B2CI 2019: The IEEE Brain to Computer Interface Competition's Gaming Event

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***Abstract*—The IEEE Baltimore Section sponsored B2CI 2019, the collegiate Brain to Computer Interface competition, to strengthen their relationships with local university and college engineering departments. A primary goal was to use the processing of brain waves as a mechanism for exciting students about electrical engineering principles and the systems engineering build approach. An ancillary goal was to raise student awareness as to the limitations of computer games for disabled players. The competition was designed to motivate students by providing three alternative events in which to compete. One of the events was the brain-controlled computer game contest. Universities were invited to organize teams to design and code games that utilized EEG signals from a headset as a significant part of the game play. This paper describes the EEG technology, details on the brain-controlled computer game event, and lessons learned for future competitions.**

Keywords—gaming competitions, brain computer interfaces, digital signal processing, EEG, disabled gamers

I. INTRODUCTION

One of the missions stated on the website of the IEEE is to build a platform to introduce careers in technology to students around the world. Xue and Larson stressed the need for software development and engineering skills at all degree levels in both the private sector and the government job sectors [1]. As John Sargent stated in the CRS Report in 2017, there is a need "to improve science, technology, engineering, and math (STEM) skills to prepare a greater number of students to pursue science and engineering degrees [2]." He went on to emphasize that those STEM skills are vital to economic growth, national defense, and other societal needs. Creating computer games offers one path to learning those skills.

Recognizing the pressures on academia to produce students with STEM skills, the IEEE Baltimore Section set out to encourage college and university students to enroll and continue in engineering and computer science majors. The means they chose to accomplish this goal was to create a competition that would require learning new skills and inspire the application of skills already acquired in their coursework. Faculty members from universities who were also members of the local IEEE Baltimore Section met with the private sector members of the section in 2018 to sketch out a concept for a STEM competition. A steering committee was formed in the spring of 2018 with the objective of holding a competition the following year.

The decision was made to use brain wave technologies as the overarching theme of the competition. This offered both an opportunity for hardware engineers to design equipment to process the electrical waves that are measurable on a scalp, and for software engineers to process that data. It also allowed for computer game developers to become involved, as the brain wave headsets opened new gaming design possibilities. It was felt that brain computer interfaces (BCI) was a new enough field that most students had not encountered it as part of their studies.

Since there was already a BCI Society for researchers, faculty, principal investigators, and post docs, the IEEE Baltimore selected Brain To Computer Interface, abbreviated as B2CI, as the name for their competition for undergraduates. There are multiple names for the brain wave technologies. The first is brain computer interfaces, usually abbreviated as BCI. Other names are brain machine interfaces (BMI) and human machine interfaces (HMI), both of which have other implications. The IEEE Baltimore had two factors that they considered in naming the competition B2CI. First, they wanted to emphasize the directional nature of the competition from the brain to the computer. Teams could not enter anything involving from the computer to the brain, thus eliminating neurofeedback or any of the technologies that inject electricity into the brain. The second consideration was to distinguish this

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undergraduate oriented competition from advanced graduate level work in neuroscience.

Seed funding for the first Brain to Computer Interface competition, was provided by the IEEE Baltimore Section. The IEEE Brain Initiative provided additional funding. IEEE Brain Initiative is a cross-discipline collection of IEEE Societies, such as the IEEE Computational Intelligence Society, the IEEE Robotics and Automation Society, and the IEEE Systems, Man, and Cybernetics Society (brain.ieee.org).

Having decided upon a theme it was discovered that a major group of potential beneficiaries of products that could process brain waves would be disabled citizens. Consequently, the State of Maryland Department of Disabilities Technology Assistance Program (MDTAP) was recruited as cosponsor for the competition. The National Electronics Museum granted B2CI 2019 the use of their Pioneer Hall venue for the competition which was held on 2 March 2019.

A. The Three Competitive Events

With the theme of brain wave technologies established, the B2CI 2019 steering committee developed and ran three competitive events. The first event was the Brain-Drone Race, the second was the Brain-Controlled Computer Games, and the third was the Open Showcase. All three of the events were structured with the following criteria:

1. A headset had to acquire brain wave signals
2. The wave data must be processed by a computer
3. The computer would send commands to a device

The implementation and scoring metrics for each event was designed to focus on narrow aspects of engineering that would make a given event unique. The Brain-Drone Race had an emphasis on designing and building headsets, and the associated signal processing required to establish a reliable control signal to control the drone movements. There were minimum two required commands that had to be generated from the headset data to control an aerial drone: *ELEVATE* and *MOVE*. Those commands were to be sent to a drone to drive it only in the forward direction. The Brain-Controlled Computer Game event was designed for creating commands from the raw data that could control a game. The emphasis was on imaginative use of brain waves through a headset as opposed to the conventional input devices for gaming. The purpose of the Open Showcase event was created to allow student teams to build and bring anything that met the general BCI criteria outlined above: headset-computer-device.

