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Brain-Computer Interface Technology's Impact on Human Personhood, Identity, and Dignity

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In 2021, a research team from the Howard Hughes Medical Institute reported a significant advance with exciting potential for people with locked-in syndrome—a condition caused by brain injury, stroke, or diseases such as amyotrophic lateral sclerosis (ALS) that render patients unable to speak.[1] The research team surgically implanted an array of electrodes in the motor cortex of a 65-year-old male who was paralyzed from the neck down due to a spinal cord injury. Using a machine-learning algorithm, the researchers trained the device to convert patterns of neural activity into letters by asking the patient to imagine writing letters. With the device, the patient could "write" 90 characters per minute (between 8 and 18 words) with an error rate of around 5%. (The average smartphone user can type about 115 characters per minute.) With an autocorrect feature, the error rate dropped to 2%.

In 2023, the same team extended their work by developing a speech-to-text device implanted in the brain of a patient with ALS who could no longer speak. A neuroprosthesis consisting of two microelectrode arrays was implanted in a small area of the ventral premotor cortex and a small part of Broca's area. This brain region, located in the left frontal lobe, serves a crucial role in speech and language production by coordinating motor functions for speech, helping articulate words, and forming sentences. The researchers trained a recurrent neural network to convert brain activity into text at 62 words per minute.[2] Normal human speech produces about 160 words per minute. Using a general English vocabulary of 125,000 words, the patient produced text with an error rate of 23.8%. For a smaller word set of 50 words, the error rate was 9.1%.

The researchers improved their neuroprosthesis in 2024 by designing one that required microelectrode arrays to be implanted only in the left ventral precentral gyrus of the brain's frontal lobe.[3] This new device, which converted neuronal activity into text and text into speech via a voice synthesizer that mimicked the patient's pre-ALS voice, achieved an accuracy rate of 99.6% for a 50-word vocabulary and a 90.2% accuracy for a vocabulary of 125,000 words. With further training, the neuroprosthesis helped the user attain a 97.5% accuracy for the larger vocabulary. By the end of the study, the patient could carry out conversations at a rate of 32 words per minute.

These neuroscientists hope that their work will lead to clinical devices that help people with locked-in syndrome regain the ability for rapid communication, stave off isolation and depression, and improve their quality of life. Access to these neuroprostheses could even shape end-of-life care for such patients.

Reports like these have become commonplace in the technical literature, and they highlight the remarkable advances that have taken place with brain-computer interface (BCI) technology. BCIs may revolutionize clinical treatments not only for people with locked-in syndrome but also

for amputees and people with paraplegia and quadriplegia. Beyond medical use, some technologists are eyeing BCI technology for nonmedical applications (such as education and gaming). Others recognize this technology's potential to provide cognitive enhancements for healthy individuals. Some bioengineers are even exploring BCIs to tether human brains together.

All of these applications—medical and nonmedical—raise a host of ethical questions. For Christians, BCIs also present theological questions. For example, how does BCI technology affect human personhood, identity, and dignity? This paper makes the case that BCI technology can have a positive impact on personhood, as it is defined in relationship to the image of God, and consequently human dignity. I assert that personhood arises out of God's image. I maintain that the image of God entails aspects of ontological, functional, and relational qualities, and all human beings exist in the image of God. Yet, those functional aspects evidenced by the call to advance human flourishing and steward the Earth (Gen 1:28) can be aided by advances in BCIs. However, some of the cutting-edge applications of such technology raise significant ethical concerns, many of which also intersect with questions about personhood, identity, and human dignity. Thus, the technical complexity of this advancing form of technology renders it difficult to generalize its impact. It must be assessed on a case-by-case basis.

For a Christian perspective to impact our culture regarding this exciting and, at times, frightening emerging biotechnology, it is critical to engage the actual state-of-the-art technology and not a caricature of it. Unfortunately, it is not uncommon for people to react to the hype surrounding BCIs instead of engaging the actual work that is being performed by bioengineers. Furthermore, as Sun and Ye point out, people sometimes discuss ethical issues from a general standpoint that neglects specific features and applications of BCI technologies.[4] In short, to effectively engage ethical and theological issues, a Christian must possess an informed understanding of BCI technology.

Introduction to BCI Technology

One of the most significant milestones in BCI technology came in 1973, when Jacques Vidal, a computer scientist from UCLA, proposed the idea that the brain's electrical activity could be used to control external devices.[5] However, due to the requirement for real-time processing of vast amounts of data, bioengineers made little progress toward fulfilling Vidal's pioneering ideas and vision for BCI technology. In the last several years, BCI research has moved into the mainstream with an explosion of research publications and breakthroughs.[6] Two factors help explain this dramatic change. One is the increased power and decreased cost of computer hardware and software along with growing insight into brain signaling. It is now possible for researchers to reliably direct brain electrical activity into external hardware. The second factor is sociological; BCI technology is now viewed positively. According to Nicolas-Alonso and Gomez-Gil, "The chances of using BCIs as auxiliary technology that might serve severely disabled people has increased social acceptance in this field and the need to accelerate its progress."[7] As a result, BCI technology is beginning to transition from the lab to clinical settings.

The key conceptual principle behind this technology relies on the discovery that the activity within networks of neurons located in human brains constitutes actual information of the same character as that transmitted between machines. Accordingly, this neurological information functions as a control system for humans in the same way that control systems use information to regulate machines' activities. For this reason, information can flow from a biological system to a machine, directing the machine's operation. In turn, information can flow from a machine to human brains, providing feedback about the external world.[8] The discovery of electrical activity in animal and human brains and the invention and clinical use of EEG technology affirm this key principle.

Types of BCIs

Several excellent reviews describing BCI technology in detail have been published.[9] For convenience, this paper will summarize key features relevant to this study.

Researchers use different schemes to classify BCI technology. One of the most useful categories describes the invasiveness of the technology.

Noninvasive BCIs

This type of system usually involves fitting a modified EEG cap on the patient's head with electrodes that contact the scalp. These contacts pick up electrical activity in the brain. An obvious advantage of this BCI is that it does not require surgery to install. Unfortunately, it suffers from poor resolution and signal strength.

