Why? Baratgin *et al*. do not say. According to the model theory, the disjunction refers to a conjunction of three possibilities:

A and not-B

not-A and B

A and B

and one impossibility: not-A and not-B. (Disjunctions of the form A or not-A refer to two possibilities: A, and not-A, because the conjunction, A and not-A, yields the null model, akin to the empty set.) Because A does not imply the second possibility in the conjunction, i.e., not-A and B, the conjunction is false. The inference above is accordingly invalid in the model theory. Baratgin *et al*. object that these semantics make almost every disjunction true. However, from any true proposition, A, both logic and p-logic spawn an infinity of inclusive disjunctive conclusions, each containing a new proposition:

A or B.

A or B or C.

A or B or C or D.

... and so on *ad infinitum*.

These inferences are invalid in the model theory, which therefore renders fewer disjunctions true than does either logic or p-logic.

The model theory explains the vagaries in human inference, it predicts correctly more phenomena than any other theory (Table 3 in [1]), and, so far, it remains a feasible integration of deductive and probabilistic reasoning [10,11].

[1]Princeton University, Princeton, NJ, USA
[2]New York University, New York, NY, USA
[3]Naval Research Laboratory, Washington, DC, USA
[4]University of Pennsylvania, Philadelphia, PA, USA

*Correspondence:
Johnson-Laird, P.N. (phil@princeton.edu).

http://dx.doi.org/10.1016/j.tics.2015.06.014

References

1. Johnson-Laird, P.N. *et al.* (2015) Logic, probability, and human reasoning. *Trends Cogn. Sci.* 19, 201–214
2. Adams, E.W. (1998) *A Primer of Probability Logic*, Center for the Study of Language and Information
3. Baratgin, J. *et al.* (2015) The new paradigm and mental models. *Trends Cogn. Sci.* 19, 547–548
4. Kraus, K. *et al.* (1990) Nonmonotonic reasoning, preferential models and cumulative logics. *Artificial Intellig.* 44, 167–207
5. Khemlani, S. and Johnson-Laird, P.N. (2012) Theories of the syllogism: a meta-analysis. *Psychol. Bull.* 138, 427–457
6. Chater, N. and Oaksford, M. (1999) The probability heuristics model of syllogistic reasoning. *Cogn. Psychol.* 38, 191–258
7. Johnson-Laird, P.N. *et al.* (1999) Naive probability: a mental model theory of extensional reasoning. *Psychol. Rev.* 106, 62–88
8. Khemlani, S. *et al.* (2014) Naive probability: model-based estimates of unique events. *Cogn. Sci.* 1–43
9. Goodwin, G.P. (2014) Is the basic conditional probabilistic? *J. Exp. Psychol. Gen.* 143, 1214–1241
10. Orenes, I. and Johnson-Laird, P.N. (2012) Logic, models, and paradoxical inferences. *Mind Lang.* 27, 357–377
11. Khemlani, S. *et al.* (2014) Causal reasoning with mental models. *Front. Hum. Neurosci.* 8, 1–15

Scientific Life

# Cognitive Enhancement and Beyond: Recommendations from the Bioethics Commission

Anita L. Allen[1,2] and Nicolle K. Strand[1,*]

**Media outlets are reporting that cognitive enhancement is reaching epidemic levels, but evidence is lacking and ethical questions remain. The US Presidential Commission for the Study of Bioethical Issues (Bioethics Commission) has examined the issue, and we lay out the commission's findings and their relevance for the scientific community.**

## Cognitive Enhancement and Beyond: Defining the Scope

This year, the US Bioethics Commission, of which the authors are a Member and staff member, respectively, released the second volume of its report on neuroscience and ethics – *Gray Matters: Topics at the Intersection of Neuroscience, Ethics, and Society* [1]. In it, the Bioethics Commission explored public and scholarly debates relating to improved understanding of the brain and nervous system. Among them was the debate over the use of so-called 'cognitive enhancement.'

The term 'cognitive enhancement' generally refers to a measure for expanding or augmenting the human capacity to think, feel, react, and remember, potentially 'beyond the species-typical level or statistically-normal range of functioning' [2]. Because novel applications of science to expand human capacities are nearly always controversial, it is not surprising that the novel use of neuroscience to enhance cognition is hotly contested.

An April 2015 *New York Times* article examined debates surrounding the growing use of the stimulant drug Adderall by young adults without the condition for which it is indicated. Adderall and other stimulants are used off-label by individuals who desire to increase their competitive advantage by working longer hours with greater attentiveness while sleeping less [3]. At every turn, we see headlines announcing 'epidemic' amphetamine use by high-achieving students seeking top grades and standardized test scores. Advertisements for high-tech brain-stimulation devices claim to make us more focused or improve our learning and memory, while essentially the same brain-boosting effects are claimed for low-tech approaches – such as dietary supplements including omega-3 fatty acids derived from fish oil and a good night's sleep. Researchers say that particular drugs can dampen memories to ease the emotional pain of victims of trauma.

