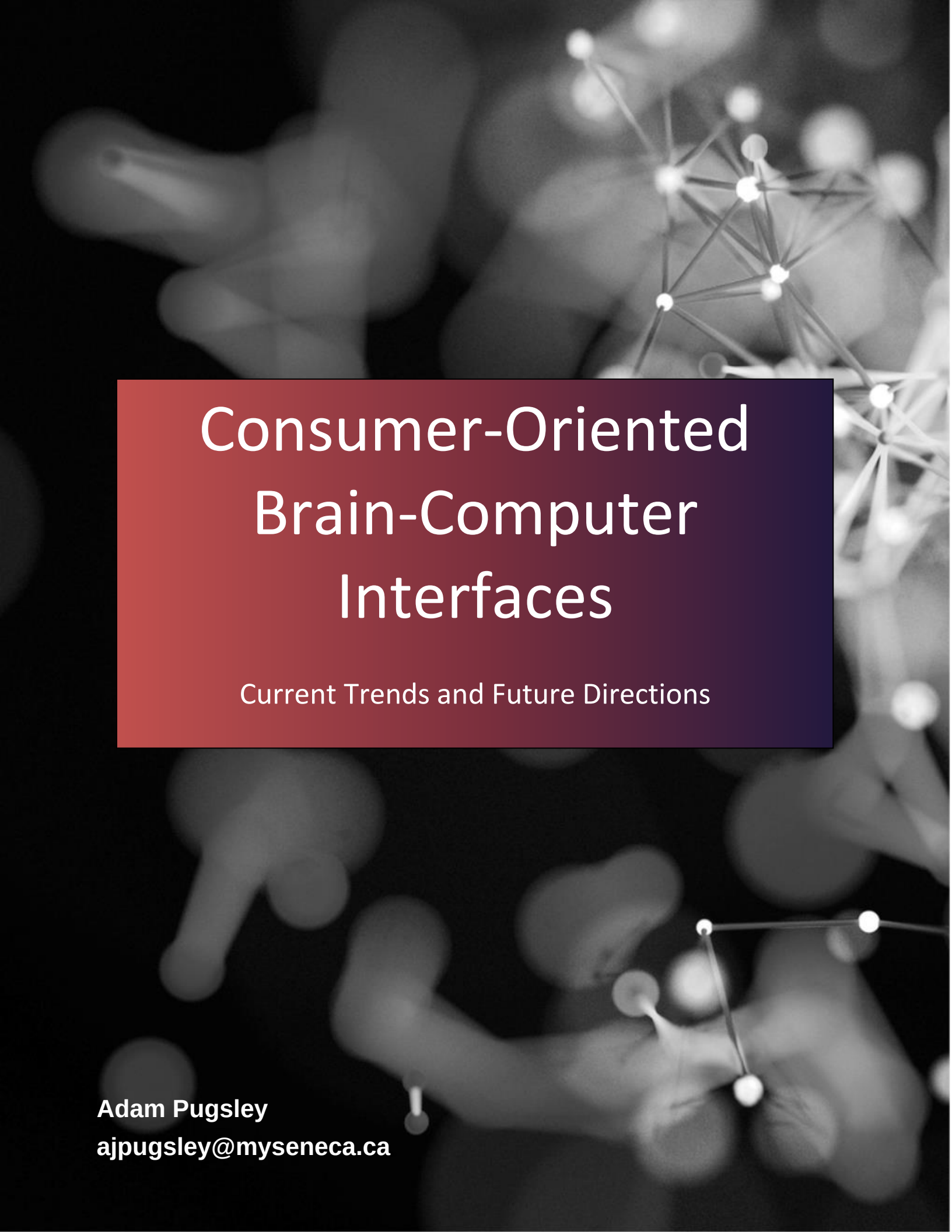

Consumer-Oriented Brain-Computer Interfaces

Current Trends and Future Directions

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Abstract

Brain-computer interfaces (BCIs) are systems that allow for direct information transfer between a human brain and an external device. The development of consumer-oriented BCIs has the potential to drastically change the way in which humans relate to digital technology.