Semi-Invasive BCIs

To overcome the limitations of noninvasive BCIs, bioengineers have explored placing electrodes directly on the brain surface. This approach eliminates the signal loss that occurs when the electrical activity from the brain passes through the skull and scalp. However, it requires surgery to position the BCI on the brain surface. Earlier versions required wires to pass through the skull and scalp. This issue has largely been resolved with Bluetooth® technology, but the technique still suffers from poor resolution.

Invasive BCIs

Some biomedical researchers have sought to improve the resolution by directly implanting these systems into the brain. This approach allows researchers to stimulate and record the average electrical activity of thousands of neurons in specific regions of the brain. Unfortunately, this improvement comes at a cost. The process of inserting electrodes into the brain can damage tissue, lead to scar formation, and trigger an immune response. Over time, glial cells in the brain migrate to the electrodes and coat them, which leads to loss of function.

Neuralink has developed a BCI that improves upon the limitations of invasive systems.[10] Instead of using rigid, fixed geometry microelectrodes, Neuralink's technology relies on more flexible gold filaments that are coated with a biocompatible polyimide polymer. These two features prevent bleeding and damage to brain tissue when the microelectrodes are inserted. They also reduce the brain's immune response. Neuralink has also developed a microsurgical robot capable of inserting

6 threads per minute, which allows each thread to be inserted into the brain with exacting microscopic precision. This process permits the BCI to be implanted into specific brain regions while avoiding blood vessels.

Work in BCI technology focuses on creating efficient channels for the information flow between the human brain and the machine. There are five sequential stages to this information flow: (1) signal acquisition, (2) preprocessing or signal enhancement, (3) feature extraction, (4) classification, and (5) the control interface.[11] These five stages capture the brain's electrical activity for mathematical processing in a way that renders it usable for controlling external devices.

The goal involves converting these patterns into signals that communicate the patient's intentions to the external device and, in doing so, provide the user with the means to control an external device. The most common means of converting intention into action is referred to as active BCI, by which the user trains with the BCI to either learn to modulate their brain activity (by imagining they are moving their arm, for example) or to train the BCI system using machine-learning algorithms to decipher user intent.

Coupling Artificial Intelligence and BCI Technology

One of the most significant advances in BCI technology involves coupling it with AI. This pairing improves the accuracy and reliability of these systems.[12] AI systems are adept at recognizing patterns in complex data, making them ideal for processing the electrical information coming from neural tissue and deciphering user intent, particularly for more sophisticated and complex applications. AI-driven BCI systems are also adaptable, and they process information instantly, whereas traditional BCI systems can take up to several seconds to complete this step.

Combining AI with BCI technology does have drawbacks. For example, using these two technologies together requires vast amounts of training data, which is time-consuming to generate. The training data must be high-quality. If not, it will compromise the performance of the AI-powered BCI system.

Medical Uses of BCI Technology

Biomedical researchers continue to explore an ever-expanding range of medical uses for BCI technology.[13] In addition to helping people with locked-in syndrome to communicate, this technology can be employed by people with amputations and quadriplegia to control robotic limbs. People with quadriplegia and paraplegia can use the technology to gain mobility through the control of exoskeletons. Also, BCIs may help stroke patients recover lost motor function.

BCI technology can also be used to electrically stimulate different brain areas in patients with neurological disorders such as Alzheimer's, Parkinson's, and Huntington's diseases, Tourette's syndrome, dystonia, and essential tremor. Biomedical researchers are also exploring ways that passive, noninvasive systems may diagnose mental illness and sleep disorders. Electrical stimulation may play a role in treating addiction, depression, anxiety, anorexia, obsessive-compulsive disorder, and schizophrenia. It may also help treat insomnia.

Nonmedical Applications of BCI Technology

While the primary interest in BCI technology has resided in the clinical arena, interest is now growing for nonmedical applications.[14] For now, nonmedical use primarily centers around noninvasive technology.[15] Apart from educational uses, most nonmedical applications are intended for healthy users.

Education

The prospects of using BCI technology in education have received significant attention.[16] Researchers think that these systems can provide students with immersive learning experiences and may help students improve focus and memory. Passive, noninvasive BCIs might even help diagnose and assist students with learning disorders.

Gaming and VR

One nonmedical application of BCI technology that currently receives significant attention is gaming. Current noninvasive BCI equipment is slower, less accurate, and has lower bandwidth than conventional interfaces. Current touchless alternatives, such as voice and gesture control, are superior to BCIs for gaming purposes. It appears that the motivation to use BCI technology for gaming may have more to do with the experience and novelty than anything else. Some technologists are exploring this technology for virtual reality systems. While performance is currently substandard, it does allow for input that goes beyond the use of limbs. Allison et al. refer to this condition as an "induced disability"—a condition in which fully mobile individuals do not have full use of their limbs because their hands are busy.[17] For example, surgeons, mechanics, soldiers, and pilots may find themselves in situations where both hands are busy. BCI technology may allow them to control devices that enable them to complete their work.[18]

Art

One of the more interesting uses of BCI technology is for creating and experiencing art.[19] For example, artists have used the technology to control robotic limbs that paint based on the artist's brain waves. BCIs have also been used at interactive displays in art galleries, where the artist's brain activity creates a unique visual display.

Sports

BCI technology may have a place in sports psychology by helping players improve and perform well under pressure. Through neurofeedback, athletes can learn to manage stress and performance anxiety. They can also learn to achieve better concentration and focus, allowing them to find the "zone" and remain in it.

Brain-to-Brain Interface Technology

One provocative advance in BCI technology involves tethering brains together, referred to as brain-to-brain interfaces (BBIs). The feasibility of BBI technology was demonstrated by Yoo et al. in 2013.[20] Using a noninvasive system, a human test subject caused the tail of an anesthetized rat to twitch. With an EEG cap, the human subject initiated an ultrasound burst that focused on the motor area of the rat's brain that controlled tail movement. The time delay from thought to tail movement was about 1.5 seconds.

