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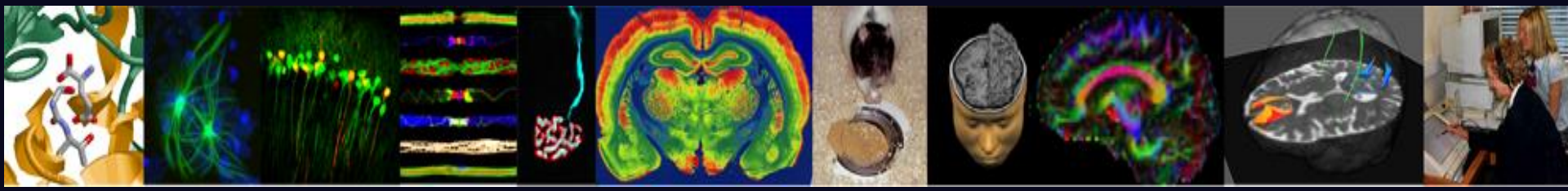

THE VIRTUAL REALITY EVERYDAY ASSESSMENT LAB (VR-EAL): ADOPTING IMMERSIVE VIRTUAL REALITY IN THE NEUROPSYCHOLOGICAL ASSESSMENT OF COGNITIVE FUNCTIONS

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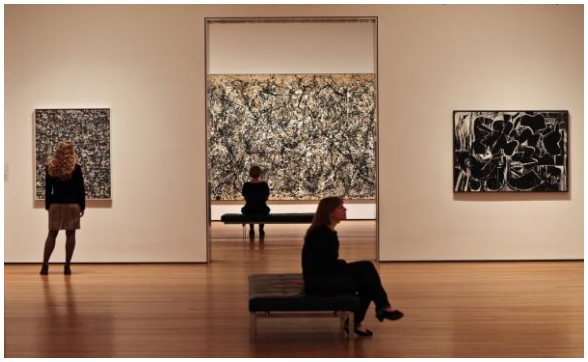
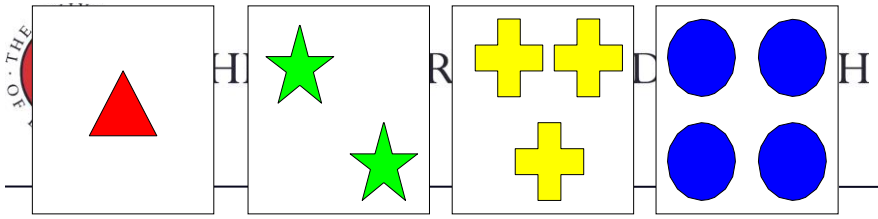
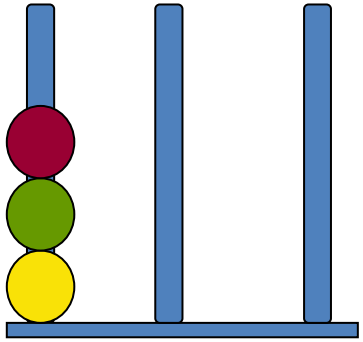
Goal directed behaviour

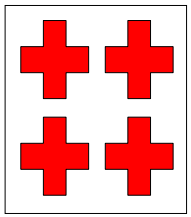


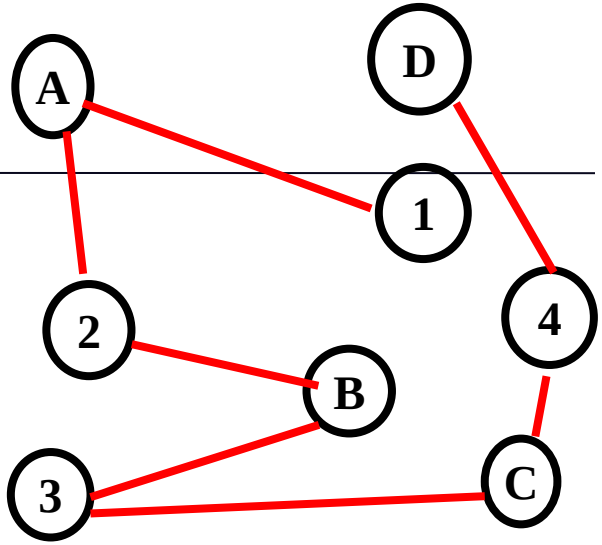



Executive functions enable people to plan and regulate their behaviour to achieve their desired goals, particularly when facing novel or difficult situations.









F
frog
flipper
finger
fudge
fad
frog
fall
full

RED BLUE ORANGE YELLOW
GREEN RED PURPLE RED
GREEN YELLOW BLUE RED
YELLOW ORANGE RED GREE
BLUE GREEN PURPLE RED

The dough was put in the hot……

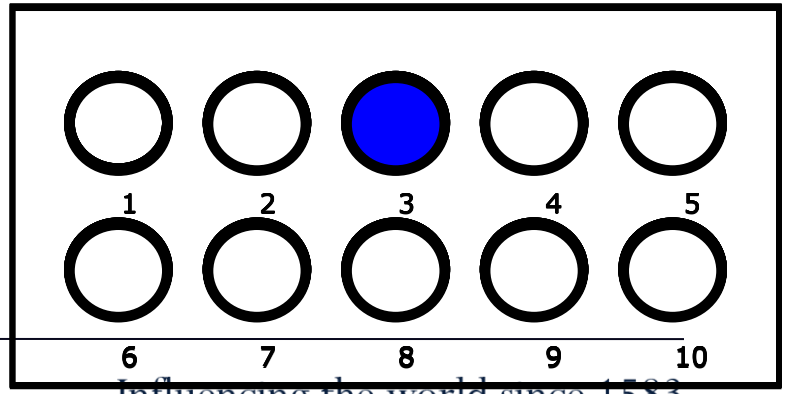
Somewhat related….sink/bread
Unrelated….train

