Validation of a Virtual Reality Flanker Task

Radhika Amin, *Department of Molecular, Cell, and Systems Biology*
Phoebe Tat, *Department of Psychology*
Aaron Seitz, *Ph.D., Department of Psychology*

ABSTRACT

The Flanker task is a neuropsychological test designed to measure inhibitory control–the ability to ignore automatic responses in order to reach higher goals. The traditional, tablet form of the Flanker task is widely used and well-cited. Recently, the UCR Brain Game Center has developed a Virtual Reality (VR) Flanker game. After the project is created, the next step is to validate its usefulness with a pilot study, which is the focus of this research paper. This pilot study addressed two central research questions. The first research question was: would the newly developed VR Flanker task measure inhibitory control as well as the traditional, tablet Flanker task? In Pilot Study 1, participants were first randomly assigned to either the VR or computer form of the Flanker task, and then utilized the alternative platform in the second session. The second research question was: would different versions of the VR Flanker task yield different measurements of inhibitory control? In Pilot Study 2, participants were randomly assigned to either the Regular VR Flanker task or the Jitter VR Flanker task during the first session. The second session employed the version that participants were not assigned to in the previous session. The study compared the standard performance measure of the difference in reaction time between congruent and incongruent tasks (Flanker effect) in both Pilot studies. The results demonstrate that VR Flanker tasks are a valid way to measure inhibitory control. Pilot 1 found that Flanker effects produced in the tablet and VR Flanker tasks are similar, while Pilot 2 found that greater Flanker effects could be produced with a different presentation of stimuli in the virtual environment. Once it is established that the VR task measures inhibitory control as well as the tablet version, there would be multiple benefits for neurological tools and testing in different populations. The advantage of a VR Flanker game is that it can serve both as a fun method to assess Flanker effects and as a training tool. Long-term use of a validated VR Flanker task could allow us to emulate real-world situations and lead us to better understand populations struggling with inhibitory control.

KEYWORDS: Flanker, virtual reality, inhibitory control

FACULTY MENTOR - Dr. Aaron Seitz, Department of Psychology

Professor Aaron Seitz is a well-established investigator and internationally recognized as an expert on mechanisms of perception attention and learning and memory using behavioral, computational and neuroscientific methodologies. As the Director the UCR's Brain Game Center for Mental Fitness and Well-being, he is committed to translating lab-based research into approaches to benefit life in the real world. The lab works to disseminate game software instrumented with expert knowledge to optimize human brain processes with an aim to make scientifically principled brain games that translate to performance in real-life activities. His research led to new insights regarding the roles of reinforcement, attention, multisensory interactions, and different brain systems in learning.

Radhika Amin

Radhika is a fourth-year Neuroscience major. She has worked as a Research Assistant and Assistant Research Coordinator at the UCR Brain Game Center for the past 4 years. With funding from the RISE Internship and the Campbell Fellowship, she has had the opportunity to study the interaction of brain structure and function in diverse populations. Radhika is currently President of UCR Best Buddies and Student Facilitator of the R'Course Cognitive Assessments and Their Applications. She hopes to pursue further education and conduct health-related research, finding novel ways to help individuals that are affected by cognitive disorders.

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INTRODUCTION

The Flanker Task

The Flanker task is a neuropsychological task in which the participant must respond to a centrally presented target stimulus surrounded by distractor stimuli (**Figures 1 & 2**) (Davelaar, 2009). The Flanker task measures inhibitory control, a crucial executive function that is heavily relied upon during daily activities. Inhibitory control is the ability of one to control their behavior and ignore external lures to reach higher goals (Diamond, 2013). For example, a student who chooses to ignore a text message during a lecture to pay attention to the professor is exhibiting inhibitory control because they are ignoring external lures and focusing on the larger goal of doing well in the class. Inhibitory control is an important facet in the domain of cognitive function, as it influences daily decision-making. The Flanker task—the difference in reaction time between congruent and incongruent trials—is a primary measure of inhibitory control in the Flanker task. In congruent trials, the target stimulus is in the same orientation as the distractor stimuli, while in incongruent trials, the target stimulus is in a different orientation than the distractor stimulus (Davelaar, 2009). The traditional, tablet version of the Flanker task is the gold standard in the field of neuropsychology to measure inhibitory control. The UCR Brain Game Center has recently developed a VR version of the Flanker task, and the properties of this task are examined in the present study.

