance traits from a lower compared to a higher baseline due to a belief that enhancing below-average traits would not violate the principle of fairness. Sabini and Monterosso (2005) explored this concept in their survey of undergraduate students, which found that providing the bottom 10% of performers with access to performance-enhancing drugs was seen as less unfair than if the top 10% had access, or if everyone had access.

Safety

The overwhelming majority of respondents would not enhance within a net zero-sum scenario. This replicates the findings of Ball and Wolbring (2014), where the use of potentially harmful interventions was seen as unacceptable in the absence of medical need. These findings implicate the moral importance of the treatment/enhancement distinction in public opinion. Subjecting one’s child to risks by giving the child medical treatment may be permissible if the aim is to prevent suffering and restore health. However, these same risks appear unjustifiable to the majority of lay people when the goal is enhancement.

Traits under consideration for enhancement

Authenticity. Based on the responses to question 5, “this would fundamentally change who my child is,” it can be inferred that lay people view empathy as most fundamental to a 10-year-old child’s self by comparison with the other traits considered. Motivation (P) was similarly viewed as a more fundamental trait, while Motivation (E) and Math were seen as less fundamental. The different perceptions of Motivation (P) and Motivation (E) could perhaps reflect the view that Motivation (E) fluctuates according to a child’s mood and the type of activity she is engaged in, whereas Motivation (P) is a core part of her personality that will remain more or less consistent over time.

Our finding that there is a reluctance to enhance traits perceived as more fundamental replicated the results of previous studies (Cabrera et al. 2014; Riis et al. 2008). However, unlike participants in the studies by Riis et al. (2008), our respondents were more likely to enhance a below-average mood than a below-average math ability. It is possible that of the five traits

considered, respondents would have most closely associated their child's well-being with mood. Math ability, by contrast, may have been viewed as less important to well-being and therefore as less attractive for enhancement, despite being perceived as less fundamental to self.

Our respondents' assessment of trait fundamentality differed from former studies examining self-enhancement by adults. Both the U.S. and Canadian participants recruited in a Mechanical Turk study by Cabrera et al. (2014) and the undergraduate students in the surveys by Riis et al. (2008) viewed mood as more fundamental to self than motivation.³ In contrast, we found that motivation was seen as more fundamental to self than mood. This may be related to the fact that one's identity is acquired through interaction with the environment in which one grows up. Therefore, young children may not yet have a fixed fundamental self that can be interfered with by enhancement (Nagel and Graf 2013). Lay people may believe this difference between adults and children can be used to distinguish fundamental traits based on age. Mood and Motivation (E) could be viewed as unstable in childhood, gradually becoming stable and therefore fundamental with age. However, this contrasts with the views expressed by parents in the study by Ball and Wolbring (2014). These participants felt that cognitively enhancing their child could change her "natural" or innate abilities, which would result in her being unable to express or even identify her "true self."

Achievement and authenticity

Respondents disagreed that enhancing with tDCS would be unfair or would cause their child's achievements to "not be his or her own doing." Moreover, other parents using tDCS for their children was not considered cheating. On the other hand, tDCS was seen as detrimental to the degree of struggle necessary for the development of good character. This seems contradictory. There is a belief that enhancement would discount effort, and yet also the view that a child's achievements would still be her own doing and therefore that authenticity, as it relates to achievement, would not be violated.

Our findings conflict with a review of over 40 studies, which found that a little more than half of respondents in most surveys believed that authenticity as it relates to achievement is violated when using pharmacological cognitive enhancements. A slight majority in those studies also viewed pharmacological cognitive enhancement as providing an unfair advantage to users, a situation that was seen as cheating (Schelle et al. 2014). However, previous surveys have usually focused on the use of Ritalin by university students. Tertiary education is generally more competitive than primary school, and, moreover, Ritalin may be perceived as enhancing traits that afford a greater advantage (e.g., concentration, alertness) than the traits investigated by our study.

Banning tDCS

We found that respondents were more likely to support a ban on empathy enhancement, whereas a ban on enhancing math

ability and mood received more opposition by comparison with the other conditions.

