Let's Play: Increasing Accessibility Awareness and Empathy Through Games

Devorah Kletenik
kletenik@sci.brooklyn.cuny.edu
Brooklyn College, City University of New York
Brooklyn, USA

Rachel F. Adler
r-adler@neiu.edu
Northeastern Illinois University
Chicago, USA

ABSTRACT

In order to increase empathy and foster conversation around accessibility, we created three games, simulating disabilities, that are geared towards engaging beginner CS and non-CS students to learn about accessibility. Each game has four rounds: game mode, simulation mode, game+accessibility mode, and simulation+accessibility mode. We tested the games on 113 students from two universities and report on performance and survey results that show that playing our games induced student empathy towards people with disabilities and motivated them towards accessible design.

CCS CONCEPTS

• **Human-centered computing → Accessibility**; **Accessibility**; • **Social and professional topics → Computing education**; **Computing education**; • **Applied computing → Computer games**.

KEYWORDS

accessibility, empathy, computing education, computer games

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1 INTRODUCTION

Computer accessibility, which is broadly defined as having computer interfaces that are designed and developed so that people with disabilities can "perceive, understand, navigate, and interact" with them [44], is increasingly recognized as an important component of software development. A growing interest in teaching accessibility in Computer Science (CS) programs has resulted in the creation of new curricular activities to teach accessibility. Just as Fiesler et al. proposed that "the logical place to begin emphasizing ethics is on day one of computing education," [15] we feel an identical claim can be made regarding teaching accessibility. We argue that accessibility should be taught as early as possible to CS-majors and non-majors. A major goal in teaching novice students is to build awareness of the need to design accessibly and to increase empathy for people with disabilities, emphasizing the *whys* of accessibility over the *hows* (for which they may lack the technical knowledge to implement). To spur such awareness and empathy, we created games that simulate disabilities and are playable even by novices. The games include a strong focus on engaging students with challenging, competitive and fun gameplay to attract them to learn about accessibility. The primary contribution of our simulation games is to help other instructors easily teach empathy and to foster conversation around accessible design.

Our work expands on the accessibility literature and work others have done creating a series of experiential learning labs [12] but we target novice CS and non-CS students, thus keeping the simulation games simpler and emphasizing student engagement.

In creating and researching the games, our goals were to discover:

R1. Do disability simulation games increase student empathy towards people with disabilities and their likelihood of considering disabilities when designing software?

R2. Can disability simulation games help students consider the inclusion of accessible designs for all applications regardless of the purpose of the software (e.g., recreational vs. duty-bound)?

R3. How are performance and emotions impacted when simulating disabilities both with and without accessibility options?

2 BACKGROUND AND RELATED WORK

As awareness about the importance of teaching accessibility increases within the CS community, a large number of educational initiatives centered on teaching accessibility have been created, such as the addition of new standalone courses [6, 24, 30, 34, 45], general education courses for all majors [27], graduate programs [3, 7] and even MOOCs [17] on the topic of accessibility. In addition, accessibility topics are now incorporated into existing courses as diverse as web design [18, 38, 47], Human-Computer Interaction (HCI) [28, 29, 33, 36, 48], design thinking [40, 41], software engineering [13, 31], programming [10, 20], mobile app development [14], student capstone projects [4, 16], as well as in multiple courses across an undergraduate curriculum [46]. Pedagogical methods in these courses include lectures, accessibility assignments and projects, service learning, including people with disabilities in the team or as stakeholders, guest speakers, and hands-on exercises trying out assistive technology devices such as screen readers. A recent initiative explored micro-professional development opportunities for faculty in accessibility topics mapped to course objectives [22]. Resources for instructors include the *AccessComputing* Knowledge Base [26] and the Teach Access consortium [23].