Research Aims

This paper summarizes the results from our Pilot studies, which aimed to validate if VR was a viable way to deliver Flanker stimuli and measure inhibitory control. Because these studies are expensive and time-consuming, pilot studies are necessary to establish proof of concept. Small-scale studies also help identify potential issues when the project is scaled. In these preliminary Pilot studies, we administered the different Flanker tasks to only a small group of individuals with the intent of later moving to larger populations to then fully validate the VR Flanker task. Hence, our first research question was: would our newly developed VR Flanker task measure inhibitory control as well as the traditional, tablet Flanker task? Once it was established in Pilot 1 that the VR Flanker task successfully measured inhibitory control, we developed and studied different versions of the VR Flanker task in Pilot 2. Our second research question was: would different versions of the VR Flanker task yield different measurements of inhibitory control? To answer both research questions, we compared and analyzed the Flanker effect (difference in reaction times between congruent and incongruent trials) averages of the participants across the different types and versions of Flanker tasks.

Previous Research

There are several validated versions of computerized tablet Flanker tasks (Davelaar & Stevens, 2009; Grainne, 2009; Kramer et al., 2013; McLoughlin et al., 2009; Oeri et al., 2019; Shimada et al., 2015). For instance, the UCR Brain Game Center has previously validated a computerized tablet version of the Flanker task, which is administered in several batteries to measure inhibitory control in different populations. In contrast to a tablet task, a virtual reality (VR) task could provide additional control in designing environments that could not be replicated in real-life experiments (Morel et al., 2015). After validation of the VR Flanker task, it could be utilized to study the inhibitory control abilities of populations that struggle with inhibitory control. Manipulating real-world situations in VR Flanker environments may also offer a therapeutic benefit to individuals of such populations in the future. These situations that were once unable to be studied can now be safely replicated in a lab setting. A VR Flanker task could furthermore serve as an enjoyable method to assess Flanker effects and as a training tool. It is important that participants are engaged and exert effort while performing the Flanker task because it allows for a more accurate measurement of their inhibitory control abilities. While a few VR Flanker tasks have been validated, they are not easily accessible (inexpensive and able to be administered in a variety of lab contexts) and do not require the participant to use their full range of arm motion (Armstrong et al., 2012; Ribeiro et al., 2021). For instance, VR Flanker tasks in previous studies have only required participants to use finger taps or hand movements to respond to stimuli (Ribeiro et al., 2021).

Current Research

The Brain Game Center's recently created VR Flanker tasks address several of the aforementioned issues. Our VR Flanker task uses full body movement and could become accessible for individuals to use. We first developed Regular VR Flanker, which was a replication of the Tablet Flanker task on a virtual platform. Regular VR Flanker consisted of the stimuli spawning or originating at the same place in the virtual environment. In Pilot 1, we compared Flanker effects on our developed VR Flanker with the Brain Game Center's tablet form of the task. Then, modifications (i.e., changes in timing and placement of stimuli) were made on the VR Flanker task. Jitter VR Flanker consisted of stimuli that were originating at different places in the virtual environment. In Pilot 2, we Flanker effects of our Regular VR Flanker were compared with our Jitter VR Flanker.

MATERIALS AND METHODS

Participants

The study was divided into two pilot studies within a three-week period spanning early to mid-April 2023, with 9 students (66.7% female, 33.3% male) participating in Pilot 1 and 7 students (57.1% female, 42.8% male) participating in Pilot 2. The distribution of participants' ages ranged between 18-30 years old. Due to the current Pilot studies serving as a preliminary experiment to determine its reliability and feasibility of deployment upon a larger population, the small total sample size reported does not reflect the full scale of our research. Each pilot was further partitioned into two sessions to counterbalance the tasks and eliminate order effects, with the second session scheduled between 1 to 5 days after the first session. Participants were randomly selected using UCR Brain Game Center's roster of undergraduate research assistants and were not provided compensation for their participation. Each selected participant was asked to volunteer their time for a short activity and did not receive further details about the study. All participants indicated having either normal or corrected-to-normal vision using supplemental eyewear (e.g., glasses, contacts). Participants from both pilots were administered a written consent form before Session 1 and a feedback survey after Session 1. All tasks within the current study were administered in a quiet, enclosed room with minimal decor to reduce potential distractions and interference with participant performance.

