Thinking Outside the Lab: VR Size & Depth Perception in the Wild

RAHUL ARORA, University of Toronto, Canada
JIANNAN LI, University of Toronto, Canada
GONGYI SHI, University of Toronto, Canada
KARAN SINGH, University of Toronto, Canada

1 EXPERIMENTAL PROCEDURE DETAILS

In this section, we provide additional details on participant demographics and gamification procedure.

1.1 Full Demographics Details

Participants' countries of residence are shown in Table 1, while VR device usage statistics are displayed in Table 2. The inset figure shows the fields of view and resolutions of the headsets utilized. We had also asked two questions to judge participants' experience with 3D distance and size judgement tasks—experience with 3D action games such as first-person shooters and with 3D design and modelling tools—on 5-point Likert scales, with 5 being the highest degree of self-reported experience. Participants were highly experienced with 3D games, with 38 answering 5 and 15 answering 4 (median 5). Experience with 3D design and modelling tools was lower (median 2), with only 5 participants reporting extensive experience with such software.

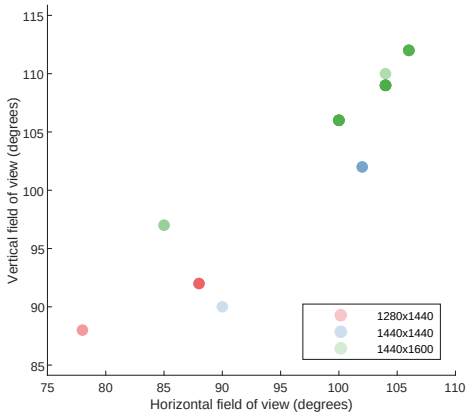

Fig. 1. Field of view reported by all the headsets utilized in the study, coloured by the marketed screen resolution per eye.

1.2 User Controls Details

The study controls were designed to be simple and easily extensible to diverse controllers. Participants could use any available one-dimensional input button to control the size of the *comparison* cube in the *size matching* tasks. This was chosen to be the y-axis of a thumbstick or trackpad on the controller. As participants held it near one of the extremes for time t, the size S_{comp} was increased (or decreased) by an amount $c\mathrm{v}(t)\Delta t$, where Δt is the time since the last update, $c \in \mathbb{R}^+$ is a positive constant, and $\mathrm{v}(t)$ is the rate of change at time t. In order to reduce the impact of the kinetic depth information and to allow large changes to the cube size efficiently, we model $\mathrm{v}(t)$ with an acceleration term. That is, $\mathrm{v}(t) = at$, where $a \in \mathbb{R}^+$ is a positive constant. The *comparison* cube distance is controlled analogously in the *distance bisection* tasks.

The only other control is a "confirm" button, for which we use the primary push button on the controller, typically called the "A", "X", or "Menu" button, depending on the device.

Authors' addresses: Rahul Arora, University of Toronto, 40 St. George Street, Toronto, Ontario, Canada, arorar@dgp.toronto.edu; Jiannan Li, University of Toronto, 40 St. George Street, Toronto, Ontario, Canada, jiannanli@dgp.toronto.edu; Gongyi Shi, University of Toronto, 40 St. George Street, Toronto, Ontario, Canada, gongyi.shi@mail.utoronto.ca; Karan Singh, University of Toronto, 40 St. George Street, Toronto, Ontario, Canada, karan@dgp.toronto.edu.

Table 1. Participants' countries of residence.

Country	# participants
United States	36
Canada	5
France	2
Germany	2
Belgium	1
Czech Republic	1
Denmark	1
Finland	1
India	1
Indonesia	1
Italy	1
Mexico	1
Netherlands Antilles	1
Norway	1
Poland	1
Romania	1
Spain	1
United Kingdom	1

Table 2. Full list of devices used by the participants.

