Harassment in Medical Education: A Psychophysiological Perspective through the Analysis of Electrodermal Activity

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ABSTRACT

Harassment detrimentally impacts the well-being and education of medical learners and can consequently affect patient care quality. However, effective interventions to prevent and address harassment are lacking. Simulation-based training is a novel and promising educational approach to this problem that allows learners to actively practice combatting harassment within a controlled, yet emotionally stimulating and safe environment. This quasi-experimental crossover design study explored the psychophysiological and behavioural responses of 33 medical trainees observing simulated harassment as part of a curricular training program. We drew on the 4D Bystander Intervention Framework to classify behavioural responses. Electrodermal activity (EDA) and subsequent bystander intervention behaviours were assessed, accounting for individual differences. Learners were randomly assigned into one of two groups: one received video training before participating in simulations (video-first group), and the other experienced the reverse sequence (simulation-first group). Results of a mixed effects multilevel model indicated that harassment significantly elevated emotional arousal levels in both groups relative to their baseline. Using logistic regressions with cluster robust standard errors EDA did not emerge as a significant predictor of the likelihood or choice of intervention in either group, suggesting that EDA reflects immediate emotional psychophysiological reactions but is not an antecedent of specific behavioural choices. The video-first group exhibited statistically significantly higher arousal levels during harassment events than after and showed a higher likelihood of intervening than the simulation-first group. The findings have implications for understanding psychophysiological and behavioural responses within learning environments within and beyond the medical field.

RÉSUMÉ

Le harcèlement nuit gravement au bien-être et à la formation des apprenants en médecine et peut par conséquent affecter la qualité des soins aux patients. Cependant, les interventions efficaces pour prévenir et traiter le harcèlement sont insuffisantes. La formation par simulation est une approche éducative nouvelle et prometteuse pour résoudre ce problème, permettant aux apprenants de s'exercer activement à lutter contre le harcèlement dans un environnement contrôlé, mais émotionnellement stimulant et sécurisé. Cette étude quasi-expérimentale en crossover a exploré les réponses psychophysiologiques et comportementales de 33 stagiaires en médecine observant un harcèlement simulé dans le cadre d'un programme de formation curriculaire. Nous nous sommes appuyés sur le cadre d'intervention des témoins en 4D pour classifier les réponses comportementales. L'activité électrodermale (AED) et les comportements d'intervention des témoins ont été évalués, en tenant compte des différences individuelles. Les apprenants ont été assignés aléatoirement à l'un des deux groupes : l'un a reçu une formation vidéo avant de participer aux simulations (groupe vidéo en premier), et l'autre a suivi la séquence inverse (groupe simulation en premier). Les résultats d'un modèle multiniveau à effets mixtes ont indiqué que le harcèlement élevait significativement les niveaux d'activation émotionnelle dans les deux groupes par rapport à leur niveau de base. En utilisant des régressions logistiques avec des erreurs standards robustes au niveau des clusters, l'AED n'a pas émergé comme un prédicteur significatif de la probabilité ou du choix d'intervention dans l'un ou l'autre groupe, suggérant que l'AED reflète des réactions psychophysiologiques émotionnelles immédiates mais n'est pas un antécédent des choix comportementaux spécifiques. Le groupe vidéo en premier a montré des niveaux d'activation significativement plus élevés pendant les événements de harcèlement qu'après et a montré une probabilité d'intervention plus élevée que le groupe simulation en premier. Les résultats ont des

implications pour la compréhension des réponses psychophysiologiques et comportementales dans les environnements d'apprentissage dans le domaine médical et au-delà.

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AUTHOR CONTRIBUTIONS

Professor Jason M. Harley (*J.M.H.*) supervised this entire thesis and was involved throughout the entire process. Keerat Grewal (*K.G.*), Tiina Törmänen (*T.T.*), Byunghoon "Tony" Ahn (*B.T.A.*), Myriam Johnson (*M.J.*), and Dr Ning-Zi Sun (*NZ.S.*) also provided wonderful contributions as outlined below.

Chapter 1 to Chapter 5 were written by N.M. and J.M.H. provided feedback for each section. Chapter 4 is the manuscript, accepted for presentation at the 18th International Conference on Motivation (ICM 2024; Bern, Switzerland). This manuscript is intended for submission to the journal, Computers in Human Behavior.

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Formal Analysis: N.M. carried out all phases of the physiological and video data analyses, with direction and feedback from J.M.H., K.G. and N.M. conducted the statistical analysis with direction and feedback from J.M.H. In addition, M.J. took part in the interrater agreement to evaluate the possibility of bias in coding the bystander intervention methods.

Investigation: B.T.A. and J.M.H. conducted the recruitment of the participants with support from NZ.S. B.T.A., N.M. and M.J. conducted data collection sessions with aid from K.G.

Resources: B.T.A and J.M.H. designed and developed the educational videos and simulation scenario used during data collection sessions. NZ.S. provided feedback.

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ABBREVIATIONS

CVT	Control-Value Theory
EDA	Electrodermal Activity
ANS	Autonomic Nervous System
PNS	Parasympathetic Nervous Systems
SNS	Sympathetic Nervous System
SCL	Skin Conductance Level
SCR	Skin Conductance Response
RQ	Research Question
SR	Senior Resident
MS	Medical Student
CDA	Continuous Decomposition Analysis
TTP	Trough-to-Peak

CHAPTER 1: INTRODUCTION

Medical education is an inherently rigorous, long and demanding journey, characterized by its high stakes, intense pressure, and the significant responsibilities placed upon trainees (Ebrahimi & Kargar, 2018; Razzaque et al., 2023). This unique educational pathway is designed not only to impart a vast body of knowledge but also to cultivate the necessary skills and resilience required for medical practice. However, the very nature of this training, while essential for preparing competent professionals, can exert considerable stress and pressure on medical trainees (Arnsten & Shanafelt, 2021; Satterfield & Becerra, 2010). The pressure may further stem from the progressively increasing workload and the emotional and physical tolls of patient care (e.g., violence, mortality rates) (Atherley et al., 2019; Satterfield & Becerra, 2010).

The learning environment itself is often fast-paced and competitively intense (Huang et al., 2021; Rodriguez Santana, 2021), where trainees are expected to quickly assimilate complex information, make critical decisions, and perform intricate procedures. Further, the consequences of errors can be dire, not just for the trainees' careers but for patients' well-being. Trainees, due to their inherent lack of experience and skill for independent practice, may frequently face clinical scenarios beyond their current capacity to manage independently. This inherent gap in expertise underscores the critical need for supervision and a well-defined hierarchical framework within medical training, aimed at safeguarding patient safety and ensuring the highest standards of care (Vanstone & Grierson, 2022).

The Hierarchical Structure of Medical Education

Hierarchy in medical education reflects the structured nature of clinical practice, establishing a system where individuals hold different levels of authority and responsibility (Vanstone & Grierson, 2022). This classification is pivotal for several reasons: it provides a clear chain of command, allows for an effective and progressive transfer of knowledge and skills from experienced professionals to more novice learners, and upholds standards of patient care (Vanstone & Grierson, 2022).

Such a structure exists primarily to create an organized environment where the layered complexity of medical training and practice can be managed effectively (Vanstone & Grierson, 2022). It ensures that tasks are assigned according to the level of medical expertise, providing trainees with a structured pathway for progressive responsibility and learning. At its best, the hierarchy fosters a supportive learning environment where experience and knowledge are passed down through clear mentorship channels, and those at the top of the hierarchy lead by example (Salehi et al., 2020). At its worst, the pressures and challenges of a high-stress environment, as well as influences from diverse cultural and societal backgrounds (Raihan et al., 2020), can pave the way for instances of harassment (Bahji & Altomare, 2020). The power dynamics embedded in hierarchies may foster and sustain power imbalances that contribute to a culture of harassment (Hsiao et al., 2021; Salehi et al., 2020; Vanstone & Grierson, 2022) where trainees may feel powerless to speak out against harassment or unprofessional behaviour for fear of retaliation or jeopardizing their careers (Singh & Singh, 2018). The differential in power can be so pronounced that behaviours which constitute harassment may be dismissed or rationalized as part of the process, fostering an environment where such conduct becomes normalized (Bahji & Altomare, 2020). Trainees may come to accept harassment as a routine, or even expected, aspect of the medical training environment, a harmful concession that can perpetuate a cycle of abuse in future generations (Bahji & Altomare, 2020; Fnais et al., 2014).

The acceptance and normalization of harassment has undermined the integrity of medical education (Lall et al., 2021) and can have lasting detrimental effects on individuals and the culture of medical institutions (A. F. Cook et al., 2014; Singh & Singh, 2018). Therefore, while the hierarchical structure in medical education serves a critical function in training competent medical professionals, it is imperative that the medical education system acknowledges and actively works against the normalization of harassment, safeguarding the learning environment's integrity and the welfare of its community.

Understanding Harassment

A range of harassment definitions are available, encompassing behaviours such as mistreatment, intimidation, discrimination or bullying. Definitions typically focus on the victim's perceptions, but differ in terms of duration, frequency, intent to harm and behaviours included (Carter et al., 2013). The Resident Doctors of Canada described harassment as encompassing any behaviour, educational process, or tradition that induces fear in learners or detrimentally affects the learning environment (*Intimidation & Harassment Prevention | Resident Doctors of Canada*, n.d.). Echoing this perspective, the Royal College of Physicians and Surgeons of Canada characterizes harassment as any unwanted physical or verbal behaviour that offends or humiliates the individual (*Creating a Positive Work Environment*, n.d.). Beyond physical or verbal acts, harassment can manifest as unwanted sexual advances, psychological degradation, or discriminatory treatment based on personal characteristics (Fnais et al., 2014).

The prevalence of harassment in medical education is alarmingly high among medical trainees across various specialties, with reports indicating that up to 75% of learners have encountered at least one form of harassment during their medical education (*2018 National Resident Survey | Resident Doctors of Canada*, n.d., p. 33,34; Fnais et al., 2014; Li et al., 2010). Given the pervasive nature of harassment, it therefore becomes crucial to delve into the consequences it holds for individuals, the learning environment, and the broader medical community, shedding light on the far-reaching effects of this issue.

Consequences of Harassment

In 1982, Silver (Silver, 1982) highlighted the concerning shift in medical students' attitudes by comparing their outlook before and after joining medical school. He noted a troubling transition where students, initially alert and enthusiastic, became frightened, depressed, and overwhelmed with frustration during their medical training; reminiscent of “battered child syndrome” in foster children (Silver, 1982). Being one of the first studies to shed light on the issue of harassment in medical education, Silver suggested that the issue of abuse in medical training, albeit widespread and pervasive, was perhaps an integral part of becoming a physician (Silver, 1982). Since then, several studies have addressed this issue and found that harassment, in fact, has detrimental effects that can manifest both at the individual and organizational levels, significantly impacting trainees' well-being and the overall efficacy of medical training programs (Fnais et al., 2014).

Individual Level

Harassment within medical education significantly influences trainees, with its effects categorized across three dimensions: emotional well-being, physical health, and the professional development of the trainees (Fnais et al., 2014; Haviland et al., 2011).

Emotionally, trainees face heightened feelings of distress, anxiety, and depression, often exacerbated by the dread of recurrent mistreatment. This emotional burden can further lead to diminished self-esteem and self-confidence (Frank et al., 2006; Lall et al., 2021). Trainees may begin to question their capabilities and worth, leading to an increased vulnerability to self-doubt (Jenkins et al., 2018) and a reduced trust in their professional competencies (Bahji & Altomare, 2020). Additionally, the strain of harassment can permeate personal lives, affecting trainees' relationships as they may exhibit increased irritability, mood swings, and social withdrawal (Colenbrander et al., 2020). Professionally, harassment can derail trainees' development, with some considering leaving their medical programs or shifting away from medicine altogether (Bates et al., 2018). The stress associated with harassment can disrupt cognitive functions, impeding the acquisition and retention of crucial skills and knowledge necessary for their academic and clinical performance (Dias & Scalabrini-Neto, 2017; Katz et al., 2019). Stress and anxiety can further contribute to cardiovascular risks and a weakened immune system (Carter et al., 2013; Ebrahimi & Kargar, 2018). In some cases, trainees might resort to alcohol or substance misuse as a coping mechanism, adding another layer of health concern (Bahji & Altomare, 2020).

Trainees experiencing, and also witnessing (Katz et al., 2019), such outcomes due to harassment could have a decline in the effectiveness of their training, exhibit an increased likelihood of making critical medical mistakes (Dias & Scalabrini-Neto, 2017), and show a diminished capacity to provide an optimal level of patient care, all of which can significantly compromise patient safety (Bahji & Altomare, 2020; Chew et al., 2023; D. J. Cook et al., 1996; Fnais et al., 2014; Katz et al., 2019; Li et al., 2010; Riskin et al., 2015).

Organizational Level

A learning environment marred by harassment jeopardizes the well-being and safety of trainees and therefore degrades the overall quality of the clinical learning space (Bahji & Altomare, 2020). Such environments not only undermine the reputation of medical training institutions but also deter potential talent from entering the profession, further straining the healthcare workforce. Organizations may face financial implications (Carter et al., 2013; Mistry & Latoo, 2009) due to harassment, including costs associated with absenteeism, turnover rates, potential lawsuits, and reduced productivity (Carter et al., 2013). Acknowledging and mitigating the multifaceted impacts of harassment in medical education is crucial not only for the well-being of current trainees but also to halt the perpetuation of such behaviours into future generations of medical professionals. Effective strategies can gradually break the cycle of harassment, creating a healthier and more supportive medical community.

It is important to note that harassment is a pervasive issue that extends beyond the confines of any single sector, affecting environments as diverse as workplaces, higher academic institutions, and early educational settings. In professional contexts, bullying and harassment undermines innovation and employee well-being, leading to a toxic atmosphere that impacts productivity and morale (Mistry & Latoo, 2009; Raihan et al., 2020). In higher education and academia, it threatens the educational journey of both students and faculty, leading to reduced engagement and potentially damaging the institution's reputation (Henning et al., 2017). Even in early education, bullying disrupts the developmental path of young learners, shaping their future interactions with educational systems and affecting their sense of security and belonging (Saracho, 2017).

Young victims often face challenges such as low self-esteem, depression, and anxiety, which can hinder their social adjustment during critical early school years (Arseneault et al., 2006; Rigby, 2003). These individual struggles can contribute to a broader deterioration of the school climate, as distressed students are less engaged and more likely to struggle academically and socially (Rigby, 2003). Meanwhile, bullies risk escalating their antisocial behaviours, which may not only continue into adulthood but also foster a culture of fear and intimidation within the school (Sourander et al., 2009).

The exploration of harassment across various sectors provides crucial context for understanding its specific manifestations in medical education. This comparison is vital as it highlights that despite differences in environments, the fundamental challenges and detrimental effects of harassment are consistent across sectors. Therefore, it is imperative to identify and implement anti-harassment interventions and trainings that are truly and objectively effective. Discovering strategies that effectively reduce harassment can have implications beyond medical education, offering potential templates that could be adapted and applied across various professional and educational settings to foster safer, more respectful environments.

Anti-Harassment Efforts

Consequently, efforts to combat harassment (i.e., anti-harassment efforts) within medical education and healthcare settings have seen a range of initiatives aimed at creating safer and more supportive environments (Mazer et al., 2018). However, the effectiveness of these measures often encounters various hurdles, necessitating a closer examination and expansion of current practices (Bloom et al., 2023; Mazer et al., 2018).

Progress and Challenges: An Overview

Medical institutions typically establish comprehensive anti-harassment policies and training programs that articulate definitions of harassment, map procedures addressing incidents, and prescribe potential consequences for violations. These policies are foundational in setting institutional standards for conduct and providing a structured approach to addressing harassment.