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2.1 Motivation

Faculty members who teach accessibility reveal that a driving force behind many of these educational initiatives is the goal of inculcating students with *empathy* for those with disabilities [37] and to have students reach an understanding of "technology barriers faced by people with disabilities" [42]. This dovetails with the findings of a workshop that found that there are areas "where developers struggle to empathise with accessibility issues and subsequently design interactions for this demographic," as well as a "lack of understanding in how a person with disability uses technology" which "impacts on how technology interactions are designed" [11]. A driving goal, therefore, of accessibility education must be to help students understand the needs of people with disabilities.

One good method for inspiring empathy is through the inclusion of field trips, service learning and working directly with people with disabilities [16, 31, 33, 37, 40, 41, 48]. In particular, students who interacted with external stakeholders who had visual impairments had increased levels of sympathy, whereas no such increases were shown in students who learned about accessibility but had no direct connection; thus accessibility *knowledge* alone "may not be enough to motivate students to address accessibility barriers" [32]. This work suggests that to motivate our students in accessibility, we need to make it real to them.

A drawback, however, of service learning and field trips, is their lack of scalability. Finding populations with disabilities for students to interact with is an approach that must be pursued anew by each instructor. Such efforts are subject to geographic, time, and monetary constraints. In fact, a survey of accessibility literature found that courses in which accessibility was taught in short modules tended not to "use guest speakers with disabilities, simulated disability, or interaction with people with disabilities," which are "common strategies for courses to support teaching empathy, but often require more knowledge and community contacts than the other instructional methods" [2].

Of all of these methods, however, simulations – once created – *can* be easily used even by instructors with fewer resources. Although simulations must be undertaken with care to avoid overgeneralizing from the experience, they can still be a valuable tool in building empathy and awareness [25, 39, 43].

A number of simulations have been created for students and/or developers to "experience" disabilities. In particular, in the Accessibility Learning Labs (ALL) [12], students interact with software, then with a simulated disability, and then are instructed as to how to make the software accessible. Finally, they interact with the software once they have repaired it. The ALL also have integrated slides, quizzes and videos of people with disabilities, making them an extensive, robust and scalable learning tool. However, the labs require students to have a technical background and, while this can be useful for CS majors in the midst of their education, for students just learning to code the important goals of empathy and awareness can get lost amidst the instructional content. Further, their results indicated that their simulation labs alone did not appear to motivate students sufficiently [12].

Our goal, therefore, was to create simulations that would be suitable for beginner CS students and non-majors, while being engaging to capture their attention and interest. In this paper, we outline a set of challenging and competitive computer games with the goal of creating awareness about accessibility and inspiring empathy in beginner students.

3 METHODS

3.1 The Accessibility Games

We first developed a prototype of the application as part of an undergraduate student project in an HCI course. The students conducted observations and interviews primarily of college students with and without disabilities about their experiences playing games. Participants reported liking games that are challenging and stimulating.

The prototype was implemented using Marvel, a collaborative prototype design platform. As part of the class project, the prototype underwent heuristics evaluation by four students from another project in the course using Nielsen's 10-point usability heuristics [35]. The prototype was further modified based on usability testing on six participants primarily targeting early CS college students.

A Web-based version of the prototype was developed by CS students using HTML, CSS and JavaScript and are playable in a browser without the need to install another application. The games feature balls of red, green and yellow that move across the screen. Players are told to click on a red or green ball (color chosen randomly; yellow is intentionally a distractor). If they succeed, they get a point; if not, the computer "opponent" gets the point and the player loses a point. After a ball is clicked, another color is chosen and gameplay continues until the time limit of 30 seconds per round is reached.

We created three versions of this game, simulating the following disabilities: color blindness, auditory impairments, and physical/motor impairments. For each disability, the game proceeds in four rounds:

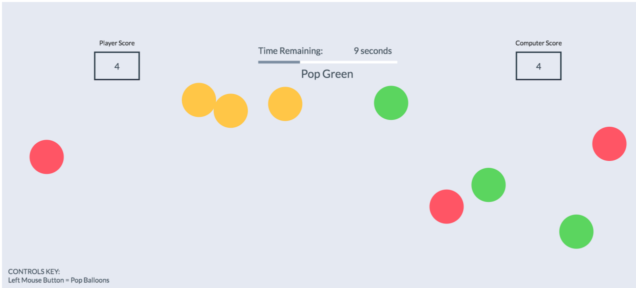
1. Game mode: No simulated disability
2. Simulation mode: Player plays with simulated disability
3. Game+accessibility mode: No simulated disability and game is accessible
4. Simulation+accessibility mode: Player plays with simulated disability and game is accessible

