Engaging publics in imagining the future of engineered living materials

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Defined as any "composite material that has a biologically derived component and a synthetic component"[1], engineered living materials (ELM) are technologies that respond to environmental cues, are able to remodel, self-organise and self-heal. An alternative definition of 'animate materials' identifies the key defining characteristics of this type of materials as being active, adaptive and autonomous.[2] A standard approach entails genetically engineering cells to optimize the biosynthesis and assembly of cellular materials, such as cellulose, enzymes and structural proteins, or to express materials derived from other organisms. Emergent ELM applications include the design of macroscopic functional materials deploying fungi, mammalian cells or consortia of unicellular organisms. ELMs are seen to have "the potential to transform virtually every modern endeavour from healthcare to infrastructures to transportation"[3].

These potential wide-ranging implications for domains across society suggest ELMs, as a research field, could benefit from drawing on 'responsible research and innovation' framework (RRI). RRI is a set of approaches that aims to support the collective, reflexive exploration of possible technological futures, through inclusive and responsive processes.[4] Given the exploratory nature of ELM research, it has been suggested that public engagement in ELMs should foster collective imagination, "harnessing ideas, creating a repository of ideas for future applications of animate materials"2. To address this challenge, we drew on the methodology of speculative design[5] and invited members of the public to participate in a set of activities aimed at exploring and discussing the social implications of these new materials for everyday life in the future.

Methods

Our main aim was to assess the feasibility and fruitfulness of using speculative design methodologies in engaging stakeholders in discussing the social and ethical implication of future ELMs. Speculative design enables anticipatory engagement that is essential to responsible innovation, while facilitating contributory membership, which are usually restricted by expertise boundaries. In order to ensure that participants were able to envision future ELM uses, we designed a set of activities building from existing experiential knowledge to scaffold engagement with set of scenarios as probes through which speculative ideas could be generated and made manifest. We structured the workshops in two phases: 1)Participants were asked to place familiar organisms along dichotomous scales of roles, relationships and perceptions, followed by a group discussion. 2) We developed collaborative story telling templates -3 fictional scenarios of technological use (Fig 1) - intended as prompts to elicit collective sense making.

Given the structure of the activities we designed, we envisaged a sample size of 12-15 participants, distributed across two workshops. We obtained a diverse sample (N=10), with a good spread and fair proportionality in relation to the stakeholder map we drafted, including individuals working in medicine, nature conservation, science, engineering, market research, amateur gardening, farming, games design, and art.

Workshops (2×3 hrs) were conducted online, recorded and transcribed verbatim. We used standard qualitative data analysis techniques[6] to identify themes and forms of reasoning used by participants to make sense of our possible futures with ELMs. The value of qualitative data is less on its

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generalisability and more on the ability to identify unknown dimensions of stakeholder and public views on emerging technologies. Our analysis should be further validated by extending data collection points. Ethical approval was obtained from the Durham University Dept of Sociology Ethics Committee.

Results

Our analysis identified three main themes in the data (see Table). Participants made sense of the type of relationship ELMs' would entail in everyday life by reflecting on issues of control and predictability. They saw ELMs as requiring a more user-centred collaborative form of engagement than standard engineered materials. While it was acknowledged that ELMs might decrease the amount of control users have of the technologies they use, a key uncertainty was whether this required foregoing the core functionality that ELMs were designed for. How to balance core, engineered function against other values was our second main theme. Participants attempted to set parameters of acceptability of the autonomous and adaptive behaviour that ELMs might display by imagining specific breaches of expectations we ordinarily hold about the performance of technologies (safety, predictability, reliability, etc). Our last theme was the collective recognition that maintaining the balance of values - between safety, reliability, adaptability etc – required increased responsibility on the part of the user. Participants reflected on the importance and the social tensions inherent to the practice of maintenance and care of living materials.