A significant component of these efforts is the reporting mechanisms, which are vital for addressing harassment incidents (Cipriano et al., 2023). However, their success can be compromised by concerns about confidentiality, fear of retaliation, or doubts regarding the transparency and efficacy of the follow-up process (Chung et al., 2018; Vargas et al., 2022). Additionally, support services like counseling and peer groups play a crucial role in assisting those affected by harassment, though their effectiveness largely depends on the community's trust and awareness of these resources (Chung et al., 2018; Vargas et al., 2022). Moreover, the ways in which harassment is expressed can differ vastly among individuals, influenced by their unique demographics, beliefs and personal experiences (Kumar et al., 2021). This diversity can make harassment subtle and challenging to recognize, complicating the consistent application of anti-harassment policies. Effective training programs in medical institutions therefore serve not only to educate staff on recognizing the varied forms of harassment but also on how to address them appropriately (Chew et al., 2023). These programs (e.g., workshops, seminars or lectures) are designed to raise awareness, shape behaviours, and foster a culture of respect and professionalism (Mazer et al., 2018).

Additionally, their effectiveness can vary and has been shown to be minimal (Mazer et al., 2018). The content has been shown to lack depth, be disengaging, and fail to resonate with participants (Chew et al., 2023; Thivierge-Southidara et al., 2020); therefore creating a need for content that is relevant to the specific environment of the institution and includes practical examples. To this end, interactive, scenario-based training offers an alternate enhanced learning experience, contrasting with less effective passive sessions where participants may attend but not actively absorb or apply the information (Medeiros & Griffith, 2019). For more effective programs, detailed information on harassment and practical tools like bystander intervention strategies (Chew et al., 2023; Haynes-Baratz et al., 2021) should be integrated and their retention by participants should be evaluated in real-time, underlining the importance of active learning and engagement for meaningful behavioural change (*Evaluating the Effectiveness of Interventions to Prevent and Address Sexual Harassment: Proceedings of a Workshop - PubMed*, n.d.; Krathwohl, 2002a).

Active Bystander Training

Active bystander training has emerged as a significant measure in the landscape of anti-harassment initiatives within various fields including medical education (Chew et al., 2023; Coker et al., 2015). This approach empowers individuals to intervene in situations where harassment is witnessed, fostering a community-wide responsibility to challenge inappropriate behaviours and support victims (McMahon & Banyard, 2012). This educational program designed to equip individuals with the knowledge and skills necessary to recognize and safely intervene in situations where harassment or other forms of inappropriate behaviour occur. Unlike traditional training programs that primarily focus on the victims or perpetrators of harassment, active bystander training emphasizes the role of witnesses in preventing and addressing these incidents (Coker et al., 2015).

This form of training is predicated on the idea that providing witnesses with tools to address and prevent harassment, can create an environment where harassment is less likely to be tolerated or go unchallenged (Chew et al., 2023; Haynes-Baratz et al., 2021). By educating all members of an institution on how to respond effectively to observed incidents of harassment, the program aims to reduce the incidence and mitigate the effects of such behaviour. The effectiveness of active bystander training lies in its ability to spread responsibility across the community, encouraging a collective action against harassment and fostering a culture of support and accountability (Famouri et al., 2023). Active bystander training provides the bystander with strategies known as the 4D's to address harassment (*The 5Ds of Bystander Intervention. Right to Be.*, n.d.): direct, distract, delegate, and delay. Taking a *direct* approach involves confronting the behaviour or offering support to the victim in the presence of the harasser. The *distract* method is more indirect, aiming to defuse the situation without direct confrontation, such as creating a diversion that allows the victim to distance themselves from the harasser. *Delegation* is about seeking assistance from others, often those with more power or authority, to address the harassment. Lastly, *delay* focuses on providing support to the victim after the incident, ensuring they feel heard and supported even if immediate intervention was not possible.

Incorporating active bystander training into medical education not only addresses harassment but also aligns with the broader goal of nurturing empathetic, responsive, and ethical medical professionals. By understanding and practicing these intervention strategies, medical trainees and staff can contribute to a more respectful and supportive educational and clinical environment (Coker et al., 2015). That being said, such practices are not yet commonly incorporated into anti-harassment initiatives within medical institutions (Mazer et al., 2018).

In this study, we explore the integration of active bystander training into simulation-based education, aiming to provide a more dynamic and immersive learning experience (Alessi, 2000), allowing trainees to apply the knowledge they have learned (Al-Elq, 2010) and enhance their understanding of anti-harassment trainings.

Simulation-Based Education

Simulation-based education is esteemed for its capacity to accurately emulate complex scenarios that professionals in various fields may encounter in their daily practice (Al-Elq, 2010; Lee, 2005; Yao & Huang, 2021). This approach offers a safe environment where learners can engage, act, and importantly, learn from errors without real-world repercussions—making it particularly advantageous for medical training (Palter & Grantcharov, 2010).

The foundational principles of simulation-based training are embedded in educational theories that prioritize repetitive and deliberate practice as a pathway to proficiency (Duvivier et al., 2011). The concept, often encapsulated by the 10,000-hour rule, suggests mastery is attainable through extensive practice (Ericsson et al., 1993). However, given the constraints of contemporary medical training schedules designed to balance educational rigor with well-being (Gelfand et al., 2004; Moonesinghe et al., 2011), attaining such extensive hands-on experience is challenging. Simulation-based training therefore offers a concentrated form of experiential learning, enabling learners to engage in high-quality practice within a condensed timeframe (Palter & Grantcharov, 2010).

Additionally, simulation-based training offers a unique avenue, where learners immerse themselves and actively participate in context and competency specific scenarios, compelling them to make critical decisions based on the given situation and develop object-related skills (Brydges et al., 2015). This immersion helps consolidate theoretical knowledge with practical application, enhancing learning effectiveness (Kaufman & Professor, 2010), and ultimately improving patient care (D. A. Cook et al., 2013).

In the context of anti-harassment training, simulation-based approaches incorporating active bystander training offer an innovative way to equip medical professionals with the necessary skills to recognize, intervene, and respond to harassment scenarios effectively. By providing a realistic, immersive experience coupled with the opportunity for repeated practice and feedback, simulation-based training holds great promise for fostering a proactive and supportive culture in medical settings, ultimately contributing to the reduction of harassment in the workplace.

Previous Studies Using Simulation-Based Active Bystander Training

Previous research highlights the efficacy of simulation-based active bystander training in medical education, equipping participants with the skills to identify and address harmful scenarios, while allowing them to practice applying this knowledge. Chew and colleagues (Chew et al., 2023) focused on developing a simulation-based active bystander training session for medical students to empower them to address disrespectful behaviour. The training included pre-recorded video vignettes, card games, and immersive simulation, followed by advocacy and inquiry debriefs.

Through questionnaires the study found significant improvements in students' self-rated knowledge and preparedness to act as active bystanders in the workplace, emphasizing the efficacy of simulation in enhancing students' responsiveness to harassment. Famouri and colleagues (Famouri et al., 2023) also focused on active bystander training using standardized patient methodology and a brief presentation on microaggression examples and how to address them to teach residents how to navigate difficult encounters, specifically targeting instances of harassment. The participants were residents from various specialties who engaged in simulation scenarios, followed by debriefing sessions. The results demonstrated improvements in residents' confidence and competence in addressing harassment, highlighting the potential of simulation-based training to equip medical professionals with the necessary skills for intervention in real-world situations. Similarly, another study (Calardo et al., 2022) introduced the Realizing Inclusion and Systemic Equity in Medicine: Upstanding in the Medical Workplace (RISE UP)—an antibias anti-racism communication curriculum. It comprised three hybrid workshops involving pediatric residents, introducing tools for addressing bias, video simulations, and guided role-play. The curriculum aimed to enhance residents' responses to discrimination, emphasizing the practical application of learned strategies in real scenarios. The results showed an increase in participants' preparedness to address racism and discrimination, a notion aligned with the findings of a study by Tyson and others (Tyson et al., 2024) where bystander intervention training integrated in role playing and simulations was found to significantly increase medical students and healthcare professionals' sense of responsibility to intervene in discriminatory situations. Participants engaged in simulated discrimination scenarios via role-play to practice real-time interventions in a controlled, virtual setting, and were offered a handbook and educational videos including information about harassment and bystander intervention strategies and education. Results showed that the role-playing component was particularly effective, with participants reporting increased confidence and ability to intervene in discriminatory situations via evaluation surveys. Further, a study by Thivierge-Southidara and others (Thivierge-Southidara et al., 2020) aimed to evaluate the effectiveness of simulation as an adjunct to traditional teaching methods such as videos for medical students in recognizing and reporting intimidation. Participants included medical students who underwent simulation sessions designed to improve their ability to identify and respond to intimidating behaviour. The study's findings suggested that while simulation-based training increased awareness, it did not significantly impact the students' likelihood to report harassment, indicating the need for further research to optimize, or evaluate, training methods.

These studies, predominantly relying on self-reported questionnaires, assessed the *perceived* effectiveness of anti-harassment training in medical settings. While valuable, the self-reported data can be influenced by respondents' biases, potential inaccuracies, or intentional deception, limiting their reliability as objective measures (Zarjam et al., 2013). Furthermore, while all five studies demonstrate the potential for simulation-based education to enhance recognition and intervention skills regarding harassment, the long-term effectiveness and real-world application of these skills remain uncertain and prone to the participants' subjectiveness, indicating a need for more comprehensive evaluation methods that measure actual behaviour in harassment scenarios.

I note that this thesis is derived from a larger study where related but distinct analyses were carried out. Specifically, Johnson and colleagues (Johnson et al., 2024) employed inductive thematic analysis (i.e., non-reliant on the 4D strategy framework) to provide a rich qualitative description of behavioural responses medical residents had in regards to the harassment situation. In addition, Ahn and colleagues (Ahn et al., 2024a) utilized a simulation performance checklist to assign *numerical values* to trainee's use of the 4D strategies across the whole simulation. In other words, they received a “check” for engaging in a strategy once. Their score, out of five, was calculated based on their use of the four strategies. Ahn and colleagues (Ahn et al., 2024b) examined whether participants with specific emotional profiles utilized specific 4D strategies based on their hierarchical cluster analysis, but their identification of the strategies were based on their simulation performance checklist mentioned above. Hence their analysis did not comprehensively take every harassment event into account. My research via behavioural coding went beyond the performance checklist in regards to identifying and using all potential harassment events in analyses. If the resident responded to the harassment, their response was coded based on the 4D strategy framework. This approach, combined with an analysis of participants' electrodermal activity (see Chapter 2) allowed for a thorough understanding of harassment and bystander intervention methods within the simulation through the perspective of one’s psychophysiological responses.

Next, we delve into the theoretical framework we draw upon for this thesis.

Theoretical Framework

Simulations in medical education, by nature, can evoke a spectrum of emotions, including anger, relief and stress (Brasil et al., 2021), which is instrumental in how learners process information and respond to the training. Learning is not only a cognitive process, but emotional experiences play a crucial role in shaping a learner's engagement, motivation, and performance outcomes as well (Bajunaid et al., 2016; Pekrun et al., 2017). The emotional reactions elicited within these simulated environments can therefore stimulate learners to concentrate their attention and cognitive resources on the tasks at hand, thereby optimizing their approach to achieving the set objectives (i.e., anti-harassment) and ensuring the effective acquisition of the intended skills (Harley et al., 2019).

Emotions, as multifaceted phenomena, emerge in response to specific stimuli and are shaped by an individual's appraisal of these stimuli (Pekrun et al., 2017; Stark et al., 2018). Central to understanding emotions within academic settings is Pekrun's Control-Value Theory (CVT) of achievement emotions (Pekrun, 2006). This theory characterizes emotions through two primary dimensions: valence, which spans from positive to negative, and activation, from deactivating to activating states (Pekrun, 2006). Pekrun's CVT underscores the significant influence of achievement emotions—emotions that are intrinsically linked to achievement activities or outcomes—on a learner's engagement, decision-making, and performance. By categorizing emotions based on their valence and level of arousal, CVT provides an understanding of how various emotional states can affect achievement (Harley et al., 2019; Jarrell et al., 2017). Positive activating emotions, such as hope and enjoyment, typically enhance achievement, whereas negative deactivating emotions, like boredom and hopelessness, tend to hinder it. Moreover, the theory acknowledges that emotions with mixed characteristics, such as positive deactivating emotions (relaxation, relief) and negative activating emotions (anger, anxiety), can have nuanced effects on learning, depending on their intensity and the learning context.

In this study, our focus narrows to one particular dimension of emotions: arousal. Learning is not a passive receipt of information but an active, multifaceted process that engages cognitive, affective, and physiological dimensions of the learner. This engagement leaves a "physiological footprint," particularly in the form of arousal (Hebb, 1955), which is essentially the degree of physiological activation in response to stimuli within the environment. Arousal, therefore, is a critical component of the learning process, influencing the learner's cognitive engagement (Barnes et al., 2016; Cain & Lee, 2016), attention (Fox et al., 2001), memory (Marchewka et al., 2016), and decision-making processes (Dawson et al., 2007; Juvina et al., 2018). In the context of medical education, where the acquisition of complex skills under high-stress conditions is common, understanding the optimal levels and variations in arousal in response to stimuli becomes crucial. Arousal levels that are too low can lead to disengagement and ineffective learning, while excessively high arousal, potentially exacerbated by negative experiences such as harassment, may lead to cognitive overload and increased medical errors (Dias & Scalabrini-Neto, 2017; Duffy et al., 2015; Norman et al., 2017; Sanbonmatsu & Kardes, 1988). The Yerkes-Dodson law (Hanoch & Vitouch, 2004; Yerkes & Dodson, 1908), illustrating an inverted U-shaped relationship between arousal and performance, suggests that both too little and too much arousal can impair performance.

It therefore becomes imperative to examine the complex effects of harassment on arousal and behavioural outcomes in medical training. We aim to move beyond reliance on self-reported data and subjective perceptions (Zarjam et al., 2013) to capture anti-harassment intervention effectiveness by capturing the physiological underpinnings of arousal and its impact on behavioural outcomes in simulation-based active bystander training environments.

The following chapter will focus on Electrodermal Activity (EDA) as a direct measure of arousal. We will explore how EDA provides a window into the body's physiological reactions to specific stimuli.

CHAPTER 2: THE LANGUAGE OF SKIN: ELECTRODERMAL ACTIVITY

As we transition into a focused exploration of EDA, it becomes pivotal to first understand the broader context of psychophysiological signals and their significance in educational research. Psychophysiological signals offer a window into the intricate interplay between one's physiological states and psychological processes, providing objective and quantifiable data that shed light on the individual's internal experiences. Psychophysiological measures, such as EDA (Edelberg, 1977), heart rate (Kreibig, 2010), electroencephalography (Hanoch & Vitouch, 2004), and pupillometry (Marchewka et al., 2016), all serve as tangible manifestations of the body's response to cognitive and emotional stimuli (Cacioppo et al., 2000). These real-time signals allow researchers to transcend the limitations of self-reported data, offering a more nuanced and immediate picture of how learners react and adapt to various educational environments and challenges (Cacioppo et al., 2000; Caruelle et al., 2019; Galy et al., 2012). This objectivity is particularly valuable in contexts like medical education, where understanding the physiological underpinnings of learning and the corresponding responses can lead to more effective training methods and strategies.

Skin conductance or EDA stands out amongst psychophysiological measures as a highly reliable method for assessing arousal and psychophysiological sates (Boucsein, 2012). Recognized and validated across various studies, EDA offers a robust, and non-intrusive means of capturing the sympathetic nervous system's activity through skin conductance changes (Horvers et al., 2021).

An Overview of the Underlying Physiology

The human body's nervous system is divided into two main parts: the central nervous system and the peripheral nervous system. The central nervous system is composed of the brain and spinal cord, serving as the core of our nervous system, while the peripheral nervous system encompasses all other neural elements outside this core, including the somatic, autonomic, and enteric systems (Christopoulos et al., 2019). Here, of particular interest is the autonomic nervous system (ANS), a pivotal segment of the peripheral nervous system and the control chain tasked with managing the body's automatic and visceral functions. Operating subconsciously, the ANS orchestrates a range of involuntary actions, such as regulating heart rate and blood flow, ensuring the seamless operation of critical bodily functions (Christopoulos et al., 2019). ANS includes subsystems with distinct roles: the sympathetic and parasympathetic nervous systems (SNS and PNS, respectively). The SNS gears the body for action, initiating the fight-or-flight response in the face of stress, thereby heightening arousal (Boucsein, 2012). Conversely, the PNS acts as a counterbalance, promoting relaxation and recovery, guiding the body back to a state of equilibrium post-stress (Boucsein, 2012).