In addition to having students play the game without a simulated disability (Round 1) and in simulation mode with and without accessibility options (Rounds 2 and 4, respectively), we felt it was important for students to see how accessible design can look to someone who does not have disabilities (Round 3). We intentionally use a consistent competitive game across all disabilities where the user is playing against the computer and can win (or lose) each round.

Color blindness: In Round 1, there are visually distinguishable colors (Figure 1a). In Round 2, we simulated deuteranopia, a common form of red-green colorblindness[1] by recasting the colors of the balls (Figure 1b). In Round 3, the colors are restored, with accompanying accessible labels 'R,' 'G,' and 'Y' to indicate the colors (Figure 1c). Finally, in Round 4, there is simulated deuteranopia with labels (Figure 1d).

Audio impairment (Deafness): Round 1 is similar to Round 1 of colorblindness, but the written color prompts ("Pop Green") were

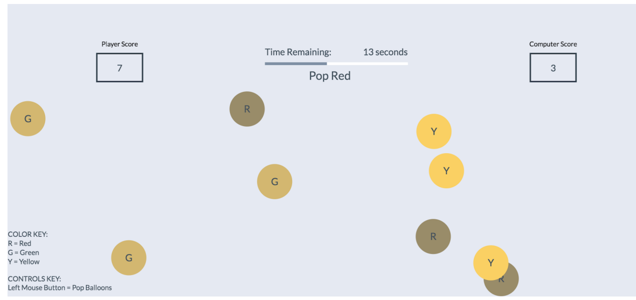
[1] We chose red-green colorblidess as it is the most common form of colorblindness [19]. Of the various forms of red-green colorblindnesses, deutanomaly/deuteranopia are the most prevalent [21].



(a) Colorblindness, Round 1

(b) Colorblindness, Round 2

(c) Colorblindness, Round 3



(d) Colorblindness, Round 4

Figure 1: Colorblind Simulation Game

removed and replaced with spoken prompts. In Round 2, the volume is turned off, so it is impossible to hear and know which color to pop. Round 3 has spoken prompts (volume on) with additional written prompts for accessibility, and Round 4 has the volume off but includes written prompts.

Physical/motor impairments: Round 1 is the same as Round 1 of colorblindness. In Round 2, jitteriness is added to the mouse movement, so that it is difficult to focus it and click. In Round 3, the jitteriness is removed and keyboard support added (Shift to choose balls, Enter to select). Round 4 has the jitteriness return, but with the additional keyboard support.

After the four rounds are completed, a brief page with information about accessibility for that disability is presented.

3.2 Measures

In order to ascertain whether participants' attitudes and empathy improved with respect to designing for people with disabilities after completing our accessibility games, we interleaved survey questions with the gameplay. Below we capture the following measures:

Attitude: Immediately before and after playing the games, students were asked to complete a survey (see Figure 2). The survey included a series of 5-point Likert style questions (1=Strongly Disagree; 5=Strongly Agree). The first four questions were adapted from an attitude survey about stereotypes about elderly people and technology [5], which we modified to attitudes regarding people with disabilities.

Challenges: We added three additional items pertaining to an awareness of challenges and frustrations felt by people with disabilities and the goal of incorporating accessibility into their own future designs. We examined the reliability of the three added questions by calculating Cronbach's alpha which was reliable at 0.70 in the pre-survey and 0.78 in the post-survey.

Task Domain: Our survey also included open-ended questions relating to which potential users participants would include when testing a voting kiosk, modified from [32], and when testing a racecar game. The latter question was included to see if students consider accessibility differently in different task domains.

