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Using VR-based interventions, wearable technology, and text mining to improve military and Veteran mental health

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ABSTRACT

Introduction: Virtual reality (VR)-based interventions, wearable technology and text mining hold promising potential for advancing the way in which military and Veteran mental health conditions are diagnosed and treated. They have the ability to improve treatment protocol adherence, assist in the detection of mental health conditions, enhance resilience and increase a patient's motivation to continue therapy. **Methods**: This article explores five cutting-edge research projects designed to leverage VR-based interventions, wearable technology, and text mining to improve military and Veteran mental health. A computer-animated virtual agent provides online coaching for posttraumatic stress disorder (PTSD) patients in their own homes to enhance treatment compliance. A head-mounted display safely immerses PTSD patients in a virtual world to relive past experiences and associate them with new meanings. Gaming and simulation technology are tested as a way to improve resilience and performance in military members in deployment-related scenarios. Guidelines are developed for the creation of wearable assistive technology for military members and Veterans. Text mining is explored as a way to assist in the detection of PTSD. **Results**: VR-based therapy, gaming and simulation, wearable assistive and sensory technology, and text mining hold promise for diagnosing, monitoring, and treating military mental health conditions. **Discussion:** The five research projects presented have made promising contributions to the field of military and Veteran mental health, either by advancing diagnostic trajectories, contributing to therapy or enhancing the process by developing new approaches to delivering preventive or curative care.

Key words: military and Veteran mental health, NATO, PTSD, simulation technology, text mining, virtual reality, VR-based interventions, wearable technology

RÉSUMÉ

Introduction : Les interventions en réalité virtuelle (RV), les technologies prêt-à-porter et l'exploration de texte offrent le potentiel non négligeable de faire progresser le diagnostic et le traitement des troubles de santé mentale chez les militaires et les vétérans. Elles peuvent améliorer l'adhésion au protocole de traitement, contribuer au dépistage des troubles de santé mentale, accroître la résilience et améliorer la motivation du patient à poursuivre le traitement. **Méthodologie** : Le présent article explore cinq projets de recherche de pointe conçus pour stimuler l'utilisation des interventions en RV, de la technologie prêt-à-porter et de l'exploration de texte afin d'améliorer la santé mentale des militaires et des vétérans. Un agent virtuel animé fournit un encadrement en ligne au domicile même des personnes présentant un trouble de stress post-traumatique (TSPT), afin de favoriser l'adhésion au traitement. Un visiocasque immerge les patients ayant un TSPT en toute sécurité dans un monde virtuel pour leur faire revivre des expériences et les associer à donner de nouveaux sens. Les jeux vidéo et la technologie de simulation sont mis à l'essai pour améliorer la résilience et le rendement des militaires dans le cadre de scénarios liés au déploiement. Des directives sont en cours d'élaboration relativement à

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la création de technologie d'assistance prêt-à-porter pour les militaires et les vétérans. L'exploration de texte fait l'objet de recherches pour contribuer à dépister le TSPT. **Résultats** : Les traitements en RV, les jeux vidéo et la simulation, le port de technologie d'assistance ou de technologie sensorielle prêt-à-porter et l'exploration de texte se révèlent prometteurs pour le diagnostic, la surveillance et le traitement de troubles de santé mentale chez les militaires. **Discussion :** Les cinq projets de recherche présentés apportent une contribution prometteuse au domaine de la santé mentale des militaires et des vétérans, que ce soit en faisant progresser les trajectoires diagnostiques, en contribuant au traitement ou en améliorant le processus grâce à de nouveaux modes de prestation des soins préventifs ou curatifs.

Mots-clés : exploration de texte, interventions en RV, OTAN, réalité virtuelle, santé mentale des militaires et des vétérans, technologie prêt-à-porter, technologie de simulation, TSPT

INTRODUCTION

This article presents five cutting-edge research projects that are designed to leverage VR-based interventions, wearable technology and text mining.

