Theory in Biosciences (2024) 143:229–234
https://doi.org/10.1007/s12064-024-00423-6

CORRESPONDENCE

Postmortem communication

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Received: 20 April 2023 / Accepted: 27 July 2024 / Published online: 3 August 2024
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Abstract
The phenomenon of near death and dying experiences has been both of popular interest and of scientific speculation. However, the reality of mental perception at the point of death is currently a subjective experience and has not been formally evaluated. While postmortem gene expression, even in humans, has been evaluated, restoration of postmortem brain activity has heretofore only been attempted in animal models, at the molecular and cellular levels. Meanwhile, progress has been made to translate brain activity of living humans into speech and images. This paper proposes two inter-related thought experiments. First, assuming progress and refinement of the technology of translating human brain activity into interpretable speech and images, can an objective analysis of death experiences be obtained by utilizing these technologies on dying humans? Second, can human brain function be revived postmortem and, if so, can the relevant technologies be utilized for communication with (recently) deceased individuals? In this paper, these questions are considered and possible implications explored.

Keywords Brain activity · Communication · Near death experience · Postmortem

Introduction

The concept of near death and dying experiences has been of considerable popular fascination; in addition, scientific speculation and analysis have attempted to evaluate this phenomenon (Martial et al. 2020; Evrard et al. 2022). In 1755, Guillaume-Lambert Godart in his *La Physique de l'Aˆme Humaine (Physic of Human Soul)* discussed reading of human brains, relevant to both living and deceased, to derive the history of sensations from the appearance of brain "fibers" (Gibert et al. 2011). However, Godart did express some skepticism of whether a possible examination of "fibers" could yield an understanding of the actual underlying knowledge manifesting in the observed brain structure. However, we can see that the desire to "read" human brains is centuries old. Literature has gone further in considering the implications of these states; for example, in Edgar Alan Poe's story *The Facts in the Case of M. Valdemar*, "mesmerism" is used to "fix" a man at the point of death, with communication possible with the man in that state. In Philip K. Dick's book *Ubik*, cold temperature is used to keep the recently deceased in a hibernated state from which periodically (at least for a time) brain wave activity can be activated, with communication between the deceased and the living. There have been a variety of short stories, novels, television show episodes, and movies featuring a conscious, communicating disembodied human brain, e.g., of a decreased individual. These fictional examples indicate an underlying public interest in a subject's perception of experience at and beyond the point of death and the possibility of physical, science-based postmortem communication with the deceased. However, an advanced practical approach to the topic has not been formally evaluated. While postmortem gene expression, even in humans, has been evaluated and its implications considered (Bordonaro 2019), even a partial restoration of postmortem brain function has heretofore only been attempted in animal models (Vrselja et al. 2019).

An objective analysis of near death and postmortem experiences would require approaches to translate human brain activity into interpretable data. Progress has been made to translate brain activity of living humans into images (Shen et al 2019) and speech (Li et al. 2021; Singh and Gumaste 2021; Proix et al. 2022). For example, work has been performed to translate brain activity, as measured by functional magnetic resonance imaging (fMRI), into interpretable images (Shen et al. 2019). Thus, deep neural networks

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(DNNs) were utilized for image reconstruction based on fMRI data from subjects based on both actual image presentation as well as imagined mental imagery (Shen et al. 2019). Both natural object images as well as symbols were analyzed by this method. While superior results were obtained with actual presented images directly observed by the subject, some success was obtained with reconstruction of imagined mental imagery of artificial shape symbols (Shen et al. 2019). Future advancements of these technologies may be able to effectively reconstruct internally constructed images such as those from dream states, hallucinations, and near death experiences, as well as postmortem brain activity.

There has also been progress in interpreting imagined speech via electroencephalogram (EEG) analysis of brainwave activity (Li et al. 2021; Singh and Gumaste 2021; Proix et al. 2022). Despite some technical problems, the findings (Singh and Gumaste 2021) suggest the future possibility of robust reconstruction of imagined speech, allowing for communication directly from a subject's brain activity. We can speculate about the possibility of bidirectional communication, not only from a subject's brain activity to a recipient, but the reverse as well. This possibly could be achieved via reversal of some of the techniques used to translate brain activity and which have been proposed for brain–machine communication (Ganesh et al. 2017). Thus, by extensions of the technologies, stimulation of the appropriate parts of a subject's brain can transmit images and/or speech from outside agents to that brain. The current manuscript further considers the possibility that this bidirectional communication can occur with a postmortem brain.

