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Can Eye Tracking Detect Implicit Bias Among People Navigating Engineering Environments?

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Abstract

There is resurging interest in the presence and impact of implicit bias in both formal and informal engineering environments. Implicit bias refers to the unconscious associations and stereotypes an individual ascribes based on affiliation with a particular identity that impacts attitudes, actions, and behaviors. Though individuals may hold egalitarian views, they can still act in ways that reflect an implicit bias that is incongruent with their greater beliefs and/or intentions. While literature and tests on implicit bias exist, to our knowledge, a method to specifically gauge biases that exist in the perceptions and dynamics relating to engineering environments, more directly, does not.

This study introduces a novel mixed-methods approach that incorporates biometric testing to gain insight and evidence into the biases that may exist among faculty and students engaging in engineering environments. Specifically, informed by literature on microaggressions and implicit bias, an eye-tracking paradigm is used to draw evidence on existing biases related to sexism, ageism, racism, ableism, and classism. In this study, when prompted, participants are asked to select from a pool of options based on the information presented in a specific scenario. During this selection, the participant's eye movements, specifically their fixation regions and times, are collected to later correlate with their chosen selections. Preliminary findings from this study found individual specific implicit biases to exist. The insights of this work could complement efforts to create awareness of bias for impacting the adoption of attitudes and behaviors more conducive to the cultivation of inclusive environments.

Keywords: Engineering, undergraduate, graduate, faculty, eye-tracking

Introduction

Implicit bias refers to the unconscious associations and stereotypes an individual ascribes based on affiliation with a particular identity that impacts attitudes, actions, and behaviors. For such reasons, implicit bias is both pervasive and damaging because people that hold egalitarian views often are unaware that they unconsciously hold biases that impact the way they make decisions about others [5]. Among the American population, based on data collected from the Implicit Association Test, a test created at Harvard University to measure unconscious bias, 90-95% was suggested to harbor the “roots of unconscious prejudice” [5].

Engineering environments are no exception to the presence of implicit bias. The need to make engineering environments more inclusive is a particular challenge in a profession where the majority of people experience an ‘inclusion privilege’—a phenomenon where those who already feel included often fail to recognize inclusion as an issue, perceive the barriers to inclusion faced by other engineers or see the need for action to remove those barriers [3]. For a relatively unceasing time, the engineering profession has been characterized by a heteronormative culture where women, racial and ethnic minorities, persons with disabilities and people from low socioeconomic backgrounds among others have navigated as members of underrepresented groups. Although the number of women and minorities in the engineering and computer science professions has increased over the last 40 years [1], parity issues with regard to race, gender and ability status still exist. Millions of dollars have been invested to make engineering more diverse and inclusive as the problem is complex. However, one aspect stems from a lack of understanding of the experiences of people from underrepresented groups in engineering [2]. Despite all of the investments, a significant amount of work remains to actualizing true cultures of inclusion in engineering.

Acknowledgement that people from underrepresented groups often do not receive equal professional exposure, quality of preparation, and/or support to pursue engineering offers preliminary insight into the presence of implicit biases that exist within engineering environments. Understanding the presence of implicit bias is critical to developing more inclusive engineering environments. Whether implicitly or explicitly understood, the phenomenon is essentially a web of complex emotionally and psychologically chained perceptions that help construct an individual personality. A method of enabling people to not only become aware of their biases, as in the Harvard IAT, but also recognizing how that bias may manifest in given situations would be a necessary step to reducing implicit bias.

Biometrics involve readings of physiological data to correlate with observations and are one of the most widely used mediums for accurately assessing complex emotional and psychological behaviors of a user. Similar studies have used biometric sensors for the attainment of statistical analysis leading to highly unbiased results regarding implicit perspectives of race [4]. While self-reported actions and perceptions may differ from implicitly analyzed perspectives and tolerances [6], eye-tracking and other biometric utilizations allow for unbiased analysis of a person's psychological personality through analysis of their body's actions and behaviors when invoked by certain stimuli. This aids in conveying a medium of transparent observation into the mind of the subject. Adding eye-tracking biometrics into this assessment of personal bias presents another element to the experiment that other tests do not. Specifically, analyzing a person's physical reactions to such controversial topics and using that information to find inconsistencies with their self-reported answers is essential to showing potential hidden bias that is not typically observed self-reported tests. Eye-tracking is one such method that has been used to investigate biased attention and prejudice towards other groups, specifically [9-10].

