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Virtual Reality at Workplace for Autistic Employees: Preliminary Results of Physiological-Based Well-Being Experience

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ABSTRACT

Emotional health problems in the workplace often hinder the integration and retention of autistic employees (AE), a challenge identified in many sectors. Recent literature highlights the consequences of these problems, such as burnout leading to reduced productivity and resignation. Previous research supports the effectiveness of virtual reality (VR) for training a variety of specific skills (e.g. riding a bus or plane travel), as well as more complex social skills, such as emotion recognition and functional communication. In addition, existing studies on using physiological self-monitoring in AE training offer a promising approach to promoting improved emotional health. The present paper reports on implementing a VR system that simulates workplace training and integration and enables real-time monitoring of three physiological signals, in five post-secondary autistic students. Using an Oculus Quest 2 and non-clinical grade sensors, the researchers delivered the VR intervention over three days to each participant. At the end of these interventions, the researchers measured the perceived satisfaction of these integrated systems, based on several technological criteria, on a 5-point scale. The integrated system received an overall rating of 4, suggesting its likelihood of acceptance and use. A preliminary analysis of a participant's physiological responses to this VR intervention is also presented. This preliminary report suggests the efficacy of a VR workplace simulation and physiological self-monitoring in promoting emotional well-being and basic task training for post-secondary AE. The researchers' observations and the proposal of a theoretical framework to enhance real-time emotional communication based on physiological markers for AE are also discussed.

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Introduction

Recent surveys indicate a worrying 85% unemployment rate among autistic employees (AE) with a post-secondary degree. Even those who find employment often find it challenging to maintain their jobs to the desired extent, and many remain unemployed [1]. Research has been conducted to propose viable solutions to adapt work environments to accommodate AE [2, 3]. In a first study, a TRIZ-based methodology was used to identify strategies for improving workplace adaptation for AE, which aimed to improve recruitment and job integration processes, and levels of job retention. Among the many criteria identified, a prominent concern of the focus group was to understand and address their emotional well-being in the workplace, a key challenge that directly affects job retention [4].

Physiological self-monitoring has proven to be a useful assistive technology for autistic people. In this study, we question to what extent it is possible to couple this approach with a virtual reality simulation of the workplace to study the physiological responses linked to the emotional health of AE during the job-related tasks execution in the workplace?

To address this research question, the following four objectives were outlined to:

1. Implement a physiological self-monitoring system for emotional self-regulation in a simulated virtual environment.
2. Determine the impact of the virtual work environment on physiological indicators related to the emotional health of AE.
3. Assess the satisfaction of AE towards the proposed self-

monitoring system and its integration in a virtual workplace simulation.
4. Elaborate a methodology for interpreting the emotional health of AE that allows associating their feelings with biometric data collected during temporally specific events.

Literature Review

Assessing the well-being of AE for their inclusion in the workplace is effective [5]. These assessments rely primarily on communication protocols regarding fixed facts that must be well-structured and address job satisfaction and general feeling during working hours [6]. Accurately assessing a task-related sentiment can be a significant challenge for AE for various reasons [7]. Indeed, workplace communication adaptations present obstacles, such as difficulty with social interactions, oral instructions, or crowded places. However, depending upon the context and the moment, the reaction of the EA would not be the same. Faced with the observation that it is not possible to produce a list of situation categories that can be modeled on what an employee is experiencing in a specific context, we have turned to a different approach [8]. In order to understand why AE are feeling differently than neurotypical people during a workplace social interaction, we need to consider that AE display an atypical sense of self boundaries. Indeed, AEs' perception of self is often referred to as atypical ipseity, which encompasses of course the AE, others and the environment [9]. According to Cooper, emotional cues from others are part of the AE perception and need to be considered in new workplace interaction strategies [10].

