

Through the Eyes of Women in Engineering

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▶ **To cite this version:**

Hui-Yin Wu, Johanna Delachambre, Lucile Sassatelli, Marco Winckler. Through the Eyes of Women in Engineering: An immersive VR experience. Texts of Discomfort, Carnegie Mellon University: ETC Press, pp.387 - 414, 2021, 978-1-7948-8071-9. 10.1184/R1/17071172 . hal-03515116

HAL Id: hal-03515116
https://inria.hal.science/hal-03515116

Submitted on 6 Jan 2022

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Medium: Virtual reality (3D) via GearVR or Oculus / WebGL (for online experience)/ Video (for replay)
Year of Release: 2020
Link to the artwork:
https://www.i3s.unice.fr/Through-the-eyes-of-women-in-Engineering/
Video artist: https://vimeo.com/458997431



Through the Eyes of Women in Engineering

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"[How much discomfort is enough or too much for an audience?"]; while such questions cannot be easily answered, they need to be asked in order to critically detect the blind spots of the society."

ICIDS 2020 Jury

Through the Eyes of Women in Engineering: an immersive VR experience

Abstract

Young women frequently face implicit behavioral biases – through unfriendly gaze, gestures, or speech – in all aspects of their daily lives. This is particularly true in the field of engineering, where women are a minority, making it emotionally difficult for them to fit in and feel at home, and deterring young women to enter these fields. Yet these systematic implicit biases are very hard to observe without being the target of such behavior and being accustomed to the current "norms" and "ways of acting" in the society. At their root is the misalignment between the stereotypes associated with femininity, and those associated with computer engineering – a misalignment whose keystone is how the gaze of others objectifies the body of women, and whose consequence and means of perpetuation is discomfort. Our objective is to create an interactive piece to communicate the discomfort of women in engineering, to tell their stories and expose this misalignment. To address this objective, we harness virtual reality to create an experience that embodies the user in the place of a woman character who travels through three common scenes in her life as an engineer. We design different gaze interactions, gestures, and speech styles that reflect common patterns for implicit behavioral biases, including objectification, isolation, and belittlement. The piece is an application that can be experienced in a headset or in a web browser.

Keywords

implicit gender biases, women in engineering, virtual reality, embodiment, objectification male gaze

Introduction

Feeling uncomfortable, under unexplainable pressure just entering a conference room and sitting in the audience. Being complimented on our looks when being introduced to a new colleague and not being able to pinpoint what is wrong with a seemingly benevolent comment. Or is there something wrong with me and my perception after all?

Implicit behavioral biases – in the form of unfriendly gaze, gestures, or speech – are a shared aspect in the daily lives of young women, particularly those pursuing higher education and careers in engineering, where they are a minority. While these implicit biases are pervasive, they are very hard to observe without being the target of such behavior or when one is made to believe and accept that these are the current "norms" and "ways of acting" in the society. This makes it emotionally difficult for them to fit in amongst their peers and colleagues, brings about feelings of confusion, self-doubt, and frustration when confronting these norms of the society, and eventually deter young women to enter these fields.

This trend is reflected in the numbers. In computer science and engineering, woman representation continues to decrease. Women occupy roughly 11% of executive positions in America's tech hub Silicon Valley and make up just 24% of computer science jobs in the US, down from 37% in 1995 (NCWIT, 2016). The proportion of women in computer and information technology studies in western countries continues to decline: 37% in 1984, 12 to 17% today (NCWIT, 2016; MESRI, 2020). Literature in sociology, experimental psychology, social cognition and neuroscience has shown that the reasons for which high-school girls do not generally pursue higher education in engineering are complex, but can be generally formulated as a major misalignment between the stereotypes associated with femininity, and those associated with computer engineering – a misalignment whose keystone is how the gaze of others objectifies the body of

women, and whose consequence and means of perpetuation is discomfort.

Our objective is to create an interactive piece to communicate the discomfort of women in engineering, to tell their stories and expose that misalignment. To address this objective, we harness virtual reality to create an embodied experience to expose this misalignment. Our piece embodies the user in the place of a woman character who travels through three common scenes in her life as an engineer. To carry the experience and generate the feelings in all the subtle ways the gender bias is perceived but hardly describable, we design specific interaction techniques occurring between the embodied character and the avatars in the scene. The Non-Player Characters (NPCs) in these scenes react to the player-character using different gaze interactions, gestures, and speech styles that reflect common patterns for implicit behavioral biases, allowing the user to experience these biases first-hand, and reflect on how to create more accommodating environments in fields dominated by men.