The focus of the workshop was to prompt reflexive reasoning on our interactions with ELM technology as this enables understanding of collective imaginary that structure engagement with new biotechnologies. Here, the question of control and predictability became paramount: participants made sense of their relationship with technology by redescribing their present and past experiences (see Table 1.1 and 1.2). Some technologies make the users feel caught in the grip of forces they can do little about, while others empower their users (Table: 1.2). This contrast between what can be labelled technological determinism, on the one hand, and social control, on the other, enabled participants to engage with the ELMs specificity. For them, the question was whether they enabled more or less control of processes technological innovation processes. In other words, participants were concerned with the path dependence of ELM development and implementation

Scenarios (Fig 1) were useful in that they prompted deliberations about the technological user and ELMs challenges to assumptions of function. In this, one of the main issues discussed in our workshops was the extent to which active, adaptive and autonomous materials would retain the core functionality for which they were designed or engineered. Participants reflected on the value of handling and relying on materials that were predictable, that's to say, knowable from a user's point of view (Table 2.1). They agreed that ELMs could challenge some of the assumptions about what one could know and expect from materials and collectively explored the acceptable boundaries of surprise within 'rationally designed' materials. In this, they balanced the value of efficiency with other forms of worth that materials might provide.

The group's consensus was that as long as materials adapted and self-repaired to continue to fulfil their intended purpose(s), ELM might offer added dimensions through which users can engage with them. These were not functional uses, and emphasised playfulness, aesthetics and 'liveliness': the creativity of life itself, one might say (Table 2.2). Although secondary, these uses were drawn upon time and again in the workshops to demonstrate the distinctiveness of ELMs. Part of the collaborative relationship with materials, as the group defined it (see above), was that both parties – human and non-human- were seen as capable of generating change within the relationship as part of the 'give and take'.

Participants reflected on the consequences of implementing ELMs on various areas of peoples lives and suggested that it entails a higher level of participation in the day-to-day management of this 'technology' (Table 3.1. and 3.2). participants were keenly aware that the consequence and trade-off of a more collaborative relationship with ELMs was that it requires more commitment from users. participants seemed to agree that one of consequences of ELM implementation was that it would demand specific kinds of people – committed, imaginative, skilful, etc. – as its users. There were thus concerns expressed that ELMs would be designed with this – "average white male" – in mind and ignore the diversity of possible users.

Participants were also interest in exploring the alternatives of relying on individual users to guarantee the ELMs sustainability (3.2). They agreed that there should be systems in place to support individuals sustain their investment in ELMs maintenance

Discussion

Speculative design methodology is effective in engaging and eliciting public views on ELMs. Participants were able to meaningfully engage with the proposed tasks, and generate reflective, rich discussions on the topic. This, we propose, was significantly facilitated by the structure of the workshops which supported focus on issues while not making access to membership and participation reliant on previous knowledge and expert status. In this regard, the design fiction approach enabled participants to engage with dimensions of technologies normally reserved for designers, engineers, scientists or policy makers. It enabled participants to articulate their own vision of how these technologies could be put into use in everyday life, and the normative implications that ELMs bring to bear.[7]

In these imaginaries, key themes in our data were control, functionality, unpredictability and maintenance. The issue of control links with debates on how to govern uncertain or potentially undesirable innovations. It is the aims of RRI interventions to emphasise the search for alternative scenarios and technological options and embed accountability upstream in innovation pathways. We aimed to explore visions and understandings on the part of non-specialists, where this was posited as a complex balance between functional predictability and other technological values. Participants emphasised that, in ELMs, organic form-generation should never trump pre-planned function . They recognised however that this maintaining this balance depended on users, and that, in this respect, ELMs required a redistribution of tasks and skills of users and devices.

The workshops brought to bear the normative assumptions embedded in ELMs. In particular, discussions highlighted the hidden work of putative users that ELMs might rely on. A societal move towards a circular economy, entails value production in recycling, re-use and repurpose, which depends heavily on users behaviour. In contrast to the policy making emphasis on 'the technological challenges' involved in this transition, our workshops highlighted the importance of involving users in imagining this shared future. It is well known that users play a fundamental part in contesting, modifying or influencing innovation. Involving users as stakeholders in specific ELM development is a requisite for their success in delivering environmental sustainability.

The workshops generated rich data on the practices and reasoning entailed in the maintenance of living things, which participants saw as relevant to ELM use. our analysis suggests that the practice of care and an attention to what is involved in the care of things is fundamental to the shaping of future ELMs. As the stories and scenarios that participants developed make clear, caring weaves lives, human and non-human, together. In these, humans are not only considered as skilful users but also as a living component, whose needs evolve and adapt in concert with the other living and non-

living components of the material.[8] This means that we need to explore in more deeply existing knowledge of living with living materials to define, anticipate and explore future uses of ELMs. We therefore recognise that the themes we identified in our data should be explored in further qualitative and quantitative research on responsible innovation on ELMs.

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