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Work-in-Progress—Exploring the Therapeutic Potential of Fear Conditioning Using Virtual Reality for Victims of Gender-Based Violence: A Physiological Computing Approach Using Sweat-Sensing Bodysuit

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Abstract. Gender-based violence (GBV) is a deeply entrenched issue with widespread effects that go beyond the physical to profoundly affect victims' psychological well-being. Those subjected to GBV are at risk of developing several mental health conditions, such as post-traumatic stress disorder (PTSD), anxiety, and depression. These conditions are often intensified by physiological symptoms, including hyperhidrosis, or excessive sweating. This symptom not only highlights the ongoing fear response in victims but also contributes to their social anxiety. To effectively address these multifaceted psychological responses, it is crucial to understand the underlying mechanisms of fear, which involve specific brain circuits that affect both behavior and physical reactions. Despite the progress in neurological research, the specific dynamics of these processes, especially within the context of GBV, remain largely unexplored. This highlights the necessity for novel therapeutic methods. One innovative approach is the "Virtual Reality Therapy Model," which utilizes immersive virtual environments to provoke and control fear responses safely. Additionally, integrating a sweat-sensing bodysuit equipped with advanced physiological computing can significantly enhance our ability to monitor and analyze the physical signs of trauma. However, implementing these technologies faces several challenges, including the precise analysis of sweat biomarkers and customizing VR experiences to accurately reflect personal fear and trauma scenarios. This work-in-progress paper explores the potential of these integrated technologies for GBV therapy, examines the challenges involved, and discusses future prospects for research and treatment methodologies.

Keywords: Gender-Based Violence, Fear Conditioning, Sweat, Mental Disorders, Virtual Reality, Therapy, Simulation, Recovery, Sweat-Sensing, Physiological Computing, Participatory Research.

1 Introduction

Gender-based violence (GBV) is a global concern for all of humanity. It cuts across all cultures, regions, religions, and economic boundaries affecting every class, race, ethnicity, age, belief, nationality, and sexual identity. GBV is "an umbrella term for any harmful act that is perpetrated against a person's will and that is based in socially ascribed (i.e., gender) differences between males and females" [1]. While men may experience GBV, in general one-third of the world's female population experience more sexual violence, more severe physical violence, and more control from male partners [1]. By comparing the levels of vulnerability of females with males, it is known that women are eight times more frequently vulnerable to violence than men [1]. Several factors contribute to the conceptual framework of GBV, including domestic violence, physical assault, rape, sexual abuse, female genital mutilation, slavery, forced prostitution, and early or forced marriages [2, 3]. Over 35% of women experience some form of GBV in their lifetime. Being the most common victims of GBV, women experience high first onset of mental disturbance within 1-5 years after the exposure to violence leading to perpetual disorders symbolizing 58% of the world's population [5, 6]. Some of the known disorders include depression, post-traumatic stress disorder (PTSD), substance abuse, anxiety, attempted suicide, eating disorder and many more.

2 Emotional and Psychological Consequences Faced by and Its Effect on Gender-Based Violence Victims

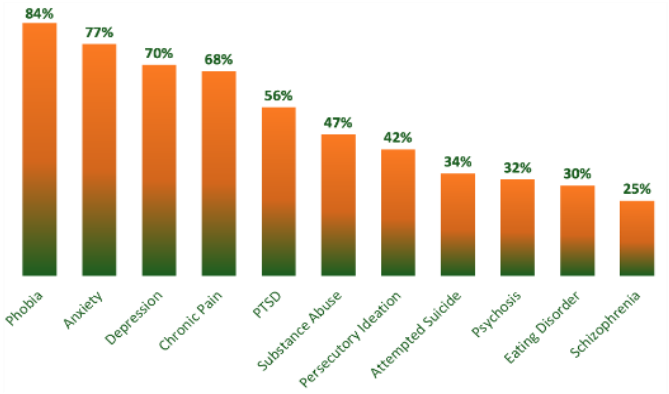

Fig. 1. Mental Disorders Associated with Gender-Based Violence [4, 5].

