

## Type of XR and Technologies/Platforms Used

Soundscape		Installation		Augmented Reality		Augmented Virtuality		Virtual Reality	
technology	platform	technology	platform	technology	platform	technology	platform	technology	platform
The Sensorium – Hinterberger (2011)		ColourVision – Wiethoff & Butz (2010)		Multisensory Interactive Window – Angelini et al. (2015)		Powered to Play – Seaborn (2016)		PsychicVR – Amores et al. (2016)	
surround speakers, EEG, projector, GSR, pulse, respiration	Thought Translation Device, PC, DMX control unit	camera, RGB lights	C++ video analysis software, DMX converter	touch screen, camera, diffuser, air blower	PQLab G4S multitouch overlay, HD camera, All-In-One Touchscreen PC, Google Chrome web & .NET app	smartphone	Android or iOS, Javascript framework (Appcelerator Titanium), Google Maps API	HMD, EEG	Oculus Rift, Interaxon Muse
Sonic Cradle (mod) – Kitson et al. (2014)		ORGONA – Bal (2013)		Catching Fireflies – Eubanks (2011)				Emotional Beasts – Bernal & Maes (2017)	
surround speakers, respiration	Thought Technology ProComp2, Max MSP	motion sensor, microphone, projector	Kinect, Arduino, Processing	smartphone	Android			HMD, PPG, GSR, mocap suit	HTC Vive, Shimmer3, Perception Neuron, Unreal
SOLAR – Prpa et al. (2015)		ORGONA Underwater – Bal (2013)		Inner Garden – Roo et al. (2017)				Cemetery & Park VE – Chittaro et al. (2017)	
surround speakers, respiration, EEG	Thought Technology ProComp2, Max MSP, Emotiv EPOC, Unity	motion sensor, microphone, projector	Kinect, Arduino, Processing	projector, respiration, HR, (HMD)	www, Unity, Open Vibe, ASUS short-throw projector, Kinect v1, Mio Fuse smartwatch (Oculus Rift DK2)			HMD, PPG	SonyHMZ-T1, Thought Technology ProComp Infiniti
Sonic Cradle + – Prpa et al. (2016)		ORGONA Chakra – Bal (2013)		MikuMikuDance – Sakamoto et al. (2015)				Angkor Wat – Choo & May (2014)	
surround speakers, respiration, EEG	Thought Technology ProComp2, Max MSP, Interaxon Muse, Unity	motion sensor, projector	Kinect, Processing	projectors, cameras, motion sensor	Kinect, OpenNI, Skype			HMD, EEG	Oculus Rift DK2, Emotiv EPOC
Sonic Cradle – Vidyarthi (2012)		ORGONA Prana – Bal (2013)		Virtual Aquarium – Sakamoto et al. (2015)				Osmose – Davies & Harrison (1996)	
surround speakers, respiration	Thought Technology ProComp2, Max MSP	motion sensor, projector	Kinect, Processing	accelerometer, mirror display	3-axis accelerometer			HMD, respiration vest, posture sensors	Division Dvisor HMD, Polhemus Fastrak, custom breathing vest
								Strata – Du Plessis (2017)	
								HMD, EEG, GSR, HR, respiration	Oculus CV1, Interaxon Muse, custom conductive band
								Realistic Avatar Communication – Garau et al. (2003)	
								CAVE, HMD	ReaCT by Trimention, Silicon Graphics Onyx w/ two Polymus Fastraks, DIVE software
								Virtual Sophrologist – Gu & Frasson (2017)	
								HMD, EEG	EMOTIV EPOC EEG, Windows Unity Server UDP to VR, Samsung Gear VR
								Virtual Meditative Walk – Gromala et al. (2015)	
								Stereoscopic viewer, GSR	DeepStream, GSR fingerclip
								RelaWorld – Kosunen et al. (2016)	
								HMD, EEG	Oculus Rift DK2, QuickAmp, Open Vibe framework
								EmoCat – Muñoz et al. (2016)	
								HMD, smart watch, headphones, gamepad	LG G Watch R, Samsung Galaxy S4 w/low-cost HMD, PhysioVR, Unity
								VR DBT – Navarro-Haro et al. (2017)	
								HMD	Oculus Rift DK2
								Life Tree – Patibanda (2017)	
								HMD, microphone	Smartphone w/ HMD, respiration headset
								Pulse Breath Water – Prpa et al. (2017)	
								HMD, respiration belt	Oculus Rift DK2, Thought Technology, Max MSP patch, M+M middleware, Unity
								Google Earth VR – Quesnel & Riecke (2017)	
								HMD, camera	HTC Vive, Logitech HD C270 webcam and LEDs casting unidirectional light
								DEEP – van Rooij (2016)	
								HMD, respiration	Oculus Rift DK1/2