Another important methodological advance is the restoration of some activity, at the molecular and cellular levels, including maintenance of neuronal morphology, in the intact postmortem porcine brain (Vrselja et al. 2019). Thus, an ex vivo perfusion system allowed for a degree of structural, molecular, and cellular functionality even after a postmortem interval (PMI) of 4 h. The authors were careful to note that at no point in this study did the brain exhibit any sign of higher order functions, such as awareness or perception; there was no global brain activity as measured with electrocorticography (ECoG), even though there was a restoration of global cerebral metabolism (Vrselja et al. 2019). However, the authors cite probable future methodological advancements, leading to ethical considerations (see below) concerning the need to "preclude" the possibility of reactivation of awareness in the revived brain. Thus, reactivation of awareness and perception in a revived postmortem brain is likely possible given improved methodologies; one possibility is that functional restoration of brain function postmortem may be more technologically feasible if the PMI is kept relatively short, and the authors mention longer perfusion times as an unknown factor in the restoration of brain activity that is measurable with ECoG or EEG (Vrselja et al. 2019). For the current manuscript, we will assume (ethical questions aside for the moment) that technological advancements, coupled to careful timing of interventions, would allow for a more complete restoration of postmortem brain function that includes awareness, perception, and the ability to communicate. In this scenario, *conscious* brain activity of a deceased individual could be revived at some point postmortem. One could also speculate that continued methodological advancements would allow such full functional restoration even after longer PMIs, for example longer than the 4-h PMI that allowed for partial restoration of the porcine brain.

Therefore, the current manuscript proposes two interrelated thought experiments that assume continued progress in techniques (Fig. 1) of translating human brain activity into speech and images, including the (reverse) ability to convey speech and images, via electronic (or other) stimulation, into the recipient brain. Further, we will assume advancements

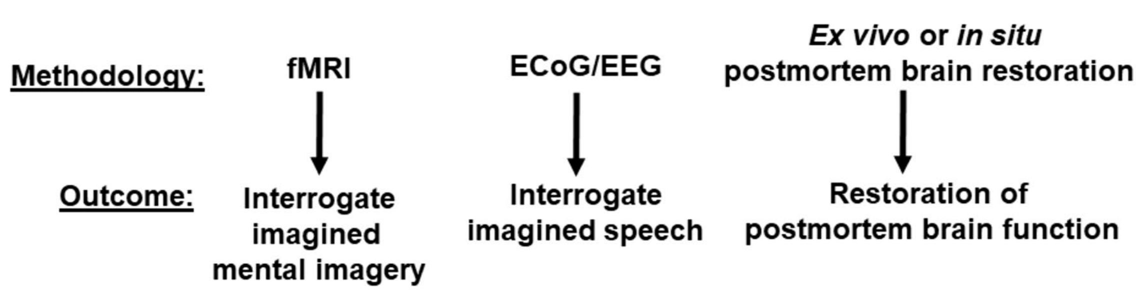

Fig. 1 Possible technologies for evaluating human near death and postmortem experiences. A number of methodologies can form the core of the proposed experimental approaches. For example, fMRI can be used to interrogate imagined mental imagery at the time of death and also in restored postmortem brains, and ECoG/EEG can serve the same purpose for imagined speech. Techniques used to restore some degree of ex vivo porcine brain function postmortem can be adapted and extended for human subjects, for the objective of obtaining at least some degree of conscious awareness and perception. Significant advancements in all of these methodologies would be expected and required to perform the experiments outlined in the current manuscript. Included in these advancements would be the possibility of in situ postmortem brain restoration

in restoring higher order brain function in recently deceased individuals. These thought experiments consist of two questions: First, can a more objective analysis of near death experiences be obtained by utilizing these technologies on dying human volunteers? Second, can human brain function be revived postmortem and, if so, can the relevant technologies be utilized for communication with (recently) deceased individuals? Therefore, in this paper, these two questions are considered and possible implications are explored.