The activation of the SNS can be observed through its automatic regulation of certain physiological processes, notably sweating. Since sweat glands are exclusively innervated by the SNS, its activation upon encountering a stimulus (e.g., a sudden loud noise) triggers an increase in both the activation of eccrine sweat glands and the secretion volume from these glands (Christopoulos et al., 2019). This process produces a psychophysiological response that becomes apparent on the skin and enhances its electrical conductance due to the water content in sweat (Boucsein, 2012), measurable through EDA signals (Boucsein, 2012). This response is particularly pronounced in the hands' palms and soles, areas more sensitive to emotional stimuli than to temperature changes.

Characteristics and Analysis

EDA can be recorded through various methods, with the approach used in this study being the use of exosomatic measurements via direct current. This technique utilizes an external energy source, constant voltage or current, to capture signals primarily influenced by changes in resistance. The skin and sweat glands, possessing both resistive and capacitive properties, contribute to these variations, allowing for a detailed analysis of EDA responses (Boucsein, 2012).

Recording EDA signals necessitates the use of specific electrodes and devices due to their unique characteristics and acquisition sites (Boucsein, 2012). The quality of EDA data is significantly influenced by the electrodes used. For consistent and accurate EDA recordings, employing electrodes made from identical materials is crucial. Silver-silver chloride (Ag/AgCl) electrodes are the gold standard for EDA measurements, as they effectively reduce electrode polarization and the potential bias between electrodes (Hossain et al., 2022).

The electrodes are commonly positioned on the subject's fingers, but this might not always be feasible for certain data collections and study designs. The effectiveness of skin conductance measurement at any given body site is influenced by factors like the density and size of sweat glands, the output of individual glands, and the neural control over these glands (Hossain et al., 2022). The palmar (the palms of the hands) and plantar areas (the soles of the feet), known for their high eccrine sweat gland density, are typically favored for EDA measurements. Alternatively, the wrists have been recognized as reliable sites for EDA collection as well, with numerous studies confirming a strong correlation between EDA signals obtained from the wrist and traditional palmar sites (Fletcher et al., 2010; Poh et al., 2010; Sano et al., 2014).

EDA analysis differentiates between tonic and phasic components: the skin conductance level (SCL) and the skin conductance response (SCR), respectively (Benedek & Kaernbach, 2010b; Boucsein, 2012; Dawson et al., 2007). SCL represents gradual variations in EDA, indicating a baseline level of physiological arousal. In contrast, SCR, associated with discrete, emotionally charged or physical stimuli, captures swift fluctuations within EDA. SCR is produced by an outgoing burst of sympathetic nervous activity, which arises from the temporal and spatial integration of spikes initiated by the sudomotor nerve. Regions with a denser presence of these glands exhibit a higher rate of SCR occurrences, signaling increased sympathetic arousal (Christopoulos et al., 2019) (i.e. emotional arousal). This thesis therefore focuses on SCR signals, as an increase in SCR frequency or amplitude is typically seen as an indication of heightened emotional arousal (Horvers et al., 2021; Törmänen et al., 2023).

The characteristics of a SCR in response to a stimulus exhibit a distinct pattern (Benedek & Kaernbach, 2010a; Boucsein, 2012). The period from the onset of a stimulus to the start of the SCR is known as latency. Typically, the latency for SCR ranges between 1 and 5 seconds, though longer latencies can occur (Boucsein, 2012). After this latency period, the SCR increases until it peaks, meeting a minimum threshold amplitude of 0.01 to 0.05 μS, with 0.05 μS being the most commonly used criterion in psychophysiological research (Boucsein, 2012; Horvers et al., 2021). In the absence of further stimulation, the SCR then gradually declines, a phase referred to as SCR recovery (Boucsein, 2012).

To accurately identify and quantify SCR signals, it is essential to address the issue of superposing SCRs. When two SCRs occur in close succession, the onset of the second response can be obscured, or they might merge to appear as a single response (Benedek & Kaernbach, 2010b). Addressing this issue is feasible in the analysis stage.

The various methods currently utilized for SCR quantification can generally be categorized into the classical trough-to-peak (TTP) method and computational model-based approaches. The TTP scoring method in EDA analysis has several limitations that can affect its effectiveness in research. TTP measures the amplitude difference from the lowest to the highest point of the SCR but does not account for the shape or full temporal dynamics of the SCR, such as rise time or recovery. This simplicity means it may not accurately capture the complexity of SCR dynamics, particularly in scenarios with frequent, overlapping SCRs. Such overlaps can cause TTP to underestimate response amplitudes or fail to distinguish between separate responses, leading to inaccuracies in interpreting arousal or emotional states. Within the computational model-based approaches, several mathematical methodologies can be employed to deconvolve overlapping EDA signals, enhancing the precision of SCR analysis. Lim and colleagues (Lim et al., 1997) introduced a curve-fitting approach to distinguish SCRs unaffected by prior signals. Alexander and others (Alexander et al., 2005) proposed converting the EDA signal into a time series using a shorter constant for better clarity. Additionally, mathematical modeling and deconvolution techniques by Bach and others (Bach et al., 2009), and Benedek and Kaernbach (Benedek & Kaernbach, 2010b) have further refined the analysis. Specifically, Benedek and Kaernbach's non-negative deconvolution method more precisely separates EDA into tonic and phasic components, allowing for the isolation of SCRs and enabling more accurate measurement of response parameters. This deconvolution method, available in Ledalab (ledalab.de), allows for an accurate identification and quantification of SCRs.

Previous Studies

EDA has become a critical tool in educational research for assessing emotional and physiological responses during learning processes. A systematic review by Horvers and colleagues (Horvers et al., 2021) provides a comprehensive examination of EDA's applications in educational research, highlighting its ability to offer real-time, objective data on learners' emotional reactions—insights that are traditionally challenging to capture. This measure is increasingly utilized in various educational settings to probe aspects such as emotional engagement, stress levels, and attention, thereby helping to understand how students respond to different educational content and settings. Despite EDA's growing application, Horvers' review identifies substantial gaps and inconsistencies in its usage, particularly the lack of standardized methodologies for collecting, processing, and analyzing EDA data. These methodological disparities, ranging from the choice of devices to the analytical techniques employed, limit the comparability of studies and constrain the broader applicability of findings. Moreover, the review underscores the necessity for multimodal research approaches that integrate EDA with other data streams like behavioural observations and cognitive assessments, to enrich the understanding of learning processes.

Building on this foundational understanding of EDA's capabilities and challenges, we see its specific application in the context of medical education, particularly within simulation-based learning environments. For instance, a study by Bhoja and colleagues (Bhoja et al., 2020) explores EDA's utility in measuring physiological responses to stress among anesthesia residents during simulated medical emergencies. The findings suggest that through targeted team training, it is possible to modulate EDA responses, reduce anxiety, and potentially enhance performance under stress. Such insights affirm the value of incorporating EDA measurements into healthcare training to tailor scenarios that optimize stress levels for better learning outcomes. Additionally, Harley and others (Harley et al., 2019) examined how emotion regulation strategies affect learners' EDA levels and outcomes in medical simulations. They discovered that SCRs—indicators of heightened arousal—can significantly and positively predict diagnostic success. In contrast, the study by Quick et al. (Quick et al., 2017) presented a targeted approach by measuring EDA during surgical procedures to gauge clinical competence. The findings demonstrated that EDA responses, both tonic and phasic, varied with the surgeon's level of training, with a notable decline in arousal indicators as residents gained experience. This decline in phasic EDA responses was interpreted as a decrease in stress, correlating positively with increased clinical competence. However, Binkley and colleagues (Binkley et al., 2019) provided a crucial caveat by revealing that while EDA measures physiological arousal, it does not necessarily correlate directly with technical skills in surgical simulations. This finding suggests that while EDA is valuable for assessing emotional and stress responses, its utility as a standalone measure of surgical proficiency is limited.

Further illustrating EDA's relevance, Pijeira-Díaz and colleagues (Pijeira-Díaz et al., 2018) investigate arousal levels among high school students in an advanced physics course, noting a significant correlation between higher arousal states during exams and better academic performance. This correlation suggests the importance of maintaining optimal arousal levels to maximize learning effectiveness, an insight particularly relevant to the high-stakes nature of medical training simulations. Additionally, studies like that of Törmänen and colleagues (Törmänen et al., 2023), which integrate video and SCR frequency measurements, demonstrate how EDA can elucidate the complex interplay of emotions in learning activities, further highlighting its potential to refine educational practices in medical simulations.

These insights underscore the promising role of EDA in advancing medical education, particularly within the high-stakes realm of simulation-based learning. By effectively gauging psychophysiological responses, EDA empowers educators to finely tune training environments, optimizing both learning outcomes and the educational experience. However, the scope for applying EDA extends into more sensitive and complex training areas, such as anti-harassment education—a critical yet overlooked aspect of medical training. Despite the importance of understanding and mitigating harassment in medical settings, the integration of EDA-based assessments within anti-harassment training in clinical simulations has not been explored. This gap in research presents an opportunity to investigate the psychophysiological underpinnings of trainees' responses to observing harassment scenarios within simulated environments.

CHAPTER 3: AIM

Psychophysiological measures like skin conductance serve as invaluable tools for capturing the subtle nuances of emotional responses in real-time, offering a window into the physiological underpinnings of affective processes. This thesis aims to contribute to the existing body of knowledge by assessing the impact of harassment incidents on the psychophysiological responses of medical trainees, as measured by EDA signals, during high-fidelity simulations in clinical settings. Further, this thesis aims to investigate whether changes in psychophysiological responses due to harassment events are associated with the medical residents' likelihood and choice of intervention strategies. Through this, we seek to shed light on how psychophysiological emotional responses may influence behavioural decisions in critical situations, contributing valuable insights into the dynamics of emotional arousal and response in medical training contexts. The influence of training sequence on these dynamics is investigated.

This study is guided by the following research questions:

RQ1. Do medical trainees' i) training sequence group (simulation-first or video-first), ii) the timepoint when their EDA is measured (during or after harassment events), and/ or iii) the interaction between the two predict their EDA?

RQ2. Do medical trainees' training sequence group (simulation-first or video-first) and EDA during harassment events predict i) their likelihood to intervene, or ii) the specific nature of the intervention strategies they adopt in response to harassment?

CHAPTER 4: MANUSCRIPT

Harassment in Medical Education: A Psychophysiological Perspective through the Analysis of Electrodermal Activity

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Abstract

Harassment detrimentally impacts the well-being and education of medical learners and can consequently affect patient care quality. However, effective interventions to prevent and address harassment are lacking. Simulation-based training is a novel and promising educational approach to this problem that allows learners to actively practice combatting harassment within a controlled, yet emotionally stimulating and safe environment. This quasi-experimental crossover design study explored the psychophysiological and behavioural responses of 33 medical trainees observing simulated harassment as part of a curricular training program. We drew on the 4D Bystander Intervention Framework to classify behavioural responses. Electrodermal activity (EDA) and subsequent bystander intervention behaviours were assessed, accounting for individual differences. Learners were randomly assigned into one of two groups: one received video training before participating in simulations (video-first group), and the other experienced the reverse sequence (simulation-first group). Results of a mixed effects multilevel model indicated that harassment significantly elevated emotional arousal levels in both groups relative to their baseline. Using logistic regressions with cluster robust standard errors EDA did not emerge as a significant predictor of the likelihood or choice of intervention in either group, suggesting that EDA reflects immediate emotional psychophysiological reactions but is not an antecedent of specific behavioural choices. The video-first group exhibited statistically significantly higher arousal levels during harassment events than after and showed a higher likelihood of intervening than the simulation-first group. The findings have implications for understanding psychophysiological and behavioural responses within learning environments within and beyond the medical field.

Keywords

Psychophysiology, electrodermal activity, medical education, simulation-based education, harassment.

1. Introduction

Harassment in medical education has a strikingly high occurrence, with up to 75% of learners reporting having experienced at least one form of harassment during their medical training (*2018 National Resident Survey | Resident Doctors of Canada*, n.d.; Bahji & Altomare, 2020; Fnais et al., 2014). Medical education, with its high stakes and intense demands, inherently imposes considerable stress due to the extensive volume of information, precision of skills needed, and the emotional impact of patient care (Arnsten & Shanafelt, 2021; Satterfield & Becerra, 2010). This pressure is exacerbated by a fast-paced and competitive learning environment, underpinned by a hierarchical structure that dictates the flow of knowledge, skills, and responsibilities from experienced professionals to novices (Hsiao et al., 2021; Salehi et al., 2020). While this hierarchy is crucial for patient safety and care quality, it also engenders power imbalances that can foster a culture of harassment (Vanstone & Grierson, 2022). Harassment comes in many forms, such as microaggressions and discrimination (Bahji & Altomare, 2020), and is defined as any behaviour, educational process, or tradition that induces fear in learners or detrimentally affects the learning environment (*Intimidation & Harassment Prevention | Resident Doctors of Canada*, n.d.). Such an environment may hinder learners from addressing harassment due to fears of retaliation negatively affecting their evaluations, reputation, and learning opportunities, ultimately normalizing harassment as an inevitable companion of medical education (Bahji & Altomare, 2020). Similar patterns of harassment and bullying prevalent in academic settings and corporate environments echo these issues. In academic settings, bullying among faculty and students has been extensively documented, revealing profound effects such as psychological distress, diminished academic performance, and heightened turnover rates amongst victims when compared to their non-harassed peers (Bondestam & Lundqvist, 2020; Henning et al., 2017). Likewise, in corporate settings, workplace bullying leads to long-term emotional distress, mental health problems, decreased job satisfaction, and reduced productivity (Raihan et al., 2020; Siuta & Bergman, 2019). These commonalities across fields—characterized by power dynamics, high-pressure environments, and a prevailing fear of retaliation—create scenarios where victimized individuals feel powerless to challenge harassment. Reflecting on these patterns, medical education reveals a similarly hostile environment where longstanding (Silver, 1982) and harmful behaviour during medical training (Bahji & Altomare, 2020) is associated with increased psychological and physical health issues such as depression and anxiety, helplessness, suicide ideation, and psychosomatic and musculoskeletal complaints (Bahji & Altomare, 2020; Carter et al., 2013). Learners experiencing these challenges may see a decline in the effectiveness of their training, a greater propensity to commit serious medical errors, and ultimately a reduced likelihood of delivering optimal patient care (Bahji & Altomare, 2020; Fnais et al., 2014; Li et al., 2010). On an organizational level, the repercussion costs related to harassment may include, but are not limited to, increased job dissatisfaction, higher turnover rates, and overall reduced productivity (Fnais et al., 2014; Katz et al., 2019).

Despite the recognition of these detrimental effects, while numerous training programs within clinical settings have implemented measures such as policies, lectures, workshops, and seminars to tackle harassment, they often fall short due to their lack of engagement, relevance to real-world clinical scenarios, and insufficient emphasis on active participation (Bahji & Altomare, 2020; *Intimidation & Harassment Prevention | Resident Doctors of Canada*, n.d.; Lall et al., 2021; Mazer et al., 2018). As an alternative and more effective solution, simulation-based education shows promise in directly addressing these gaps. Simulations ensure a direct connection between the learning experience and the application of skills in real-world contexts (Al-Elq, 2010), preparing learners to navigate, for instance, complex interpersonal dynamics such as harassment effectively. They accelerate the learning curve by allowing learners to actively practice and learn in a safe environment that is tolerable to errors, and provides an avenue for assessment and feedback (Al-Elq, 2010; Chew et al., 2023; Weinger et al., 2017). Simulations are particularly effective instructional methods when the learning process requires learners to process and reflect on their emotional reactions to a situation (Al-Elq, 2010; Krathwohl, 2002b; Lambert et al., 2019), ultimately improving self-efficacy (Rønning & Bjørkly, 2019) and more effective learning (Bandura, 1997).