Device	# participants
Valve Index	17
Oculus Quest	15
HTC Vive	10
Oculus Rift S	5
Lenovo Explorer (Windows MR)	3
Samsung Odyssey+ (Windows MR)	3
Oculus Rift	2
HTC Vive Pro	2
HTC Vive Pro Eye	1
Acer AR101 (Windows MR)	1
Dell Visor (Windows MR)	1

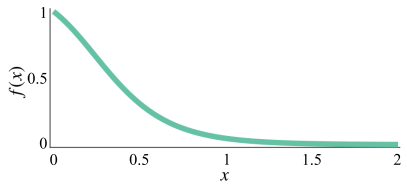

Fig. 2. Scoring function.

1.3 Gamification Scoring Details

Participants had access to an online leaderboard to see their score, as well as their position relative to others. The top ten participants received an additional gift card worth US $15. The leaderboard is shown in Fig. 3.

The score was computed out of 1000, along with an additional bonus of 100 points each for the second and third session, leading to a maximum possible score of 1200. The score for each experiment block Ξ_{block}, out of a total of 250, was computed as follows.

$$\Xi_{block} = \Xi_{base} + \xi_{trial}\left(\sum_{t\in\{1,\ldots,15\}} \mathrm{f}_t\right) \tag{1}$$

The base score Ξ_{base} was set to 25 points, thus participants received at least 100 points for a session, irrespective of their responses. The per-trial maximum score ξ_{trial} was 15. f_t gives the score for each of the 15 trials in a block.

$$\mathrm{f}_t = f(x) = \left(1 - \frac{x}{x + \exp(-3x)}\right). \tag{2}$$

This sigmoid-like function gives a maximum when the difference between the accurate response and the chosen response is 0, and increases symmetrically when it deviates to either direction (Fig. 2). Here x is a transformation applied on the participant's response as follows. In a *size matching* trial, let the size difference corresponding to the participant's response be $y = S_{comp} - s_{ref}$. Then we set x to be $|y|/0.3$. Similarly, for the *distance bisection* trials, given the chosen *comparison* distance R_{comp}, we set $x = |2R_{comp} - r_{ref}|/0.3$.

1.4 Study Deployment and Implementation Details

Please note that all material related to study deployment is included in supplemental ZIP archive **S3**. Participation calls on Facebook and Reddit linked participants to a static webpage (**S3d**) that provided essential study and compensation details. A Google Form[1] (**S3e**) accessible from the webpage first obtained participant consent, followed by a second screen showing the short (2.5 minute) instructions video (**S3b**) hosted on YouTube[2]. While Google Forms does not provide a method to ensure that participants watched the instructions video till the end, YouTube statistics confirmed that most participants watched the bulk of the video. As an additional safeguard to ensure that participants understood the tasks, the study procedure included explanatory text and practice trials for both the *protocols*. In the third section of the Form, participants were provided with application download links (**S3g–i**). The study application was developed in the C# programming language using the Unity engine[3].

After completing a session, the application supplied a randomly-generated username to the participant, which was used to authenticate the remaining survey portion of the Form. Survey questions were aimed at understanding participants' strategies and the perceived differences between various conditions.

Fig. 3. Screenshot of the online leaderboard (vertically clipped).

Participants were not required to complete any of the above steps for additional sessions. They could simply restart the downloaded program and complete another session. A unique ID associated with the participant's device ensured that they could not complete more than three sessions. All the study data was uploaded to a Back4App server[4] hosting the open source Parse platform[5].

2 RESULTS WITH FIRST SESSION DATA ONLY

In the main document, we reported results for mean size ratio for *size matching* tasks and mean distance ratio for *distance bisection* tasks and the respective standard deviations. The reported results utilize participant judgements across all the sessions (recall that many participants completed multiple sessions). The mean size ratio was 1.094 ± 0.428, while the mean distance ratio was 0.469 ± 0.157. If we only utilize data from participants' first session, thus weighing all participants equally for computing summary statistics, the mean size ratio was found to be 1.091 ± 0.464 and the mean distance ratio 0.464 ± 0.178. Clearly, the mean values are very similar, consistent with our observation that no learning effects were observed.

[1] https://docs.google.com/forms
[2] https://www.youtube.com
[3] https://www.unity.com
[4] https://www.back4app.com
[5] https://parseplatform.org/