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Scientific Life

Cognitive Constraints Shape Public Debate on the Risks of Synthetic Biology

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We consider efforts to understand public perceptions of synthetic biology, describing a novel cognitive science approach indicating that cognitive biases constrain risk perceptions of synthetic biology. We discuss the implications of these findings and outline how they may be harnessed to improve the quality of public debate.

Synthetic Biology and Public Engagement

Synthetic biologists aim to design, build, and control biological parts, organisms, and systems in order to fulfil human goals, ultimately to recast biology as an engineering discipline. Alongside the rapid expansion of the field over the last decade has come an evolving consideration of the ethical and social implications of synthetic biology technologies. Early notions of public engagement as an exercise in education have been replaced by more sophisticated ideas of inclusive interactions with a diversity of publics [1]. One important upshot of this is that end-users are increasingly encouraged to make their views heard from the earliest stages of innovation, and there is increasing emphasis on incorporating these views into the structure of synthetic biology research. Examples include the important role of responsible research and innovation (RRI) in the UK's Synthetic Biology Research Centres – WISB (Warwick University), BrisSynBio (Bristol University), UK Centre for Mammalian Synthetic Biology (Edinburgh University), Nottingham SBRC (Nottingham University), Open Plant SBRC (Cambridge University) – and the Oxford-Warwick-Bristol Centre for Doctoral Training in Synthetic Biology (SynBio CDT).

Notwithstanding these positive developments, we argue that there has been an important gap in efforts to understand and anticipate reactions to synthetic biology technologies. Specifically, we propose that there are cognitive constraints on ordinary reasoning about synthetic biology technologies, and that these constraints have significant practical implications for the quality of public debate around synthetic biology. Several decades of research in the cognitive sciences have demonstrated that people commonly rely on heuristics – mental shortcuts or patterns of intuitive reasoning – to make decisions and form judgments [2]. These heuristics served a clear purpose in our evolutionary past, aligning with reliable structures in the physical and social worlds to streamline and optimise our thoughts and behaviour. Such intuitive thinking can, however, lead us astray, especially in contemporary situations, underpinning recurring cognitive biases in our interactions with the world. For example, prominent research has demonstrated the impact of heuristics and biases in financial decision-making, undermining classical notions of economic rationality and fundamentally changing the field of economics [3].

A Novel Approach: Cognitive Constraints on Evaluating Synthetic Biology

A large body of research has demonstrated that human cognition also constrains thinking about science and technology (Box 1). We propose that cognition will place specific constraints on thinking about synthetic biology. The field of synthetic biology poses unique challenges to ideas about the boundaries between life and non-life, the evolved and the designed, and the natural and the synthetic. These distinctions correspond to the intersection of well-studied domains of intuitive human reasoning; most notably, cognitive constraints on reasoning about the biological world [4–7], and constraints on moral reasoning about human actions. There is little doubt that the interaction of these intuitive cognitive frameworks will significantly impact reasoning about the engineering of life.

We have already begun to empirically investigate this novel idea and have found evidence that intuitive essentialist reasoning about biology (Box 2) shapes risk assessments of specific synthetic biology technologies [8]. Our research indicates that genes provide a particularly compelling placeholder for ideas of 'essence', such that the deliberate addition of foreign genes (from another organism, or a new-to-nature gene) is reasoned about as changing an organism's essence, with implications for both moral and risk evaluations of the modified organism. A prominent theory from the moral cognition literature holds that moral concerns are not restricted to issues of harm (i.e., the moral disapproval of actions that cause pain and suffering) but also encompass moral concerns about physical or social impurities [9]; even harm-free actions can be deemed morally wrong if they violate notions of purity or sanctity. Our research indicates that changing an organism's essence by adding a foreign gene violates notions of moral purity, leading not only to more negative moral evaluations of the technology, but also, importantly, more negative risk assessments [8].

The cognitive constraints conferred by essentialist thinking and intuitions about moral purity have two important consequences when people come to assess the risks of synthetic biology

Box 1. Cognitive Approaches to the Understanding of Science and Technology

Many cognitive biases relate to the casual-explanatory frameworks that we apply to the natural world, encompassing a kind of 'folk' biology and physics that guide our intuitive responses to the world around us. Research has shown that these frameworks can exert a powerful influence on the way people reason about the scientific realm, with implications for the effective communication of core scientific principles to the wider public [4–7,11,12]. More recently, researchers have proposed that specific aspects of cognition may constrain perceptions of biotechnologies such as vaccinations [13] and GMOs [14].