Figure 1 illustrates the devastating emotional and psychological impacts endured by victims of GBV. It provides a clear quantitative analysis of the long-term psychological and mental health consequences that these victims face, significantly surpassing those encountered by the general population. Substance abuse emerges as a notable coping mechanism, with a staggering 47% of GBV victims resorting to drug use on the day of the assault itself, alongside a pronounced prevalence of alcohol use disorders. This represents a desperate attempt to manage the overwhelming stress and trauma of their experiences. Anxiety is another significant concern, with the data showing that abused women are over three times more susceptible to this condition compared to their counterparts, highlighting the pervasive atmosphere of fear and uncertainty that surrounds them. Depression is diagnosed in an astonishing 35%-70% of GBV victims, reflecting the profound emotional toll and sense of hopelessness that the violence instills in them. Schizophrenia not only increases the risk of becoming a victim but also shows a 25% lifetime prevalence of rape among those diagnosed, suggesting a complex interplay between mental health issues and susceptibility to GBV. Eating disorders, affecting 30% of those with a history of sexual abuse, often manifest as a control mechanism over one's body in response to previous violations. The prevalence of traumatic events within this demographic varies between 37% and 10%, underlining the severe psychological repercussions of such experiences. The chart also points to a compelling 84% correlation between persecutory ideation and experiences of violence, predominantly rooted in anger, showcasing how deeply these traumatic experiences infiltrate victims' thoughts and perceptions. Physical pain, reported by 42% of victims, often remains a silent testament to their ordeal, with many injuries being inflicted by intimate partners. The grim reality of GBV is further underscored by the heightened risk of attempted suicide, starkly illustrating the desperate circumstances that many victims find themselves in. Additionally, the relationship between psychosis and GBV reveals a significant elevation in risk, particularly for women, suggesting a severe impact on their overall mental health stability. This comprehensive data set underscores the urgent need for targeted mental health interventions and robust support systems. It is essential to address both the immediate and long-term needs of GBV victims, ensuring they receive the holistic care necessary to heal and recover from the deep-seated impacts of such violence.

3 Manifestation of Fear and Fear Conditioning in Gender-Based Violence Victims

In the context of GBV, it is essential to understand both the origins and manifestations of fear in victims. Fundamentally, fear is a core emotional state, not just characterized by subjective feelings of terror or visible reactions like screaming or running. These responses signal fear but do not capture its full essence. Instead, fear acts as a foundational force that produces both the internal experience and external behaviors of fear in certain situations or in response to particular stimuli. This fear response is highly adaptable, triggered by specific cues that vary with the situation and individual, showcasing the intricate nature of fear beyond simple reflexive reactions. This adaptability allows fear to persist or even precede direct interaction with the triggering event, highlighting a disconnection from immediate causes.

The distinction between fear and anxiety is significant; fear is generally a transient, adaptive response to an immediate threat, triggering a fight-or-flight reaction. In contrast, anxiety represents a prolonged state, often linked with the anticipation of a threat and a focus on future safety, reflecting a broader difference between acute

emotions and enduring moods. Neuroscientific studies have identified different brain areas involved in fear and anxiety; for instance, the central nucleus of the amygdala is crucial for fear responses, whereas the bed nucleus of the stria terminalis is involved in anxiety [9]. This complexity extends to categorizing fear into anxiety, fear, and panic—each associated with varying levels of threat proximity and distinct behavioral adaptations [7]. Further research has delineated specific fear circuits within the brain that respond to different threats—pain, predators, or social threats—with each circuit activating certain regions of the amygdala and hypothalamus through diverse sensory inputs like touch, smell, and vision.

Classical fear conditioning, originally described by Pavlov (1927), is an associative learning process where an organism learns to link two stimuli [26]. For example, the sound of laughter (unconditioned stimulus) during a speech can lead to a fear response (unconditioned response). Consequently, the previously neutral act of giving a speech becomes a conditioned stimulus, eliciting a fear reaction (conditioned response). This form of conditioning is recognized as a key pathological mechanism in anxiety disorders [27, 28, 29]. Additionally, operant conditioning, which involves learning through the consequences of behavior, also plays a critical role in the development of mental disorders. For instance, a student may cease volunteering for presentations if criticized harshly, demonstrating how social interactions and reactions from others can become stimuli in operant learning processes. However, research into operant conditioning specific to mental disorders affecting GBV victims remains sparse.

Addressing these complexities, Virtual Reality (VR) provides a controlled environment that mitigates uncontrollable contextual and environmental factors, offering a unique setting for understanding and treating such disorders [30]. VR allows for the application of diverse stimuli and the direct measurement of responses through verbal ratings, fear-potentiated startle, or electrocardiographic data, facilitating experiments in fear conditioning in a realistic and standardized manner [31]. Crucially, VR also helps prevent avoidance behavior, which is significant in treating anxiety and depression, thereby enhancing the efficacy of therapeutic interventions [32]. Overall, the outcomes of conditioning experiments conducted in VR environments have been very promising [33].