Neurol Sci
DOI 10.1007/s10072-015-2276-0

ORIGINAL ARTICLE

How many segments are there in an orange: normative data for the new Cognitive Estimation Task in an Italian population

Federica Scarpina[1,2] · Guido E. D'Aniello[1] · Alessandro Mauro[2,3] · Gianluca Castelnuovo[1,4] · Sarah E. MacPherson[5,6]



Penfield & Evans (1935)

"One day about fifteen months after operation she had planned to get a simple supper for one guest (WP) and four members of her own family. She looked forward to it with pleasure and had the whole day for preparation. This was a thing she could have done with ease ten years before. When the appointed hour arrived she was in the kitchen, the food was all there, one or two things were on the stove, but the salad was not ready, the meat had not been started and she was distressed and confused by her long continued effort alone. It seemed evident that she would never be able to get everything ready at once. With help the task of preparation was quickly completed and the occasion went off successfully with the patient talking and laughing in an altogether normal

"Her own home provided in some ways a better background for study than the consulting room of the psychologist."

Certain capacities are not captured in the standard neuropsychological assessment e.g., planning, preparatory steps, weighing up considerations, decision-making. There is no clearly correct solution and many different activities may have to be scheduled over the time available.

Patient EVR (Eslinger & Damasio, 1985)

Wisconsin Card Sorting Test

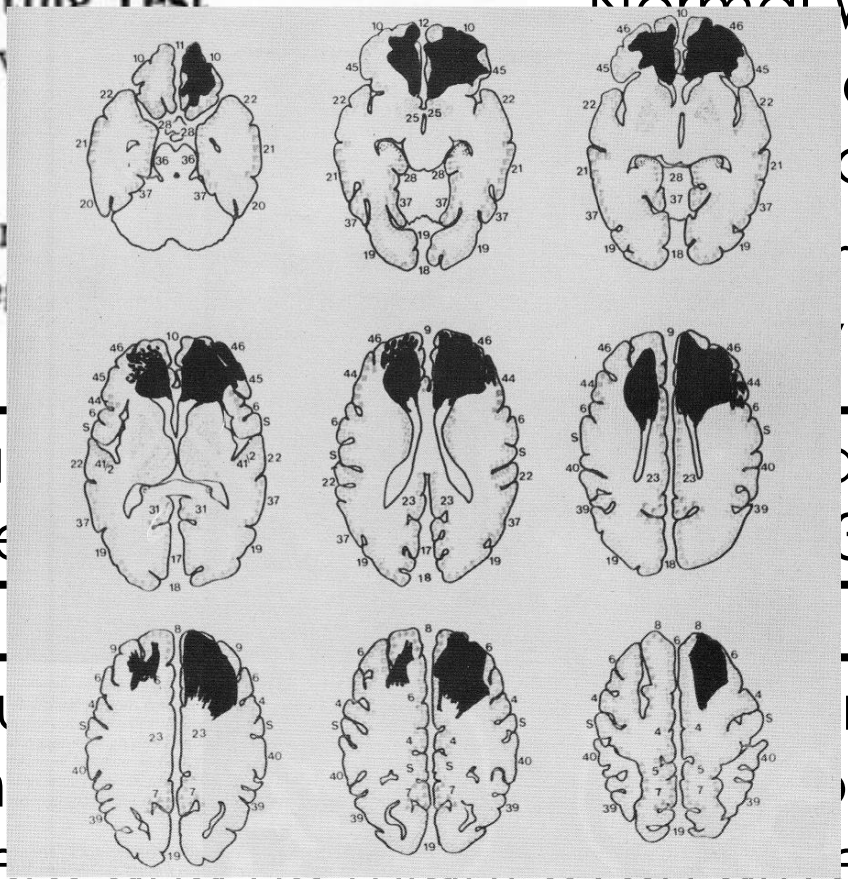
No. categories achiev

No. sorts

No. errors

No. perseverative err

No. trials to 1st cate



Normal Wisconsin Card
est
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esponses on
e Estimation

Norma
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exe
30.

Takes hou
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indecisiven
lan, menu,
atmosphe
e there to
see how busy it is – and still not decide!!!

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Multiple Errands Test (MET)

- Simple tasks
  - Buy a brown loaf
  - Buy throat pastilles
- Be at position X in 15 mins time.
- Write on a postcard:
  - The shop with the most expensive item
  - Price of a pound of tomatoes
  - Coldest place in Britain yesterday

Rules:
Spend as little money as possible.
Take as little time as possible.
No shop should be entered unless buying something.
Do not to use anything not bought on the street (other than a watch).

TABLE 5. ERRORS ON MULTIPLE ERRANDS

	Cases			
	1	*2*	*3*	*Control*
Inefficiencies	6*	9*	5*	1.4 (1.1)
Rule breaks	5*	8*	8*	1.6 (1.3)
Interpretation failures	1	1	1	0.4 (0.7)
Task failures	0	5*	4*	1.1 (1.4)
Total errors	12*	23*	17*	4.6 (2.1)

* More than 2 SD worse than the control subjects.

Inefficiencies e.g., entering the same shop twice

Interpretation failures e.g., birthday card rather than postcard

Rule breaks e.g., leave without paying

Task failures e.g., not buying soap and leaving without buying anything.

All 3 patients impaired, in particular on rule breaks and inefficiencies.

