Resilient IN: Design of an Interactive Narrative HRV-Biofeedback Game to Develop Stereotype and Social Identity Threat Resilience

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Abstract. Stereotype threat and social identity threat are social phenomena that adversely affect underrepresented groups within STEM (i.e., women and people of color). While there are existing programs and techniques for training resiliency against these threats, the use of biofeedback and serious games may prove useful to enhance the efficacy and engagement of such training. In this paper, we present the work in progress on our interactive narrative biofeedback game (Resilient IN) that utilizes resonant frequency heart rate variability to train player resilience to stereotype and social identity threat as they move through a mock interview at a tech company within the game. Specifically, we discuss the design of the game in detail—focusing on how specific elements of the design draw from existing literature to evoke and train resilience during play, as well as design and validation of the game narrative/script with individuals in the technology and engineering industry. Finally, we provide future directions for the work, such as upcoming studies to validate the game's efficacy in evoking and training resiliency to different kinds of threats.

Keywords: Social identity threat · Stereotype threat · Serious games · Heart rate variability · Biofeedback

1 Introduction

Women and people of color are grossly under-represented in engineering and computer science. Blacks and Hispanics constitute only 6% and 7% of the Science and Engineering workforce relative to their participation in the U.S. workforce as a whole i.e. 15% and 16%, respectively [59]. Similarly, women account for only 27% of computer and mathematical scientists and 16% of Engineers [59]. They

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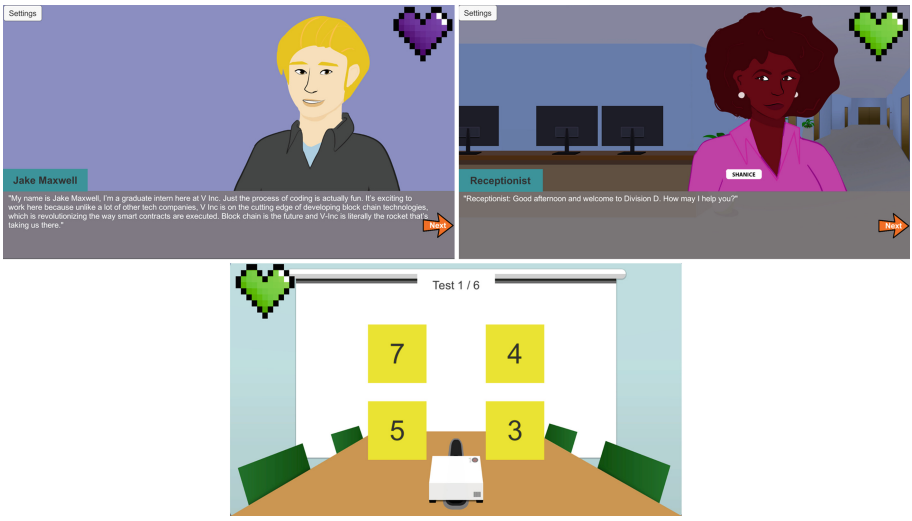

Fig. 1. Three scenes from Resilient IN. The first scene (left) is an interaction with one of the interns. The second scene (right) is the player's interaction with the receptionist. The third scene (bottom) is the working memory task that the players will attempt.

also exit these domains at higher rates than men—over 32% leave STEM degree programs in college [13] and those who graduate are less likely than their male counterparts to work in a STEM occupation [67].

Research suggests psychosocial factors such as stereotypes about gender roles, and intellectual abilities of women and people of color [64,65] with beliefs that brilliance is integral to success in certain STEM fields [5,20,34,36] contribute to these disparities. Indeed, stereotypes linked to racial and gender social identities have been shown to degrade the performance of some individuals belonging to under-represented groups [1,64,65]—a phenomenon called social identity threat.

Conversely, biofeedback trains individuals to consciously elicit a parasympathetic response (e.g., achieve a state of rest and relaxation) [2,10,21]. This can effectively repattern physiological responses to stimuli [43], with lasting effects on psychological well-being, socio-emotional function [41,42] and performance [9,10]. There is also evidence to suggest that biofeedback training controls responses to anger inducing stimuli [21], and aids in emotional intelligence and regulation [70].