METHODS

1. Virtual coaching

Posttraumatic stress disorder (PTSD) has a high impact on quality of life[1] and, although effective treatments exist,[2] barriers to care still prevent many survivors of trauma, including military members and Veterans, from receiving the care they need.[3] Some of these barriers could be removed with the help of technology, such as systems that allow for participation in online therapy at home. Such systems provide a cost-effective, privacy-sensitive and accessible option for therapy, but also have challenges. One main challenge is the ability to provide patients with personalized support, a factor particularly relevant to exposure therapy for PTSD, as it requires patients to actively confront individualized fears. Virtual agents (computer-generated, animated, virtual human characters) are one way to address this issue, as they have been shown to improve treatment compliance and even treatment outcomes in other domains[4] (Figure 1). However, using a virtual agent for PTSD treatment has its own unique challenges. Therefore, the technology for the Virtual E-coaching and Storytelling for PTSD (VESP) therapy project sought to investigate how a virtual agent could enhance treatment compliance by informing, assisting and motivating patients.

Psychoeducation is an important part of exposure therapy for PTSD, as it provides information to patients about why it is helpful to confront traumatic memories.[5] In standard therapy, such information is usually presented by a therapist. A virtual agent could verbally present this information, but technology also offers other options, such as allowing patients to read the text on screen. Presentation by a virtual agent might increase trust in the agent and reading the text may allow a user to better remember the information. To study this further, an experiment was performed where participants were

Figure 1. Four different virtual agents

presented with psychoeducation about expressive writing. One group received the information verbally from a virtual agent, while the other group read text from a computer screen. Afterward, a virtual agent asked both groups to select a negative memory to write about. Data shows that, while participants' attitudes toward the agent and recollections of information presented influenced how well they adhered to the task, neither of the groups was directly affected by the way in which the information was presented. However, when controlling for these two factors, the group that received the information textually showed better adherence than the group that received the information verbally from the virtual agent.[6]

The core of exposure therapy for PTSD is the recollection of memories. Given the difficulty of this task, assistance can be very helpful. One potential way for a virtual agent to offer personalized assistance is through asking the right questions. To equip a virtual agent with knowledge on which questions are relevant, at the Technical University in Delft, an ontology was created for traumatic memories. This ontology provided the virtual agent with information about the types of locations, objects and people that are likely to be associated with the memories. Additionally, the ontology stored information about questions relevant to the locations, people and objects. In a study involving recollection of holiday memories, a similar ontology was shown to increase the level of detail provided in answers to an agent's questions.[7]

Due to the difficult nature of exposure therapy, it is important that patients are motivated, as sometimes, symptoms get worse before they get better. To offer personalized motivational messages, a virtual agent requires knowledge of what to say in a particular situation. For this reason, experts were asked to provide motivational statements for imaginary patients who had a specific type of symptom progression and a specific level of trust in a good therapy outcome.[8] Using this input, a motivational system, capable of generating personalized messages, was built. A recent study showed that motivational messages can improve reported motivation and trust, and that personalized motivational messages are particularly important in situations where symptoms initially worsen.[8]

The three studies discussed demonstrate how a virtual agent can inform, assist and motivate patients during home-based, online treatment of PTSD. The multi-model memory restructuring system (3MR) is one version of a home therapy system involving a virtual agent. The system operates with a digital diary to describe memories (Figure 2) and also has a virtual environment where memories can be recreated.[5] This work shows how a virtual agent can help increase detailed memory recollection, adherence to treatment protocol and motivation to continue therapy, with an eventual goal to improve treatment outcomes in home therapy for PTSD as it is thought that this engages patients in performing therapy, and by spending time with it facilitates recall. Moreover, it helps structure and contextualize past experiences.

2. VR Exposure-based Rehabilitation in Immersive Contexts (ERIC): A novel high-tech way to personalize exposure-based treatment of PTSD using VR

Virtual reality (VR) with a head-mounted display (HMD) is a technique that can be used to actualize/