Equipment Specifications

The Tablet Flanker task was conducted from the UCR Brain Game Center application, Recollect, via a stock 32 GB memory 6th-generation iPad running iOS 15.4. The VR Flanker task, developed by the UCR Brain Game Center, was administered using Meta Platforms' second-generation virtual reality headset, a stock 128 GB memory Oculus Quest 2 running v38.0. In Pilot 1, researchers randomly assigned participants to begin Session 1 with the tablet Flanker task or the VR Flanker task. In Pilot 2, participants were randomly assigned to begin with the Regular VR Flanker or the Jitter VR Flanker. To eliminate order effects, participants utilized the device they were not assigned to in Session 1.

The UCR Brain Game Center developed both the Tablet and VR versions of the Flanker task using a small selection of programs installed on a Windows 10 operating system. The Tablet Flanker task was developed using Unity, a game engine supporting desktop and mobile platforms, while the VR Flanker task was developed using Unreal Engine 4, a game engine designed for desktop applications. The assets within the VR Flanker task, such as the glowing sabers and interactive targets, were modeled in Blender, an application supporting the modeling, texturing, and rendering of 3D objects.

Materials

UCR Brain Game Center's tablet Flanker task instructs participants to quickly indicate if the centrally presented arrow amongst a set of five arrows is pointing to the left or the right by pressing the corresponding triangular button (**Figure 1**). For instance, in Figure 1, the participant would respond with "left" since that is the direction of the middle arrow. Researchers did not provide further information beyond the task instructions.

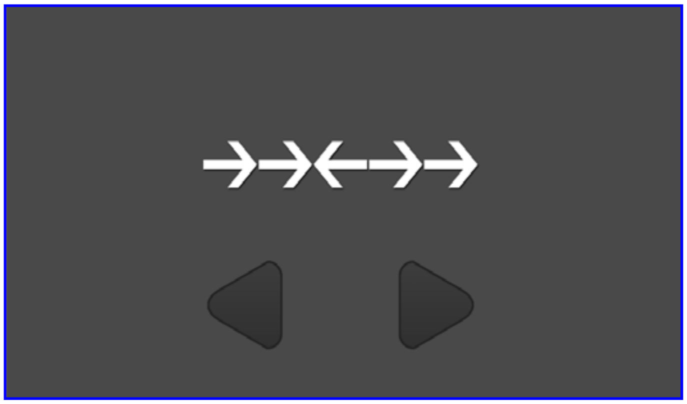

Figure 1. Tablet Flanker.

In our VR Flanker, participants are spawned into an immersive, three-dimensional environment wielding two glowing sabers. They are presented with a series of targets containing visible arrows and must slash through them by grasping a handheld controller and moving their arm along the horizontal axis depending on the orientation of the centrally presented arrow (**Figure 2**). To ensure accuracy, researchers instructed participants to capture their full range of motion by moving their arms and shoulders rather than limiting the movement to their wrists. The player's score, which reflects the number of correct responses provided within the time limit of each trial, is displayed above the targets and can be monitored throughout the session.

