Student Understandings of Race and Racial Bias in Computing Environments

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Introduction

This mixed-methods study examines the relationship between undergraduate computing students' understandings of race and their awareness of racial bias in computing environments. Despite global demands for computing expertise, Black, Latine, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander people remain significantly underrepresented among students, faculty, and industry professionals [1], [2]. While prior broadening participation efforts focus on increasing representation [3], [4], [5], less attention has been paid to how students' perceptions of race may influence their recognition of racial bias in computing contexts. We explore the relatively under-researched topic of undergraduate (computing) student perceptions of race and the impact of these perceptions on their experiences and worldviews, especially in the context of academic and career trajectories.

Amid ongoing federal attacks on diversity, equity, and inclusion (exemplified by the current president's recent inaugural address stating that the U.S. should be a colorblind and merit-based society), race-neutral rhetoric continues to persist in and shape public discourse. This assertion, which calls for racial neutrality while ignoring, if not dispelling, long-standing systemic issues, continues to uphold narratives that the lack of representation is due to a lack of ability. The framework of race-evasive racism [6] is thus essential to understanding how students conceptualize race and advancing equity in computing education. The following research question guided this study: How do undergraduate students' definitions of race and perceptions of biological differences between races influence beliefs about racial bias in computing environments?

Literature Review

Student definitions of race often vary and conflict, with categorizations based on biology, power, embodiment, culture, ancestry, identity, and concept. For example, Johnston-Guerrero [7] found that students of color frequently interpret race through frameworks of power and identity, where significant personal experiences shape their perspectives. In contrast, white students often engage with race through academic learning, demonstrating varied pathways to racial understanding [7]. Broader literature on the persistence of race-evasive ideologies in higher education points to a lack of visibility of systemic inequalities, which then perpetuates student discomfort discussing race [7], [8], [9].

While connections have been explored between the frequency of conversations about race and undergraduate perceptions of privilege and advantage [10], there is limited research on how undergraduates come to define race. Lee, Aini, Sya'bandari, Nurlaelasari, Ha, and Shin [11] found that Korean biology students often develop biological views of race due to educational exposure to genetics and physical traits, inadvertently reinforcing essentialist ideas (i.e., the view that people have a set of attributes necessary for their identity). Similarly, undergraduate students in U.S. colleges who conceptualized race biologically were more likely to endorse stereotypes and view racial disparities as unsolvable, while those with socially constructed views were more likely to engage in cross-racial interactions and hold more diverse social networks [12].

Applying this research to computing undergraduates, perceptions of race as biologically determined may lead students to see race as fixed and computing as a "neutral" field that is unaffected by racial dynamics. However, the relationship between race and science, technology, engineering, and mathematics (STEM) (as examined by Hazari, Sadler, and Sonnert [13]) reveals

that minoritized students reported lower science self-perceptions, thus showing how racial biases exist in STEM and computing, impacting the identity formation and belonging of undergraduate STEM and computing students.

Calls to action in previous work stress the importance of fostering cultural competence and integrating discussions of race into computing curricula to address racial bias in the field [14]. These interventions challenge biologically essentialist conceptions and promote more inclusive environments. Nonetheless, research on biological definitions of race (as defined by computing undergraduates) and their effects on departments, curriculum, and belonging remains limited.

Motivation

This paper seeks to fill an important gap in the literature on how computing undergraduates define race and the influence of these definitions on perceptions of racial bias in computing environments. Using a mixed-methods approach, this study provides insights for postsecondary scholars, educators, and leadership that can lead to more inclusive and equitable practices in academic and professional computing environments.

Positionality

Our research team is composed of a multitude of disciplinary backgrounds, including computer science; electrical and computer engineering; public policy; higher education; physics; statistics; cultural anthropology; gender, sexuality, & feminist studies; and sociology. Our varied lived experiences span racial (e.g., Black, Latine, and white), gender (e.g., men and women), and academic identities (e.g., undergraduate and graduate students, postdoctoral scholars, and faculty).