The tendency of respondents to oppose bans on enhancing math ability and mood conflicts with the views of tDCS researchers, the majority of whom thought tDCS should not be made available to the public (Riggall et al. 2015). However, it is important to note that our respondents were asked to consider a hypothetical version of tDCS that is known to be safe and effective, when in reality it has a poorly understood risk-benefit ratio.

Our findings also contrast with the findings of Riis et al. (2008) from their surveys regarding adult self-enhancement. The majority of participants in their study supported a ban on math ability enhancement (53%), whereas most did not desire a ban on enhancing motivation, empathy, or mood.

The difference between the results of our study and those of Riis et al. (2008) could be explained by fundamentality strongly influencing both the willingness to enhance and the desire to ban access to tDCS for our respondents. Although it is acceptable for adults, as autonomous beings, to make decisions for themselves that others may disapprove of, parents should make decisions for their child guided by what is in his best interests. Presumably, lay people believe it would not be in the best interests of children to have their fundamental self interfered with, and this may explain our respondents' support for a ban on enhancing empathy but not math ability.

A ban on empathy enhancement garnered the most support in our study. Empathy can be distinguished from the other traits considered in this study because it does not directly serve the self-interests of the child. Others could take advantage of an enhanced child's increased capacity for compassion, and this concern may have underpinned support for such a ban. This may also explain why the majority of respondents in Empathy would not even wish their child could have a better than above-average capacity, compared to a minority in the other conditions.

Understanding the general public's views allows us to postulate the policy decisions that would be supported in the United States specifically, but perhaps also in culturally similar Western countries. Our data suggest that the public would not support banning the use of tDCS for enhancing nonfundamental traits, as long as doing so would be safe and not against a child's best interests. This is likely related to our finding that lay people do not think tDCS would violate authenticity (as it relates to accomplishments), nor do they think it would constitute cheating.

Implicit coercion

We found that respondents were more likely to give tDCS to their child if other parents were using it for their children, and as a result their child could be disadvantaged without it, which is consistent with previous studies (Ball and Wolbring 2014; Schelle et al. 2014). Together with our finding that the majority of people would not be willing to enhance, this suggests that many lay people averse to enhancers could feel compelled to give their children tDCS due to implicit coercion. Therefore, if tDCS were found to have side effects, it may be wise to introduce regulation to prevent its misuse on children.

Unnatural means

There was a modest dislike of the tDCS procedure and its unnaturalness in this sample, with parents being significantly

³Defined as perseverance in the study by Cabrera et al. (2014) and as "motivation to accomplish one's personal goals" in the studies by Riis et al. (2008).

more averse to the artificial nature of tDCS than nonparents. This is in keeping with previous studies, which have found a preference for enhancers perceived as natural over artificial ones (Ball and Wolbring 2014; Marteau et al. 1995; Schelle et al. 2014). The qualitative study by Ball and Wolbring (2014) identified that a factor underlying this preference is parents' intuition that natural enhancers (such as vitamins) are lower risk, and only have beneficial effects or no effects at all. In reality, this is not always the case (e.g., some vitamins can be toxic in high doses). Regardless, this is an objection about the safety of enhancers, not their unnaturalness. It remains uncertain whether lay people in our sample and in other studies believe that "natural" products are superior to artificial ones because of their naturalness, or for other reasons.

Parental status

Parents expressed significantly more negative enhancement attitudes in Empathy and Motivation (E) compared to nonparents. As previously noted, Empathy was assessed as a more fundamental trait. Motivation (E) enhancement, on the other hand, could alter the preferred hobbies of a child. It is therefore plausible that these parents shared similar concerns to the parents in the study by Ball and Wolbring (2014), who feared that enhancement would interfere with their child's ability to express or even identify his "true self."

Parents were significantly less willing to enhance below average capacities compared to nonparents. This may be partly explained by our finding that parents were more likely than nonparents to agree that giving tDCS would communicate to their child that he is unacceptable, and would make him feel inadequate or rejected. Parents in our sample appeared to agree with those in the study by Ball and Wolbring (2014), who worried that giving cognitive enhancers would damage the parent-child relationship by making their child feel unworthy, unloved, and excessively pressured to achieve success.

