

Memory Performance as a Function of Modality and Context: Revealing the Cognitive Mechanisms Underlying Enhanced Memory in Virtual Reality

Virtual Reality

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Supplementary Material

S1

List of all 120 scenes used as stimulus material.

luVRe video code	Description
X_0104	Amsterdam: Ship and maritime museum
X_0105	Amsterdam: Old elbtunnel egoshooter
x_0108	Amsterdam: The interior of a submarine (1)
x_0109	Amsterdam: The interior of a submarine (2)
x_0203	Aquarium: Dwarf mongoose
x_0302	Hotel ("Hotel Arcona"): Restaurant without guests
x_0307	Hotel ("Hotel Arcona"): Livingroom with guests (1)
x_0407	Car drive: Passing in underground car park in the light
x_0501	Museum of emigrants: People waiting at a port ready to ship out
x_0502	Museum of emigrants: Dark wooden bedroom
x_0601	Bloody bathroom: Blood-smeared bathroom (1)
x_0701	Farm: Aviary with doves
x_0703	Farm: Cows in barn (outside)
x_0706	Farm: Horse in box
x_0802	Atomic shelter: Switchboard
x_0804	Atomic shelter: Entrance of the shelter
x_1003	Nature scenes: Forest at dawn (1)
x_1006	Nature scenes: Meadow at dusk and frightening noises (passing train)
x_1007	Nature scenes: Field path
x_1101	Fire service: Alarm in changing area of the firefighters
x_1103	Fire service: Fire engines drive out of the garage with flashing lights (from outside)
x_1201	Soccer: Watching people playing soccer from the sideline
x_1302	Museum in Hamburg: Dungeon torture chamber
x_1305	Museum in Hamburg: Miniature Wonderland train station
x_1401	Scaffolding: On the scaffolding of a high house
x_1501	Abandoned building: Woman spraying graffiti on the wall of an abandoned building

x_1604	Hamburg City: Botanic Garden
x_1605	Hamburg City: Deers
x_1606	Hamburg City: Fun fair
x_1608	Hamburg City: Empty beachclub
x_1613	Hamburg City: Willkomm-Höft (Ship Greeting Station Welcome Point)
x_1614	Hamburg City: Woman singing and playing the guitar
x_1701	School of dance ("Tanzschule Hull"): Couple dance on a large dance floor (view from the stage)
x_1707	School of dance ("Tanzschule Hull"): Joint dance, led by the moderator (Flashmob) (1)
x_1710	School of dance ("Tanzschule Hull"): Showact: HipHop dancing (1)
x_1801	Kidnapping: Masked man kidnaps jogging woman on a dark path
x_1902	Kart racing: starting scene
x_1910	Kart racing: Kart race with view from the grandstand
x_1915	Kart racing: Kart racing and driving underneath the camera
x_2001	Art gallery: Artist working on his artwork
x_2003	Art gallery: Art installation (2)
x_2103	Mixed Martial Arts (MMA): Two men training together (1)
x_2106	Mixed Martial Arts (MMA): A man is training with weights
x_2202	Motorbike ("Motorrad Bolte"): Two motorcyclists do stunts and ride on a single wheel
x_2301	Emergency department: Trauma room
x_2304	Emergency department: Ward room (1)
x_2308	Emergency department: Man on a gurney
x_2310	Emergency department: Mortuary of a hospital
x_2317	Emergency department: Ambulance arrives at the hospital
x_2701	Prison: Original pantries
x_2703	Prison: exterior view on cells
x_2903	Swimming centre: Free fall slide
x_3101	Spain/Granada: Sunset view: Mirador de San Cristóbal
x_3103	Spain/Granada: Courtyard of Carmen de los Mártires
x_3105	Spain/Granada: Inner yard of Carmen de los Mártires
x_3106	Spain/Granada: Cathedral in Granada