Assets of VR in psychological sciences

- Automation of the assessment/rehab/training
- Augmented control on the testing/training environment
- Enablement of otherwise impossible studies
- Ecological validity
- Augmented prediction of everyday performance

Caveats in the implementation of VR

Cost of the development of VR software

VRISE, VR sickness, or Cybersickness



Cybersickness symptoms and effects

Symptoms	Effects
Nausea	Reduced overall cognitive performance
Dizziness	Increased temperature and heart-rate.
Disorientation	Increased brain activity and connectivity
Fatigue	
Instability	

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A s ew

Non-ergono nvironment

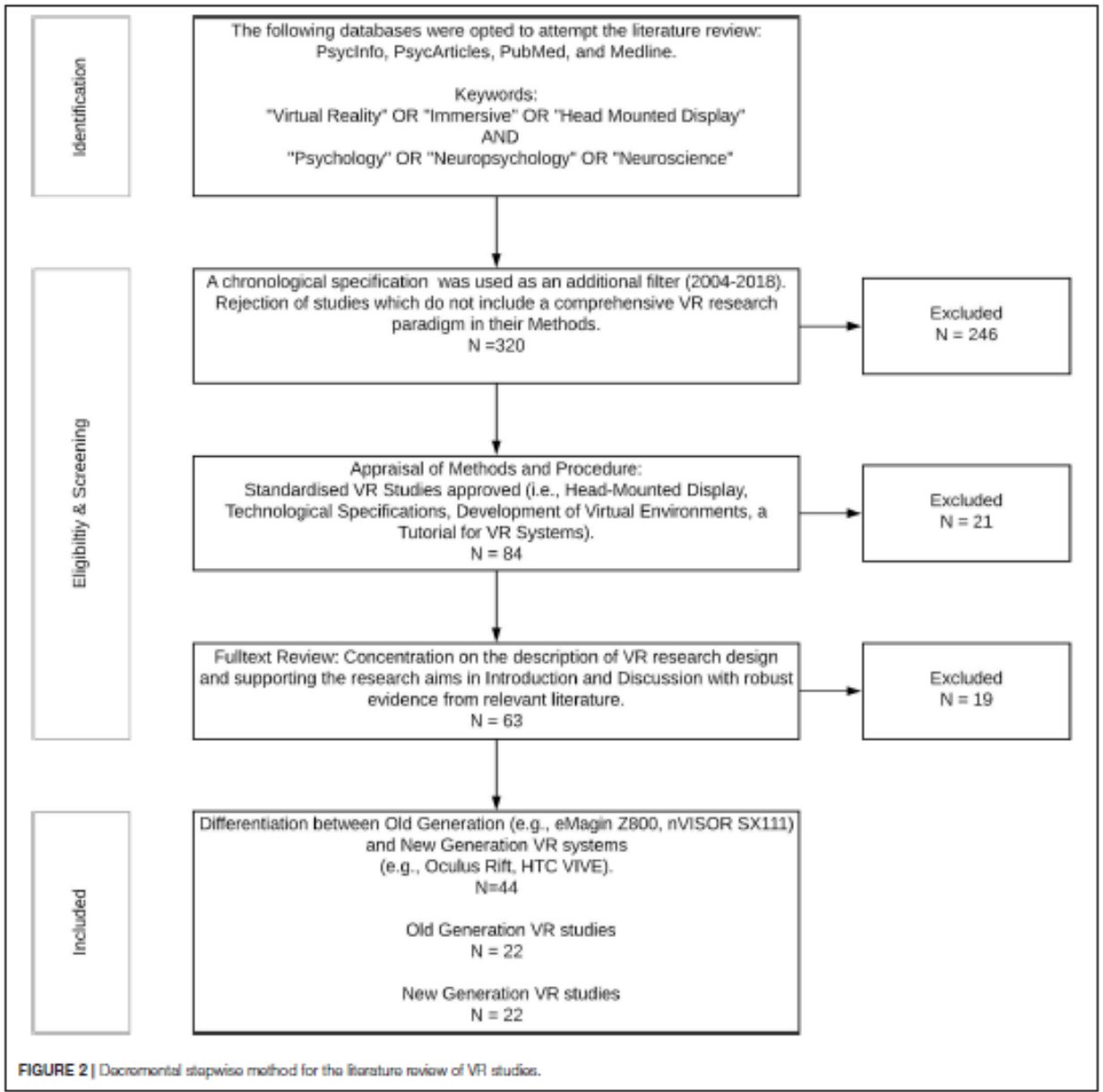


FIGURE 2 | Decremental stepwise method for the literature review of VR studies.

Kourtesis, P., a).
Technologic ntation of
virtual reality
technologic cience,
13, 342.

Summary table of VR HMD specs

Product	Generation	Resolution (per eye)	Display screen	Refresh rate	FOV (Diagonal)	Motion trackers and sensors (Type and quantity)
VFX 3D	Old	480 × 240	LCD	45 Hz	45°	–
VUZIX Wrap 1200	Old	852 × 480	LCD	60 Hz	35°	Unknown type (1), 3 magnetometers, 3 accelerometers, and 3 gyroscopes
eMagin Z800 3DVisor	Old	800 × 600	OLED	60 Hz	40°	–
nVisor SX111	Old	1,280 × 1,024	LCD	60 Hz	110°	–
Oculus rift development kit 1	New	640 × 800	LCD	60 Hz	110°	–
Oculus rift development kit 2	New	960 × 1,080	OLED	75 Hz	110°	–
Minimum hardware criteria for the avoidance of VRISE	NA	>960 × 1,080	OLED or LCD	≥75Hz	≥110°	Tracking should be adequately rapid and accurate to facilitate ergonomic interactions
Oculus rift commercial version	New	1,080 × 1,200	OLED	90 Hz	110°	Accelerometer, gyroscope, magnetometer, 360° constellation tracking camera
HTC VIVE commercial version	New	1,080 × 1,200	OLED	90 Hz	110°	Sensors (>70) including MEMS, magnetometer, gyroscope, accelerometer, and laser position sensors, lighthouse laser tracking system (2 base stations emitting pulsed InfraRed lasers), front-facing camera

Kourtesis, P., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2019a). Technological competence is a precondition for effective implementation of virtual reality head mounted displays in human neuroscience: a technological review and meta-analysis. *Frontiers in Human Neuroscience*, 13, 342.