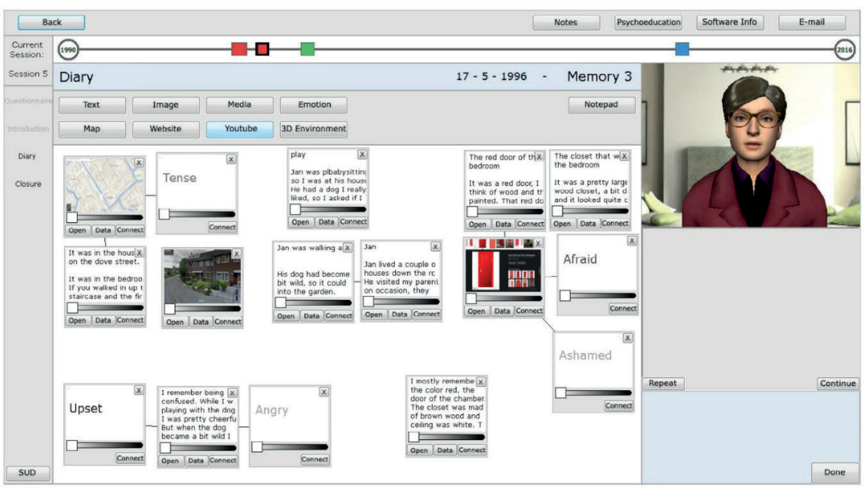

Figure 2. Digital diary to describe memories is a virtual environment in which memories can be recreated

realize the objective of interaction and engagement in a scenario that has taken place in the past. This has benefited the military and Veteran population to simulate battlefield experiences at various locations in the world and personalize experiences. With modern techniques, such as eye tracking, voice-to-text, wearable sensing devices and a protocol based on exposure, an immersive treatment can be offered that has a strong capacity for eliminating anxiety-conditioned experiences and reconsolidating dysfunctional cognitive schemes. Fragmented relaxation exercises can also be built into VR so patients can create a phased exposure. Finally, there is a narrative element in the VR environment that can provide new meaning to experiences and store them in a personal document.

VR is an advanced form of human-computer interaction[9] that enables users to interact with computers and digital content in a more natural and sophisticated manner compared to what is provided by standard keyboard or mouse devices. Immersive VR can be produced by combining computers, HMDs, body-tracking sensors, specialized interface devices, and real-time graphics to immerse a participant in a computer-generated, simulated world that changes in a natural and intuitive way using head and body motion. This project (named below) offers a novel way to provide graded exposure in a virtual world. Novel VR exposure-based therapies are increasingly reliant on immersion and gamification. Typical HMD systems allow for an immersive world that provides participants with the ability to explore sensations, feelings and memories in a safe environment, and interact with elements that remind them of the distant past. The Military Mental Health Care of the Dutch Armed Forces developed a novel VR-based interactive system built on layers of immersion in a virtual world. The project was exposure-based and focused on immersion and guided imagery with personal pictures. The approach was similar to the novel 3MR,[10] except this system is used in a sedentary position.

VR with HMD is a technique that can be used to actualize/realize the objective of interaction and engagement with a scenario that has taken place in the past.

Sometimes, patients cannot properly enter an imaginary state. Even when they can, a therapist cannot always imagine exactly what they see. As a result, the patient often has to describe both their feelings, as well as the imaginary vision being experienced. This may affect the patient's ability to remain immersed in the imagined state. In close co-operation with the Military Mental Health Care Unit of the Royal Netherlands Army, the Simulation Centre of the Netherlands Armed Forces in Amersfoort built a VR demonstrator, called the Exposure-based Rehabilitation in Immersive Contexts (ERIC). Using ERIC, a patient can be immersed in a chosen, safe virtual world, such as a beach, study or forest, while seated in a chair. The patient is seated at a table that houses a series of control elements, including a radio, objects to reduce fear, and has visual and verbal 3D contact with a therapist through a virtual TV. The patient is asked to organize a series of self-selected photos into a book and supply them with cognitive and affective stamps (Figure 3). The therapist will help with ordering and rating the cognitions associated with the trigger images and will follow the patient's gaze with a built-in eye tracker. The patient will learn to tolerate traumatic affect and identify cognitive associations with trigger images, while having the ability to control their exposure.

Exposure will be offered through a stepped approach and relaxation exercises can be used in the virtual world. Several techniques are available to practice self-control under conditions of increasing exposure, including biofeedback (visualization of heart rate alterations to mitigate fear), battle breathing and relaxation exercises such as listening to music. Sessions are designed to allow participants to control exposure in the immersive virtual contact. Since the connection between the subject and the therapist is virtual, this approach can be used either in standard settings, where the patient and therapist are in the same physical location, or from a distance, when the patient and therapist cannot be in the same physical location due to travel time or other reasons.

This project is a work in progress, aimed to optimize personalization for military members and Veterans with PTSD.[11] Future directions include: implementing text to speech to capture connotations for images, including triggers to reduce fear, controller-free interaction, event logging, external sense stimulation with heat, wind and smell, and more. During development, the product will be tested by the Military Mental Health Care Unit and will be validated by an official military authority for operational use.