Section II presents relevant existing work. We motivate the design of our piece with theoretical analyses of that discomfort in Section III. This review provides crucial keys to then be able to reproduce synthetically that discomfort. From there, we design different gaze interactions, gestures, and speech styles that reflect common patterns for implicit behavioral biases, including objectification (when walking on the street), isolation (among peers in a lab), and belittlement (when asking a question at a conference). Section IV describes the technical tools used to program the application and Section V elaborates on the creation process, presenting the story and scenes, and detailing the types of interactions. Finally, in Section VI, we reflect on the interactions we had with the visitors of the online exhibition and discuss the potential of VR to contribute to the gender inequality challenge. Section VII concludes the chapter and discusses future work.

Related works

If VR has been most profitable in the gaming industry so far, going from synthetic to real scenes shot with a 360° camera rig makes VR a whole new medium whose immersive capacity provides an unprecedented feeling of presence. VR can indeed be envisioned as a new art form and has been even dubbed "the empathy machine" (Milk, 2016), making for a powerful instrument in a broad range of goals. Domains such as documentaries, storytelling, and journalism (De la Peña et al., 2010) are where the impact of VR can be most substantial and with a much wider adoption than games. An increasing amount of content is being produced, leveraging the anticipated empathy-triggering power of VR to raise awareness on sexual harassment and belittlement (Aitamurto et al., 2018; Facebook, 2020), or to increase the number of women enrolling in engineering studies (NYU Tandon School of Engineering).

Peck et al. (2013) showed that embodiment of light-skinned participants in a dark-skinned virtual body significantly reduced implicit racial bias against dark-skinned people. Banakou et al. (2013) showed that people's mental representations of their own body can be altered with VR. Embodying adults in the body of a 4-year-old child or a scaled-down adult body causes an overestimation of object sizes, while shifting the identification of the self towards child-like attributes. Tajadura-Jimenez et al. (2017) show that auditory cues strengthen the embodiment illusion.

Barreda-Angeles et al. (2020a) question the empathy-triggering power of VR contents. They examine the interplay between empathy towards the characters of a 360° video and the user's enjoyment of the immersive experience. Results show that the user's enjoyment may negatively impact the level of empathy. Barre-

da-Angeles et al. (2020b) unveil that cognitive information processing (focused attention, recognition and recall of information) can be impaired by an immersive presentation.

The above works indicate that leveraging VR to raise awareness and possibly lead to empathy must be carried out through careful design. Therefore, to raise awareness towards important issues, aiming for an immersive experience built on embodied cognition should come before enjoyment or thinking. On complex issues, the VR experience can therefore be envisioned as a conditioning step, possibly before carrying out advanced reflection and exchange outside of VR.

Regarding gender inequality, Facebook (2020) released its "VR for inclusion: Women in tech" content, but did not assess its effect. Aitamurto et al. (2018) examined perspective taking and attitude change when participants watched a video showing gender prejudice enacted against a woman engineer in three modalities: a 360° video where each hemisphere corresponds to the camera placed at the woman's or man's head, a 180° video and a flat control video. Participants were adult men and women, whose perception of gender inequality was measured before and after the experiment. The results show intricate effects: while the 360° split view increased the viewers' feeling of personal responsibility to resolve gender inequality, people choosing to spend more time in the man's perspective felt less responsibility to address gender inequality.

Recently, Barreda-Angeles et al. (2021) carried out an innovative work to co-create a 360° video with middle-school students, to convey a school bullying experience from a first-person perspective. Analysis of self-reported and physiological measures of emotional state show the effectiveness of VR to elicit higher arousal and to increase empathy towards the victims.

Motivation and theoretical ground

The need for an embodied experience to understand what it is like to undergo internalized bias and prejudice can be concisely explained with an analysis by Bourdieu (1998): "If it is true that [...] the recognition of domination always presupposes an act of knowledge, this does not imply that one is justified in describing it in the language of consciousness [leading] one to expect the emancipation of women from the automatic effect of awareness, ignoring [...] the opacity and inertia that result from the inscription of social structures in bodies." (p. 62).

