Online Appendix: Large Language Model-assisted Speech and Pointing Benefits Multiple 3D Object Selection in Virtual Reality

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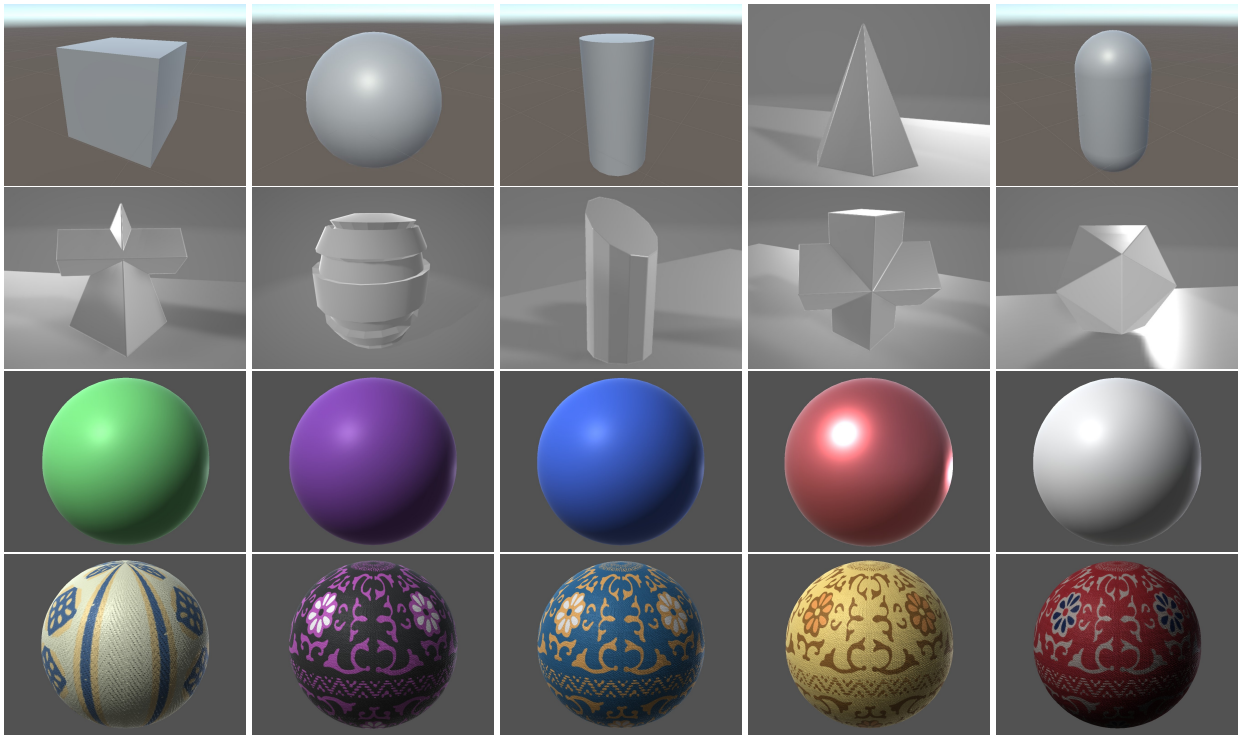

Fig. 1: Images of 10 object shapes and 10 object colors presented in the pre-experiment survey. The first and third row include shapes and colors which we expected were easily identifiable. Shapes and colors in the second and fourth row were expected to be more difficult to reference verbally. Based on the survey results, shapes and colors from the last column were not included. The names of the remaining shapes and colors are listed as follows. First row: cube, sphere, cylinder, pyramid; Second row: pyramid cuboid, barrel, truncated cylinder, cross; Third row: green, purple, blue, red; Fourth row: white pattern, purple pattern, blue pattern, yellow pattern.

A Pre-Experiment Survey and Findings

Prior to the user study introduced in this paper, we distributed an online pre-experiment survey to determine which object shapes and object colors were easy to reference verbally and which were not.

A.1 Participants

Of the 21 participants who responded to this survey, 52.6% were male and 47.4% were female. The age of participants ranged from 19 to 43, and no disability of any form was reported.