In a related vein, serious games are used in many different contexts to help teach resilience [7,31,38,57] and have been utilized in combination with biofeedback to help train emotion regulation [52–54] and stress management [7]. However, to our knowledge, there has never been a game developed that utilizes biofeedback and is concerned with stereotype threat.

In this paper, we present our work in progress creating a Resonant Frequency Heart Rate Variability-Biofeedback (HRV-Biofeedback, hereafter) game to address stereotype and social identity threat. Specifically, we will discuss

the design and development of our serious game, Resilient IN, for training resilience towards stereotype and social identity threat in a non-laboratory environment (see Fig. 1). Specifically, the game is designed to investigate physiological responses to stereotype and social identity threat-i.e., possible relations between resonant frequency heart rate variability and working memory, as well as changes in cardiovascular reactivity from rest to task (reactivity) under stereotype and social identity threat. In order to achieve this, the game integrates HRV-Biofeedback to facilitate emotion regulation training. Notably, this is the first serious game to address stereotype and social identity threat through biofeedback, allowing for novel future empirical inquiry and research findings that could inform a new generation of interventions that leverage biofeedback training in serious games to attenuate various stereotype and social identity threats.

2 Background

2.1 Stereotype and Social Identity Threat

Social Identity Threat (SIT) is a psychosocial phenomenon where members of stereotyped groups experience concern and anxiety over confirming, as a self-characteristic, a negative stereotype about the group [66]. When examined solely in testing or evaluation contexts, social identity threat is referred to as stereotype threat. Thus, the former concerns outcomes other than performance, and the latter, which falls under the larger umbrella of social identity threat, pertains to the negative impact of stereotypes relative to performance or evaluation outcomes.

For instance, the stereotype that 'women aren't good with numbers', can impede their performance on quantitative tasks in environments where these stereotypes are made salient. In typical experiments, members of marginalized groups complete challenging tasks in stereotype-relevant domains under one of two conditions: (a) non-threatening contexts, where no stereotypes are highlighted, or (b) contexts where negative stereotypes alleging intellectual inferiority in the domain are made salient. A stereotype threat effect is observed when members of stigmatized groups exposed to negative stereotypes about their group under-perform relative to their counterparts who have not been exposed to the stereotype. A long-term consequence of chronic exposure to social identity threat is domain disidentification and attrition from the domain [65].

The stereotype threat process model [62] identifies three distinct but interrelated processes by which ST disrupts performance: a physiological stress response that impairs prefrontal processing, active self-monitoring which affects regulation of attention, and efforts to suppress negative thoughts and emotions that arise during cognitive tasks [62]. Although negative emotions set off a cascade of neural and physiological responses that interfere with task performance, underperformance due to social identity threat is less a function of these emotions than it is how they are regulated. Both theory and research implicate emotion suppression as maladaptive and a primary mechanism through which social identity threat impedes performance [61]. There is converging evidence that social

identity threat depletes executive resources (i.e., working memory) via emotion-suppression [32], which impairs the phonological aspects of working memory responsible for supporting complex cognitive activities [4], and leads to inefficient cognitive processing [48,68] that under social identity threat, individuals from stereotyped groups (i.e. women, and people of color) frequently use emotion suppression as an emotion regulation strategy, to the detriment of working memory [32] and hence task performance; and that cognitive reappraisal can successfully reverse the performance deficits observed when emotion suppression is used to downregulate emotions under threat [32,37].

2.2 Techniques for Developing Resiliency

Several interventions to counteract stereotype threat exist e.g., self-affirmation [8,63], adopting a malleable view of intelligence [22], and teaching about ST [32,58]. So far, only one intervention has addressed emotion regulation, which is a key pathway to mediating the phenomenon: The Stereotype Threat Reduction Intervention Program (STRIP, hereafter). STRIP [55] is an evidence and skills-based intervention designed to reverse stereotype threat induced performance deficits among women and students of color. It provides metacognitive monitoring and emotion regulation skills-training to combat two major and related pathways critical to the stereotype threat process: active self-monitoring, which affects regulation of attention, and the suppression of negative thoughts and emotions that arise during cognitive tasks [61].