As researchers, we acknowledge that our identities, training, and lived experiences influence our interpretations of data and the framing of this study. Some of us have navigated computing spaces as members of groups that are historically underrepresented, and these differences contribute to our understanding of race and racial bias in academic and professional computing environments. These nuanced experiences not only differentially affect our experiences, they also shape how we approach questions of race and racial bias in computing.

Theoretical Framework

This research uses the theoretical framework of race-evasive racism developed by Bonilla-Silva [6]. Race-evasive racism critically examines the racially motivated social structures, relations, and practices that continue to subordinate marginalized identities within the modern confines of legality. Four primary frames of race-evasive racism (Table 1) are used independently or in conjunction to justify racial attitudes and aggressions: naturalization, cultural racism, minimization of racism, and abstract liberalism.

Bonilla-Silva's race-evasive racism framework is essential for understanding racial perceptions and addressing racist beliefs, particularly in this current societal moment where leaders across various sectors (including government, industry, and education) advocate for "racial neutrality." These frames, which frequently appear in discourse to rationalize discriminatory views and practices, highlight how efforts to eliminate race from societal discourse—despite centuries of racial subjugation—constitute a form of discrimination comparable to overt racism.

Table 1. Four Frames of Race-Evasive Racism

Race-Evasive Racism Frame	Definitions and Examples
Naturalization	Normalizes racially motivated trends and inequities as "natural" and "just the way things are." For example, the underrepresentation of Black, Latine, American Indian/Alaska Native, and Native Hawaiian/Pacific Islander people in computer science is often attributed to personal preference.
Cultural Racism	Ascribes the racial subjugation stemming from societal policies to the cultural choices of identity groups. For example, the assumption that Black and Latine students struggle academically because their families do not emphasize STEM as much as white or Asian families overlooks the broader, systemic educational barriers.
Minimization of Racism	Limits discrimination to overt racism while overlooking covert forms and asserts that the racial effects of slavery no longer persist. For example, arguments that downplay the lasting effects of slavery and systemic racism ignore persistent structural inequalities and have contributed to the elimination of diversity programs in some tech companies.
Abstract Liberalism	Beliefs that society functions as a meritocracy, where everyone has the same chance of success. For example, opposition to race-conscious policies such as repealing affirmative action and diversity, equity, and inclusion initiatives is often justified by claims that "everyone has the same opportunities for success as long as they work hard."

Methods

Data collection occurred during the fall 2022 and spring 2023 semesters, which included a survey distributed to students and optional, semi-structured interviews. Both instruments were motivated by the Detroit Area Study [6], [15] and Robertson, Vélez, Hairston, and Bonilla-Silva [16] protocols (see [17] for information about instrument development and validation), and Institutional Review Board approval was obtained via Duke University. Participants were recruited via computing-related listservs, postsecondary computing departments, and organizations serving groups that are historically underrepresented in computing, with intentional efforts to reach students at Historically Black Colleges and Universities (HBCUs) and Tribal Colleges and Universities (TCUs), as these are the only minority-serving institutions that were founded to serve students identifying as Black and American Indian/Alaska Native, respectively. The semi-structured interviews lasted approximately 60 minutes and were virtually conducted by external interviewers who were not part of the research team. Interviewers and interviewees were matched based on shared ethnoracial identity (as defined by survey respondents). Incentives were provided via a raffle for $20 gift cards and $50 gift cards for all interview participants.

Table 2 presents the survey and interview participant demographics. The total sample sizes of the survey and interview were 552 and 46 students, respectively. Collected demographics include race, gender, disability status, first-generation student status, and country where respondents spent their formative years. Respondents selecting more than one race were grouped into "Multiple Races" categories. "Multiple Races (0)" refers to those that are historically overrepresented in computing (i.e., white, Asian, and Middle Eastern or Northern African), "Multiple Races (1)" refers to one ethnoracial identity that is historically underrepresented

(6.7%), and "Multiple Races (2+)" refers to two or more ethnoracial identities that are historically underrepresented.