We hypothesize that the active presentation of these biases through a personal experience to high-school girls can potentially reveal to them the roots of these internalized biases, and the immediate impact they have on their career choices. But how do we find a general enough experience on which high-school girls can begin building this understanding?

On the one hand, we start from a constitutive concept of the norms of femininity, as identified by Beauvoir (1949): the gaze of others on we women, objectifying our body, which has a great impact on our vision of ourselves and our aspirations. The body is therefore central to the construction of the vision of ourselves, and VR is the key medium to convey the feelings all the way to the most inner perceptions and thoroughly question them. On the other hand, we expose the general representation of computer science through geek culture, and the implicit association between leadership positions and middle-aged upper-class white men.

The impact of the gaze of others: the objectification of the body at the root of the difference

As synthesized by the philosopher Garcia (2018), for Beauvoir, "to understand what a woman is means to understand what it is like to live in first person, that is as a subject, a body first constructed - by the gaze of men - as an object." (p. 175). This analysis is made in sociology by Bourdieu (1998): "Everything in the genesis of the female habitus and in the social conditions of its actualization contributes to making the female experience of the body the universal experience of the body-for-others, constantly

exposed to the objectification operated by the gaze and speech of others." (p. 90). This constitutive element of the gendered identity of adolescent girls has two consequences that are of interest here.

The first consequence is that the attitude prescribed more or less implicitly to young girls is to attract gaze, often to stage oneself, but always to appeal and please others (Chollet, 2012). As boys and girls align their career choices with the vision of their self, girls overwhelmingly head for studies and careers as caregivers and educators: they are expected to take care of others, not to oppose them (Monnot, 2009).

The second consequence is that "little girls learn to understand themselves not only as weak and fragile but as weaker and more fragile than boys" (Garcia, 2018, p. 215). This perceived weakness translates into an acute lack of self-confidence and a feeling of incompetence. For example, Demoulin and Daniel (2013) show that at equivalent average marks, between the start and end of the first year of high school, girls are less likely than boys to maintain their choice of scientific major for the last two years of high school. As Chollet (2018) puts it, "eternally mimicking the helplessness and vulnerability of extreme youth is a way to comply in a society that condemns confident women." (p. 158).

Thus, making a higher-education choice in contradiction with the gender norm may lead to difficulties or increased pressure, anticipated mostly unconsciously by the adolescent.

The image of computer engineering is not aligned with the stereotypes associated with women

As described by Collet (2006), the so-called geek-hacker culture arrived in the 1980s from the USA and lastingly pervaded the imaginary in the 1990s and 2000s, with representations of video gamers and computer scientists exclusively as white men conveyed in the media. Figure 2 shows a typical configuration of esports tournaments. Geek culture has mostly male heroes, and relies on fantasies of power, might and domination. Such fantasies align with hegemonic masculinity traits taught to boys and not to girls, and are therefore deeply internalized by boys (Chu, 2014). Thus, the

psychological traits we associate with computer science and engineering, often seen through the lens of geek culture, and in turn to leadership positions (such as self-assertion and disruptive behavior) are at odds with the traits we normally consider feminine. Moreover, it has been shown that computer science (like mathematics, physics, philosophy) nurtures the idea that abilities are innate, which makes these fields more problematic for women because genius is seen as an exclusively masculine trait (Leslie at al, 2015). Gradually, the unconscious association geek-gamer-hacker-computing-tech entrepreneur is shaping the image of computer science and shaping the supposed prerequisites to enter these studies and careers.

Therefore, this fundamental divergence between the social stereotypes shaping the general perception of computer engineering and those associated with femininity is at the root of the feeling of discomfort of women in these fields, that can deter students from choosing these studies, or hinder the quality of life and performance of women pursuing these careers. Our piece aims to make the user feel the gaze of others and its impact on the vision of their self, and make the user experience this subtle discomfort and feeling of not-belonging in the computer engineering world.


1

Tool support for creating an immersive experience

With our goal in mind to create this embodied experience of discomfort, we set about seeking the suitable means to realize the application and scenes. Here we present the design considerations and sketch-up of our framework, and well as the tools we chose to realize our artwork.