VR software necessary characteristics

User Experience

Adequate level of immersion

Pleasant VR experience

High quality graphics

High quality sounds (spatialized)

Suitable hardware (headset & peripherals)

VR software necessary characteristics

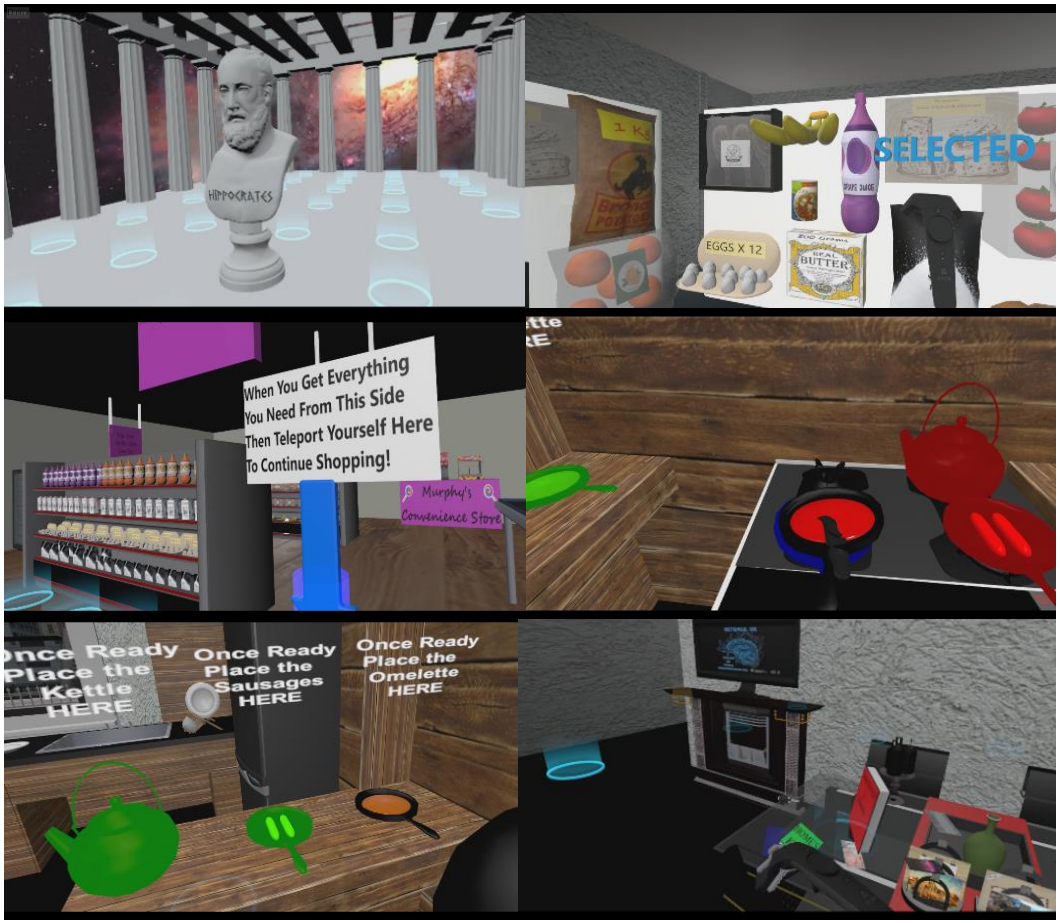
Game Mechanics

Suitable navigation (e.g., Teleportation)

Availability of physical movement

Ergonomic & naturalistic interactions

- Picking/Placing items
- Using items
- Two-handed interaction



VR software necessary characteristics

In-Game Assistance

Comprehensive and explicit tutorials

Helpful tutorials of adequate duration

Helpful in-game instructions

Helpful in-game prompts

VR software necessary characteristics

Absence of VR-Sickness Symptoms

Nausea

Dizziness

Disorientation

Postural Instability

Fatigue

Summary table of VR software specs

Domains	User experience	Game mechanics	In-game assistance	VRISE
Criteria	An adequate level of immersion	A suitable navigation system (e.g., Teleportation)	Digestible tutorials	Absence or insignificant presence of nausea
	Pleasant VR experience	Availability of physical movement	Helpful tutorials	Absence or insignificant presence of disorientation
	High quality graphics	Naturalistic picking/placing of items	Adequate duration of tutorials	Absence or insignificant presence of dizziness
	High quality sounds	Naturalistic use of items	Helpful in-game instructions	Absence or insignificant presence of fatigue
	Suitable hardware (HMD and computer)	Naturalistic 2-handed interaction	Helpful in-game prompts	Absence or insignificant presence of instability

Kourtesis, P., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2019a). Technological competence is a precondition for effective implementation of virtual reality head mounted displays in human neuroscience: a technological review and meta-analysis. *Frontiers in Human Neuroscience*, 13, 342.

