Virtual reality to memorize complex 3D shapes

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Abstract

Thanks to keener microscopy techniques, microscopy data are of increasingly high complexity. Analysis of this data by humans requires sharpened visualization tools. To this end Virtual Reality (VR) could be a tool of interest, as it immerses the user in a virtual environment along with its data. We conducted an experiment comparing the ability of a user to memorize and recall 3D objects using VR or traditional desktop visualizers we developed. These 3D objects correspond to the shape encapsulating small moving particles. This process yielded no significant difference between the user's results and the null distribution. Nonetheless, we observed a significant progression in VR not observed when using the desktop version of our software.

Intro

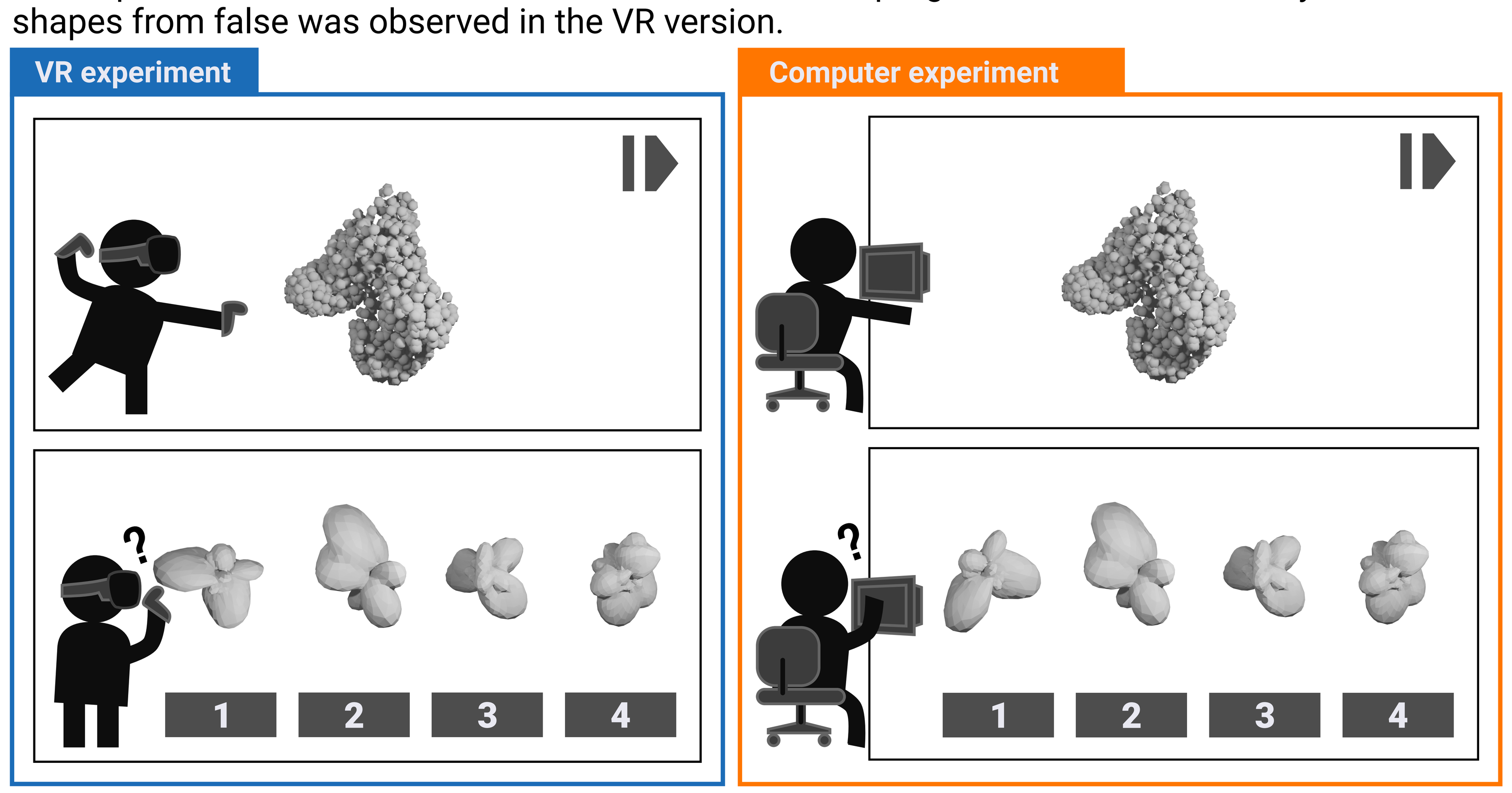
Light Sheet Fluorescence Microscopy (LFSM) allows 3D video imaging of multi-celled organisms. To this day, these datasets are most commonly displayed on desktop 2D screens while Virtual Reality (VR) could provide more intuitive contact with this data.