Interoception and mental health are proven to be deeply linked [11]. During this process, AE may have difficulty identifying the cause of their feelings, given the complexity and multiple source of these perceived feelings, especially when they come from external entities. As a result, alexithymia manifests and produces a tendency to focus more on external events rather than one's own feelings [12]. That interpretation fuses internal feelings with external signals and produces a never ending alert mode. The AE continuously assesses their environment for potential threats or changes for which they need to adapt [13]. Neurodivergent's constant state of vigilance might explain why an AE may find a familiar and safe environment less stressful. Due to the neurological recognition of repeated environmental data, social training for AE involves using assistive technology that could promote safety feelings, as it increases self-limits [14, 15]. However, despite this training, AEs intrinsically perceive external events as part of themselves. To belong in the workplace, the AE strives to compensate for their atypical self-perception [16]. Yet, unfamiliar situations, especially those involving unexpected social interactions, often occur in the workplace and can trigger unanticipated emotional experiences [17]. Furthermore, to avoid being judged or stigmatized, AE undergo considerable effort to mask their struggles, which could lead to psychological discouragement that can be detrimental to their emotional health [18-20]. Moreover, they try to keep their diagnosis secret [21]. Given these observations, communicating the emotional problems experienced by AE is a complex task. Most of the time, when AE finally ask for help and need special accommodations, they have already surpassed a safe mental state, putting them at risk of experiencing burnout [22].

Current Intervention

The hypothesis driving this study suggests that if AE engage in real-time self-monitoring, it could aid them in managing their emotions more effectively, ultimately helping them reach their objectives [23]. Notably, it has also been shown that this approach yields positive results for autistic people [24]. Its application, however, requires the provision of a specific context. This article details a methodological approach for setting up a physiological-based self-monitoring system within a workplace simulation intended for online workplace training of AE. This system prepares AE for possible unexpected social circumstances in the workplace. In addition, it allows for a more accurate understanding of employers' expectations, which would create a favourable professional environment.

This report forms part of a comprehensive study that seeks to explore the intricate interplay between the emotional health needs and expectations of AE in the workplace. The findings and comprehensive analysis of this larger study extend beyond what is covered in this particular article. For a more detailed exploration and insights, please refer to our "Impulsion" project website at https://www.criv.online/impulsion-frqsc. In brief, the various phases of this extensive study included the following steps:

1. An online survey was conducted with representatives of inclusive companies and students with disabilities in Quebec, Montreal and Sherbrooke on the employability of post-secondary students living with a disability.
2. We conducted an ergonomic study in an inclusive company employing AE, which identified key organisational patterns between tasks, situations and employer expectations.
3. We collected testimonies from managers, mentors who have worked with AE and a creation of a focus group. This focus group included human resources representatives and representatives of the Quebec Association for Equity and Inclusion in Post-Secondary Education (AQEIPS).
4. We conducted a literature review related to the needs of AE in the workplace.

What emerges from these previous stages is the importance of being able to identify when the mental health of AE may be undermined. This has become our main objective and we have decided to propose a methodology capable of providing real-time insights into their emotional well-being in the workplace, particularly while they engage in specific tasks. To achieve this, we have opted to convey their emotional well-being through physiological indicators, drawing from both brain activity and parasympathetic activity.

These preliminary results are part of a larger ongoing analysis studying participants' physiological responses to this VR intervention to promote their well-being in the workplace and facilitate positive social interactions. For this study we made use of a module that simulates VR-based workplace training and integration combined with a physiological self-monitoring system. We report on the perceived satisfaction of these integrated systems based on 14 technological criteria and preliminary results of the physiological responses of a participant during a VR intervention session.

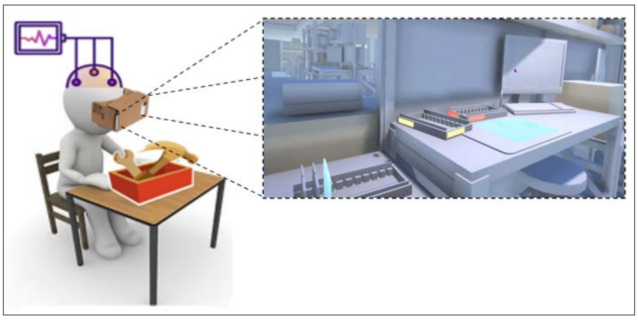

Figure 1: In the context of a work environment simulation that aims to remotely train AE, we propose the integration of a

physiological self-monitoring system in order to make the user aware of their own physiological markers based on cerebral activity and parasympathetic activity. These markers are intended to be easily communicated to the AE in real time while exploring the virtual environment.