1.1. Previous Anti-harassment Simulation Training Studies

Active bystander training, focusing on providing individuals with the tools to intervene in harassment effectively when witnessing it (Coker et al., 2015), has recently started to be explored within simulation-based environments (Calardo et al., 2022; Chew et al., 2023; Famouri et al., 2023; Thivierge-Southidara et al., 2020). This integration allows for a nuanced rehearsal of harassment scenarios, bridging the gap between theoretical knowledge and its practical application in challenging interpersonal situations. The emerging research in this field, while indicating potential, highlights the need for further investigation to better understand, and ultimately optimize, the impact of bystander simulation-based training on promoting a culture of support and accountability within medical education. Chew and colleagues (Chew et al., 2023) devised a simulation-based training for medical students focused on active bystander intervention against disrespectful behaviour, utilizing video vignettes presenting scenarios of harassment, a themed card game encouraging critical discussion on workplace behaviours, and immersive simulations to practice intervention strategies with follow-up discussions. Results of questionnaires showed marked improvements in students' perceived knowledge and readiness to intervene in harassment scenarios, highlighting simulation's effectiveness in enhancing perceived responsiveness. Similarly, Famouri and colleagues (Famouri et al., 2023) recruited residents from diverse medical fields to participate in simulation scenarios with standardized patients, a brief presentation on microaggressions and how to handle them, and subsequent debriefing sessions. These activities led to increased self-reported confidence and skill in recognizing and handling microaggressions and harassment. This was further supported in a study that highlighted the effectiveness of bystander intervention training in empowering medical students and healthcare professionals to challenge discrimination and harassment (Tyson et al., 2024). Tyson and colleagues demonstrated a significant increase in participants' sense of responsibility and ability to intervene in simulations, as reflected in evaluation surveys. Participants engaged in role-playing exercises, delivered online, with facilitators and actors to realistically simulate discrimination scenarios, complemented by resources such as a handbook and educational videos on bystander intervention methods, effectively prepared them to handle discriminatory situations across various settings (Tyson et al., 2024). Another study(Thivierge-Southidara et al., 2020) assessed the effects of video presentations and simulated intimidation scenarios, where two actors (a surgeon and a student) re-enacted intimidation scenarios based on previously reported events, on reporting rates among medical students. Despite an increase in awareness, the study found no significant change in the likelihood of reporting intimidation from pre- to post-intervention surveys, underscoring the necessity for additional research to refine or assess the effectiveness of training methods. Conversely, Calardo and others (Calardo et al., 2022) reported an increased readiness to address racism and discrimination through pediatric resident workshops using workshops, videos of simulations and guided role-play of responses to racist scenarios in small groups for effective learning.

These studies have provided valuable insights by predominantly using self-report questionnaires to gauge the effectiveness of interventions, focusing on participants' perceptions and perceived prospective behaviour changes in harassment scenarios. However, self-report measures are subjective and can be influenced by respondents' biases and potential inaccuracies due to memory, or intentional deception, limiting their reliability as objective measures (Zarjam et al., 2013). Building on these insights, this article is derived from a larger study where related but distinct analyses were carried out. Johnson and colleagues (Johnson et al., 2024) employed inductive thematic analysis, independent of the 4D strategy framework, to provide a rich qualitative description of medical residents' behavioural responses to harassment. In addition, Ahn and colleagues (Ahn et al., 2024a) utilized a simulation performance checklist to assign *numerical values* to trainee's use of the 4D strategies across the whole simulation. In other words, they received a "check" for engaging in a strategy once. Their score, out of five, was calculated based on their use of the four strategies. Ahn and colleagues (Ahn et al., 2024b) examined whether participants with specific emotional profiles utilized specific 4D strategies based on their hierarchical cluster analysis, but their identification of the strategies were based on their simulation performance checklist mentioned above. Hence their analysis did not comprehensively take every harassment event into account.

Our study aims to build upon these foundational efforts by exploring the objective and real-time impacts of bystander simulation-based training during a clinical procedure, using psychophysiological measures, offering a closer examination of how such training might influence the learners' emotional states and real-world actions over time in response to harassment.

1.2.Theoretical Framework

To assess learners' emotional states, psychophysiological measures were used—involuntary bodily responses that reflect psychological states (Cacioppo et al., 2000). Psychophysiological measurements are objective (Cacioppo et al., 2000) and can reveal physiological changes linked to emotions that individuals might not consciously acknowledge, yet still influence behaviour despite not being explicitly recognized (Caruelle et al., 2019; Winkielman & Berridge, 2004).

Emotions, as multifaceted phenomena, emerge in response to specific stimuli and are shaped by an individual's appraisal of these stimuli (Pekrun et al., 2017; Stark et al., 2018). Central to understanding emotions within academic settings is Pekrun's Control-Value Theory (CVT) of achievement emotions (Pekrun, 2006). This theory characterizes emotions through two primary dimensions: valence (positive or negative) and activation or arousal (deactivating or activating) (Pekrun, 2006). CVT underscores the crucial influence of achievement emotions—emotions that are intrinsically linked to achievement activities or outcomes—on a learner's engagement, decision-making, and performance. By categorizing emotions based on their valence and level of arousal, CVT provides an intricate understanding of how various emotional states can affect achievement (Harley et al., 2019; Jarrell et al., 2017). Positive activating emotions, such as hope and enjoyment, typically enhance achievement and learning, whereas negative deactivating emotions, like boredom and hopelessness, tend to hinder them (Jarrell et al., 2017; Pekrun et al., 2017). Moreover, the theory acknowledges that emotions with mixed characteristics, such as positive deactivating emotions (relaxation, relief) and negative activating emotions (anger, anxiety), can have nuanced effects on learning, depending on their intensity and the learning context (Jarrell et al., 2017; Pekrun et al., 2017).

1.3. Emotional Arousal and Learning

In this study, our focus narrows to one particular dimension of emotions: arousal. Learning is not a passive receipt of information but an active, multifaceted process that leaves a "physiological footprint," particularly in the form of arousal (Hebb, 1955). Arousal is a critical component of the learning process, influencing the learner's cognitive engagement (Barnes et al., 2016; Cain & Lee, 2016), attention (Fox et al., 2001), memory (Marchewka et al., 2016), and decision-making processes (Dawson et al., 2007; Juvina et al., 2018). A study by Pijeira-Díaz and others[47] revealed that low arousal states were more prevalent and lasted longer than high arousal states within classroom settings, highlighting the challenges in maintaining learners' engagement and the need for interventions to address low arousal in educational settings. A positive correlation between arousal during the course exam and academic achievement was identified, underscoring the importance of arousal in learning outcomes. Arousal levels that are too low can lead to disengagement and ineffective learning, while excessively high arousal, potentially exacerbated by negative experiences may lead to cognitive overload and increased medical errors (Dias & Scalabrini-Neto, 2017; Duffy et al., 2015; Norman et al., 2017; Sanbonmatsu & Kardes, 1988). In the context of medical education, where the acquisition of complex skills under high-stress conditions is common (Ebrahimi & Kargar, 2018), understanding the variations in arousal in response to stimuli like harassment becomes crucial.

To do so, arousal must be quantified: electrodermal activity (EDA) recordings have been extensively studied, and are widely accepted as real-time, accurate, and non-intrusive means of measuring one's emotional arousal (Boucsein, 2012; Dawson et al., 2007). EDA encompasses the variations in the skin's electrical characteristics triggered by alterations in eccrine sweat gland function, which increases with emotional intensity elicited through a variety of external or internal stimuli (Caruelle et al., 2019). Eccrine sweat glands are solely innervated by the sympathetic nervous system (SNS) which triggers the fight-or-flight response, indicating activation (Benedek & Kaernbach, 2010b; Boucsein, 2012).

EDA signals can be distinguished between tonic (skin conductance level; SCL) and phasic (skin conductance response; SCR) components (Boucsein, 2012). SCL indicates slow varying changes in EDA, while SCR reflects rapid changes and is associated with specific stimuli such as those emotionally arousing or perhaps a sudden loud noise. SCR is produced by an outgoing burst of sympathetic nervous activity (Faghih et al., 2015) and an increase in its frequency or amplitude is typically seen as an indication of heightened sympathetic arousal (Boucsein, 2012; Horvers et al., 2021). The occurrence of a SCR could be anticipated 1-5 seconds (Boucsein, 2012) following an arousing stimulus due to the latency inherent in EDA responses (i.e., time from stimulus onset to SCR onset).

While the intricate analysis of physiological measures requires specialized expertise, potentially limiting their usage compared to more conventional options such as self-reports(Faghih et al., 2015), EDA's capacity to uncover unconscious emotional states makes it a valuable tool for refining educational strategies. This premise is echoed in the systematic review by Horvers and colleagues (Horvers et al., 2021), which highlights the methodological variability in EDA application within learning contexts and advocates for standardization. The review underlines EDA's capability to shed light on emotional and cognitive states during learning processes. Törmänen and colleagues (Törmänen et al., 2023) share the same message and offer robust methodological approaches for EDA analysis by incorporating a variety of data sources including video recordings and SCR frequency measurements in classroom settings to investigate the complex interplay of emotions during learning activities. They identified four distinct clusters of socio-emotional interaction episodes based on EDA data, underscoring the potential of psychophysiological measures to enhance our understanding of the relationship between affect, regulation of learning, and collaborative dynamics. In the medical education sphere, Harley and others (Harley et al., 2019) examined how emotion regulation strategies affect learners' EDA levels and outcomes in medical simulations. They discovered that SCRs—indicators of heightened arousal—can significantly and positively predict diagnostic success, reinforcing the significance of exploring arousal for educational effectiveness.

These studies not only enrich the methodological toolbox for researching learning processes but also highlight the importance of considering physiological responses, such as EDA's application to monitor emotional arousal in designing educational interventions. Nonetheless, to the best of our knowledge, the application of EDA within the context of anti-harassment training, specifically through simulation-based education in medical settings, remains unexplored.

1.4. The Current Study

To address this gap, this article leverages EDA to investigate the impact of medical trainees observing harassment events during high-fidelity bystander training simulations in high-stress clinical settings. Via behavioural coding focusing on *all* harassment events and measuring emotional arousal through EDA in such specialized training contexts, we aim to unveil nuanced aspects of how trainees are impacted and respond to observing harassment scenarios, offering valuable insight on the efficacy of simulation-based educational strategies aimed at combating harassment in medical environments. This study is guided by the following research questions:

RQ1. Do medical trainees' i) training sequence group (simulation-first or video-first), ii) the timepoint when their EDA is measured (during or after harassment events), and/ or iii) the interaction between the two predict their EDA?

RQ2. Do medical trainees' training sequence group (simulation-first or video-first) and EDA during harassment events predict i) their likelihood to intervene, or ii) the specific nature of the intervention strategies they adopt in response to harassment?

2. Methodology

2.1. Participants

Our participants were a subsample of a larger research study. Upon receiving approval from the Institutional Review Board, the larger study recruited 88 first and second-year Internal Medicine residents at a North American University. The current study focuses on 56 of these residents, as the rest were part of a control group the larger study required that was outside the scope of the present study. Of the 56 residents, 36 consented to the collection and recording of both audio-visual and EDA data. Three residents were excluded due to missing data, resulting in a final sample of 33 participants (Figure 1). This figure is consistent with sample sizes commonly encountered in health professions education research working with highly specialized and small trainee samples as well as studies with multimodal data which tend to be smaller due to challenges with data loss (D. A. Cook & Hatala, 2015; Tekian et al., 2020). The study was conducted over a span of approximately 10 months, from September 2022 to June 2023, and was embedded within the curriculum. Participants who completed an optional follow-up survey were offered the incentive of entry into a raffle for a gift card. Residents had a mean age of 27.62 years (SD = 2.82), 42% were female, and 67% self-identified as a visible minority (Arab, Black, etc.). Additionally, 36% had previous experiences with harassment, which included verbal or emotional abuse, physical abuse, sexual harassment, discrimination based on race, gender identity, cultural/religious background, sexual orientation, or pregnancy/childcare status.

2.2. Study Design

With a quasi-experimental crossover design, trainees were randomly assigned to one of two groups: The video-first group (*N* = 15) who initially viewed a series of educational anti-harassment training videos. They subsequently engaged in a standardized anti-harassment simulation centered around a central line insertion procedure. The simulation-first group (*N* = 18) experienced these components in reverse order.

2.2.1. Video Series

The anti-harassment training component was created by the research team, collectively lasting 37 minutes and 44 seconds. These videos were divided into five key modules, each targeting a specific aspect of harassment awareness and response within healthcare settings, including active bystander strategies. These strategies (Coker et al., 2015; Famouri et al., 2023; *The 5Ds of Bystander Intervention. Right to Be.*, n.d.) are rooted in evidence-based techniques: direct action to confront the harasser or situation, distraction to interrupt or divert focus and de-escalate, delay by responding post-incident with support to the victim, and delegation by seeking help or reporting to someone in authority or better positioned to intervene.

2.2.2. Simulation

Medical trainees participated as junior residents in a central line procedure simulation where they witnessed, as bystanders, ongoing simulated harassment perpetuated by a senior resident (SR, played by a standardized participant) towards a medical student (MS, played by a standardized participant). Every scenario followed a standardized format, detailed in a guide that specified the scenario's structure, scripts, and delivery approach. The harassment events were pre-scripted, with the SR characterized as impatient, obnoxious, and rude without resorting to screaming or physical intimidation. The MS, portraying a first-year medical student, was directed to exhibit nervousness, hesitation, and a lack of preparedness in answering questions. Graduate students and one volunteer undergraduate student, including those who helped develop the script and were working on dissertation or theses from the study, served as standardized participants along with simulation centre staff because of lack of availability of simulation centre staff and/or professional actors due to human and material resource constraints and the ongoing COVID-19 pandemic. Simulation staff and graduate students played different roles at times due to availability, but all received the same training. Trainees and students playing an active role in simulations is not uncommon (Botelho et al., 2024; Tyson et al., 2024). A simulation technician was present to manage any technical problems and to enable learners to employ the delegate method of intervention if desired.

The selection of the central line procedure was grounded in its relevance and educational value in the Internal Medicine curricula. This procedure, requiring completion on a high-fidelity manikin (CAE Blue Phantom Central Line Ultrasound Training Model), was selected after consultation with physicians and simulation experts. It was deemed sufficiently challenging, ensuring cognitive engagement without necessarily overshadowing the focus on the harassment intervention. The simulations lasted between 10-12 minutes, with participants receiving a briefing in advance. Supplemental material is included in the Appendix to provide readers with additional information about this work.

2.3. Measures

2.3.1. Harassment Events and Intervention Methods

During the simulations, high-quality video and audio data were recorded, with strict adherence to ethical standards and participant consent. All recordings were thoroughly checked for technical integrity and harassment events, perpetuated from the senior resident towards the medical student, were clearly marked from their beginning to their end. These segments were referred to as *during harassment*. Those shorter than 5 seconds were excluded, resulting in the exclusion of 104 out of 304 events (34%). This left 200 events (66%) eligible for analysis. The 5-second threshold for harassment duration was decided upon to ensure the duration was long enough to elicit a meaningful physiological response within the constraints of the EDA signal's response time (Caruelle et al., 2019).

Immediately after the end of the *during harassmen*t segment, the next phase was identified as the *after or post-harassment* segment. The length of the post-harassment segment was set at a minimum of 10 seconds and a maximum of 60 seconds. This range was established to ensure sufficient time for intervention behaviours to be observed and coded, while also aligning with prevalent literature norms on EDA latency and peaks-per-minute in EDA studies (Horvers et al., 2021; Pijeira-Díaz et al., 2018, 2019). The videos then underwent behavioural coding (Table 1) to mark whether the learner intervened in harassment events, and if so, what method was used (i.e., direct, distract, delegate and delay). For a subset of the recordings (20%), interrater reliability was evaluated for the identified categories between two analysts, demonstrating a perfect consensus ($\kappa = 1$).