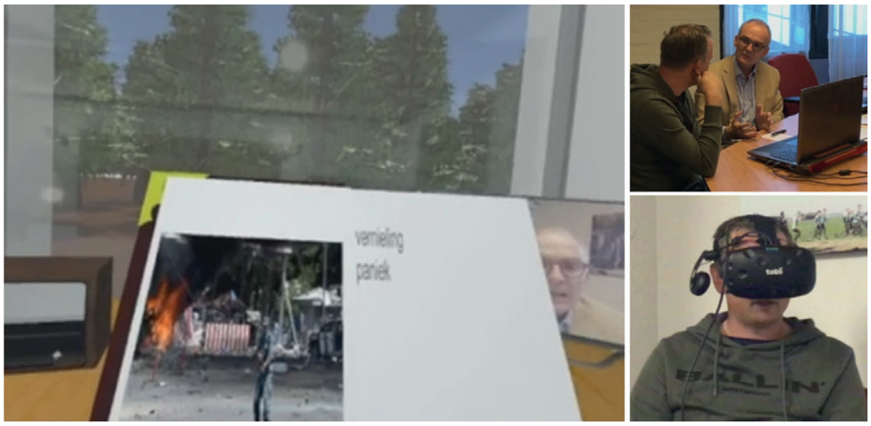

Figure 3. VR view from the HMD of a patient. A book on a table displays self-selected images. The self-selected images are displayed on the left page. Text to describe memories and emotions connected to the images can be added on the right page. A computer screen on the table of the patient (left) allows for virtual contact with the therapist. The window outside displays a virtual world that can be changed according to needs. Behind the book there is a radio where the patient's favorite music can be played, serving as reminders for the images displayed. Between images, there is opportunity to play distractor games, or perform relaxation techniques. This environment is calibrated to increase the overall immersion of the experience to maximize engagement. On the right are pictures of the setting of the intervention.

VR = virtual reality; HMD = head-mounted display

3. VR gaming and simulation to induce, measure, and gather feedback on the stress response of soldiers: Project AMPERE (augmenting military performance and resilience enhancement)

Dealing with high levels of emotional, cognitive and/or physiological stress is an essential skill of soldiers, since their profession requires performing in complex and high-pressure environments. At the same time, enhancing military resilience and troop performance, ensuring a high level of operational readiness among forces, and providing the best care for military personnel, is one of the most important challenges.[12,13] The Dutch Ministry of Defence launched a research program that examined innovative approaches in resilience and performance education and training. The development of both VR gaming and simulation technology, along with applied miniaturized sensor and monitoring technology, presents a great opportunity for advancing performance in the physiological and psychological resilience of military members who may experience high levels of stress and associated underperformance during deployments. This important opportunity can be harnessed by combining these technologies, as VR gaming and simulation have the potential to introduce military scenarios relevant to the context of future deployments, as well as familiarize soldiers with tasks and duties that induce controllable and relevant stress levels in soldiers. Sensor and monitoring technology can be set to measure, classify and provide feedback on stress responses and has the potential to educate and train soldiers experiencing increases in stress how stress impacts their performance, and how to cope with – and regulate – the impacts of stress. Based on this, a VR simulation and measurement environment were developed by the Netherlands Organisation of Applied Scientific Research (TNO) containing a controllable Virtual Reality Monitoring (VRM) platform.

The VRM platform is comprised of oculus rift goggles to simulate a relevant military task environment (a military patrol mission) and to increase soldiers' immersion within the virtual simulation. Next, muscle stimulation equipment was attached that generated a pain sensation to increase stress and distraction from the task. A fan was synchronized to the screenplay to simulate an airstream whenever the patrol vehicle moved. A game controller was provided to participants to answer questions related to the task in order to measure their performance. The VRM monitoring apparatus consisted of an array of sensors and devices to measure heart rate (HR), heart rate variability (HRV), blood pressure (BP), galvanic skin response (GSR),[14] and saliva cortisol using salivettes.[15] Deriving from HR and BP measures, cardiac output (CO) and total peripheral resistance (TPR) were calculated to classify stress in challenge and threat responses.[16] During task execution, a cognitive task performance score (CPS) was registered and digitized questionnaires were used to assess mental responses, such as the Dutch version of the State and Trait Inventory[17] and the General Self-Efficacy Scale[18] to assess emotional state. Finally, the threat and challenge state were assessed to attempt to correlate the physiological with the psychological classification of threat and challenge.[19] Sixty-three cadets of the Royal Dutch Academy volunteered to participate during the initial validation experiment and to undergo the simulated military patrol scenario.

