Going Beyond “Beyond Being There”: An Inquiry into the Use of Brain-Computer Interface Technologies and Intelligent Machine Agents to Facilitate Inconspicuous Communication

Sidas A. Saulynas
Department of Information Systems
UMBC
Baltimore, USA
saulyn1@umbc.edu

Ravi Kuber
Department of Information Systems
UMBC
Baltimore, USA
rkuber@umbc.edu

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Abstract—**In this paper, we present a discussion on the potential use of intelligent machine agents and brain-computer interface (BCI) technologies to help facilitate inconspicuous communication. Members of a university marching band participated in interviews and two focus groups to examine how a marching band needs to communicate during a live performance. Results showed the need for an inconspicuous communication channel that goes beyond the normal human communication modalities. Some insights regarding the use of BCI as a means of inconspicuous communication, such as how it can be used to facilitate both one-to-one and one-to-many communication nodes as well as the need for further research and education as to its use and potential were gleaned. In addition, how intelligent agents might be used as mediators of communication, and implications for the design and the future direction of research are also discussed.**

Keywords: BCI; intelligent machine agents; inconspicuous communication

I. INTRODUCTION

Technology can be used, not only to augment existing modalities of human communication and collaboration, but to create modalities that could not exist in direct human-human interaction. In their seminal 1992 paper, “Beyond Being There”, Hollan and Stornetta [1] suggested that, in identifying communication needs, technology offers three advantages that cannot be present in the absence of technology. These include (1) support for asynchronous communication, (2) the ability to communicate anonymously, and (3) the capability to automatically archive communication.

In addition, there are some instances where communication cannot be overt, for example, when information must be disseminated so that the signal is inconspicuous to anyone other than the intended target(s) or perhaps in a noisy environment where other communication channels are not available. In this regard, technology may offer a fourth advantage to Hollan and Stornetta’s list: the ability to communicate inconspicuously, even when the communication is synchronous and the humans are co-located.

Brain-computer interface (BCI) technologies which provide the brain with a non-muscular communication and control channel [2], have the potential to facilitate this fourth advantage. While BCI has been used extensively for supporting individuals with disabilities and also for domains like computer gaming, its use has yet to be exploited as a communication channel for interaction between humans. One reason for this is that BCI technology has yet to advance commercially to the point where BCI devices can send more than the most basic of signals from human to computer. An electronic autonomous machine agent, acting as an “electronic switchboard operator”, could offer potential to enhance the utility and efficiency of the information being transmitted.

This paper is an initial discussion towards the potential development of technology that will facilitate inconspicuous communication and how intelligent machine agents could be developed to aid in that facilitation. To create initial phenomenological data that would help describe the needs and/or reasons for technology-facilitated inconspicuous communication, semi-structured interviews and focus groups were conducted using members of a university marching band. In this domain, precise actions and covert communication are required. The ability to communicate is diminished as the result of several situational factors (e.g. inability to communicate as the result of holding/playing an instrument, occlusion, or ambient noise). After defining several themes, describing how communication is currently conducted during a live performance and how BCI technology could be used to improve that communication, this paper then discusses implications for the design of an inconspicuous communication system.

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It is important to note that the authors are not suggesting that the state of technology discussed can currently facilitate such a system. Rather the goal of this paper is, through qualitative analysis, to address the following research question: *In what ways can technology be used to facilitate inconspicuous communication?* We then suggest that the potential exists for BCI along with intelligent machine agents to facilitate that need.

II. RELATED WORK

For a communication device to be inconspicuous, it must be able to be used without the need to occupy one's hands. While various technologies have been both researched and developed that go beyond the need of "hand-intensive" modes like the keyboard and mouse model that has been prevalent for over 30 years, all have potential weaknesses applied to a problem space with limited communication resources or situational impairments.

Smart phones and tablets can be used for voice communication, but must either be held while speaking, or technologies such as a Bluetooth wireless headset must be deployed. If one is attempting to enter data, either hands are required or automated speech recognition (ASR) needs to be used. Speech and/or speech recognition, when used in public, is not inconspicuous and may not work at all in noisy environments. Gesture based interfaces overcome the issue of having to type or point to a screen, but might be ineffective when the user's hands are otherwise occupied.