Methodology

Procedure

This study was aimed at male and female post-secondary students with a diagnosis of autism. Each participant explored the virtual environment by wearing a head-mounted display (HMD). A tutor (companion, representative of the company) also used a head-mounted display but was in a different room; this companion showed the virtual environment and guided the participant in the tasks to be carried out within the virtual environment. To know more about our VR simulation, please refer to our presentation video [1]. The experience took place over 3 days, during which participants explored the virtual reality interface that simulates the workplace and were guided by their companion. During the sessions, three physiological signals (Mindave© eSense metrics of Attention and Meditation and respiratory sinus arrhythmia) were collected via wearable sensors, presented in real-time within the virtual environment to the participant and stored for our analyses.

Participants considered eligible had to be adult males or females in post-secondary education, or high school seniors, and had to have a diagnosis of autism. Participants had to be able to make informed decisions and understand the development of the experiment. Participants were also required to possess a particular interest in looking for employment, or in receiving training, in a virtual reality simulated company. No previous experience with virtual reality systems was required to participate in this study. We recruited participants through a general invitation to the Laval University student community. Participants were informed of the development and the objectives of this research project, including those of the physiological signal collection and the expectations of the virtual reality simulation aimed at improving the well-being at work of EA through a form approved by our ethics committee. Each participant, of legal age, has consented to participate by signing a consent form.

Materials

The VR intervention was delivered on a head-mounted display (HMD); which presented the audiovisual stimuli to the users. The Oculus Quest 2©, (Meta) HMD used for this study allows the scene to be broadcasted from the computer, allowing the use of computing resources and thus reducing latency. Hand controllers were also used to allow the user to move freely within the virtual environment.

Physiological Measures

To measure parasympathetic activity, we used the Emotibit© sensor, a portable, lightweight, non-invasive, and wireless sensor, which can collect more than 16 biometric signals. Its 3-wavelength PPG sensor enabled us to detect volumetric variations in blood circulation. The heart rate data extracted from the PPG was collected at a frequency of one sample every 100 ms, and it was transmitted via WiFi to a computer.

To measure electrical brain activity, we used the Mindwave© Mobile 2 headset (Neurosky©), a portable, lightweight, non-invasive, and wireless EEG system, which can safely collect several EEG signals (alpha waves, beta waves, etc.), NeuroSky eSense© meters (Attention and Meditation) and eye blinks. The device consists of a headset, an ear clip and a sensor arm. The reference and ground electrode are in the ear clip and the EEG electrode is in the sensor arm, resting on the forehead above the eye corresponding to the FP1 position of the 10/20 system.

Figure 2: The experiments involved recording the user's brain activity and parasympathetic activity. (Left) The user wears the head-mounted display in conjunction with the Mindwave© Mobile 2 portable EEG headset. (Right) To measure parasympathetic activity, the Emotibit© wireless sensor was used, which allows up to 16 different biometric signals to be stored.

Offline Metric Calculations

We used the method described in Porges and Bohrer, extended by Abney to estimate the RSA value using a time-based approach [25, 26].

This method for estimating the RSA consists of three main steps:

1. The recorded PPG signal is visually inspected to remove motion artifacts.
2. Inter-beat intervals (systolic peaks) are then estimated, and a band-pass filter is applied to the entire time series to isolate the variance in the frequency range of spontaneous respiration.
3. For each time window defined as 120 seconds (5 second step) the RSA value is obtained from the filtered time series by calculating the natural logarithm of the high frequency components of the heart rate variability (0.15 to 0.4 Hz).

Attention eSense™ Metric

This metric indicates the intensity of the user's level of mental "concentration" or "focus", such as that which occurs during intense concentration and directed (but stable) mental activity. According to the manufacturer, distractions, wandering thoughts, lack of concentration or anxiety can reduce the levels of this metric.

Meditation eSense™ Metric

This metric indicates the user's level of mental "calmness" or "relaxation" and is based on a person's mental levels. Meditation is related to reducing the activity of active mental processes in the brain, and the effect of closing the eyes has been observed to shut down the mental activities that process the images in the eyes, so closing the eyes is often an effective method of increasing the level of the Meditation meter. According to the manufacturer, distractions, wandering thoughts, anxiety, agitation and sensory stimuli can lower Meditation meter levels. For the two eSense metrics mentioned, the value of the meter is indicated on a relative scale from 1 to 100.