2.3.2. EDA

The Empatica E4 device (Empatica Inc., Cambridge, MA, USA) was used to measure EDA, allowing for the extraction of the frequency of SCR as an index of the trainees' emotional arousal. Multiple studies have provided evidence of the Empatica E4's validity, demonstrating high reliability in measuring various physiological measures such as EDA in various populations and conditions (Borrego et al., 2019; Garbarino et al., n.d.; Horvers et al., 2021; Schuurmans et al., 2020). This device recorded electrical conductance across the skin using an 8 Hz alternating current, 8mm diameter silver-plated electrodes with measurements expressed in microsiemens (μS) (Empatica Inc., MI, IT. E4 WristBand from Empatica User′s Manual., 2021). The E4's design, being wrist-worn and lightweight (40g) (Empatica Inc., MI, IT. E4 WristBand from Empatica User′s Manual., 2021), was ideal for unobtrusive data collection during simulations, allowing residents to perform tasks such as the central line insertion without hindrance. Participants were instructed to place these electrodes on the ventral (inner) wrist of their non-dominant hand and fitted it comfortably . EDA data was captured continuously during the simulation at a sampling frequency of 4 Hz ($\frac{1}{4}$ second) in room temperature (Horvers et al., 2021; Schwartz & Schwartz, n.d.; Shaffer et al., 2016). Furthermore, EDA was recorded for 3-minutes (Benedek & Kaernbach, 2010b; Horvers et al., 2021) immediately before the start of the simulation as a baseline reference for each learner, allowing for meaningful comparisons of SCRs (Boucsein, 2012; Horvers et al., 2021; Hossain et al., 2022).

2.4. Data Analysis

2.4.1. Aligning EDA and Video Recordings

EDA data was precisely aligned with the corresponding video recordings of each participant through timestamps. At the start and end of each simulation, participants were instructed by the facilitator to press a built-in button on the EDA measurement device, marking timestamps that facilitated accurate alignment of physiological responses with observed harassment events throughout the simulations.

2.4.2. Software and Data Processing

The EDA signals were processed and analyzed using Ledalab (version 3.4.9, www.ledalab.de), an open-source software implemented in MATLAB (Version R2023a) (Benedek & Kaernbach, 2010b, 2010a). This setup, as per Empatica's recommendation (Empatica Inc., MI, IT. E4 WristBand from Empatica User′s Manual., 2021), facilitated efficient decomposition analysis into tonic and phasic signals, and SCR extraction from raw, unfiltered EDA data (Benedek & Kaernbach, 2010b). In spite of thorough control of measurement techniques during simulations, the behaviour and movement of individuals and/or the environmental conditions during EDA measurement can lead to the recording of artifacts (Benedek & Kaernbach, 2010a), which must be eliminated before further statistical treatment. Hence, to ensure data accuracy, all EDA sessions were visually inspected. A first-order Butterworth low-pass filter with a 1Hz cut-off frequency was applied to refine the data, eliminating high-frequency noise while maintaining its integrity (Boucsein, 2012; Kelsey et al., 2017; Subramanian et al., 2019; Taylor et al., 2015). This filter allowed for unusual steep rises stemming from artifacts, such as pressure exerted on the electrodes, to be automatically eliminated (Boucsein, 2012). Any remaining artifacts were then manually identified and corrected using spline interpolation (Posada-Quintero & Chon, 2020) for steep rises, or when SCL was at or below 0 (Boucsein, 2012; Taylor et al., 2015). This approach to data processing ensured the precision and reliability of our EDA signal analysis.

2.4.3. SCR Frequency Analysis

Continuous Decomposition Analysis (CDA) was selected over the traditional trough-to-peak (TTP) method for SCR frequency extraction (Benedek & Kaernbach, 2010a; Hardy et al., 2013; Horvers et al., 2021; Pijeira-Díaz et al., 2018). This approach, robust against noise and superimposed SCRs which has historically caused biases in SCR counts (Boucsein, 2012; Giannakos et al., 2022), accurately captures the sudomotor nerve activity signal characteristics (Benedek & Kaernbach, 2010a, 2010b). A standard threshold of 0.05 µS was set for identifying SCRs, aligning with historical practices, and ensuring comparability with previous studies (Boucsein, 2012; Horvers et al., 2021). To account for EDA latency, a 3-second delay was introduced in the analysis. This latency refers to the time lag between the onset of an emotional stimulus and the observable physiological response measured by EDA (Boucsein, 2012). By introducing a 3-second delay, the study ensured more accurate temporal alignment between the emotional stimuli presented during the simulation (i.e., harassment events) and the corresponding physiological responses recorded (Boucsein, 2012; Silva et al., 2012), thereby enhancing the precision and reliability of the data analysis.

Emotional arousal during the simulation for both during and post-harassment events was quantified through a moving window, featuring a window width of 5 seconds and a moving step of 1 second (Pijeira-Díaz et al., 2018, 2019; Törmänen et al., 2023). This method was pivotal in capturing the subtle and dynamic shifts in EDA, indicative of the emotional arousal in trainees during the simulation. A window of 5 seconds was chosen to provide adequate temporal resolution for observing significant SCR fluctuations, and to be aligned with the harassment event threshold for consistent temporal correlation. Concurrently, the 1-second step ensured a continuous and more accurate assessment. This means the frequency of SCRs within each 5-second window was calculated, followed by a shift of the window by 1 second for recalculating the following segment. The values obtained from the moving window analysis were subsequently averaged over the entire length of each specified period (i.e., during or post harassment; Figure 2). This approach allowed for a detailed, time-sensitive examination, enabling the tracking of rapid emotional arousal shifts, essential for comprehending physiological responses in high-fidelity simulations.

Events where the total amount of SCR detected was zero, indicating potential hypo-responders, were identified, and excluded as outliers. Doing so allowed for an automatic exclusion of sessions with improper electrode-skin contact due to wristband maladjustment.

2.4.4. Statistical Analysis

RQ1. Multilevel (ML) analysis was employed due to the nested structure of our observations, baseline observations and post-harassment observations separated for each harassment event, within participants. Acknowledging individual differences is crucial when interpreting biosignal data, as unique physiological and psychological attributes among participants can lead to variations in biosignal readings, including EDA (Meijer et al., 2023). Differences in the number of sweat glands per individual, for example, are among the factors that can affect these readings (Boucsein, 2012). ML accommodates for the presence of multiple observations per participant, which may meaningfully impact our data. ML analysis was performed in Stata (version 18 BE). For RQ1, 16 harassment events were excluded across all participants due to overlaps between the post-harassment and during-harassment periods of subsequent events. This exclusion was necessary to avoid artificially inflating EDA arousal levels in RQ1, which specifically analyzed EDA during and post-harassment. Consequently, the total usable harassment events for RQ1 were 184 across.

RQ2. A logistic regression with cluster robust standard errors was used to examine whether psychophysiological responses during harassment events could predict whether the participants intervened in the ongoing harassment. Subsequently, a multinomial logistic regression with cluster robust standard errors was run to determine whether physiological responses during harassment events could predict the specific intervention method employed by the residents. Overlap was not a concern applicable to RQ2, as it did not focus on post-harassment EDA, but rather on intervention behaviour in the post-harassment period, rendering the overlap of EDA irrelevant. Consequently, RQ2 retained all 200 events.

Covariates, including age, gender, visible minority status, previous harassment experiences, and baseline EDA levels, were controlled for in both research questions.

3. Results

3.1. RQ 1: Harassment Timepoint and Training Sequence Group's Impact on Learners' EDA

Table 2 lists the demographic information of participants. Observations were defined according to baseline observations and post-harassment observations being separated for each harassment event. A mixed-effect ML model was constructed with observations, nested within harassment events (level 1) nested within participants (level 2). The regression analysis, with 342 observations, was used to examine variations in trainees' arousal levels across groups, using frequency of SCR peaks as an index, during and immediately after harassment events compared to baseline (Table 3). The analysis revealed a significant increase in arousal levels both during ($\beta = .993$, $p < .001$, power > .99) and after harassment events ($\beta = .757$, $p < .001$, power > .99) compared to the baseline for both groups. A significant difference was also observed between during (est. $M = 1.90$) and after harassment events (est. $M = 1.51$, $p < .001$, power > .99) not accounting for group assignment. Here, we observed that medical trainees' EDA was statistically significantly higher during compared to after harassment events. When looking at the interaction between group assignment and timepoint, both groups had significant differences during and after harassment arousal levels when compared to their baseline arousal (all $p < .001$, all power > .82). However, when comparisons were made between during and after rather than between these two episode labels and baseline, the video-first group had significantly higher arousal level during (est. $M = 1.98$) compared to after harassment (est. $M = 1.47$, $p = .001$, power = .97). No such statistically significant result was observed for the simulation-first group.

The intraclass correlation coefficient (ICC) for the participant level indicates the proportion of variance in the outcome that is due to differences accounted for by level 2 membership, in this case between individuals within the study (Hox, 2002; Lorah, 2018; Schoot, 2017). ICC represents a measure of strength of association and is an index of effect size (Snijders & Bosker, 2012). In this case, ICC of .46 implies 46% between-subject variability, indicating that the nesting of harassment events within participants is important to account for, as done in our analysis.

3.2. RQ 2: EDA, Training Sequence Group and the Subsequent Intervention Behaviour

Logistic regression with cluster robust standard errors revealed only group assignment as a key predictor in trainees' likelihood to intervene during harassment events, with the simulation-first group being less likely to intervene ($\beta = -1.49$; $p < .01$, power = .90) (Table 4). EDA during harassment did not statistically significantly predict whether residents chose to intervene at all ($p = .31$).

Table 5 lists the frequency of intervention methods employed by residents in response to harassment scenarios. Using a multinomial logistic regression with cluster robust standard errors, we found that EDA during harassment was not significant (all $p > .05$) in predicting the type of intervention behaviour residents employed (i.e., direct, distract, delegate, delay) (Table 6). For the distract method, no predictor emerged as significant when accounting for family wise error rate (adj. $\alpha = .01$). Finally, we see that the video-first group was more likely to use the delay method to intervene in the harassment ($\beta = -1.83$; $p < .01$, power = .81), compared to the simulation-first group.

4. Discussion

This study delved into the psychophysiological responses of Internal Medicine trainees in simulated harassment situations during central line procedures. Simulations offered a feasible and ethical platform for this exploration, providing a controlled environment with numerous psychological safety measures built in for residents to engage with and respond to harassment. Our objectives were twofold: RQ1 to determine the changes in trainees' emotional arousal in the face of harassment, and RQ2 to assess how this arousal influenced their decisions to intervene.

The results demonstrated a marked rise in the learners' arousal levels during and post-harassment events, relative to baseline measurements, emphasizing the significant emotional impact of harassment on trainees. CVT suggests that an individual's emotional response in learning contexts is shaped by their perceived control over the situation and the value they attach to the task at hand. The increased arousal observed may reflect the trainees' recognition of harassment as a threat within their clinical environment, impacting both their sense of control and the value placed on maintaining a safe learning environment. This was particularly evident in the video-first group, which showed heightened arousal during harassment events compared to afterward and was more likely to intervene, suggesting increased engagement and alertness (Hardy et al., 2013; Pijeira-Díaz et al., 2018) facilitated by the preparatory video material. These interventions were informed by an increased perceived control and a deeper understanding of harassment's serious implications, which were emphasized in the training. This combination of heightened arousal and enhanced readiness translated into effective intervention behaviours, showcasing how well-targeted educational content can significantly influence both emotional responses and practical actions in high-stress scenarios.

Interestingly, although trainees exhibited increased emotional arousal during harassment, this did not predict their intervention behaviours, suggesting that other factors than immediate psychophysiological responses, potentially prior experiences, individual perceptions, or perhaps a fear of retaliation due to hierarchy, may play a more pivotal role in decision-making processes following harassment scenarios (Mainwaring et al., 2023). Additionally, the suitability of intervention behaviours may vary significantly depending on the specific context of the scenario and the intensity of the harassment experienced. Certain responses may be deemed more appropriate or effective in some situations than others, influencing the trainees' choice of action (Mainwaring et al., 2023). The observed lack of a predictive relationship between EDA and intervention behaviour in harassment scenarios among medical trainees could be further explained by their years of training in maintaining composure under stress, a key aspect of medical education enhanced through time, competence and confidence (Binkley et al., 2019; Quick et al., 2017). Such expertise likely helps residents regulate their physiological responses in challenging situations, suggesting that the influence of emotional arousal on their decision-making might be moderated by their developed self-regulation skills. The absence of the direct impact of arousal on decision-making processes highlights the multifaceted nature of behaviour in clinical settings, and further underscores the importance of incorporating EDA into such studies. EDA can uncover valuable physiological information that is not readily apparent through observation of behaviours alone, providing deeper insights into the underlying dynamics of learner responses (Boucsein, 2012).

Our analysis of intervention strategies in harassment scenarios revealed distinct patterns in trainee behaviour. Specifically, when examining the delay method, we found a notable difference between groups. Trainees who received video training first (video-first group) were more inclined to use this method. This preference for a measured response could be driven by an understanding, possibly imparted by the video content, that such an approach minimizes the risk of retaliation from more senior individuals. It underscores the influence of preparatory educational content on promoting strategic decision-making in complex environments. Neither group assignment nor EDA levels were found to predict the use of direct or distract methods in addressing harassment scenarios. This suggests that the choice between confronting harassment head-on or using distraction does not depend on how the trainees were first introduced to the material or on their emotional arousal during the training. This may indicate that factors outside our study's scope may play a crucial role in shaping these decisions, opening avenues for further research.

Finally, this article makes methodological contributions by sharing a novel approach to analyze discrete learning moments through synchronized video and EDA data. By integrating these two data channels, we offer a refined method for capturing and understanding the nuanced psychophysiological responses during specific educational interactions, particularly in high-stress scenarios like those simulated in medical training. This methodology allows for a more granular analysis of how trainees react to instances of harassment, linking visible behaviours captured on video with the corresponding physiological arousal measured through EDA. Furthermore, recognizing the variability in how EDA is analyzed across studies (Horvers et al., 2021), our research contributes to the field by implementing a novel and standardized approach to EDA analysis and reporting to ensure more consistent and reliable results in psychophysiological research.

4.1. Limitations and Future Work

This study faced some limitations. The number of participants ($N = 33$) was small, due to the logistics of the data collection, including resident consent to video recordings and psychophysiological data. Nonetheless, this is a common limitation in studies involving medical trainee populations (D. A. Cook & Hatala, 2015) and did not negatively affect the power of any statistical analyses (i.e., statistical power was sufficient). Future studies should incorporate residents from various specialties. Moreover, although the baseline for our study was not established during complete relaxation due to time constraints, its inclusion remains a key strength

(Horvers et al., 2021). This baseline, even if not perfect, provided a crucial reference point for comparing arousal changes, enhancing the robustness of our findings by enabling us to assess the psychophysiological impact of harassment more accurately. The exclusion of harassment events shorter than 5 seconds, while necessary for ensuring clarity in our data analysis, did omit some instances of harassment. This decision allowed us to focus on more sustained interactions, which provided clearer insights into the psychophysiological responses of trainees. The present study used EDA as a highly sensitive index of emotional arousal. Future analyses incorporating additional physiological indices like heart rate variability could enrich our understanding of emotional arousal, offering a broader perspective on the body's response to various stimuli alongside EDA data. Notably, due to resource constraints, we have relied on simulation centre staff and laboratory student members who were part of the research team to participate in the simulation as standardized participants. Therefore, utilizing professionally trained actors and actresses is a future direction for this research. Finally, the focused analysis of EDA during specific simulation segments may not fully capture the broader physiological impacts of the medical procedure and harassment. This was done in order to focus specifically on the results of harassment events, and not the affective impacts of the technical procedure. Future research could separate the procedural and harassment aspects in simulations to analyze EDA's responses more distinctly.