Indeed, VR was found to enhance scientific investigation in various sectors as they increase the user's interaction and comprehension of the virtual data. In this context, our mentor researcher Léo Blondel developed a VR software for visualizing large moving microscopy datasets produced by LFSM.

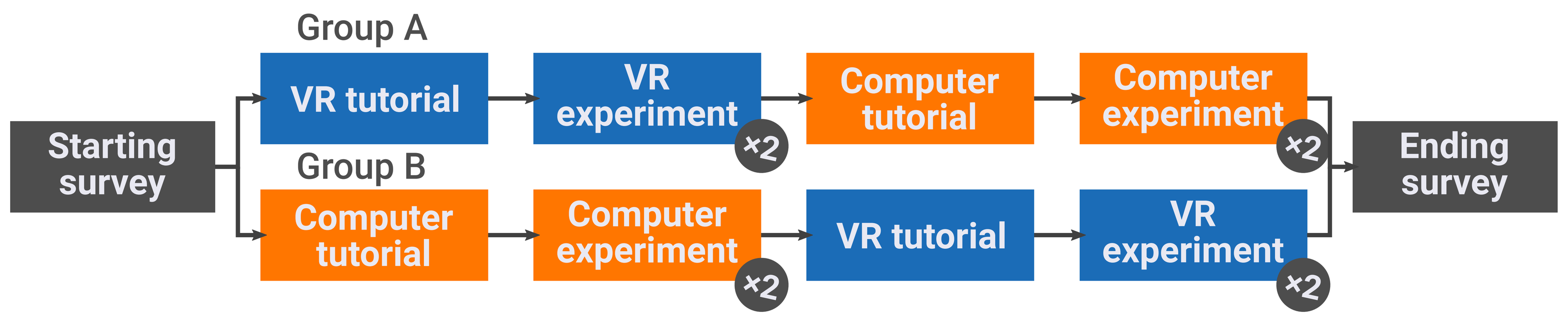
We want to appraise the impact of using a VR headset or a flat 2D screen on one's ability to interpret 3D time-evolving objects as the encapsulating shape of moving particles.

We exposed users to a video sequence of time-evolving complex datasets. These datasets are composed of small cell-like particles moving along complex organized patterns. Users were asked to observe the global shape drawn by the particles. They were then shown a set of 14 3D meshes. 7 of these were extracted from the sequence, later referred to as "true shapes", while the later called "false shapes" were randomly generated. Participants were asked to sort the true shapes by chronological order of apparition in the sequence. This procedure was executed twice in VR and twice on a desktop 2D screen for each participant with two different datasets.

VR and computer results distributions did not differ significantly. In fact, these distributions did not prove to be significantly different to the null distribution. No significant impact can be assessed on the user's ability to track the changes in global shape when using the VR or the desktop version of our software. However, a notable progression in users' ability to tell true shapes from false was observed in the VR version.



