

BCI DEFINITIONS

Overall Purpose

The idea of a brain-computer interface (BCI) is becoming far more common in the public consciousness with the ever-increasing depictions of BCIs in popular news media, entertainment, and even governmental regulations. Further, BCIs have moved out of the purely academic world and towards commercial translation as an increasing number of private companies are developing BCIs for a variety of purposes. These BCIs include external devices that may be considered as exempt devices from a regulatory perspective, as well as surgically implanted systems that are regulated by national or international governmental agencies.

As the International Brain-Computer Interface Society, we believe it is important to put forward a clear and comprehensive definition of a brain-computer interface that reflects both the history and current state of the field, that simply captures the essential aspects of what a BCI is and is not, and that is useful for the Society in both internal and external communications. There have been numerous definitions of BCIs created by individual scientists in the field, or by other societies and organizations. Here, we intended to adopt or develop a definition that has broad acceptance within the academic community of scientists, engineers, and clinicians that have an interest in BCIs.

Status update

On February 5, 2024, the BCI Society called for input among the wide spectrum of BCI stakeholders on several key considerations and possible definitions of a BCI. A total of 147 respondents, 94 of whom identified as BCI Society members, filled out the survey, which is a great number! Thank you all for taking the time to fill out the survey and for sharing your thoughtful opinion. We really appreciate it!

At this stage, we would like to inform you about the responses to the survey, and ask you for a vote on the working definition of a BCI. This definition is intended to remain in place for 2 years. After that period, the BCI Society will consider if revision is required or not, based on input shared by the different stakeholders until that time, and based on how the field evolves.

Survey responses

The survey contained three multiple choice questions related to specific components of the definition:

1. Should a definition of a BCI more clearly define the brain as the interface target, rather than the entire central nervous system (CNS)?
2. Should a definition of a BCI include a description of a system that (only, or in addition to reading and decoding brain signals) modulates or modifies brain function?
3. Should a definition of a BCI require the brain activity to contain information about the ongoing intention of the user?

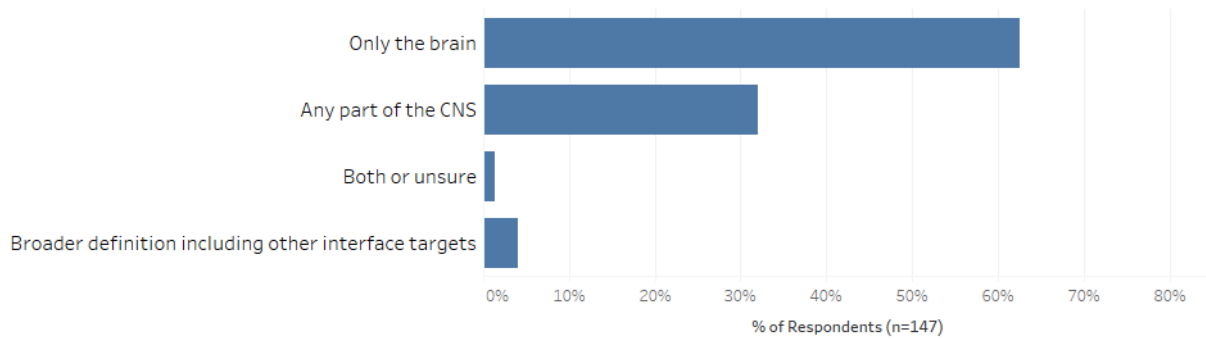
Also, the survey contained a multiple-choice question that asked about the preference of respondents for the 2012 Definition of Wolpaw and Wolpaw, for one of three proposed revised definitions, or for yet another definition.

In the figure below, the results of these four multiple choice questions are provided. From the results, it can be inferred that the majority of respondents feels that 1) only the brain can be the interface target of a BCI, 2) the flow of information can be from the brain to the environment, from the environment to the brain, or both, 3) it is not necessary for the brain activity measured during BCI use to contain information about the intention of the user. In addition, and in line with these responses, revised definition 3 was preferred over the alternatives.