The STRIP emotion regulation intervention protocol supplants maladaptive emotion regulation strategies like emotion suppression responsible for impairing cognitive processing under social identity threat [62], with a combination of adaptive emotion regulation skills like cognitive reappraisal, psychological distancing, and attentional regulation, which that exert little to no cognitive cost to these cognitive processes. Here, participants learn to increase or decrease their psychological distance from an emotional event (psychological distancing), mentally re-frame the meaning of emotionally charged stimuli to change the trajectory of negative emotions (cognitive reappraisal), and consciously direct attention to focus on selective information to magnify the experience of select stimuli (attentional regulation).

The metacognitive skills component of STRIP re-directs self-monitoring to focus on problem solving strategies which facilitate rather than impede efficient cognitive processing. Specifically, it focuses on honing metacognitive monitoring skills to improve student calibration by imparting skills necessary to (a) accurately judge task performance, (b) identify gaps in their knowledge (c) develop strategies to close these gaps (d) assess their own monitoring skills during task performance will be taught and practiced. Here, attentional regulation is deployed to train students to focus on the elements, which would help redirect focus from concerns over the threatening stereotype to the task at hand.

Our game is designed to support and enhance STRIP's emotion regulation protocol specifically by integrating it with HRV-Biofeedback training to improve

(a) HRV (b) performance, (c) working memory, executive functions and affective control, all of which are typically impaired under SIT.

2.3 Biofeedback in Serious Games

Biofeedback trains individuals to consciously elicit a parasympathetic response (achieve a state of rest and relaxation) [2,10,21], which can effectively repattern physiological responses to stimuli [43], with lasting effects on psychological well-being, socio-emotional function [41,42] and performance [9,10]. Through biofeedback, newly learned response patterns become increasingly familiar to the brain and feed-forward neurological connections to a new set point [43].

There is evidence to suggest that biofeedback training controls responses to anger inducing stimuli [21], and aids in emotional intelligence and regulation [70]. Students who receive biofeedback training are also more effective at self-activating the optimum (desired/trained) psychophysiological state under stressful conditions, which has been directly linked to reduced anxiety and improved test performance [2,9,10]. Specifically, HRV training influences brain and emotion function with lasting positive outcomes [39].

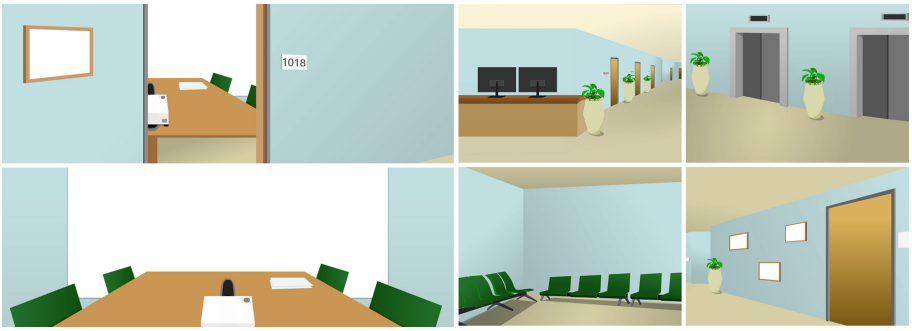

Fig. 2. Background art that was created for each scene of Resilient IN.

3 Design of 'Resilient IN' Game

Resilient IN is an interactive narrative HRV-Biofeedback game designed to train resilience towards stereotype and social identity threat through emotion regulation training. This is achieved by having players role-play through an authentic scenario where they would encounter situations that elicit stereotype and social identity threat. As players progress through the game, they are provided with continuous HRV-Biofeedback to visibly show them how stereotype and social identity threat situations are impacting them physiologically. These biofeedback signals are also monitored by the game and explicit in-game feedback is given to the player if their RF-HRV becomes too high in order to facilitate further emotion regulation training. The game is designed to measure HRV at rest

(prior to) and during gameplay in order to identify substantial changes and differences in player physiology. In this way, Resilient IN offers a safe medium for players to encounter instances of stereotype and social identity threat and practice emotion regulation techniques to combat their impact.

