

# Machine Learning and Therapeutic Strategies in VR

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## ABSTRACT

Cognitive behavioral therapy is one of the few treatment options for individuals suffering from psychological and physiological abnormalities like phobias, post-traumatic stress, stuttering, and anxiety. They are expensive in both cost and time, and are often difficult to evaluate for effectiveness. Virtual Reality (VR) can ameliorate ineffective and costly therapies, because it effectively reproduces stressful environments, and is mobile enough to be used at home. However, psychological therapies are supervised by highly trained psychiatrists whose years of experience help them diagnose patients' problems in a personalized manner. Can we use Machine Learning (ML) to glean information from patients that allow for such tailored-made therapy training for VR systems? Machine Learning of subject training history and behavior allows the system to adapt therapies to individual levels and needs. Machine Learning of sensor data that provide details of patient stress levels in time gives us moment-to-moment responses that can be used to customize their training in terms of difficulty and responsiveness. We detail use of these ML strategies in the case of helping stutterers cope with immanent episodes of public and social speaking using VR with systematic desensitization. 23 stutterers and 4 speech pathologists participated in our user studies, which refined our prototype to lower relaxation fidelity, reduce scene blur, and improve voice efficacy. Use of Artificial Intelligence (AI) in VR technology serves to enable customization and adaptive training while maintaining the ease-of-use and comparatively low cost over traditional therapeutic strategies. This research opens up possibilities of using ML to customize levels, encounters, and environmental complexity in interactive experiences utilizing biometrics and in-game behavior.

## CCS CONCEPTS

Human-centered computing -> Interaction design -> Interaction design processes and methods -> interface design prototyping.

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Computer systems organization -> Embedded and cyber-physical systems -> Robotics -> Robotic autonomy.

## KEYWORDS

Machine learning, virtual reality, stuttering, immersive therapy.

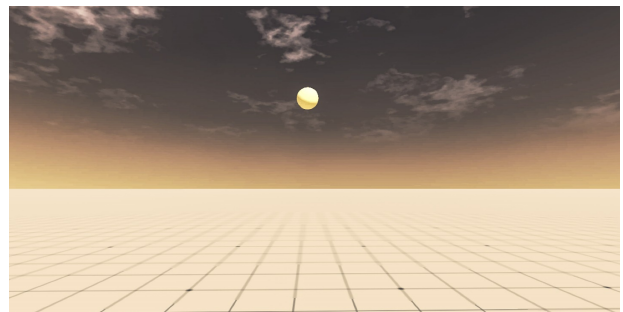
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## 1 Introduction

Machine Learning (ML) has been applied in areas as diverse as image recognition, medical diagnosis, and customer service. It has been envisioned that in the near future, we will be *surveilled* by sophisticated image algorithms, analyzed by AI doctors, and talk to virtual agents with domain-specific knowledge.

Virtual Reality (VR) is currently revolutionizing the gaming industry, but its use in installation art, professional services, and training paradigms are positioned to disrupt the industry. Immersive experiences can bypass traditionally expensive and ineffective strategies, creating physically impossible to construct buildings, simulate complex psychotherapies, and previewing mission critical tasks that can only be executed once in real life.



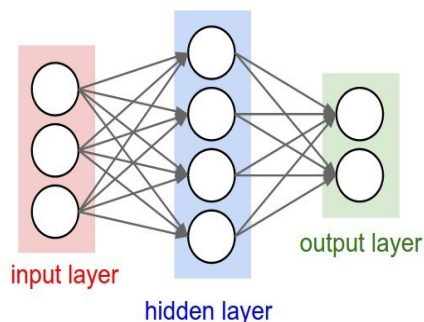
**Figure 1: VRbal: virtual reality therapy app for stutterers to train for public and social tasks that uses machine learning to customize training paradigm from behavioral and sensor data.**

If future technologies are so intricately tied to ideas of using and inventing new uses for ML and VR, are there use cases for the use of both, which combines the ability to customize and predict user experiences of ML with the immersive and portable expressiveness of VR? We explore a use case tailor-made to utilize the capabilities of ML and VR: the case of therapy-based training for dealing with anxiety and stress, in particular, in public speaking and stuttering speech in social interactions.