Box 2. Psychological Essentialism

Psychological essentialism is the theory that people hold an intuitive assumption of an internal, unobservable, essential property common to members of a natural kind; an essence or force that conveys identity and makes members of a category what they 'really are' [15]. Psychological essentialism is a fundamental and cross-culturally robust aspect of thinking, but applies only to certain types of categories; distinctions between human-designed artefacts, such as different types of furniture, are conventional and subjective, while distinctions between different animal and plant species are generally viewed as objective and natural. People need not know what an essence is, or where it is, to behave as if there is one; we readily reason in terms of some type of 'essence placeholder' as a deep, internal and causally responsible force.

technologies. The first is that a person's general tendency to worry about moral purity violations – a trait that varies across the population – is strongly predictive of their assessments of the riskiness of a given synthetic biology technology; we can tell a good deal about a person's views of the risks of a synthetic biology just by knowing their general concern for moral purity violations. The second is that those technologies that are intuitively believed to involve more change to an organism's essence will be more likely to be judged as risky; modifying a tomato plant by adding a mouse gene, for example, entails more essence change – and will be judged to be more risky – than adding a gene from a similar plant like a cucumber (Figure 1). In other words, risk assessments will vary in predictable ways based on the origin of any foreign genetic material added to an organism, with cisgenic changes deemed less problematic than transgenic. Notably, adding new-to-nature genes is judged as both substantially less morally wrong and somewhat less risky than transgenic modification with a gene from an animal (Figure 1). In light of the widespread assumption that new-to-nature approaches will be more negatively evaluated than existing transgenic technologies [1], this is a surprising finding. However, it may be that new-to-nature genes are seen not entirely as natural kinds, but at least in part as human-designed artefacts, lacking in internal, immutable essences. This would somewhat limit the threat of a new-to-nature gene to a recipient organism's essence, at least as compared with some types of transgenic modifications.

Impact of Cognitive Constraints on Innovation and Public Debate in Synthetic Biology

These cognitive constraints on reasoning about synthetic biology will have

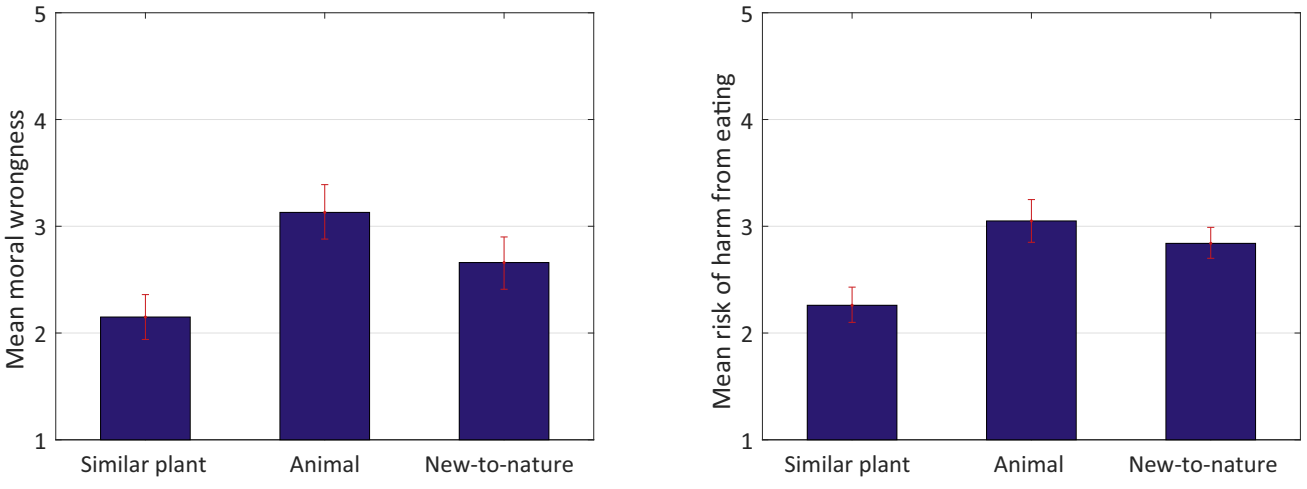

Figure 1. Mean Moral and Risk Judgments by Foreign Gene Source. Mean judgments of moral wrongness of adding a gene to a plant (left) and risk of harm from eating a plant with a gene added (right) on a scale from 1 (definitely not) to 5 (definitely yes) as they vary depending on the origin of the foreign gene added. Error bars show 95% confidence intervals around the means. The addition of a gene from a taxonomically distant animal (a mouse) is considered substantially more morally wrong than adding a new-to-nature gene ($P < 0.0001$) and somewhat more risky to eat ($P = 0.016$). The addition of a new-to-nature gene is itself considered substantially more morally wrong than adding a gene from a similar plant ($P < 0.0001$) and substantially more risky to eat ($P < 0.0001$). Figure adapted under a Creative Commons license from [8].

important practical implications for efforts to stimulate public debate and embed responsible research and innovation. One implication relates to discussions about the moral and ethical dimensions of engineering life. Moral objections are a common theme in dialogues on synthetic biology and are increasingly recognised as important elements of debates on responsible innovation. We suggest that it will be useful to understand that the source of moral disapproval is unlikely to be direct concerns about harm that the technology might cause. Rather, it is likely to stem from concerns about moral purity (i.e., concerns that the technology violates the natural order, or transgresses taxonomic boundaries). Those who find the technology morally untroubling, by contrast, will be more likely to justify their moral position in terms of a lack of potential for harm [8].