Online Metric Calculation and Real-Time Transmission to The Virtual Environment

The panel of physiological measures for auto-monitoring proposed here is based on the principle of becoming aware of one's own physiological states, which consists of using instruments to reflect physiological processes of which an individual is not normally aware so that they can voluntarily control these processes. The expected utility was to provide a useful tool for the person who is integrating to a new work environment to be able to emotionally self-regulate. Its design is a set of 3 bars showing the level of 3

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different physiological measures. This panel is displayed on the right wrist of the virtual avatar. Its design is unobtrusive, it can be consulted at any time and can also be hidden when desired. On the panel itself, there are three icons each representing one physiological signal as shown in Figure 4. The 3 physiological signals we have included are: the level of mental workload, the first icon and the first bar from top to bottom, the level of relaxation, icon and bars in the middle, and the physiological measurement of RSA which refers to the bottom bar. This numerical value is interpreted and expressed here using a very simple graphic representation that is inspired by health bar video game graphic design. To achieve the display of these signals in real time and within the virtual environment, we have employed a simple custom pipeline, represented in Figure 3. The processing flow begins with the wearable emitting its signals via WiFi (Emotibit©) or Bluetooth protocol (Mindwave©), then, using a script, an external PC received this data, and, in the case of the RSA metric, we applied some pre-processing stages of filtering, processing and calculation of the metric. This would then allows us to create a .csv file where only the last values received or calculated are stored and finally, another script embedded within the virtual reality application reads the .csv file and interprets it into the level bar format.

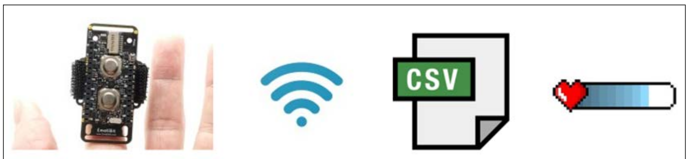


Figure 3: Pipeline for real-time communication of biometric signals to the user. The processing of this data starts with the sensor broadcasting via Bluetooth (Mindwave©) and WiFi (Emotibit©) physiological information. A script is responsible for calculating and saving the latest available values of these signals in a .csv file. Then, a second script embedded in the virtual simulation is in charge of translating this .csv file into a level bar format, inspired by the health bars in videogames.

Since the Mindwave© headset already sends a numeric value on a scale from 0 to 100, the script translated this value into a visual display, where each segment of the level bar corresponds to values in intervals of ten. That is, if at a given time the MindWave© obtained a value of 64 from the user in its Attention metric, only 6 fragments of the attention bar in the biometrics panel were displayed.

The same process was applied for the display of the real-time RSA value, however, since the Emotibit© does not generate an RSA value as such, a previous calculation step was employed. This calculation step follows the same logic as the sequence for RSA calculation described in the previous section, i.e., a time series in a specified time window is spectrally analysed, where the RSA value is obtained from the natural logarithm of the high frequency (0.15 to 0.4 Hz) components of the heart rate variability. This time window was defined at 120 seconds. The bar level then reflected the RSA value calculated from the last acquired time window.

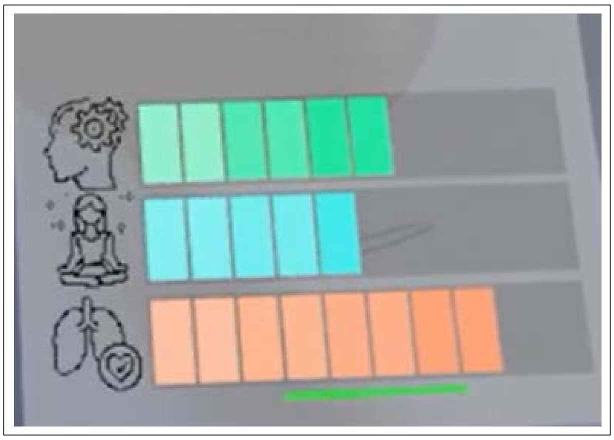


Figure 4: The small panel is displayed on the wrist of the virtual avatar, on which there are three icons representing three physiological measurements. The 3 biometric signals we have included here are: the eSense© Attention metric, the first icon and the first bar from top to bottom, the eSense© Meditation metric, icon and bars in the middle, and the physiological measurement of RSA or respiratory sinus arrhythmia which is referred to in the bottom bar.

