HickStudyVR: A Hick's Law-Based Information Processing Speed Test in VR for Large Choice Sets

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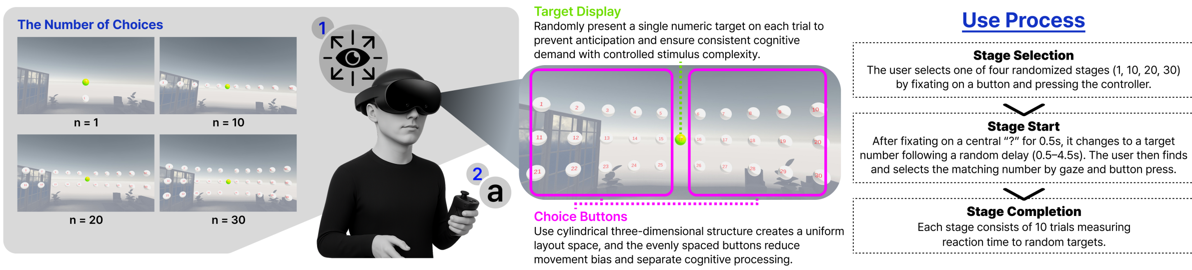

Figure 1: The user interface, workflow, and design considerations of the *HickStudyVR* app.

Abstract

Hick's law, a foundational principle in human–computer interaction (HCI), predicts that reaction time increases logarithmically with the number of equally likely choices. While its theoretical value is well established, practical applications in modern HCI remain limited, particularly for accurately estimating individual information processing speed (IPS), defined as the reciprocal of the regression slope. This study introduces *HickStudyVR*, a virtual reality–based system designed to measure IPS with high precision by minimizing perceptual and motor confounds through gaze-based aiming and controller-based selection. A pilot study with four participants showed strong adherence to Hick's law (all $R^2 > 0.94$), with IPS ranging from 5.00 to 5.56 bit/s. To further validate the system's design, future work will compare it against traditional 2D layouts to determine whether the VR-based interaction method indeed enhances IPS measurement accuracy. Additional investigations will explore the impact of stimulus type, spatial layout, and gamification on IPS estimation, supporting the development of more robust and generalizable tools for cognitive assessment in immersive environments.

Index Terms: Hick's law, choice reaction time, information processing speed, virtual reality, 3D user interface.

1 Introduction

In the 1950s, the intersection of information theory and experimental psychology produced a foundational model of human decision-making: Hick's law (also known as the Hick–Hyman law) [1, 2]. This law posits that reaction time (RT) increases logarithmically with the number of equally probable choices, formally expressed as:

$$RT = a + b\log_2(N+1) \tag{1}$$

where a and b are empirically derived constants, and N is the number of alternatives. Although Hick's law has long been recognized as a theoretical framework for understanding information processing speed (IPS), its practical application in contemporary human–computer interaction (HCI) remains inconsistent. Researchers have questioned its relevance to modern tasks, citing discrepancies between predicted and observed behavior in complex digital environments [3, 7, 8].

Despite these challenges, IPS (as inferred from the inverse of the slope parameter b) has shown substantial value in cognitive and clinical research. Prior studies have found associations between IPS and measures of intelligence [6], as well as early indicators of neurological conditions and age-related cognitive decline [4, 5].

Accurate IPS estimation, however, is difficult to achieve. In conventional implementations, the observed RT includes not only the time spent cognitively identifying the correct choice but also delays introduced by visual search and motor execution. Moreover, previous studies have largely focused on tasks involving relatively few choices, leaving the effects of large choice sets, which are common in real-world decisions, underexplored.

To address these limitations, this study investigates whether virtual reality (VR) environments equipped with eye-tracking capabilities can facilitate more precise IPS measurement. Unlike traditional displays with limited screen space, VR interfaces allow choices to be arranged freely in 3D space, potentially reducing layout-related perceptual noise. Additionally, gaze-based interaction using headsets like the Meta Quest Pro or Apple Vision Pro can minimize motor demands, enabling us to isolate cognitive processing time more effectively. We aim to assess whether this approach can extend the applicability of Hick's law to high-choice-density scenarios while yielding cleaner IPS estimates.

2 System Design

We developed *HickStudyVR*, a VR application designed to measure users' IPS under varying choice-set conditions, leveraging the spatial flexibility of immersive 3D environments. To respond, users aim at the target sphere using their gaze and confirm their selection by pressing a button on the VR controller. The system minimizes motor and perceptual confounds commonly found in 2D interfaces by combining gaze-based target acquisition with minimal-effort manual input. The app interface consists of two main components (Figure 1):

- **Target Display:** This floating sphere is rendered at the user's initial central gaze position and displays the target number to be selected in each trial.