x_3108	Spain/Granada: Living room concert
x_3304	Hotel ("Steigenberger Hotel"): Wine trade without guests
x_3305	Hotel ("Steigenberger Hotel"): Spa area with guests
x_3310	Hotel ("Steigenberger Hotel"): Room (3)
x_3312	Hotel ("Steigenberger Hotel"): Suite
x_3401	Wien City: Prater
x_3502	Dental Office: On the dentist's chair and dental assistant
x_3601	Zoo: Meerkat (1)
x_3604	Zoo: Rhinos (1)
x_3606	Zoo: Penguin
x_3611	Zoo: Arctic foxes fighting (shortly)
x_3802	Climbing: People bouldering (2)
x_3903	Car dealer: In a luxurious campervan
x_4101	Mill: Wooden attic of an ancient mill
x_4202	University Prom: Casino
x_4205	University Prom: People dancing (1)
x_4215	University Prom: Food
x_4301	Cave: Man with a flashlight in a cave
x_4403	Tattoo parlor: A young woman gets tattooed on her ankle (1)
x_4501	Ferris wheel: View from the highest point of a Ferris wheel
x_4904	Puppies: Puppies playing and sleeping on a mattress
x_5002	Mine: Sparsely lit mine tunnel with a mine wagon in view
x_5301	Supermarket: View on shelves in a supermarket and a shopping woman (distant)
x_5401	Church steeple: View over the city of Osnabrück from the church steeple ("Marienkirche")
x_5504	Escape room event: A group of young people searches and examines a room (4)
x_5703	Helicopter: Rescue team leaves helicopter
x_5804	Fitness class (gym): A group of young women pressing bench
x_5901	Shooting range: A young woman shoots at targets in a training facility
x_5904	Shooting range: An elderly man shooting with a rifle at targets
x_5906	Shooting range: People sitting in a club bar

x_6101	Hair salon: A young man's hair is cut
x_6202	Laughter yoga: Three men laughing and pointing at the viewer
x_6301	Karate dojo: A mixed group trains karate (1)
x_6402	Laser Tag Arena: Interior view of a laser tag arena during the game (1)
x_6504	Concert in a cathedral: Choir sings in a cathedral in front of an audience (3)
x_6609	Neurological surgery: Neurological surgery; unpleasant, shrieking sounds from medical devices (3)
x_6701	London: View of the Thames through a narrow passage of Wapping High Street
x_6702	London: View of the Thames from pier head, Wapping High Street
x_6708	London: Bus traffic in front of Saint Paul's Cathedral
x_6801	USA: Boston Faneuil Market
x_6802	USA: Boston USS Constitution
x_6805	USA: Boston Tea Party
x_6810	USA: Cape Cod, Ocean Edge Resort Beach (1)
x_6816	USA: New York Skyscraper
x_6820	USA: New York Highline Park
x_6903	Police operation: Police unit secures a hallway, hostage-taker comes out of an apartment with a hostage and gun
x_6913	Police operation: A man in a helmet and gun is walking through a dark corridor with a hostage and gun
x_7001	Free-range chicken farming: Chickens leave their coop
x_7101	Porta Westfalica, Germany: Viewpoint at the Kaiser Wilhelm Monument at Porta Westfalica
x_7201	Countryside around Rheine, Germany: View from an antique lookout point
x_7202	Countryside around Rheine, Germany: Memorial to the Fallen (Hünenborg at Rheine)
x_7203	Countryside around Rheine, Germany: View on a turquoise lake
x_7303	Facilities of a regional court: Detention cell (view on bars)
x_7405	Animal shelter: Medical quarantine area for cats, cats meow pitifully (1)
x_7409	Animal shelter: Indoor dog kennels, the dog in front of the viewer barks (3)
x_7501	Singing bowl therapy: A singing bowl therapist treats a young woman (1)
x_7601	Pigsty: Pigs in an indoor barn

x_7701	Paramedics on duty: Paramedics find and treat an unconscious person with abdominal wound
x_7709	Paramedics on duty: Paramedic performs CPR on patient in an ambulance (2)
x_7711	Paramedics on duty: Paramedic monitors patients in an ambulance
x_7805	Organ music in a Christian church: Organist plays a Christian church hymn on a wooden organ
x_8006	Drumming: A drummer plays a brisk rhythm including cowbell drums, the room is only dimly lit by a light chain, bright, dance-like
x_8101	Gloomy basement: Gloomy basement in flickering candlelight, strange sounds can be heard from outside (1)
x_8202	Baby/infant: A young mother feeds and cares for her baby (2)

Table S1

Test statistics for χ^2 -tests separately for each symptom of motion sickness (headache, nausea, and dizziness) and each experimental phase (encoding, retrieval).

	χ^2 -test			
	χ^2	df	p	V
Encoding				
Headache	1.97	3	.578	0.127
Nausea	1.48	3	.686	0.110
Dizziness	1.85	3	.603	0.123
Retrieval				
Headache	2.01	3	.571	0.128
Nausea	1.97	3	.579	0.127
Dizziness	9.35	3	.025	0.277

Table S2

Frequencies of the motion sickness symptoms during encoding and retrieval in all four conditions.