4 The Role of Hyperhidrosis in Trauma and Recovery

The physiological impacts of GBV on victims often manifest profoundly, with hyperhidrosis serving as a prominent example. Characterized by excessive sweating, hyperhidrosis results from the autonomic nervous system's response to stress or fear, reflecting the deep-seated turmoil victims endure. This condition goes beyond physical discomfort, symbolizing the persistent fear that disrupts a victim's life. Notably, hyperhidrosis can exacerbate the psychological symptoms of PTSD, compounding the challenges victims face in their recovery. The visible nature of this sweating can itself trigger anxiety or panic, potentially initiating a vicious cycle of stress and anxiety [10]. Research indicates that hyperhidrosis significantly correlates with an elevated risk of anxiety, depression, and attention deficit disorder (ADD), spanning all ages and genders. Importantly, the number of body sites affected by hyperhidrosis, rather than its intensity or specific location, correlates with these mental health issues, underscoring the extensive impact of this condition [11, 13, 14]. Women, in particular, report hyperhidrosis more frequently, likely due to greater awareness of the symptoms, which further contribute to social embarrassment and psychological distress [12].

Hyperhidrosis is fundamentally linked to an overactivity of the sympathetic nervous system, affecting the eccrine sweat glands. Despite thorough investigations, the direct relationship between specific emotional states or mental disorders and sweating patterns remains unclear [12, 15, 16]. However, personality studies suggest that individuals with hyperhidrosis may exhibit distinct traits such as less purposefulness and more self-transcendence, reflecting a complex relationship between their physiological symptoms and personal identity [17, 18].

In the realm of wearable technology, analyzing sweat has become a crucial method for assessing physiological responses. Sweat analysis, using smart, sensor-embedded bodysuits, could provide invaluable real-time data on GBV victims. This technology facilitates the monitoring of biomarkers like sodium, potassium, and cortisol, offering insights into the stress and anxiety levels of victims. Such detailed monitoring could pave the way for more tailored and effective therapeutic interventions, aiding in the nuanced understanding and treatment of the psychological and physiological effects of GBV.

5 Research Gap

For those affected by GBV, refuge is often found only in shelters offering temporary housing along with essential services at no cost, and regular support from advocates helping to secure longer-term housing solutions [19]. However, these facilities typically lack long-term psychological care, psychiatric treatments, or specialized

trauma-related interventions due to the brief duration of stays. Despite extensive research into GBV, there remains a glaring lack of effective treatments for the mental health issues that arise from such violence, with minimal access to necessary trauma support [20]. In communities, while certain interventions like verbal trauma therapy and programs designed to aid recovery and provide mediation are available, they are often underutilized by victims due to societal stigmas or the prevailing prioritization of marital privacy [21]. Empirical studies, including randomized trials involving survivors of sexual assault, have tried to evaluate the efficacy of treatments for conditions such as PTSD, anxiety, and depression. However, these studies often yield inconclusive results, hampered by small sample sizes and other methodological constraints.

Over the past 25 years, VR has proven effective in treating mental health disorders like substance abuse, depression, and anxiety. The THRIVE trial pioneered automated VR therapy processes, demonstrating VR's potential in clinical settings [4, 5]. Studies have successfully used VR for cue reactivity exposure therapy to significantly reduce cravings and dependency behaviors in patients with PTSD and substance use disorders. For anxiety disorders, VR has facilitated emotional processing through mindfulness and Cognitive Behavioral Therapy (CBT), significantly reducing symptoms and improving patient satisfaction. In cases of depression, VR interventions like the SPARX project, which integrates CBT into virtual challenges, have effectively decreased depression levels and increased self-compassion among participants [4, 5].

While recent studies have explored the potential of VR to address the psychological needs of individuals with various mental disorders, there is a notable deficiency in research specifically aimed at addressing the unique challenges faced by GBV victims. This highlights a significant gap in applying advanced therapeutic tools effectively to support this vulnerable population.