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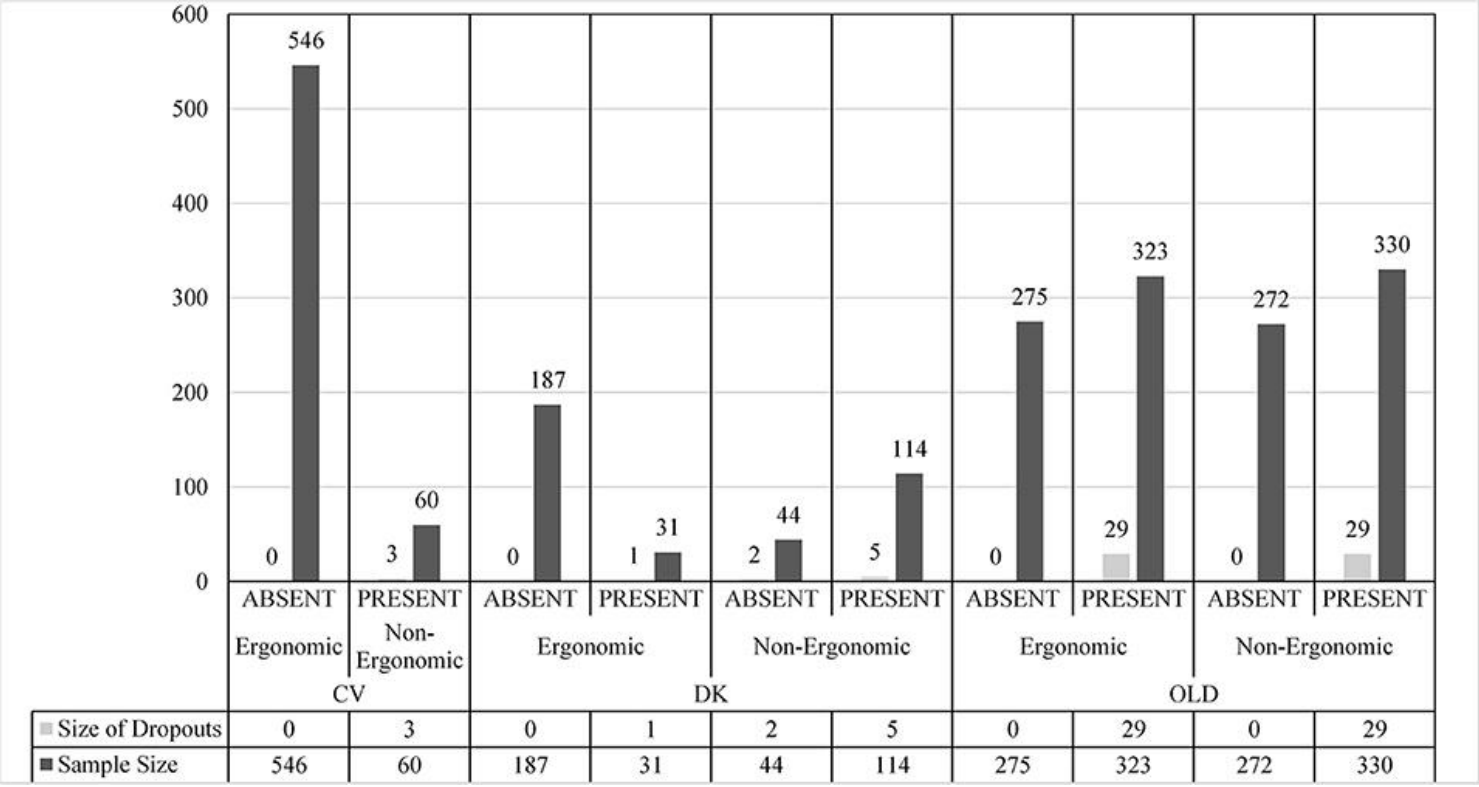
Meta-analysis of the VR psychology studies



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Developing research/clinical VR software

