Understanding How the Appearance of Brain-Computer Interface Affects People's Perceptions

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Abstract
In this work, we study how the appearance of Brain-Computer Interfaces (BCI) affect the way people perceive this technology. We collected 64 online surveys to motivate several design directions for BCI's appearance. Based on the survey's results, we developed four prototypes through critical design. We then interviewed 8 participants with various professions using the 4 prototypes through online meeting software. The diverse style of our prototypes helped stimulate conversations and solicit opinions. We find that people refer to existing head wearables with a similar appearance to understand the BCI, specific appearances could lead to stereotyping about the type of person wearing the device, and people rely on placement to infer functionality. Participants from different backgrounds interpret the appearance from different perspectives. Our research contributes to design recommendations for BCI researchers and developers. Our findings also bring awareness to the neglected accessibility implications that BCI's appearance entails.

Author Keywords
Brain-Computer Interface; Appearance; Critical Design;

INTRODUCTION
Brain-Computer Interfaces (BCI) are an emerging technology that leverages on noninvasive physiological data collected from the brain to enable radically new communica-

tion options. Over the past decade, many laboratories have begun to explore BCI technology as an assistive technology for those with neuromuscular impairments that prevent them from using conventional augmentative communication methods. BCIs provide these users with communication channels that do not depend on peripheral nerves and muscles. While the majority of studies around BCI focus on improving the accuracy or robustness of BCI, we are interested in studying how the appearance of BCI affects people's perceptions toward this technology.

In order to study this research question, we first collected 64 online survey responses through convenience sampling to gain insights about people's opinions towards both regular head wearables and head-mounted BCI devices. Based on the data analysis of the online survey through descriptive statistics, we defined a design space and created 4 different BCI prototypes, focusing on various aspects of the appearance. We then used these 4 models to conduct user interviews and gain valuable insights into people's perception of BCI. We discuss how these findings shed light on implications and further research directions for BCI researchers and designers.

BACKGROUND

Brain-Computer Interface

In recent years there has been a proliferation of research around BCI. Researchers use the noninvasive electroencephalogram (EEG) data, among other physiological signals collected by BCI, to achieve an array of tasks [13]. Studies demonstrate BCI's potential capabilities of restoring motor abilities to paralyzed individuals and assisting their daily communication [11], controlling a robotic quadcopter in three-dimensional (3D) physical space [3], or even replacing the traditional password system using the user's unique EEG data [2, 7]. Outside the research institution, a slew of inexpensive and commercialized head-mounted brain-scanning devices has caught people's attention [8, 9, 4]. Moreover, the open-source structure of some of these platforms further foster the development and democratization of BCI technology[10].

The Appearance of Emerging Technology

The appearance of robots, especially humanoid robots, has been extensively studied by researchers in the area of human-robot interaction (HRI) [1, 5, 6, 12]. Researchers find that the appearance of robots offers informative social cues and significantly influence people's interaction and perception towards the robot[6]. Furthermore, it's important to match a robot's appearance with its task to provide a clear mental model[5].

We believe that, as a novel and emerging technology, BCI devices closely relate to humanoid robots in terms of their development stage and long-term goal. To start with, they are both nascent technologies that live mostly within laboratories, yet large amounts of endeavors—from both research and industry—are being made to popularize them as mature products for a broader population. However, researchers studying BCI tend to focus on functionality improvement and neglect the appearance of the head-mounted BCI devices. Motivated by the previous research done in HRI, we ask the question: *How does the appearance of BCI devices influence people's perception toward this technology?*

METHOD

In order to answer our research question, we first created and sent out an online survey to get preliminary information about people's familiarity and perceptions of BCI devices. We then designed and prototyped 4 head-mounted BCI device models each accentuating a certain factor of appear-

Figure 1: Discreet Model

Figure 2: Familiar Model

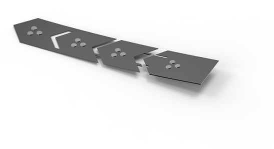

Figure 3: Aesthetic Model

Figure 4: Outrageous Model

ance. Lastly, we conducted remote interviews with these 4 prototypes to understand what factors of appearance people care about.

Survey

We created an online survey using google forms and sent it out using convenience sampling. The first part of the survey consists of contextual questions such as participants' area of study and familiarity with BCI. In the following portion, we had participants select the types of regular head wearables they wear frequently such as headphones, sunglasses, earbuds, hat, headband, etc. Then participants rated how much they cared about discreetness, uniqueness, physical appearance, fashionable(trendy), and familiarity when wearing these head wearables. In the final portion, we introduced BCI, gave a few examples of BCI head-mounted devices, and asked participants to rate how much they value the same factors as above when using a BCI device. We then had participants explain why they chose their top two factors. In total, n=64 participants took the survey.