All types of interfaces have advantages and disadvantages depending on the situation in which they are being used. However, all have at least one aspect that make them less than ideal when it comes to seamless and inconspicuous communication: All of them require at least one perceptive "sense" for information to be perceived and processed. When that sense cannot be utilized, whether it is the result of a physical, mental, or situational disability, the interface will not function or at least not function seamlessly and inconspicuously. BCI is an interface modality that does not rely on any of the traditional modes of human perception.

BCI uses electroencephalographic (EEG) signals, such as event-related evoked potential (ERP). When visual, auditory or somatosensory infrequent stimuli are mixed with frequent stimuli, the former evoke a potential in the EEG that is typically recorded by the electrodes covering the parietal lobe, usually appearing around 300ms after stimulation which is why this type of ERP is called P300 [9].

Much of the early research regarding the use of BCI has focused on the area of assistive technology. For example, BCI has been used as a means of communication for patients that have locked-in syndrome [8]. Recent studies, however, have begun to examine the use of BCI outside of the realm of assistive technology. For example, Finke et al. [3] created "MindGame", a BCI game where P300 events are translated into movements that navigate a character on a game board. Farwell and Donchin [10] showed that the P300 can be employed as a switch by means of which the subject can toggle a binary choice. In their study, four healthy subjects were able to use BCI, when presented with a 6-by-6 matrix on a computer display containing the 26 letters of the alphabet and a few one-word commands, to communicate the word "BRAIN" to the computer.

Most studies have tested the capabilities of BCI devices while the participant is in a controlled laboratory environment and while sitting down and stationary. However, for a BCI device to be used effectively in active communication, it may need to function while the users are moving. De Vos et al. [8] conducted a study where participants used BCI to record the counting of a "target" tone while ignoring two other tones on two separate trials: (1) while the subject and experimenter sat on two chairs positioned in a relatively quiet location and (2) while walking along a predefined route escorted and guided by the experimenter. The results showed an accuracy (P300 to target tone) rate of 71% for the seated condition compared to 64% for the walking condition.

Research has shown the potential for BCI to be used as a means of communicating at least basic data bits and even the potential for such communication to be feasible while in motion. But such rudimentary capabilities may not be sufficient when communication is required from human to human and/or in a multiple actor problem space. If a human needs to send a "command" to one of many humans in a group, or to a specific sub-group within a group, the BCI signal will need an "intermediary" or "switch board operator" that will be able to receive and interpret the signal, then channel a response only to the intended target(s) of the command. Software agents could be used as "operators" of that "switch board".

The use of intelligent autonomous agents has its roots in the more general research area of artificial intelligence (AI), and suggests that a cooperative environment would exist between human and machine agent where both can initiate communication, monitor events, and perform tasks [4]. Agent software is personalized, proactive, autonomous, and adaptive and can act on the "users behalf" while they are involved with other tasks [11]. An example of an architecture that has been developed is a web mining intelligent agent called the "Evolutionary Virtual Agent" (EVA) which sought to create an autonomous agent that responds to human interaction in real time appearing to "think", make decisions, and act on its own volition [5].

Previous research suggests that BCI and intelligent autonomous agents have the potential for incorporation in a system that can facilitate inconspicuous communication. A system can be designed to receive data through a non-muscular channel, have that signal autonomously and proactively adapt to the needs and intentions of a human actor, and send an appropriate signal to the intended target(s). But does there exist a need for such communication? The following section of the paper highlights a qualitative study which gathered phenomenological data to help determine the needs of a marching band for inconspicuous communication where traditional channels were not available.

III. STUDY DESIGN

The study was designed in the phenomenological tradition in order to help discover meaning and ideas for potential design. Eight (four male) members of a university marching band took part in the study. Two of the members also served as drum majors (one female). The female drum major recruited the other seven participants. The data collection consisted of three interviews followed by two focus groups.

A. Interview Procedure

Three band members (one drum major/two musicians) participated in 30 minute individual semi-structured interviews. All three also participated in the focus groups. The data gathered from the initial interviews helped create open-ended questions and scenarios which were used in the focus groups. All interviews were recorded with handwritten notes.