Results showed the VRM platform setting is able to increase physiological (HR, CO, TPR, and GSR) responses. Moreover, several psychological outputs, such as state anxiety scores, were correlated with physiological responses (cortisol samples), and the cognitive task performance scores showed a significant increase or decrease per participant. The main impact of the VRM platform was measured in the beginning of the scenario, as the cadets engaged the new environment and had to adapt to the VR task and context. In addition, at the end of the scenario, when the patrol was ambushed, physiological and mental responses increased, to some extent. Although group analyses of variance revealed no significant indices of challenge or threat, in-subject analyses showed a number of participants were challenged to perform well and three even showed indices of being threatened. These results will now be used by the Royal Dutch Academy to develop profiles of soldiers with higher or lower response rates to the simulated stress environment, in an effort to develop tailor-made VR training interventions.

4. Wearable assistive technologies as integrated design solutions: From the lab to the real world

In the field of Veteran mental health and well-being, many new wearable assistive technologies are emerging. These technologies enable the measurement of physiological and behavioural stress markers that can effectively predict a person's experienced level of stress. Predictive stress models, based on neurological data that can be used to control such wearables, are also being introduced. Despite these promising technological developments, there are still barriers to use when it comes to creating assistive technologies that can function in the context of everyday life.

Developing wearable assistive technologies as integrated design solutions would allow these technologies to move into the real world. Assistive technologies should be developed as integrated technical solutions that can function in unpredictable settings. This requires a different approach to technology development, as compared to optimizing the performance of systems, which typically requires testing (isolated) functions in controlled lab environments. Assistive technologies should be developed for those that will actually use them. The technologies should be comfortable to wear, user-friendly, socially accepted and non-stigmatizing. This can be achieved by adopting a human-centered design approach that is sensitive to the socio-cultural contexts in which these technologies will be used.

Three design guidelines to develop wearable assistive technologies into integrated design solutions

Three guidelines to develop wearable assistive technologies into integrated design solutions are proposed below. These insights come from design research conducted at Delft University of Technology in the context of health care innovation.[20,21] When wearable assistive technologies are designed according to these guidelines, there is a higher chance they will be used,[22] and thus able to make a positive impact on people and health care practices (Figure 4).

Guideline 1: Wearable assistive technologies should be appealing

The sensorial and semantic appeal of the technology is important to users considering their acceptance and

Figure 4. Relaxation training glove intended to be friendly, intuitive, and respectful. Design by Felix Quadvlieg

use.[23] Wearable technologies should feel comfortable on the body and should be easy to carry. They should be easy to use, which depends on how the user interface is designed and showcases the functions of the technology. Its form and interactivity should be consistent and should clearly communicate its function. Lastly, wearable assistive technologies can even be enjoyable to use. The materials used in the design can be beautiful, and the manner in which the device functions can be motivating, increasing the likelihood of use.

Guideline 2: Wearable assistive technologies should be respectful

Wearable assistive technologies should not replace human skills but empower users by enhancing sensitivities and capabilities. Designers and technologists require an empathic understanding of people who find themselves in challenging life situations, acknowledging the type of support required, and how technology can assist users in supporting themselves.[24] Wearable assistive technologies should be developed to provide support in respectful and collaborative ways, avoiding situations in which technology dominates or overpowers the user. Designing wearable assistive technologies that provide users with a mechanism to follow, overrule, or ignore notifications, is one way in which technology can be designed collaboratively.[25]

Guideline 3: Assistive technologies should be socially appropriate

Wearable assistive technologies are perceived to act appropriately when they are designed with awareness of the socio-cultural contexts in which they will be used. For example, wearable assistive technologies that are visible as technical devices, and perhaps produce noise, will not be appropriate for use in public settings. Potential feelings of embarrassment and stigma may prevent adoption by users,[25] although benefits of use are clear. Understanding how wearable assistive technologies are socially integrated also contributes to their appropriateness. These technologies have a presence in family life, and may be shared among peers or colleagues, or used to mediate a client-therapist relationship. In such cases, consideration needs to be given to privacy and sociability in order to determine appropriateness.