Sentiment: In order to compare how students felt after participating in each round, we asked participants to choose one of eight predefined words to describe their experience with each round: "I felt the round was: (Fun, Enjoyable, Relaxing, Educational, Boring, Confusing, Frustrating, Difficult)" (single choice). We converted each choice into a binary value to indicate positive or negative sentiment (where Positive = {Fun, Enjoyable, Relaxing, Educational} and Negative = {Boring, Confusing, Frustrating, Difficult}). We chose many of these terms from prior research [1], which had college students input a word to describe their experience with a game; we added some of our own due to the nature of our disability simulation games (e.g., "educational"). Participants could also input optional comments about their experience in each round.

Performance: Rather than examine user score in relation to computer score for each user, for simplicity, and due to its game-like nature, performance was represented as the number of rounds won. Win was computed as 1 or 0 based on whether the user's score was greater than the computer's score.

The pre-survey also asked students for basic demographic and educational background (see Table 1), and the post-survey also had one additional question asking for general comments.

3.3 Participants

In order to assess the effects of the games on student attitudes, we recruited a cohort of students to play the games and complete the surveys. We intentionally recruited students who were new not just

Figure 2: Survey given before and after the games

- **Please rate your level of agreement with the following statements:**
  1. Most current interfaces are easy for most people to use.
  2. People with disabilities are not interested in new technology.
  3. If a person with disabilities has difficulty with technology there will usually be someone around who can help.
  4. Most developers don't need to worry about providing technology suitable for use by people with disabilities.
  5. Users with disabilities are likely to face challenges when completing tasks with software.
  6. Users with disabilities are likely to feel frustrated while using software.
  7. When I design or develop software, I will try to have in mind users with disabilities.
- Suppose you are creating a computerized race car game in which a user tries to race their on-screen car with other computerized cars. Which potential users should you include when testing your prototype?
- Suppose you were charged by the Board of Elections in your state to create a new voting kiosk for use in the next election. Which potential users should you include when testing your prototype?
- List some of the challenges that people with disabilities might face when using software.

to accessibility, but to programming/CS in general. Students were recruited from two public institutions: Northeastern Illinois University (NEIU), and Brooklyn College (BC), CUNY. IRB exemption was obtained at both. At NEIU, students were recruited from two sections of an HCI course, an entry-level course that has no prerequisite and thus has many students who have not yet even taken a CS1 course. At BC, students were recruited from an electronic commerce course that contains a mix of entry-level CS students and non-CS majors and a game development course, to get a cohort of students interested specifically in games.

Several students completed only the pre-survey but not the post-survey; they are excluded from our analysis. Students who completed the pre-survey twice had only the second entry counted. We also excluded four HCI students from our analysis who had participated in designing the prototypes for the games. In total, we had 113 students whose entries we included. Demographic and educational background of the students are summarized in Table 1.

Gender		Race	
Male	86	American Indian or Alaska Native	4
Female	25	Asian	51
Other	1	Black or African American	14
Prefer not to say	1	Hispanic or Latino	17
Age:		White	20
19 – 25	88	Two or more races	2
26 – 35	18	Prefer not to say	5
36 – 45	4	**Disability Status (Select all that apply)**	
≥ 46	3	None	90
Course		Visual	1
HCI 1 (NEIU)	33	Colorblindness	2
HCI 2 (NEIU)	15	Auditory	0
Game Design (BC)	36	Physical	0
E-Commerce (BC)	29	Cognitive/neurological	3
Major		Learning disability	2
CS major	88	Other disability	4
Non-CS major	25	Prefer not to disclose	12

Table 1: Demographic and educational background of participants ($n = 113$)

In three out of four courses, students were given a small amount of class credit for participating. In the fourth, it was an in-class activity without credit assigned. Due to Covid-19, students were either assigned the activity during a Zoom class session or as an online exercise. Names and emails were recorded for the purpose of assigning credit but were removed before analysis. No other identifying information was asked of students. Informed consent was obtained from all students before beginning.