Designing the Prototypes

We designed and prototyped 4 head-mounted BCI 3D models each accentuating one of the most valued factors from our survey results. We created a discrete model, familiar model, aesthetic model, and outrageous model to cover the design space. The models were built using Rhino with the help from an expert. We did not reveal the names of these prototypes to our participants in order to solicit unbiased opinions.

When creating our prototypes we used the concept of critical design. We used our models as "artifacts intended to be carefully crafted questions" for our interviews [14].

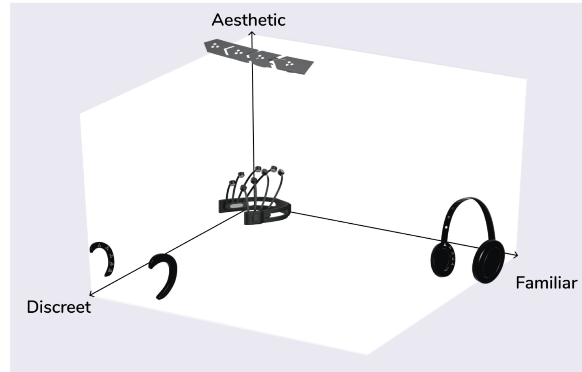

Figure 5: Design Space for the pro

Discreet Model
We accentuated discreetness by creating a small device placed behind the ear fitting the natural profile of the ear. The small size and placement allowed this device to be easily hidden and less noticeable.

Familiar Model
We accentuated familiarity by creating a device that looks like headphones. The majority of people have either seen or used headphones before. Additionally, they are noticeable, therefore, they do not interfere with the discrete model.

Aesthetic Model
We wanted to create a device that was not discreet or familiar, but looked stylish. Therefore, we created two arrow-like strips that would be placed along the forehead just below the hairline.

Outrageous Model
The purpose of this model was to look completely different from the others and look similar to a standard EEG ma-

chine. This model included a thick headband with 3 finger-like structures extending out of each side. The headband would be placed around the back of the head while the finger-like structures would rest on top of the head.

Interview with Prototypes

We conducted 8 structured interviews using our 4 prototypes. Due to the restrictions of COVID-19, we conducted the interviews remotely using Zoom and shared our screen with participants to show the models. The participants consisted of 3 BCI experts, 2 students familiar with BCI, and 3 students unfamiliar with BCI. Depending on participants' level of familiarity we gave a brief explanation of BCI and described some examples. We started the interview by showing participants one model at a time and performed a reaction card technique. For each model, we had participants choose 4 words from 20 that best related to how they felt about the model and then explain why they chose these words. We then asked questions about each individual model such as “Based on appearance, would you use this device?” and “What do you like[or dislike] about this device?”. We concluded the interview, by asking questions in regard to all of the prototypes such as “Assuming that all of these devices have the same functionality, which would you be most likely to use?” and “Under what scenarios would you want to use each device?”. For each participant we showed the models in a randomized order to help eliminate confounding variables.

RESULTS

Referring to Similar Existing Devices

A commonality we found among all of our interviews is that people referenced similar existing devices to comprehend the BCI models. This was most prominent for our familiar model and outrageous model. Every participant said the familiar model looked like headphones. Therefore, they

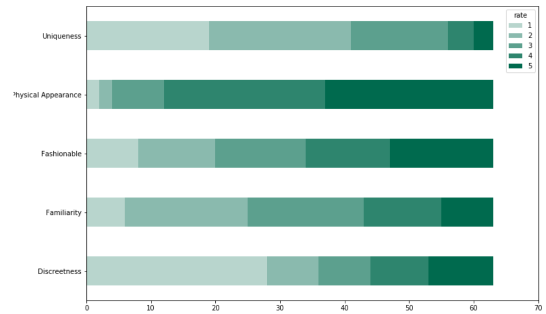

Figure 6: Online Survey: Rating for regular head-mounted wearable. Participants rated "Physical appearance" and "Fashionable" with highest grade the most.