II. BRAIN CONTROLLED COMPUTER GAMES

A. Brain Computer Interface Technology: the EEG

According to Abbass, Guan, and Tan, "a Brain Computer Interface (BCI) attempts to detect and decode brain signals then transforms these signals into actions for a machine – such as a wheelchair – to perform [3]." Electrical activity on animal scalps was discovered simultaneously in the late 1800's by a variety of independent researchers: Caton, Beck, von Fleischl-Marxow, et al., with credit for the first discovery going to Caton [4][5]. Human waves were found by Hans Berger in 1924 and given the common name electroencephalography, which is commonly abbreviated as EEG [6]. In the 1960's researcher Barry Sterman experimented with EEGs and found that cats could be trained to produce a Sensorimotor rhythm (SMR) brain state [7]. Around that time NASA became concerned by reports of astronauts hallucinating when they breathed rocket propellant, so Sterman was funded to research possible solutions. Sterman discovered that cats in the SMR brain state were resilient when exposed to rocket fuel composed of hydrazine [8]. Also, in the 1960's Spilker, Kamiya, Callaway, and Yeager reported that their graduate students could produce Alpha brain waves at will using EEGs for neurofeedback [9]. These early studies were limited to the electro-mechanical instruments available to them at that time.

Until the 1990's, BCI work remained exclusively in academic laboratories. The recent rise in BCI research was described by Abbass, Guan, and Tan in IEEE Computational Intelligence Magazine. They stated that the cause of the increase was due to two evolutions. "One is associated with the production of better and cheaper electroencephalograph (EEG) sensors/electrodes. The other is associated with recent developments in computational sciences that enabled faster and more accurate processing of the acquired signal [10]."

With faster processing speeds, and the ability to develop software in house at a reasonable cost, organizations like the Othmer Institute created equipment and EEG protocols for therapeutic neurofeedback. To their patients, their software looks like a computer game, such as driving a virtual automobile over terrain, but without controllers, only brain waves to control the acceleration. The EEG signals from their clients are presented in a 10 second sweep on a spectral display of EEG amplitudes [11]. It should be noted that the Othmer Institute only provides their neurofeedback products to licensed professionals trained in their protocols.

Within the past ten years the IEEE Computational Intelligence Society has published research on the use of EEG patterns to control objects. In one example Taher, Amor, and Jallouli described EEG control of an electric wheelchair [12]. They used EEG brain waves combined with eye and head movements to demonstrate a non-invasive method for controlling motion.

Some headsets provided by commercial vendors contain gyroscopes and can process electromyography (EMG) signals in addition to EEG signals. Raju, Yang, Li, and Cangelosi used those capabilities in an Android game [13]. The gyroscope data they obtained from a wireless Emotiv headset was used to position a cursor. Clicks in the game were determined from eye blink EMG signals. Their research used the Android SDK and Java SDK to process the data. Those coding skills are in high demand and can and should be learned by gaming students. B2CI 2019 did not prohibit the use of EMG signals but did require that EEG signals be part of the student entries.

B. Predecessor Events and Competitions

In 2015 the IEEE partnered with a manufacturer of brainwave headsets, Emotiv, to demonstrate the ability to race robotic cars at CES2015. The robot operators used Emotiv Insight headsets to read in brain waves and output data to be processed by Emotiv's Xavier software which was translated into a command to push or propel the vehicle [14]. Properly speaking this event was not a competition, as much as it was a demonstration of capability. The headset was fixed, in that only the Emotiv Insight could be used, and the Xavier software processed the data. The only variable was the ability of a given driver to focus concentration on moving the vehicle.

In 2016 Eidgenössische Technische Hochschule Zürich (ETH-Zürich) organized and ran a multi-discipline competition as a tournament for people with motor impairments. One of the disciplines was the ETH-Zurich BCI Cybathlon, which implemented a computer game virtual race they called BrainRunners. The task required Brain Computer Interface teams to compete in a computer game that required control of the game's avatar through the use of a brain wave headset. The emphasis for this event was on engineering teams creating headsets and building hardware to perform the necessary signal processing to generate a fixed set of commands.