Table 1: Description of the Possible Ranges of Values for the Level Bars of Each Metric

Signal	Color	Image	Interval values
eSense© Attention	Green		Integer value between 0 and 100, retrieved directly from the wearable.
eSense© Meditation	Blue		Integer value between 0 and 100, retrieved directly from the wearable.
RSA	Orange		Positive floating-point value, obtained from the natural logarithm of the high frequency (0.15 to 0.4 Hz) components of HRV.

Results

Perceived Satisfaction

The table 2 below presents the first results of our survey presenting the main points of the evaluations and comments of participants during their experience with our VR simulation.

Table 2: Scores for ÉSAT_DCV Questionnaire

	Mean (n = 5)	Most important items
Related to the virtual companion and physiological self-monitoring integrated system, how are you satisfied with the :	Score on 5	
1. Size	4,8	0
2. Weight	4,6	0
3. Adjustment Ease	4,0	1
4. Equipment Security	4,8	1
5. Equipment Sturdiness	4,8	0
6. Interaction Possibilities	5,0	2
7. Easy Adjustment of User Interface	4,0	0
8. Biometric Data Feedback	4,3	3
9. Easy Use of Interface	4,0	2
10. Equipment Comfort	4,0	1
11. System Effectiveness to Train Oneself	4,8	0
12. Device Learnability	4,4	1
13. Content Shown	4,2	2
14. Remote Assistance Accessibility	4,8	2
Mean Score - Global appreciation of the assistive technology	4,0	

Preliminary Report on Physiological Responses

Figure 5 shows the time series of a participant's RSA value during the use of the virtual companion interface. This session lasted 16 minutes and during this time the RSA values varied between 1.4 and 2.5 ln(ms2). Similarly, figure 6 shows the averages and confidence intervals of the RSA values during three phases of the virtual companion session: at the beginning, during the middle stage of the session, and towards the end of the session. An increase in RSA values can be observed from the beginning to the middle stage, and from the middle stage of the session towards the end.

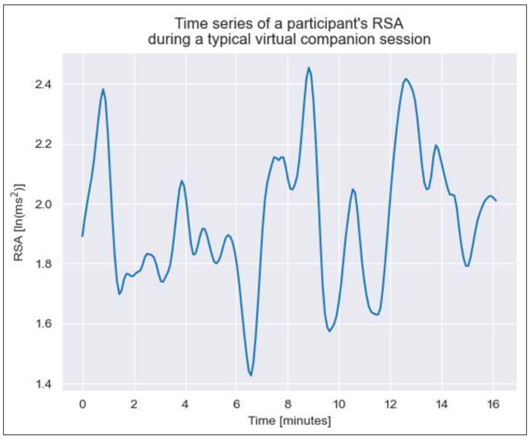


Figure 5: Curve of the RSA values of an AE during a typical virtual companion session. The series of values are retrieved from the processing of the PPG signal coming from the Emotibit© sensor. This curve also corresponds to the instantaneous values displayed in real-time on the biometrics panel inside the virtual environment.

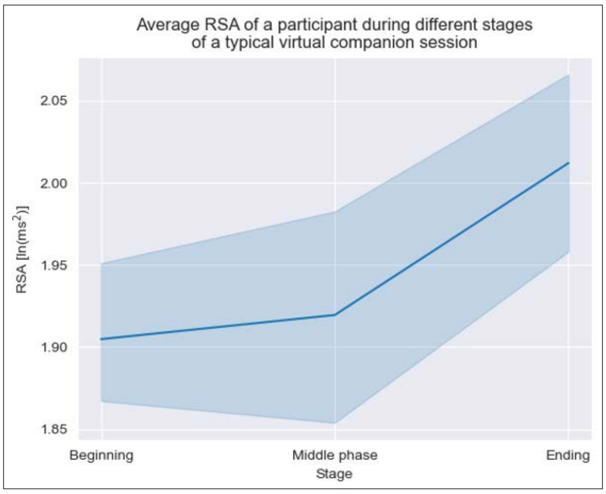


Figure 6: Curve of the average RSA values of an AE during a typical virtual companion session. The contextualization of these values corresponds to different phases of the session: at the beginning, during a middle phase and at the end of the session.