5. Text mining

The information age has made it easy to store and process large amounts of data, including both structured data (e.g., responses to questionnaires) and unstructured data (e.g., natural language or prose). As an additional source of information in assessments, textual data has been increasingly used by cognitive, personality, clinical, and social psychologists in attempt to understand human beings.[26,27,28] The question of how to handle textual data, and how to combine it with structured data in psychiatric and psychological assessments, remains a major theme to be explored. Two main research questions can be asked: (1) How can applying text mining to narratives, collected in the framework of psychiatric and psychological assessment, be used to make classification decisions (e.g., PTSD)? and (2) How can the outcome of text mining and the item response theory (IRT)-based outcomes of responses to questionnaires be simultaneously modelled to validate the text mining procedure and enhance the quality of the measurement and classification procedure? In an attempt to answer these questions, three research methodologies were applied in this study: text mining for handling unstructured data, IRT for handling structured data, and the combination of these two methods using a Bayesian framework.

RESULTS

A new intake procedure was developed for assisting in the detection of PTSD. It combined the use of advanced text mining techniques and item response modelling in one framework. The research mainly consisted of three parts: a computerized text classification of patients' self-narratives to screen for PTSD, exploring the generalizability of diagnostic criteria for PTSD in the *Diagnostic and Statistical Manual of Mental Disorders, 5th edition* (*DSM-5*) using item response modelling, and combining textual assessment of patients' self-narratives and structured interviews in the PTSD identification process. Using 300 self-narratives collected online, a textual assessment method based on the DSM already distinguished people at high or low risk of developing PTSD. The text mining approach resulted in a high agreement (82%) with the psychiatrists' diagnoses and reveals some expressive characteristics in the writings of PTSD patients.[29] Although the results of text analysis were not completely analogous with the results of structured interviews in diagnosing PTSD, it was concluded that the application of text mining is a promising addition to assessing PTSD in clinical and research settings.[29] The generalizability of DSM-5 diagnostic criteria for PTSD to various subpopulations can be explored using IRT techniques. In addition to identifying differential symptom functioning related to various background variables – such as gender, marital status and educational level – it is also important to evaluate the impact on population inferences made in health surveys and clinical trials, and on the diagnosis of individual patients. It was concluded that the DSM-5 diagnostic criteria for PTSD did not produce substantially biased results in the investigated subpopulations, and there should be few reservations regarding their use.[30]

Considering the positive effects of either text mining or IRT, as discussed above, a combination of two methods was proposed to further strengthen the benefits from both sides. Text mining and item response modelling were used to analyze patient writing and response to standardized questionnaires, respectively. The whole procedure was combined in a Bayesian framework, where the textual assessment functions as an informative prior for the estimation of the PTSD latent trait. Results show that, by adding textual prior information, the detection accuracy is increased, and the test length can be shortened.[30]

This model was adapted from psychiatric datasets to an Internet dataset that consisted of both textual posts and responses to scales related to self-monitoring skills on Facebook.[31] The importance of validating data collected from the Internet was emphasized and the relationship between self-monitoring skills and textual posts on Facebook wall was explored. Textual analysis was conducted via both structured and unstructured approaches. To link the results from these two approaches, the keywords extracted by text mining techniques were mapped onto the framework of Linguistic Inquiry and Word Count (LIWC), a commonly used psychology-related linguistic software package.[32] The variable of the word "family" was found to be the most significant predictor in LIWC. Emoticons and Internet slang were extracted as the most robust classifiers in the unstructured textual analysis. The conclusion was drawn that textual posts on Facebook walls could partially predict users' self-monitoring skills. The accuracy rate is expected to enhance if variables from LIWC, and keywords extracted from text mining, can be used in combination in future studies.

Finally, it can be concluded that the work is important, as the introduction of text mining provides a new perspective to handle structured and unstructured data in a common framework. Text mining, together with IRT, is expected to be a promising tool in psychological and psychiatric assessments in the future.[33] A next critical step is the implementation of this new approaches in current practices of screening and mental health care.

DISCUSSION

The five cutting-edge research projects presented here are designed to leverage VR-based interventions, wearable technology and text mining. They have made promising contributions to the field of military and Veteran mental health, either by advancing diagnostic trajectories, contributing to therapy or enhancing the process by developing new approaches to delivering preventive or curative care.

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