Supplementary Materials

Constructing the VR Environment

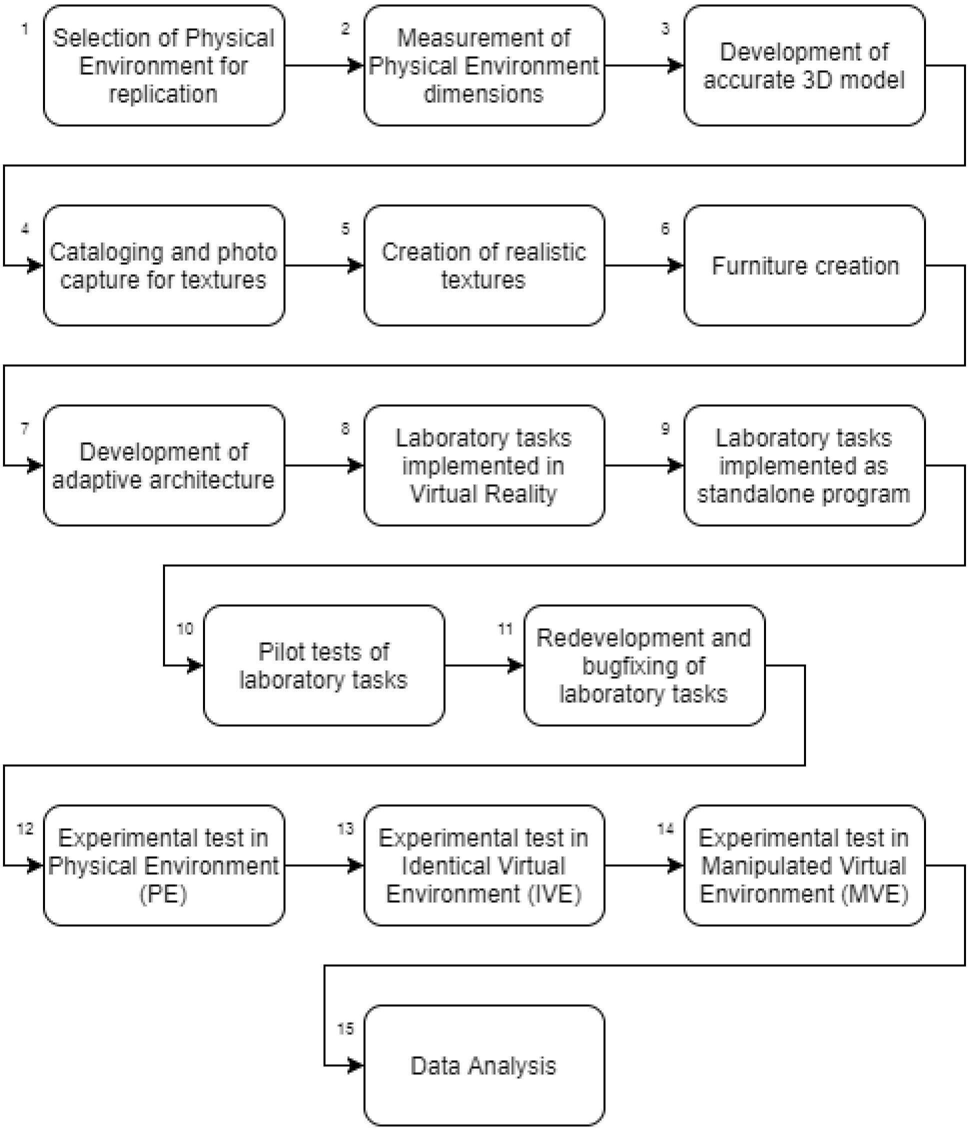
The process of creating a VE that suited our study and also satisfied the requirements described in Section 2 is outlined in Supplementary Figure 1. In this paper, we examine up to stage 13 – experimental test in IVE. However, we envision that this process be extended to also include an experimental test in a manipulated VE.