Maximum Duration of VR Experience & Session: Between 55 and 75 minutes

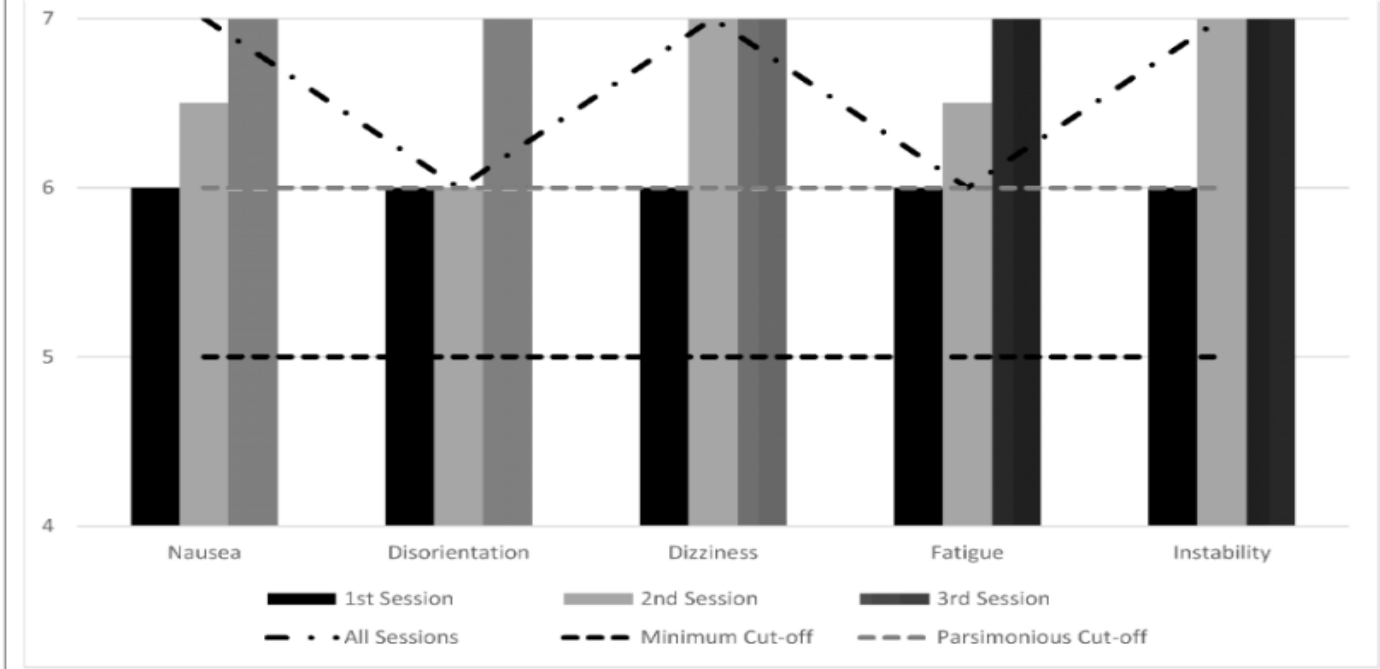
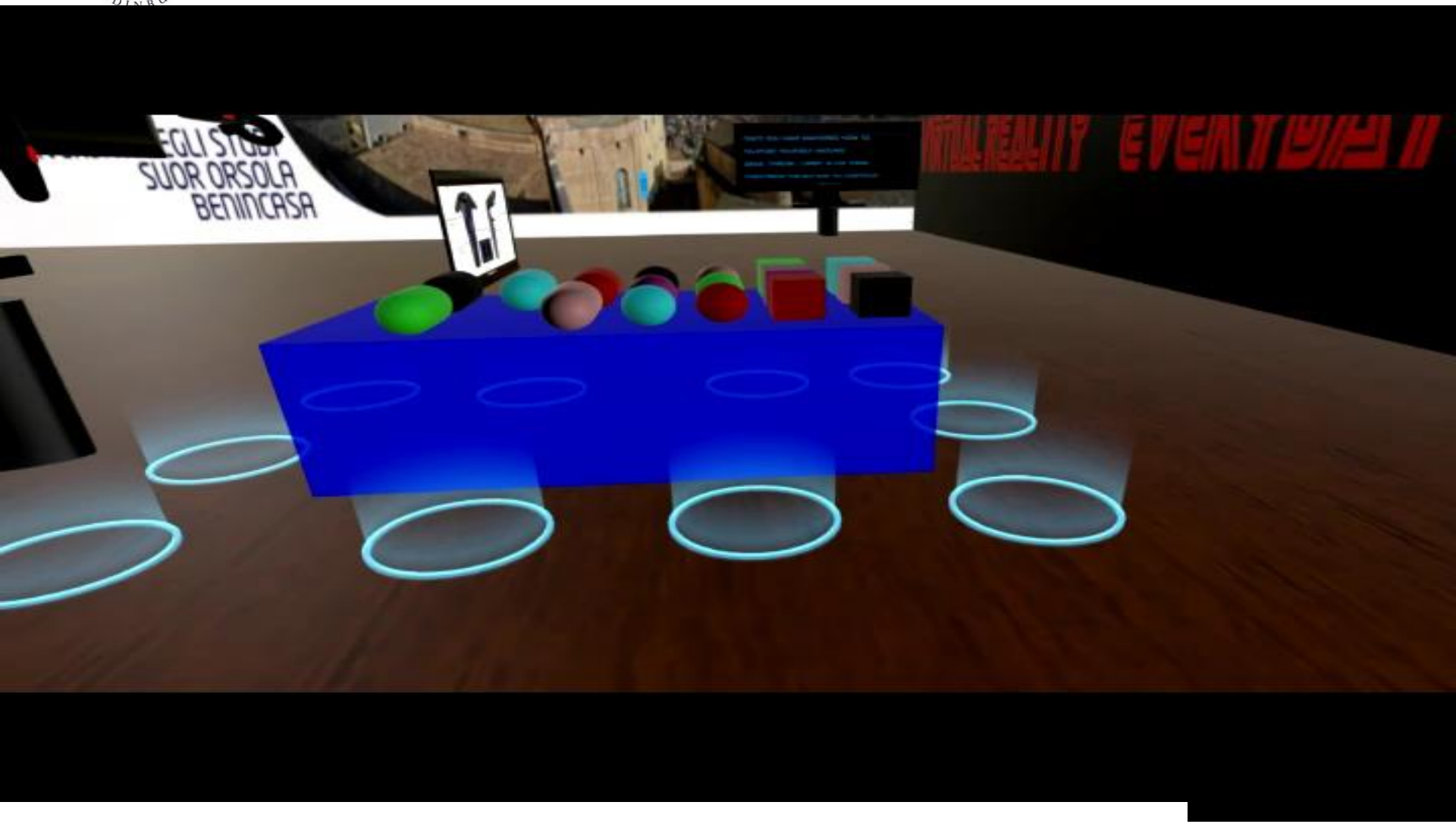


FIGURE 2 | VRISE intensity in VR sessions as measured by VRNQ. Median scores of VRISE items of VRNQ; VRNQ Minimum Cut-off (≥); VRNQ Parsimonious Cut-off (≥); 1, Extreme intense feeling; 2, Very intense feeling; 3, Intense feeling; 4, Moderate feeling; 5, Mild feeling; 6, Very mild feeling; 7, Absent feeling.

Kourtesis, P., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2019b). Validation of the Virtual Reality Neuroscience Questionnaire: maximum duration of immersive virtual reality sessions without the presence of pertinent adverse symptomatology. *Frontiers in Human Neuroscience*, 13, 417.


