

# Detecting mental disorders with sensor-based virtual reality

*Gaming technology creates environment that simulates lab assessment tests*

By Faisal Aqlan and Hui Yang



**T**he outbreak of coronavirus disease 2019, or COVID-19, has been stressful for people. The fear and anxiety about the disease are overwhelming and cause strong emotions in adults and children. People respond to stressful situations in different ways depending on a variety of factors such as background, age and the community an individual lives in.

The pandemic has forced people to become isolated, causing depression and anxiety. Hence, mental health interventions have become a central part of comprehensive COVID-19 support, care and treatment programs, with profound impacts even after the pandemic.

This public health crisis is also expected to lead to a mental health crisis due to economic adversity, job losses, isolation and stress associated with the pandemic. Mental disorders can cause a decline in cognitive function. The impact that COVID-19 will have on mental health is expected to create post-traumatic stress disorder (PTSD). Thus, there is a need for effective screening and treatment tools.

According to the World Health Organization (WHO), 35% to 85% of mental health conditions remain undetected and undiagnosed. To treat these conditions,

detection is the first step. Traditional tools used to assess mental disorders, such as interviews and cognitive tests like the example in Figure 1, are subjective and fraught with complications and subtleties. Moreover, mental disorders are often unrecognized and undertreated, which is one of the important barriers for effective care.

Rapid advances in virtual reality (VR) technology have fueled steady growth in healthcare applications. For example, virtual reality is conducive to improving medical training for decision-making and can help patients cope with pain and overcome anxiety and depression. VR can also be used to assess and treat a wide variety of medical, surgical, psychiatric

**FIGURE 1**

## **Clock drawing test**

Such cognitive tests used to assess mental disorders are subjective and often unreliable.

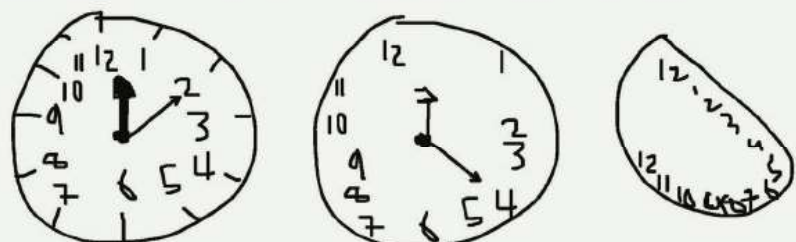


FIGURE 2



Photos courtesy of the authors

Virtual reality technology allows for professional, collaborative connection, particularly when working remotely during the COVID-19 pandemic.

FIGURE 3

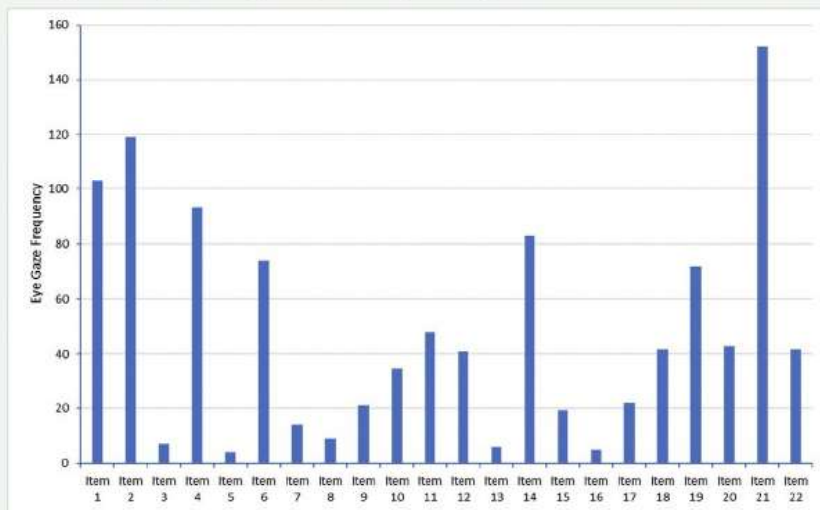


A view of a sample room in the virtual environment used in the study.

FIGURE 4

### Eye gaze frequency

A sample of the eye-tracking data gathered by the VR platform.



and neurocognitive conditions as well as to enhance the effects of conventional therapies, promote longer training sessions and reduce overall hospitalization time.

Virtual reality offers a new means of the immersive environment to assess mental disorders than traditional “gold-standard” cognitive tests. This, in turn, provides a unique opportunity for healthcare training and treatment of mental disorders in a safe, controlled environment. However, more research is needed into what makes VR therapies effective.