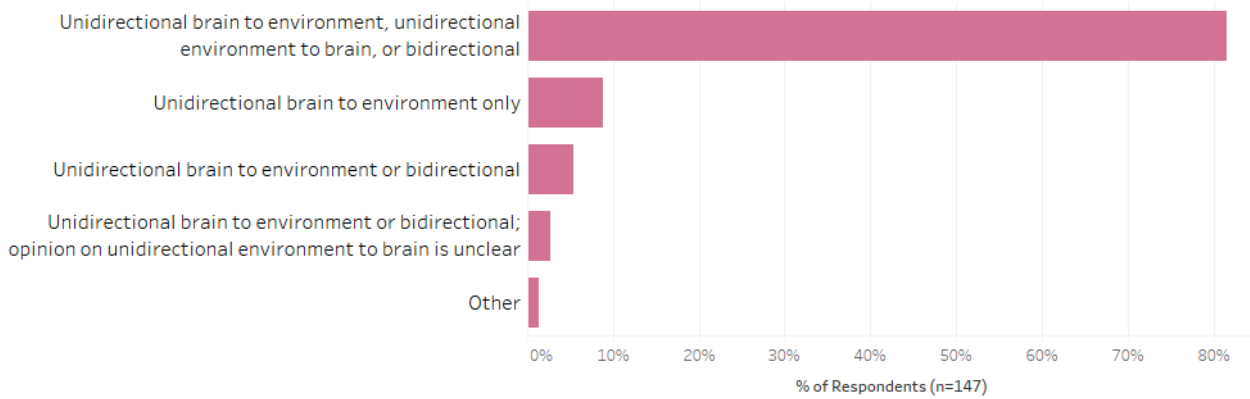
The figure displays results from all respondents, but results were similar for BCI Society members: 73.4% indicated that only the brain can be the interface target, 78.7% that the flow of information can be from the brain to the environment, from the environment to the brain, or both, and 67.0% that it is not necessary for the brain activity measured during BCI use to contain information about the intention of the user. Revised definition 3 was the preferred choice of 59.6% of BCI Society members.

Please note that some write-in responses were recoded as one of the provided response options when appropriate. We have maintained both the original and recoded response data and can share the original response distribution upon request.