								Meditation Chamber – Shaw et al. (2007)	
								HMD, GSR, respiration, pulse	VFX-3D (interactive imaging systems), Thought Technology ProComp+, SVE Toolkit

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Angeles, L., Caon, M., Couture, N., Khaled, O. A., & Mugellini, E. (2015). The Multisensory Immersive Window: Immersive Experiences for the Elderly. In <i>Adjunct Proceedings of the 2015 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2015 ACM International Symposium on Wearable Computers</i> (pp. 863-868). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/2808385.2808209">https://doi.org/10.1145/2808385.2808209</a>	Multisensory Immersive Window	enhance the older adults well-being at home	AR, tangibles	touch screen, camera	PQLab G4S multitouch overlay, HD camera, AK-In-One Touchscreen PC, Google Chrome web app, NET app	older adults	N/A	Input: opening physical window, touch gestures, wearing API, optical telepresence monitors, open/close virtual blinds, smell and air blower.	connection, nature elements, social presence	Proof of concept: human-to-human connection, increased well-being	Connecting with others remotely and discovering different places in the world.
Amores, J., Benavides, X., & Maes, P. (2016). <i>PsychVR: Increasing Mindfulness by Using Virtual Reality and Brain-Computer Interfaces</i> . <i>Proceedings of the 2016 CHI Conference on Extended Abstracts on Human Factors in Computing Systems</i> , CHI EA '16 (pp. 2-4). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/2851831.2851842">doi:10.1145/2851831.2851842</a>	PsychVR: virtually create and control fire through concentration	improve mindfulness	VR, biofeedback	HMD, EEG	Oculus Rift, Muse EEG	humans	N/A	Input: brain electrical activity, output: virtual fire created and levitates up with higher concentration	concentrate more = visual feedback; superhero metaphor	Proof of concept	Increase mindfulness through concentrating on making a virtual object levitate. Playful design through immersive environment and having superpowers
Bai, H. (2013). <i>Responsive Aesthetics for Yoga: Meditation, An Innovative Design Theory for Holistic Health that supports Autonomy and Effective Training</i> (M.Des.). Canada: Ontario College of Art & Design (Canada). Retrieved from <a href="https://search.proquest.com/open/doc/c/document_delivery.aspx?context=&amp;accountid=9243430F6E6845F4P4">https://search.proquest.com/open/doc/c/document_delivery.aspx?context=&amp;accountid=9243430F6E6845F4P4</a>	ORGONA: using your breath, you can virtually propel a cloth into space	breathing practices, borrowed from meditation and yoga practices, to foster physical and psychological empowerment	motion sensor, projection, biofeedback	motion sensor, microphone, projector	Kinect, Arduino, Processing	individuals who face mental and physical disorders	N/A	input: exhaling and x-axis body motion; output: cloth floats higher and background scrolls up when exhaling, and down when no input. Move to get under the cloth.	breath awareness and embodied physical empowerment	Proof of concept	Mind-body dialogues: a calm body breeds a calm mind. The gamified aspect allows a state of flow to create conditions for increased well-being.
	ORGONA Underwater: using your breath, create ripples in a virtual underwater	exercise of healthy behaviour	projection, biofeedback	motion sensor, projector	Kinect, Arduino, Processing	individuals who face mental and physical disorders	N/A	input: exhaling and x-axis body motion; output: cloth floats higher and background scrolls up when exhaling, and down when no input. Move to get under the cloth.	breath awareness and embodied physical empowerment	Prototype	Mind-body dialogues: a calm body breeds a calm mind. The gamified aspect allows a state of flow to create conditions for increased well-being.