The BCI Cybathlon rules defined the interface to the game which all participants utilized. Examples of two of the interface rules were "when triggering the right command on an action block, a speed boost is enabled. False positive commands are penalized [15]." All teams competed in the same multiplayer game with the competitive aspect being the brain wave signal processing capabilities of the entry. The list of commands in the game was pre-established and published in advance to the engineering teams. The challenge was to process the brain waves fast enough to correctly move the avatar using the documented interface.

ETH-Zurich's BCI Cybathlon in 2020 will entail races in six different disciples. As stated on their website, races in each discipline has tasks designed to represent situations that people with physical disabilities would encounter in everyday life. The other team competitions in 2020 will include a Powered Arm Prosthesis Race, a Powered Leg Prosthesis Race, Wheelchair teams, and Exoskeleton teams. It was clear that the Cybathlon's emphasis was on assistive technologies requiring engineering, robotics, and sensory-motor systems skills. From a gaming perspective, the game in the BCI Race was a set entity. All teams participated in the same game. The purpose was to illustrate how BCIs could be used to control different types of devices, e.g. a computer, a robotic arm or a wheelchair, with the computer game as the receiving device for commands. This made the Cybathlon BCI game an entry level event for engineering students.

The year prior, the University of Florida held their first Brain-Drone Race [16]. Their event chose to utilize only Emotiv headsets for brain wave acquisition, and only allowed for one model of drone. Since this was their first year, this simplified their event and lowered barriers for entry enabling maximum participation. During the runup to their event, the event sponsors provided a drone simulator for use by student teams. A drone driver for a team had to prove a modest level of skill on the simulator before attempting to fly a live aerial. Having established which headset to use, which software to use, and which model of drone, these constraints made this event more about students learning to control their thought patterns than it was about the hardware and software engineering to create new products.

C. The Brain-Controlled Game Objectives

Building upon the experiences of the IEEE at CES2015, ETH-Zurich's BCI Cybathlon, and the University of Florida's Brain-Drone Race, the IEEE Baltimore section defined a set of objectives for the B2CI 2019 competition. Some university faculty expressed interest in integrating BCI projects into their existing academic courses. Other gaming faculty preferred to have their students use brain wave headsets as part of a senior thesis or capstone project. In consideration of these requests from academia the B2CI 2019 committee for the Brain-Controlled Computer Game event outlined multiple learning objectives. A summary of those objectives was that the students should:

- learn, appreciate, and leverage the potential of brain-computer interfaces to transform lives.
- design user-centric brain-computer gaming interfaces for disability and rehabilitation applications.
- understand intersect between hardware - electrical engineering design parameters and software - intended game outputs.
- acquire skills to work on multidisciplinary teams and take responsibility of the design delivered.
- create a new class of computer games that could potentially be commercialized (ancillary).

One specific outcome in the design of BCI gaming interfaces would be the acquisition and analysis of the brain wave data. Here it would be important to learn how to implement computational intelligence (CI) techniques. Abbass, Guan, and Tan pointed out that data analysis expertise can be acquired in CI as a result of working on brain computer interfaces [17]. They identified Artificial Neural Networks as having applicability to BCI-based classification. They added that Fuzzy Systems are widely used within control systems, and by extension Fuzzy Systems would have a role within BCI control systems. Advanced students might attempt fuzzy multimodal frameworks to improve the BCI performance, such as was accomplished by Ko, Lu, Bustince, et al. with fuzzy Choquet and Sugeno integrals [18]. A third example of computational intelligence applied to BCI would be Evolutionary Computation which Abbass has described as being used in feature extraction and data processing.

During the creation of a scoring metric for B2CI 2019 there was no distinction between games and simulations. McCabe has stated that computer games are different than simulations, with the former engaging players with flashy graphics, music, sound effects, and sometimes a specific, customized but minimal artificial intelligence. McCabe went on to add that

with an objective of making a profit, games are inexpensive [19]. In the discourse with McCabe it was pointed out by Babij that "simulations are designed to provide accurate output which is as close as possible to the real-world outcome. Video games are designed to be fun, typically using abstraction [20]." Babij provided the following example: it is not important what type of oil is inside the engine in a video game, but this could be crucial in a simulation. B2CI 2019 permitted entries to be either games or simulations, with no distinction between the two categories. It will be noted below that this policy will be reviewed for future competitions.