Ethical considerations

It is understood that there are serious ethical implications of the proposed experimental studies (both animal and human) and possible subsequent implications derived from the ideas and hypotheses presented here. Therefore, this paper is presented as a ***thought experiment***, an epistemological construct to provoke discussion and debate; as part of this process, contributions from bioethicists and others are welcome. As part of these thought experiments, it is assumed that animal studies are conducted in such a manner to conform to all guidelines with respect to humane treatment of the subjects. Human experiments, also conducted in accordance with all appropriate guidelines, would involve fully informed and competent volunteers who understand the risks involved. Included in these risks, as have been pointed out in response to animal experiments, is the possibility that the perceptions of a revived brain will be extremely unpleasant, that unpleasant memories and associations will be invoked, and that the revived brain will not be able to convey or protest or end this unpleasant perception. In addition, another possibility is that the experience of time in this state may be altered, so that even if a fail-safe of a short revival time is built into the protocol, the perception of time elapsed in the negative condition will be longer. Indeed, the authors who produced the work on the postmortem restoration of animal brains have written that researchers must *"preclude the possibility of re-activating remnant awareness or brain functions that may result in inadvertent suffering"* (Vrselja et al. 2019). Reactivation of awareness, to an even greater extent than "remnant," is a fundamental component of the hypothetical experiments outlined here; therefore, ethical questions are paramount. The opposite is also a possibility; the revived condition may be subjectively pleasant to the subject and then the revival will end, either as part of an intentional time limit or as part of a natural degeneration in the revival process, and the subject will lose this experience that they desire. Thus, a loss of control for the subject, re: their perceived experiences and consciousness, is a central component of these ethical considerations. Indeed, the argument can be made that patient autonomy is inadequate and incompetent from the start given that consent could not be withdrawn once the revival process has started. Then again, the same could be said to hold for patients undergoing a medical procedure while under sedation. A counter-argument would be that in the proposed experiment, assuming technological feasibility, the revived brain would be experiencing some degree of consciousness lacking in, e.g., a fully sedated patient undergoing surgery. This counter-argument would assume that the revived brain would not be able to communicate to the experimenter at a level to address consent. To that last point, it would be counter-argued that such communication would not be considered legally actionable, re: consent. These issues would need to be part of any theoretical informed consent for human subjects, and ethical considerations apply to any proposed animal experiments. In summary, all the proposed experiments that follow are presented as a thought experiment to stimulate discussion. I suggest that one positive to the thought experiments of this paper is that it stimulates ethical discussion and debate of this kind, which is necessary as methodology related to this topic continues to be refined.

Hypothesis

Our hypothesis consists of two parts: First, we hypothesize that the appropriate technology, e.g., translation of brainwaves into interpretable speech/image data, will provide a more objective understanding of near death and dying experiences through extrapolation from data obtained from dying patients. Second, we hypothesize that given a combination of the technology with advancements in stimulating brain function postmortem, it will be possible to obtain speech and image data from the brains of recently deceased individuals (i.e., unidirectional communication). As a possible associated phenomenon, if bidirectional data transfer is possible, then active communication, or at minimum shared perceptions, with recently deceased individuals, will be possible.

Testing the hypothesis

In general, we propose (Fig. 2) to utilize technologies to translate brain activity into interpretable data as well as methodologies to restore functional brain activity postmortem to (a) interrogate the subjective experiences of the dying patient as they cross the threshold from life to death by deriving interpretable images, and possibly speech, from brain activity; and (b) use similar technologies on the postmortem brain to analyze images, and possibly speech, generated from an intact (deceased) human brain postmortem; and (c) to the extent possible engage in bidirectional

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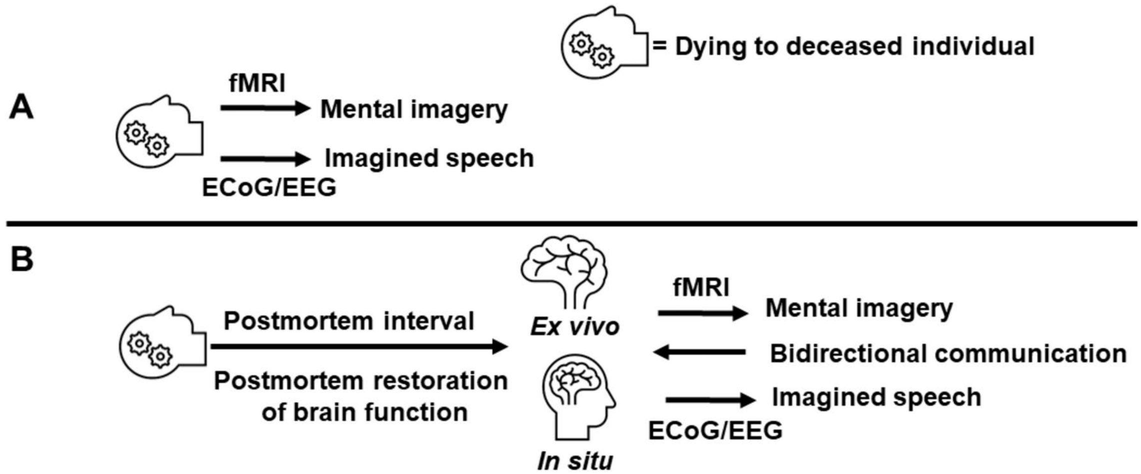