Resilient IN is built for Windows machines using Unity and the ink plugin[1] to script the game's interactive narrative. We chose the interactive narrative genre for Resilient IN's design since interactive narratives are a highly accessible genre of games due to a low demand on player actions, focus on storytelling, and role-playing elements all helping to engage a larger audience [11,69]. This accessible aspect of interactive narratives has made them highly popular with men, women, and even novices to games [12], as well as for educational/training purposes both commercially and in academia [11,18,46,50]. Furthermore, the role-playing nature of interactive narratives has been shown to be highly effective at improving player attitudes [24,25], motivation [23], knowledge [45], and skills [44]. This makes the use of interactive narrative games an ideal approach for training resiliency as it easily and intuitively enables learners to role-play through various stereotype and social identity threat scenarios.

The core design focus of Resilient IN is context as social identity threat is a highly contextual phenomenon. Specifically, context (both physical and social) is not only central to the activation of social identity threat [65], but also a key moderator of outcomes related to the phenomenon [55,56]. In our game, players are invited to a technical interview for a highly competitive software engineering internship at a non-existent brand name technology company (see Fig. 2 for in-game background art of the company). This setting was chosen since technology companies (such as those within the Silicon Valley tech industry) are notorious for being male-dominated environments [30].

Contextual elements in the game are also manipulated to make negative gender stereotypes and implicit bias of the same accessible to the player, i.e., to elicit gender related social identity threat. These elements are manipulated at two levels: (a) physical context, and (b) social interactions with others before and during the interview. Examples of the manipulating physical context include but are not limited to sexist posters in the hallway that simultaneously accentuate gender stereotypes and downplay the ability of women to compete in the tech environment, and numeric (under) representation with respect to interview candidates. The player also finds themself in the minority group of a candidate pool dominated by White men. Finally, there is a working memory task for the player to complete at the end of the interview which doubles as both (1) a diagnostic of ability and key determinant of admissions into the in-game internship program [65], and (2) a quantitative task for accessing social identity threat impact on the player's working memory. Notably, a leaderboard is present during the working memory task that shows the scores of top candidates, all of whom are male and White or Asian.

Examples of manipulating social context include the player's interactions with other candidates, staff, and the interview panel of five, which is littered

[1] https://www.inklestudios.com/ink/.

with micro-aggressions rooted in assumptions that stem from implicit gender or race bias. For instance, one of the interviewers confuses the player for a secretary and asks her for an update on back ordered office supplies, and company staff who assumes that the player is there for a different interview (to fill an entry low-level administrative assistant position) and is very surprised to learn that the player is there for the software engineering internship.

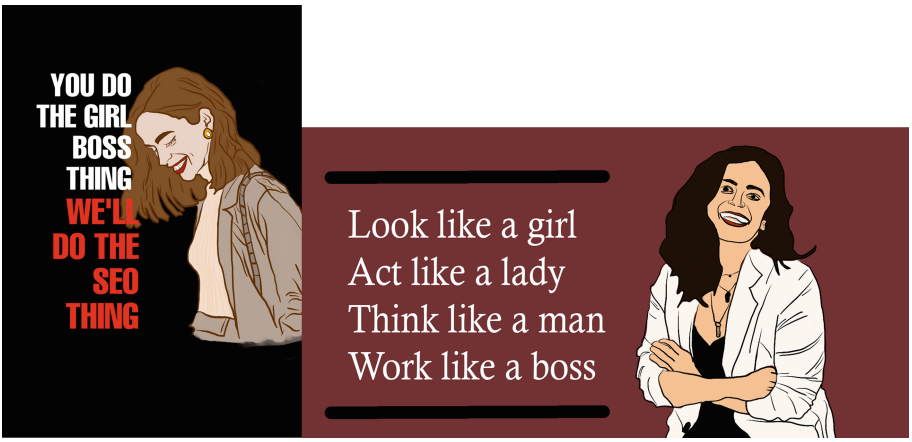

Fig. 3. Two posters that will be lining the hallways of the company as the player makes their way to the interview room. These posters are based on real world posters that have made the news in recent years due to gender stereotyping (see Footnote 2 and 3).

3.1 Environmental Biases

Even small aspects of a physical environment can have a significant impact on individuals. For instance, small decisions such as having stereotypically masculine posters (e.g., Star Wars) displayed on the wall can lower women's sense of belonging in computer science domains [14,15]. Additionally, these studies also show that the setup of classrooms in computer science courses can influence the engagement and interest of female students, and classroom arrangements that display stereotypically male artifacts diminish women's desire to enter the field relative to classrooms with artifacts that are regarded as neutral [14,15]. For this reason, we line the hallway leading up to the interview room with sexist posters (see Fig. 3 for example posters). Notably, these posters are based on real world posters that made the news in recent years for gender stereotyping[2,3]. With this we intend to further elicit social identity threat through blatant ambient sexism that draws from real world equivalents.