Considerations for virtual reality design

We consider 3D worlds that are fully synthetic, populated with scene elements, props and characters that immerse the user in 360° environments, giving them a feeling of presence in the virtual world. VR applications must afford a certain amount of autonomy in the way that users interact with the virtual world, including:

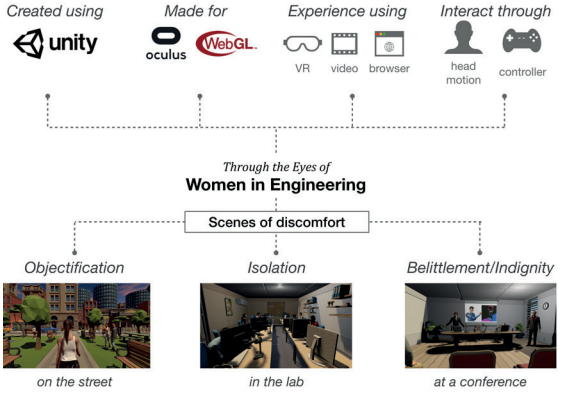
1. Immersion: the user should be offered a certain amount of autonomy to explore and interact with the world, such as to look around and move around
2. Presence: the world should respond in a way that makes the user feel that they are present in the virtual world, such as Non-Player Characters (NPCs) reacting to the player approaching

Three aspects come into play when we consider the development of VR experiences: the creation and presentation of the various multimedia content (i.e., sound and visuals), the media and technologies on which it will be deployed, and the management of user experience to allow maximum engagement with the content.

Development choices

Through the Eyes was developed using the Unity Game Engine, which is popularly adopted for creating gaming experiences in 3D, and has easy integration with a variety of VR headsets.

We chose to develop the experience for



2

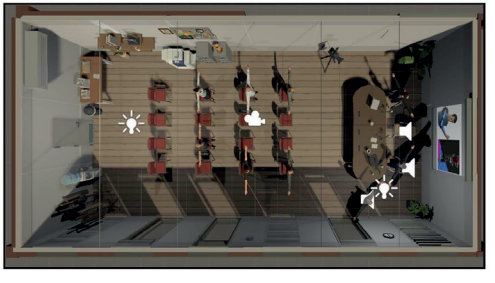
VR headsets, notably the Oculus Rift and Go, which are designed to be fully immersive in terms of graphics quality, interaction options, and sound. Simultaneously, the experience can also be installed on popular Android devices, making it more deployable, but afford much less interaction and realism.

Due to the format of the ICIDS 2020 virtual conference, we additionally distributed the application using WebGL, allowing the experience to be run from browsers such as Firefox and Chrome. However, this does not offer full immersion and is more akin to a video game experience on standard screens, with mouse and keyboard interaction. Figure 3. summarizes our project framework and content, and Figure


3

On the street


In the lab


At a conference


Outdoor scene assets


4

Indoor scene assets



Unity Multipurpose Avatars



Microsoft Rocketbox Characters

4. shows the overhead view of the three scenes described in Section V.

Content creation with toolboxes

To support a wide range of devices and taking into consideration potential latency from rendering, reducing asset size was a priority. For the 3D scenes, we used two sets of low-polygon 3D assets from Synty Studios[1] for outdoor and indoor scenes respectively, as shown in Figure 5. Populating large scenes was a greater challenge. We began with the Unity Multipurpose Avatar (UMA)[2] package, an open-source toolkit to generate real-time 3D humanoid avatars whose physique and attire can be customized. The avatars collectively share the same basic body models, allowing us to generate character groups without increasing the application size. We used UMA to populate our outdoor street scene with pedestrians. For the indoor scenes of the lab and conference, which contained less than 10 characters, we could use the Microsoft Rocketbox[3] characters with more adapted attire (Figure 6).

[1] https://www.syntystudios.com/;
[2] https://assetstore.unity.com/packages/3d/characters/uma-2-unity-multipurpose-avatar-35611;
[3] https://github.com/microsoft/Microsoft-Rocketbox.

Writing and designing a story of discomfort

We wanted to bring to life snippets of every day that would be immediately relatable and identifiable by any woman in engineering, but would be easily overlooked by and appear alien to someone just a few feet away. We settled on the idea of the role gaze plays in the perception of self both in one's own eyes and in the eyes of others. From this idea, three stories emerged to experience three scenes: in the street, in the lab, at the conference venue, animated with dialogue and realistic situations that we recollected from our experiences in each of the scenes. Each scene represents a different type of gaze and behavioral bias, and thus three different variations of discomfort. This section illustrates story behind each scene, explains the interactions we designed to convey these biases, and finally details the sound design.

