Enhance VR behavioural metrics capture age-dependent reaction time delays

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Abstract

Enhance VR is a library of games based on neuropsychological principles. Each session generates Scores and Moments. While Scores reflect the player's overall performance, Moments are designed to capture behaviour. Here, we compared the reaction times between two age groups in sessions with identical Scores. In line with the literature, we found delayed reaction times in the older population, indicating that Moments capture age-dependent changes. These results show that Moments from Enhance VR provide valuable data for studying behaviour, aiming to better understand the players decision-making processes, and laying the groundwork for the potential development of cognitive biomarkers.

1. Introduction

Besides higher ecological validity, experiences in virtual reality (VR) have the potential to generate and collect richer datasets than screen-based solutions. The unique combination of full control over the environment, the presentation of stimuli, and the high temporal resolution tracking and recording of players' actions could provide important insight into their underlying behavioural strategies and cognition (Parsons, 2015).

At Virtuleap, we have developed Enhance VR, a cognitive training and monitoring solution in VR (Brugada-Ramentol et al., 2022). With a growing library of seventeen games based on validated neuropsychological principles, Enhance VR covers eight cognitive categories: memory, attention, information processing, motor control, problem solving, spatial orientation, social cognition, and flexibility. Each game on Enhance VR generates two different types of outcomes, providing two layers of information related to the cognitive ability they target.

At a first level, each Enhance VR game session generates a Score, a value between 0 and 100, that similarly to traditional scoring systems, provides in-game feedback to maximize engagement while reflecting the players' overall performance at the end of the session. Although these Scores evaluate major variables related to the game's cognitive ability of interest, they are restricted in the amount of behavioural information they integrate.

On a second and deeper level, Enhance VR collects rich behavioural data within game-specific structures that record key events from both the app and the users' side during gameplay. These structures called "Moments" output scientifically informed variables that could be stored to reproduce and analyse gameplay offline. Collecting this information opens the possibility to study the players' behaviour in detail with data science methods, aiming to better understand their decision-making processes and the potential creation of next-generation cognitive biomarkers.

2. Methods

The Enhance VR app has 76k+ registered users. Every time a session is played by one of those users, session's Scores and Moments are stored in our cloud-based database. In addition, demographic user's information (age, gender, educational level, etc.) is collected at sign in and cross-referenced to gameplay outputs. In this manner,

Scores and game-specific behavioural metrics extracted from the analysis of Moments could be compared across different demographic segments.

Each session of Drummer was completed by a different subject, ensuring no user contributed more than a single data point to the study. For each session, the mean reaction time (RT) across all successful Go trials was calculated (trial count range, younger group: 18–29, older group: 16–29). To compare subjects/sessions with identical Scores, the population mode was used to determine the representative Score value. This value was selected because it maximized the number of samples per group (younger group: n=28; older group: n=20) from a total of 122 screened sessions. Statistical comparisons between groups were conducted using the non-parametric Mann-Whitney test.

3. Results

Drummer is an Enhance VR game focused on response inhibition, within the category of cognitive flexibility. It is inspired by the Stop Signal Task (SST, Fig. 1A) (Logan et. al., 1984). In this task, a white screen presents a fixation point followed by a directional Go stimulus (e.g., an arrow) pointing to the left or to the right. The subjects are instructed to press a left/right button in accordance with the direction of the stimulus within a short time window (Go trial). Additionally, in a proportion of trials, a Stop signal appears a brief period after the Go stimulus, in which case subjects must avoid pressing the button (Stop trial). This same logic was translated into Drummer, where players need to hit specific drums on a set following arrows that appear on a central device after a fixation period (Fig. 1B, top row). Consistently with the SST, in some trials, the arrow and drums change their colour to orange while a salient tone is played, indicating that the drum hit must be stopped (Fig. 1B, bottom row).

In this article, we present the case of Drummer as an example for the potential of Enhance VR to differentiate younger vs. older populations with identical Scores based on their Moment-derived RTs. Since it is well established that RTs increase with aging (Fozard et al., 1994; Woods et al., 2015), we investigated if Moment-derived variables could detect such performance differences that are not evidenced by the Scores. For that, we first selected a population of young players (age range 15–25 years-old) and another one of elder players (age range 55–65 years-old) whose Scores were identical after playing a single session in Drummer (see methods). Next, we processed these

sessions' Moment data and calculated the players mean RT when correctly hitting the target drum in a Go trial. As expected, this analysis showed that the elder population had significantly longer reaction times when compared to the younger population (Fig. 1C).