Figure 7 shows the time series corresponding to the values of the eSense© Attention and Meditation metrics for one participant during the use of the virtual companion interface. These values reflect the levels in these metrics obtained directly throughout the session and are based on a scale from 0 to 100. Figure 8 shows the means and confidence intervals of both metrics during three phases of the virtual companion session: at the beginning, during the middle phase of the session and towards the end of the session. A decrease in the values of the Meditation metric is observed from the beginning to the middle phase of the session, and an increase from the middle phase of the session towards the end. Additionally, a decrease in the values of the metric Attention is observed from the beginning to the intermediate phase, and from the intermediate phase of the session towards the end.

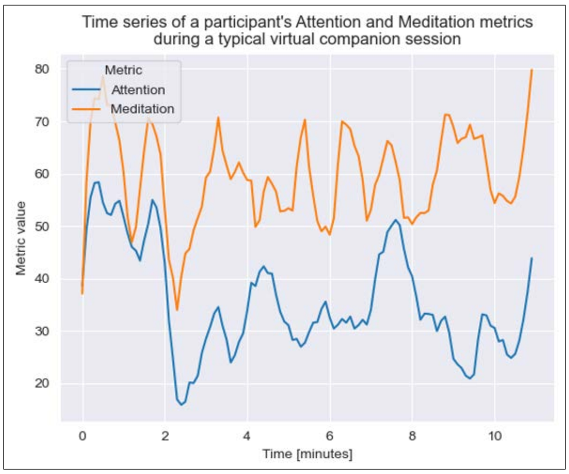


Figure 7: Curves of the values of the eSense© Attention and Meditation metrics of an AE during a typical virtual companion session. The series of values are obtained directly from the Mindwave© brain activity sensor. These curves also correspond to the instantaneous values displayed in real-time on the biometrics panel inside the virtual environment.

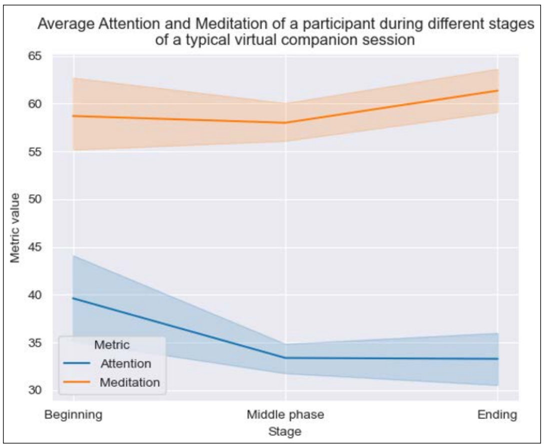


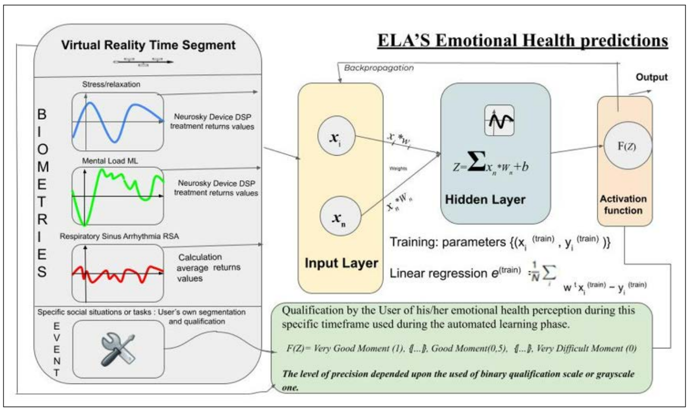
Figure 8: Curve of the average values of the eSense© metrics of an AE during a typical virtual companion session. The contextualization of these values corresponds to different phases of the session: at the beginning, during an intermediate phase and at the end of the session.

Discussion

In the preceding section, the initial results concerning the user experience of an AE during the experimental stage were detailed. This stage involved an exploration of a simulated work environment in virtual reality, with user reactions visualized in real-time via an interpretation of physiological data displayed within the VR interface. These findings demonstrate that this system offers a straightforward, portable means for identifying indicators of emotional health within the context of a work environment.