Creative process

Our creative process combined reflections on our personal experience as women in engineering with the philosophical and sociological analyses of the origins of women's discomfort in tech-related fields. Looking at the many outreach actions taken in particular with high-school girls to encourage them to participate in tech or to raise awareness on gender biases, we felt that those actions did not speak to the girls' experience. They were systematically designed by external actors, too often men or women with no first-hand experience or awareness of such subtle biases.

In our positions of student, researchers and professors in computer engineering, we felt the need to tell our stories, our colleagues' stories, those of many other women, from our own eyes and bodies. This is grounded in the phenomenological approach mentioned in Sec. III and centered on individuals' stories.

We therefore chose to proceed as fol-

lows: From the literature presented in Sec. III, we selected three behavioral biases faced by women in engineering, which are central to our experience of not belonging, and that we personally experienced ourselves. For every bias, we design a scene where it is at play to make the user experience the feelings it yields. To carry the experience and generate the feelings in all the subtle ways the bias is perceived but hardly describable, we design specific interaction techniques occurring between the embodied character and the avatars in the scene. To give context, carry gender and tell the inner feelings of the embodied character, we resort to a feminine voiceover. The biases, interaction techniques and voiceover are described below and illustrated for each of the three scenes.

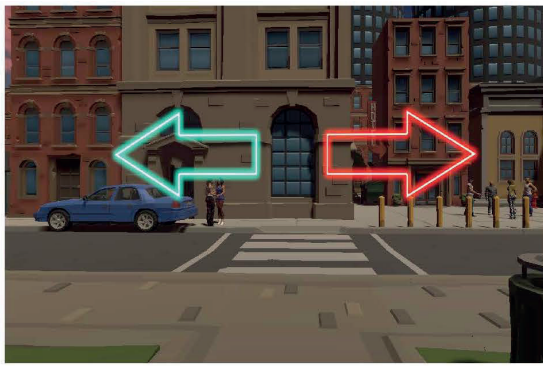
Story: three scenes of discomfort

Scene 1: On the street – Objectification – Bias of Gaze: The story starts from the generally shared activity of walking on the street, bringing the viewer into a familiar context and introducing the perspective of the woman player-character. The player follows a path through the city. She notices that men would often follow her with their gaze, and even look her up and down. Mixed with the city sounds is that of conversation, some of which she notices is about her, about her appearance, her body. The scene allows the user to discover that they are embodied in a woman's body, and are the target of the gaze and whispers. Finally, reaching their destination, the player exits through a door. In the voiceover, the embodied woman expresses her thoughts and feelings of discomfort aloud.

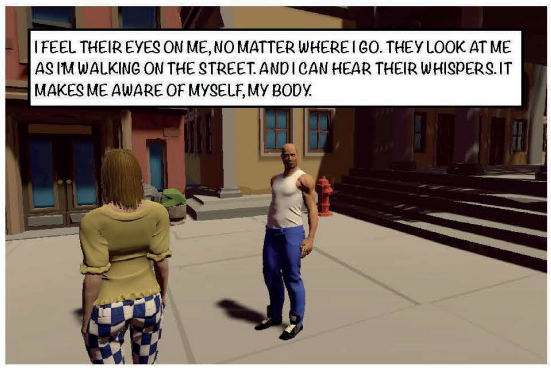
The central feeling of discomfort here is objectification. The gaze and speech of the men NPCs do not at all consider the player-character as a person with emotions, thoughts, and identity. Instead, they look at and comment on her body and appearance as if she were merely an object of interest within their view. The storyboard for Scene 1 is shown in Figure 7.


6
WHERE ARE YOU GOING? CAN I GIVE YOU A RIDE?
HELLO PRETTY GIRL. ARE YOU AVAILABLE TONIGHT?


YOU'RE CREEPY
YOU'RE THE ONE WHO'S CREEPY. LOOK YOU SCARED HER OFF.




HEY LOOK AT HER (...), THEY'RE SO SHORT
HAHA, TRUE
AND HER (...), THEY'RE SO FAT
HA HA HA !


I FEEL THEIR EYES ON ME, NO MATTER WHERE I GO. THEY LOOK AT ME AS I'M WALKING ON THE STREET. AND I CAN HEAR THEIR WHISPERS. IT MAKES ME AWARE OF MYSELF, MY BODY.