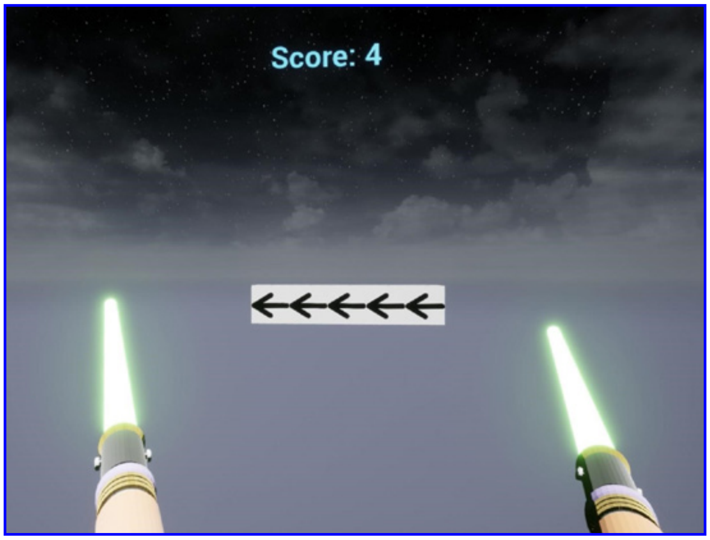

Figure 2. VR Flanker with no modifications made (i.e., Regular VR Flanker).

The Jitter VR Flanker variation used in Pilot 2 follows the same rules and objectives as the Regular VR Flanker, with the exception that targets appear in randomized areas rather than consistently spawning in the center of the screen/display (**Figure 3**).

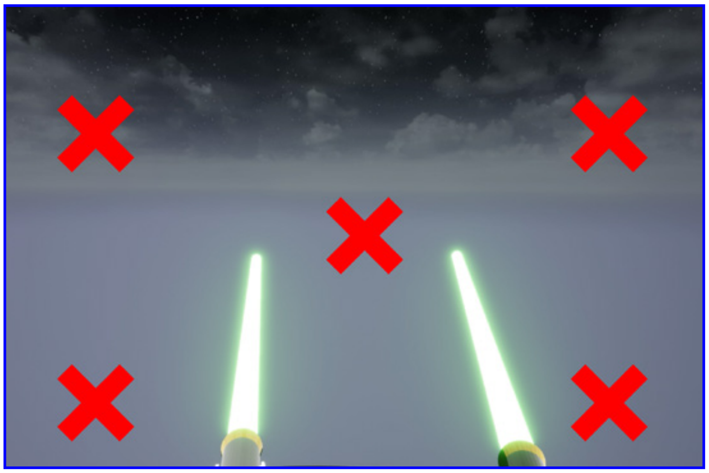

Figure 3. Possible spawn points for Jitter VR Flanker. Red Xs indicate possible spawn points.

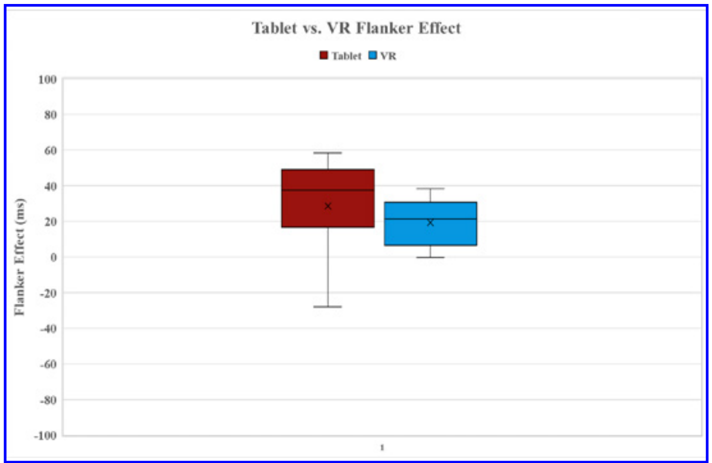

Figure 4. A box plot illustrating the Flanker effect across Tablet and VR Flanker.

RESULTS

Participants maintained similar performance across both sessions in Pilot 1, with the VR Flanker task averaging 19.25 milliseconds (ms) with a range of -27.96ms to 38.26ms and a standard error of the mean (σ_M) of 10.71ms, compared to the tablet Flanker task, which generated an average of 28.59ms and ranged -0.26ms to 58.52ms (σ_M = 4.51ms) (**Figure 4**).

Data from Pilot 1 demonstrated that we were able to achieve similar Flanker effects in the VR Flanker sessions and the tablet Flanker sessions with a correlation coefficient (r) of -0.5424 and the T-test score (*t*) of 0.3201. As shown in **Figure 5**, tablet Flanker reaction times with correct responses for incongruent trials averaged to 819.56ms (σ_M = 29.33ms) and congruent trials averaged to 791.52ms (σ_M = 791.52ms), whereas the VR Flanker average reaction time for incongruent trials was 267.17ms (σ_M = 30.79ms) and 247.91ms (σ_M = 28.65ms) for congruent trials.