SUOR ORSOLA
BENINCASA

VR-EAL

Table 1. VR-EAL tasks and score ranges

Scene	Cognitive function	Task	Score ranges
3	Prospective memory	Write down the notes for the errands.	0–6
3	Immediate recognition	Recognizing items on the shopping list.	0–20
3	Planning	Drawing the route to be taken.	0–19
6	Multitasking	Cooking task (preparing breakfast).	0–16
6	Prospective memory – event-based	Take medication after breakfast.	0–6
8	Selective visuospatial attention	Collect items from the living room.	0–20
8	Prospective memory – event-based	Take the chocolate pie out of the oven.	0–6
10	Prospective memory – time-based	Call Rose at 10 am.	0–6
12	Selective visual attention	Find posters on both sides of the road.	0–16
14	Delayed recognition	Recognizing items from the shopping list.	0–20
15	Prospective memory – time-based	Collect the carrot cake from the bakery at 12 pm.	0–6
16	Prospective memory – event-based	False prompt before going to the library.	-6–0
17	Prospective memory – event-based	Return the red book to the library.	0–6
19	Selective auditory attention	Detect sounds from both sides of the road.	0–32
20	Prospective memory – time-based	False prompt before going back home.	-6–0
21	Prospective memory – event-based	Back home, give the extra pair of keys to Alex.	0–6
22	Prospective memory – time-based	Take the medication at 1 pm.	0–6

*The tasks are presented in the same order as they are performed within the scenario.

Achievements

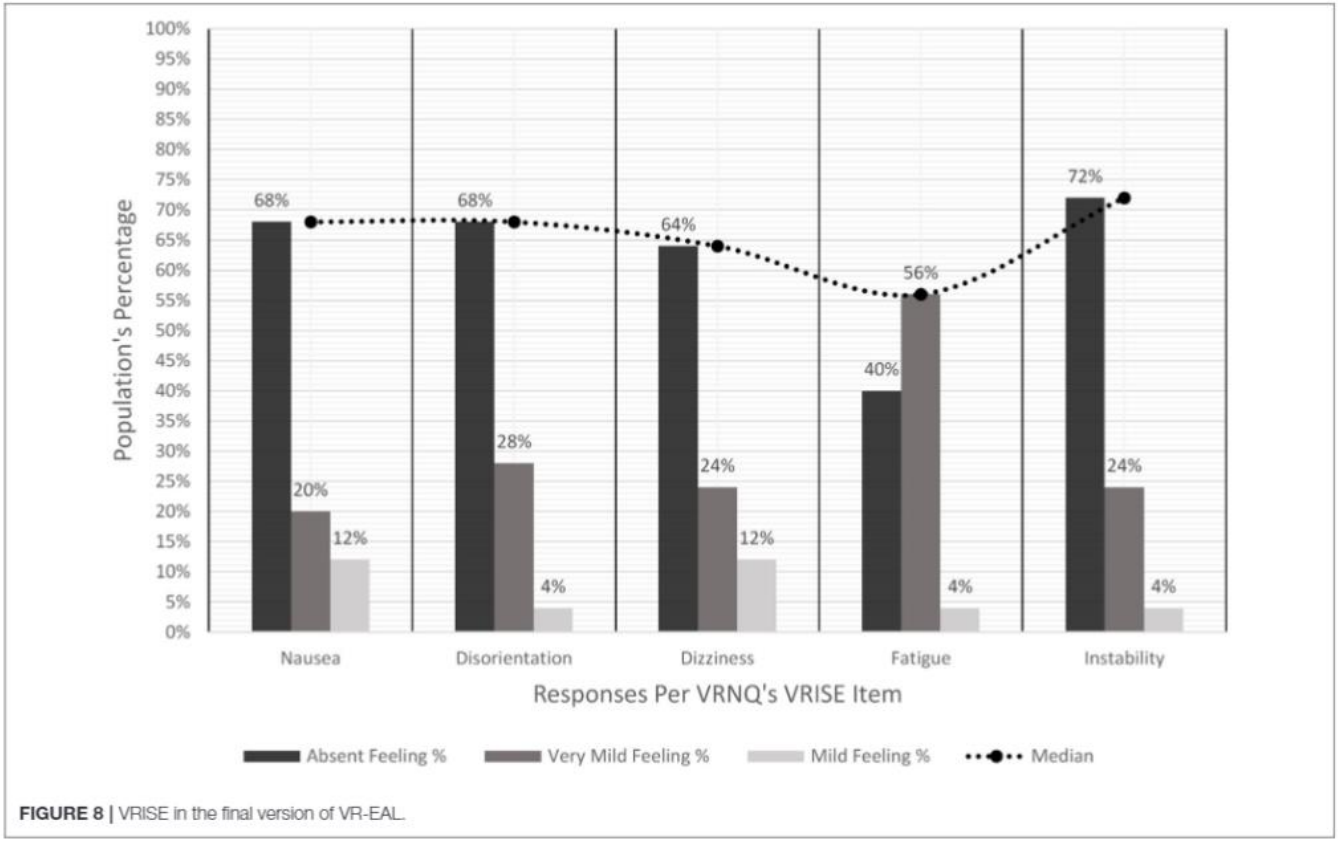


FIGURE 8 | VRISE in the final version of VR-EAL.

Kourtesis, P., Korre, D., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2020a). Guidelines for the development of virtual reality software for cognitive neuroscience and neuropsychology: The Development of Virtual Reality Everyday Assessment Lab (VR-EAL), A neuropsychological test battery in virtual reality. *Frontiers in Computer Science, section Human-Media Interaction*. 1, 12.