Table 2. Participant Demographics

	Percent of Survey Participants (N = 552)	Percent of Interview Participants (N = 46)
Race		
Asian	36.4%	28.3%
Black or from the African Diaspora	7.1%	13.0%
Latine	4.7%	6.5%
Middle Eastern or Northern African	1.4%	8.7%
Multiple Races (0)	3.6%	10.9%
Multiple Races (1)	6.7%	13.0%
Multiple Races (2+)	2.4%	2.2%
Native American or American Indian	0.8%	0.0%
Native Hawaiian or Pacific Islander	0%	0.0%
White	36.8%	17.4%
Gender		
Man	46%	32.6%
Woman	46.6%	43.5%
Non-binary or gender non-conforming	7.4%	23.9%
Has a disability or chronic condition		
Yes	18.3%	34.8%
No	81.7%	65.2%
First-generation college student		
Yes	22.8%	30.4%
No	77.2%	69.6%
Formative country		
United States of America	80.1%	69.6%
Outside United States of America	19.9%	30.4%

This work is part of a larger study on computing undergraduates' perceptions of race; thus, a subset of survey and interview questions were used in analysis. The three survey questions were:

1. Do you think there are biological differences between races? (yes or no)
2. If you had to give a definition of the word "race" or explain what it was, what would you say? (open-ended)
3. How much do you agree with the following statements? (strongly agree, somewhat agree, neither agree nor disagree, somewhat disagree, strongly disagree)
    a. University computing departments are neutral and racially unbiased.
    b. Professional computing environments are neutral and racially unbiased.

Open-ended responses were categorized as one or more of "cultural," "physical," "place of origin," or "social." Survey responses were disaggregated by race, gender, formative country, and perceptions of biological differences between races.

The interview protocol included questions about participants' initial interest in computer science, pre-college racial socialization, and views on the intersection of race and computing. Analysis began with five researchers reading through a sample of the transcripts and discussing salient parts of the interviews. Next, a codebook was developed and refined to include key constructs from Bonilla-Silva's race-evasive framework [6]. Three researchers assessed intercoder reliability using the finalized codebook on four randomly selected, uncoded interviews. The mean Cohen's kappa coefficient for each pair of researchers was above 0.82, indicating strong agreement [18]. Each interview was then coded, and overarching themes were identified at both the participant and question level.

Results

Biological Differences Between Races

Approximately 34.9% of survey respondents perceived a biological difference between races, while 65.1% did not. Figure 1 presents responses by gender and race, with races collapsed into groups that are historically underrepresented in computing (i.e., Black, Native American, Native Hawaiian, Pacific Islander, and Latine) or overrepresented.