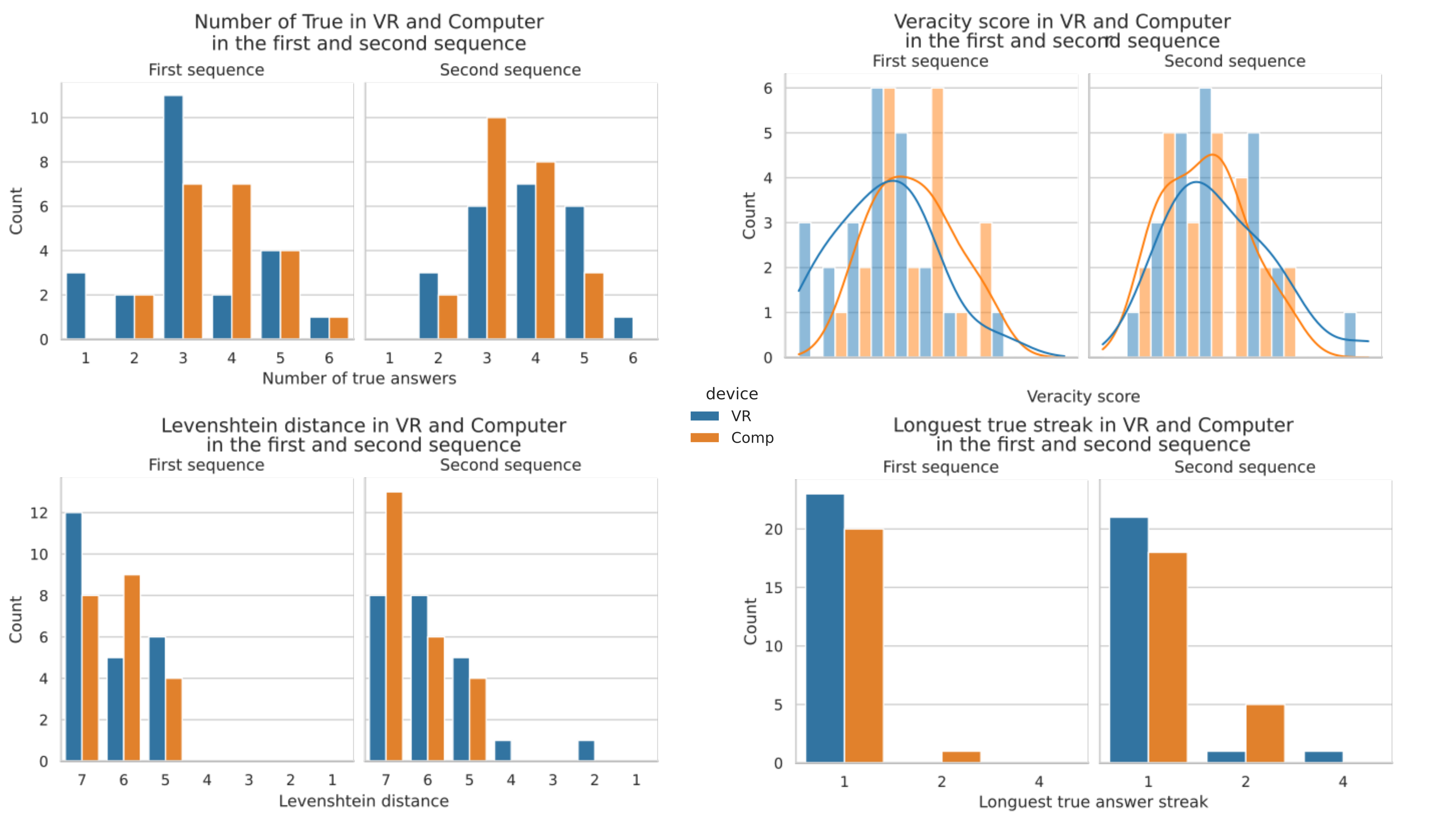
VR tutorial | VR experiment | Computer tutorial | Computer experiment



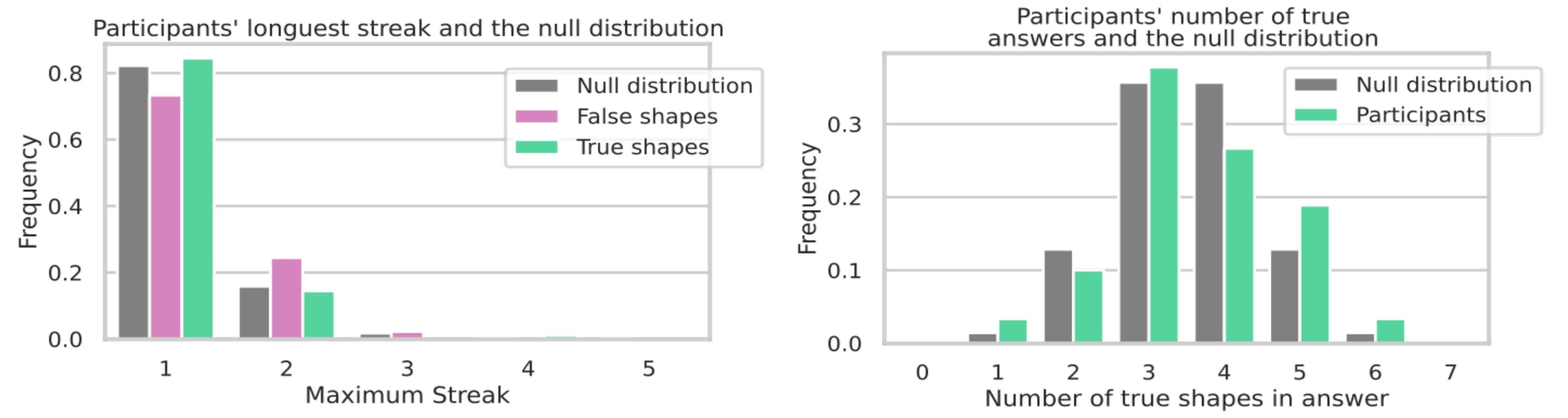
Code : https://github.com/drblobfish/score-diving-4th-dim
Bibliography : https://www.zotero.org/groups/4625494/score-4d-microscopy/library
CRI project : https://projects.learningplanetinstitute.org/projects/rRiHhgY3/summary