4 RESULTS

4.1 R1: Student Empathy and Accessibility Design as a Result of Simulated Disabilities

In our first research question, we consider whether disability simulations help generate empathy towards people with disabilities, and whether it inspires students to design in a more accessible fashion.

To answer this question, we compared the pre-survey responses with the post-survey responses using a two-tailed Wilcoxon signed-rank test, with $\alpha = .05$, as our data was non-parametric. We found statistically significant changes in the pre- to post-responses for both the Attitude and the Challenges questions. Pre-mean and median of the average Attitude response were 2.4 and 2.5, respectively; post-mean and median decreased to 2.17 and 2.25, respectively, $p < .0001$, effect size = .53. In Challenges: pre-mean and median were 3.83 and 4, respectively; post-mean and median increased to 4.11 and 4.33, respectively; $p < .0001$, effect size = .44. (Note that for the Attitude questions, the desired answer was disagreement, and hence lower numbers; the opposite is true for Challenge ones.)

Based on Cohen's [8, 9] classification of effect sizes where 0.10 – < 0.3 is a small effect, 0.30 – < 0.5 is medium, and ≥ 0.5 is large, we note statistically significant changes and at least a medium effect size with participants improving in their attitude towards people with disabilities (large effect size) and the challenges they face (medium effect size). This indicates a substantive change in student attitudes towards people with disabilities and an increase in student empathy and plans to design for people with disabilities.

We also considered the answers to the design questions, in which we asked students which users they would include in testing prototypes of racecar games and voting kiosks. Each answer was coded as a binary value, as mentioning people with disabilities or not.[2]

[2]Coding was conducted by two individuals with > 98% agreement; disagreements were discussed and resolved. One student's answer was blank and excluded from analysis.

Since our variable was dichotomous, we analyzed the pre- to post-answers using a McNemar analysis with continuity correction. Responses including people with disabilities in the racecar question increased from 54% in the pre-test to 83% in the post-test ($\chi^2(1, N = 112) = 26.69, p < .0001$), and in the election kiosk question, from 70% to 83% ($\chi^2(1, N = 112) = 10.56, p = .001$). The Cohen's g for both of these tests was .44, which is a large effect sizes (using Cohen's interpretation of $g \geq .25$ as a "large" effect size [8].)

Thus, our answer to question R1 is yes: student empathy and intent to design for people with disabilities increases after experiencing a simulated disability.

Student comments about the games were overwhelmingly positive, reflecting on how their perspective changed as a result of playing it. We highlight a few representative comments here:

"We learned about accessibility in class and we saw examples of it, but having the simulation shows how difficult it is for people with disabilities to even play a simple game, made me realize how much more effort we need to put into our design so everyone can use it. "

"It is easy to read, watch or hear how people with disabilities have it tough, but once you experience what they face it really drives the point home."

"This test made me think back to recent games and applications that I have used and realize that many of them are almost completely unsuitable for people with disabilities."

4.2 R2: Accessible Design in Different Design Situations

In our second research question, we considered whether students considered accessibility differently depending on the design scenario. Using our Task Domain questions described above (election kiosk and racecar game), we hypothesized that students would be more likely to consider users with disabilities when designing an election kiosk over a racecar game, because they may a) be more likely to think of people with disabilities (especially senior citizens) as wanting to vote than to play a car game and b) think that there is a greater need to ensure that people with disabilities can vote than that they can participate in a game.

Indeed, only 54% of participants included people with disabilities in the racecar question in the pre-survey, compared with 70% in the election kiosk question.[3] We used a two proportions Z-test to examine the difference in mentioning disabilities in the racecar game vs. election kiosk in both the pre- and post-survey. The estimated difference in proportions between the game responses and the kiosk responses in the pre-survey is 0.159 (95% confidence interval of .03 − .29, $p = .02$). After playing the accessibility games, however, this difference disappeared; 83% of participants included users with disabilities in their answers to both the racecar and kiosk questions in the post-survey.