## 2 Background

1 in 68 children in the US have been diagnosed with Autism Spectrum Disorder, and the majority of them suffer from communication difficulties. At the same time, 1% of the total population suffer from stuttering, with lifetime incidence of 5% [11]. These people with communication disorders often find social scenarios stressful. Current treatments often include practicing “pretend-play” (Applied Behavioral Analysis) with therapists to prepare them for real world scenarios. In that case study, slow repeated reading and emotion expression exercises were practiced improving the mental condition of a 10 year old [12].

However, these techniques do not awaken similar emotions in the patient as would the real situation due to the fact that it is not considered a sufficiently realistic simulation of the scenario. Moreover, therapists do not always understand the gravity of the specific situation because they don’t have the full sensory tracking data of their patients, who frequently suffer from anxiety disorders [10]. As such, tech for improving stuttering is in increasing need of being developed [16]. To address these issues, we propose a flexible, portable VR system that uses ML to interpret user responses and physical states to create individualized training paradigms to complement or reduce the need for expensive, time consuming behavioral therapies. Previous work using ML for therapy has mainly been using chatbots that check in daily with the patient, but its effectiveness has been questioned [6]. VR environments for therapy like Mimerse, CleVR, and SimSensei all lack the supervision and customization that comes with ML strategies, even though studies have shown that adaptive strategies benefit training for children with autism [13].



**Figure 2: ML: A multilayer neural network. Input layers relay info to hidden and output nodes, where the desired output “trains” the weights in the network to make subsequent inputs fall more in line. Source: Glosser.ca.**

Machine Learning as a discipline emerged originally from the work of Canadian psychologist Donald Hebb, who postulated that when two neurons fire together, their strength of connection is strengthened [8]. This insight shows how associative learning, a model for how we learn everything from behaviors-rewards to names-people, can arise in neural networks. Further development of the idea took a computational turn with the work of Frank Rosenblatt, who codified the idea computationally, but later machine learning research was hampered by discovery that simple computational model of a neuron cannot code for certain math functions such as the XOR [15].

ML research activity was partly revived with the insight that computational neurons connected together can implement complex functions (Figure 2), and importantly, an efficient algorithm devised for calculating weight changes that result from learning [18]. More recently, more complex algorithms that uses multiple layers of nonlinear neural networks adapted from earlier models [17] have been used to win Chinese character classification contests, chess, and famously the game of Go, using Google’s AlphaGo.

Virtual Reality emerged from the experience theatre concept in the 1950s, but its digital manifestation came from work on input devices as diverse as head-mounted displays and the Aspen Movie Map, created by MIT as a virtual tour of Aspen, Colorado. In that program, textures were mapped onto 3D models, providing an early immersive experience from first person points of view. Gaming is the platform that transformed VR. Consumer headsets like Sega VR and Quick Time VR began to make the technology available to everyone, while today, applications like Google Street View are making VR on the web possible. 360 degree cameras have made video production for VR possible, while companies like Oculus and HTC are optimized enough for tracking head directions to make popular use possible.

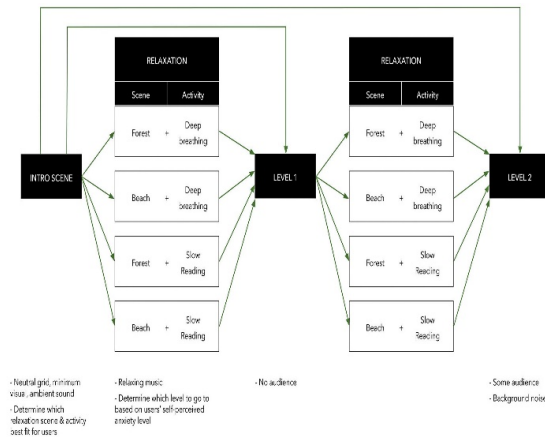


**Figure 3: VR: Sensorama, an early VR progenitor. An immersive display with stereoscopic images and stereo sound. Source: scriptanime.wordpress.com.**

### 3 Methods

To solve issues of time-intensive and costly therapies for speech and anxiety in social interaction, we worked with a team of designers, computer scientist, speech researcher, and education technologist to propose an alternative solution utilizing Virtual Reality to train subjects, fortified by Machine Learning algorithms to 1. Process understanding of speech commands and patterns, 2. Incorporate sensor input that tell us about the current state of the trainee, and 3. Provide customized step-by-step training tailored to, and predictive of difficulty level and progress of individuals.