These differing enhancement attitudes between parents and nonparents have potential implications for the normative debate regarding the genetic enhancement of embryos. Prospective parents considering embryo selection or genetic manipulation are arguably in the same position as nonparents in our sample: only imagining themselves in the role of parent. Although they make decisions that will affect their future child, they do not yet have a relationship with that child. Moreover, the embryo is not a conscious being with an identity that could feel rejected by the parent's decision to enhance.⁴ Consequently, decisions to genetically enhance before birth may be impacted by different moral considerations than those concerning enhancement during childhood.

Limitations

One limitation of this research is that the data collected were quantitative rather than qualitative. Examining responses to

questions aimed at discerning enhancement attitudes allowed hypotheses to be formed, but it was not possible to determine the exact reasons underlying the majority's reluctance to enhance with tDCS.

Since our data are quantitative, the likelihood that they can be used to accurately predict policies that would be acceptable to the public is difficult to determine. Moreover, the version of tDCS described was uncomplicated by comparison with current models being investigated. Evidence suggests that tDCS should be applied over multiple sessions to be effective (Monte-Silva et al. 2013), and moreover, tDCS is known to cause at least minor side effects such as itching and tingling of the scalp (Stagg and Nitsche 2011). The theoretical version of tDCS described to participants was easy to understand and allowed our hypotheses to be tested, but it may have reduced the applicability of findings to policy development.

A third limitation is that while our power calculation shows that our sample size was sufficient, we also conducted additional within-condition analyses. These essentially reduce the sample size to the number of respondents in the particular condition. Whether the power is sufficient for these analyses is questionable, and we do not have quantitative hypotheses based on prior empirical research to make power calculations. This part of the analysis is more exploratory, though it could be used to guide further research.

Lastly, respondent's willingness to enhance from lower compared to higher baselines was tested within rather than between conditions. As respondents progressed through questions 1 to 3, reading about below-average, then average, then above-average capabilities, it may have been apparent to them that the researchers expected a reluctance to enhance above-average children. It is possible that responses could have been affected by this arrangement of questions.

Future directions

Future research could use qualitative methods to elicit the rationale behind lay people's reluctance to enhance with tDCS. The possibility that most lay people would be willing to enhance if provided with interventions they find suitable should also be investigated, along with the reasons underlying a preference for "natural" over artificial enhancers. Since our study did not find a relationship between conservatism or need for cognition and willingness to enhance, future studies could explore other personality traits (e.g., risk aversion) and their relationship to willingness to enhance.

Conclusions

Numerous social and ethical consequences would emerge from enhancing children with tDCS, and there is wisdom in researching these before use of this technology becomes more common. This study is novel in that it was the first to examine public attitudes to this issue. The major finding was that the majority would not be willing to enhance their child with tDCS, particularly if fundamental traits were under consideration for enhancement. Our data suggest, nevertheless, that lay people may not support a ban on tDCS if it were safe and used to enhance nonfundamental

⁴Although later on as a child or adolescent, he could suspect that his parent's love is conditional on his behaving or being a certain way. For instance, on discovering that his parents enhanced his intelligence, he may worry that his parents will not accept him if he doesn't perform well academically.

traits. It would be wise to regulate the use of tDCS on children in order to prevent misuse, since individuals who are reluctant to enhance may give in to implicit coercion to give tDCS to their child.

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Author contributions

The research topic was decided in consultation between Dr. Katy Wagner and Professor Julian Savulescu. Professor Julian Savulescu also provided initial directions as to relevant areas of the literature, along with Dr. Hannah Maslen and associate professor Justin Oakley.

Dr. Katy Wagner drafted and refined the questionnaire in collaboration with Dr. Hannah Maslen and Professor Julian Savulescu. Dr. Katy Wagner then implemented the questionnaire by recruiting participants online. The resulting data set was collated and analyzed under the guidance of Dr. Hannah Maslen.

Dr. Katy Wagner drafted this article in its entirety under the kind supervision of Dr. Hannah Maslen. She reviewed and provided invaluable feedback on several drafts. Professor Julian Savulescu and associate professor Justin Oakley reviewed and provided feedback on a final draft. No other persons contributed to this article.

Conflicts of interest

None.

Ethical approval

This study was approved by the institutional review boards at the University of Oxford Central University Research Ethics Committee and the Monash University Human Research Ethics Committee.

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