	<i>mediated</i>	<i>cross-up</i>	<i>cross-down</i>	<i>immersive</i>
Encoding: Headache				
Yes	2	2	0	2
No	28	30	29	29
Encoding: Nausea				
Yes	2	1	3	3
No	28	31	26	28
Encoding: Dizziness				
Yes	4	5	5	8
No	26	27	24	23
Retrieval: Headache				
Yes	0	1	1	2
No	30	31	28	29
Retrieval: Nausea				
Yes	1	1	0	2
No	29	31	29	29
Retrieval: Dizziness				
Yes	3	6	0	8
No	27	26	29	23

Table S3

Test statistics for independent samples t-tests regarding presence in the modalities mVR and iVR during the retrieval phase (Day 2).

	Group Statistics		Independent Samples Test			
	M	SD	t	df	p	Cohens d ^a
General Presence						
mediated cross-up	4.43	1.38	−5.88	60	< .001	−1.49
	6.09	0.78				
mediated cross-down	4.43	1.38	2.39	57	.020	0.62
	3.48	1.66				
mediated immersive	4.43	1.38	−0.47	59	.639	−0.12
	4.61	1.58				
cross-up cross-down	6.09	0.78	7.99	59	< .001	2.05
	3.48	1.66				
cross-up immersive	6.09	0.78	4.73	61	< .001	1.19
	4.61	1.58				
cross-down immersive	3.48	1.66	−2.70	58	.009	−0.70
	4.61	1.58				
Spatial Presence						
mediated cross-up	4.59	1.03	−4.22	60	< .001	−1.07
	5.58	0.79				
mediated cross-down	4.59	1.03	1.84	57	.071	0.48
	4.03	1.32				
mediated immersive	4.59	1.03	−0.78	59	.438	−0.20
	4.81	1.16				
cross-up cross-down	5.58	0.79	5.62	59	< .001	1.44
	4.03	1.32				
cross-up immersive	5.58	0.79	3.06	61	.003	0.77
	4.81	1.16				
cross-down immersive	4.03	1.32	−2.46	58	.017	−0.64
	4.81	1.16				
Involvement						
mediated cross-up	4.35	1.63	−2.09	60	.041	−0.53
	5.16	1.43				
mediated cross-down	4.35	1.63	−0.30	57	.765	−0.08
	4.47	1.54				

mediated	4.35	1.63	-1.06	59	.294	-0.27
immersive	4.73	1.17				
cross-up	5.16	1.43	1.82	59	.075	0.47
cross-down	4.47	1.54				
cross-up	5.16	1.43	1.31	61	.197	0.33
immersive	4.73	1.17				
cross-down	4.47	1.54	-0.74	58	.463	-0.19
immersive	4.73	1.17				
Realness						
mediated	3.46	1.19	-2.63	60	.011	-0.67
cross-up	4.20	1.04				
mediated	3.46	1.19	0.87	57	.386	0.23
cross-down	3.20	1.09				
mediated	3.46	1.19	-1.33	59	.188	-0.34
immersive	3.84	1.04				
cross-up	4.20	1.04	3.68	59	< .001	0.94
cross-down	3.20	1.09				
cross-up	4.20	1.04	1.39	61	.169	0.35
immersive	3.84	1.04				
cross-down	3.20	1.09	-2.33	58	.023	-0.60
immersive	3.84	1.04				

a. Cohen's d uses the pooled standard deviation.

Table S4

Regression Coefficients of all IPQ subscales (General Presence, Spatial Presence, Immersion, Realness) during the encoding phase on memory performance (d') in all four conditions.

Dependent variable	Model	Sum of Squares	df	Mean Square	F	p
d' mediated	Regression	0.134	4	0.033	0.259	.902
	Residual	3.235	25	0.129		
	Total	3.369	29			
d' cross-up	Regression	0.771	4	0.193	1.013	.418
	Residual	5.136	27	0.190		
	Total	5.907	31			
d' cross-down	Regression	0.827	4	0.207	1.446	.250
	Residual	3.431	24	0.143		
	Total	4.258	28			
d' immersive	Regression	0.579	4	0.145	0.849	.507
	Residual	4.434	26	0.171		
	Total	5.012	30			

Table S5

Regression Coefficients of all IPQ subscales (General Presence, Spatial Presence, Immersion, Realness) during the retrieval phase on memory performance (d') in all four conditions.

Dependent variable	Model	Sum of Squares	df	Mean Square	F	p
d' mediated	Regression	0.185	4	0.046	0.364	.832
	Residual	3.184	25	0.127		
	Total	3.369	29			
d' cross-up	Regression	0.265	4	0.066	0.317	.864
	Residual	5.642	27	0.209		
	Total	5.907	31			
d' cross-down	Regression	0.883	4	0.221	1.571	.214
	Residual	3.374	24	0.141		
	Total	4.258	28			
d' immersive	Regression	0.520	4	0.130	0.752	.565
	Residual	4.492	26	0.173		
	Total	5.012	30			