Selection of Physical Environment

To reduce possible confounders in the comparison between the PE and IVE, we selected a laboratory designed for human performance testing to replicate in VR. The human performance laboratory is a windowless room with computer controlled lighting, ventilation, and air conditioning (Figure 2). This meant that all environmental parameters could be identical across the conditions, regardless of time of day or changes in weather. Room dimensions were taken from architectural plans and in-situ measurements. Furniture was catalogued and approximate positions marked on the architectural plans.

Creation of Identical Virtual Environment

The VE of the PSY-VR program was programmed in Unity (Unity-Technologies, 2018). A simple room structure was created based on the original architectural drawings and tweaked using the in-situ measurements. For furniture (chairs, drawers, desks, computers), prefab objects were created. These prefab objects were designed to be cloned into the scene to allow quick adjustment of the crowdedness of the room. For textures, the catalogued photos were matched to the individual objects. Relevant sections of each photo were copied and refined, then mapped onto the virtual objects (Supplementary Figure 2).



Supplementary Figure 1: Process of developing the PSY-VR system

It is vital to ensure that any performance differences between the PE and IVE are not caused by changes in the way participants interact with the environment. The VR system did not include any type of haptic feedback, therefore attempting to move objects in the IVE would immediately reduce immersion (Lok, Naik, Whitton, & Brooks, 2003). To avoid these problems, the IVE was designed so that the participants would be seated in the same location as in the PE and would not need to move out of their seat or interact with the furniture. The "play area" of the room was set as the maximum dimensions allowed by the IR sensors (see Supplementary Figure 3). This meant that if participants did get out of their seat and move around, there would not be any reduction in immersion.

Development of adaptive architecture

A major novelty of the PSY-VR system is the development of a graphical interface that could allow researchers to manipulate the environment (Supplementary Figure 4). The following manipulations are enabled: ceiling lighting (Red / Green / Blue color and intensity), room dimensions (width, height, depth), and furniture (chairs, drawers, desks, computers). A series of preset buttons allow quick saving and reloading of different layouts.

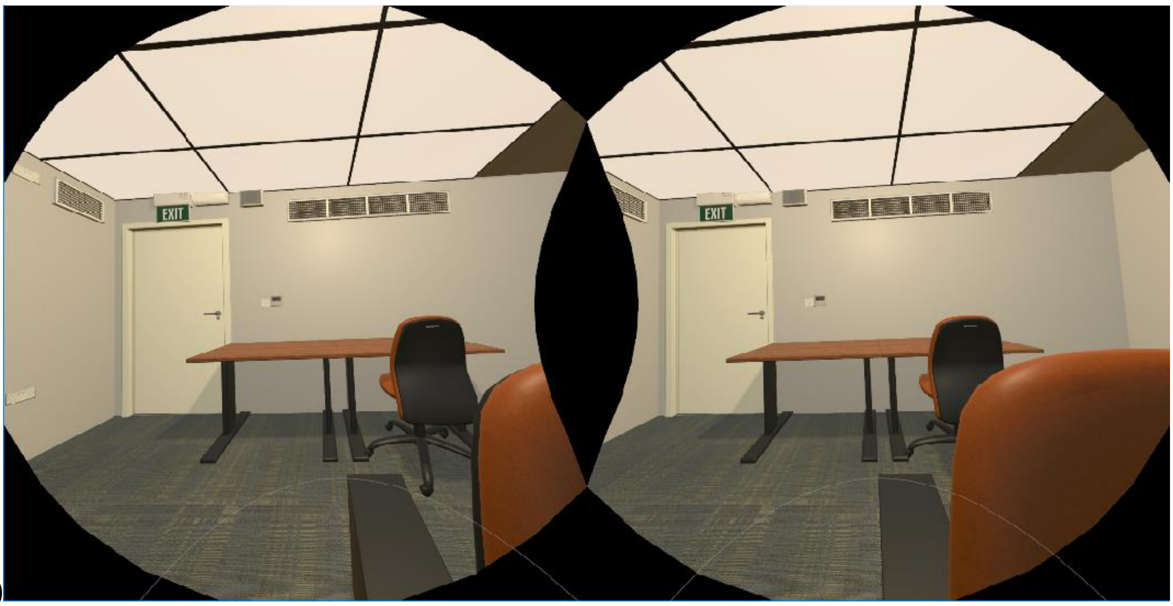
Room dimensions are adjusted within the VE by stretching the walls, floor and ceiling. Furniture that is attached to the wall (e.g. doors, light switches) can be anchored in relation to one of the walls, or move when the dimensions are adjusted. Using this stretching method, all walls in the space will be connected at all times so that it is impossible to create a break in the scenery which could reduce immersion.