WHAT COLOR DO YOU THINK HER (...) ARE?
HAHAHA
I WOULD SAY PINK.
SHUT UP! SHE MIGHT HEAR YOU.

Scene 2: In the lab – Isolation – Bias of Gesture: The player walks down an indoor corridor. She is drawn towards the sounds of unruly shouting and cursing on top of what is clearly video game music. As she approaches the source of the sound, she sees that it is a lab with rows of computers occupied all by boys. Aware of the "intrusion", the boys drop into an awkward silence and concentrate on their screens. As the player walks between the rows of computers, the boys steal glances at her, perhaps wondering whether she might stay, or if she could just go and allow them to continue their gaming. Ultimately, she does not find a place for herself, and leaves the lab. She can hear the shouting resuming as she exits the room. She leaves at the



next door.

The feeling of discomfort intended here is isolation. Departing from scene 1 where gaze and dialogue are actively directed towards the woman player, in this scene she is excluded from the gaming activities that the boys in her laboratory are taking part in. While her colleagues in the room are clearly aware of her presence, they also indicate a reluctance to interact with her when met with her direct gaze. The key takeaway here is that language and gestures are as much a vehicle of discomfort as the lack of them when they are the embodiment of implicit biases. The storyboard for Scene 2 is shown in Figure 8.

Scene 3: At a conference – Belittlement / Indignity – Bias of Speech: The player is seated in the second row of a conference audience and is listening to the end of a talk on robotics. When the talk ends, the audience is invited to ask questions. The player ponders on how to inquire on a point in the talk and attempts to strike up a conversation with the speaker. However, the speaker immediately dismisses her statement as trivial and proceeds to divert the conversation by mansplaining to her basic concepts. She is left somewhat confused by the speaker's behavior and asks to clarify her point, but is stopped by the session chair from asking a follow-up. The inner thoughts of the woman are told aloud and express frustration.

This scene introduces discomfort through indignity and belittlement in a professional setting. The speaker brushes aside the player's question, seeing it as a challenge to their work, whereas the player simply wishes to engage in a scientific discussion. The speaker further belittles the player by assuming that she is not sufficiently knowledgeable in the domain. In the end, the session chair did not intervene to guide the exchange, but rather prevented the player character from pursuing their point, which fur-




So thanks for listening, and I would be glad to answer any questions.
Anyone has questions?
... Anyone?
A. ASK A QUESTION
B. MAKE A COMMENT
Yes?
The empirical results of your robot arm are impressive. I was wondering about the robustness of the approach, that is, if a solution exists, will your approach guarantee to find it, and would it be optimal?
Thanks for the question. I would like to point out again, since it may not have been clear to you in our presentation, that our results are purely empirical —
Yes, that's what I understood, so I was wondering —
So empirical means ...
BUT THAT WAS NOT MY QUESTION, AND I OBVIOUSLY KNOW WHAT EMPIRICAL MEANS. WHY IS HE EXPLAINING IT TO ME... ?
Yes, I understood your point, but if I may follow up —
Sorry, we do not have time for follow-up questions. Perhaps someone who has not asked any questions yet?
8
B. MAKE A COMMENT

ther adds to the indignity due to the inability to have a fair and equal peer-to-peer conversation. The storyboard for Scene 3 is shown in Figure 9.

Interaction design

Different interactions and NPC behaviors are woven into each scene in order to show the user the various manners implicit behavioral biases can manifest itself in each context.

Gaze behaviors of NPCs vary between the different scenes. In the street scene, the men NPCs will begin to follow the player's progression as soon as they are within visual field, even before the player looks towards them. As the player approaches, the men will also look the player up and down, and sometimes direct comments towards the player. In the computer lab, the boy NPCs will also follow the character, but divert their gaze to their screens when the player returns gaze. The room is also completely silent, with no NPCs attempting any interaction with the player. This is magnified by the fact that voices of the NPCs can be heard when the player is in the corridor outside the computer lab, but not at all while the player is inside. In the last scene, the NPCs generally look at the speaker in the front, and only look at the player when they are in conversation with the speaker.

The player's movement in the scenes is restricted. In the first and second scene, the player camera moves automatically down a pre-designated path. The first scene is an open outdoor scene, whereas the second scene is in a more confined space. In the third scene, the player is seated in a chair at the conference venue. In all three scenes, the player is free to look around in whatever direction they wish, and only at specific points of choice making, the camera will be fixed in a direction to allow easier interaction.