6 Virtual Reality Therapy Model Using Participatory Research and Human-Centered Design [5]

GBV has demonstrably worsened health outcomes, particularly for women, since the 1970s [5]. Studies suggest women often experience more severe physical and emotional trauma than men [5]. Traditionally, interventions have focused on treatment for perpetrators. This section proposes a new perspective, prioritizing female victims of GBV. In order to shift perspectives and focus on female victims of GBV, this section provides a framework of a "Virtual Reality Therapy Model" (VRT Model) designed to mitigate emotional, psychological, and physiological trauma and promote empowerment. Moreover, this model integrates a human-centered design approach that emphasizes the well-being of women who have endured such trauma [5]. The advantage of a human-centered design approach is that it treats participants as the core element of analysis, enabling researchers to segment the population into smaller, experience-based groups [7]. This method contrasts with variable-centered studies, which may yield inconsistent results due to the varied experiences of participants, thus enhancing the generalizability of research outcomes [22].

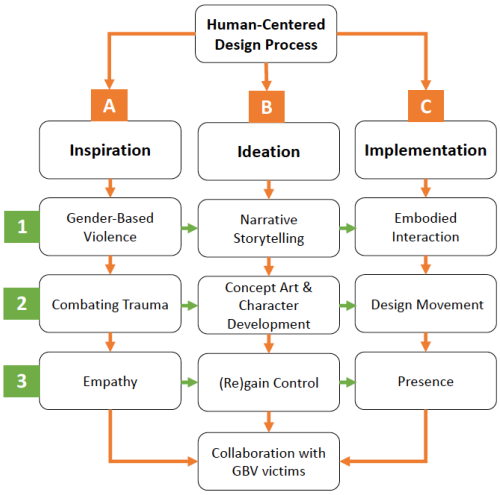

Fig. 2. Virtual Reality Therapy Model Based on Human-Centered Design Process for Gender-Based Violence Victims [4, 5].

The VRT Model aims to utilize a human-centered design approach to develop VR therapy simulations specifically tailored to the victims' needs, ensuring an iterative method that considers each participants' involvement at every

stage, resulting in a personalized and practical healing solution [23]. The design process will prioritize each victim's experience while adhering to the therapeutic principles of Carl Rogers' Person-Centered Therapy (PCT) [23]. PCT emphasizes on empathy, unconditional positive regard, and congruence, which aligns perfectly with the human-centered design approach. The development process will involve initial planning sessions, workshops, and individual consultations. These sessions will address key questions through outlining the treatment plan, creating workflows, developing prototype scenarios for feedback, building 3D virtual environments, designing and animating virtual characters, implementing software workflows, and conducting user testing throughout every stage. As depicted in Figure 2, the human-centered design process will follow three key stages: *Inspiration* will involve gathering information and understanding each victim's needs and experiences; in the *Ideation* stage, creative solutions will be brainstormed based on the gathered information; and the *Implementation* stage will focus on building and testing prototypes based on the chosen ideas.

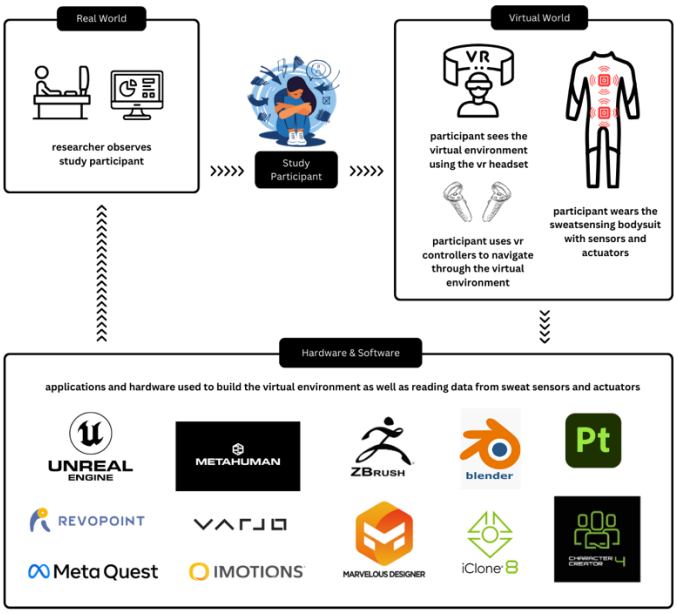

Fig. 3. Proposed Deployment of the Virtual Reality Therapy Model [4].