[2] https://www.bbc.com/news/business-51032631.
[3] https://www.theguardian.com/society/2015/aug/11/look-like-a-girl-think-like-a-man-bic-outrage-south-africa-womens-day.

Fig. 4. Character designs for Resilient IN.

3.2 Character Designs

How characters are designed also impact how they are perceived by the players. In [19], it was found that stereotypes for video game characters exist, and they are very distinct across the gender line. It is important to note these inherent stereotypes when designing characters in a game. For example, female characters were labeled mostly as provocatively dressed, thin but curvy, sexual, and subservient while male characters were labeled as powerful, aggressive, athletic, and superhero in [19]. Regarding female self-efficacy and general attitudes about women, [3] found evidence that playing a sexualized character can have a negative impact on both female self-efficacy as well as attitudes toward women in general. However, it was noted by the authors that this result was not the strongest and additional research should be done to further qualify these findings. Other research also shows that interacting with sexist men triggers social identity threat among female engineers resulting in performance deficits on quantitative tasks [36]. With our character art, we have attempted to play with the stereotypes of what a person in that job function would be. Figure 4 shows two of our interns, both white, one is an engineer, and the other is in finance. To denote the difference, the engineer is in a much more casual outfit where the finance intern is much more formally dressed. The rest of our characters also follow stereotypes to increase the stereotypes being encountered throughout the game.

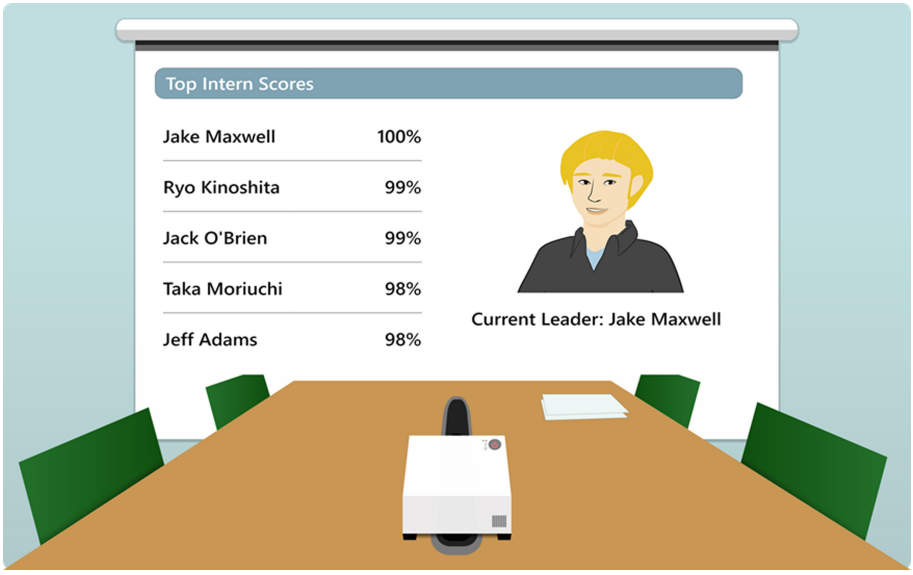

Fig. 5. The leaderboard that is present for players during their interview showing white and Asian males as the top performers.

3.3 Gamification of Leaderboards

A subset of educational gamification literature is concerned with the additional pressure that leaderboards can put on women regarding their belief in their math abilities. The stereotype that women are worse than men at math already exists, and [16] notes that the inclusion of a leaderboard is a means to making the stereotype that much more salient. Results from these researchers indicated that, in contrast with extant literature, women performed worse when in the all-women leaderboard condition as compared to all men leaderboard condition. This was attributed to a "social comparison" that researchers believed was more salient than the inherent stereotypes. Other studies have noted gamification can lead to better learning [28] and learning performance [51] and help individuals with goal setting [35], i.e., "I want to be number one on the leaderboard". However, a literature review noted that "some underlying confounding factors exist" across a multitude of gamification studies, including the "the role of the context being gamified" [27]. To investigate the effects of leaderboards on stereotype threat and resilience, we have created a leaderboard in our game that contains only males who are either white or Asian (see Fig. 5). This leaderboard is present during the entire working memory task at the end of the in-game interview.