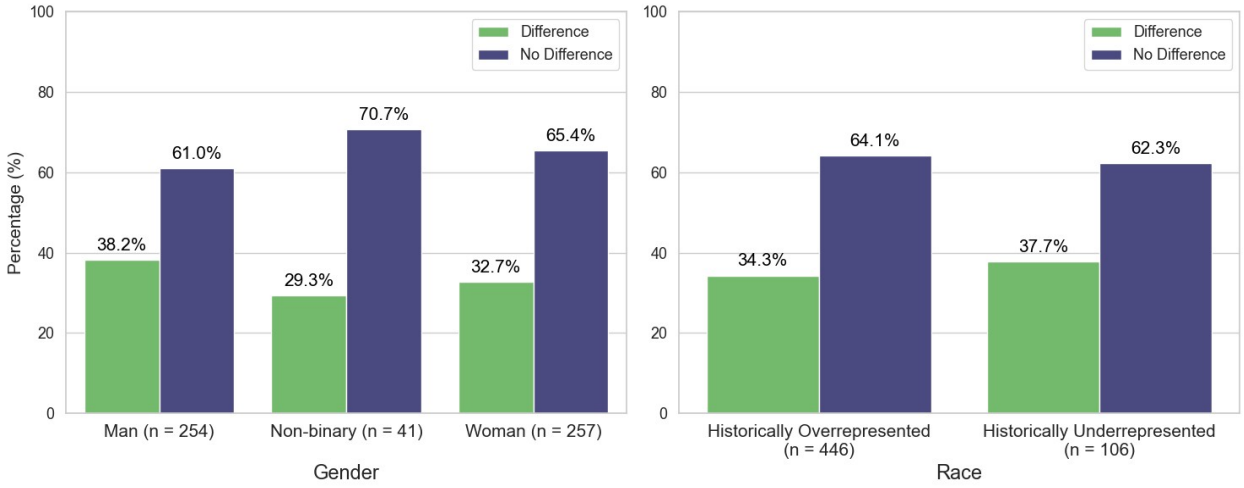

Figure 1. Perceptions of biological differences between races, by gender and race.

Men were the most likely to perceive biological differences between races, while non-binary respondents were the least likely. Additionally, respondents from ethnoracial groups that are historically underrepresented in computing were slightly more likely to perceive biological differences between races.

Further disaggregation determined that 39.4% of men from groups that are historically overrepresented perceived biological differences, compared to 31.6% of men from groups that are historically underrepresented. Additionally, 30.8% of women from groups that are historically overrepresented in computing perceived biological differences, compared to 39% of women from groups that are historically underrepresented. Finally, 55.6% of non-binary respondents from groups that are historically underrepresented perceived biological differences, compared to 21.9% of respondents from groups that are historically overrepresented.

Definitions of Race

Respondents' definitions of race were categorized into zero, one, or more of the four identified themes in Table 3 using keywords or phrases from the open-ended responses. For example, "the

color/physical characteristics of a person based on their ethnicity" was coded as both *Cultural* and *Physical,* while "a social category people are placed into often based off of skin color and ancestry" was coded as *Place of Origin*, *Social*, and *Physical*.

Table 3. Open-ended Response Themes and Corresponding Keywords

Theme	Keywords coded to this theme in free response
Place of Origin	"ancestry", "lineage", "where you're from"
Social	"social construct", "government", "exclusion"
Physical	"skin tone", "appearance", "look similar"
Cultural	"culture", "upbringing", "ethnic group"

Figure 2 displays the categorization of respondent definitions of race (Table 3) by perceptions of biological differences between races. Note that percentages do not sum to 100% because respondents' open-ended definitions of race may have contained keywords associated with multiple themes. Approximately 56.5% of those who do not perceive biological differences referenced *Physical* characteristics, 41.5% referenced *Social*, 36.9% referenced *Cultural,* and 23% referenced *Place of Origin*. Approximately 58.5% of those who perceived biological differences referenced *Physical* characteristics, 31.1% referenced S*ocial,* 41.5% referenced *Cultural*, and 32.1% referenced *Place of Origin*.