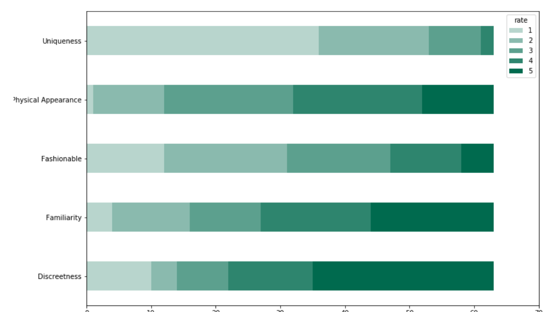

Figure 7: Online Survey: Rating for BCI. Participants rated "Discreetness" and "Familiarity" with highest grade the most.

projected all of their perceptions and experiences of headphones onto this model. For example, some of the participants expressed they do not like wearing headphones because it hurts their ears: “I don’t think I could wear this for long periods of time because headphones hurt my ears”. Due to this direct comparison, participants saw the model’s slight differences from their mental model of headphones as negative. For example, people commented on how the headband width was too thin and the ear muffs were too large. As for the outrageous model, most related it to a standard EEG machine. Therefore, they associated it with medicine and laboratory use. Because participants perceive a standard EEG machine as more comprehensive and reliable, they also perceived the outrageous model as such.One participant stated “It seems comprehensive and powerful...it looks like it would be able to get a lot more information from me.”

Additionally, due to these models’ similar appearance to existing devices, they expected similar functionalities. Participants linked the functionalities of headphones to the familiar model. When we asked what they thought this device would be used for, responses included collecting brain data while listening to music or playing video games.Some participants made comments like ”maybe it could track my mood while listening to music”. Similar to a standard EEG machine, participants thought the outrageous model would be able to capture a wider range of brain data and be used for medical purposes such as monitoring a brain disorder. Furthermore, all of the participants said that they would not assume the familiar model to be a BCI device because it looks just like headphones. Whereas, all of them stated they could tell the outrageous model would be used to collect brain data because they related it to EEG.

These results offer recommendations and guidelines for BCI designers to construct their devices in a way that offers clear affordance and user-friendly functionalities.

Stereotyping BCI as Medical Treatment

When people perceived the BCI model as a medical device, they stereotyped the type of person wearing it as having a disability. This was most apparent for the outrageous model. As mentioned above, people associated the outrageous model with a standard EEG headset, which is used for medical practices. All participants expressed they would only wear this device in private because they didn’t want people to think something was wrong with them.[“quote about only wearing alone”] Additionally, when asked what they would think if they saw someone wearing this device, people made comments like “I would think they were in a mental asylum” or that they were “in a research study getting treatment”.

Furthermore, there were similar comments made about the aesthetic model. Participants also did not want to wear this device in public because they didn’t want others to think they were abnormal. One participant said they would assume someone wearing this device would “be using it as a drug replacement”. Another participant expressed the device reminded them of a medical device for treatment, but they wouldn’t look negatively upon it because they’ve used neurofeedback treatment before.

We hope this finding brings awareness to researchers and designers who are developing BCI as an assistive technology. Without carefully designed appearances, BCI devices could inadvertently bring sigma and stereotype to people who’re wearing them–even the initial goal is to assist the users. An assistive technology that overlooks key affective design dimensions would cause harm to society and jeopardize the growth of related areas.

Placement Matters

We found that both experts and general audiences rely largely on the location of the electrodes more so than the appearance to infer the BCI device's function. As expected, the BCI experts had more detailed answers about device functionality due to more knowledge about brain regions, but the general audience also related the device functionality to what part of the brain it covered. When asking what the discreet model would be used for, experts may offer detailed explanations going in-depth about the cerebral functions. For example, one of the experts explicitly argued that the discreet model "should detect something about speech and words as it's near the temporal lobe" whereas the aesthetic model was "placed at the frontal cortex and related to emotion or some high-level thinking analyzing."On the other hand, the non-experts would reply with "what does this part of the brain do? Is that the temporal lobe? I'm not sure what the temporal lobe does but it [the functionality] would have something to do with that." We also noticed that, because of lacking related knowledge about the brain structure, non-experts tend to hesitate about whether or not to use a particular device.

This finding contradicts our hypotheses of expecting people to base functionality off of the appearance of the device. Across all participants, the device's head placement was a larger factor in predicting functionality than appearance. When being asked "under what scenarios would you use this device," participants would combine the two factors(the appearance of BCI and the head placement) to make the decision. For example, one participant mentioned that she would "use the second model(discreet model) during the daily commute" as that model "could hide behind my ear and at the same time

We further conclude that the appearance and the head placement of BCI both reveal unequal amounts of information for people with different background knowledge. We encourage BCI researchers and designers to reflect on these findings and think about how would they make the functions of their BCI more transparent to general audiences who don't necessarily have proficient knowledge to understand the interface system.

FUTURE WORK

We plan to continue this research in the future and take a deeper look into our research findings. In the future we would want to have a larger and more diverse sample size inorder to gain statistically significant results and obtain more culturally diverse perspectives. We also would like to create higher fidelity prototypes and conduct in person testing to be able to get more accurate responses. Lastly, we would like to cover a greater design space by creating more models accentuating other dimensions.

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