Research Purpose and Questions

The purpose of this work in progress study is to investigate whether implicit biases exist among people navigating engineering environments. This population consists of engineering students, faculty and staff. However, in the current phase of the pilot, only students have been tested. Based in the microaggressions model as a framework, certain scenarios were presented to correlate with choices that would represent physical manifestations of traditional gender role prejudice-and-stereotype ridden behavior, assumptions of status and ability, and common themes of microaggressions that send the message that people of color are generally not as smart as Whites and women are less capable in math and science than men, respectively [7-8]. The lens of this study was strategically selected to target real-world parallels to how these specific biases might manifest in engineering environments. Self-reported measures of implicit bias have been shown to be in contrast to observed behavior [6]. The use of eye-tracking biometrics is an effective means of obtaining data that would usually be veiled by an individual's personal-mental filter, therefore limiting the concepts they think about to what they choose to explicitly vocalize. This work will serve to investigate correlations between selections to presented scenarios and results of collected eye-tracking data.

Methods

The study was designed to inform the following research questions:

RQ1: How do the choices selected in a presented scenario compare to the areas of fixation as measured by an eye-tracking task?
RQ2: How do participants respond when presented an opportunity to correct implicit bias?

Specifically, eye-tracking biometric sensor data was obtained using a GazePoint eye-tracker while participants completed surveys seated in front of a computer monitor (see Figure 1). Approval from the Institutional Review Board was obtained for this work. Ten participants participated in the study and their demographic data is presented in Table 1. Participants were recruited from those that expressed interest to flyers posted across campus. All participants were from a STEM, if not engineering, discipline.

Table 1. Participant demographics.

Participant	Age	Race/Ethnicity	Inclusive training (required)	Personnel level	Academic Discipline	Parent/Guardian Education Level	Ability/Disability Status
Participant 1	19	Asian- Chinese	Yes (Not required)	Undergraduate Student	Engineer (Undecided)	Bachelor's Degree	Preferred not to answer
Participant 2	19	Hispanic, Latino, or of Spanish origin	No	Undergraduate Student	Technological Entrepreneurship and Management	Bachelor's Degree	No, did not identify with a disability or impairment
Participant 3	22	Hispanic, Latino, or of Spanish origin- Mexican	Yes (Required)	Undergraduate Student	Biomedical Engineering	Less than High School Diploma	Yes, long-term medical illness
Participant 4	18	White/Caucasian- Ashkenazi Jewish	Yes (Required)	Undergraduate Student	Software Engineering	Doctoral or Professional degree	Yes, mental health disorder
Participant 5	18	White/Caucasian	No	Undergraduate Student	Engineering Robotics	Some college or Associate degree/Trade degree	
Participant 6	26	Black, African American	Yes (Not required)	Graduate Student	Management	Master's Degree	No, did not identify with a disability or impairment
Participant 7	20	White/Caucasian	No	Undergraduate Student	Computer Science	Master's Degree	No, did not identify with a disability or impairment
Participant 8	18	Black, African American	No	Undergraduate Student	Robotics		
Participant 9	19	Asian	No	Undergraduate Student	Engineer (Undecided)	Master's Degree	No, did not identify with a disability or impairment
Participant 10	19	White/Caucasian	No	Undergraduate Student	Robotics Engineering	Master's Degree	Yes, disability or impairment not listed

Participants completed two choice selection surveys sequentially to analyze the implicit perspectives among students navigating engineering environments. Each question prompted participants to make selections of the people presented based on the participant's personal and social beliefs. Participants were in no way persuaded to have an affinity for a particular answer choice over others, so all recorded answers originated only from participants' implicit perspectives. Participants moved through the survey as they made their selections taking an average of 5 minutes to complete each part of the survey.