In 2014, a research team from the University

of Washington described the first human-to-human BBI.[21] They designed a noninvasive BBI that used an EEG to record the brain activity of the "sender" and transcranial magnetic stimulation (TMS) to deliver the information to the motor area of a "receiver's" brain. The researchers designed an experiment in which the two test subjects, located remotely from one another, had to cooperate to play a computer game. With this configuration, the sender transmitted information over the internet, which caused the receiver to press a touchpad at the desired time.

In 2019, the same research team reported on a multi-person BBI, which they dubbed the BrainNet.[22] This BBI involved three human subjects: two senders who transmitted brain signals via the internet using EEG, and one receiver whose occipital cortex was stimulated using TMS. The receiver was unable to see the computer screen and had to decide to rotate a block or keep it in the same orientation, based entirely on the information transmitted to his brain by the two senders who *could* see the computer screen. Using EEG, the receiver's decision was transmitted to the computer system. The average accuracy of completing the task for five sets of three distinct test subjects was just over 80%.

Cognitive Enhancement with BCI Technology

Researchers have a great deal of interest in using BCI technology for cognitive enhancement. These applications involve both medical and nonmedical uses, and often the line between the two is not distinct. Cognitive enhancement is defined as improvement in acquiring and generating knowledge and understanding of the world, which requires the user to gain enhanced capability to focus attention, form knowledge, store and retrieve memories, exercise judgment, and perform evaluations.[23] Preliminary work indicates that noninvasive BCIs can be used to improve cognition in patients with Alzheimer's disease and other forms of dementia by helping them to regain memory, focus, and executive function.[24] Other researchers are exploring how BCI systems might improve cognition in healthy elderly people with mild cognitive decline.[25] Both research programs show promise.

Noninvasive, passive technology has helped neuroscientists better understand the brain areas and processes that underlie cognition, a first step in using BCI technology to improve cognition in compromised and healthy individuals. Use of noninvasive systems shows promise for improving memory and performance for numerous tasks, including complex problem solving.[26] With this initial success, it is not difficult to envision commercially available, wearable, noninvasive equipment routinely used by healthy people to improve their cognitive skills.

Some bioengineers are exploring the use of collaborative, noncommunicable BCIs for cognitive enhancement.[27] Unlike multi-user BBIs, the brains of users do not communicate. Instead, the BCIs feed information from each user, process it, integrate it, and then execute a single action. This multi-user BCI technology has been used to control robots and play video games.

Finally, bioengineers hope multi-user BBIs will facilitate cognitive enhancement. In this case, multiple people collaborate through direct brain connections to engage in cooperative problem-solving. Jiang et al. regard multi-person BBIs as "a social network of connected brains."[28] Multi-user BBIs are ideal for work that requires sustained alertness and attention that may include continuous monitoring of instruments and other information sources, processing that information, and executing an action in response to the information.[29] Examples of these jobs include aircraft pilots, power plant workers, and surgeons.

Ethical Concerns

Despite the promising medical and nonmedical applications, BCIs raises various safety, ethical, and societal concerns. It is critical to be aware of the types of ethical concerns associated with this technology, because many of them interdigitate with interest in understanding the impact of this technology on personhood and protecting human dignity. To identify and understand the range of these issues, Burwell et al. carried out a scoping review of the medical literature using PubMed as a bibliographic database.[30] Their review was published in 2017. Because of rapid advances in BCI technology, Coin et al. recognized the need to update the work,

systematically reviewing the academic literature for ethical concerns from 2016 to 2020.[31] In 2024, a third group performed a PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) study of the academic literature published from 2018 to 2023, seeking to identify the ethical themes that appeared regarding BCI technology.[32]

All three studies identified the same safety, ethical, and societal concerns. Coin et al. added concerns about animal welfare, and Livanis et al. added concerns about use of BCI technology for human enhancements. Based on the three studies, the safety, ethical, and societal concerns can be grouped using these 10 criteria: (1) user safety, (2) humanity and personhood, (3) autonomy, (4) stigma and normality, (5) privacy and security, (6) research ethics and informed consent, (7) responsibility and regulation, (8) justice, (9) animal welfare, and (10) human enhancement.

Though these analyses have been conducted from a secular framework, Christians will undoubtedly share many of these qualms. Some have a theological dimension and raise questions about personhood, identity, and human dignity. A brief survey of these issues lays the groundwork for a theological analysis of BCI technology.

User Safety

Perhaps the most common concern is user safety, and it is most pressing for invasive and semi-invasive systems. Damage to the brain during electrode insertion is a grave concern. So is the scarring of the neural tissue triggered by the glial cell response to the electrodes. Additionally, postsurgical complications raise worries. Bioengineers and ethicists have also expressed misgivings about the short- and long-term health effects of BCI technology. For example, what are the effects of repeatedly stimulating the brain with electrical impulses?

Humanity and Personhood

Several questions arise when it comes to humanity and personhood. When machinery becomes integrated into the human body, does that lead to a loss of humanity? How do BCI technologies impact users' perceptions of themselves and their place in society? Does this technology compromise the user's authenticity?

Also, a BCI that stimulates the brain changes people. It alters their cognition. It can alter their behavior and personality. Will people who use these systems lose themselves? Conversely, BCIs may enable people with locked-in syndrome to communicate. They may also grant people with quadriplegia and paraplegia the mobility and self-sufficiency that helps them recover a sense of humanity and personhood.

Autonomy

The capacity for self-determination is important in and of itself, but it also impacts other ethical issues such as informed consent. Many people working with BCIs worry that the technology undermines users' autonomy, particularly for applications that involve coupling the BCI with machine-learning algorithms and AI. These mathematical tools are necessary for extracting user intent from complex brain activity. But is the action that results directed by the user, by a collaboration of the user and the BCI, or by the BCI itself?[33]

Behavioral and personality changes associated with some applications are also concerning. If the patient's personality has changed, how can we be sure that the user's decisions are the same as they would have been before receiving the BCI?

On a positive note, technology that helps users communicate helps recover their autonomy, allowing them to express their desires with nuance. This capacity is particularly important for people who are locked in who often can only signal their desires with a simple "yes" or "no."