Industrial engineering faculty, including the authors and their students from the NSF Center for Health Organization Transformation (CHOT) at Penn State University, have developed a sensor-based virtual reality environment for mental disorders. The team uses rapidly advancing gaming technology to develop a transformative platform VR that integrates sensing technology and artificial intelligence for metacognitive interventions of mental disorders (see Figure 2).

The virtual reality environment simulates a medical clinic where patients take part in mental health assessment tasks designed to mimic common mental health simulations conducted in nursing labs. The research also investigates the effectiveness of the use of intelligent agents for effective metacognitive strategies. These models combine user inputs with the data collected from external sensors to improve metacognitive interventions of mental disorders.

The virtual reality environment includes a set of tasks the user can complete, the first of which is an implementation of the Mini-Mental State Exam (MMSE). This consists of tasks designed to test orientation, immediate recollection, attention and calculation, and recollection.

The virtual environment illustrated in Figure 3 also includes static and dynamic situations based on the Boston Cookie Theft prompt (see related article, Page 34). The goal of these events is to gather eye-tracking data and benchmark with the spoken feedback from the user.

Sample data for the eye gaze frequency of the objects the participant looked at while in the VR environment is seen in Figure 4. The eye gaze is recorded every 10 milliseconds.

To achieve a quantitative measure of mental disorders, we developed a new measure of metacognitive performance

by integrating signal detection theory with conflict and error algorithms as shown in the following equation:

$$\xi = \sum_{i=1}^T [\sigma\Phi^{-1}(Y_i) - (\Phi^{-1}(C_i) + \Phi^{-1}(E_i) + \Phi^{-1}((C\&E)_i))] \quad (1)$$

In the formula,  $\xi$  is the metacognitive awareness measure;  $T$  is the set of tasks;  $\Phi^{-1}$  is the inverse normal distribution;  $Y$  is the correct task execution;  $C$  is the conflict (performing a task different from what the person is thinking measured by eye tracking); and  $E$  is the error (performing a wrong task). The conflicts and errors are defined in reference to the average performance of individuals without mental disorders.

Lower values for  $\xi$  indicate that the user has more errors and conflicts than correct tasks while performing the virtual reality simulation, which can be used to measure mental disorders. Two simulated datasets for 10 tasks are generated; one dataset for a person without mental disorders and the other for a person with mental disorders.

Figure 5 shows the performance of a person without mental disorders and Figure 6 shows the performance of a person with mental disorders. By referencing to the equation, a person without cognitive disabilities has more correct tasks than errors and conflicts. The person with mental disorders has fewer correct tasks than errors and conflicts.

Another example, shown in Figure 7 (on Page 35), is for a virtual assessment of schizophrenia, a serious mental disorder that causes people to interpret reality abnormally. The simulation includes an audio file mimicking voices heard by those who have schizophrenia. Users are instructed to listen to audio

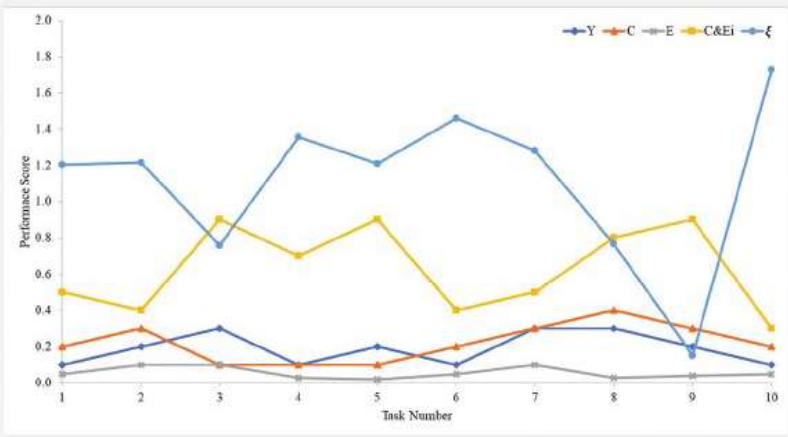
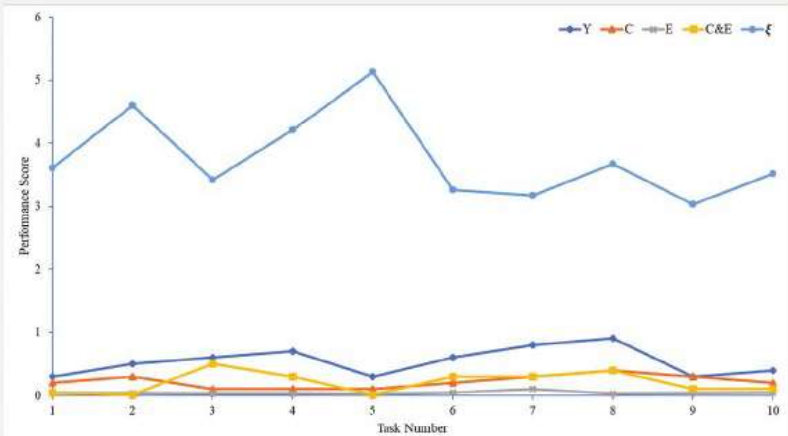
through headphones and write down their thoughts while doing so. They are also asked to complete questionnaires while audio is still playing. Further, they are asked to solve word puzzles and test reading comprehension.