Pilot 2 compared the Flanker effects of our Regular VR Flanker with our Jitter VR Flanker results. We were able to achieve a Flanker effect in both VR versions of the task, with the Jitter VR Flanker effect yielding higher Flanker effects (*r* = -0.1527, *t* = 0.1593). The Regular VR Flanker produced an average Flanker effect of 36.98ms, with a range of -8.67ms to 66.70ms (σ_M = 4.33ms), and the modified Jitter VR Flanker held a comparable average of 48.83ms, with a range of 36.90ms to 65.40ms (σ_M = 9.35ms) (**Figure 6**).

On average, the reaction time of correct responses for incongruent trials in Regular VR Flanker was 473.34ms (σ_M = 25.97ms) and that of congruent trials was 436.36ms (σ_M = 21.96ms). The Jitter VR Flanker's reaction time for incongruent trials averaged 531.56ms (σ_M = 16.94ms) and averaged 482.73ms (σ_M = 13.55ms) for congruent trials (**Figure 7**).

Consistent across both pilot studies, participants completed a feedback survey about their experience with the assessments.

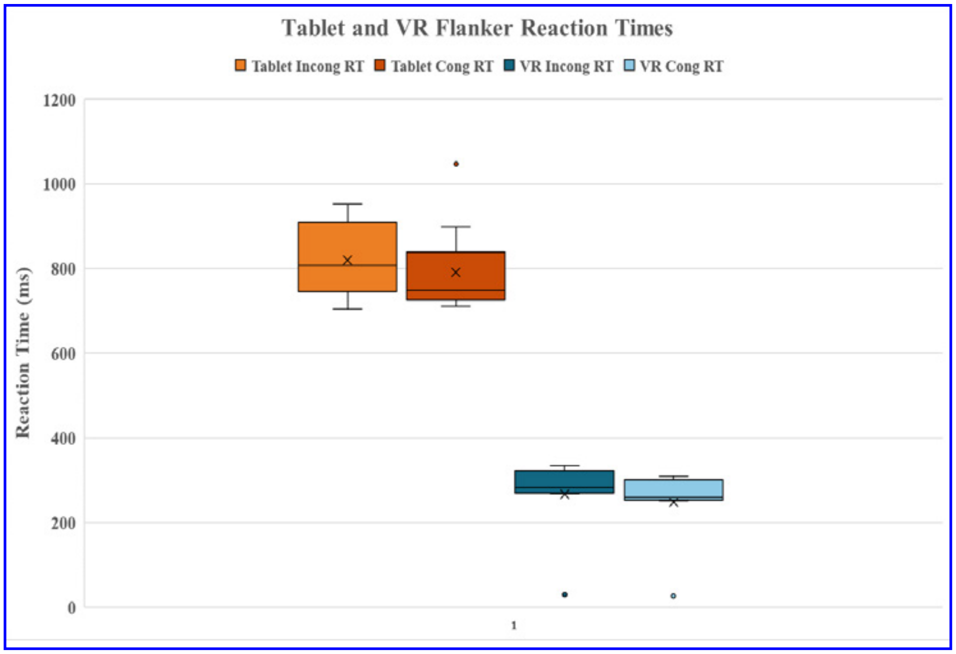

Figure 5. The average response times to stimuli between Tablet and VR Flanker, with considerations of congruency in the targets

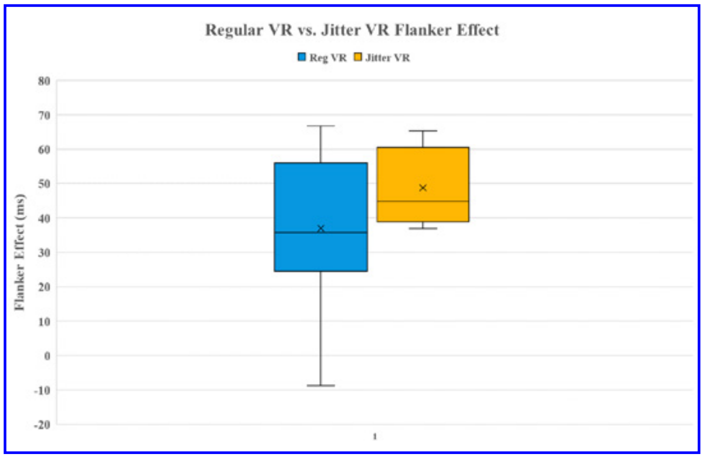

Figure 6. A box plot demonstrating the Flanker effect between the Regular VR Flanker task and the Jitter VR Flanker task.