3.4 Biofeedback Training

Biofeedback has been utilized in a variety of contexts within the serious games field. For example, researchers have studied its effectiveness for training stress management skills [7,52,53,68] and others have studied if it can improve problem-solving ability in individuals with chronic brain injury [33]. A study has also been done on teaching emotion regulation in financial traders [31]. These studies exemplify a few of different types of biofeedback that can be utilized, including heart rate [7], heart rate variability [70] and skin conductance/breathing rate [52,53]. These studies also share a common outcome: biofeedback training led to better decision-making skills and emotion regulation.

Stereotype threat and SIT in particular are marked by increases in blood pressure [6] and sympathetic activation, i.e., increased heart rate and beta electroencephalography (EEG) activation [47]. To explore the impacts of our HRV-Biofeedback training, the signals that we intend to assess during gameplay are: *mean arterial blood pressure*, *pre-ejection period*—a near pure measure of sympathetic nervous system activation of the heart—and players' *HRV*. More specifically, emotional regulation capacity will be assessed using HRV, which will be computed from electrocardiography (ECG) by analyzing the variability in timing between R-R intervals. Emotion suppression, which is the primary mediating pathway for stereotype threat to occur, is characterized by decreased heart rate [17,26], increased mean arterial blood pressure [17], and lower cardiac output and ventricular contractility in combination with higher temperature, pulse, and respiration [40]. Therefore, in addition to heart rate, these additional physiologic signals of reactivity to stereotype threat and SIT will be assessed using impedance cardiography during gameplay.

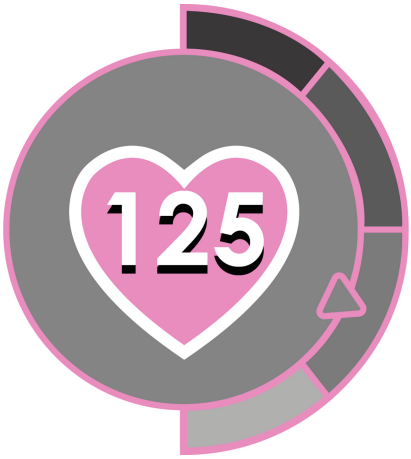

Fig. 6. The HRV-Biofeedback UI. It is shown on the top of the screen during gameplay, and provides both numeric feedback of the player's current resonant frequency HRV as well as iconic feedback of how that value relates to the player's baseline resonant frequency HRV range.

We are also approaching our design similar to [70], where it was determined that the addition of a visual representation of biofeedback in the game helped players to breathe better. Therefore, the HRV-Biofeedback will be displayed on screen for players to see real time feedback during gameplay (see Fig. 6). Specifically, the HRV-Biofeedback UI displays both numeric feedback of the player's current resonant frequency HRV as well as iconic feedback of how that value relates to the player's baseline resonant frequency HRV range. As a player's resonant frequency HRV value goes up, the UI will change color to reflect one of four different states: 1) *Within Baseline* where the player's HRV is within their normal baseline; 2) *Above Baseline Warning* where the player's HRV is within one-half of one standard deviation above their normal baseline; 3) *Above Baseline* where the player's HRV is above one-half of one standard deviation of their normal baseline but below one full standard deviation; and 4) *Way Above Baseline* where the player's HRV is more than one full standard deviation above their normal baseline. Additionally, when a player's HRV reaches the *Above Baseline* level or higher, the game will pause and prompt players to employ one of the STRIP emotion regulation protocols (such as cognitive reappraisal) [55].