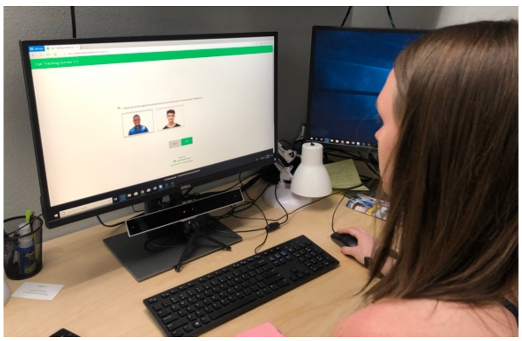

Figure 2. Eye-tracking setup.

Each of the questions focused on a concept we believe to address an implicitly biased perspective that manifests in engineering, particularly misconceptions associated with race, gender, age, ability, and class. Some of the questions were also considered to have intersecting concepts such as ones that addressed race/ethnicity and gender or ability and gender. The choices presented within a given question held some in efforts to see what selections participants made. For example, in a question targeted at gender and ability status, participants were asked, "*Which student do you think is the assistant at their engineering school's makerspace/engineering lab*?" and is shown in Figure 2. Participants then had to choose from one of three options presented where one choice showed a man with a physical disability, another showed a woman with a physical disability and the other showed a man with an invisible disability (which was intentionally not stated). As demonstrated in Figure 2, race/ethnicity and age were held constant across the composition of the group while visible ability status and gender varied. The selection made was used to represent an individual's bias.

Question 1: Which student do you think is an assistant in their engineering school's makerspace/engineering lab?

Figure 2: Example question from choice selection survey administered to participants.

The second survey part consisted of identical questions to the first with one drastic exception, an additional answer option that read, "there is not enough information to determine," was also provided as an answer choice. The hypothesis was that presentation of this option would allow participants who believed they could not answer the question and/or refused to assume any information regarding the individuals presented in the choice to have an alternative. Pictures of the individuals provided as choices were changed in the second survey to minimize familiarity with the choices to a given question.

Along with the self-reported data, all of the choices for each question were analyzed using areas of interest (AOI)—a designated area framing each selection choice—data analysis to show fixation points of subjects within the designated tiles as shown in figure 3. This data was compared with the reported selections to show congruence between the long fixation points, which were recognized as potential contemplation points of the option that the subject was considering the most, and what they actually ended up choosing. We hypothesized contrasts between these observations to represent the difference between explicitly reported answers and implicitly considered answers, which we use to define subjects' individual implicit perspectives and biases in this pilot study.

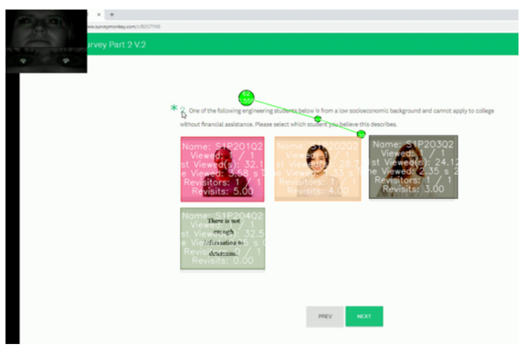

Figure 3. The colored tiles labeled 1-4 represent the four AOIs for the given question.

Results

The following table shows the answer choice and frequency for each of the questions in part 1 of the survey. The most frequently reported response for each question can be ascertained from Table 2. Most participants indicated the name "*Jamal Vazquez*" to belong to the young Latino male. The young Latino male presented in question 2 was most commonly chosen to be the

Table 2: Collective results from survey part 1.