Stigma and Normality

For some people, disability is a stigma. Will social pressure influence disabled people to seek BCI technology when they otherwise would not? Of course, BCIs may help remove the stigma associated with disability and help patients recover a sense of normalcy.

What if people view others who use BCI systems as "cyborgs"? This unfortunate label would be mitigated if BCI use becomes prominent among healthy people and the technology is viewed as normal.

Privacy and Security

We take for granted that our thoughts are private, but BCIs could change that freedom. BCIs extract information from our brains. The existence of that information (outside the human brain) represents a potential loss of privacy for the BCI user. In principle, once the information about a patient's mental states, psychology, and private thoughts is public, it can be sold to third parties. More maliciously, the user could be blackmailed under the threat that their private thoughts will be made public. The loss of privacy is exacerbated in the case of BBI systems in which multiple users have their brains tethered together.

Brainjacking (unauthorized control) also causes uneasiness because this technology increasingly uses wireless technology and relies on access to the internet for other uses. Both make the user vulnerable to bad actors who could force them to engage in unintended actions.

Research Ethics and Informed Consent

Can a BCI user really give informed consent? If a person with locked-in syndrome consents to participate in pre-clinical studies, they might be able to indicate "yes" or "no," but can they communicate their exact wishes? The technology and its effects on the brain are complex. Because they suffer from locked-in syndrome that results from impaired brain function, can investigators be sure that these patients fully understand what they are giving assent to or rejecting?

Some treatments alter behavior and personality. If so, once a patient's brain is stimulated with a BCI, is the decision to continue with the study truly what the patient would have wished prior to the treatment? For patients with locked-in syndrome or quadriplegia or paraplegia, some ethicists and technologists worry that participants' involvement in studies may stem from desperation and not truly be a voluntary act.

Also, what happens to the patient when the study comes to an end? Or the company goes out of business, and the device is no longer supported? It seems cruel to give a person with locked-in syndrome the capacity to communicate and then take it away because the study is complete and funding is no longer available. Gilbert et al. interviewed patients who had their BCI

systems removed and learned that they felt a deep sense of loss. This loss made them question whether taking away access to BCI technology constitutes a violation of patients' human rights.[34]

Responsibility and Regulation

If a BCI user causes harm, who is at fault? The user? The BCI? The people who developed and installed the technology? For more sophisticated applications, machine learning algorithms or AI are paired with BCI technology. As a result, it is not clear if an action is strictly due to user intention or some combination of user intention coupled with the BCI's influence. These systems also make mistakes—they are not 100 percent accurate in deciphering user intent. When mistakes happen, the action is unintended. But who is responsible?

Concern about responsibility only becomes amplified for BBIs.[35] Who is responsible for an action? Is it the sender? Is it the receiver? Is it both?

Justice

Will everyone who could medically benefit from BCI technology have access to it? And what about nonmedical applications? Healthy users who have access to this technology will have advantages that could be regarded as unfair, particularly if the systems are expensive. This disparity gives wealthy individuals an advantage that could widen the socioeconomic gap.

Animal Welfare

Many advances in BCI technology have been achieved thanks to animal studies that help establish feasibility and serve as the basis for developing and refining the technology. Nevertheless, using animals (particularly nonhuman primates, which are regarded as highly sentient) as test subjects raises concerns about animal welfare and cruelty.

Human Enhancements

Advances in BCI technology legitimize the transhumanist movement and place theoretical ideas about human enhancement within reach. BCIs can be used, at least in principle, to enhance human cognition beyond natural biological limits. They can also be used to enhance users' strength by empowering exoskeletons or robotic

prosthetic limbs. These enhancements threaten human identity. They also raise ethical questions about experimenting on healthy people to develop technology for enhancement purposes.

Personhood and the Protection of Human Dignity

With an understanding of the state of the art of BCI technology and an appreciation of ethical issues raised by ethicists and investigators working in the field, it is next necessary to define personhood and describe human identity and human nature from a Christian perspective, before reflecting about the impact of BCI technology on personhood, human identity, and human dignity.

A Definition of Personhood

By no means is the task of defining personhood straightforward, in part because secular and Christian views fundamentally diverge. Most secular perspectives take a strictly functional view of personhood, which can be ambiguous. Persons are afforded dignity and respect and are granted human rights if they are sentient and display certain cognitive capacities.[36]

A Christian worldview regards personhood in ontological terms as an essential aspect of human nature. The basis for human personhood resides with the image of God. Because all human beings are "in Adam," they bear God's image and have personhood independent of functional capacities.[37]

If the basis for human personhood rests on the image of God, then it is important to define the concept. As conceptualized here, conservative and evangelical scholars generally hold to one of three views: (1) the resemblance view (also called the substantive view or the structural view), which emphasizes how human nature and attributes resemble God's nature; (2) the representative view (also called the functional view), which emphasizes human responsibility to rule and steward creation; and (3) the relational view, which emphasizes the unique relationship that humans have with God.[38] These three views are not mutually exclusive. The best way to understand the image-of-God concept is a combination of the three, with each one reflecting a facet of what it means for human beings to reflect God's image. Yet, the resemblance view seems to be preeminent because it incorporates the other two perspectives.[39] In contrast to other creatures, if image bearers have the responsibility to uniquely care for the creation or uniquely form a relationship with the Godhead, then these two features require that humans have unique qualities compared to other animals. For that reason, the resemblance view will be the primary perspective of God's image used to assess the impact of BCI technology on human dignity, though other aspects, such as the relational view, will be considered as well.

But what about people who do not possess distinct qualities that define the image of God due to their stage of development (human embryos and fetuses)? How about those who never developed these capabilities because of a developmental disorder, or who lost them due to a neurological disease or brain injury? Is the image of God absent in them? These questions stand as the primary objection to the resemblance view.[40]

In the face of this challenge, it is critical to keep in mind that every human being bears God's image because they are "in Adam."[41]Human dignity and value stem from our ontological status in Adam, with the unique qualities that define human beings flowing out of our essential nature. If the brain has not fully developed or is damaged from injury or disease, the image of God cannot be fully expressed, but it is not absent. In this sense, human personhood has an ontological basis that gives rise to unique functional qualities that are generally observable for most human beings. Unlike the secular view of personhood, functionality doesn't define personhood in a Christian perspective. It consequentially arises.