3.5 Design and Validation of Interactive Narrative Script

Resilient IN features an individual invited to a technical interview at a competitive company. It is designed to elicit gender-related social identity threat, which is achieved by manipulating context at two levels: (a) physical context, (b) social interactions with others before and during the interview. The script, written by the 1st Author, was grounded in empirical studies which show that

elements in the physical context, such as numeric representation [29,49], as well as sexist social interactions [37,60] can trigger and exacerbate social identity threat. In this way, the dialog and interactions within the script are written to subtly evoke SIT. For instance, certain characters assume the player is interviewing for a non-technical position upon first meeting, some interviewers will show disapproval of the player's university, all interviewers and company executives are male and predominately white, and conversely most female characters are in non-technical or lower ranking positions. Importantly, we wanted to ensure that these interactions were authentic to real world scenarios and interactions encountered by individuals within the technology and engineering industry. Therefore, we validated the script for authenticity with professionals in that industry.

Participants. The authenticity of the script was validated with 20 individuals in the technology and engineering industry. The sample constituted 10% White women, 30% minority (Black/Hispanic) men and 60% minority women. Additionally, 90% of the sample held mid to senior level executive positions in their careers. Companies like Google, Riot games, JP Morgan, IBM, and Amazon were represented in the sample.

Procedure. Respondents read the script and completed a short survey where they were asked to rate the authenticity of the script and qualitatively share what elements of the script were most authentic and/or inauthentic. Authenticity ratings were anchored on a 10-point Likert scale ranging from 1 (not authentic at all) to 10 (very authentic).

Results. The script received very high authenticity ratings, with mean, median and mode scores of 8.5, 7 and 10, respectively. Overall, respondents were able to identify incidents of microaggression in the script, and find them very relatable, given their own personal experiences in the workforce. The parts of the script that respondents found most authentic were incidents where the player was mistakenly assumed to have stereotypical job roles, and the surprise others expressed when they found out that the player was in a role counter to the stereotype. These incidents were most relatable to the content validators because at some point in their careers, they too had experienced implicit messages that devalued their intellectual contributions, based on others' views that they did not belong and that they needed to be grateful just to be "a part of the room". There were hardly any suggestions regarding how to improve the authenticity of the script, except for one that suggested increasing more scrutiny of the play with security prior to being let into the main building.

4 Discussion

The purpose of validating the script was to ensure that the game feels like a real-life situation in order to increase the likelihood of transfer of emotion regulation from the game to the real world. Utilizing our combination of HRV-Biofeedback training and a serious game, the authentic environment will enable players to train emotion regulation at low-stakes and ultimately reduce the impact from stereotype and social identity threat they will experience in the real world.

4.1 Need for Game-Based Tools to Develop Resiliency

As aforementioned, to our knowledge there does not exist a game with the intentions of teaching resilience for those that are experiencing stereotype and social identity threat. We believe this is an area that could greatly benefit from a game of this nature. Games for helping teach resiliency already exist in different contexts, including low-income community risk resilience [38], industrial safety resilience training [54], and general academic resilience [57]. In each of these instances, the researchers utilized the game to simulate reality. For example, in one study the research goal was to determine what was needed for the community to create better plans in the future to help become more resilient in the face of adversity. In this work, three different games were developed that enabled players to gradually gain an understanding into how complex scenarios regarding risk can be as well as allow them to practice developing strategies to mitigate risk. In Resilient IN, we similarly intend to utilize an interactive narrative role-playing game to authentically simulate real world stereotype and social identity threat and allow players to practice mitigating their effects to prepare for the real-life scenarios they will encounter.

5 Future Work

Moving forward, we plan to conduct multiple studies of the game to examine if (1) the game appropriately elicits stereotype and social identity threat, and (2) the utility of incorporating the HRV-Biofeedback in training emotion regulation in players as well as if this results in them developing stronger resiliency. We also plan to continue researching and identifying additional aspects where we can include more liminal or subliminal messaging.

6 Conclusion

In this paper, we present the design of Resilient IN—a novel HRV-Biofeedback game that integrates resonant frequency heart rate variability for training resilience to stereotype and social identity threat. We discuss the design of the game in detail—focusing on how specific elements of the design draw from existing literature to evoke and train resilience during play, i.e., through the use

of environmental biases, character designs, gamification of leaderboards, and HRV-Biofeedback training. We also discuss the design and validation of the authenticity of the game narrative/script with individuals in the technology and engineering industry. Notably, to our knowledge, this is the first serious game to address stereotype and social identity threat through HRV-Biofeedback, allowing for novel future empirical inquiry and research findings that could inform a new generation of interventions that leverage biofeedback training in serious games to attenuate various stereotype and social identity threats.

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