VR vs Computer

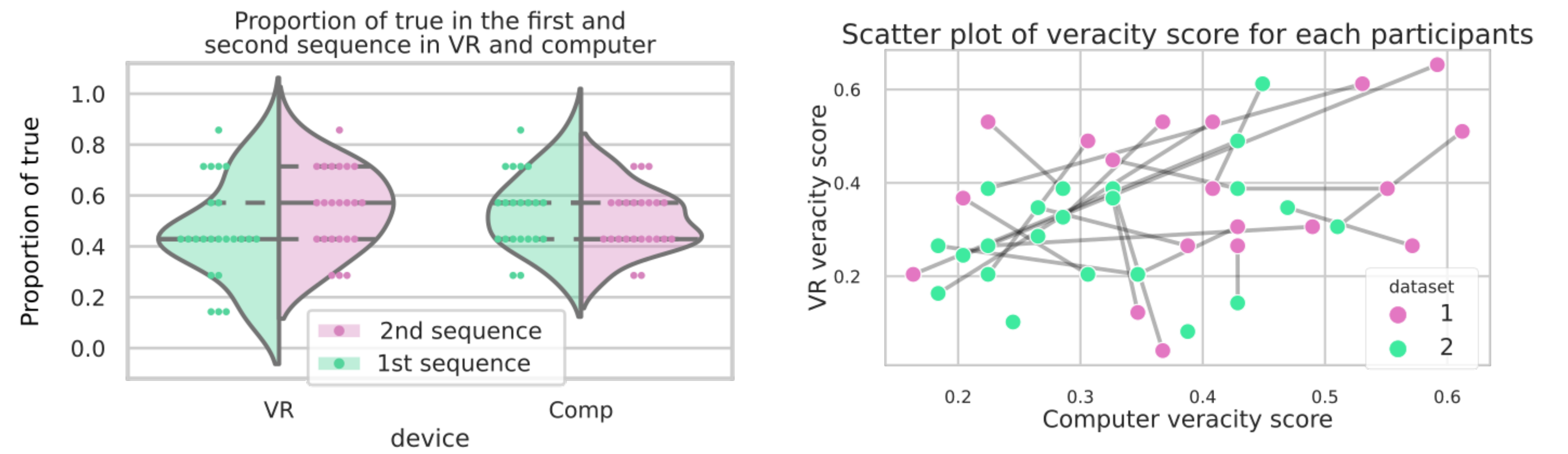
Participant's answers were evaluated by different scoring functions : 1) the number of true shapes in the shape selected by the participant, 2) the longest streak (LS) of sorted adjacent true shapes, 3) the Levenshtein distance between the participant's answer and the correct answer and 4) the sum of the distance of each true shape to its correct positions, named "veracity score".



Here we compare these scores between Computer and VR with respect to experiment order. For almost all experiments we observe no significant difference (Mann-Whitney U test (MWUt) : p-values>0.05). However, for the first experiment, participants had significantly lower Veracity Scores in VR than Computer (MWUt: p-value=0.023). They also obtain a nearly significantly lower Levenshtein distance for the second experiment (MWUt: p=0.06).