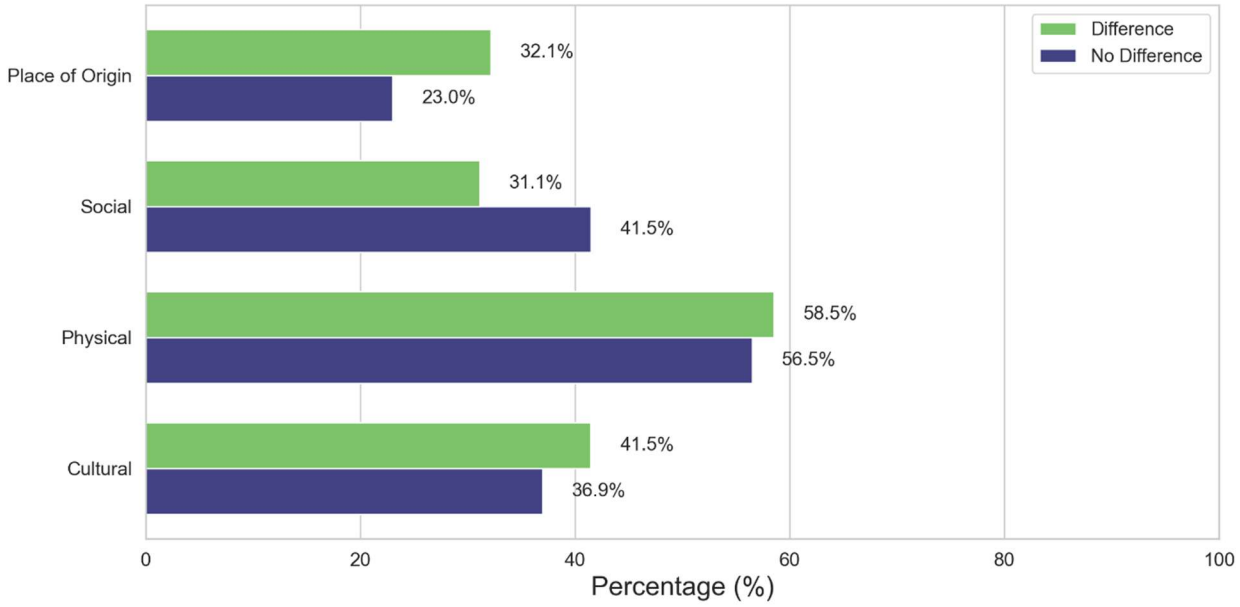

Figure 2. Thematic categorization of respondents' definitions of race, by perceptions of biological differences

Many interviewee definitions of race echoed the survey responses. For example, when defining race as *Physical* features, interviewees often cited biological differences between races. A white, male junior shared, "*Well, to some extent, [race] is linked to biology… It's the aggregation of your genetic phenotype, right? Your skin color, your features, your genetics."*

Interviewees who defined race as *Place of Origin* spoke most prominently about identity being tied to geographical location. For example, a white and Latino, male sophomore shared, "*I would*

define race as people coming from a certain area … where they all share a collective identity of some sort."

Responses from interviewees who defined race as *Social* ranged from superficial to detailed reflections of race as a social construct. Interviewees with more detailed reflections tended to reference other frames of race and describe what they meant by "social construct." For example, a Middle Eastern/Northern African, female sophomore shared:

> *I would define race as a social construct that is reinforced by the U.S. hegemonic power that is based upon classification, like physical attributes of how people are perceived and perceived geographic origin. I would define the racial categories as those defined by the U.S. Census, um, Black or African American, white or Caucasian, Asian and Asian American... [A social construct] is something that has a real effect on people and people's lives and our experiences but is not based in any real science.*

Conversely, some interviewees defined race as a social construct but were unable to explicitly define this phenomenon. For example, a white and Native American, non-binary sophomore defined race as, "*I would say that, um, race is a social c-, social construct that has varied throughout history. Um, but I would say that ethnicity is a solid quantitative subject."*

Perceptions of Computing Departments and Professional Environments

Respondents had differing perspectives about neutrality and racial bias in academic and professional environments (Table 4). Most respondents noted these spaces were not neutral. However, academic environments were perceived to be more neutral than professional ones.

Table 4. Respondents' Beliefs of Racial Neutrality in Computing Environments

	University Environments	**Professional Environments**
Agree	28.26%	15.94%
Neither agree nor disagree	21.38%	18.30%
Disagree	50.36%	65.76%

Further disaggregation by perceptions of biological differences between races revealed a similar pattern. Of the respondents who perceived biological differences between races, 33.7% and 20.2% believed academic and professional environments were neutral, respectively, while 43.5% and 60.1% did not. Of the respondents who did not perceive biological differences between races, 25.3% and 13.6% believed academic and professional environments, respectively, were neutral, while 54.5% and 69% did not.