This idea presupposes a duality in human beings consisting of both material and immaterial natures. Because some BCIs are embedded in the brain (for invasive systems) and can alter a patient's cognitive skills, behavior, and personality, it is necessary to pose a model for the relationship between our material and immaterial natures as part of the process of defining personhood.

Human beings are a composite of material and immaterial natures. We are body and soul. The image of God does not merely reside in our immaterial self. Human beings in their entirety are made in God's image.[42] Our material and immaterial natures are integrated yet can be separated. Upon death, the soul goes to be with God. In this condition, as a bodyless soul, we are not in our natural state. With our resurrected bodies, both immaterial and material natures will once again be reunited.

This integration of material and immaterial natures that can be separated has been called holistic dualism.[43] In this model, our brain becomes an instrument for the expression of our immaterial nature, which echoes the idea that the ontological foundation of the image of God finds functional expression through the human brain. Accordingly, a dynamic interaction takes place between our brain (body) and our soul (mind and spirit), with changes in our brain influencing our mind and spirit.[44] In turn, our mind and spirit can influence our brain.

In summary, in this study, the definition of personhood used to assess the impact of BCI technology on human identity and dignity, rests on the image of God, with the image of God regarded as a composite of the resemblance, representative, and relational views. While these three perspectives focus on distinct features, they are not mutually exclusive. Still, the resemblance view encompasses the other two perspectives. To uniquely serve as God's representative or to have the unique capacity to relate to God requires qualities that only human beings possess. Moreover, the model used in this study is shaped by the concept of mutualistic dualism, recognizing an interplay between the immaterial and material natures of human beings, with the fullest expression of the image of God requiring a healthy brain.

BCI's Impact on Personhood, Identity, and Human Dignity

Assessing how BCIs affect human personhood, identity, and dignity is not straightforward. It involves a complex interplay between science, technology, ethics, and theology.

Positive Considerations

Despite the complexity of this undertaking, it is clear that BCI technology has the potential to uphold human personhood, identity, and dignity, particularly for people with locked-in syndrome or quadriplegia or paraplegia. BCI systems help patients previously unable to do so to communicate thoughts, ideas, and emotions. Some BCI users will be able to compose music, direct musicians, and create artwork.[45] The technology provides mobility to immobile patients by controlling robotic limbs and exoskeletons so users can regain some self-sufficiency. Without question, BCI technology promotes human flourishing in these patients and should be pursued with vigor.

Ontologically, these people have inherent worth and dignity because they bear God's image, whether or not they can communicate, move about, or care for themselves. For these individuals, this technology offers a way to *express* the image of God. In interviews, patients using BCI systems reported that the technology makes them feel human again. It changes the way they perceive themselves. It enhances their sense of self-worth.[46] Patients also expressed gratitude that they had the opportunity to socialize with others again, and they valued the chance to participate in activities. They also felt proud that they could contribute to medical advance. This gratitude reflects the relational aspect of the image of God, by which humans have the capability of relating to God and others. As part of the image of God (according to the resemblance view), human beings were created as social beings.

Improving cognition in patients with neurological disorders—or helping elderly patients regain lost cognitive skills—promotes human flourishing by restoring self-worth and dignity and regaining the capacity to express God's image.

Using BCIs to help diagnose and treat mental health disorders or to promote relaxation is beneficial and does not compromise human identity. And for mental health patients who have an addiction or live with depression or severe mental health disorders such as schizophrenia, helping them manage these diseases helps them recover lost dignity and self-worth.

It also helps them to fully express God's image.

While still in the pilot stage, another use of BCI technology that has the potential to deliver positive results can be found in the educational arena. Currently, this technology is costly and may not be widely available to students from lower socioeconomic strata and it may require specialized training to implement it. So, equitable access to the technology becomes a concern. Still, BCIs could improve educational outcomes, and exploration of these types of applications should be welcomed. BCI technology may help students better realize their potential and use their giftedness to contribute to society and serve the church. Again, this application could possibly promote human flourishing and allows a more complete expression of God's image.

Theological Uneasiness

Human dignity—the inherent worth each human possesses because they are persons who bear God's image—includes autonomy and accountability. Each person's autonomy is a reflection of their capacity for free will and self-direction, which enables moral choices. As part of the image of God according to the resemblance view, human beings possess an inherent understanding of right and wrong and a desire for justice. As image bearers, human beings are accountable for their actions and moral choices. Denying a person autonomy and accountability for their actions undermines their personhood. One ethical issue with BCI technology is the potential loss of autonomy, especially for applications that involve machine-learning algorithms and AI. Uncertainty about who makes decisions (the user, the user in collaboration with the BCI, or the BCI itself) is problematic. These systems make errors when deciphering user intent. This uncertainty not only raises questions about autonomy but also about responsibility for the action. In both cases, the user's personhood and dignity are undermined. For example, in an interview with a patient equipped with a BCI powered by AI, researchers learned that this person eventually gave up autonomy. She stopped listening to her instincts and ceded her decisions to the BCI system. She eventually let the system instigate her decisions.[47]

Another autonomy-related concern involves the effect that brain stimulation has on personality. Using BCI systems to stimulate the subthalmic nucleus and the globus pallidus interna—brain structures involved in motor control—can help control the motor symptoms of Parkinson's disease, but they also render the patient less risk-averse.[48] This change raises a question about consent for subsequent treatments with BCI technology. Would the patient have granted consent if their personality did not change? This potential loss of autonomy compromises the patient's dignity and undermines their agency.