At some points in the story, the player is given what resembles a choice through a menu, but these choices are not presented to the player in a manner where they can make a decision on a logical or rational basis. Ultimately they are put in similar if not identical outcomes. These occur in Scene 1, to select which direction to go in, and in the third scene, to choose how to inte-

ract with the speaker.

Sound design

The voiceover is instrumental to convey the gender of the player-character and narrate the feelings to guide the experience. Women and men speaking the characters' voices and dialogues were recordings by the authors as well as from volunteers known to the authors, though they have mostly asked to remain anonymous. All dialogue content was scripted by the authors.

All the scenes feature ambient environmental sounds from Creative Commons licensed clips. The first and third scenes used ambient street sounds and indistinct conversation sounds of men from Youtube Audio Library (CC-BY-3.0). The second scene features office sounds such as keyboard typing, mouse clicking, and paper shuffling sounds from the Sound Gallery (CC-BY-4.0).

Reflections on the ICIDS 2020 exhibition

This year's virtual conference offered two events for the artists of the exhibition: the main event on Discord voice channels that allowed conference attenders to approach the artists directly for a close discussion, and the social event plus a panel hosted on Gather Town that served as a more general exchange between artists.

Target audience and awareness

Given the rise in awareness towards gender issues through multiple recent movements including #MeToo, the message that we aimed at communicating through our piece was not really shocking or unfamiliar to our audience. On the contrary, many attendees of ICIDS were women in engineering fields who struggle day to day with the very feelings of discomfort shown in our piece. Thus, many wanted to know: why did we create this experience, and who was it targeted towards?

A few lively discussions surrounded the topic of men being the target audience of the artwork. Our original intention was to help high-school girls become aware of issues of bias in engineering, and be forces of change in their future studies and careers. However, throughout the development, we came to realize that some scenarios – particularly the laboratory and scientific conference – may be far off from experiences of younger students. On the other hand, male colleagues and scientists did express surprise and were unaware of the implicit behavioral biases shown in the piece, never having been a minority in the field nor subject to catcalling. With the immersion provided through VR, the experience could also serve to raise awareness amongst the general public and for men in engineering fields, to promote change in multiple directions.

User experience and behavioral change

Another important point that came up during discussions, foreseen as future work, is the possibility of conducting user studies and collecting feedback on the experience itself. Our motivation for *Through the Eyes* is indeed to investigate the potential of VR to contribute to the challenge of gender equality.

The first aspect is to understand how narratives relying on embodied cognition and embedded in a video game-like content influence user experience. In the field of Human Computer Interactions (HCI), studies of user experience are comprised of numerous dimensions (such as stimulation, mean and value, etc.). Of interest to us are those that assess how such content can impact the immediate state of the user such as identification and emotions including arousal and empathy. Their means of evaluation then rely on self-reported (e.g., questionnaire, comments), experimenter-reported (e.g., direct observation, discourse analysis) and psychophysiological measures (e.g., electrodermal activity, heart rate, EEG). Barreda-Angeles et al. (2021) collected both self-reported and psychophysiological measures on middle-school students watching a video on school bullying in two dif-

ferent formats: flat screen and 360° with a headset.

The second aspect is to understand the effectiveness of VR for invoking long-term changes in people's everyday lives and perspectives – and in the case of *Through the Eyes,* raise awareness of implicit behavioral biases towards women in engineering fields, or trigger empathy in the user. This aspect is more challenging as it requires follow-up studies with users over longer-time periods after the experiment to observe its lasting effects. It is however crucial for VR to be considered as a true lever towards tackling complex societal issues. Dasgupta (2015) showed that having a same-sex mentor in the first year of college for STEM women students significantly improves students' sense of belonging and confidence, resulting in a lasting impact on their education choices in subsequent years. However, we are not aware of similar long-term evaluations of the impact of a VR experience, and discuss this point as a future work in Section VII.

General discussion on discomfort

Over friendly drinks and vibrant exchanges during the social event, the question of this year's theme "Texts of Discomfort" arose. How did artists choose to include discomfort in their pieces, and in particular, how much discomfort was enough or too much for an audience?