As our aim is to identify the effect of the visual environment (PE vs IVE) on participants, a task involving attention appears to be the most suitable. We therefore replicated the Eriksen Flanker Task (Eriksen & Eriksen, 1984) for use in the VR. Note, however, that this protocol could be used with a number of different laboratory tasks to identify how the visual environment affects different aspects of cognition. In particular, with only changes in the input script file we can currently run versions of the go/nogo (Bezdjian, Baker, Lozano, & Raine, 2009), two-alternative forced choice (Pankratz, Fausti, & Peed, 1975), bivalent shape task (Mueller & Esposito, 2014), match to sample task (Englund, Reeves, Shingledecker, Thorne, & Wilson, 1987), continuous performance task (Klee & Garfinkel, 1983) and the Simon interference task (J. R. Simon, Sly, & Vilapakkam, 1981). In other words the system is highly scalable. The flanker task was created in Unity for ease of use in the VR system. A standalone shell was also created to enable the task to be used in the PE. The flanker task uses pre-scripted XML files to control the timing and presentation of stimuli, and all responses are logged into a separate XML file for each participant. The pre-scripted XML files allow the experimenter to define the duration of the stimulus, inter-stimulus interval (ISI), maximum response time, etc. For this task, we set the fixation to appear for 100ms, the ISI to 300ms, the stimulus duration to 100ms, the inter-trial interval to 600ms and the maximum response time to 500ms.

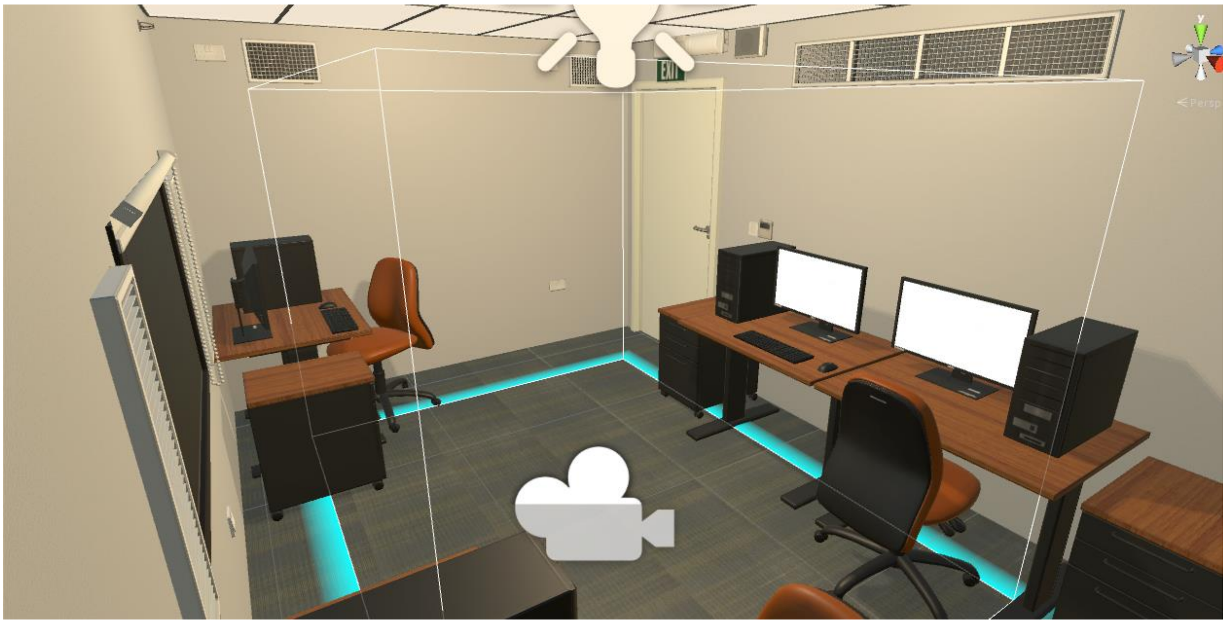
a)

b)

c)