BBI systems are in their infancy as a technology, yet they raise various concerns about privacy, autonomy, and responsibility, all three of which impact human dignity. In multi-user BBI systems, it is not clear who initiates the action and who should be responsible for its outcome. Human beings often collaborate. Group decisions often involve deliberations before plans are executed. In these partnerships, each person's identity is retained. Anyone can withdraw if the group is about to engage in a collective action with which he or she is uncomfortable. But it is unclear if this possibility exists for contributors to multi-user BBIs. If not, then the technology threatens participants' autonomy and forces them to assume responsibility for actions they would otherwise have opposed.

Human dignity entails privacy, and it is a right afforded to those with personhood status. Humans have an identity rooted in God's image, which includes private thoughts, emotions, and experiences that if shared could be unjustly exploited to cause harm to themselves or others. Privacy prevents dehumanization, with protected information shared within trusted relationships. One of the most sacrosanct aspects of privacy is the privilege of having your own thoughts and the freedom to choose to whom one discloses those thoughts. Having private thoughts publicly exposed is a direct assault on an individual's dignity. Thus, if BCI and BBI systems lead to a loss of privacy, then they threaten human dignity.

Do BCI and BBI technologies threaten human identity? In principle, they could if the user's brain is significantly modified through the technology. Noninvasive

technology should not be viewed as a threat. Even though some noninvasive BCI applications, such as brain stimulation, may alter personality and behavior, it does not fundamentally change human identity. On the other hand, invasive systems pose a concern.

However, current uses of invasive BCI technology, even when coupled with machine-learning algorithms and AI, do not seem to pose much of a threat. Based on interviews with people equipped with invasive systems, the opposite seems to be the case.[49] These people report feeling *more* human. They quickly integrate with the BCI and external devices controlled by the system. They say that the BCI feels as if it is a natural part of them and that they have not changed. They are the same person.

Greater anxiety exists for BBI technology. Of course, collaboration is very much a part of human experience and is how God made us as image bearers. Though we are individuals, we are social beings. We are created to be in relationship with one another. One aspect of our nature that makes us exceptional is our capacity to create and live within complex hierarchical social structures. We seek out one another to work together. As members of the church, we are described analogically as part of a body, with each person possessing unique giftings that harmonize with others' talents to accomplish the church's mission.

BBI technology *seems* like a natural extension of the collaborative, social aspect of our nature. Tethering brains together may even make collaborations more potent and effective. So, depending on the specific design of the BBI system and the application, tethering brains together into a momentary collective may not pose a threat to human identity. Other applications in which the collaboration is permanent would be problematic. Each person would lose their identity as a unique and valuable individual as they meld into the collective. They would also be stripped of individuality and mistreated in ways that are incompatible with the dignity they possess.

What about more radical, futuristic applications of BCI technology? If they require more extensive modifications to the brain, BCIs could fundamentally alter human identity. This concern particularly applies to technologies designed to enhance human beings beyond our natural biological limits. In those cases, they transcend the boundaries God instituted when he created us.

Conclusion

Christians should regard BCI technology, at least for the current state of the art, as a positive advance. Many medical and nonmedical applications can potentially restore a lost sense of personhood, identity, and human dignity. BCIs can help people who live with severe medical conditions. While the image of God is inherent to every human being, it must be expressed, and in some instances this technology enables the expression of the image of God and allows people to exercise their full giftedness. Yet this technology raises vexing ethical and theological issues. By recognizing these concerns, it should be possible to mitigate them, at least for now.

Given the scientific and technical complexity of BCI technology and its range of applications, Christians cannot generalize when engaging this emerging biotechnology. We must take advances on a case-by-case basis and pay close attention to users' experiences. Their firsthand accounts will inform us as we navigate ethical and theological issues. We also must keep an open mind. It is conceivable that some applications that appear to undermine human personhood, identity, and dignity may ultimately be of little concern. Likewise, others that seem nonproblematic may, in practice, become deeply concerning.

With an eye toward the future and the development of advanced applications, Christians must continue to ponder what it means to be made in the image of God. We need to develop more complete anthropological models that emphasize the dynamic interaction of our material and immaterial natures. These efforts will require interdisciplinary collaboration among theologians, philosophers, neuroscientists, engineers, technologists, and others. Such collaboration entails that Christians stand at the forefront of the technological breakthroughs with the detailed knowledge and wise counsel to drive ethical conversations.

References

1. Francis R. Willet, Donald T. Avansino, Leigh R. Hochberg, Jaimie M. Henderson, and Krishna V. Shenoy, "High-Performance Brain-To-Text Communication Via Handwriting," *Nature* 593 (2021): 249–54, https://doi.org/10.1038/s41586-021-03506-2.

2. Francis R. Willet, Erin M. Kunz, Chaofei Fan, Donald T. Avansino, Guy H. Wilson, Eun Young Choi et al., "A High-Performance Speech Neuroprosthesis," *Nature* 620 (2023): 1031–36, https://doi.org/10.1038/s41586-023-06377-x.

3. Nicholas S. Card, Maitreyee Wairagkar, Carrina Iacobacci, Xianda Hou, Tyler Singer-Clark, Francis R. Willett et al., "An Accurate and Rapidly Calibrating Speech Neuroprosthesis," *The New England Journal of Medicine* 392, no. 7 (2024): 609–18, https://doi.org/10.1056/NEJMoa2314132.

4. Xiao-yu Sun and Bin Ye, "The Functional Differentiation of Brain-Computer Interfaces (BCIs) and Its Ethical Implications," *Humanities and Social Sciences Communications* 10, no. 878 (2023): https://doi.org/10.1057/s41599-023-02419-x.

5. Jacques J. Vidal, "Toward Direct Brain-Computer Communication," *Annual Review of Biophysics and Bioengineering* 2 (1973): 157–80, https://doi.org/10.1146/annurev.bb.02.060173.001105.

6. Fancun Li, Ding Zhang, Jie Chen, Ke Tang, Xiaomei Li, and Zhaomeng Hou, "Research Hotspots and Trends of Brain-Computer Interface Technology in Stroke: A Bibliometric Study and Visualization Analysis," *Frontiers in Neuroscience* 17, no. 1243151 (2023): https://doi.org/10.3389/fnins.2023.1243151.