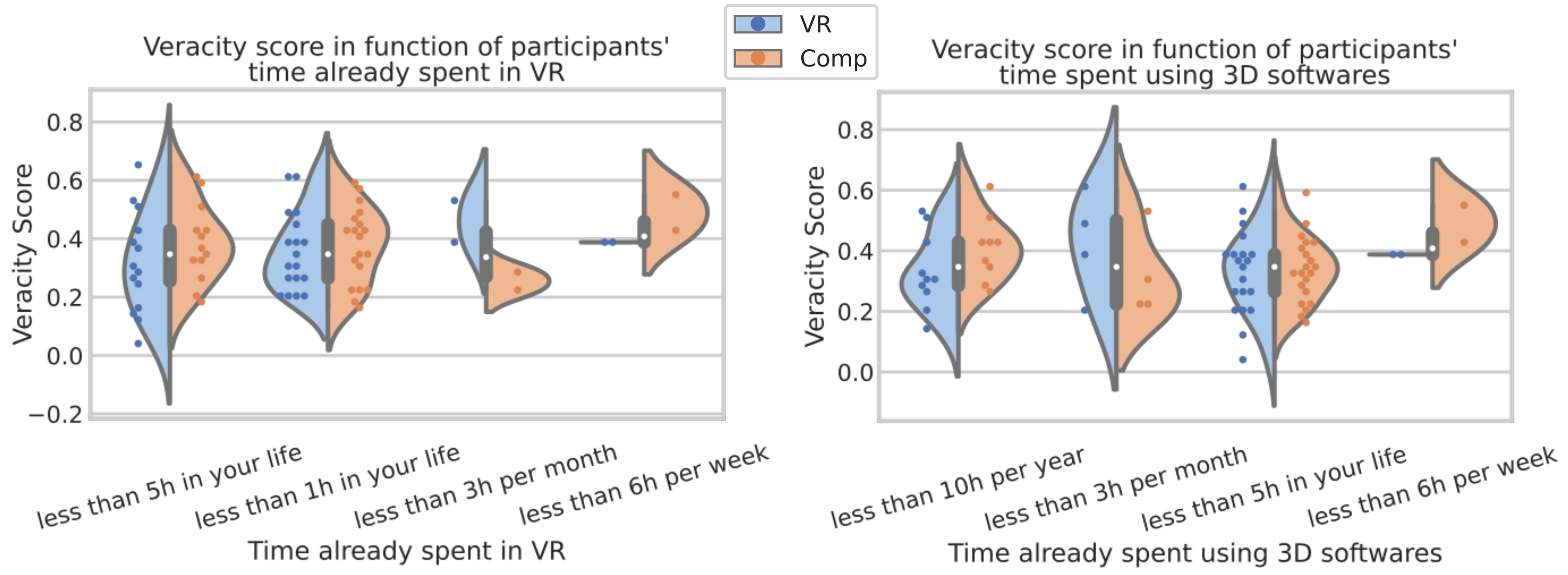


We compare the distribution of the number of true answers with a hypergeometric distribution (N=14, K=7, n=7) and find no significant differences. This shows that the experiment was too difficult and that participants mainly guessed rather than used their memory. We compare the distribution of the LS taken both forward and backward with the null distribution (sampled with 10 000 random draws). We find the LS of false shapes to be significantly longer than under the null hypothesis (MWUt: p=0.01). This suggests participants used the fact that adjacent shapes look similar in the sorting part of the experiment and not only their memory. However, no significant difference was found between the null hypothesis and LS of true shapes.