This whitepaper aims to provide a brief overview of the latest consumer-oriented BCI devices and discusses the near-future implications of adopting such technologies.

“The global brain-computer interface market size is expected to reach USD 3.7 billion by 2027.”

- *Grandview Research*

Problem Statement

As global reliance on computers and smartphones continues to increase, innovators seek ways to make our relationship with tech as seamless as possible. Currently, we use our hands and fingers to interface with our digital tools. But what if we could control our devices with only our minds?

Over the past decade, several companies have begun developing consumer-oriented BCIs that promise to allow you to do just that. As with any new emerging industry, there are many players with developing or recently available products to offer.

Figure 1. Source: The Scientist

Introduction

For decades, science fiction authors and philosophers have pondered the implications of our ever-increasing entanglement with technology. In a 1991 episode of *Star Trek: The Next Generation*, a crew member of the *USS Enterprise* creates a device which allows him to directly communicate with the ship's computer via his brain and greatly increase his intelligence. The fusion of brain and machine proves to be a powerful and disruptive combination.

Fast forward to the year 2021, and such technologies are now moving from the realm of science fiction to reality. Academic innovation in the field of BCIs has sparked a new wave of consumer product development. Several companies have consumer-oriented brain-computer interface devices either already available to the public or currently in development.

What are brain-computer interfaces?

BCIs are systems that allow a human brain to communicate directly with an external device. BCIs allow users to control devices such as computers, smartphones, or artificial limbs using only brain activity.

How do they work?

BCIs record brain activity using a variety of neuroscientific methods, including:

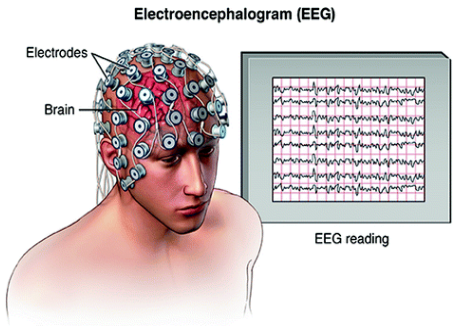


Figure 2: Taki Hasan Rafi et al.

Method	Description
Electroencephalography (EEG)	Measures neuronal electrical activity through an array of sensors placed on the scalp.
Magnetoencephalography (MEG)	Measures the magnetic field created by neuronal electrical activity
Functional near-infrared spectroscopy (fNIRS)	Optically measures changes in the brain's blood oxygen levels
Surgical implants	Measures electrical activity in the brain using surgically implanted electrodes

Table 1: Common BCI data collection methods

Consumer-oriented products most often use EEG technology (*Fig. 2*) to record brain activity and provide insights into brain functionality.

Consumer products

In addition to the research oriented BCI devices available today, several companies are pioneering the way for affordable, consumer grade BCIs.

What is currently available?

Many consumer-oriented products are already on the market.

NeuroSky Mindwave

Figure 3. Source: NeuroSky

NeuroSky (*Fig. 3*) was one of the first companies to offer a consumer-oriented EEG BCI product, launching their MindSet wearable in 2009. The company's current line of MindWave EEG headsets "safely measures brainwave signals and monitors the attention levels of individuals as they interact with a variety of different apps." (*NeuroSky*).

InteraXon Muse

Figure 4. Source: InteraXon

Another early player in the EEG headband market, Toronto based InteraXon launched their first Muse headband in 2014. Their current line of products includes the Muse 2 (*Fig. 4*) and Muse S. The Muse products are designed to provide feedback on user's meditation and sleep habits, allowing for insights into one's quality of attention and sleep. The headbands easily connect to a mobile device via Bluetooth and are some of the most user friendly devices currently available on the market.

Neurosity

Figure 5. Source: Neurosity.

Neurosity's Crown headband device is specifically targeted to software developers to help increase focus and productivity (*Fig. 5*). The Crown generates scores based on focus and calmness. Using this data, the Crown can mute phone notifications when it determines you are trying to focus and can even play songs from your Spotify account that your brain reacts to best.