A.2 Procedure

In the survey, participants were given images of ten object shapes and images of ten object colors, among which we expected five shapes and five colors to be easily identifiable, and the rest to be more difficult to reference verbally. For each object shape or color, they were asked to name it in no more than two words. The ten images within each section are presented to participants in random order. If participants found some of the object shapes or colors hard to describe, they had the option to choose not to describe it. Subsequently, participants were given ten images of different target objects among a set of distractor objects in the background. The ten target objects were chosen such that all object shapes and all object colors were included, and participants were asked to name the target object to distinguish it from other objects in the scene in no more than three words. Finally, participants were asked to provide their name and preferred means of communication if they wish so that they could be notified of the subsequent object selection user study.

A.3 Results

Figure 1 shows the images of all object shapes and colors that were included in the survey. According to the survey results, 100%, 90.5%, 85.8%, 76.2%, 52.4% of participants referred to objects in the first row as 'cube', 'sphere', 'cylinder', 'pyramid', and 'capsule' respectively. Based on these results, we dropped the capsule object shape and included only the first four objects as easily identifiable objects in the user study. Similarly, 85.7%, 81%, 71.4%, 57.1%, and 47.6% were unable to reference object shapes in the second row verbally. We

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dropped the last shape and kept the first four shapes in the second row as object shapes which were difficult to reference verbally. In the survey, 9.6% of participants referred to the first object as 'pyramid', 9.6% referred to the second object as 'barrel', 4.8% referred to the third object as 'truncated cylinder', 19.2% referred to the fourth object as 'cross'. Therefore, we assigned the names 'pyramid cuboid', 'barrel', 'truncated cylinder', and 'cross' to the first four shapes in the second row in the user study.

For object colors, 100%, 100%, 95.5%, 76.1%, 52.6% of participants referred to the colors in the third row of Figure 1 as 'green', 'purple', 'blue', 'red', and 'white', and only the first four colors were included in the study. 90.5%, 81%, 76.2%, 71.4%, and 66.7% of participants were not able to reference the colors on the last row verbally, and the last color was excluded from the study. For participants who attempted to reference the colors, as the names chosen for each color were drastically different, we decided to name them as 'white pattern', 'purple pattern', 'blue pattern', and 'yellow pattern' to maintain consistency.

In the third section of the survey, participants were asked to name objects with a certain shape and color to distinguish with other objects. For some objects, both the shape and color was easy to reference, examples of which included the purple cube (90.4% participants were able to describe it as 'purple' and 95.2% were able to describe it as 'cube'), the white pyramid (66.8% described it 'white' and 81.2% described it as a 'pyramid'), and the blue capsule (71.4% described it 'blue' and 57.2% described it as a 'capsule'). Some objects had either an unfamiliar shape or an unfamiliar color, for example the white pattern sphere (only 4.8% participants described 'white pattern' and 67.1% described it as a 'sphere'), the red pattern cylinder (4.8% participants described 'red pattern' and 62.4% described it as a 'cylinder'), the green cross (57.5% participants described 'green' and 28.7% described it as a 'cross'), and the red pyramid cuboid (28.8% participants described 'red' and only 4.8% described 'pyramid cuboid'). Other objects had both an unfamiliar shape and an unfamiliar color, such as the blue pattern deltahedron (none of the participants described 'blue pattern' and only 9.6% described 'deltahedron'), the yellow pattern truncated cylinder (only 4.8% participants described 'yellow pattern' and 4.8% described 'truncated cylinder'), and the purple pattern barrel (none of the participants described 'purple pattern' and only 9.6% described 'barrel').

A.4 Implications

The pre-experiment survey provided evidence to determine which object shapes and colors were easy to reference verbally and which were not. Based on the 4 shapes and 4 colors which were easy to reference, we constructed the LOW perplexity condition; Based on the 4 shapes and colors which were difficult to reference, we constructed the HIGH perplexity condition; Based on the 2 shapes and colors which were most easy to reference, and the 2 shapes and colors which were most difficult to reference, we constructed the MEDIUM perplexity condition. For further reference, the complete version of the pre-experiment survey and anonymized results can be found on OSF in the 'Supplemental Materials' folder within the linked GitHub directory.