	Interactive Chakras-based Breathwork: visualize your breath as a virtual outline of a person with an orb of energy	focus on breathing and relaxation from meditation practices	projection in dark room, biofeedback	motion sensor, projector	Kinect, Processing	individuals who face mental and physical disorders	N/A	input: inhaling with arms up → inhale sound, outline of virtual body mirrored, fireflies move inward, and circle decreases into the virtual body, exhaling with arms down → exhale sound, outline of virtual body lights up with chakras, fireflies move outward, and circle increases outward	visual and auditory cues help user breath smoothly and deeply, gradually, the exhales move toward the chakras until only the breath is left - abstract orb that responds to breathing, representing transcendence.	Strong calming effect. Reprogramming of clarity, awareness to breathing, visuals and audio helpful indicators of progress; Arm movements natural way to signify breathing. Circle visuals should be reversed to be congruent with actual body expanding/contracting during breathing. Music should be simple and related to holistic health.	Cathartic healing through breathwork and gradual transcendence provided by natural bodily movements and visual/auditory feedback to show performance.
	ORGONA Prana: interaction of above system with extended narrative and more auditory feedback	focus on breathing and relaxation from meditation practices	projection in dark room, biofeedback	motion sensor, projector	Kinect, Processing	individuals who face mental and physical disorders	N/A	Same as above except with cosmic background imagery moving clockwise and counter-clockwise with inhalation and exhalation, respectively. Chakras disappear first, then reappear in reverse order to complete the experience.	Same as above; repeated in reverse order of chakras.	Positive experience; relaxing; visuals good feedback for performance; audio can be intrusive; End of experience unclear.	Use of visual feedback that was both abstract and related to spiritual practices of bodily sensations and chakras helped users to relax and focus on their breath.
Bernal, G., & Maes, P. (2017). <i>Emotional Beasts: Visually Expressing Emotions Through Avatars in VR</i> . <i>Proceedings of the 2017 CHI Conference on Extended Abstracts on Human Factors in Computing Systems</i> , CHI EA '17 (pp. 2395-2400). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/3027083.3032307">doi:10.1145/3027083.3032307</a>	Emotional Beasts: affective expression in social VR	fostering deep, emotionally compelling human-to-human connection	VR, biofeedback	HMD, PPG, GSR, mocap sensor suit	HTC Vive VR headset, Shimmer3 sensor, Perception Neuron suit, Unreal Engine	humans	N/A	input: heart rate, skin conductance (emotional arousal), output: reactive fur and particle system brightness/color	Visually express emotions. VR avatars project non-verbal cues from the wearer's emotional state	Proof of concept	VR avatars project non-verbal cues from the wearer's emotional state so that virtual users can both communicate and perceive emotions in social VR
Chittka, J., Simon, R., Cieslinski, C., & Fabbro, F. (2017). <i>Mortality salience in virtual reality: experiences and effects on users' attitudes towards risk</i> . <i>International Journal of Human-Computer Studies</i> , 101, 10-22. <a href="https://doi.org/10.1016/j.ijhcs.2017.03.002">doi:10.1016/j.ijhcs.2017.03.002</a>	Cemetery and Park VE: using VR to elicit mortality salience	morality salience is linked to increasing positive health and well-being, including mindfulness	VR, biofeedback	HMD, PPG	SonyHMZ-T1 stereoscopic HMD, Thought Technology ProComp Infinit Encoder	108 (95 Female)	input: Nintendo Nunchuk joystick, output: movement in VE	Visual mortality cues such as tombs, burial recesses, and a group of mourners attending a funeral	VR users projected more mortality cues	Proof of concept	Cemetery VE elicited death related themes compared to park VE; Increased risk perception for both the self and others; Harm Avoidance as a personality factor is a mediating trait for risk perception; mindfulness personality not a factor; heart rate variability was increased.
Choo, A., & May, A. (2014). <i>Virtual Mindfulness Meditation Virtual Reality and Electroencephalography for Health Gamification</i> . 2014 IEEE Games, Media, Entertainment (Game).	Angkor Wat: virtual guided seated meditation that is gamified for learning mindfulness	mindfulness has many health benefits, so training can help encourage positive functioning	VR, biofeedback	EEG	Emotiv EPOC EEG	N/A	all who would like to learn mindfulness	input: brain electrical activity; output: virtual flowers bloom in VE	The more flowers in bloom, the higher the player's meditative scores. A lower meditation score will have fewer flowers in bloom at any given time	Proof of concept	Use of visual feedback shows learning progress of meditation, which may accelerate the positive benefits of meditation. Calming visuals and audio contribute to relaxed state.