VR-EAL validity

Table 7. Bayesian correlations between the VR-EAL and the Paper-and-Pencil tests

Paper-and-Pencil scores	VR-EAL scores	r	BF_{10}	SP
CAMPROMPT – Total	Total PM	0.82^{***}	3.20e+9	~ 100%
CAMPROMPT – Event-based	Event-Based PM	0.73^{***}	3.97e+3	~ 100%
CAMPROMPT – Time-based	Time-Based PM	0.67^{***}	2.61e+2	~ 100%
RBMT – Immediate recall	Immediate Recognition	0.77^{***}	7.34e+7	~ 100%
RBMT – Delayed recall	Delayed Recognition	0.82^{***}	3.90e+9	~ 100%
TEA – Map total score	Selective Visual Attention Accuracy	0.48^{**}	50.53	95%
TEA – Map total score	Selective Visual Attention Speed	0.46^{**}	34.99	93%
RSAT – Accuracy	Selective Visual Attention Accuracy	0.43^{*}	16.94	89%
RSAT – Accuracy	Selective Visuospatial Attention Total Score	0.61^{***}	2101	99%
RSAT – Speed	Selective Visuospatial Attention Speed	0.49^{**}	63.15	96%
RSAT – Accuracy	Selective Visuospatial Attention Accuracy	0.58^{***}	778.50	99%
TEA – Elevator Counting with Distraction	Selective Auditory Attention	0.70^{***}	8.91e+4	~100%
BADS – Key Search	Planning	0.80^{***}	4.65e+8	~ 100%
CTT – 1	Planning	0.47^{**}	41.74	94%
CTT – 2	Planning	0.51^{***}	109.73	97%
CTT – 1	Cooking Task	0.70^{***}	9.88e+4	~ 100%
CTT – 2	Cooking Task	0.80^{***}	8.75e+8	~ 100%
BADS – Key Search	Cooking Task	0.62^{***}	2.99e+3	99%

The alternative hypothesis specifies that the correlation is positive. $^{*}BF_{10} > 10$; $^{**}BF_{10} > 30$; $^{***}BF_{10} > 100$; r = Pearson's r; SP = Statistical Power at $\alpha < .05$; BADS = Behavioral Assessment of the Dysexecutive Syndrome; CAMPROMPT = Cambridge Prospective Memory Test; CTT = Color Trails Test; PM = Prospective Memory; RBMT = Rivermead Behavioral Memory Test; RSAT = Ruff 2 and 7 Selective Attention Test; TEA = Test of Everyday Attention; VR-EAL = Virtual Reality Everyday Assessment Lab.

Ecological validity & administration time

Table 8. Comparison between administration time and participants' ratings of verisimilitude and enjoyment for the VR-EAL and paper-and-pencil tests

Paper-and-Pencil Test		VR-EAL	BF_{10}	SP
Total Administration Time	>	VR-Session Time	1.224e+11***	~ 100%
Testing Pleasantness	<	VR-Testing Pleasantness	188,842***	~ 100%
Total Verisimilitude	<	VR-EAL Verisimilitude	4.898e +15***	~ 100%
Ecologically Valid Tests/Tasks Verisimilitude	<	VR-EAL Verisimilitude	3.575e +13***	~ 100%
CAMPROMPT Verisimilitude	<	PM Verisimilitude	1.179e +9***	~ 100%
BADS Key Search Verisimilitude	<	Planning Verisimilitude	1.950e +13***	~ 100%
CTT Verisimilitude	<	Cooking Task Verisimilitude	6.849e +21***	~ 100%
RSAT Verisimilitude	<	Visuospatial Attention Verisimilitude	2.635e +13***	~ 100%
TEA Map Verisimilitude	<	Visual Attention Verisimilitude	3.774e +12***	~ 100%
TEA Elevator Counting with Distraction Verisimilitude	<	Auditory Attention Verisimilitude	4.36e +11***	~ 100%
RBMT Story Recall Verisimilitude	<	Episodic Memory Verisimilitude	1.244e +7***	~ 100%

*$BF_{10} > 10$; **$BF_{10} > 30$; ***$BF_{10} > 100$; SP = Statistical Power at $\alpha < .05$; BADS = Behavioral Assessment of the Dysexecutive Syndrome; CAMPROMPT = Cambridge Prospective Memory Test; CTT = Color Trails Test; PM = Prospective Memory; RBMT = Rivermead Behavioral Memory Test; RSAT = Ruff 2 and 7 Selective Attention Test; TEA = Test of Everyday Attention; VR = Virtual Reality; VR-EAL = Virtual Reality Everyday Assessment Lab.

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VR methods v traditional method: The example of the Virtual Reality Everyday Assessment Lab

No human bias
Automated procedure
Good precision
Control over the testing environment
Ecologically valid testing

Kourtesis, P., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2020b). Validation of the Virtual Reality Everyday Assessment Lab (VR-EAL): an immersive virtual reality neuropsychological battery with enhanced ecological validity. *Journal of the International Neuropsychological Society*, 1-16.

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VR methods v traditional method: The example of the Virtual Reality Everyday Assessment Lab

Shorter Administration Time
More Pleasant Testing Experience
Substantially more ecological valid
Better Predictions of Everyday Performance
Better Insights on Everyday Cognition
Significant Contribution to the Theoretical Framework of Cognitive Functions

Kourtesis, P., Collina, S., Doumas, L. A. A., & MacPherson, S. E. (2020b). Validation of the Virtual Reality Everyday Assessment Lab (VR-EAL): an immersive virtual reality neuropsychological battery with enhanced ecological validity. *Journal of the International Neuropsychological Society*, 1-16.

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