In Pilot 1, when asked to choose the most challenging evaluation between the tablet Flanker and the VR Flanker, a greater part of the participants reported that the tablet Flanker was more difficult than the VR Flanker (**Figure 8a**). Correspondingly, a greater number of participants also reported enjoying the VR Flanker task as opposed to the tablet Flanker task (**Figure 8b**). However, the measure of enjoyment levels was similar between the two tasks (t = 0.005353).

In Pilot 2, however, most participants reported encountering the most difficulty during the Regular VR Flanker assessment (**Figure 9a**). Despite these discrepancies in difficulty, participants noted similar enjoyment levels among each task (t = 0.2891) (**Figure 9b**).

DISCUSSION

In both Pilot studies, we aimed to validate that our VR Flanker task is a viable option for measuring inhibitory control while also studying the properties of different versions of the VR task. Pilot 1 aimed to recreate the Flanker effect of the tablet version of the task within the context of VR. The sessions in Pilot 1 used different forms of stimuli, yet the data extracted from the VR Flanker sessions (shown in **Figure 9**) closely resemble the results derived from the VR Flanker sessions. Therefore, we can deduce that our VR context successfully created a Flanker effect and the two tasks measure the same construct of inhibitory control. Overall, the data gained from the study demonstrates that the Flanker effect was produced from both of our developed VR Flanker tasks. The objective of Pilot 2 was to create a Flanker effect in the VR versions of the Flanker task, while also building upon the foundation created by Pilot 1 and further identifying which forms of stimuli would elicit a greater Flanker effect. A larger Flanker effect shows that participants likely experienced more conflict, causing them to exert greater inhibition when switching between congruent and incongruent trials. This allows us to better gain an

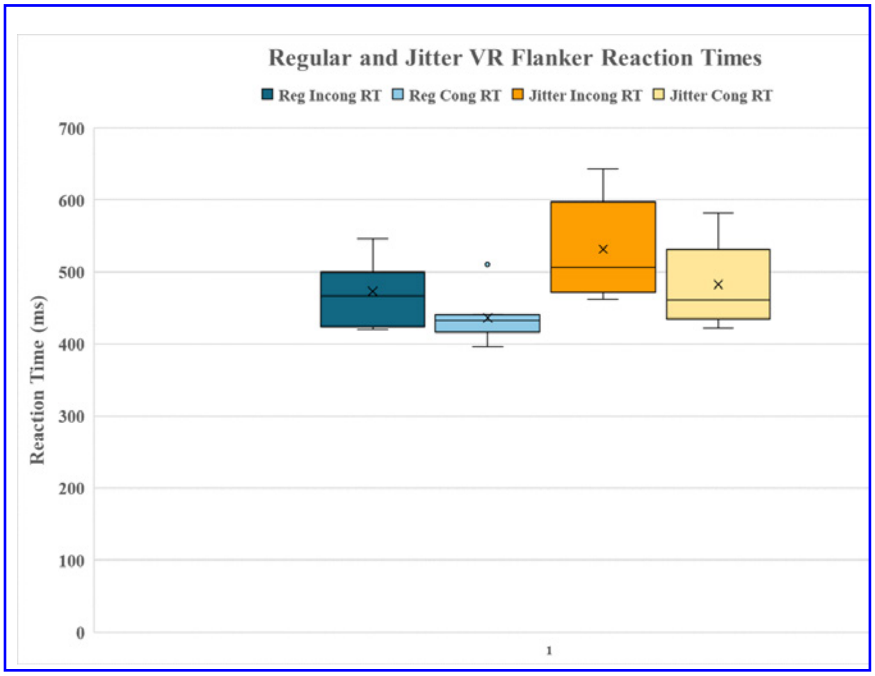

Figure 7. The average response times to stimuli between VR Flanker variations, with considerations of congruency in the targets.