Questions surround all these methods of cognitive enhancement, including: do they really work? Do they tamper with moral autonomy and personality? Is it ethical to employ them? Is there an ethical line between simply preventing or treating deficiencies to achieve 'normal' functioning, and using drugs or devices to make us better, even 'super-human'? Ought we to expend resources trying to make perfectly normal people smarter or more efficient? The Bioethics Commission attempted to answer some of these questions, and clear a path for reasonable, informed, and productive discourse.

## Looking Beyond Cognitive Enhancement

Through *Gray Matters*, the Bioethics Commission sought to engage the public in a discussion of the cognitive enhancement debate, and moved beyond it to assess a wider array of interventions, technologies, behaviors, and environmental conditions that can affect many aspects of the human brain and nervous system. We used the term 'neural modifiers' to refer to this wider array of mechanisms of brain and nervous system change.

We identified three broad categories of neural modifiers: those that are intended to maintain or improve neural health within normal limits; those that are meant to treat disease or deficiency; and, most controversial, those that are intended to expand or augment beyond normal function. We asserted that no category of neural modification – even those that make us better than 'normal' – is inherently ethical or unethical. Instead, each neural modifier should be assessed on its own terms, on a case-by-case basis, to determine whether use is ethical in a particular context. Stakeholders and members of the public need to ask questions to make this ethical assessment, such as: what is the method and purpose of the neural modifier? Is it safe and effective for that purpose? Who is choosing the modifier, and is anyone being coerced? Who might be harmed by its use? Who might benefit? Will those benefits and harms be justly distributed?

## Being Mindful of Hype

Neuroscience research holds tremendous promise, but it is also the subject of excessive media hyperbole. The Bioethics Commission cautions against over-claiming and exaggeration. Conversations about neural modification and cognitive enhancement in particular generate hype among scholars, journalists, and the public. For example, attention-grabbing headlines tend to exaggerate the potentially enhancing effects of drugs such as Ritalin and Adderall that are normally used in the treatment of attention deficit hyperactivity disorder; Provigil, prescribed for sleep disorders and alertness; and devices including transcranial magnetic stimulation and transcranial direct current stimulation to treat brain injuries and stroke. In general, the actual enhancing effects of these interventions are far lower than expectations would suggest [4]. Neuroscience research demonstrates that some drugs and brain-stimulation devices can have modest enhancing effects on some cognitive abilities in healthy individuals under particular conditions [5,6]. However, the size and duration of these effects and their generalizability to real-world settings remain uncertain [7]. Hyperbole can distort ethical analysis and debate with unfounded and inflated expectations. More importantly, it can put people in harm's way, because alleged benefits overshadow less-publicized known risks and side effects, including long-term effects. Scientific researchers can play a role in mitigating hype by participating in the process of reporting and publicizing results, and working to ensure that they are communicated responsibly.

## Recommendations for the Scientific Community

We made five recommendations to a variety of stakeholders with the goal of facilitating ethical research and use of neural modifiers (Table 1). Several of those recommendations have direct applications to the scientific community. First, we urged

Table 1. Recommendations to Facilitate Ethical Research and the Use of Neural Modifiers

| Recommendation Summary | Stakeholders Targeted |
|---|---|
| *Recommendation 1. Prioritize existing strategies to maintain and improve neural health*<br>• Prioritize existing, low-tech strategies rather than novel, high-tech neural modifiers that are often very expensive and might have minimal or uncertain benefit | Researchers and research funders |
| *Recommendation 2. Prioritize treatment of neurological disorders*<br>• Prioritize research to treat neurological disorders to improve health and alleviate suffering | Researchers and research funders |
| *Recommendation 3. Study novel neural modifiers to augment or enhance neural function*<br>• Support research on the prevalence, benefits, and risks of new neural modifiers to augment or enhance neural function | Researchers and research funders |
| *Recommendation 4. Ensure equitable access to novel neural modifiers to augment or enhance neural function*<br>• Ensure equitable access to beneficial, safe, effective, and morally-acceptable neural enhancers | Policymakers and other stakeholders |
| *Recommendation 5. Create guidance about the use of neural modifiers*<br>• Develop guidance for clinicians, employers, parents, educators, and patients about the use of neural modifiers and their potential risks and benefits<br>• Do not prescribe medications with uncertain or unproven benefits and risks to children and adolescents who do not have neurological disorders. | Professional organizations, other expert groups, and clinicians |

prioritizing existing, low-tech strategies for maintaining and improving neural health, rather than novel, high-tech strategies that are often very expensive and have uncertain or unproven benefits. A great deal of evidence exists that healthy diet, adequate exercise and sleep, and high-quality education are associated with improved and healthy cognitive function, and are safe and carry virtually no risk of harm. Public health measures such as lead-paint abatement and requirements for toxin-free workplaces support neural health. Continuing to advance science in these areas can help the public improve its understanding of optimal lifestyles and environmental conditions.