Student responses lend credence to our hypotheses as to why accessibility might be thought of more frequently with election kiosks with comments such as *"I would not want to create a Florida punch vote scenario"* and *"[I would include] people with any kind of disability whether it be visual, audible, physical, or cognitive because you want everyone to be able to vote."*

[3] The pre-survey response rate may have been artificially high because students (1) were told there was an accessibility activity and (2) saw the pre-survey question asking about the disabilities of the participants.

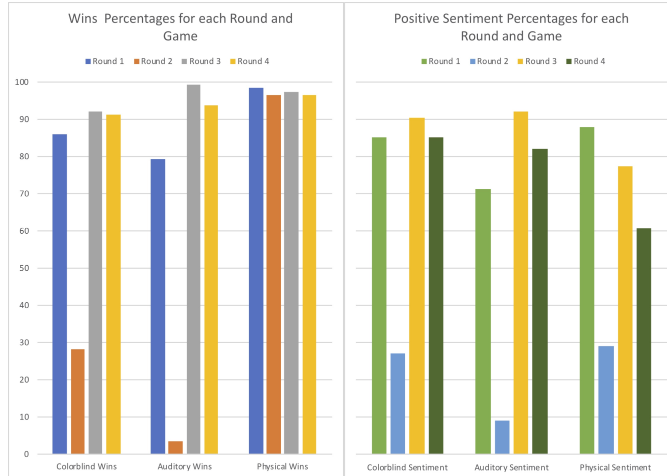


Figure 3: Percentage of wins and positive sentiment emotions, per round per game

4.3 R3: Students' Perceptions of Disability Simulations

Our third research question is how students experience disability simulations, because the experience is central to our goal of developing student empathy. To evaluate students' perceptions of the simulated disabilities, we compared their performance and sentiment in the rounds of the games that simulated disabilities (Rounds 2 and 4) vs. those that did not (Rounds 1 and 3).

The results are given in Figure 3.[4] For each round of each game, we give the percentage of player wins (of total rounds of play) and the percentage of the emotions that had positive sentiment.

For each accessibility game and for each category (wins/not wins, positive/negative emotions), we ran a Cochran's Q test, a non-parametric statistical test used for nominal dichotomous data with more than two related groups to determine whether the results were statistically significant. For the tests that were statistically significant, we followed up with post-hoc pairwise McNemar tests, using the Bonferroni p-adjustment method, to determine which round comparisons were significant.

As can be seen from the graphs, players had a harder time playing the games in the simulated disability mode (Round 2) of both colorblind and auditory disability modes, as evidenced by the high proportions of player losses in those rounds. These results are significant for both the colorblind ($Q(3) = 181.64, p < .0001$) and auditory ($Q(3) = 260.49, p < .0001$) games, with pairwise McNemar tests showing statistical differences between Round 2 and the other rounds with $p < .0001$ for both disability types. The exception to this is the physical disabilities, in which no significant difference was detected with regard to performance ($Q(3) = 6, p = .11$). This is consistent with the game platform, in which it was extremely difficult to distinguish colors in the colorblind disability round and impossible to hear which color to pick next in the auditory disability round. However, although the simulated physical disability made it *harder* to control the mouse, it was still possible to succeed at this

[4] Three students indicated that the volume did not work on their computer and were excluded from the analysis of the auditory disabilities game. We considered excluding two colorblind students but their performance did not seem to have been affected, nor did it impact the analysis.

round. This was made explicit in several student comments, such as *"I had to change my strategy of just clicking once to be effective; to clicking multiple times so I can guarantee I clicked the dot."*

While there were no significant differences in terms of wins in the physical condition, there was significance difference in sentiment for all three disabilities ($Q(3) = 149.66, p < .0001$ for colorblind, $Q(3) = 199, p < .0001$ for auditory, and $Q(3) = 110.89, p < .0001$ for physical disabilities). Students reported experiencing negative emotions while playing Round 2 far more often than in all other rounds; pairwise McNemar tests showed $p < .0001$ for all three disability modes when comparing Round 2 to the other rounds. Student comments contained explanations for these negative emotions; for example, *'In round 2 it says pop green but I could not see green balloons,"; "The second round without audio was virtually impossible to win since it relies on luck rather than skill."* Interestingly enough, even though players had an easier time winning Round 2 in the physical disabilities game, they still felt significantly more negative towards the round than the other rounds; for example, a comment from a student who won a physical Round 2: *"The second round definitely felt unfair. It was like playing a different game, hovering over the correct circle but timing till you press at the correct moment."*