We proposed to use galvanic skin response to keep track of user stress levels as training progresses, recognizing points of difficulty. Use of GSR has been previously applied to cloud-based VR for speech anxiety [19]. In addition, computer vision would be utilized to help subjects interpret the expressions they observe, providing an alternative way to understand emotions of others through visual cues that make up an expressive language. Machine Learning enables a virtual environment that adapts to the user's needs as training progresses. Unlike weekly therapies, ML tracks user feedback and her focus of attention so that they can learn in a customized way whenever they are ready to train. These technologies provide a socially safe and optimized learning experience that can build communication skills. We aim to replace the currently outdated practices of Applied Behavioral Analysis, and produce an example of the level of high precision and realism that a customizable VR experience could have in the future when fortified with ML.



**Figure 4: User flow of the training and relaxation sessions. Sensor data from GSR and other user movements are used by the ML to determine the difficulty of the next training.**

We wish to focus on an individual user, who has a communication disorder, seeing how she interacts with our customizable VR experience. We built a specific scenario in VR that our target audience typically practices in a role-playing setting (i.e. walking through a public park and interacting with strangers, speaking in an auditorium, a one-on-one meeting, etc.). The objective of the prototypes are to illustrate with precision how our concept would work on a specific use-case. By

integrating human-centered design into our prototyping process and developing our minimum viable product over multiple iterations, we integrated user testing results to refine a VR demo of the specific scenario involving customization through ML.

The scope of this project goes beyond behavioral therapy and special education. VR fortified by ML can also lead to innovations in entertainment, advertising, and digital media. The implementation of a smart Augmented or Virtual Reality environment could not only have the potential to create more realistic new media experiences, but also further the idea of customization in these newly emerging spaces.



**Figure 5: A stuttering subject participating in user study to determine the factors that influence how well he is able to proceed during speech training sessions.**

### 4 Results

#### 4.1 Preliminary Tests

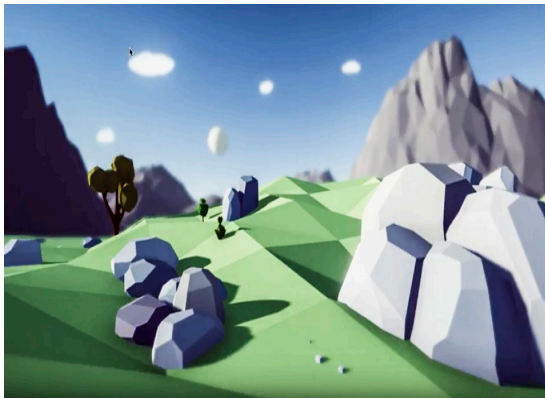
We first interviewed speech language pathologists to see what the current treatment strategies are like. The consensus appear to be that exposure therapies, in which the patient is exposed to the circumstance which usually causes stuttering, is required. It appears that often cognitive behavioral therapies proceed using systematic desensitization, which is the substitution of a non-threatening relaxation response in place of the fear response that came with speaking. In this counter conditioning procedure [3], subjects learn that the lack of fear response that comes with relaxation can be paired with fearful situations, so that subsequent exposure leads them to conjure up the feeling of relaxation every time speech opportunities are triggered. However, the amount of fear associated with desensitization is often not set ideally, because only appropriate levels of relaxation should accompany appropriate levels of fear. Inspired by this strategy, we attempt to implement systematic desensitization in a graded, customized manner using ML that utilizes sensor data to understand user mental states.

When we talked to stutterers, another piece of the puzzle came into focus. According to them, how they perceive the audience they are talking to causes them either stutter or speak fluently. For example, Daniel M. says that if he knew the person he's speaking to is aware of his stuttering, he'll actually stop stuttering,



because of decrease in social pressure to engage this knowledge. He also suggests that what he learns from therapy in the therapist's office is not generally applicable to the outside environment of loud noises and distractions because of the drastic differences in the two environments. He wishes there's a way to prepare for social interactions like job interviews in a progressive and immersive way. In summary, the perception of other's state of mind appear to influence how stutterers perform in stressful situations.