Fig. 2 Experimental procedures to interrogate the dying mind as well as engage in postmortem communication. **A** We propose to use advancements in techniques such as fMRI and ECoG/EEG to analyze imagined images and speech produced by the human brain as the dying patient crosses the threshold between life and death and in the subsequent immediate postmortem period. **B** Advancements in brain restoration techniques will be used to restore (at some postmortem interval) some degree of conscious brain function (ex vivo or in situ), including awareness and perception, in the postmortem brain. Techniques such as in (**A**) will analyze imagined images and speech in this state; we also suggest the possibility of bidirectional communication with the postmortem brain, assuming sufficiently advanced and adapted methodologies

communication with the postmortem brain. Preliminary animal experiments, focused on images, and species-specific vocalizations would be performed first, followed by subsequent work on dying human volunteers.

Interrogation of the death experience would be a more straightforward analysis, utilizing suitably advanced image and speech reconstruction technologies, of the subjective perceptions of the subject as they pass from life to death and into the immediately subsequent postmortem period. Such analyses can be performed on the intact subject or corpse. With respect to postmortem communication, one determinant of methodology would be the time interval after death (i.e., PMI). Technology utilized to interrogate the subjective experience of the dying individual as they cross the life/death threshold could be used in the (relatively) recent or immediate postmortem state, particularly, if "death" is defined as the cessation of heart activity rather than cessation of all brain activity. In this case, maintenance of the experimental interrogation of the subject past the point of death can be feasible on the intact corpse, assuming residual brain activity exists. However, if we wish to interrogate the subjective experience of the subject at some more extended period postmortem, *passed the point of brain death*, then it is likely necessary to utilize approaches, based on published work on animal models (Vrselja et al. 2019), that allow the ex vivo (disembodied) brain to be revived and maintained outside of the body. Technological advancements may allow for brain activity to be revived postmortem in situ, in the intact human body, which is likely to be more palatable for potential subjects and their relatives. We will consider all of these possibilities, acknowledging that for the foreseeable future, interrogation of postmortem states on revived brains would necessitate the disembodied ex vivo situation, while at the same time leaving open the possibility that advancements in the field may allow for in situ brain revival at some point in the future.

These thought experiments could involve a comparison of subjective perception from a revived ex vivo postmortem brain after a certain PMI to that of an ex vivo brain immediately after removal. In addition, we can consider comparisons of ex vivo human postmortem experiences to interpretable data obtained from brain activity of in situ brains of living animals. Is there something special about the time-elapsed postmortem state, independent of other variables?

The reverse flow of information from researcher to subject as part of bidirectional communication could be attempted via appropriate stimulation of relevant areas of the dying subject's or postmortem brain, using modification of brainwaves or other methodologies. This would of course, as all the proposed experimental work, require significant progress in the areas of translating brainwaves into speech and images (and vice versa). Work on using brainwaves to allow for brain–machine communication (Ganesh et al. 2017) can be extended to include a fully bidirectional flow of information.

Animal studies can also be conducted, e.g., preceding the work on human subjects to optimize the relevant methodologies. These animal studies would have the side benefit of advancing an understanding of animal cognition and promoting animal–human communication, assuming that methodologies can be developed to translate brainwaves of animals of higher cognition into interpretable data and to also communicate data into the animal brains through, e.g., electronic (or other) stimulation/modification of brainwaves and/or the appropriate areas of the brain.

We expect that interrogation of the human brain during and immediately after death would produce images and other interpretable data consistent with reports of near death experiences, therefore providing a more objective understanding of these phenomena. This of course would be contingent upon sufficient methodological advancements. Assuming the technological expertise exists to restore some degree of conscious human brain function at some postmortem intervals, after postmortem brain death, at least in the ex vivo scenario, it is reasonable to expect some degree of interpretable mental imagery, and speech data, from this state. However, the extent and type of such data are difficult to predict; one possibility is that the data obtained from the postmortem brain would be an extension of that observed in the dying brain. It is also difficult to predict if bidirectional communication would be possible even in the ex vivo scenario; whether this would be more feasible in situ, if auditory function is preserved, is unknown. Indeed, it is uncertain whether in situ postmortem brain restoration itself would be feasible, or what the maximal length of the PMI for which effective restoration of brain function (for the purposes outlined here) would be possible.