7. Luis Fernando Nicolas-Alonso and Jamie Gomez-Gil, "Brain Computer Interfaces, A Review," *Sensors* 12, no. 2 (2012): 1211–79, https://doi.org/10.3390/s120201211.

8. Peter Mahon, *Posthumanism: A Guide for the Perplexed* (Bloomsbury, 2017), 31–32.

9. Nicolas-Alonso and Gomez-Gil, "Brain Computer Interfaces"; Drishti Yadav, Shilpee Yadav, and Karan Veer, "A Comprehensive Assessment of Brain Computer Interfaces: Recent Trends and Challenges," *Journal of Neuroscience Methods* 346, no. 108918 (2020): https://doi.org/10.1016/j.jneumeth.2020.108918; Simanto Saha, Khondaker A. Mamun, Khawza Ahmed, Raqibul Mostafa, Ganesh R. Naik, Sam Darvishi et al., "Progress in Brain Computer Interface: Challenges and Opportunities," *Frontiers in Systems Neuroscience* 15, no. 578875 (2021): https://doi.org/10.3389/fnsys.2021.578875; Aleksandra Kawala-Sterniuk, Natalia Browarskam Anur Al-Bakri, Mariusz Pelc, Jaroslaw Zygarlicki, Michaela Sidikova et al., "Summary of Over Fifty Years with Brain-Computer Interfaces—A Review," *Brain Sciences* 11, no. 1 (2021): 43, https://doi.org/10.3390/brainsci11010043; Zhi-Ping Zhao, Chuang Nie, Cheng-Teng Jiang, Sheng-Hao Cao, Kai-Xi Tian, Shan Yu et al., "Modulating Brain Activity with Invasive Brain Computer: A Narrative Review," *Brain Sciences* 13, no. 1 (2024): 134, https://doi.org/10.3390/brainsci13010134; Janis Peksa and Dmytro Mamchur, "State-of-the-Art on Brain-Computer Interface Technology," *Sensors* 23, no. 13 (2023): 6001, https://doi.org/10.3390/s23136001.

10. Elon Musk and Neuralink, "Integrated Brain-Machine Interface Platform with Thousands of Channels," *BioRxiv* (August 2, 2019), https://doi.org/10.1101/703801.

References (continued)

11. Nicolas-Alonso and Gomez-Gil, "Brain Computer Interfaces."

12. Evelyn Karikari and Konstantin Koshechkin, "Review on Brain-Computer Interface Technologies in Healthcare," *Biophysical Reviews* 15, no. 5 (2023): 1351–58, https://doi.org/10.1007/s12551-023-01138-6.

13. Zhi-Ping Zhao et al., "Modulating Brain Activity"; Peksa and Mamchur, "State-of-the-Art on Brain-Computer Interface Technology."

14. [[14]] Anton Nijholt, Jose Luis Contreras-Vidal, Carmille Jeunet, and Aleksander Väljamäe, "Editorial: Brain-Computer Interfaces for Non-Clinical (Home, Sports, Art, Entertainment, Education, Well-Being) Applications," *Frontiers in Computer Science* 4, no. 860619 (2022): https://doi.org/10.3389/fcomp.2022.860619; Peksa and Mamchur, "State-of-the-Art on Brain-Computer Interface Technology."

15. Sergi L. Shishkin, "Active Brain-Computer Interfacing for Healthy Users," *Frontiers in Neuroscience* 16, no. 859887 (2022): https://doi.org/10.3389/fnins.2022.859887.

16. Nuraini Jamil, Abdelkader Nasreddine Belkacem, Sofia Ouhbi, and Christoph Guger, "Cognitive and Affective Brain-Computer Interfaces for Improving Learning Strategies and Enhancing Student Capabilities: A Systematic Review," *IEEE Access* 9 (2021): 134122–47, https://doi.org/10.1109/ACCESS.2021.3115263.

17. Brendan Z. Allison, Bernhard Graimann, and Axel Gerd Peter Graeser, "Why Use a BCI if You Are Healthy?" presented at *ACE Workshop: Brain-Computer Interfaces and Brains* (June 2007): 7–11.

18. Allison, Graimann, and Graeser, "Why Use a BCI if You Are Healthy?"

19. Mirjana Prpa and Phillippe Pasquier, "Brain-Computer Interfaces in Contemporary Art: A State of the Art and Taxonomy," in *Brain Art: Brain-Computer Interfaces for Artistic Expression,* ed. Anton Nijholt (Springer, 2019), 433–46, https://doi.org/10.1007/978-3-030-14323-7_3.

20. Seung-Schik Yoo, Hyungmin Kim, Emmanuel Filandrianos, Seyed Javid Taghados, and Shinsuk Park, "Non-Invasive Brain-to-Brain Interface (BBI): Establishing Functional Links Between Two Brains," *PLoS ONE* 8, no. 4 (2013): e60410, https://doi.org/10.1371/journal.pone.0060410.

21. Rajesh P. N. Rao, Andrea Stocco, Matthew Bryan, Devapratim Sarma, Tiffany M. Youngquist, Joseph Wu et al., "A Direct Brain-to-Brain Interface in Humans," *PLoS ONE* 9, no. 11 (2014): e111332, https://doi.org/10.1371/journal.pone.0111332.

22. Linxing Jiang, Andrea Stocco, Darby M. Losey, Justin A. Abernethy, Chantel S. Prat, and Rajesh P. N. Ra, "BrainNet: A Multi-Person Brain-to-Brain Interface for Direct Collaboration Between Brains," *Scientific Reports* 9, no. 6115 (2019): https://doi.org/10.1038/s41598-019-41895-7.

23. Catrina Cinel, Davide Valeriani, and Riccardo Poli, "Neurotechnologies for Human Cognitive Augmentation: Current State of the Art and Future Prospects," *Frontiers in Human Neuroscience* 13 (2019): 13, https://doi.org/10.3389/fnhum.2019.00013.

24. Xiyuan Du, "Brain Stimulation Techniques-Based Neuroregulatory in Alzheimer's Disease," *Proceedings of SPIE* 12924, Third International Conference on Biological Engineering and Medical Science (January 8, 2024): https://doi.org/10.1117/12.3013070.