Computer games have a variety of different purposes, depending upon the player/user of the game. These include entertainment, eSports, education, and simulation. With multiple categories, such as action or adventure games, construction games, shooter games, strategy games, or role playing, there is a rich and vast palette from which a team could choose to create an entry to the competition. B2CI 2019 did not distinguish between the categories, nor were students restricted to only submitting games. Simulations were allowed, but none of the teams submitted simulations. The implications of simulators are discussed below in section III-B.

D. The 2019 Brain-Controlled Game Event

Computer games serve different purposes, depending upon the player/user of the game. The intent of B2CI 2019's Brain Controlled Computer Game event was for student teams to create gameplay that specifically utilized the brain interface. One possibility, although not the only one, was to control all the maneuvers of the game's avatar based on the EEG signals being picked up from the target player's headset. Across the board students avoided this alternative, as it limited their options to only the signals from a headset as a replacement for a controller. The methods preferred by student teams were to add the brain wave headsets as a complement to conventional controllers.

Any number of other gameplay designs were also allowed, provided the designers included some aspect of the game utilizing a brain wave interface. For example, conventional controllers might be used to move an avatar, while commands processed from the EEG headset could control the visibility of the avatar. An alternative game design might give a player enhanced capabilities, such as more speed, when the EEG headset sensed a positive pattern match. There were no limits as to the creative possibilities.

Unlike the Brain-Drone Race which was a timed race with a quantifiable measurement determining the winner, evaluation of the games was much more subjective. For B2CI 2019 the steering committee requested help from professional game developers to define the metrics for scoring entries. Many of the metrics were the same metrics as for a conventional game, i.e. visuals should be attractive, sound effects relevant and provide feedback, nothing obscene, no copyright infringements, etc. With the addition of brain wave headsets to the game, new rubrics had to be developed. Some excerpts from the scoring sheet relevant to BCI were:

- Game mechanics make meaningful use of neural headset
- Non-neural interface performs non-overlapping role
- Rules can be discovered through cause-and-effect experimentation

Professional game developers volunteered to be the judges the day of the event. First place was awarded to the University of Baltimore's Simulation and Game Design program. Some of the judges' comments for the winning entry were:

- Neural headset was used to look around the world to scare away or neutralize enemies
- Pathway the player is placed on connects thematically with the character being placed in the wheelchair – mimics the loss of agency experienced by the patient assumed by the player
- VR headset could have been added as an alternative

The winning entry was not a complete product, and deficiencies were noted by the judges. The students had undertaken this effort as part of a capstone project and were still working on completing the game. For example, one judge noted that presentation materials should always be preloaded on the computer in a format accessible without WiFi.

There were students who had attempted to create games that would utilize BCI but were not able to compete in B2CI 2019. Three examples are illustrative. The first was an undergraduate who took one of their existing games and modified it for BCI. The basics of the game had elements of the avoidance strategies found in Pac-Man. The game had an objective to avoid being hit by multiple other automobiles, in the same way that Pac-Man avoided the ghosts. The student added functionality that would increase the driver's speed if the BCI headset sent a specific command. The problem for the student was in the integration of a headset with the game. The student was unable to get the headset system to pass data to the computer. It directly relates to the third learning objective described in Section II.C.

The second example was a two-player game in the form of an automobile drag race. The brain waves from the headsets would cause a given automobile to move forward. In game format this mimicked the IEEE robot car race that was exhibited in CES2015 and described earlier. In this case the student was able to get commands from the headset through the computer processing and successfully send a "GO" command to one automobile in the game. The student was not satisfied with the overall functionality of the product, and chose not to enter the competition. It directly relates to the fourth learning objective described in Section II.C.

The third example was a Brain-Drone Race team that built their own custom headband. Their headset had four electrodes using hardware from OpenBCI, a non-profit that provides open-source brain-computer interface (BCI) hardware. The team used visual stimuli - white screen with a black dot - to obtain reliable alpha waves measured from the occipital lobe of the brain. The team processed the EEG signals using a Python script. After filtering and noise removal, the average signal power was used

as a threshold for the commands. A value above the threshold was used to send commands to lift a drone and hover at a certain altitude. If the power decreased below the threshold, the drone landed. On the day of the competition the team could not run in the competition as a faulty charger drained the batteries leaving the drone inoperable. This related to both third and fourth learning objectives described in Section II.C.

E. Considerations in Brain-Controlled Games

A natural consideration in brain-controlled games are the potential benefits to participants. Generally, video games have shown benefits to players across a plethora of dimensions. Cognition is one such domain which we feel has crossover interest with both the modified Pac-Man game as well as the automobile drag race. More specifically, as Granic [21] discovered, video games produce demonstrable improvements in attention focus, hand-eye coordination, enhanced spatial reasoning skills, and richer learning and memory episodes.