Duiven, C., & Hanson, J. (1998). <i>Omniplex: Towards Broadening the Analytics of Virtual Reality</i> . <i>SCIP 1997 Proceedings</i> , 4(1), 25-29. <a href="https://doi.org/10.1145/249806.249806">doi:10.1145/249806.249806</a>	Omniplex: a virtual environment that allows users to shed their habitual ways of looking at and behaving in the world	self-transcendence: the goal is to experience the real world in a fresh way, reawakening a fundamental sense of their own "being-in-the-world"	VR, biofeedback	HMD, Respiration vest	Division DVIator HMD, Pothemus Fatrak, custom breathing vest, Onyx RealityEngine2, software SAAPHIRE and DK1 development libraries, SIG's Performer and GL graphics libraries	humans	N/A	input: breath, posture tilt; output: movement vertical, movement horizontal	Emphasis on "being" rather than "doing." Atain full-body immersion through meditation and tai chi practices. Creating a sense of floating through breath and balance. Breath in to move up, breath out to move down; tilt body in direction you want to move horizontally. Evocative audio and human voices to reaffirm the role of the physical body in the virtual space.	Feeling calm, a loosening of the boundaries between self and world, simultaneous feeling of disembodiment (because of the visual aesthetic, being able to float and pass through things) and embodied (due to reliance on breath and balance, emotional, egoistic).	By enabling people to experience the unusual sensations of floating and falling through things, they are freed of their usual, habitual ways of being in the world; this effect, in combination with the use of breath, stillation and metaphorical content, appears to induce heightened awareness.
Du Plessis, I. (2017). <i>Strata: A Biometric VR Experience</i> . ACM SIGGRAPH 2017 VR Village, SIGGRAPH '17 (pp. 141-142). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/3059936.3059972">doi:10.1145/3059936.3059972</a>	Strata: a biometric VR experience	immersive experience connects us to our own emotional state, teaching us to calm and focus our minds	VR, biofeedback	HMD, EEG, GSR, HR, breathing	Oculus CV1, Muse EEG, custom conductive band	humans	N/A	input: brain electrical activity, heart rate, skin conductance, breathing rate; output: levitate upward through five fantastical worlds as you reach meditative state, biometrics change audio and visual components	Mindfulness training to stress alleviation, meditation, anger management, empathy counselling	Proof of concept	Reach meditative state and levitate upward → reaching higher state of consciousness, letting go of distraction thoughts. See visuals and audio change to gain introduction on own internal states.
Eubanks, A. (2011). <i>Catching Fireflies: A Pervasive Augmented Reality Game for Android Phones</i> . (V. A. Clincy, Ed. <i>Proceedings of the 48th Annual Association for Computing Machinery Southeast Conference</i> (Lecture '11), 363-366)	Catching Fireflies: an AR game designed to draw people outdoors and appreciate nature	Calming, nostalgic experience	AR	smartphone	Android	humans	N/A	input: camera, GPS coordinates, touch screen; output: vibration, animation of capturing firefly	Besides the camera and GPS, the application uses sound, vibration, the proximity sensor, accelerometers, and orientation sensors to encourage players to relieve their outdoor childhood memories of catching fireflies.	Nostalgia, getting outdoors, appreciation of nature, movement	The app encourages players to go outside and partake in an activity they might not be able to do otherwise - catch fireflies. It is a playful way to get people to interact with the real environment and move their bodies, which has positive physical and psychological effects.
Garaou, M., Slater, M., Vinayagamoorthy, V., Biondi, A., Steed, A., & Sasse, M. A. (2003). <i>The Impact of Avatar Realism and Eye-Track Control on Perceived Quality of Communication in a Shared Immersive Virtual Environment</i> . <i>Proceedings of the SIGCHI Conference on Human Factors in Computing Systems</i> , CHI '03 (pp. 525-530). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/958291.958293">doi:10.1145/958291.958293</a>	Communicating with realistic avatars in immersive virtual environments	Increasing social presence and communication	VR	CAVE, HMD	RealTOR by Trimension, Silicon Graphics Onyx with two Pothemus Fasttrak, DVE software	48 (24 Female)	input: analogique joystick, 5 button 3D mouse, head tracking device; output: movement, head position and orientation	Use of high-realism avatars and non-random gaze will increase social presence and communication in VEs	Inferred gaze high-realism avatar helps increase social presence and ease of communication	More realistic avatars and gazing at us can help increase social presence, in turn having a positive impact on communication in social VR settings.	