Interviews provided similar perspectives, citing industry-wide statistics and observations as justifications. A Latine, non-binary sophomore shared, "*In general, it is pretty racially biased in the sense that there are a lot more white [and] Asian workers in the industry. And so it's very biased in their favor."*

This sentiment contrasts the perspectives on racial representation in academia: participants were more likely to recite personal anecdotes supporting observed neutrality and lack of racial bias. For example, a white, male junior shared:

> *I feel that [computer science academia] is racially unbiased, but once again, my experiences aren't really representative of everyone's. I have not heard of anybody thus far being racially discriminated upon in the computer science academia at my*

department at my school… Looking at the people that work in computer science in, in the academia and the faculty at my department, it's like a, it's a big mishmash racially.

Respondents also shared that the diversity of their departments was evidence of a lack of racial bias. For example, a Black, male senior from Nigeria shared:

I feel like [computer science departments] are unbiased… For example, in my department, we have a very large population of diverse students. People from Asia, from the Caribbean, from Africa, from the Indigenous United States.

Respondents who viewed computing spaces as neutral and racially unbiased were also more likely to define race by biological differences. For example, white men who agreed that professional environments were neutral were more likely to perceive biological differences between races (70.2%), compared to white men who disagreed with respect to neutrality in professional environments (56.5%).

Discussion

Across all thematic categorizations of race (Figure 2), *Physical* was referenced the most by students, regardless of their beliefs in biological differences between races (58.5%) or not (56.5%). This can be explained in two ways: 1) respondents who refuted biological claims but still used terms that were coded as *Physical* in their response, or 2) a disconnect between student responses and actual beliefs. The results of Figure 2 were collected from the survey item asking if there are biological differences between races (yes/no) and to define race (open-ended). Interview responses further support the likelihood of a disconnect between what students think they should say vs. what they believe (as indicated by respondents who could state race is a social construct but could not articulate what that means).

Students who indicated biological differences between races were more likely to perceive both academic and professional environments as neutral. This pattern suggests that beliefs about race may shape, or be shaped by, how students interpret racial bias in computing spaces. Students who understand race as biological may be less likely to recognize systemic inequities or biases because they see differences between races as inherent. Therefore, they are more likely to perceive computing spaces as neutral, compared to students who define race differently, even when disparities exist.

Moreover, the perception that academic environments were less racially biased than professional ones was heavily influenced by positive experiences within familiar academic spaces. However, by depicting professional spaces as the primary source of racial bias, students incorrectly assume that the academic spaces they currently navigate are insulated from these issues [19], [20]. Additionally, while most respondents rejected the idea of inherent biological differences between races, they acknowledged that racial ideologies drive behaviors and attitudes. This highlights a potential disconnect between what students profess to believe and their biases that may operate implicitly.

Finally, it is important to note that while a slightly larger percentage of students from groups that are historically underrepresented in computing indicated biological differences between races (Figure 1), this demographic was approximately 25% of the sample size, compared to those from groups that are historically overrepresented. This group also included respondents with multiple ethnoracial identities (with at least one from a group historically underrepresented). Research indicates that even people with identities that are historically minoritized may display hegemonic

beliefs, especially when their formal education centered dominant identities [21]. Approximately 80% of survey respondents spent their formative years in the U.S. The lack of adequate or accurate discussions of race, if at all, in K-12 education in the U.S. means it is not unexpected that students from groups that are historically underrepresented may reflect this belief.

Reflection of Race-Evasive Racism Framework

To further contextualize the results, the findings are analyzed through Bonilla-Silva's race-evasive racism framework and supported by examples from student responses to the quantitative and qualitative instruments [6], [15].