From analyzing the primary findings of this experimental phase, it became clear that while the physiological representation model implemented does provide a quick snapshot of physiological state extremes, it does not facilitate more nuanced or complex interpretations. For instance, it falls short in distinguishing whether a detected stress level stems from simple excitement or from actual work pressure. Moreover, cross-referencing with another metric does not contribute to a more precise contextual understanding of the user's emotional state. It results critical to remember that the relevance of biometrics is contingent upon the context, and post-experience analysis that incorporates this context could be greatly beneficial.

Indeed, within the scope of this study, the physiological signal interpretation is restricted to the feelings elicited in the immediate moment of the simulation. However, it does not provide any qualifiers for the emotions experienced nor allows for specific moments to be discerned in retrospect. If, for instance, an employee wishes to delve deeper into their emotional responses during specific segments of the simulation, and further practice self-assessment, the current system does not support the selection of a specific time slot during the experiment or the ability to label that exact moment with the user's impression of their emotional state.



To address this issue, an approach that considers the unique perspective of individual users while maintaining simplicity in the process is proposed. The Recurrent Artificial Neural Network (RNN) architecture offers a simple methodology for implementing automated various associations between user's qualifying judgments and the numerical data reflecting their physiological state. This association is strictly confined by the user's choice of specific moment segmentations within the VR system. These segments could pertain to a particular task, conversation, or location. This segmentation provides a reference for all physiological measurements and enables the user to describe their feelings during the event. This is crucial as this feedback will be used during the machine learning phase of the RNN. The system is then able to operate in real-time, providing users with not only indicators but also predictions of their potential feelings.

Perspectives

It is worth noting that the approach demonstrated here employed a basic method, with a binary output to simplify the process. However, rather than a strict "0 or 1" response, we would recommend employing a continuous function ranging from 0 to 1 to qualify each biometric measure per time frame. It is also important to recognize that although each measure was treated individually for demonstration purposes, the learning phase could be somewhat demanding as it must be conducted separately for each user, signal, and treatment. Another approach could incorporate all data into a single neural network architecture using implicit representations as described in Li's literature review [27]. Such a neural network type would streamline a portion of the analysis, focusing only on the final phase to implement the learning step, which would be predicated on the overall emotional statement of the segmented time frame.

Nonetheless, the utilization of Recurrent Neural Networks (RNN) in this context engages the user at every stage in evaluating their corporate training and collaborative sessions. This aligns with the main objective, to ensure that the AE participates in every step of the problem-solving process. One could potentially use pre-existing databases that provide a statistical norm for each physiological signal, thus bypassing the need for RNN when evaluating whether a signal indicates excessive stress or cognitive load. However, using such a statistical "norm" can prove problematic when applied to neuroatypical individuals. This approach is overly generic to capture the unique manifestations of AE, and comparison against a "norm" has been shown to potentially cause social harm to AE [28].

Therefore, the proposed methodology necessitates active AE participation and assessment at every step, as it is designed to be implemented with, by, and primarily for them. They hold the decision to share their results relating to demonstrate a particular situation. Ethically, it is not advisable to allow access to others without consent as it could produce undesired consequences. Furthermore, results capture a specific moment and are not reflective of one's overall efforts, as the adjustment process using biofeedback is a training process which takes time. The system offers AE a straightforward mean to self-assess their wellbeing at the workplace. It doesn't pinpoint the exact cause of a specific feeling but provides part of the context. With minimal recording of raw data, it also ensures data security for users hesitant to share diagnostic information.

In essence, this system provides a method for self-assessing emotional states at the workplace during specific situations and is designed to support job retention. It's essential to note that biofeedback and signal processing are just facets of the system. The collaborative guidelines provided in an exploratory way could be equally significant in fostering inclusivity and understanding. While the details are not fully discussed in this study, providing a space for AE to express, practice, and share their personal interests could be beneficial for employers in fostering a more emotionally supportive environment and enhancing job retention for AE [29]. Considering these avenues, it could also be very relevant to keep the digitized universe and the specific support even when the AE is present in the physical workplace space, with the help of, for example, augmented reality. We would like to continue this work in this direction in our next studies.

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