Gonnella, D., Torio, X., Choo, A., Karamegal, M., & Shaw, C. D. (2015). <i>The Virtual Meditative Walk: Virtual Reality Therapy for Chronic Pain Management</i> . <i>Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems</i> , CHI '15 (pp. 261-264). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/2702323.2702344">doi:10.1145/2702323.2702344</a>	Virtual Meditative Walk: enable chronic pain patients to learn Mindfulness-based stress reduction (MBSR)	Reduce pain and increase psychological health	VR, biofeedback	Stereoscopic viewer, GSR	DeepStream VR, GSR finger picks	chronic pain patients	6 (3 Female)	input: GSR arousal levels; output: virtual weather system	light log in the forest, for example, recedes as a patient's GSR levels start to stabilize in favor of a mindful state. Alternatively, the fog thickens and draws closer when the patient's arousal levels increase.	mindfulness-based stress reduction (MBSR)	biofeedback helped users more easily learn mindfulness practices and provided a distraction from pain, which in turn decreased their overall pain over time.
Gu, G., & Prasson, C. (2017). <i>Virtual Sophologist: A Virtual Reality Neurofeedback Relaxation Training System in Brain Function Assessment in Learning</i> (pp. 176-185). Springer, Cham. <a href="https://doi.org/10.1007/978-3-319-67015-9_16">https://doi.org/10.1007/978-3-319-67015-9_16</a>	Virtual Sophologist: VR and EEG relaxation training system	Increased relaxation	VR, biofeedback	HMD, EEG	EMOTIV EPOC EEG, Windows Virtual Serger UDP to VR, Sansing UDP	humans	6 (2 Female)	input: brain waves; output: virtual text and audio feedback	physical measures, mindfulness-meditation, nature elements	relaxed, increased mindfulness, decreased stress/anxiety	VED supports a calming environment: Seaside, Japanese Garden and Waterfall. Relaxation feedback keeps participants in the present moment.
Harrison, J., Lo, P., Orr, T., & Taylor, L. (2006). <i>A Responsive and Pervasive Audio Device to Stimulate Exercise and Fitness in Children</i> . <i>CHI '06 Extended Abstracts on Human Factors in Computing Systems</i> , CHI EA '06 (pp. 1837-1842). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/1124541.1124799">doi:10.1145/1124541.1124799</a>	Immersive soundscape where users control and vary music tempo based on measured activity level	Help stimulate exercise and fitness	immersive soundscape	audio device, pedometer	TBD	children aged 8-11	15	input: movement; output: music	Increase movement → increase music tempo; decrease movement → decrease music tempo	Positive reception from concept testing	Moving the body to music (dancing) is a fun activity that also promotes both physical and mental health. Children are active without imposing stricter educational means of activity.
Hilderberger, T. (2011). <i>The Sensorium: A Multimodal Neurofeedback Environment</i> . <i>Adv. in Hum.-Comp. Int.</i> , 2011, 311-310. <a href="https://doi.org/10.1155/2011/724204">doi:10.1155/2011/724204</a>	Sensorium: a neurofeedback environment that allows people to experience signals from their nonperceptible body processes visually and audiotically	Improving bodily awareness and self-regulation to promote positive change	immersive soundscape and light room, biofeedback	immersive soundscape	Projector, surround speakers, EEG, skin conductance, pulse finger sensor, repplier strip	humans	20 (11 Female)	input: brain electrical activity, heart rate, skin conductance, breathing; output: changes in light and sound	Positive slow potential shifts as generated on the cortex in relaxing moments should lead to a blue coloured environment while negative shifts normally reflect attentive moments in which the brain produces a readiness state (i.e., the "Beretschkaufreuzer") which turned the environment into red.	Almost all of them reported an increase in contentment, relaxation, happiness, and inner harmony. They also reported a widening in their body consciousness.	Use of colours corresponding to certain emotional states (blue/red). Visual and auditory representation of internal states provide concrete feedback, so users can change their states and see that automatically if successful or not.
