Emotional Virtual Reality Stroop Task: an Immersive Cognitive Test

Deniz Mevlevioğlu
d.mevlevioglu@cs.ucc.ie
University College Cork
Cork, Ireland

Sabin Tabirca
tabirca@cs.ucc.ie
University College Cork
Cork, Ireland

David Murphy
d.murphy@cs.ucc.ie
University College Cork
Cork, Ireland

Figure 1: The Virtual Reality waiting room environment

ABSTRACT

Stroop Colour-Word Task has been widely used as a cognitive task. There are computerised and Virtual Reality versions of this task that are commonly used. The emotional version of the task, called the Emotional Stroop Colour-Word task is commonly used to induce certain emotions in a person. We are developing an application that brings the Emotional Stroop Colour-Word task into Virtual Reality. The aim of this application is to elicit different stress levels on the user and to record associated brain, heart and skin activity using wearable sensors. It is an immersive application that includes a tutorial, artificial intelligence generated audio instructions and a logging system for the user activity.

CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Virtual reality**; • **Applied computing** → **Health informatics**.

KEYWORDS

biosensors, biosignals, VR, emotional Stroop, Stroop color-word test, anxiety

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1 INTRODUCTION

Stroop Colour-Word Task (SCWT) is a commonly-used and well-established task that is used for a number of reasons such as assessing cognitive interference inhibition performance and being able to identify one feature in the presence of an interfering, distractive feature [3]. This effect is commonly referred to as the Stroop Effect. The person who takes the test is asked to identify the colour of a word. The classic task generally involves two conditions. In the first, the colour of the word matches the text written, for example, the word red is written in red ink. In the second, the text and the colour of the word are different, for example, the word green is written in red ink, thus creating the interference effect. The task aims to identify how good the person is at performing well under the interference effect. This task, however, has been used for a variety of other reasons, one being to use it to elicit certain stress or emotional responses. Emotional Stroop Colour-Word Task involves a third condition, where words from the affective norm for English words (ANEW) [2] are used to elicit certain emotions [15].

We are working on an application that brings this emotional version of SCWT into virtual reality (VR). The reason for developing this system is to use it as part of an experiment to classify different levels of anxiety [6]. This is necessary in order to make a system of anxiety prediction that is generalisable and objective.

1.1 Related Work

There are several applications of SCWT applied into VR which is commonly referred to as VRST [4, 8]. However, there are no current applications of the emotional version of the task into VR.

2 DESIGN & IMPLEMENTATION

There are two scenes in the application. One is the waiting room scene that is the main experience. The other one, called the nature scene, is to accommodate users who want to be taken out of the task early. It involves the well-established physiological sigh breathing exercise [5] coupled with visually pleasant scenery and ambient audio to help the user wind down.

Unity3D was used to develop the VR experience [14]. VR best practices were followed to ensure high performance and user comfort [13]. Attention was paid to frame rate stability to decrease the chance of VR sickness in the user. HTC Vive and Oculus Rift S were used to test the system.

2.1 Stroop Task

The Stroop task consists of three stages. The first stage is the congruent stage, where the text and the colour of the word are congruent. The second is the interference stage, where the text and the colour of the word are incongruent. Lastly, the third stage is the emotional stage, where negatively connotated words are used. There are 50 questions in each stage, and 10 questions to warm up. The reason these stages were not mixed is to get constant, long-term reading on the anxiety of the user with signals. The timing of the task can be seen in table 1.

To display the instruction text and Stroop test, a big screen was used (fig 5). The colours are placed on a platform that is easy to reach and apart from each other to prevent accidental clicking. To make sure that the user knows they clicked on the button, three modals of feedback is given. First is visual feedback, a bright yellow highlight around the button. The second is auditory feedback, a click sound when the button is clicked. The third is haptic feedback, a short vibration of the controller that the user is holding. For the instructions and the tutorial, there are both text and audio to accommodate different types of users. After each stage, the user is asked to log their anxiety using the same platform, which switches between buttons and a slider. The user is prevented from carrying on unless they log their anxiety. This ensures three different types of assessment of anxiety; physiological sensors, self-report and task performance.

2.2 Graphics

The graphics are designed to be true-to-scale and realistic, but not photo-realistic to avoid uncanny valley and have better performance.

To keep this application familiar to the user and accommodating to people who are not accustomed to VR, the waiting room scene involves a place where people are used to seeing often. Modelled after a common clinic waiting room, the scene involves usual waiting room items such as coffee tables, magazines, plants, bookcases, reception, and television screens.

The nature scene involves a scene of an open field with grass, flowers and trees.

2.3 Audio

Audio is generated to sound like a middle-aged British man. Voice-over is used in both scenes.

The nature scene involves some ambient sounds associated with nature such as wind blowing and leaves rustling.