Indeed, the association between playing a video game and greater cognitive abilities has been experimentally validated by Unsworth [22]. Further research by Anguera and Gazzaley [23] also demonstrated a positive relation between video games and cognitive abilities when the video game treatments were paired with specific cognitive exercises. Overall, players of game have shown specific improvements in memory, attention or focus, and fluid intelligence [24]

There are additional considerations for game players who are disabled. One of the cochairs of B2CI 2019 met with Mark Barlet, the founder of AbleGamers, in February 2019 in preparation for the BCI game event. AbleGamers is a non-profit that works with disabled game players to provide technologies such as mouth controllers, eye gaze, and other specialized custom devices (ablegamers.org). Barlet described how disabilities might hinder a game player, in that some movements might be more difficult or not even possible. Although assistive technologies are available, some players might resort to pillows for positioning, Velcro, tape, or something as simple as a rubber band placed around the trigger button. Barlet identified some of the major benefits of playing computer games were the camaraderie and companionship aspects. AbleGamers aims to reduce social isolation by creating communities of disabled players.

AbleGamers has created a collection of design patterns for game developers called the Accessible Player Experience Design Patterns (APX). They offer this tool to game developers so that games can be built in a manner that is inclusive to a wide range of players. Their aspiration is that developers will use the patterns to design games that will allow players with disabilities to customize how they play the game. The staff at AbleGamers was aware of BCI technologies but felt that BCI was not mature enough to be usable by their players. AbleGamers has agreed to help add APX considerations into the rules for future B2CI events.

F. Lessons Learned from the Brain-Controlled Game Event

One important lesson learned on the day of the competition was that only the game player and the judges could see the game in action. It became obvious that during the evaluation of a given team's game a giant screen or overhead projection would have given multiple spectators a view of the game. It was observed that other events at B2CI 2019 such as the Brain-Drone Race were well attended by visitors because the sound of a buzzing drone drew attention and it had a visible, moving object.

This first year there were no multiplayer game entries the day of the competition. One multiplayer automobile race game was demonstrated the month before the event, however the university team failed to finish the game in time for the event. Nor were there any entries that utilized virtual reality (VR) headsets. VR was allowed under the rules, but not specifically encouraged, therefore no teams entered. It was observed that all games entered in the competition were based on the Unity engine. Students had asked if they could use Unreal or other engines. The judges had no restrictions on how the game was created, but the only entries used Unity.

A consideration for the next B2CI competition has been to include psychology students in some capacity. How this will be done is yet to be determined. It is believed that neuroscience majors would be interested in this competition. One suggestion has been that extra points should be added to a score if the team was composed of members from multiple disciplines. An example might be a team composed of engineering, computer science and psychology majors.

III. FUTURE CONSIDERATIONS

As part of a lessons learned process after the event was over, the steering committee outlined some considerations for future events. The first was the timing of the event during the academic year. The second was the importance of simulators, and the need to distinguish between games and simulators. The third was a desire to expand the number of universities and students participating. The IEEE Baltimore Section would like to see growth in the number of students entered in future competitions. The fourth was sharing of the students work with future participants. The fifth was the inclusion of cyber considerations of BCI in the competitions.

A. Selection of an Event Date

For the 2019 competition most student teams completed their projects in a very short time in their spring academic semester. One of the questions that was asked by some faculty was if the competition could be held later in the academic year. The feeling was that the integration of brain wave headsets would be an excellent topic for a senior thesis or for a semester capstone project. A competition date in early March meant that a student who started their project at the start of a semester in January only had eight weeks to prepare. On the other hand, if students started in the Fall semester they could leverage working on it over two semesters as a Capstone project.

This was a difficult decision because there were other faculty that felt that holding a competition too close to final exams in May would be a distraction. This issue was open to discussion, but for 2019 the decision was made by the steering committee to announce the competition in early fall 2018, thus students had six months lead time. For the next competition the B2CI steering committee has already selected 5 April 2020 as the date, giving an extra four weeks.

B. Importance of Simulators

B2CI 2019 allowed entries to be either games or simulations, without distinguishing between the two. This was an oversight in the creation of the rules for the event. The B2CI steering committee intends to review this and decide as to how to proceed in future competitions.