5. Conclusion

A rigorous EDA analysis methodology within individual learning research in medical education has been presented. The study's exploration into the psychophysiological impacts of observing harassment provides critical and highly novel insights into underlying psychophysiological responses and the effectiveness of different training sequences. The statistically significant arousal levels observed during, and post-harassment events help highlight the influence of such negative interactions on trainees, underscoring the urgency of addressing harassment within medical education—especially considering that most harassment is *not* simulated. Our psychophysiological data could not predict residents' decision-making regarding intervention likelihood, emphasizing the complex interplay of cognitive, emotional, educational and situational factors in behaviour. Making these emotional responses visible, such as through a dashboard (i.e., digital visualizer), could provide trainees with valuable insight. Specifically, doing so could help highlight the underlying responses that harassment can induce even when it does not lead to direct action. In other words: it could help trainees better understand the psychological impact of harassment even on individuals other than those targeted by it. This could potentially help motivate individuals to engage in bystander interventions more often or sooner. The need for specialized anti-harassment trainings is emphasized to further explore learners' arousal levels, while acknowledging trainees' diverse backgrounds and experiences, enabling them to effectively address harassment through strategies they, personally, feel comfortable using. To our knowledge this is the first evaluation of EDA in an active bystander simulation focusing on harassment in medical education, and aims to lay the foundation for subsequent research in this area. The implications of our study reach beyond medical education, however, offering valuable perspectives for designing anti-harassment initiatives across different professional domains.

Tables and Figures

Table 1

Coding of Harassment Intervention Behaviours

Intervention	Definition	Example
Direct	Directly confronting the behaviour or situation. It entails clear communication with the harasser, indicating that their behaviour is unacceptable and requesting its cessation. This approach is characterized by its straightforwardness and immediacy in addressing the issue.	*"That kind of language is not okay."* *"This is inappropriate."* *"We need to focus on the patient/task at hand."* *"This is a learning environment, and everyone's here to learn."*
Distract	Aims to defuse the situation without direct confrontation. It involves creating a diversion or engaging in an unrelated activity to temporarily shift focus away from the problematic behaviour, thereby providing an opportunity to deescalate tension or remove the victim from the situation.	*[Participant towards SR] "I'm sorry but could you please hold this real quick?"* *Sharing anecdotes, telling jokes.* *Interrupting harassment with another topic.*
Delegate	Involves seeking assistance from another party, such as an authority figure or another bystander. It is particularly useful when the situation requires intervention from someone with more authority or when the bystander feels unable to intervene directly.	*Alerting the harasser's superior or peers, those with equal or more power than them.* *Asking the delegate to take the harasser out of the room.*
Delay	Entails offering support to the victim after the incident has occurred. It recognizes situations where immediate intervention is not feasible or appropriate, focusing instead on post-event support, validation of the victim's experiences, and exploring further steps for addressing the issue.	*"What they did was not okay, that type of behaviour is not acceptable here."* *Asking if they are okay, checking in.* *Guiding them through resources available.*

Table 2

Demographic Information of Participants (EDA > 0)

Demographic	N_{unique}	N_{total}	Mean ± *SD* (Range)
Age, years			27.67 ± 2.91 (24-34)
Gender			
Female	11	167	
Male	16	175	
Ethnicity			
Visible minority	12	183	
Caucasian	16	159	
Prior Experience of Harassment			
Yes	9	108	
No	18	234	
Training sequence group			
Video-first	13	160	
Simulation-first	14	182	
Timepoint			
During harassment		139	
Post harassment		92	
Baseline		111	

Note. *SD* = standard deviation.

Table 3

Mixed-Effects Multilevel Regression Results: Relationship between EDA and Harassment Timepoints

	Null	***Timepoint and Training Sequence Group***	***Timepoint and Training Sequence Group with Covariates***
	β(SE)	*β(SE)*	*β(SE)*
Fixed Effects			
Intercept	1.17**(0.18)	.83**(0.22)	.15
EDA Baseline		Ref.[a]	Ref.[a]
During harassment timepoint		.99**(0.16)	1.00**(0.16)
Post-harassment timepoint		.75**(0.15)	.76**(0.15)
Training sequence group[b]		-.47(0.31)	-.42(0.38)
During harassment timepoint x Video-first group[c]		.58*(0.21)	.58*(0.21)
Post-harassment timepoint x Video-first group[c]		.32(0.20)	.31(0.20)
Visible minority status			.05(0.32)
Gender[d]			-.39(0.30)
Age			.03(0.07)
Prior experience of harassment			.44(0.33)
Random Effects			
PID (Identity)	.78	.58	.45
Harassment	.46	.03	.03
ICC			
PID (Identity)	.46	.45	.43
Harassment	.46	.47	.46

Note. $N = 342$. * $p < 0.05$ ** $p < 0.01$. β = coefficient. *SE* = standard error. ICC = Intraclass Correlation Coefficient. PID = Partcipant ID.

[a] Ref indicates the reference category to which comparisons were made

[b] Training sequence group refers to the learners' group assignment where 0 indicates the video-first group and 1 indicates the simulation-first group

[c] The interaction terms During harassment timepoint x Video-first group and Post-harassment timepoint x Video-first group compare the EDA responses between the video-first group and the simulation-first group during and after harassment, respectively

[d] Gender is coded as 0 for female and 1 for male

Table 4

Binomial Logistic Regression with Cluster Robust Standard Errors Results: EDA's Impact on Intervention Behaviour

					95% CI	
	OR(*β*)	*SE*	*z*	*P*	*LL*	*UL*
EDA during harassment	1.23(.21)	.21	1.01	0.31	-.20	.62
Training sequence group[a]	.22(-1.49)**	.50	-3.01	<0.01	-2.46	-.52
EDA baseline	.84(-.17)	.21	-0.81	0.42	-.58	.24
Gender[b]	.58(-.55)	.69	-0.80	0.42	-1.89	.80
Age	.99(-.01)	.07	-0.15	0.88	-.14	.12
Visible minority status	.17(-1.76)**	.66	-2.65	0.01	-3.05	-.46
Prior experienced of harassment	.11(-2.17)**	.81	-2.70	0.01	-3.75	-.59

Note. N =94. $\chi^2(7) = 19.24$. $p = .01$. Pseudo $R^2 = 0.13$. OR = Odds ratio β = coefficient. *SE* = standard error. CI = confidence interval. *LL* = lower limit. *UL* = upper limit. * $p < 0.05$. ** $p < 0.01$.

[a] Training sequence group refers to the learners' group assignment where 0 indicates the video-first group and 1 indicates the simulation-first group

[b] Gender is coded as 0 for female and 1 for male

Table 5

Frequency of Intervention Methods Employed by Residents in Response to Simulated Harassment Scenarios

Intervention	N_{Total} (%)	$N_{Video\text{-}frst}$	$N_{Simulation\text{-}first}$
Direct	17 (18.1%)	9	8
Distract	28 (29.8%)	16	12
Delay	15 (16.0%)	9	6
Delegate	0	0	0
Did not intervene	34 (36.2%)	9	25

Note. This table presents the frequency of various intervention methods employed by the residents across both training sequence groups, alongside instances where interventions were not utilized.

Table 6

Multinomial Logistic Regression with Cluster Robust Standard Error

	Null	***EDA and Training Sequence Group***	***EDA and Training Sequence Group with Covariates***	
	β(SE)	*β(SE)*	*β(SE)*	*RRR*
Direct				
Intercept	-.07(.58)	.28(.68)	6.69(6.02)	801.99
EDA during harassment	-.35(.19)	-.32(.19)	-.03(.23)	.97
Training sequence group[a]		-.71(.77)	-1.38(.90)	.25
EDA during baseline			.10(.41)	1.11
Visible minority status			-2.34**(.68)	.10
Gender[b]			-1.51(.86)	.22
Age			-.14(.20)	.87
Prior experience of harassment			-3.42**(1.13)	.03
Distract				
Intercept	-.10(.53)	.32(.53)	.22(1.96)	1.25

EDA during harassment	-.09(.18)	-.54(.21)	.33(.27)	1.39
Training sequence group[a]		-.93(.57)	-1.32(.56)	.27
EDA during baseline			-.28(.28)	.76
Visible minority status			-1.66(.89)	.19
Gender[b]			.22(.88)	1.24
Age			.04(.05)	1.04
Prior experience of harassment			-1.71(1.14)	.18
Delay				
Intercept	-.85(.55)	-.36(.51)	2.01(1.92)	7.47
EDA during harassment	-.01(.20)	.04(.21)	.30(.28)	1.35
Training sequence group[a]		-1.18*(.46)	-1.83**(.45)	.16
EDA during baseline			-.23(.23)	.79
Visible minority status			-1.60**(.59)	.20
Gender[b]			-.71(.72)	.49
Age			-.02(.06)	.98
Prior experience of harassment			-1.83(.84)	.16

Note. N =94. Pseudo R^2 = 0.11. β = coefficient. *SE* = standard error. RRR = Relative risk ratio. * $p < 0.05$. ** $p < 0.01$.

[a]Training sequence group refers to the learners' group assignment where 0 indicates the video-first group and 1 indicates the simulation-first group

[b]Gender is coded as 0 for female and 1 for male

Figure 1

Participant Inclusion and Exclusion Flow Diagram for the Current Study

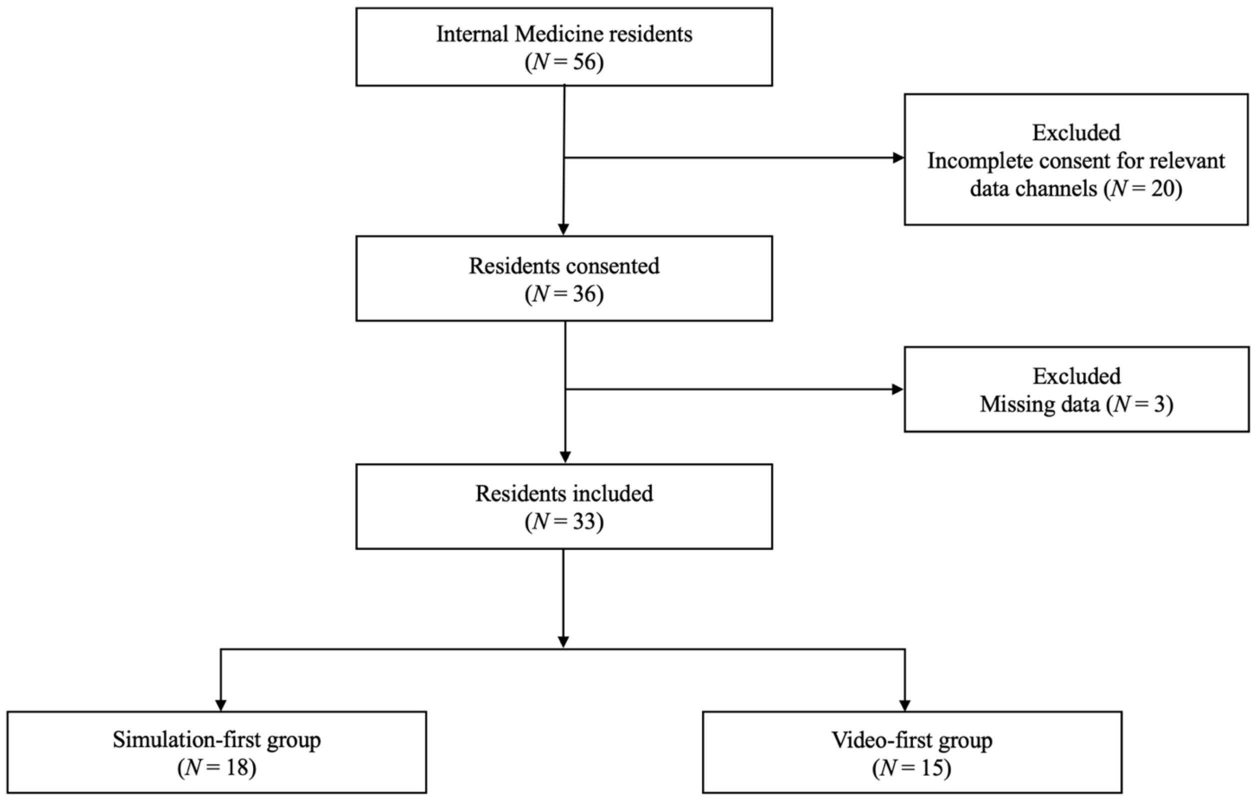
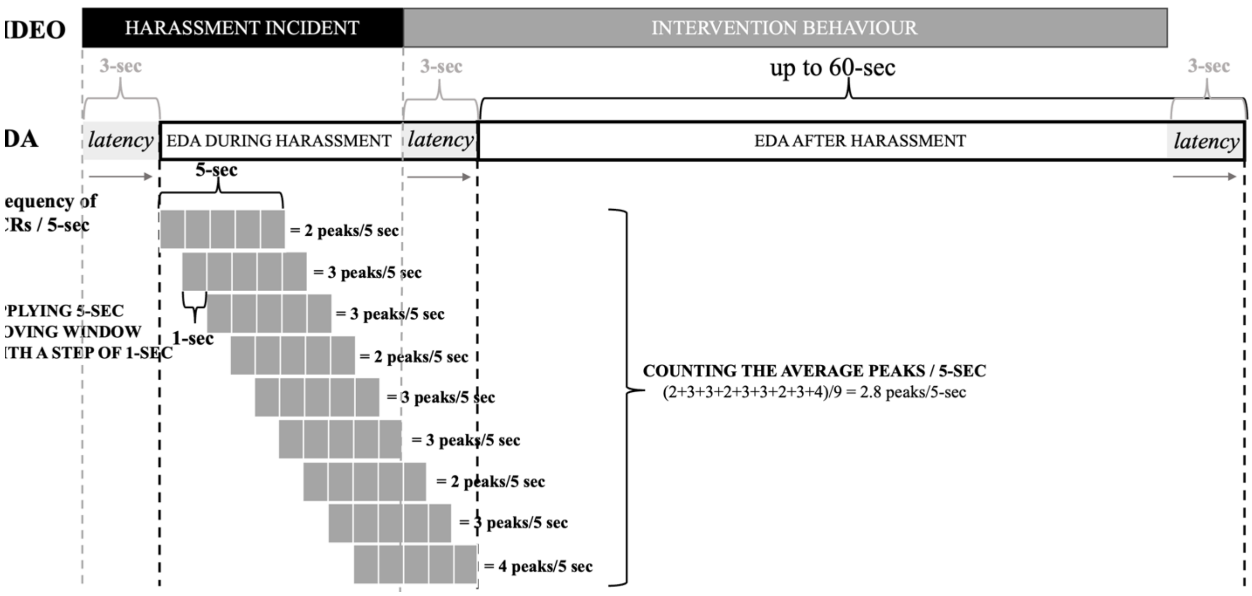


Figure 2

Methodology Employed for Analyzing the EDA Data



Note. A 3- second delay was incorporated to the onset of each event to account for the EDA latency. We then calculated the average frequency density of SCRs per 5-second segment for each event, using a moving window with a window width of 5 seconds and a moving step of 1 second. This method ensures accurate arousal measurement within the shortest feasible physiological time frames. This figure demonstrates the moving window applied to a sample frequency of SCR peaks in each 5 second segment of an abstract harassment event, followed by its 'after' period that starts once the harassment event is finished and could last up to 60 seconds.

Supplemental Material

Appendix A. Psychological Safety

We have deliberately incorporated psychological safety into our anti-harassment educational intervention, especially concerning the harassment bystander simulation component. We ensured such incorporation through the following methods: 1) following the Healthcare Simulation Standards of Best Practice (Watts et al., 2021); 2) consulting various content and education experts; 3) iterative development to script creation, including running through the simulation with graduate students and content and education experts, and adapting the script accordingly, 4) following strict ethics guidelines of our institutional review board; 5) analysis of data from our research findings; and 6) other considerations. We note that while providing education on harassment can indeed be sensitive to our learners, harassment has been widely and extensively reported to compromise healthcare professional trainees' psychological and, in some cases, physical, safety. Failing to equip medical trainees with tools to better manage harassment directed toward themselves or others stands to perpetuate, not protect them, from harassment. Internal Medicine and Surgery residents were selected because they are programs who have identified a need to better equip residents with tools to combat harassment. In this simulation, we focused on bystander interventions as we felt residents getting practice dealing with indirect harassment would be psychologically safer than having them practice managing harassment directed at them.