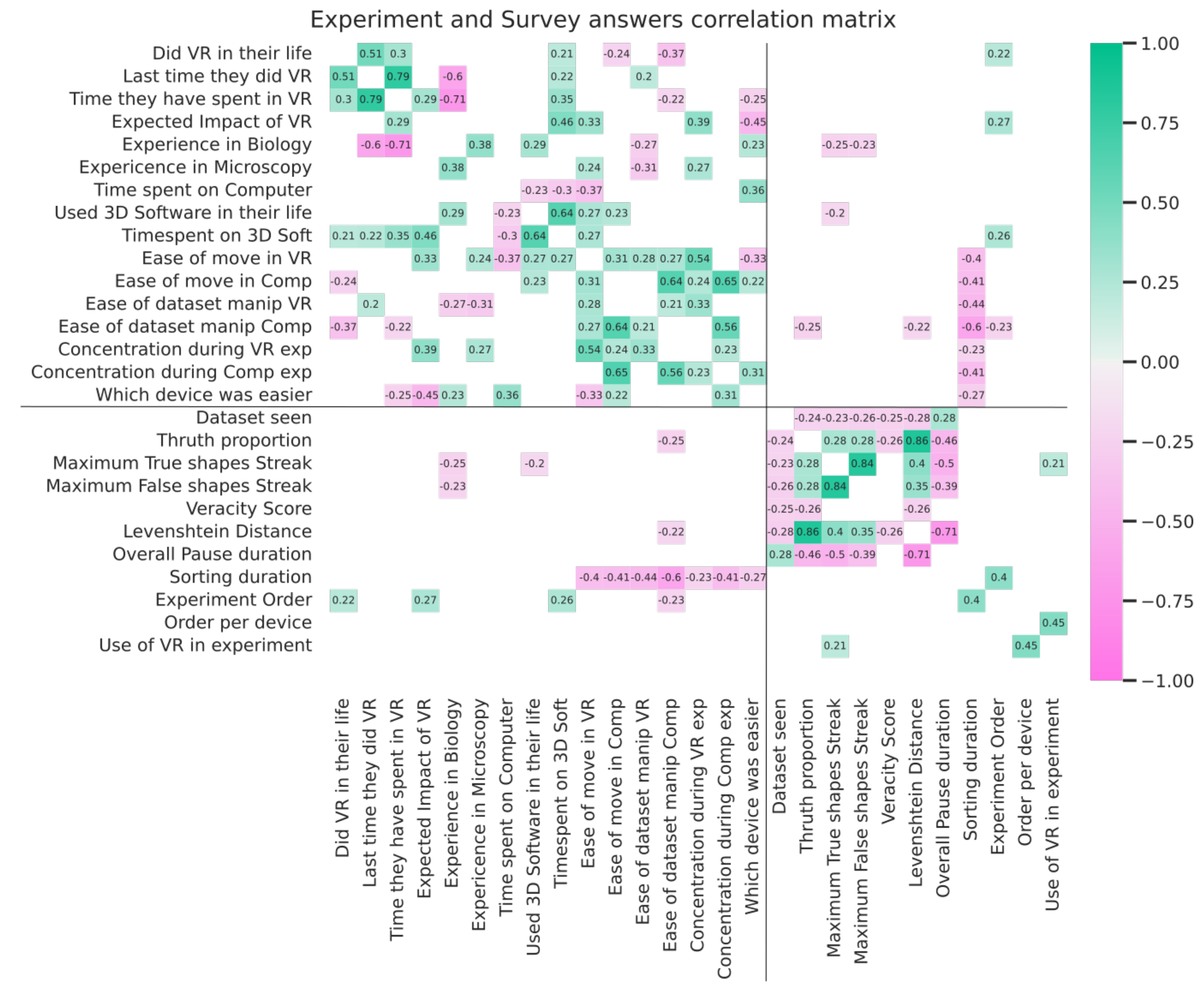


Participants improved their proportion of true answers between the first and second sequence. This improvement is significantly higher in VR than with 2d screens. (MWUt: p=0.023). Dataset 1 is significantly associated with higher veracity scores (MWUt: p=0.005). For dataset 2, the veracity score of each participant in VR and with a 2d screen could be positively correlated (pearson correlation, p=0.064). This would suggest some participants were better than others, therefore that they didn't randomly guess their answers.

Other extraneous factors



No link was found between the results of participants and their experience with VR and 3D softwares. However, our sample lacked participants experienced with VR.



The correlation matrix summarizes the significant correlation found between the measured variables (p>0.05, Pearson correlation and point biserial correlation for dichotomous variables). The score functions are coherently correlated.

Discussion

Our lack of clear results is mostly due to the difficulty of the participants' task. To assert that VR permits a better apprehension of the global shape of 3D time-evolving datasets this study should be performed anew using simpler datasets. We observed a better progression between the first and second experiment in VR than with 2D screens. This could be caused by the fact that the majority of the users had scarcely ever used a VR set before and hence needed an accustoming phase, or that the results are to keep on increasing if more experiments were performed. This could be assessed by doing more experiments with each participant and using a sample with more diverse experiences with VR.

Selected bibliography

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