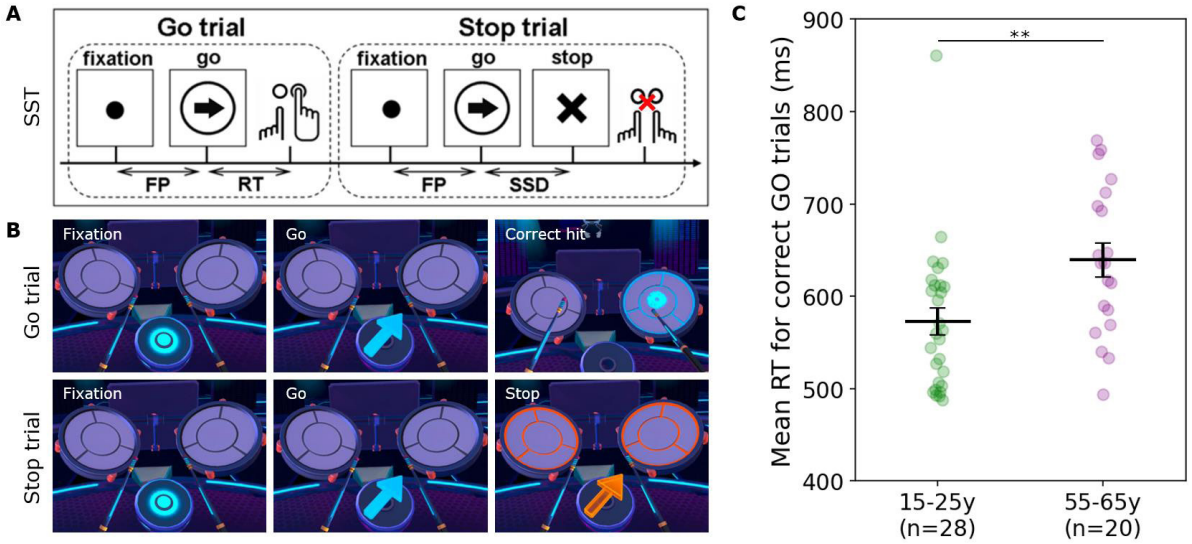

Figure 1: **A.** *Go and Stop trials structure in the Stop Signal Task. FP, fixation period; RT, reaction time; SSD, stop signal delay. Adapted from Logan et. al. 1984.* **B.** *Images from Drummer showing Enhance VR's translation of SST to a VR environment and the key events from Go and Stop trials in the game.* **C.** *Mean session reaction time for correct Go trials in Drummer for the younger and older populations, Mann-Whitney U test comparison of mean reaction times between age groups, p=0.004. Each datapoint represents a single session from a different subject. Black horizontal lines: mean. Error bars: SEM.*

4. Discussion

In line with the literature, our data shows that reaction times increase in an age-dependent manner. In the last decades, several groups have reproduced this phenomenon using a variety of paradigms (Fozard et al., 1994; Hardwick et al., 2022; Woods et al., 2015). Slower processing, decreased motor speed, and greater cautiousness are some of the reasons proposed to underlie these changes in the elder population. However, the subject is still under debate, and, in our case, we should also consider a possible contribution of lower digital literacy.

Our results show that Moments in Drummer capture subtle changes in reaction times across the studied groups. This finding highlights the importance of incorporating data structures that record timings, accuracies, error types, and related metrics when designing cognitive activities. These variables provide more granular information about players' behavioural strategies, potentially offering deeper insights into their cognitive processes. This is particularly important when compared to more traditional performance scores, which, as shown by our data, do not always reflect subtle differences between groups.

It is worth noting that this paper presents an individual example of a single metric from only one of our games. However, Enhance VR currently covers eight cognitive categories with seventeen games from which dozens of behavioural metrics could be extracted. Thus, similar metrics

from different games (for example, reaction time) could help develop new measurements across games when transversally integrated, revealing more insights on players' behavioural strategies than when isolated.

Although the data presented here focus on a single session at one point in time, Enhance VR's capacity to store longitudinal data enables the evaluation of metrics across sessions as a time-series progression. This approach allows for longitudinal follow-ups that can be accessed through Virtuleap's organizational dashboard, which provides both tabular and graphical access to Moment's data in a navigation friendly interface (www.virtuleap.com). This is especially interesting for healthcare professionals using Enhance VR games to monitor patients because, if further studies confirm the sensitivity of our behavioural metrics, or a combination of them, they could potentially work as biomarkers of cognitive deficits in the future.

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