We first thoroughly incorporated the Healthcare Simulation Standards of Best Practice into our simulation design. The guideline highlights psychological safety as a required component in the overall simulation design. Specifically, the aspect of psychological safety is highlighted when concerning the pre-briefing, facilitation, debriefing, operations, outcomes and objective, and professional integrity in developing and delivering simulation-based training (Bowler et al., 2021; Decker et al., 2021; McDermott et al., 2021; Miller et al., 2021; Persico et al., 2021). Our simulation satisfies all of the outlined requirements by:

1) Clearly conveying the learning objectives and expectations during the pre-briefing and acknowledging the simulated nature of the learning environment. This included conveying how the harassment the learner will witness as a bystander is *simulated*, and therefore not real, and simulated for the purpose of practicing the harassment bystander intervention strategies.
2) Providing relevant instructional materials directly related to our simulation training that will help the learners understand and contextualize their simulation experience.
3) Allowing the participants to ask any questions prior to beginning the simulation for them to understand the ground rules.
4) Providing a non-competitive environment and clarifying that their performance in the simulation will not impact their academic or career standings in any ways.
5) Providing the simulation in an environment that allows for privacy, confidentiality, and open discussion.
6) The simulation ended with the facilitator and the involved standardized participants showing positive interactions and clearly acknowledging that any of the negative interactions during the simulation were indeed simulated. For example, the facilitator would always thank the standardized participants (i.e., actors) for their acting. In addition, the standardized participants themselves would acknowledge their acting and show positive interactions between themselves and the learner to illustrate how the simulation staffs are cohesive and no harassment occurred.

7) Providing debriefing that again emphasized the simulated nature of the harassment the learner witnessed, and the learning objectives and outcomes.
8) Explicitly stating in our simulation facilitation documentation an emphasis on the simulated nature of the harassment the learner will witness.
9) All stakeholders, including the simulation center staff, standardized participants, administrators, facilitators, researchers, and learners were all aware of the simulated nature of the harassment featured in the simulation. We ensured this by hosting a series of meeting, and ensuring all stakeholders had received our simulation facilitation documents that outline all details concerning our simulation.
10) Providing resources such as the institution's student wellness center that the learners can consult in case of any distress.

Second, we consulted various content and education experts concerning the nature of the harassment featured in our simulation, and how to best align the designed harassment interaction to the learning objectives, simulation fidelity, and psychological safety. Specifically, our simulation design has been vetted by:

1) Dr. Ning-Zi Sun: Associate Professor and Internal Medicine Residency Training Program Director, Department of Medicine, Faculty of Medicine and Health Sciences, McGill University
2) Dr. Jean-Sébastien Pelletier: Assistant Professor and Surgical Foundations Program Director, Department of Surgery, Faculty of Medicine and Health Sciences, McGill University

3) Dr. Liane Feldman: Chair of the Department of Surgery, Faculty of Medicine and Health Sciences, McGill University and Surgeon-in-Chief of the McGill University Health Centre (MUHC)
4) Dr. Gerald Fried: Associate Dean of Educational Technology and Innovation and Director of the Steinberg Centre for Simulation and Interactive Learning
5) Caroline White: Simulation Specialist Advisor at the McGill University Health Centre's Interprofessional Simulation Centre (MUHC-i-Sim)
6) Niki Soilis: Education Manager (at time of consultation) at the Steinberg Centre for Simulation and Interactive Learning, Faculty of Medicine and Health Sciences, McGill University
7) Dr. Melina Vassiliou: Associate Professor and Adar Chair of Surgical Education, Department of Surgery, Faculty of Medicine and Health Sciences, McGill University
8) Other research laboratory members with medical degrees: Dr. Osamu Nomura, and Dr. Lucia Patino Melo

Additionally, the following content and education experts were consulted with and vetted our approaches to ensuring psychological safety:

1) Dr. Farhan Bhanji, Associate Dean of Education, Faculty of Medicine and Health Sciences, McGill University

Third, we have gone through an iterative development process for our simulation. The lead developer gathered existing resources and guidelines on similar simulation training. He then conducted multiple phases of internal testing and rehearsals within the research team to create an initial draft of the simulation. This draft was circulated within the broader laboratory of the lead developer for further testing and refinement. Other collaborators, along with content and education experts, were invited to provide feedback and iterate on the initial versions of the simulation. Throughout every major iteration, the team's focus included not only the fidelity of the simulation but also the psychological safety of the prospective participants. All feedback regarding psychological safety was thoroughly evaluated and carefully implemented into the simulation design. After multiple tests of different types of harassment scenarios and subsequent reflections, we decided that, for example, no racially or sexually discriminatory remarks should be made. The principal investigator oversaw the development of the simulations, and actively took part in the rehearsals and deliberation of the simulation. These measures helped ensure the psychological safety of our participants while providing realistic harassment scenarios with a high degree of believability.

Fourth, we have followed the ethics guideline at our institutional review board, with the board reviewing the everything related to our research and education objectives. This included all documents relating to our facilitation documents, simulation scripts, and all other related rationales and documentation for delivering our educational intervention. Following the review board's guidelines, we have deliberately:

1) Proposed rationale for our simulation training—it provides a safe space for trainees to practice the bystander strategies covered by our instructional video series, and provides an opportunity for learners to receive tailored feedback for refining their mastery.
2) Provided consent forms that detailed how our learners are not forced to participate in our intervention in any way. Our educational intervention did require the learner to be present to start their training, or provide valid reasons for absence as our intervention was part of the *official curriculum* of our learners. However, the participants were allowed to stop at any time, and they had full autonomy of how they interacted in the

simulation (i.e., they were not forced to engage in the simulation in any specific way). Furthermore, learners could participate in the intervention, but opt out of the research study.

3) Specify the associated benefits and risks concerning the educational intervention. Specifically, we have specified the possibility of learners experiencing upsetting feelings during their educational intervention. However, we have also explicitly specified that they can at any time stop participating in the intervention, ask questions at any time during the intervention. In addition, the learners have a direct line of contact to the McGill Student Wellness Hub in case of any distress.

Fifth, at the time this document was written we had run 72 residents from surgery related departments, and 69 residents from internal medicine through this simulation. We have not received any concerns or complains about psychological safety from the residents. Conversely, several residents, especially from surgery, suggested that they would like to be challenged more, for example, by not knowing which simulation station would include the harassment training scenario: a measure we had included to maximize psychological safety. In addition, the data we collected on residents' self-reported emotions towards our simulation training supports psychological safety. Specifically, concerning our first internal medicine resident cohort to go through our simulation training, the mean value of the residents' self-reported anxiety was 2.92/5.00 (n=51), where 3 indicates the residents felt "neutral" when asked whether they felt anxiety towards the simulation activity (5 indicates that they "strongly agreed" that they felt anxiety, while 1 would indicate they "strongly disagreed" that they felt anxiety). On the other hand, mean value of enjoyment was 3.88/5.00 (n=52), reflecting how residents would generally agree that they felt some enjoyment towards the simulation activity. Based on our findings, we believe while the simulation was designed to be challenging, the residents did not report it being emotionally distressing.

Lastly, our other considerations included having our simulation training focus on bystander intervention first, as opposed to dealing with harassment directly targeting the learner. We believed that only after establishing mastery of dealing with harassment that indirectly affects the learner, we should explore how we can scaffold our learners to deal with harassment that directly targets them. This consideration of our learners' prerequisite skillset and knowledge also aligns with the Healthcare Simulation Standards of Best Practice. Further, we carefully avoided any harassment remarks that could be reasonably viewed as discriminatory, including but not limited to disability, race, gender, sex, sexual orientation, or religion. We did this to help minimize any potential triggers.

For the simulation scenario progression outline, please see Supplementary Material B. For the debriefing guideline for simulation facilitators, please see Supplementary Material C. For prebriefing guideline for simulation facilitators, please see Supplementary Material D. For consent form given to the participants for our internal medicine cohorts from the 2022-23 school year, see Supplementary Material E.

Appendix B. Simulation Scenario Progression Outline

Timing (Approx.)	SPs Actions	Expected Intervention	Possible Cues
0-1 min	Junior resident (JR): gets into gown and gloves • Senior resident (SR) helps		
1 min	Medical Student (MS): rushes into the scene ** First harassment scene	It may be too early to expect interventions	

	e.g., "Nobody asked why you were late. Just stand over there"		
1-3 min	JR: Prep insertion kit • Take catheter, cap two side ports • Flush saline for each port • Try thumbing the guide wire • Attach the finder needle to the syringe – drop some lidocaine ** Second harassment scene *e.g., "*Sigh… please don't drop your binder. What's wrong with you"*	Direct: Declare abuse as inappropriate Distract: Makes a joke or comment to ease tension Delegate: Call technician for help	
3-5 min	JR: Locate the site of insertion with the ultrasound. • Apply gel to suspected site Locate the jugular ** Third harassment scene *e.g., "What do you mean, in your opinion. Medicine is based on facts. If you didn't prepare, why are you even here?"*	Direct: Declare abuse as inappropriate Distract: Makes a joke or comment to ease tension Delegate: Call technician for help	Technician: Looks over at the scene
5-6 min	JR: Inject lidocaine to the surrounding area.		
6-8 min	JR: Locate jugular triangle; insert the finder needle guided by the ultrasound. • Apply negative suction pressure as you advance • Try drawing venous blood • Hold and stabilize needle – remove the syringe. Inset wire. • One hand should always be holding the wire ** Fourth harassment scene *e.g., "How do you not know to stay away from the sterile field? Are you an idiot?"*	Direct: Declare abuse as inappropriate Distract: Makes a joke or comment to ease tension Delegate: Call technician for help	Technician: Looks over at the scene

8-10 min	JR: Make NIC incision Then place dilator • Feed it over the wire Insert catheter • Wire should poke out of the middle port • Push the catheter into the skin Remove wire • Place last cap on the middle port • Flush each of the port with saline ** Fifth harassment scene *e.g., "This is dumb. I can't waste my time on this. Good luck with this one."*	Direct: Declare abuse as inappropriate Distract: Makes a joke or comment to ease tension Delegate: Call technician for help	Technician: Looks over at the scene
10-11 min	MS seems shocked. MS stands around for a moment, unsure what to do.	Delay: Check up on MS Delegate: Call technician for help	MS: "That was rough"

Appendix C. Debriefing Guideline for Simulation Facilitators

This simulation debriefing utilizes the PEARLS Healthcare Debriefing Tool

Setting the Scene

- Create a safe context for learning
- State the goal of the debriefing
- Sample phrases:
    - "Ok, so we have 10 minutes for debriefing. Before we start, I'm going to emphasize that this was all a simulation, and nothing said during the simulation was for real. Now, the goal of the simulation was to apply intervention strategies as a bystander to stop harassment, while being engaged in a technical procedure. Let's try to answer in simple one or two sentences to the next following questions."

Reactions

- Explore feelings
- Solicit initial reactions and emotions
- Sample phrases:
    - "How did you feel overall about the simulation?"
        - "What part of the simulation made you feel this way?
    - "When did you realize the medical student was being harassed?"
    - "When you first realized the medical student was being harassed, how did you feel?"
    - "How did you feel about being able to practice being a bystander in a harassment situation?"

Description

- Clarify facts
- Develop shared understanding of case
- Sample phrases:
    - How would you describe the intervention method you've chosen?
        - So, when the medical student started to get harassed, it seems like you chose ____ strategy, since you did ____.

Analysis

- Explore variety of performance domains
- Explore performance domains
- Sample phrases:
    - "What did you think you did well in intervening the harassment?"
    - "If you could re-do this simulation right now, is there anything you'd try differently?"
    - "Do you think you did well on your central line insertion?"

Summary/Application

- Identify take-aways
- Instructor centered (lack of time to be learner-centered)
- Sample phrases:
    - The key learning points were ____, and you can further your mastery by focusing on ____.

Appendix D. Pre-briefing Guideline for Simulation Facilitators

Read to the simulation learner:

- "Welcome to the anti-harassment simulation training. I'll be your facilitator for the simulation. You'll be participating in this simulation with standardized participants but otherwise you will be working alone. The objective of this simulation is for you to practice technical skills while effectively applying bystander intervention strategies in a harassment scenario. The technical skill we have chosen for this scenario is a central line insertion."
- "The scenario is as follows: You are a junior resident in a simulation setting, performing an internal jugular central line insertion on a mannikin simulator. With you are a medical student and a senior resident. The medical student is there to observe you and learn, while the senior resident is there to supervise and grade both your and the medical students' performance. The senior resident will harass the medical student. There will be a simulation technician on standby in case of any issues. Think of an intervention strategy you can use to remedy the harassment."
- "For the central line insertion, the patient will already have been positioned, and the tools you need are already gathered. The draping is already complete. You will begin the procedure starting from getting into the gown and gloves, priming the instruments, and using the ultrasound to locate the insertion area. You will not be suturing at the end of the procedure. Instead, if you reach this step of the simulation, consider the central line insertion to be complete. Before you insert the central line, you are expected to inject lidocaine in the surrounding area—please assume the drug takes effect immediately without waiting"
- "Remember, the harassment occurring here is not real, and is simulated for your learning."

- "Before we begin, I'd like to answer questions you have for this simulation."

Appendix E. Consent Form Given to Participants

Dear Potential Participant,

We would like to invite you to participate in our study, that is examining the attitudes and knowledge about harassment amongst graduate medical trainees. This research is funded by the Social Sciences and Humanities Research Council of Canada.

About the Study

Promoting resident well-being is a critical goal of educational institutions because it affects their academic achievement, retention in programs, and if not promoted, can lead to burnout and more serious problems such as depression and suicidal thoughts. Despite the related risks, research has shown that students and trainees from health sciences programs, such as medicine and nursing have been exposed to a high prevalence of harassment for decades, with no sign of meaningful improvement. Therefore, it is essential to provide support by enhancing students and trainees' awareness and knowledge about harassment. We invite you to participate in this study, which will involve you taking part in the anti-harassment training intervention designed to be integrated into various educational programs such as the Academic Half Days or the Surgical Foundations Bootcamp. The study will be linked to the anti-harassment training program and will take place at the appropriate simulation centre (e.g., Steinberg Centre for Simulation and Interactive Learning, or the Simulation Laboratory at the McConnell Centre for Innovative Medicine).

The first part of the educational study will involve you completing a questionnaire. These may contain questions regarding the following: 1) your experiences of harassment, 2) perceptions and attitudes regarding harassment and related policies, 3) motivation, 4) cognitive load, 5) emotions pertaining to learning harassment in healthcare education and related intervention techniques, 6) behavioural tendencies for dealing with harassment, and 7) knowledge about harassment and intervention strategies. The first part of the study will also involve you viewing a series of videos.

The second part of the study will involve you participating in a simulation designed to train bystander intervention strategies. This simulation may be part of your curriculum or educational program you are enrolled in (e.g., Academic Half Days, OSCEs). Regardless of your participation in this study, you will get to participate in these educational programs (i.e., the difference is whether we get to collect additional data or not). This second part of the study will be delivered to you in a separate session from the first part of the study.

For the duration of the educational study, when possible, you will be asked to wear an electronic wristband (like a smart watch like an Apple Watch) that will measure physiological data such as heart rates. You will be given a laptop computer to fill out the questionnaires and watch the educational videos. In the case where it is appropriate, you may be shown the educational videos in a group setting through a projector or on a monitor. The videos may also be sent or be shared with you via online meetings.

We would also like to ask if we could record videos/audios of the simulation, and use the data recorded from the videos for the purpose of data analyses. In addition, we are asking if we can use the recorded video/audios for the purpose of research dissemination (e.g., presenting them at educational and training sessions).