B. Focus Group Procedure

Each 60 minute focus group consisted of four band members (each group with three musicians/one drum major). Band communication during a live performance was discussed and scenarios based on the findings from the interviews were used to facilitate ideas from the participants in regard to the need for ad hoc communication and possible situational impairments to communication. To inform participants to the potential and limitations of BCI technologies, a 5 minute video was shown describing the Emotiv EPOC BCI headset (Figure 1) which was then passed around. The remainder of the session focused on the use of BCI as a means to communicate with each other. The main difference between the groups was that data gleaned from the first group was used to refine the content and flow of the second group in the tradition of theoretical sampling.

Figure 1. Emotiv EPOC device. Data from 14 EEG channels can be collected to determine emotional information, conscious thought and identify subtle facial gestures made (www.emotiv.com).

Figure 2. Marching band moving in formation (www.stevenson.edu).

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Examples of scenarios presented to focus groups included:

1. The person in front of you has just messed up and is about to cause a cascading collision effect. How would you communicate to get the situation back on track?
2. You are looking straight ahead but missed a gesture performed by the drum major because your instrument blocked your vision. Now you are potentially going to create a cascading error. How do you recover?
3. *Added to Focus Group 2* - You notice that someone five places in front of you is in the wrong spot. How would you communicate the error to avoid a collision?

IV. FINDINGS

A. Interviews

Participants suggested that the drum major is responsible for communicating with members of the band. He/she signals timing and pace via gestures and eye contact. The band must always be looking "straight ahead" at the drum major (Figure 2). Occlusion can disrupt communication due to the size of some instruments resulting in missed gestures from the drum major. "Listening across the band" was described as a kind of distributed situational awareness achieved by hearing the volume and tempo of the band as a collective to help in the adjustment of individual performance.

Mistakes were described as being prevalent in performances. The most common, a "collision", occurs when someone collides with another creating a cascading error. During these events, non-drum major controlled ad hoc communication within the ranks occurs which often consists of physically coming into contact with the band member in need of redirection by means of a touch or a push in an effort to create redirection.

B. Focus Group 1

Much of what was learned during the interviews was confirmed. In addition to gestures/eye contact, a communication tool called "dutting" (literally uttering a "dut" sound several times in tempo) is used to make sure that members of the marching band are where they are needed. The music itself and how it is being played also contains information regarding where to be positioned and the pace of movement.

Participants described what they would do if a collision occurred. Because they need to look straight ahead, they are very dependent on peripheral vision. The remedy is usually eye contact, or if not possible, actual physical contact usually in the form of pushing the out-of-position band member with a free hand in the correct direction. For example, one participant noted, "This person who went the wrong way…I put my hand out to show him go this way because I was in the middle of playing and couldn't talk…I didn't push him noticeably but I pushed him enough so that he knew to go that particular way. It still put everyone around us two or three counts behind the move."

About halfway into the session, the Emotiv EPOC BCI headset video was shown followed by the passing around of the headset. The group was then asked to comment on BCI technology and then its potential use within a live performance setting. It was evident that the concept of BCI was a novel idea that went beyond the mental models the participants had regarding the interface. For example, the first two reactions were somewhat extreme ranging from "Scary" to "Great idea." Part of the concern seemed to be fear of loss of locus of control. One participant noted, "It starts with a game and then it will eventually evolve into everyone being able to read each other's minds."

Participants also thought of ways that a section leader could send adjustments with his/her mind. For example, one participant noted, "…your section leader is the one that is giving the commands…that will help…it will create more precision on the field". Even the band members who were reticent about the technology stated that BCI use would eliminate the need for verbal communication reducing collisions. As one participant noted, "It will stop us from saying, 'stop' or having to yell". When discussing sending and receiving signals, even the reticent participants were beginning to see value.

C. Focus Group 2

This group began with brainstorming possible ways that humans communicate. Then they were asked which of the suggestions could be used to communicate during a live performance. The remainder of the session was structured as Group 1 with additional, more focused scenarios.

Group 2 confirmed the observations of Group 1, often strengthening ideas presented. The first comment regarding BCI after the video was shown was, "Is it real?" Then during the continuing discussions, several suggestions for BCI potential use to support communication were offered. For example, one participant suggested, "…the drum major could wear a piece like this. He could potentially look at a person and say 'hey, take three steps back'…and only that person would hear it…" suggesting that a BCI transmission would replace the need to both "look" and "say".