Survey Question	Answer Choice and Responses		
Which one of the engineering students do you think the name "Jamal Vazquez" belongs to?	Young Black Male 22% (n=2)	Young Latino Male 78% (n=7)	
One of the engineering students below is from a low socioeconomic background and cannot apply to college without financial assistance. Please select which student you believe this describes.	Young Black Male 11% (n=1)	Young Asian Male 22% (n=2)	Young Latino Male 67% (n=6)
One of the people below is a tenured engineering faculty member. Please select the individual you believe this describes.	Older White Male 67% (n=6)	Middle-Aged White Male 33% (n=3)	Young White Male 0% (n=0)
One of these professors is in the Nursing program, while the other is an Engineering professor. Please select which you think is in Nursing.	Young White Male 56% (n=5)	Young Indian Female 44% (n=4)	
Which student do you think is an assistant in their engineering school's Makerspace/Engineering Lab?	Young White Male in Wheelchair 44% (n=4)	Young White Male not in Wheelchair 56% (n=4)	Young White Female with Crutches 0% (n=0)

thought of as the student that would not be able to apply to college without financial assistance (78%). When asked about the tenured engineering faculty, most people (67%) selected the older White male to be the individual having tenure. It is worth noting here that no participants chose the young White male. For the question asking which of the two professors was in nursing, 56% of the participants selected the young White male over the young Indian female. And, in the last question asking which student was believed to be an assistant in the engineering school's makerspace or engineering lab, 56% of participants selected the young White male not in a wheelchair and no one selected the young White female with crutches.

The same questions were presented in part 2 of the survey with the exception that the pictures were changed to prevent a learning effect and an additional response was added allowing participants to also have "there is not enough information to determine" to choose as an option. The responses are indicated in Table 3. Participants were evenly split indicating the name "*Dominic Mendoza*" to belong to the young Latino male (44%) and with "there was not enough information to determine" (44%). In the question asking which student was from a low socioeconomic background, the responses varied with "there is not enough information to determine" (56%), young Black female (22%), young Latina female (22%) and no one selected the young Asian female. With regard to identifying the tenured faculty member, 56% of the participants chose "there was not enough information to determine", 33% chose the middle-aged White female, 11% chose the middle-aged White Male and no one selected the middle-aged Black female. When asked to select the nursing professor over the engineering professor, 44% of the participants selected the older Black female, 33% selected the older male and 22% indicated "there was not enough information to determine." In the final question of part 2 of the survey, 56% of the participants selected the young Latino male not in a wheelchair as the assistant in the engineering school's makerspace or engineering lab. The remaining participants chose "there was not enough information to determine," 33%, and the young White male in the wheelchair. No one selected the young White female with crutches.

Table 3: Collective results from survey part 2.

Survey Question	Answer Choice and Responses			
Which one of the engineering students do you think the name "Dominic Mendoza" belongs to?	Young Black Male 11% (n=1)	Young Latino Male 44% (n=4)		There is not Enough Information to Determine 44% (n=4)
One of the engineering students below is from a low socioeconomic background and cannot apply to college without financial assistance. Please select which student you believe this describes.	Young Black Female 22% (n=2)	Young Asian Female 0% (n=0)	Young Latina Female 22% (n=2)	There is not Enough Information to Determine 56% (n=5)
One of the people below is a tenured engineering faculty member. Please select the individual you believe this describes.	Middle-Aged White Male 11% (n=1)	Middle-Aged White Female 33% (n=3)	Middle-Aged Black Male 0% (n=0)	There is not Enough Information to Determine 56% (n=5)
One of these professors is in the Nursing program, while the other is an Engineering professor. Please select which you think is in Nursing.	Older White Male 33% (n=3)	Older Black Female 44% (n=4)		There is not Enough Information to Determine 22% (n=2)
Which student do you think is an assistant in their engineering school's Makerspace/Engineering Lab?	Young White Male in Wheelchair 11% (n=1)	Young Latino Male not in Wheelchair 56% (n=5)	Young White Female with Crutches 0% (n=0)	There is not Enough Information to Determine 33% (n=3)

Additionally, average gaze durations for each question and all of its options are depicted in Figures 4. The time displayed represents the average time each option was looked at in the time that participants spent on that question. These times were calculated based on the amount of time the eyes were measured to have fixated in the AOI as shown in Figure 3. Each response had its own AOI that was established in the GazePoint software. From Figure 4, you can see the option with the longest gaze duration for each question. For questions 2, 3 and 4, as listed from top to bottom in Tables 2 and 3, the choices with the longest gaze durations are not the most commonly selected answers. Specifically, question 3 shows to have the greatest delta between the gaze duration of the most commonly reported answer and the choice associated with the longest gaze.