Data from the surveys, videos, and audios will be analyzed to determine the quality of our educational intervention. During the on-site simulation, you would receive regular feedback from your educator/facilitator/debriefer as usual. Your participation will not affect your performance evaluations. Nothing from the simulation scenario (e.g., Standardized Patient script, medical case information, etc.) would change from normal. We would not be changing or affecting the content of the educational activity.

We would be asking for permission to use your recorded data (which will include an audio/video of you during the simulation) which might feature your face/body/voice (this data will be kept confidential and won't be shared or published without your explicit consent). Should you choose not to participate or opt-out of specific data collection channels, your specific data will **not** be collected (for applicable data channels) or used for dissemination of research information and all identifying features of your person will be removed from the applicable recordings (audio/sensory/surveys).

You will be required to use your McGill account to participate in the study. This study will take approximately 60 minutes to complete for the first part. The simulation we have prepared for the second part of the study should take approximately 15 minutes.

Benefits and Risks

Our research will provide information on understanding what harassment is, how harassment can impact health professions trainees, and what resources are available to combat harassment. Our research will also provide an opportunity for you to practice bystander intervention strategies in a safe, controlled environment, with the addition of receiving individualized feedback. The findings of the study will support educational efforts to improve trainees understanding of harassment. You may also learn different strategies and resources that you can employ in the future if you encounter or witness a harassment situation.

While this is an educational, rather than a clinical study, there is still a small possibility that you may experience some upsetting feelings while thinking about harassment in education. If at any time you become distressed or upset, you may choose to stop participating in the study. You may also ask questions (see contact information below) at any point during the study. You may also contact the McGill Student Wellness Hub if you experience distress at 514-398-6017 (Downtown), 514-398-7992 (Macdonald Campus).

Confidentiality and Data Management

The information collected from the study will be shared through educational presentations and workshops. Key findings will also be shared to the general public through media outlets. Your information will be kept confidential and any identifiable information that you provide will not be disclosed in any reports or presentations.

The video/audio data will not be used in any way for formal evaluations of your performance. While the results from this study may be published, your identity will not be revealed. To protect your privacy, your information will be identified using numbers and/or letters (i.e., a participant ID). Only investigators and members of their research labs will have access to your raw video/audio data. While audio and video files may contain identifiable information such as participants' names or faces, these and all other associated files will be assigned to participant IDs and will not be shared with anyone without your explicit consent. Also, only investigators in charge of the study will know the participant ID linked to you.

All collected data and identifiable information will be stored in a password protected institutional cloud-based SharePoint account that will only be accessible by the principal investigator, investigators, collaborators, postdoctoral fellows, graduate research assistants, lab research coordinator, and an information technology technician during the conduct of the research and dissemination of results. Anonymized data will be stored in a separate password protected institutional cloud-based SharePoint account folder and be available to these research members and other research team members, including co-applicants and collaborators. The data will be kept up to five years after termination of project. After five years, the electronic data on the cloud-based database will be deleted to ensure secure disposal.

In addition, this consent form includes an optional consent question about whether we can use your raw audio and video recordings during dissemination of the results (e.g. at conferences, journal submissions, or education and training sessions). This is OPTIONAL and will not in any way affect your involvement in the study.

Lastly, whether you have participated or asked to withdraw your data from the study will not be known by your program director.

Compensation

There is a chance for financial compensation for participants fully completing the study, including the follow-up questionnaire. If you fully complete the study, you will be entered in a raffle for a chance to win a $25 EverythingCard electronic gift cards (your choice of gift card from many eligible stores; e.g., Amazon, Gap, Starbucks, etc.). Each participant will have a guaranteed 1 in 4 chance (25%) to win.

Ethics Approval and Contact

This study has been reviewed and approved by the Research Ethics and Compliance in the Faculty of Medicine and Health Sciences at McGill University (IRB: A07-B71-22B). If you have questions regarding the rights of participants, please contact the Research Ethics office at McGill University at ilde.lepore@mcgill.ca or by phone at (514) 398-8302. If you have questions regarding the study, please contact the study coordinator, Tony Ahn: sails-lab.med@mcgill.ca.

Thank you for your consideration to participate in our study. For updates regarding the study results, please visit our website at https://www.mcgill.ca/sails-lab/. If you agree to participate in our study, please indicate your consent from the following prompts under the section "Declaration of Consent".

Declaration of Consent

I have read the above information and have had the opportunity to have all questions answered to my satisfaction. I am aware that participation is voluntary, and that I may choose to consent below to have my audio/video recordings used for research purposes. I am also aware I may choose to consent to the collection of sensory recordings in addition to survey data. I agree to participate in this study. I am aware that by agreeing to participate in this study, I do not give up any of my legal rights.

I consent to participate in the self-report surveys and have my survey data collected and used for research purposes.

[ ] Yes
[ ] No

I consent to have my recordings via audio and video data collected and used for research purposes.

[ ] Yes
[ ] No

I consent to have my psychophysiological sensor data collected and used for research purposes.

[ ] Yes
[ ] No

______________________________ ______________________________

Signature of Participant

Signature of Person performing informed consent

______________________________ ______________________________

Name of Participant

Name of Person performing informed consent

Date: DD / MM / YY

Date: DD / MM / YY

Optional (Additional) Consent

I consent to having my video/audio records (videos featuring my face/body/voice) that will be gathered during this study used (e.g., played or shown) during dissemination of the results of this study at conferences and other venues (e.g., academic journals, educational and training sessions).

[ ] Yes
[ ] No

Signature of Participant

Signature of Person performing informed consent

Name of Participant

Name of Person performing informed consent

Date: DD / MM / YY

Date: DD / MM / YY

References for Supplementary Materials

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CHAPTER 5: DISCUSSION

This study explored the psychophysiological responses of 33 Internal Medicine residents to simulated and standardized harassment scenarios during a central line insertion procedure on a manikin, across two distinct training sequence groups: simulation-first and video-first. Via high-fidelity simulations we provided a realistic yet ethically sound environment for observing the learners' responses to witnessing harassment, mitigating actual patient risk (Al-Elq, 2010). The primary aim was to investigate how different training sequence groups influenced trainees' emotional arousal—measured by changes in SCR frequency (Boucsein, 2012)—during and following harassment events. Additionally, the study assessed how this induced arousal impacted the likelihood of trainees in each group actively intervening in harassment events, thereby exploring the interplay between emotional arousal and behavioural outcome in high-pressure medical settings.

Implications for Theory and Practice

The findings revealed significant increases in the arousal levels of trainees during and after harassment events compared to their baseline arousal levels. According to Pekrun's CVT (Pekrun, 2006), emotional responses in learning contexts are shaped by an individual's appraisal of control over the situation and the value they assign to the task at hand. In this scenario, the increase in arousal can be understood as reflecting the trainees' appraisal of the harassment as a critical threat within their clinical environment, which affects both their perceived control over the situation and the value they place on maintaining a safe learning environment. Moreover, the sustained arousal in the post-harassment period compared to the baseline arousal levels likely represents ongoing emotional processing (Kołodziej et al., 2019) and cognitive engagement (Bukoski et al., 2016). Furthermore, we saw the group exposed to the anti-harassment videos prior to engaging in the simulation (video-first group) exhibited elevated emotional arousal levels during the harassment scenarios compared to after the harassment. This notion further supported by CVT, indicates elevated levels of emotional arousal due to the increased awareness from the preliminary exposure to video materials that raised awareness before the simulation began. The enhanced arousal during harassment events could further reflect an increased psychological engagement or heightened awareness triggered by the preliminary contextual understanding provided by the video content. This insight is pivotal, indicating that the preparatory cognitive framing offered by video education could potentially augment the sensitivity and readiness of trainees to recognize and react to harassment, thereby influencing the effectiveness of anti-harassment training sequences in medical education. In other words, a deliberately structured training sequence integrating helpful video training components provides trainees with a structured approach to recognize and respond to observing harassment more effectively.

Additionally, the trainees assigned to the video-first group were more likely to take action during harassment incidents. The videos, by clarifying the complexities and consequences of harassment, not only enhanced awareness but also equipped trainees with effective strategies for intervention. This preparation likely bolstered their perceived control, making the harassment scenarios seem less daunting and more manageable. Furthermore, the videos emphasized the serious implications of harassment, thereby heightening the value trainees placed on intervening, which they came to view as a personal responsibility and a necessary step in promoting a safe training environment. This informed and readiness-enhanced mindset facilitated by the video content might explain why these trainees were more prepared and willing to engage in intervention behaviours when faced with harassment.

On the other hand, despite the trainees exhibiting heightened emotional arousal during harassment, these responses did not predict their intervention behaviours. This suggests that factors beyond immediate psychophysiological reactions—such as prior knowledge and experiences, personal values, and perceived consequences—may significantly influence decision-making after harassment incidents (Fischhoff & Broomell, 2020). Moreover, the context and severity of the harassment likely affect the appropriateness of various intervention strategies, shaping the trainees' choice of action. Furthermore, the lack of a direct correlation between emotional arousal, as measured by EDA, and intervention behaviours residents might be further understood through the lens of their advanced training and self-regulation abilities. Medical education, especially at the postgraduate level, emphasizes remaining composed under pressure, which could enable residents to modulate their physiological responses in stressful situations (Binkley et al., 2019; Quick et al., 2017). Such training might mitigate the direct impact of physiological arousal on decision-making processes, further highlighting the complex interplay between cognitive, emotional, and educational influences on behaviour.

Furthermore, the examination of intervention strategies employed by trainees during harassment scenarios highlighted distinctive behavioural patterns. In particular, a significant trend emerged in the use of the delay method, with the video-first group showing a greater likelihood of employing this approach. This inclination towards a more measured response could be explained by the video training, which could help participants perceive it as a safer strategy that minimizes the risk of retaliation from superiors. This finding suggests that preparatory educational materials can significantly shape strategic decision-making in complex scenarios. On the other hand, the study did not find any significant predictors, either from group assignment or EDA levels during harassment, for the use of direct or distract methods in tackling harassment. This indicates that the decision to confront harassment directly or to employ distraction techniques might be influenced by other factors not captured within this study's framework, pointing to potential areas for future research. Notably, no instances of delegation were recorded amongst residents, which could indicate a lack of perceived authority or resources within the simulation to effectively use this strategy, or it might reflect a training gap in encouraging reporting or seeking help. It is also likely that the residents did not ask for help and did not employ the delegate method to demonstrate their ability to work independently, reinforced by the expectation that this is part of their development as a physician in training (Jansen et al., 2021).

As noted in an earlier section, previous studies have explored anti-harassment interventions, but our research offers a novel approach that is unprecedented in the field. This study uniquely involved Internal Medicine residents engaged in a dual-task simulation, performing clinical technical tasks on a mannequin while simultaneously navigating harassment scenarios. This design adds a layer of realism by mimicking actual medical situations where harassment can occur during critical procedures, potentially disrupting both the procedure and the trainee's learning curve. Furthermore, we employed a combination of Electrodermal Activity (EDA) measurements and video recordings to objectively quantify emotional arousal and observe participant behaviours in real-time. The use of EDA provided a quantifiable, objective measure of arousal, reducing the reliance on potentially biased self-reported data. Coupling this with video data enabled us to conduct a real-time assessment of how effectively participants applied intervention techniques during the simulation. This methodological approach not only enhanced the reliability of our findings but also offered deeper insights into the immediate effects of harassment within a clinical setting and the efficacy of the intervention methods used by the participants.

Implications for Methodology

Building on the review by Hoovers (Horvers et al., 2021), our study acknowledges the critical need for standardized protocols in EDA analysis and thorough reporting to enhance the quality and comparability of psychophysiological research. We documented each step of our data collection and analysis process to hope to set a precedent for future studies and to address the gaps highlighted in previous research: 1) We provided a comprehensive account of our data collection methodology, including specifics about the device used, its placement on the participants, and a detailed explanation of any missing data along with the reasons for such occurrences. 2) We described our pre-processing and processing procedures in depth. This included clarifying how we cleaned the signals, the methods used to remove artifacts, and the specifics of any filters applied, including their frequency and order. We chose these settings based on their suitability for capturing reliable EDA signals and justified why these particular choices were made. 3) We outlined our approach to establishing a baseline, specifying its duration and how it was integrated into our analysis to ensure consistency and accuracy in measuring arousal responses. The deconvolution method employed was detailed, explaining how we separated the EDA signal into tonic and phasic components. This process is crucial for isolating the physiologically relevant signals associated with specific harassment events. 4) Finally, we described how we calculated the variable of interest, SCR frequency, for the event of interest. This step is vital for interpreting the psychophysiological impact of harassment scenarios accurately and was reported with precision to facilitate understanding and replication.

Notably, our analysis leverages the strength of statistical tests that account for the nested nature of the data, ensuring that the individual differences among participants are also considered. This methodological approach is a significant strength because it allows for more precise and accurate interpretations of the data. By acknowledging the nested structure, we are able to control for variability both within and between individuals, which is crucial in studies where multiple observations per participant are involved. This approach enhances the robustness of our conclusions by ensuring that the statistical inferences more accurately reflect the true effects of the interventions, free from confounding influences that individual differences might introduce.

This work hopes to contribute to the field by providing detailed explanations of the methodologies used, enhancing the ability of future studies to replicate our approaches effectively.

Limitations and Future Directions

Our exploration, while insightful, navigates within the bounds of certain limitations. This study primarily relied on EDA to assess emotional arousal, which, while valuable, does not encompass the full spectrum of one's underlying processes and bodily responses to stimuli. Future studies should incorporate a broader array of measures and data streams (e.g., heart rate variability, facial expression analysis) to gain a more comprehensive understanding of residents' reactions in similar scenarios. Furthermore, our participant pool was restricted to 33 Internal Medicine trainees, limiting the generalizability of our findings. Nonetheless, this is a common figure in studies involving medical populations (D. A. Cook & Hatala, 2015) and did not harmfully affect the power of any statistical analyses. Future research could expand to include residents from various medical specialties and countries, and explore different bystander training simulations, beyond our specific scenario, to assess the impact of harassment across a wider range of clinical settings. The simulated nature of the harassment scenarios may not fully replicate real-life dynamics, particularly the unfamiliarity between the participating residents and SPs (i.e., senior resident and medical student), which could influence performance and communication. While the portrayal of senior residents and medical students by different SPs in the span of months of conducting the study introduced variability that could have influenced the intensity of harassment scenarios and subsequently, the residents' responses, this variability has been accounted for through the use of our cautiously chosen statistical analysis. Shifting the focus to the methodology used in this study, the baseline physiological states of the residents were not established in a completely relaxed or calm environment due to the practical constraints of integrating this study into their curriculum. Consequently, using it as a covariate might have masked some of the EDA responses. The exclusion of harassment events shorter than 5 seconds was another limitation, as it potentially omitted data. However, this threshold was necessary to align with the physiological latency of the EDA response, ensuring that only significant arousal responses specific to harassment events were analyzed within the procedural context. Moreover, the focused analysis of EDA during only harassment segments may not fully capture the broader physiological impacts of the medical procedure and harassment. This was done in order to focus specifically on the results of harassment events, and not the impacts of emotional arousal on the technical procedure. Future research could alter the script the actors used to separate the procedural and harassment aspects in simulations to analyze EDA's responses to both separately. Additionally, future studies could be conducted to explore the effects of harassment incidents and subsequent emotional arousal on their clinical performance.

In sum, while this study provides critical insights into the psychophysiological responses of medical trainees to harassment and shines a light on the importance and effect of training sequencing, the outlined limitations and suggested future directions aim to enhance the robustness and applicability of research in this vital area of medical education and professional development. This study presents a robust EDA analysis within medical education research, offering new insights into the psychophysiological effects of harassment on medical trainees. The significant arousal levels detected during and after harassment underscore the profound impact of such negative interactions, highlighting the need for comprehensive anti-harassment training within the medical field. Although psychophysiological data do not predict intervention decisions, they reveal the intricate influence of cognitive, emotional, and educational factors on trainee behaviour. This research, a pioneering evaluation of EDA in harassment-focused bystander simulations in medical education, lays the groundwork for future studies and informs broader anti-harassment efforts across various professional settings.

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