In the image, the small red button on the wall is used to turn the audio file on and off. The whiteboards can be used to com-

FIGURES 5 & 6

### Comparing data

Figure 5 shows the performance variations of a person without mental disorders; Figure 6 shows the same for a person with mental disorders. (Y: correct task execution; C: conflict; E: error; C&E: conflict and error;  $\xi$ : metacognitive awareness measure)



## Domestic image helps spot disorders

The Cookie Theft picture was created by researchers with the Boston Diagnostic Aphasia Examination to identify cognitive skills and disabilities. It was published by Harold Goodglass and Edith Kaplan in 1972, and revised in 1983 and in 2001.

The picture depicts a familiar domestic scene: A mother drying dishes in the kitchen next to a sink that is overflowing. Meanwhile, two children are trying to take cookies from a jar in the cupboard. A boy has climbed onto a stool to reach the cookie jar and the stool is rocking precariously while a girl stands next to the stool with her hand outstretched.

Patients are shown the picture and asked to describe all that is happening in it. The responses are then used to identify a range of clinical conditions and aptitudes, including perceptual modalities (auditory, visual, and gestural), processing functions (comprehension, analysis, problem-solving) and response modalities (writing, articulation, and manipulation).

Sources: Research Gate, [www.researchgate.net](http://www.researchgate.net); Taylor & Francis Online, [www.tandfonline.com](http://www.tandfonline.com).

## Schizophrenia simulator

A snapshot from the virtual reality environment shows the doctor, audio button and boards that enable users to write, draw and answer survey questions.



## Caregiving uses for VR on the rise

Researchers continue to find new applications for virtual reality technology in healthcare-giving scenarios.

One platform created by Los Angeles-based Embodied Labs, an immersive educational technology company, uses virtual reality software to train healthcare professionals working as caregivers for older adults. It was founded four years ago by Carrie Shaw and her sister Erin Washington, whose mother was diagnosed with early-stage Alzheimer's disease while Shaw was a freshman at the University of North Carolina.

"I was really scared of my mom's diagnosis," she told *The New York Times*.

The software allows users to virtually look into the body and mind of someone confronted with aging issues, whether it's cognitive decline such as Alzheimer's, age-related vision and hearing loss or neurodegenerative diseases such as Parkinson's and dementia. It can provide medical students, nurses, certified nursing assistants, assisted-living staff members and family caregivers a first-person understanding of the challenges their aging patients face.

"What I try to do with Embodied Labs is to provide that understanding gap, so people can get to that point faster than I did," Shaw said. "It's the convergence of aging, emerging technology and the need to transform our work force training methods in health and aging care."

The company sells a hardware kit along with a software license to customers that include senior living communities, telecommunications companies, colleges and universities and government agencies.

Another immersive technology company has created a therapy program for mental health treatment that earned a UK Digital Experience Award.

Oxford VR's platform helps people tackle social avoidance based on cognitive behavioral therapy. CBT is a form of therapy that helps people change patterns of thought and behaviors that can lead to depression and anxiety.

The company's first clinical trial used virtual reality to help people overcome a fear of heights. The trial showed that VR therapy can benefit individuals as well as support healthcare providers facing staffing issues. The results were published in *The Lancet* in 2018.

"As the world becomes ever more digital, pushed forward by lockdowns globally in reaction to the COVID-19 pandemic, virtual platforms will play a larger role in society," said Arvind Tewari, Oxford VR's chief operating officer.

plete the questionnaires and solve the puzzles. Users can also write on the board using a virtual marker.

The goal of the study to develop a VR simulation environment was to improve clinical judgment and treatment of mental disorders such as anxiety, depression and schizophrenia by improving metacognitive skills. A future

study will continue to improve the simulation environment by adding more tasks and considering different types of mental disorders. ❖

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