It was recognized that any of the teams entered in the live, moving device competitions needed a simulator so that the team members could practice. The ability to practice on a simulator for teams in the Brain-Drone Race proved useful, so they could quickly make corrections during the code development process. Furthermore, for safety reasons teams could not fly a live drone in a computer lab as they were developing software. Simulators provided a reasonable solution.

The availability of a simulator proved crucial on the day of the competition. The Brain-Drone Race teams were expected to set up their headsets about 30 minutes before they were to perform. The winning team tested their headset as part of their warmup exercises by using a drone simulator. When it came time to perform, they knew that their headset was working when they could not get their live drone to accept commands. They discovered that their Bluetooth connections were wrong; they made a quick adjustment to their computer settings and went on to a successful run for the win.

The importance of the combination of BCI working in conjunction with simulators cannot be understated. In a study on how drowsiness impacts perception and the ability to control a vehicle Liang, Lin, et al., used a virtual reality simulator with EEG to monitor alertness [25]. The practicality of allowing a sleepy operator to drive a real vehicle to measure variances from the center of a cruising lane is obvious. With the addition of a brain to computer interface to a simulator, they were able to gather EEG data and apply linear regression models. We would expect IEEE students who participate in future events to emulate this process.

C. Expanding to IEEE Region 2

The IEEE Baltimore Section is part of IEEE Region 2, which hosts a regional Student Activities Conference (SAC) once per year. Region 2 covers the wider mid-Atlantic area (http://sites.ieee.org/r2/about/) encompassing eight states. The SAC offers college and university students the chance to enter a variety of competitions. The 2019 Region 2 SAC included student-built Sumo robots, a micro mouse maze race, and a hackathon. The 2019 SAC had over 240 engineering students in attendance, representing 27 universities.

A representative from the IEEE Baltimore Section did a presentation on B2CI 2019 at the IEEE Region 2 SAC. Based on the reception by the students, one of the outcomes was that the SAC leadership will be adding brain to computer interfaces as a new competition at SAC 2020. The B2CI 2019 steering committee is committed to merging their brain to computer interface events into the 2020 IEEE Region 2 SAC which will be held at the University of Maryland Baltimore County campus on 3-5 April 2020.

D. Collaboration and Sharing

As part of the Lessons Learned process after the event it was discovered that the source code from the student entries had not been collected. Some of the steering committee members felt that the pathway to increasing future participation was through sharing the code from the winning teams. Other students might review the entries and decide that they could improve upon those products. With a stated goal of inspiring engineering students, the sharing of code from successful teams was agreed to be necessary. Unfortunately, materials were not collected in advance nor on the day of the competition for the computer game events. The brain drone race source code for the first-place team was collected and posted to https://dropbox.com by Dr. Blanchard's LASR Academy along with an offer to collaborate with any interested parties. Future competitions will include a requirement for sharing and collaboration.

E. Cyber Security

The last area for future consideration is cyber security. There is a growing literature foundation for applying common principles of network, information, and data security to noninvasive brain-machine interfaces [26][27]. Such work supplies a robust research pathway for the faculty involved as well as the competition participants. In fact, two of the authors have a group of undergraduate students involved in conducting a critical review of applicable cyber security controls on BCI devices. Further, there is interest in converging cyber competitions [28] into the brain-machine interface contests. Doing so would enable an additional competition format for two-year and four-year students with which to engage, thus expanding their workforce training as well as their ability to practice learned concepts.

One aspect of cyber security taught to undergraduates is authentication of users. Biometric identification topics normally include retinal scans or fingerprints. The U.S. government's National Institute of Standards and Technology (NIST) is part of the National Initiative for Cybersecurity Education (NICE), a partnership between government and academia. Biometric identification has been recognized by NICE as a foundational level skill for security professionals with the CBSP certification, the Certified Biometrics Security Professional. Laszlo and Jin's recent proof of 100% accuracy in identifying individuals with EEGs when their brain activity changes in response to a series of images [29] makes adding cyber security to a BCI competition imperative.

IV. Conclusion

The IEEE Baltimore Section was very pleased with the number of participants and the quality of the entries to the 2019 BCI competition. The goal of fostering a closer relationship with Baltimore area universities was successful in that new faculty and new student clubs joined in the competition and joined the IEEE Baltimore Section. There was also a significant amount of interest from students who did not participate in this year's events, but who stated they would enter next year.

Adding to the interest level from institutions local to Baltimore City (the IEEE Baltimore Section) will be the potential for increasing the number of universities and colleges participating in BCI events because of the merger of B2CI with Region 2 of the IEEE.

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More information about the competition can be found at: http://sites.ieee.org/Baltimore/b2ci/.

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