Second, we urged prioritization of treatment of neurological diseases and injuries, versus the development of new drugs and devices solely to make people smarter. The burden of neurological disorders is high and is projected to increase considerably in future years with an aging population. Neurological disorders are estimated to affect as many as a billion people globally, including millions of people in the USA alone [8]. One of the primary goals of neuroscience is to prevent and treat these disorders. Directing research funding towards treatment, rather than enhanced cognition, helps to improve the lives of millions of individuals, attends to justice, and honors the primary goal of scientific inquiry.

However, although we recognized the need to prioritize both low-tech strategies to improve neural function and new techniques to treat disease, we did not ignore newer, high-tech enhancement techniques. Our third recommendation was that research should be conducted on the prevalence, benefits, and risks of new neural modifiers to augment or enhance neural function. Very limited evidence of this type exists for the off-label use of stimulant drugs such as Adderall or the use of brain-stimulation techniques including transcranial direct stimulation to improve cognition in healthy people. Before society can make accurate ethical assessments of these novel enhancement techniques, we must understand them.

If research does demonstrate that particular novel neural enhancers are safe and beneficial, then stakeholders must seek justice in their distribution. In our fourth recommendation, we urged that policymakers ensure equitable access to beneficial neural enhancers. In our society, access to existing services and opportunities, such as education and nutrition, is not equal across individuals or groups. However, societal tolerance of inequity in access to other crucial goods does not make inequity right, nor should it hamper society's efforts to reduce or eliminate inequity where we can. If safe and effective novel forms of cognitive enhancement become available, they will present an opportunity to insist on a distribution that is fair and just. While not eliminating all other less tractable forms of injustice in the distribution of neural health and well-being, it is possible to ensure that any new forms of safe and beneficial neural modification do not worsen those injustices.

## Concluding Remarks

By broadening the discussion of cognitive enhancement to include all forms of neural modification, the Bioethics Commission has expanded the scope of the current debate. Neural modification – to maintain or improve brain health within typical or statistically normal ranges, treat neurological disorders, and expand or augment neural function – raises a set of ethical considerations. Our recommendations are intended to serve as a resource for scientists, physicians, and policymakers. We hope they will spark a broader discussion of these issues and serve as an impetus for scientists to consider how the research they conduct today could transform society, for better or worse, in the years to come.

[1]Presidential Commission for the Study of Bioethical Issues, 1425 New York Ave NW, Washington, DC 20005, USA

[2]Office of the Provost, University of Pennsylvania, 120D College Hall, Philadelphia, PA 19104, USA

*Correspondence: nicolle.strand@bioethics.gov (N.K. Strand).

http://dx.doi.org/10.1016/j.tics.2015.08.001

References

1. Presidential Commission for the Study of Bioethical Issues (2015) *Gray Matters: Topics at the Intersection of Neuroscience, Ethics, and Society*, Presidential Commission for the Study of Bioethical Issues
2. Allhoff, F. *et al.* (2011) Ethics of human enhancement: an executive summary. *Sci. Eng. Ethics* 17, 201–212
3. Schwarz, A. (2015) Workers seeking productivity in a pill are abusing ADHD drugs. *New York Times* 18 April
4. Repantis, D. *et al.* (2010) Modafinil and methylphenidate for neuroenhancement in healthy individuals: a systematic review. *Pharmacol. Res.* 62, 187–206
5. Cakic, V. (2009) Smart drugs for cognitive enhancement: ethical and pragmatic considerations in the era of cosmetic neurology. *J. Med. Ethics* 35, 611–615
6. Maslen, H. *et al.* (2014) The regulation of cognitive enhancement devices: Extending the medical model. *J. Law Biosci.* 1, 68–93
7. Farah, M.J. *et al.* (2014) Cognitive enhancement. *WIREs Cogn. Sci.* 5, 95–103
8. World Health Organization (2006) *Neurological Disorders: Public Health Challenges*, World Health Organization

Forum

# Resolving Ambiguities of MVPA Using Explicit Models of Representation

Thomas Naselaris[1,*] and Kendrick N. Kay[2,#]

**We advocate a shift in emphasis within cognitive neuroscience from multivariate pattern analysis (MVPA) to the design and testing of explicit models of neural representation. With such models, it becomes possible to identify the specific representations encoded in patterns of brain activity and to map them across the brain.**

MVPA is a powerful analysis tool that is replacing activation (or subtraction-based) analysis as the go-to method for