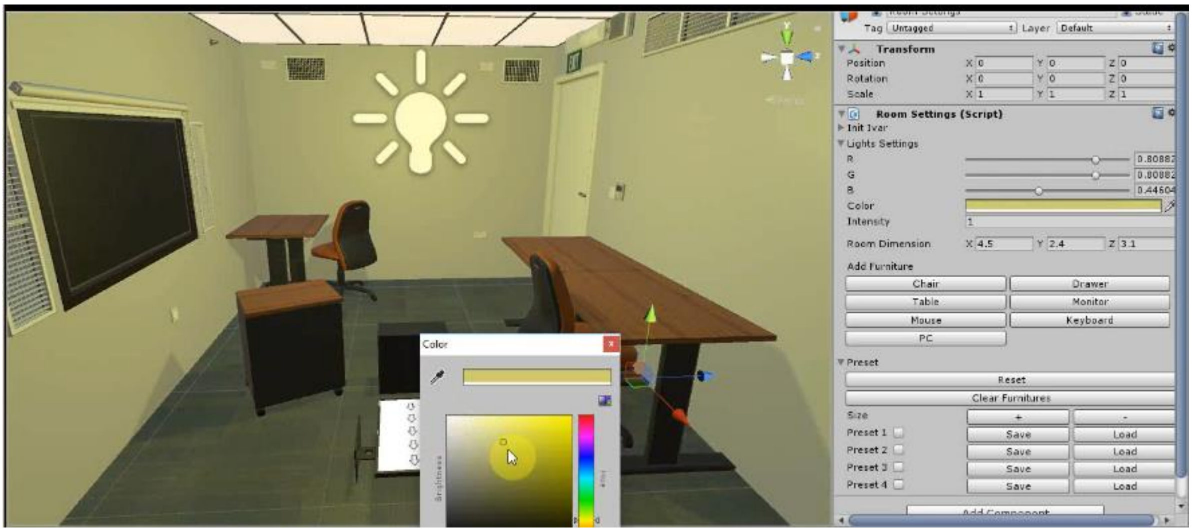


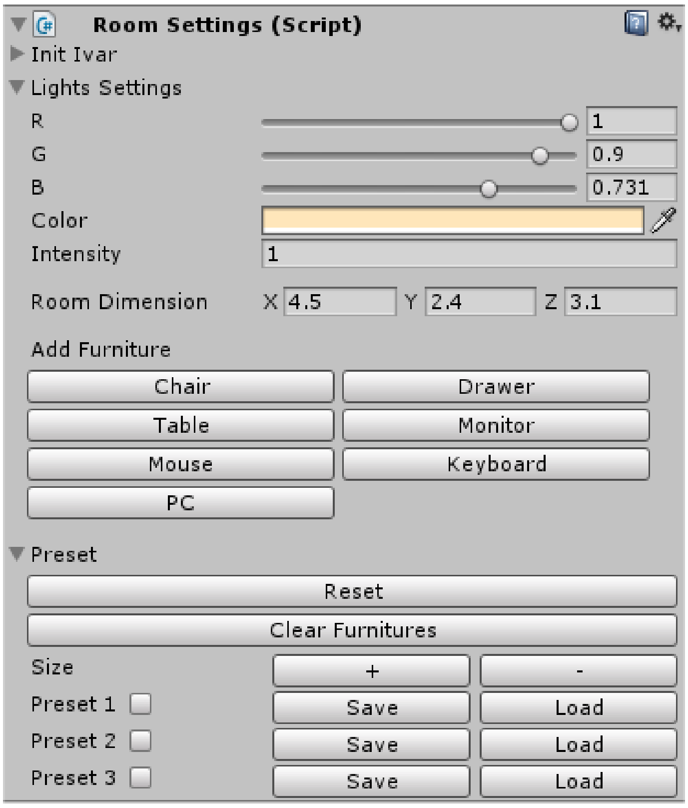
Supplementary Figure 2: Comparison of the IVE and the PE. a) Overall room comparison, during addition of furniture, b) comparison of wall details, c) view inside the IVE before addition of PCs.