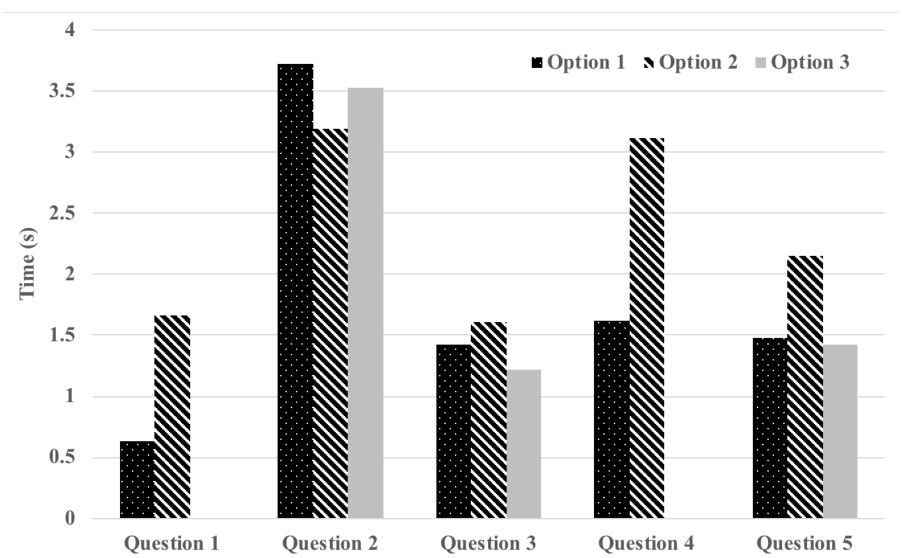

Figure 3: Average gaze durations for part 1.

Figure 4 displays the average gaze durations for part 2 of the survey. For the responses to questions 1, 4 and 5, there is agreement between the most commonly selected answer and the AOI with the longest average gaze duration. In question 1, participants selected the young Latino male to be "*Dominic Mendoza"* and there was an associated gaze time of 1.8 seconds. Although, an equal number of participants chose "there is not enough information to determine," the gaze duration for that choice was lower. Question 2 had the longest gaze duration for the young Latina female, but the most commonly reported choice was "there is not enough information to determine." Lastly, in question 3 regarding the tenured engineering faculty member, people looked at the middle-aged White female the longest. The greatest delta in gaze durations from the longest gaze and the most reported response was found in question 3 of part 2 of the survey.

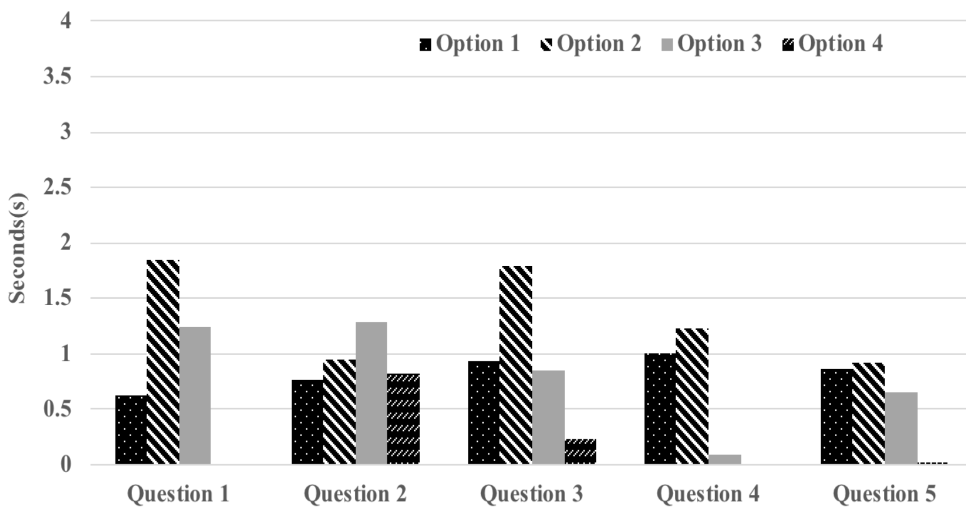

Figure 4: Average gaze durations for part 2.