Murf AI [1] was used to generate the AI voice over. Audacity [12] was used to edit both the voice-over and ambient sounds in the nature scene.

2.4 Interaction

The control scheme is developed to be easy to learn and intuitive. It involves no two-dimensional interface features, all the controls are included in the three-dimensional scene itself. Interacting with buttons and elements on the screen is a matter of moving their hand (the controller) to the relevant buttons. To accommodate the needs of the users, the pacing at the start is set by the user. The user can choose when they want to start the tutorial and the actual experiment. Additionally, an exit button is added to the interface to make sure that the user has control over when they can leave the experience.

SteamVR interaction system was used in the experience [11]. The interface elements were all made from scratch with usability in mind. The interface platform was made for the average user in mind, with the possibility to add some personalisation in the future with regards to height. The interface includes a start button, colour buttons, an exit button and a VR slider for logging their current anxiety level. The interaction system includes visual, auditory and haptic feedback. To click most buttons, the user simply needs to move their hand (the controller) on the button. For the VR slider, they need to hold down the trigger button to close their hand around the handle and move the handle accordingly. This is indicated by using the SteamVR controller button hint class, which highlights the button on the controller and provides haptic feedback to draw the user's attention.

2.5 Biosignals

Biosignals recorded in the experience include electrical brain activity, skin conductivity level and pulse rate.

Electrical brain activity is measured using Myndplay Brainband [7], skin conductivity level and pulse rate calculated from photoplethysmogram (PPG) are measured using the Shimmer GSR device[10]. The data that is collected is to be used for machine learning models that try to predict anxiety in real-time, so processing that can not be applied on the spot are omitted. Pulse rate, measured in beats per minute, is the least reliable of these signals in terms of continuous output. So, to avoid noisy data, outliers are removed in real-time. To do this, mean beats per minute and the standard deviation is calculated over the course of three minutes. Values that are three standard deviations or more apart from the mean are removed. The signals are sampled every second and recorded in an external .csv file.

2.6 Logs

The biosignals, user answers to questions, and the biosignals are all recorded into an external .csv file and timestamped accordingly.

Table 1: Flow of the stroop task

Tutorial	Warm up	Congruent	Break	Warm up	Incongruent	Break	Warm up	Emotional
1m	30s (10 questions, 3s each)	2m30s (50 questions, 3s each)	15s	30s (10 questions, 3s each)	2m30s (50 questions, 3s each)	15s	30s (10 questions, 3s each)	2m30s (50 questions, 3s each)

Figure 2: Congruent stage

Figure 3: Incongruent stage

Figure 4: Emotional stage

Figure 5: Three stages of the Stroop task

Figure 6: The VR slider used to log anxiety

3 SOFTWARE TESTING

The software was tested using two sets of hardware and maintained a stable 100 frames per second on each. The first of them used an HTC Vive head-mounted display (HMD), GeForce GTX Titan X graphics card (GPU) and Intel i7-5820k processor. The second used an Oculus Rift S HMD, RTX 3070 GPU and Ryzen 5 3600X processor. The controls were responsive and worked as intended in both cases.

The application was tested on two users for feedback during the development. An open-ended interview was used to record their feedback to improve the application. The interview included questions about the comfort of the hardware, intuitiveness of the tutorial, usability of the interface and general feedback. In terms of comfort, both users said that they were aware of the sensors at the start but forgot about them as the experience went on. One of the testers, due to their height, said that they had difficulty looking at both the buttons and the screen at the same time. Working on this feedback, the distance between the screen and the user, as well as the height of the buttons have been adjusted. Another user mentioned that the start button was too close to the colour buttons and they should be separated. Following this feedback, the height of the start button has been adjusted.

4 DISCUSSION

Based on developer testing, the current system is sufficient to administer the Stroop task and measure its effects of it on physiological signals. Experiments are necessary to see if it delivers the intended varying levels of anxiety and also the Stroop interference-effect. The wearable technology raises some concern in terms of comfort and immersion, however, care has been taken to make sure the minimum amount of interference is taking place by using small and non-intrusive devices that work through Bluetooth.

4.1 Current Limitations

Unfortunately, the current test, like a lot of variations of the Stroop task, is not accessible to people with colour-blindness. It is currently under consideration as to what can be done for it to be accessible to everyone. Additionally, people with dyslexia and illiteracy might not experience the same effect, as they can ignore the interference

and negative emotions on the third stage [9]. Thus, these groups are to be excluded from the experiment.

5 CONCLUSION

The Emotion Virtual Reality Stroop Task aims to fill a hole in VR research by providing a means to classify different levels of anxiety objectively by using VR content. It aims to be generalisable, however, there are some populations that it fails to include. Future research will check its validity with the multimodal system of physiological and self-report measures.

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