Considerations of 1. using relaxation as a method of systematic desensitization and 2. Daniel and other users' assertion that the difficulty comes hand-in-hand with the audience they are speaking to in a social situation, provided us the blueprint for creating a user flow for the patient's interaction with the ML system (Figure 4). The system is based on refinement of the prototype using feedback from 19 user tests that determined the fidelity of the interaction, the speed of the ML engine, blurriness, and other parameters. After a brief intro, we allow users to go into a relaxation scene of their choice based on ML recognition (using IBM Watson SDK) of their voice commands that indicate their preference (either forest or beach). During the scene, they perform a simple task in systematic desensitization that helps prepare them for performance (either a deep breathing exercise or slowly reading text, both suggested by our speech pathologists). Then they are given a task of introducing themselves in a realistic 360-degree video scene to a simple audience. The desired training at the speech scene can be repeated with different amounts of difficulty corresponding to number of people present, noise level, and other cues designed to distract the user.



**Figure 6: Example of a VR relaxation scene used to prepare users for subsequent exposure to speech situations. Sensor recordings during this scene is utilized by the ML agent to determine the appropriate level of difficulty in training.**

Throughout the process, a Galvanic Skin Response sensor was attached to the fingers of a user so that we can monitor how much stress he is under [1]. EDA anxiety levels have been found to increase over course of time spent in VR therapy due to exposure [20]. Machine Learning will utilize the averaged stress level over a five second window in the preparatory relaxation scene to determine the level of difficulty level in the speech training scene,

just as we do with voice input. Thus ML takes in as input layers the stress level sensor data, voice commands, and previous user training and learns a model which predicts the level of desired difficulty to use for speech training, which is adjusted by having different levels of distractors such as number of audience present, noise loudness, and amount of distracting movements. When fully implemented, the ML agent acts as a guide much like the chatbot therapist [6] as she determines user stress levels, previous training, and current speech nervousness patterns, and provides the right scene difficulty level for the systematic desensitization process.



**Figure 7: The Galvanic Skin Response (GSR) sensor attached to fingers of a stuttering subject, used to determine stress levels that are used by the ML algorithm.**

#### 4.1 Public Workshop

We obtained an open space in Brooklyn called the VRbar, where for only \$28 people can use VR for as much as they would like for 30 minutes. We received permission from the owner to download the final VR applications.

Participants gathered at this open space prior to the workshop commencing. They included M., S., Y., and D. We prepared the questions listed below in order to receive relevant feedback. If they agreed strongly with the statement they answered the question with a 5, if they didn't agree at all they answered with a 1. Personal comments were also collected on the feedback sheet.

1. Please rate your impressions of this VR experience.
2. Would you like to visit vrbar occasionally in order to continue using this app?
3. Do you believe that creating a story is helpful in interviewing for a job, and helpful for explaining the symptoms of stuttering?
4. Do you believe that practicing socializing scenes via a VR app are necessary for interviewing for a job?
5. Do you believe that talking about stuttering with others will result in an acknowledgment of your own stuttering?
6. Do you believe that acknowledging your own stuttering will eventually lead to building your confidence?

7. Did the story you submitted help when practicing the VR app?
8. Did seeing other people's stories or your own story on WebVR before practicing for the interview help you in the practice?
9. Did you experience any psychological change after practicing the VR app compared to before?
10. Did you experience any change when actually interviewing or speaking in front of others after practicing the VR app compared to before?
11. Did the relaxation experience you underwent in VR actually help you feel relaxed?
12. When actually speaking in front of others in VR, did you experience any feelings of tension?
13. If you can think of any ways to improve the VR app, please let us know.
14. Please write down the differences in levels of social anxiety (as a percentage) that you feel for each of these situations: before submitting the story, after submitting the story, and after submitting the story and practicing on the VR app.
  1. Before submitting story:
  2. After Submitting Story
  3. Practicing VR app
15. After going through the entire process of submitting a story, watching that story on the VR app, and practicing the interview, please share your thoughts about the experience.

Among the feedback we received were the following: “the interview practice takes places in a room with 360 degree video footage of many different people sitting in chairs all facing you; I felt very embarrassed. Because of this, I was able to practice introducing myself while feeling the same kind of nervousness I would during an actual interview. In order to properly converse with the AI without the outside world interfering, the interview had to take place in an open space like that at vrbar, which felt kind of strange. An app where you can practice in your own home would be much more convenient. When the AI was encouraging you to relax by having you do things like deep breathing, I could feel myself relaxing. It was almost a meditative experience.”

Another participant was quite eager to use the product but still waiting for the right time: “If VRbal was actually made into a product, I think it would definitely help people who suffer from social anxiety brought about by stuttering. In the past I have spent a lot of money on therapy, so if I could use this app everyday instead I would be able to save a lot of money as well. It would also benefit the people who don't have the money to spend on care by giving them access to appropriate Speech Language Pathologists. However, in its current state the project may not be able to motivate people to want to continue using it regularly.”