In the case of risk assessments, the impact of cognitive constraints has a different set of implications. While it is important not to overlook debate and scientific uncertainty in some areas of risk assessment [10], there do exist areas of scientific consensus. For example, it is widely agreed that, when it comes to the potential risk of harm from eating a genetically engineered organism, it is not the origin of the genetic material that confers risk, but rather the function of the genetic alteration, for example, whether it could cause the organism to express a new toxin [https://www.nationalreview.com/2016/07/gmo-labeling-unnecessary-meaningless-and-misleading/]. Our findings indicate that lay-assessments of risk – and even more specifically, lay-assessments of the risk of harm from eating – deviate sharply from this consensus, with variations in gene-origin underpinning substantial differences in risk perception. Helpfully, a cognitive approach does not just allow us to uncover whether lay-persons' perceptions of risk deviate from scientific consensus, it also provides a theoretical framework for understanding why they deviate, holding out the prospect that the impact of the relevant cognitive constraints might be mediated or reduced by certain interventions. Such an enterprise would be novel as applied to synthetic biology risk perceptions but would follow a long tradition of leveraging theoretical insights to reduce cognitive bias in other domains. In the area of biology education, for example, tools have been developed to reduce the deleterious effect of essentialist reasoning on learning core tenants of evolutionary theory [5,11]; similarly targeted tools could plausibly be woven into both formal and informal activities and discussions around synthetic biology.

Improving the Quality of Public Debate

It is important to make explicit that leveraging cognitive insights to improve the quality of public debate about synthetic biology does not constitute instrumental research; in other words, it does not entail an agenda-driven approach with the aim of 'persuading' the public of particular benefits of synthetic biology. After all, in the case of synthetic biology approaches involving new-to-nature genes, it seems that cognitive constraints may in fact confer an unwarranted advantage to proponents of the technology, leading such technologies to be seen as intuitively safer than their transgenic predecessors. Rather, the methods and theories of the cognitive sciences provide an opportunity to shed light on the structures, processes, and details that matter to ordinary people as they evaluate these extraordinary new technologies, to explore how this varies across populations, and to ensure that – as we balance potential risks against proposed benefits – the scales are accurately stacked.

Acknowledgements

WISB is a BBSRC/EPSRC Synthetic Biology Research Centre (grant ref: BB/M017982/1) funded under the UK Research Councils' Synthetic Biology for Growth programme. L.S. is a Research Career Development Fellow in the School of Life Sciences funded by the University of Warwick.

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https://doi.org/10.1016/j.tibtech.2018.09.002

References

1. Marris, C. (2015) The construction of imaginaries of the public as a threat to synthetic biology. *Sci. Cult.* 24, 83–98
2. Tversky, A. and Kahneman, D. (1974) Judgment under uncertainty: heuristics and biases. *Science* 185, 1124–1131
3. Kahneman, D. (2003) Maps of bounded rationality: psychology for behavioral economics. *Am. Econ. Rev.* 93, 1449–1475
4. Coley, J.D. and Tanner, K.D. (2012) Common origins of diverse misconceptions: cognitive principles and the development of biological thinking. *CBE-Life Sci. Educ.* 11, 1–7
5. Coley, J.D. and Tanner, K. (2015) Relations between intuitive biological thinking and biological misconceptions in biology majors and nonmajors. *CBE-Life Sci. Educ.* 14, ar8
6. Kelemen, D. and Rossett, E. (2009) The human function compunction: teleological explanation in adults. *Cognition* 111, 138–143
7. Shtulman, A. and Schulz, L. (2008) The relation between essentialist beliefs and evolutionary reasoning. *Cognitive Sci.* 32, 1049–1062
8. Swiney, L. (2018) Intuitive biology, moral reasoning, and engineering life: essentialist thinking and moral purity concerns shape risk assessments of synthetic biology technologies. *PsyArXiv* http://dx.doi.org/10.31234/osf.io/pzy98 Published online July 10, 2018
9. Graham, J. *et al.* (2011) Mapping the moral domain. *J. Pers. Soc. Psychol.* 101, 366
10. Jefferson, C. *et al.* (2015) *Synthetic Biology and Biosecurity: How Scared Should We Be?* King's College London
11. Emmons, N.A. and Kelemen, D.A. (2015) Young children's acceptance of within-species variation: implications for essentialism and teaching evolution. *J. Exp. Child Psychol.* 139, 148–160
12. Shtulman, A. (2017) *Scienceblind: Why Our Intuitive Theories about the World Are so Often Wrong,* Basic Books
13. Miton, H. and Mercier, H. (2015) Cognitive obstacles to pro-vaccination beliefs. *Trends Cogn. Sci.* 19, 633–636
14. Blancke, S. *et al.* (2015) Fatal attraction: the intuitive appeal of GMO opposition. *Trends Plant Sci.* 20, 414–418
15. Gelman, S.A. (2003) *The Essential Child: Origins of Essentialism in Everyday Thought (Oxford Series in Cognitive Development),* Oxford University Press