In addition, discussions of formation and tempo, and even suggestions that and intelligent system might be able to train and adjust itself were considered. As one participant speculated, "If there were a way to [have access to] an external metronome where only we can hear it…we [could] get the audio of just the tempo."

V. DISCUSSION AND DESIGN IMPLICATIONS

It was clear as the result of the interviews and focus groups that there is a desire and need for additional open channels of communication that are not always available when performing live. The concept of a "collision", for example, was mentioned often and appeared to be universally accepted as a major issue. Using technology as a means to collaborate to overcome the inability to adequately signal for correction, or the use of potentially unprofessional "workarounds" was welcomed by all who participated. Participants saw the potential value for such technology-assisted collaboration occurring both in one-to-one as well as one-to-many communication situations.

Add to this, the complexity of situational impairments for loud and/or chaotic environments, such as is usually experienced by a marching band during a live performance. Because ad hoc adjustments are often needed, but the communication sources are limited or non-existent, the need to explore the development of such a system is clear. The problem space in which humans must work is becoming more complex with an increasing number of issues and tasks that users must constantly keep track of [11]. Since machine agents can be designed for autonomy as well as adaptability, some of the cognitive processes required to achieve a desired goal can be effectively offloaded to the system. This is an example of one of the motivations for the creation of machine agents. Having a personal assistant, human or machine, eases the burden of an increasingly crowded problem space.

The value of this assistance is certainly not limited to the "non-expert" user. The members of a marching band can certainly be considered experts in their domain, yet they still encounter minutia that must be addressed in a timely and often inopportune situation. In baseball, the team's manager can be considered an expert in their domain, but still needs the assistance of a "bench coach" to keep track of important minutia like pitch count, or a particular batter's tendencies against a right-handed pitcher. Expert and novices alike operate in an ocean of cognitive overload. The life raft offered by an assistant can provide a valuable resource to keep them afloat.

With this clear desire to improve communication, it was interesting to note the dichotomy of reactions to the use of BCI as a means for that facilitation. However, it is also not completely surprising. The interview questions never mentioned BCI. The focus groups were structured so that the first half focused on the problem space, then only in the second half was the potential technology solution introduced and discussed. It was hoped that a rich discussion of the problem would then lead to a healthy discussion of a potential solution. What was clearly gleaned from the discussion was a lack of understanding of the capabilities of BCI. Resistance was expressed with the fear of the unknown as its source, but perhaps more importantly, the fear of loss of locus of control. Not understanding how BCI works, lead to fears of mind reading and/or the transmission of thoughts that were not meant for transmission.

When this concern is extrapolated to consider the use of machine agents the locus of control issue might be exacerbated. Ben Shneiderman, in a debate with Pattie Maes, indicated that one of the goals for effective human-computer interaction should be to provide the user with a "feeling of being in control and therefore…responsible for the decisions they make." [11] One of the concerns with the use of machine agents is the potential of relinquishing of that control to the machine. Perhaps this concern is echoed in the trepidation expressed by the study participants over the use of BCI.

All this being said, even those initially reticent to the technology began, by the end of the sessions, to acknowledge the potential utility of such a system in their domain. The participants identified the value that such a system would add to the collaborative process. However, it is evident that they would need to be convinced that their concerns regarding the potential misuse of the technology were addressed.

The progression from semi-structured interviews to the two focus groups provided insight into the group communication needs and also to the potential of BCI as a means of facilitating that communication in situations that available modalities do not provide ideal support. Both groups were open and active to keeping the discussion on point. Scenarios helped inspire more thoughtful and focused discussion. As a result of the qualitative data that was gathered, the following implications for design may be considered.

A. Education and training of BCI

BCI is still a relatively new technology and it was clear that it is not very well understood. The worry about using BCI erroneously and reactions ranged from disbelief to fears of "mind-reading". It is clear that consideration must be given to help educate users as to what BCI can and cannot do as well as its functional feasibility. For example, showing how BCI could be used to only transmit conscious thought, as well as demonstrating how BCI can be controlled, might allay worries regarding the transmission of involuntary commands.