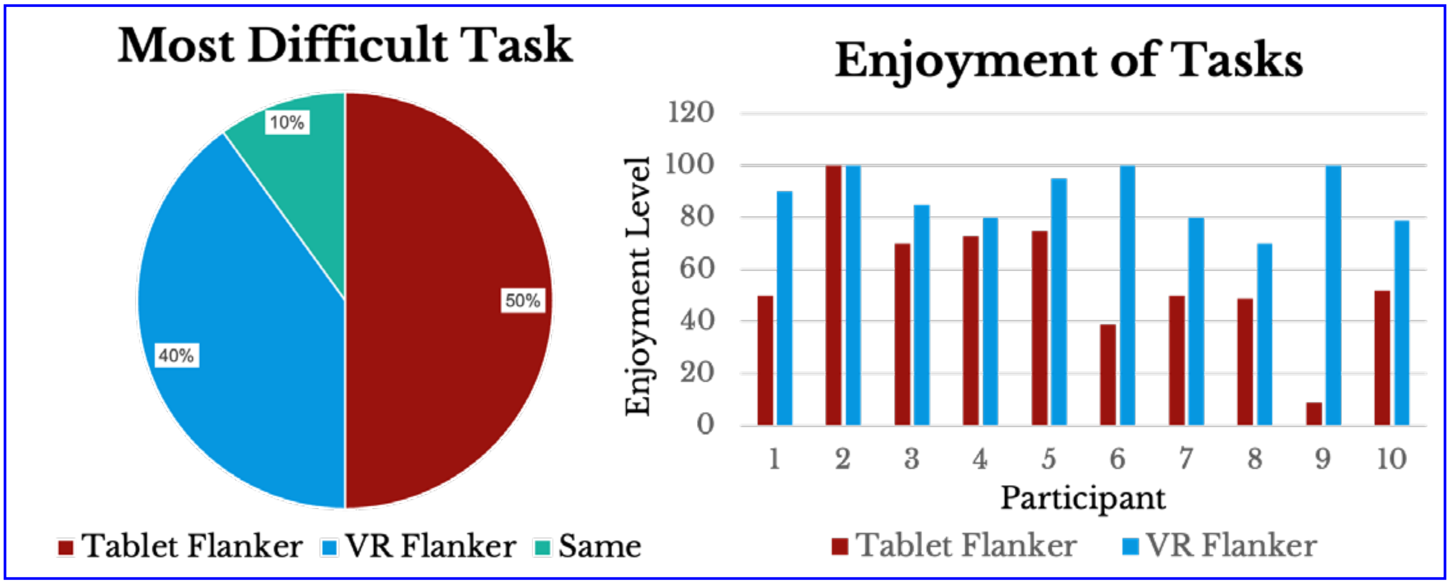

Figure 8(a,b). A visualization of the survey responses we received following the first session of Pilot 1. **(a)**. When asked to report which of the two tasks they found most challenging, the participants' responses. **(b)**. Distribution of individual submissions reporting enjoyment levels for each task.