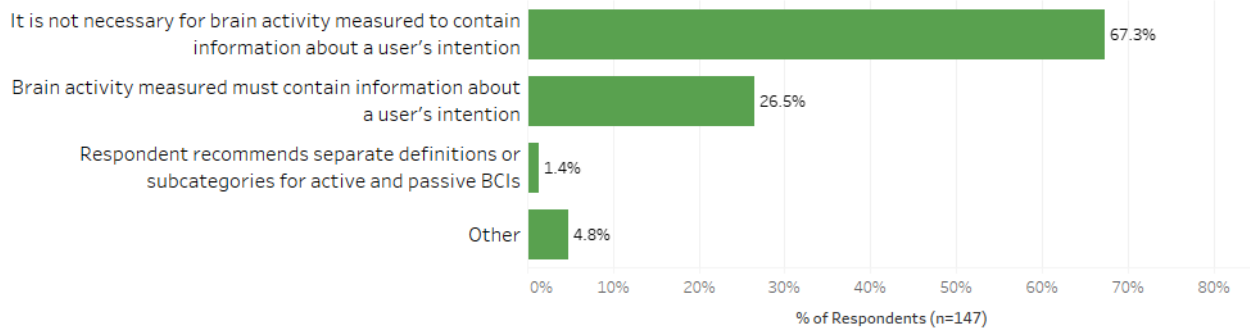
Interface target



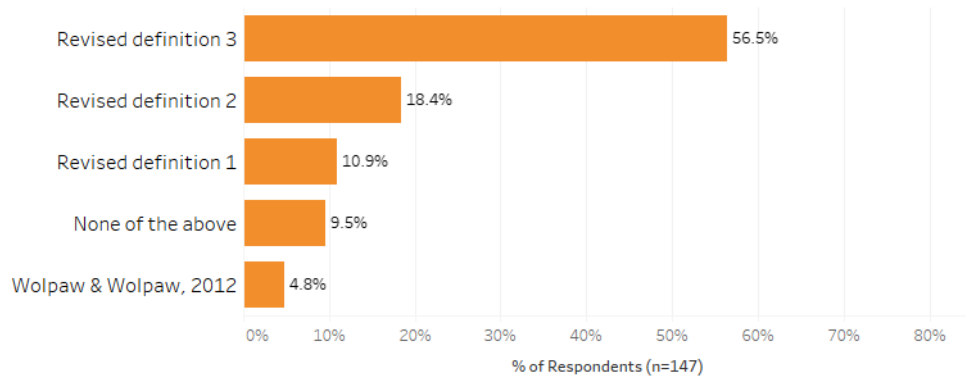
Flow of information



User intention



Preferred definition



In addition to the answers to the multiple choice questions, many respondents provided valuable comments and suggestions. From the answers to the multiple-choice questions and the comments, it became clear that different respondents had quite different opinions on specific topics, and that it is difficult to satisfy the whole BCI community with one specific definition. To ensure maximum broad support for a definition, the BCI definition committee decided to follow the majority votes to the multiple-choice questions, and take Revised Definition 3 as a starting point. Based on the answers to the open questions, the committee also concluded that one topic requires further attention. Several respondents indicated that the flow of information can be brain-to-environment, or bidirectional, but no environment-to-brain only. This distinction was not made in the multiple choice options in original the survey, however. Therefore, we here propose two options for a working definition of a BCI for a vote. Both options also include small changes, **indicated in red**, in comparison to Revised Definition 3, inspired by comments of the respondents. The explanation of key terms below the two options applies to both proposed working definitions.

Next step

Based on the answers to the multiple choice and open questions, the BCI Society calls for a vote on a working definition for a BCI:

Option 1.

A brain-computer interface is a system that measures brain activity and converts it in **(nearly) real-time** into **functionally useful** outputs to replace, restore, enhance, supplement, and/or improve the natural outputs of the brain **and/or** modifies brain activity using **targeted delivery of stimuli to create functionally useful inputs to the brain**, thereby changing the ongoing interactions between the brain and its external or internal environments.

Option 2.

A brain-computer interface is a system that measures brain activity and converts it in **(nearly) real-time** into **functionally useful** outputs to replace, restore, enhance, supplement, and/or improve the natural outputs of the brain, thereby changing the ongoing interactions between the brain and its external or internal environments. **It may additionally** modify brain activity using **targeted delivery of stimuli to create functionally useful inputs to the brain**.

Key terms:

- “Brain” includes the cerebrum, the diencephalon, the brainstem, and the cerebellum. It does not include the cranial nerves. Furthermore, it does not include the measurement of intention or information (that could have originated in the brain) obtained from downstream areas of the nervous system (e.g. peripheral nerves or muscles).
- “Computer” may refer to a device typically referred to as a computer, but also to other computerized devices, such as robot arms, electrical stimulation devices, powered wheelchairs etc.
- The terms “internal”, “external”, “input”, and “output” should be read in relation to the brain as defined above.

The BCI Society hereby asks for your vote to use Option 1 or Option 2 as a working definition for a BCI.

Please note that the selected working definition will not serve as a strict delineation of the interests of the BCI Society: knowledge gained in the wider areas of interaction between the CNS and its external and internal environments, neuroimaging, neurostimulation etc will remain highly valuable for the development of usable BCIs.

Vote

Which of the two options do you prefer as a working definition of a BCI?

- Option 1
- Option 2
- None of the above