The ***minimization of racism*** frame commonly appears in undergraduates' reflections on their own experiences. Undergraduates have more lived experience in academic environments, which is shaped by personal interactions and observed classroom dynamics. This often translates to a reliance on anecdotal indicators of racial bias or the lack thereof. For example, several respondents cited not having "heard of anybody being racially discriminated," as evidence of the neutrality of academic computing spaces. Conversely, because many undergraduates have limited exposure to professional environments beyond internships, conferences, or secondhand accounts, they rely more heavily on statistical data (e.g., employment disparities) to evaluate bias in these spaces [19], [20]. Students indicated academic/professional programs to increase diversity as well as instances of "reverse discrimination" (via "diversity hiring") as evidence that racism was not present.

The ***cultural racism*** frame was made evident through open-ended survey responses, where race was defined through shared "collective identity" or linked to ethnic group traits, drawing on cultural explanations for behaviors that subtly shift focus away from systemic racism. For example, a respondent stating that race is defined by "people coming from a certain area … where they all share a collective identity" can be interpreted as reinforcing cultural racism if this identity is later used to explain disparities in computer science participation. While some responses may not overtly blame cultural reasons for inequality, the emphasis on cultural characteristics without acknowledging institutional exclusion implicitly reflects this frame.

The ***abstract liberalism*** frame is reflected in the percentage of respondents who view academic and professional environments as neutral. The higher tendency to perceive neutrality in academic environments, as compared to professional, suggests a belief amongst respondents that academic institutions operate primarily on merit-based principles. Furthermore, the stronger association of neutrality beliefs with perceptions of biological racial differences demonstrates how abstract liberalism and cultural racism can operate together. This connection between frames reinforces biologically deterministic views of race and perpetuates racial biases through neutrality and meritocracy.

The ***naturalization*** frame further aligns with the observed relationship between beliefs in racial neutrality within computing spaces and definitions of race as biological. Students who view race as biological may already naturalize the role of systemic inequities by attributing group differences to innate traits. As a result, these students are more likely to apply the same naturalization principles to their perceptions of computing spaces, which ignores the role of structural bias. Similar to previous findings in biology, students who hold biological views are more inclined to dismiss systemic influences on both racial identity and computing spaces [11].

These frames demonstrate how students' reliance on personal experiences can obscure perceptions of racism. In academic environments, students' direct immersion may blur recognition of systemic factors; in industry, the reliance on aggregate data highlights broader trends but lacks the nuance of lived experience. Taken together, these observations reinforce the importance of examining how proximity to and familiarity with an environment influences perceptions of bias.

Limitations

Despite numerous recruitment efforts, participation from HBCUs and TCUs was low. Thus, students from institutions that were not founded for the specific purpose of preparing graduates from minoritized ethnoracial identities are overrepresented, and the analysis may be lacking varied perspectives on perceptions of racial bias and neutrality when immersed in majority-minority academic spaces. In addition, certain demographics had low response rates, making it more difficult to draw conclusions about these populations. For example, only four respondents identified as American Indian or Alaska Native; therefore, any trends detected could possibly be due to random variation. Lastly, the sentiment analysis of open-ended survey responses was unable to parse out differences between respondents' understandings of race as a social construct, since responses ranged from a few words to a single sentence.

Conclusion and Future Work

This study examined how definitions of race and perceptions of biological differences between races influence undergraduate students' perceptions of racial bias and neutrality within academic and professional computing environments. Overall, students perceived racial bias as less prevalent in academic versus professional environments, which was underscored using statistical information to describe racism in professional environments versus anecdotal examples for academic environments. While most students did not cite biological differences between races, those who did had higher rates of agreement that academic and professional spaces were neutral. Additionally, most students defined race through physical attributes. These findings demonstrate a discrepancy between students' perceptions of neutrality in academic and professional environments: this discrepancy can be addressed via curricula, programs, and discussions that better incorporate topics of race and racial bias as well as student insights. Future work will expand on this research by analyzing new responses to the survey, which was revised and redistributed in the fall 2024 semester to examine the impact of sociopolitical changes such as the overturning of race-conscious college admissions.

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