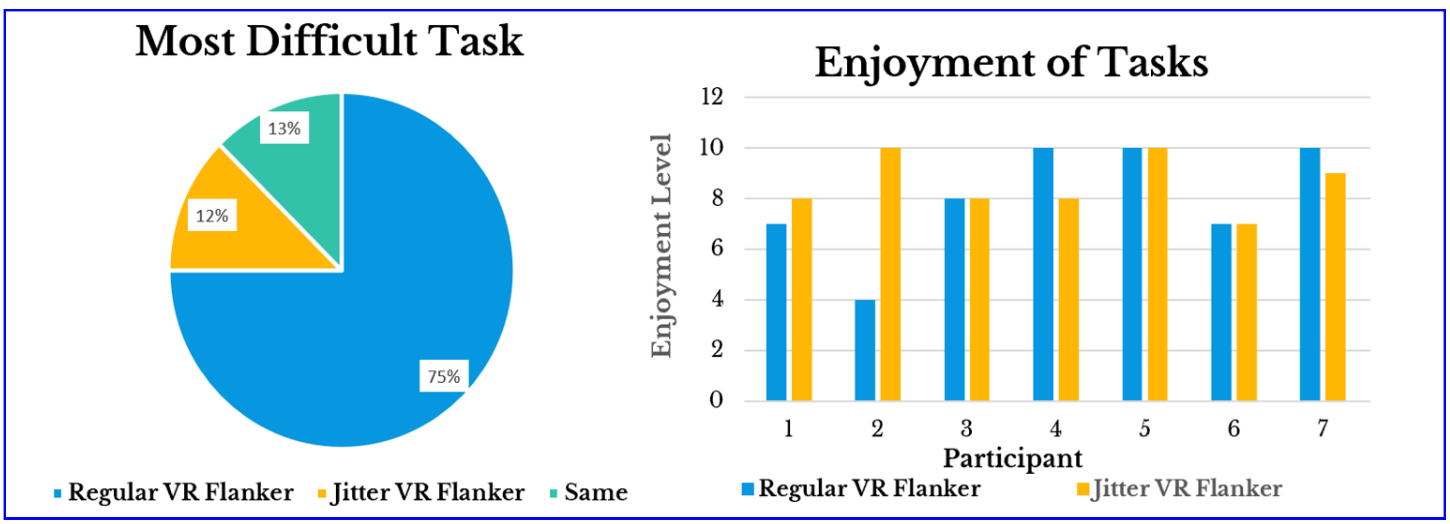

Figure 9(a,b). A visualization of the survey responses we received following the first session of Pilot 2. **(a)**. The participants' responses when asked to report which of the two variations of VR Flanker they found most challenging. **(b)**. Distribution of individual submissions reporting enjoyment levels for each variation.

accurate measurement of the participant's true inhibitory control abilities when they need to exercise inhibition in life situations. Results from both Pilot studies indicate that we achieved a Flanker effect in our VR Flanker tasks. Hence, this supports that our VR Flanker task can consistently and accurately measure the inhibitory control abilities of individuals. We can infer that the Jitter VR Flanker variation successfully produced a greater Flanker effect through its spatial experimentation. The placement of stimuli in different areas in the virtual environment may require greater cognitive processing of the frontal lobe, leading to a greater Flanker effect. In Pilot 1, participants found the difficulty of the tablet and VR versions were similar. However, a greater number of participants found the VR version more enjoyable. This suggests that the VR environment may yield higher engagement levels from the participants, while also maintaining the same level of challenge. In Pilot 2, participants found the Regular VR task to be more complex than the Jitter VR task, but the enjoyment of the tasks was similar. This was unexpected, as we predicted the participants would have greater difficulty responding to the dispersed stimuli in the Jitter VR task than in the Regular VR task. Our prediction, however, was supported by the larger Flanker effect produced in the Jitter VR Flanker. Hence, this could indicate that participants may have been more alert during the Jitter VR task, causing them to perceive the task as being less difficult. Furthermore, participants may enjoy VR tasks regardless of the difference in the presentation of the stimuli in the VR environment.

FUTURE DIRECTIONS

Because this field is still developing, our research can help establish an important baseline. Current studies conducted at the UCR Brain Game Center designed to measure inhibitory control across diverse populations can implement our VR Flanker Task. In the future, we will administer the Regular VR Flanker task to a larger sample and examine the replicability of the preliminary results. We also plan to incorporate participant feedback as we further develop and change the Flanker tasks in VR. Moreover, we are working on extending the framework to add other inhibitory control tasks such as stopping and rule-switching. We are working on adding game elements such as levels, distractors, and point systems to increase participants' enjoyment of the task. These developments would help us contribute to the Brain Game project by allowing us to study how new VR versions of the Flanker task could create more significant Flanker effects. In the long term, analyzing performance measures of the VR Flanker task will elucidate the IC abilities of various populations. We could thus understand the general population better and help individuals that struggle with inhibitory control, such as those with substance use disorders or attention-deficit/hyperactivity disorder (ADHD).

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