B. Headset customization and design

Any headset that would be used by a group, such as a marching band, would have to be worn in a way to fit underneath and within the structure of that group's clothing and/or equipment. For example, the BCI headset would need to be designed so that it could fit under the headgear currently worn by band members.

C. One-to-many communication

BCI could be used when a drum major needs to communicate only to a certain section of the band in a way where the communication signal is delivered only to the intended targets and that no other band member can misinterpret as a communication meant for them. In addition, the drum major or section leader can send simple worded commands globally as needed. In terms of output, even if direct brain-to-brain communication could not be developed, some form of audio or even tactile signal could be received. A situationally aware intelligent machine agent could be used to make a determination as to the most appropriate signal type based on the ambient conditions.

D. One-to-one communication to various group nodes

BCI could be used for ad hoc one-to-one communication within the ranks in order to communicate any live adjustments that might be required. This would eliminate the need for the current, less professional workarounds such as direct physical contact. These adjustments can also occur from band leaders as well creating a communication channel that cannot exist without the use of technology.

E. Augmenting existing equipment

BCI and intelligent machine agents could also perhaps be used to augment the use of existing equipment. If the drum major is "feeling" the tempo of his/her metronome, BCI could be used to send the tempo globally so that all members of the band are "feeling" a uniform tempo and reduce the burden on the drum major. If the intelligent machine agent could also "learn" through situational awareness, adjustments could occur without the need for direct involvement of the drum major which could further reduce his/her load.

VI. LIMITATIONS AND FUTURE WORK

Current BCI technology is limited in its capabilities. It is slow relative to more traditional control schemes and preliminary evaluations of commercially viable headsets such as the Emotiv EPOC device have consisted largely of proofs-of-concept rather than true empirical research [6]. There is also the issue of being able to send signals from areas of the brain in such a way as to not create cognitive dissonance with any active cognitive brain function. While machine agents may have not developed to the point where they are capable of the semantic level of interpretation necessary to provide seamless interaction, given the potential cognitive overload issue with using BCI in an active situation, their role in an eventual solution is important.

BCI technology cannot currently be used for communication between individuals. However, intelligent machine agents may be developed that can act as "intelligent switchboard operators"; by which EEG signals sent from the brain are captured by a BCI device then directly interpreted and translated into useful output. Saulynas et al. [7] proposed a system for intelligent assistance during live presentations where a machine agent could be used in conjunction with either BCI or automated speech recognition (ASR) to interpret a presenter's need for ad hoc material. In their proposed system, the machine agent would be able to (either by direct command or semantic understanding) determine that a new slide, or a slide from a previously archived presentation, is needed by the presenter and incorporate that slide seamlessly into a live presentation.

If seamless assistance could be developed and incorporated with BCI, the ability to communicate inconspicuously can be facilitated in ways that face-to-face communication, or other technological modalities could not accommodate. This preliminary study has shown that there exists the need to support inconspicuous communication for activities such as communication in a marching band during a live performance.

There are implications, however, that reach beyond the domain of a marching band. Conditions that result in situational impairments for all traditional perceptual channels: improper lighting conditions that can affect visual signals; ambient noise that can affect aural signals, ambient tactile stimulation that can affect haptic communication, can all have an effect on our ability to both send and receive information. There are situations were traditional modes of communication could be dangerous if used. If one is driving an automobile, communication using any traditional modality could be a distraction from the actual driving task. Or if one is engaged in covert activity, for example, during a military operation, the use of, or detection of, any attempt at communication could prove fatal.

Given this, future directions of this research would include a deeper examination of the BCI technology in any domain where communication is needed. Perhaps more global inconspicuous communication themes exist that could inform the design of technology designated to facilitate those needs.

VII. CONCLUSION

This paper has provided a preliminary theoretical inquiry into the need for inconspicuous communication and how technology might be used to facilitate that need in ways that would not be possible in face-to-face communication. In particular, we examined the use of BCI and intelligent machine agents as the technological facilitators for any potential system that would be developed for use in inconspicuous communication. The hope of the authors is that this inquiry will inspire discussion and lead to additional research.

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