Although Round 4 also simulated disabilities, the game design was now accessible. As shown in Figure 3, performance in Round 4 was not negatively impacted. The sentiments in auditory and colorblindness games were likewise no more negative than in Round 1. In the physical game, the sentiment was significantly more negative ($p < .0001$) than Round 1, although still significantly more positive than in Round 2 ($p < .0001$). Although we don't have a definitive answer as to why students were more negative in this round, student comments provide some clues, suggesting that we use a key that doesn't interfere with the sticky keys, and have a fixed ordering of the balls selection (not randomized). It is, however, still clear that the keyboard support was overwhelmingly helpful compared to using the jittery mouse, e.g.*"I feel like that I was able to enjoy the game more with the keyboard support in round 4."*

We conclude that simulating disabilities helps students understand the difficulties of using inaccessible software; providing accessibility options mitigates those difficulties, motivating accessibility.

5 DISCUSSION

We created games that are engaging and competitive to help inspire student empathy of people with disabilities. We found that students were less likely to have negative stereotypes about people with disabilities after playing the games and more likely to understand the challenges faced by people with disabilities and to consider such users in hypothetical design scenarios. These results are novel, compared to previous findings that suggested that disability simulations alone were insufficient to induce empathy [12]. We conjecture that the challenging and competitive nature of our games emphasized the difficulties of disabilities.

An additional finding is that students were more likely to consider users with disabilities when thinking about designing an item that seemed more universal and essential (election kiosk vs. racecar game). However, after playing games that simulated disabilities, they considered users with disabilities equally in the game scenario.

Finally, students were overwhelmingly more likely to lose the games when playing in simulated colorblind/deaf mode with no accessibility options. Their reported emotions were much more likely to be negative, e.g. frustrated or confused, when playing in this simulated disability mode for any of the three disabilities portrayed. These effects were largely not present when disabilities were simulated but accessibility options were present. This helped students to realize how accessible design can help compensate for some of the challenges faced by people with disabilities.

These findings help ascertain the role that simulation games play in teaching accessibility. Our games are freely available at http://gooddesignforall.com for other instructors to use. Because they do not draw on any technical knowledge, they are suitable for CS novices, non-majors, K-12 students, as well as experienced CS students and developers.

While the goal of our work is to create these accessibility modules, our secondary goal was to provide our students with opportunities to consider accessibility through research projects. Therefore, we intentionally offered the opportunities to create the prototypes and develop the games to undergraduate students, including a colorblind student whose perspective was particularly helpful. This project thus benefited two sets of students: the creators and the players. A few of the students who implemented the game plan to work in accessibility in the future. One student has already started another research project focusing on people with disabilities.

5.1 Limitations and Future Work

Our study does have several limitations. We wanted to break down the answers to our research questions based on the student demographic/academic characteristics summarized in Table 1. However, this left us with sample sizes that were too small and underpowered for analysis. We leave it as future work to investigate the effects of some of these variables on our research questions.

Another limitation is that we rely on self-reported student answers as opposed to their actual design choices. Although we did see accessibility integration into several student projects following their playing these games, these were purely anecdotal; participation in this study occurred too late in the semester to be able to track its effect on student work. Given the discrepancy between student reports and actions (e.g. [32]), we plan to investigate the impact on student projects in future work. We'd also like to conduct a longitudinal study to observe the longer term effects, given the reports of accessibility efforts that did not effect long-term change [48].

Other future work includes improving the usability of the physical impairments game (by modifying the accessibility key and order of selected balls), adding other games (simulating blindness and neurodiversity), including a control condition where some participants receive readings on accessibility instead of the games, and testing modified versions of our games on K-12 students and teachers.

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