25. Ping-Chen Tsai, Asangaedem Akpan, Kea-Tiong Tang, and Heba Lakan, "Brain Computer Interfaces for Cognitive Enhancement in Older People—Challenges and Applications: A Systematic Review," *BMC Geriatrics* 25, no. 36 (2025): https://doi.org/10.1186/s12877-025-05676-4.

26. Cinel et al., "Neurotechnologies for Human Cognitive Augmentation," 13.

27. Cinel et al., "Neurotechnologies for Human Cognitive Augmentation," 13.

28. Jiang et al., "BrainNet."

29. Vladimir A. Maksimenko, Alexander E. Hramov, Nikkita S. Frolov, Annika Lüttjohann, Vladimir O. Nedaivozov, Vadim V. Grubov et al., "Increasing Human Performance by Sharing Cognitive Load Using Brain-to-Brain Interface," *Frontiers in Neuroscience* 12, no. 949 (2018): https://doi.org/10.3389/fnins.2018.00949.

30. Sasha Burwell, Matthew Sample, and Eric Racine, "Ethical Aspects of Brain Computer Interfaces: A Scoping Review," *BMC Medical Ethics* 18, no. 60 (2017): https://doi.org/10.1186/s12910-017-0220-y.

31. Allen Coin, Megan Mulder, and Veljko Dubljevic, "Ethical Aspects of BCI Technology: What Is the State of the Art?" *Philosophies* 5, no. 4 (2020): 31, https://doi.org/10.3390/philosophies5040031.

32. Efstratios Livanis, Polychronis Voultsos, Konstantinos Vadikolias, Panagiotis Pantazakos, and Alexandra Tsaroucha, "Understanding the Ethical Issues of Brain-Computer Interfaces (BCIs): A Blessing or the Beginning of a Dystopian Future?" *Cureus* 16, no. 4 (2024): e58243, https://doi.org/10.7759/cureus.58243.

33. O. C. van Stuijvenberg, D. P. S. Samlal, M. J. Vansteensel, M. L. D. Broekman, and K. R. Jongsma, "The Ethical Significance of User-Control in AI-Driven Speech-BCIs: A Narrative Review," *Frontiers in Human Neuroscience* 18, no. 1420334 (2024): https://doi.org/10.3389/fnhum.2024.1420334.

34. Frederic Gilbert, Marcello Ienca, and Mark Cook, "How I Became Myself After Merging with a Computer: Does Human-Machine Symbiosis Raise Human Rights Issues?" *Brain Stimulation* 16, no. 3 (2023): 783–89, https://doi.org/10.1016/j.brs.2023.04.016.

35. Elisabeth Hildt, "Multi-Person Brain-to-Brain Interfaces: Ethical Issues," Frontiers in Neuroscience 13, no. 1177 (2019): https://doi.org/10.3389/fnins.2019.01177.

36. Fredrick J. White, "Personhood: An Essential Characteristic of the Human Species," *The Linacre Quarterly* 80, no. 1 (2013): 74–97, https://doi.org/10.1179/0024363912z.00000000010.

37. Isaac Kantola, "A World of Difference: A Comparison of the Worldview Differences Regarding Personhood and Human Rights," *NEXUS: The Liberty Journal of Interdisciplinary Studies* 1, no. 1 (2023): 7, https://doi.org/10.70623/CQBR7302; Mark A. Strand, "The Meaning of Personhood," *Perspectives on Science and the Christian Faith* 50, no. 2 (1998): 88–94, https://www.asa3.org/ASA/PSCF/1998/PSCF6-98Strand.html.

38. C. John Collins, *Science and Faith: Friends or Foes?* (Crossway, 2003), 124–32; Richard Middleton, *The Liberating Image: The Imago Dei in Genesis 1* (Brazos, 2005), 27–34.

39. William Lane Craig, *In Quest of the Historical Adam: A Biblical and Scientific Exploration* (Eerdmans, 2021), 365–70; Andrew Ter Ern Loke, *The Origins of Humanity and Evolution: Science and Scripture in Conversation* (T&T Clark, 2022), 95–106.

40. John F. Kilner, "The Image of God and Human Dignity: Recovering a Biblical Treasure," in *Created in the Image of God: Applications and Implications for Our Cultural Confusion,* ed. David Dockery with Lauren McAfee (Freefront Books, 2023), 19–44. A detailed presentation of Kilner's view can be found in John F. Kilner, *Dignity and Destiny: Humanity in the Image of God* (Eerdmans, 2015).

41. Andrew Ter Ern Loke, *The Origins of Humanity and Evolution: Science and Scripture in Conversation* (T&T Clark, 2022), 98.

42. Craig, *In Quest of the Historical Adam*, 370–76.

43. A detailed description and defense of holistic dualism can be found in John W. Cooper, *Body, Soul and Life Everlasting: Biblical Anthropology and the Monism-Dualism Debate* (Eerdmans, 2000).

44. Matthew S. Stanford, *The Biology of Sin: Grace, Hope, and Healing for Those Who Feel Trapped* (InterVarsity Press, 2010), 15–26.

45. Eduardo Miranda, "Plymouth Brain-Computer Music Interfacing Project: From EEG Audio Mixers to Composition Informed by Cognitive Neuroscience," *International Journal of Arts and Technology* 3, no. 2–3 (2010): 154–76, https://doi.org/10.1504/IJART.2010.032562.

46. Johannes Kögel, Ralf J. Jox, and Orsolya Friedrich, "What Is It Like to Use a BCI?—Insights from an Interview Study with Brain-Computer Interface Users," *BMC Medical Ethics* 21, no. 2 (2020): https://doi.org/10.1186/s12910-019-0442-2; Gilbert et al., "How I Became Myself."

47. Gilbert et al., "How I Became Myself."

48. Liam Drew, "Agency and the Algorithm," *Nature* 571 (2019): S19–S21, https://doi.org/10.1038/d41586-019-02214-2.

49. Kögel, Jox, and Friedrich, "What Is It Like to Use a BCI?"; Gilbert et al., "How I Became Myself."