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Building communication neurotechnology for high stakes communications

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When designing neurotechnologies to assist people with communication disabilities, neuroscientists and engineers must consider both the speaker's perspective and the listeners' ability to judge the voluntariness and accuracy of decoded communication. This is particularly important in personally significant communication contexts for which there are profound legal and societal implications.

Communication neurotechnology that is based on detecting and interpreting neural signals to produce intelligible speech, writing or typing has the potential to offer remarkable new opportunities for people unable to communicate owing to limited voluntary motor function. For example, trials conducted by BrainGate have shown that neural signals recorded via an implant from the hand area of the motor cortex can be used to operate a mouse and to navigate a keyboard to type[1]. Overt or mimed speech has also been decoded and synthesized from electrocorticography arrays positioned over the articulatory areas of the motor cortex and perisylvian auditory areas[2–4], and advances in the encoding and decoding process have allowed these steps to be achieved at the speed of normal communication[5,6]. Progress has also been made on decoding imagined vowels and words from neural activity[7–9]. Some of this work has been funded by Facebook, which is pursuing these possibilities with the goal of developing ways to control devices using brain activity, also a goal of Elon Musk's Neuralink.

These developments offer the possibility of opening a channel of interaction with people whose impairments preclude the use of existing forms of communication. They may also offer a more rapid method of communication for those who are able to use existing assisted and augmented communication technologies, such as those controlled through eye gaze, head movements or other gestures. The possible benefits of implementing communication technologies for a wide range of needs are immense, but the challenges are no less daunting. Recently, brain–computer interface researchers have argued that the translation of this research to effective use is being held back in part by inadequate attention to usability during the development process, and a rigorous user-centred design approach should be adopted to address this[10]. We agree with this view and emphasize here two dimensions of user-centred design that are important for communication neurotechnology. First, usability is context-specific, and the needs of people engaging in day-to-day communications differ from those involved in highly significant communication contexts such as medical or legal decisions. Second, while the speaker is the primary end user, the needs of the listeners are inherently part of the usability of a communication neurotechnology and must be considered.

For users of communication technologies, errors in day-to-day matters could be frustrating but are unlikely to cause serious enduring harm. Consider, though, the types of rare but high-consequence communication contexts that are critical to supporting users' interests in security, agency and participation. These include giving legal testimony, articulating legally enforceable decisions about medical treatment, voting and other such situations that demand a high degree of confidence in the output of a communication device. Errors in communication in these contexts may harm not just the user but also third parties. For example, miscommunication in the medical context could impede the recognition of decision-making capacity or result in life-changing treatment decisions. Problems with testimony may lead to miscarriages of justice or jeopardize a person's ability to testify. Errors in voting would undermine the right to participate in democratic processes. If communication neurotechnologies are to be usable for these demanding and important contexts, they should be deliberately engineered to afford users the ability to signal and correct errors and to enable listeners to reasonably rely upon the accuracy of the output.

National and international governmental and non-governmental bodies with interests in brain–computer interfaces and other neurotechnologies such

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https://doi.org/10.1038/s41583-021-00517-w

as the US Food and Drug Administration (FDA), the European Commission, the Organisation for Economic Cooperation and Development (OECD), the Institute of Electrical and Electronics Engineers (IEEE), and the International Neuroethics Society offer useful resources to which neurotechnology developers can turn for assistance with user-centred design principles and relevant ethical considerations. For example, the Brain/Neural Computer Interaction (BNCI) Horizon 2020 project, funded by the European Commission, offers a detailed discussion of how to apply the user-centred design approach to brain–computer interfaces.

Usability analysis typically focuses on three metrics: effectiveness (how accurately and completely a task can be accomplished), efficiency (how much time or effort must be invested to accomplish the task) and satisfaction (a user's comfort with or acceptance of the device). Usability is context specific, and part of user-centred design is to specify the context of use. End-users may be most immediately interested in technology that will support their most urgently needed communication function, which may be day-to-day needs[10]. However, the less frequent but higher stakes contexts should also be envisaged from the beginning to ensure the broadest possible usability of the technology.

Communication is an interpersonal interaction, in which both speaker and listener have specific requirements that must be met to establish viable communication. From the listener's perspective, more is needed than intelligibility and acceptable speed. In the communication of highly consequential information and decisions via communication neurotechnology, the listener must be enabled to judge whether a communication is voluntary (that is, intentional) or instead inadvertently transmitted. One concern that has been expressed in relation to imagined speech detection is that dialogue that a person meant to remain internal may be detected and transmitted[10]. Furthermore, the listener must be able to judge whether the content of the communication has been accurately decoded. The degree of confidence required is proportionate to the significance of the information being exchanged or the decision being taken.

Various possible design elements have been described that might help to address the problem of listener confidence in the voluntariness and accuracy of neurotechnologically-mediated communication. A 'brain-switch'[11] could help to ensure the voluntariness of communications by using two distinct neural signals, one to indicate the intention to use the device (activating or de-activating the control state) and one that represents the content of the intended communication. To address concern about inaccuracy, playback mechanisms could allow a person to hear and approve communications before they are transmitted, or signals could be incorporated to allow a user to endorse or retract a transmitted statement[12]. If artificial intelligence is used to improve decoding efficiency, for example by detecting context and guessing at the likely subject of communication, transparency about this step would also assist the listener in understanding the potential for biasing of the message. Elements like these, and others yet to be imagined and created, will be vital tools to realize the full potential of these communication neurotechnologies to support the full inclusion of people who are poised to benefit.

As communication technologies expand beyond those that rely upon eye gaze and head movement to include the detection and interpretation of neural signals, we argue for a comprehensive consideration of potential use contexts, including those that involve high-stakes communications. While supporting everyday communication is of critical immediate importance, so too is supporting less frequent but highly consequential communication, which holds such legal, personal and social significance.

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Acknowledgements
The authors gratefully acknowledge the comments of P. Wood on the use of communication neurotechnology in the context of living with late stage ALS. We also thank E. Snell (Snell Communications), T. Ladd (Cognixion) and the International Neuroethics Society for support for the workshop Breaking Through: Neurotechnology for High Consequence Communication and Decision-Making (Toronto, 2019) that inspired this Comment.

Competing interests
The authors declare no competing interests.

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