In *Through the Eyes*, we had a pre-defined theme of discomfort that we wished to follow for each scene. The focus was to make the user aware of the implicit behavioral biases by putting them in the place of the target of such biases. Moreover, it is not our intent to make the user feel like the NPC behaviors are personal attacks. These scenes thus needed to be sufficiently general, portraying not just "a single" experience of harassment or bias, but a "collective" experience of all women being subject to systematic bias. Therefore, in our choices of scenarios to portray, we chose not to focus on

discomfort that is explicit or aggressive in nature, but the kind that is hard to observe when one is not the target of the behavior, or when we are accustomed to the current "norms" and "ways of acting" in the society and unaware of these systematic biases.

In his *The Defense of Poesy*, Philip Sydney pointed out that poesy "is an art of imitation, [...] a speaking picture, with this end,—to teach and delight." (Sydney & Cook, 1890, p. 9) Discomfort is not meant to stop the user from feeling the wonders and joys of being immersed in a virtual 3D scene, and to try to interact with the scene. Rather it serves the function of teaching, of also bringing to light how VR and storytelling can be a vessel to communicate such subtle types of bias and foster discussions around gender equality without people feeling victimized or being pointed fingers.

Conclusion and future work

Through the Eyes sprung out of our strong motivation to initiate a contribution to address the challenge of the underrepresentation of women in the tech industry, engineering research, and higher education in these fields. Discomfort being the manifestation of the divergence between the stereotypes associated with women and those associated with engineering, we devised a piece where VR is leveraged to create an embodied discomfort commonly experienced by women in the engineering world.

Our immediate future work is to build on such an approach to work with high-school students and jointly identify with them how to use VR for their peers to more tangibly perceive what implicit gender biases are, and how they impact them. Specifically, given the importance of the body in the construction of a feminine

self during adolescence, we intend to leverage VR to co-create better suited experiences for high-school students to identify the hidden reasons for their education choices, rooted in the implicit biases we are all prey of. Implicit biases cannot be erased, but understanding their impact on our decisions enables us to exert control and make decisions better aligned with who we want to be. *Through the Eyes* will be used to prompt discussion and analysis during the co-creation process.

Acknowledgements

We thank the volunteers for the voice-overs of men characters, who wish to remain anonymous. For the video trailer, we thank women engineers Evgenia Kartsaki and Selma Souihel for lending us their voices. This work was partly supported by the French government, through the UCA JEDI and EUR DS4H Investments in the Future projects ANR-15-IDEX-0001 and ANR-17-EURE-0004. This work was partly supported by EU Horizon 2020 project AI4Media, under contract no. 951911 (https://ai4media.eu).

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Images

1. *Through the Eyes of Women in Engineering* is a virtual reality application that takes the user on a journey through three everyday scenes in the life of a woman minority in the field of computer science and engineering: on the street (middle), in the lab (left), and at a conference (right);
2. An esports tournament. Image credit to sirusgaming.com ©;
3. The application was developed on Unity for Oculus headsets, compiled to WebGL. Three scenes of discomfort were created to demonstrate the various implicit behavioral biases and associated discomfort a woman in the field of computer science and engineering felt in their everyday lives;
4. An overhead view of the three scenes made in our application. White icons indicate positioning of lighting, cameras, and sound sources;
5. We used two sets of assets designed by Synty Studios for the indoor and outdoor scenes. The 3D models were low-polygon due to application size and latency considerations, but provided a large enough variety of props and environmental elements to create rich and lively scenes;
6. To populate our scenes, we used the Unity Multipurpose Avatars (UMA) and Microsoft Rocketbox toolboxes. UMA allowed the real-time generation of diverse characters without compromising application size, which was very suited to populating the first city scene with pedestrians. Rocketbox provided professional models adapted to portraying characters in the second and third scenes;
7. In scene 1, the player experiences objectification from men on the street. She has a choice of movement direction (upper-right) in the beginning, and has a voiceover of her thoughts (lower-middle) on how she feels watched and talked about (text bubbles do not appear in the app);
8. In scene 2, the player feels isolation from colleagues in a computer lab. As she approaches, there are sounds of the boys gaming, but they fall silent when the player enters the room. She notes the awkward interactions with her colleagues (lower-left) and feels out of place (lower-middle);
9. In scene 3, the player experiences belittlement and indignity at a scientific conference. She is seated in the audience. After the talk, she interacts with the speaker (upper-middle), but receives unfriendly and belittling responses, which she notices and questions (lower-middle).

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