Upcoming Products

NextMind views its product as "reducing the gap between thought and action." (*NextMind).*

Figure 6. Source: NextMind

easily attaches to a strap on the back of a hat or VR headset in order to record activity in the brain's visual cortex. This data allows users to control devices by simply focusing their attention on tasks they would like to perform. NextMind's software development kit allows users to do anything from play video games to control coffee makers with just a thought.

"Unlocking the brain and learning how to read and write our neural code is the single most consequential and exciting adventure in the history of the human race."

- *Bryan Johnson, CEO of Kernel*

What is being developed?

Several companies have products available for preorder or in development.

Neurable Enten

Neurable's Enten headphones (*Fig. 7*) feature EEG sensors built into the ear pads. Enten records brain activity and provides feedback aimed at boosting focus and productivity. Enten allows you to track your focus throughout the day, control notifications, and get custom made playlists with songs that improve focus. The Enten headphones are currently available for preorder.

Figure 7. Source: Neurable

Kernel Flux and Flow

Kernel offers two high-resolution brain-computer interfaces: Flux and Flow. Flux is a wearable helmet that uses MEG sensors to record activity from the entire cortex. Flow (*Fig. 8)*, on the other hand, uses fNRIS to record blood flow patterns across the brain. Presales of both products are set to launch in Q3 2021.

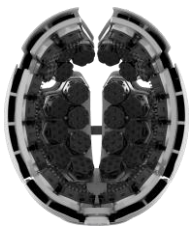


Figure 8. Source: Kernel.

Neuralink

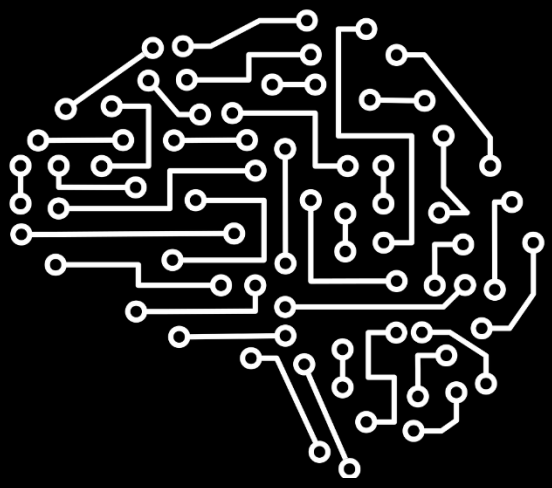
Figure 9. Source: Neuralink.

Like any of Elon Musk's ventures, Neuralink made quite a splash when publicly announced in 2017. The Link (*Fig. 9)* is a neural implant designed to interface directly with the brain using microscopic, surgically implanted threads. To implant the Links, Neuralink is currently developing an automated neurosurgery robot which will be able to perform the installation operation with greater accuracy than a human hand. Ultimately, the goal is to allow users to control external devices such as a smartphone with their thoughts.

Near-future impacts of BCI technology

Since BCIs typically monitor attention, focus, and flow, BCI technology will likely be adopted first in workplace environments with the goal to improve productivity. Many companies already offer stress-reduction programs with the hopes of increasing wellness and job performance. If BCIs could be used the same way, this would be a potentially large area of uptake.

Writing in the Harvard Business Review, Alexandre Gonfalonieri predicts that "in the future, the most 'dangerous' jobs will *require* the use of BCIs." Gonfalonieri gives the example of The Royal Automobile Club of Western Australia, an organization that used EEG headsets to investigate the relationship between inattention and traffic accidents. In the future, BCIs could prove integral a variety of industries to improve worker safety and effectiveness.



Conclusion

The consumer-oriented BCI industry is still in its infancy. Widespread adoption and further development of BCIs has the potential to fundamentally change our relationship to technology. In the coming years, the market for these devices is set to grow dramatically. It is likely that the consequences of these technological developments will be felt for a long time to come.

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