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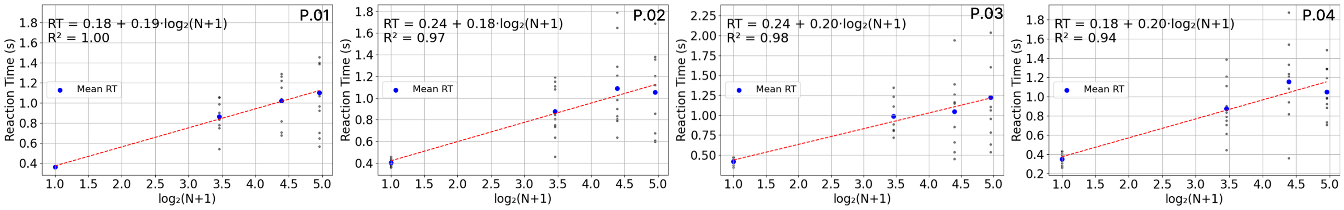

Figure 2: Regression plots showing the relationship between reaction time (RT) and $\log_2(N+1)$ for each of the four participants.

- **Choice Buttons:** The selectable items are implemented as spherical buttons, arranged in a horizontal sequence from left to right, with numbers increasing from 1 (leftmost) to 10 (rightmost). When more than ten choices are required, additional rows appear below in the same structured pattern.

2.1 User Testing

To evaluate the effect of VR-based interaction on IPS, participants performed the task using the proposed *HickStudyVR* system. Four participants (2 male, 2 female), aged 21–24 years (M = 22.8, SD = 1.5), completed the test using a Meta Quest Pro headset (1800 × 1920 resolution per eye, 90 Hz refresh rate).

Participants performed the task by using their gaze to aim at spherical choice buttons and a VR controller to confirm their selection. The task involved responding to a target display showing a random number and selecting the corresponding choice button as quickly and accurately as possible.

The number of choices was manipulated across four levels: 1, 10, 20, and 30. Each condition consisted of two sessions of 10 trials, with the first session used as practice. The system recorded each trial's RT and selection accuracy.

2.2 Results

No failed trials were recorded for any of the three participants. After applying the interquartile range method to detect and exclude potential outliers, we conducted a linear regression analysis. Figure 2 presents the relationship between RT and $\log_2(N+1)$ for each participant. In all three cases, the linear model showed an excellent fit (all $R^2 > 0.94$), consistent with the classic Hick's law trend. The estimated IPS ranged from 5.00 to 5.56 bit/s (M = 5.20 bit/s, SD = 0.23 bit/s), and the intercepts (interpreted as baseline sensorimotor latencies) ranged from 0.18 s to 0.24 s (M = 0.21 s, SD = 0.03 s). These findings support a robust logarithmic increase in RT with increasing choice set size and reveal modest yet meaningful individual differences in IPS.

3 Future Works

While the current version of *HickStudyVR* was designed with heuristics to reduce potential confounds in IPS measurement, its design decisions have not yet been fully validated through systematic empirical studies. In particular, it is necessary to conduct a comparative study against a traditional layout to verify whether the use of VR-based interaction, specifically, gaze for aiming and a controller button for selection, truly contributes to improved IPS measurement accuracy. To enhance the reliability and generalizability of IPS estimation, further research is needed to address the following open questions:

- **RQ1:** In a VR context, how do variations in stimulus characteristics, such as the visual form of the target (number, letter, symbol), color schemes, or 3D shape, affect IPS estimation accuracy? Should VR-based IPS testing rely on uniform, standardized stimuli to ensure measurement consistency, or is there value in embracing richer, more diverse stimuli that better reflect real-world complexity?

- **RQ2:** What spatial arrangement of choice buttons in 3D space leads to the most efficient gaze-based target acquisition and minimal response variance? While the current system uses predefined choice-set sizes (1, 10, 20, 30) with fixed layouts, future work should explore adaptive layout algorithms that can dynamically generate the most optimal spatial configuration for any number of alternatives within the user's field of view.

- **RQ3:** Given the high level of immersion that VR can provide, particularly in game-like environments, can deeper engagement and motivation be leveraged to improve the precision of IPS measurements? Exploring the role of gamification and immersive design in enhancing task performance offers a promising direction for future development.

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