Discussion

The findings from this study are complex, and as this is a work in progress paper, reveal that there is so much to unpack in this work. This was the first step in our attempt to investigate whether associations exist between what people report (their answer choice) and where people's eyes fixate (their average gaze durations). The results showed that although there was sometime alignment between the most frequently chosen answer and the AOI with the longest gaze duration, that was not always the case. Further work will be necessary with a significant data set to allow for statistical analysis so that any potential relationships between these two outcomes can be identified.

The scenarios presented in the questions were chosen specifically to represent some of the biases that may play into actions, behavior and decision making for people navigating engineering environments. Associating names to a race (question 1) can be perceived as stereotyping, implicit bias, or even a microaggression—insults, whether intentional or unintentional, which communicate hostile, derogatory, or negative messages to target persons based solely upon their marginalized group membership. Ascribing a student to be from low socioeconomic background and not being able to apply to college without financial assistance with only having their physical appearance is similar. The research team was intentional to integrate these types of examples, investigating the perceptions as influenced by age, gender, race, class, ability status, ethnicity and a couple of intersections of these identities (i.e., a woman with a disability). It was the hypothesis that these types of assumptions are often made in engineering environments regarding people, their competence and expectations based solely on visible identities and preconceived notions, implicit biases and stereotypes held associated with those identities. We sought to create an experiment that not only investigated whether there was validity to the claim, but also created an opportunity to see how their biases could potentially show up in a given environment. One obvious example of this is demonstrated in responses to the fifth question in both parts of the survey. When participants are asked who is likely to be the assistant in their engineering school's makerspace or engineering lab, people pick the person that is not in a wheelchair. An implicit assumption here could be that because people are not displaying a visible disability, they are more able and/or not associated with disability. This choice demonstrates the bias that people have to often ignore invisible disabilities. Further, when a woman with crutches was presented, representing intersectionality—having two or more marginalized identities— here, being a woman with a disability, no one chose her and four people choose the male pictured in a wheelchair.

We cannot begin to claim to know exactly what is happening here, but we are certain that this requires further investigation. This is also evident by the most counterintuitive finding in the work. The rationale in presenting the same questions in the second part of the survey, but with the choice of "there is not enough information to determine" was to provide participants with an out from having to make a choice without having any context in the first place. We actually expected participants to stop us during the first part of the survey to inquire as to how they were supposed to be making these choices or even gripe about having to make them with no information. Of the pilot sample included in this analysis, that did not happen. We also expected that with the availability of the option "there is not enough information to determine," in the second part of the survey, participants would choose that for every question. The logic behind presenting this answer choice was that there was not enough information presented in any of the questions to make an educated guess about the status and condition of the individuals depicted in the questions. Due to this, we expected that to be the most chosen answer because it was indeed the only correct one. That also did not happen across the board and serves as evidence that we need to further address the presence of implicit biases among engineering community members. Moving forward we will address some of the current limitations to this preliminary investigation, mainly expanding to a larger sample size, so that associations can begin to be made to better understand which people are making what choices and why. Having a greater sample size will enable us to investigate correlations between the options chosen and the participants' own demographics.

Conclusion

This preliminary investigation provided us with tremendous insight. The next phase of this study will involve conducting a mixed-methods approach to gain a deeper understanding of the phenomenon observed. Incorporating a larger sample size that is more reflective of the varied personnel in engineering will help us create a more inclusive and well-rounded dataset for analysis. From this study, anecdotal evidence, at least, has been generated to show that people navigating engineering environments do hold implicit bias. Further work is necessary to understand the ways in which eye-tracking can be used to accurately detect such biases.

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