Supplementary Figure 3: IVE with play area set (marked by the blue bounding box on the floor).

a)





b)

Supplementary Figure 4: The PSY-VR interface. a) Example of modifications to lighting in the virtual environment using the graphical interface. Changes can be made and viewed in real time. b) Close-up of graphical point-and-click interface for adding furniture, adjusting key aspects of the room, and loading premade layouts.

Results

Supplementary Table 1: t-tests of all measures

	P	Mean PE	Mean IVE	T	CI Low	CI High	BF01
Mean Reaction Time (RT)	0.625	276.161	279.897	0.490	-11.437	18.909	5.381
RT Standard Deviation	0.124	50.124	53.748	1.558	-1.018	8.267	1.867
RT Skewness	.669	0.381	0.345	-0.429	-0.199	0.128	5.465
Minimum RT	0.354	115.886	106.575	-0.933	-29.200	10.577	3.925
Maximum RT	0.532	466.977	470.450	0.627	-7.541	14.486	5.021
Mean number of Errors	0.266	0.093	0.108	1.120	-0.012	0.042	3.316
Mean Errors (congruent trials)	0.366	0.074	0.086	0.910	-0.014	0.038	4.058
Mean Errors (incongruent trials)	0.282	0.170	0.195	1.084	-0.021	0.072	3.503
Mean RT (first 1/3 of task)	0.339	277.543	284.998	0.962	-7.967	22.877	3.898
Mean RT (second 1/3 of task)	0.881	277.415	278.623	0.150	-14.822	17.238	5.935
Mean RT (last 1/3 of task)	0.847	273.712	275.337	0.193	-15.121	18.371	5.905
Mean Errors (first 1/3 of task)	0.993	0.089	0.089	0.009	-0.025	0.026	5.985
Mean Errors (second 1/3 of task)	0.149	0.090	0.111	1.457	-0.008	0.049	2.211
Mean Errors (last 1/3 of task)	0.134	0.100	0.127	1.518	-0.008	0.062	2.001

Supplementary Table 2: Model 3 effects

	Estimate	SE	T-value	DF	P-Value	CI Lower	CI Higher	*d*
Intercept	280.149	5.180	54.083	52527	< .0001	269.997	290.302	-
Condition	7.310	7.507	0.974	82	.333	-7.623	22.243	0.215
Trial Order	-0.012	0.002	-7.309	52527	< .0001	-0.015	-0.009	-0.064
Condition x Trial	-0.011	0.002	-4.586	52527	< .0001	-0.015	-0.006	-0.040

Supplementary Table 3: Model 7 effects

	Estimate	SE	T-value	DF	P-Value	CI Lower	CI Higher	*d*
Intercept	0.084	0.010	8.835	52527	< .0001	0.066	0.103	-
Condition	-0.002	0.014	-0.137	82	0.892	-0.029	0.026	-0.030
Trial Order	0.000	0.000	2.892	52527	0.004	0.000	0.000	0.025
Condition x Trial	0.000	0.000	3.833	52527	0.0001	0.000	0.000	0.033

Supplementary Table 4: Model 11 effects

	Estimate	SE	T-value	DF	P-Value	CI Lower	CI Higher	*d*
Intercept	277.351	4.936	56.186	47267	< .0001	267.676	287.026	-
Condition	4.891	7.154	0.684	82	0.496	-9.339	19.122	0.151
Congruency	17.261	0.811	21.293	47267	< .0001	15.672	18.850	0.196
Condition x Congruency	3.917	1.190	3.291	47267	0.001	1.584	6.251	0.030

Supplementary Table 5: Model 14 effects

	Estimate	**SE**	**T-value**	**DF**	**P-Value**	**CI Lower**	**CI Higher**	***d***
Intercept	0.074	0.009	8.194	52527	< .0001	0.057	0.092	-
Condition	0.012	0.013	0.899	82	0.371	-0.014	0.038	0.199
Congruency	0.094	0.004	21.555	52527	< .0001	0.086	0.103	0.188
Condition x Congruency	0.016	0.006	2.444	52527	0.015	0.003	0.028	0.021