The VRT Model will leverage participatory research throughout its development, ensuring victim voices are central to the design process [8]. The initial stage will immerse participants in a controlled environment that will evoke fear related to their lived experiences. This engagement will be crucial for both researchers and participants. It will allow victims to confront their trauma in a safe space, while researchers will gain empathetic insights to inform the design of therapeutic VR simulations. The ideation phase will build upon these shared experiences. Through storytelling workshops and concept development sessions, victims will actively participate in shaping the VR narrative, ensuring it reflects their experiences. The implementation stage will prioritize their feedback through iterative testing. The VR solution will constantly be refined based on participant input to guarantee its effectiveness in aiding recovery. Empathy will remain paramount throughout the process, guiding interactions between participants and researchers. This survivor-centered approach will synthesize insights from the engagement of victims to inform the design of VR interventions. Storytelling will play a crucial role in empowering the participants. By sharing their journeys, they will gain a deeper understanding of their experiences and will begin to express their emotional struggles. This narrative aspect will directly feed into the development of the VR content. The content design will specifically focus on embodying the victim's perspective and fostering a sense of control through gamification and reward systems. Implementing this model will necessitate an agile management approach [25]. This will involve iterative testing and continuous incorporation of participant feedback to ensure that the VR simulations positively affect participants' lives. Embodied interaction, movement design, and a strong sense of presence will be central to creating immersive VR experiences that support healing and empower victims on their journeys.

Figure 3 illustrates the proposed deployment of the VRT Model in which the research team will monitor a study participant who will be immersed in a virtual environment. The participant will use VR controllers to navigate this space while wearing a personalized sweat-sensing bodysuit equipped with sensors and actuators designed to detect physiological responses to sweat. This data, along with other metrics such as body temperature,

will be transmitted in real-time through the iMotions platform. The research team will then analyze these responses in real-time to better understand the participant's reactions and adjust the therapy accordingly.

7 Sweat-Sensing Bodysuit

In understanding and aiding the recovery of GBV victims, the sweat-sensing bodysuit will represent a significant breakthrough. This soft, embroidered electrochemical garment will integrate the innovative Janus textile to monitor the victim's physiological signals. The design will utilize transparent conducting wefts, luminescent warps, and conductive threads, achieving a remarkable balance between comprehensive biomarker monitoring and superior comfort. The core of the bodysuit will lie in its electroluminescent component, featuring Ambient Cathode Electroluminescent (ACEL) fibers powered by silver nanowire (AgNW) electrodes. This core will serve a dual function: acting as a network of highly sensitive sweat sensors and simultaneously translating physiological data into a real-time visual display using LED technology [24]. These sensors will track a range of biomarkers, including glucose, lactate, and various ions, with impressive accuracy. The key advantage of this bodysuit will lie in its ability to make the invisible visible. It will transform the abstract measurements of physiological health into clear patterns that can be observed and interpreted in real-time. This feature will go beyond aesthetics; it will create a bridge between the physical and the conceptual, offering both victims and researchers immediate feedback and a deeper understanding of the body's responses to trauma.

8 Challenges

The proposed treatment using sweat analysis and VR fear simulations for GBV victims might face significant challenges related to sweat variability. Individual differences in sweat production, influenced by factors like exercise intensity and conditions like anhidrosis or hyperhidrosis, might complicate data collection. Additionally, linking sweat biomarkers to vital signs might become problematic due to fluctuating biomarker concentrations, particularly in dehydrated states, and limitations in current sweat-sensing technologies. On-skin wearable sweat sensors offer a potential solution by collecting and analyzing sweat directly, reducing evaporation and rapid biomarker degradation. However, they also introduce issues such as skin irritation and potential cross-contamination. Near-skin sensors, which continuously channel sweat to electrodes, can help mitigate these problems but might not fully resolve the difficulty in correlating sweat data with the emotional and psychological responses of GBV victims during VR simulations. Effectively addressing these complexities will require innovative, collaborative approaches to ensure that the data collected is accurate, reliable, and truly representative of the victims' physiological and emotional states during treatment.

9 Conclusion

This proposed project is in its early stages, yet it holds substantial promise for transforming into groundbreaking research. By refining biosensing technology and addressing current challenges, this initiative aims to significantly enhance our understanding of both the physiological and psychological states of GBV victims. This could lead to more effective and empathetic treatments. Integrating physiological computing with emotional well-being, this project has the potential to set a new standard for future trauma-informed therapeutic interventions.

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