We have shown that in a VR environment for training purposes, Machine Learning using sensor and speech inputs can be used to customize a solution for appropriate types of training that is essential for the gradual process of assimilation critical in, for example, speech therapy for stutterers.



**Figure 8: Persons who stutter gather for a workshop at VRbar for a public user session demonstrating the utility and limitations of a Minimum Viable Product VR-based systematic desensitization therapy for stuttering.**

## 5 Discussion

For those suffering from stress and anxiety issues like PTSD, stuttering, and phobias, the possibilities for convenient, low-cost, low-profile, context-specific treatment options have been scarce, but the advent of VR technology, in conjunction with customization by the way of Machine Learning, have made technological solutions possible.

In the clinical test regime, PTSD following September 11 attacks have been treated using exposure therapy in VR with significant reduction in clinical severity scores compared to waitlist controls [4]. Although effective in clinical settings, the promise for illness that can be treated with less drastic means in consultation with psychologists may prove to be a more useful use case for VR. For example, anxiety in public speaking have been treated with VR for university students, indicating reduced heart rate and Subjective Units of Stress Scale ratings over the course of therapy [7]. VR was shown to be significantly more effective than 2D visualization in reducing public speaking anxiety in students [9]. Moreover, skin resistance levels are reduced over the course of training in a 20-minute VR session for those who have phobia of flying [23]. In all these cases, measures of stress and anxiety shows efficacy of VR in treating disorders that do require covert intervention (like PTSD). This suggests that certain disorders that require more frequent treatment sessions without over-exposure may benefit from the convenience and efficacy of VR treatments.

These studies also did not take advantage the ability to tailor training during the process of treatment so that patients are getting ideal levels of exposure over time. So far, Machine Learning has only been used to detect stress levels rather than customize the treatment [2]. ML promises to take therapeutic strategies to a new level of customization that comes with ability to sense bodily states. As proposed in our project, using GSR and other sensors of physiological activity in conjunction with detecting head movements in VR allows us to detect subjective stress levels, which allows customization of treatment strategies over the long haul, so that subtle differences in response to treatment can make a difference in the level of exposure in subsequent trials. Moreover, by changing the number and type of

distractors in the treatment environment as well as the location of treatment itself, the exposure can be tailored to conditions like a specific speech at a company or a specific context like at a wedding or at a conference. It can even set the general noise level, frequency of distracting phone rings, or incidence of distractions like babies crying or people coughing. The ability to change these parameters using ML is a hall mark of VR therapy that has yet to be fully taken advantage of.

At our final demo at an audience of designers, technologists, and speech pathologists, we found that the responsiveness of the Watson agent is critical to perceived intelligence of the engine. While the ML system doesn't require the voice agent per se, the speed delay is due primarily to voice recognition. Reducing delay in future technology will be paramount to usability. We also found that users like to use their clothing and immediate items to indicate stress, such as stretching, grasping, and crumpling. Thus, we have created prototypes to see if yarn fabric can be used as digital anxiety sensors for the VR system. In this project, we created fabric weaved sensors that uses separated conductive yarn material to detect human gestures like grasping, stretching, and stroking [14]. This "Weavable Tech" strategy further increase the ability to detect subjective stress, providing additional sensor data for ML that can help improve VR treatment over time. Moreover, subjects reported being more comfortable with detection of gesture responses with soft sensors over traditional chemical sensors that impede their movements.

Another technology that would help with determination of user behavior is eye tracking during anxious moments. Eye flicker, loss-of-contact, and avoidance of gaze is particularly prominent during and before moments of stutter [20]. By detecting gaze during training and testing sessions in VR, we can gauge not only when speakers are anxious, but we can also infer what they are anxious about. For example, socially anxious speakers spend less time gazing at those with conflicting opinions than normal individuals [5], and exhibit greater general gaze avoidance in both positive and negative situations [22]. Eye tracking in VR may be able to tell us the source of anxiety in speech by examining areas of gaze avoidance.

Although we postulated ML strategies in VR in the context of therapeutic strategies, development of these techniques may lead us to general artistic and game applications. Adaptive learning of audience responses, selections, and behavioral data customizes level design, context details, and character development, allowing experiences to exhibit subtle user-dependent changes that reflect human emotional states.

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