Brain function and death irreversibility

The term "brain function" is used in this paper. It is important to distinguish "cellular function" from effective "brain function" (the latter of which includes the possibility of sensation, perception, and consciousness). Previous work in this field has stressed that whatever cellular activity that has been observed has not been correlated to brain function (Vrselja et al. 2019). The second part of the experimental methodology in the current paper presupposes that artificially induced postmortem brain function allowing communication is possible. This assumption is the foundation of this section of the paper and it is of course possible that restoration of effective brain function postmortem will not be possible. However, as a thought experiment to stimulate discussion and debate, and as an epistemological tool to dissect questions about the biology of death, the paper may have utility even if cellular activity practically is unable to manifest a level of effective brain function allowing for communication, even with projected methodological advances. I note that the first set of proposed experiments, that of interrogating the dying brain for images to illuminate the concept of near death experiences, may be technically feasible even if postmortem restoration of effective brain function is not.

While I respect the arguments for irreversibility as a definition of death (Gligorov 2023), there are fine points as to what we are defining as "death" with respect to the current paper. Therefore, a person declared legally dead after a period of no cardiovascular activity or detectable (normal) endogenous brain function is considered "dead" for the current work. Further, I note that the objective of "postmortem communication" is not reviving a dead individual back to life, but temporarily restoring a degree of brain function (if technically possible, which it may not be) in a legally dead individual to allow for one-way or two-way communication with that brain function. The individual would still be considered dead; what is occurring here is a temporary restoration of artificially induced (exogenously influenced) brain function in the context of an individual who had already experienced "brain death." This is not reversible death. It is artificial stimulation of brain function for a time, within a certain period postmortem, to allow for one-way or two-way exchange of information. This of course gets into issues of definitions, but the biological objectives, independent of how one wishes to define "death," are clear.

I also acknowledge that sensation, perception, and consciousness may be fundamentally distinct from restoration of molecular and cellular activity, and it may not be biologically possible to derive the former from the latter, a situation that would underscore irreversibility (Gligorov 2023). Again, the reader is cautioned not to directly equate brain activity at the molecular and cellular level with sensation, perception, and consciousness. An association may be possible (what the current paper presupposes) but it may not be possible, and some believe that it cannot be biologically possible.

However, we must use caution with arguments concerning the irreversibility of death that depend on established experience of irreversibility; hence, "death is irreversible because we have heretofore observed it to be irreversible." We also need to consider the theoretical possibility of future radical technological advances that can alter what we currently believe is biologically possible.

Discussion

We will proceed at this point assuming that (a) the proposed experiments are technically feasible and (b) it is decided that they are ethically appropriate. Thus, primarily, given those caveats, this work would enhance our understanding of human cognition and perception, yield objective data regarding near death experiences, and extend the understanding of these processes to the (immediate) postmortem period. From the standpoint of public benefits, the work suggests the possibility of the findings of communication, or at least some exchange of perceptions, between the recently deceased and their loved ones, which may bring emotional benefit and closure to the dying process. The findings can also be used to make the process of dying less disturbing for the patient. For example, we can determine conditions for the dying patient that would result in more positive imagined mental imagery during the dying process. One practical utility of this proposed technology would be the ability to gain heretofore inaccessible insights into an individual's perception of cause of death. In theory, interrogating the brain of a recently deceased homicide victim could provide information concerning the identity of the perpetuator. Of course, such forensic investigative data would not be, and could not be, used as definitive legal evidence in an investigation. The accuracy of such information can be questioned for the purposes of legal proceedings. However, the information could be used to "jumpstart" a stalled investigation to then obtain legally actionable information; we can consider the occasional use of psychics in police work, which suggests that exotic methods would be used in cases of extreme necessity. Obviously, there would be serious ethical concerns (see above) about such approaches; for example, state actors or others could abuse such technologies to interrogate and/or punish dying or (recently) deceased individuals such as political dissidents, accused criminals, suspected spies, and enemy combatants. Once again the author stresses that the ideas proposed here are introduced merely as a thought experiment to stimulate debate and discussion. On a more immediately practical and less controversial level, the methodologies developed and data produced from the approaches proposed here can be used for incidental developments, such as improved communication with disabled/comatose living humans with whom effective communication is difficult, and/or to facilitate animal–human communication.

Acknowledgements The work was supported by the Geisinger Commonwealth School of Medicine.

Author's contribution M.B. is responsible for the entire manuscript, including conception, writing, and preparation of figures.

Funding The authors did not receive support from any organization for the submitted work.

Data availability No materials were used to for this manuscript, and no experiments were performed to produce this manuscript.

Declarations

Conflict of interest The author has no conflict of interest to declare that are relevant to the content of this article.

Ethics approval Not applicable.

Code availability No code has been utilized or described in this article.

Consent for publication MB gives my consent for the information detailed in this publication to be published in the journal *Theory in Biosciences.*

Cell line Not applicable.

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