Janssen, J., H. van den Broek, E. L., Westerink, J. H. D., & M. (2012). <i>Time to your emotions: a robust personal affective music player</i> . <i>User Modeling and User-Adapted Interaction</i> , Dordrecht 22(3), 255-279. <a href="https://doi.org/10.1007/s11042-011-9107-2">https://doi.org/10.1007/s11042-011-9107-2</a>	Affective Music Player (AMP): selects music for mood enhancement based on biofeedback	Improve or enhance mood	immersive soundscape, biofeedback	Headphones	Philips SBC HP4400 headphones, NeXus-10 apparatus of Mind Media b.v.	humans	3 Males	input: skin temperature; output: corresponding music of mood	decreasing skin temperature → positive mood song; increasing skin temperature → negative mood song	The validation of the AMP was successful. The songs selected to reduce skin temperature did indeed decrease skin temperature.	Personalized music model that was first trained through regression and kernel density estimation, and then used as a way to guide affect (mood).
Kilson, A., Recife, B. E., & Viderholm, J. (2014). <i>Sonic Cradle: Investigating Meditative Aspects of Immersive Technology</i> (pp. 1-4). Presented at the NCF-GRAND 2014 Conference, Dallas, Canada. Retrieved from <a href="http://openurl.ezproxy.usu.edu.ca/1348/">http://openurl.ezproxy.usu.edu.ca/1348/</a>	Sonic Cradle: an interactive system designed to encourage a meditative attentional pattern akin to mindfulness	Encourages people to self-regulate and manage their stress in a healthy way	immersive soundscape, biofeedback	respiration physiological sensor, sound-sound	Max MSP, Thought Technology ProComp2	novice meditators	30	input = breathing from abdomen and chest; nod breath to add sounds, breath quickly to subtract sounds	Mindfulness practice → Sonic Cradle Interaction Call focused attention → focus on respiratory control through sound interaction Wandering mind → Wandering mind sounds change Meta-awareness → Automatic breathing as attention is brought back to sounds and user wonders how their breathing controls it	Decentering: awareness of one's experience with some distance and identification rather than being carried away by one's thoughts and feelings. The increased decentering score we found after Sonic Cradle shows that participants were able to emotionally detach themselves from their thoughts and feelings while still acknowledging that they are there.	Playful, non-invasive made experience inviting. Dark room with only soundscape decreased distractions and allowed focus on breathing and present moment. Selected sounds were meditative in nature - neutral or calm yet still energetic enough to keep attention. Easy to learn mapping to explore breath. Auditory feedback on performance.
Kosunen, J., Salminen, M., Järvelin, S., Ruonala, A., Revaia, N., & Janas, G. (2019). <i>RelaWorld: Neuroadaptive and Immersive Virtual Reality Meditation System</i> . <i>Proceedings of the 21st International Conference on Intelligent User Interfaces</i> , UII '19 (pp. 205-217). New York, NY, USA: ACM. <a href="https://doi.org/10.1145/3286787.3286798">doi:10.1145/3286787.3286798</a>	RelaWorld: a neuroadaptive virtual reality meditation system that combines virtual reality with neurofeedback to provide a tool that is easy for novices to use yet provides added value even for experienced meditators	Meditation in general and mindfulness in particular have been shown to be useful techniques in the treatment of a plethora of ailments	VR, biofeedback	HMD, EEG	Oculus Rift DK2, Quickamp, Open Vibe framework	novice meditators	43 (26 Female)	input: brain electrical activity; output: virtual levitation and opacity of energy bubble around user	Increase in the power of the beta band (concentration) will produce floating; increase in the alpha band (relaxation) will increase the opacity of the energy bubble surrounding the user.	RelaWorld system elicits deeper relaxation, feeling of presence and a deeper level of meditation when compared to a similar setup without head-mounted display or neurofeedback.	the head-mounted display generates higher meditative states when compared to the same system displayed on a normal screen. NeuroFeedback further enhances the experience, providing higher levels of presence as reported by the users.
Mauro, J. E., Paulino, V., Vasanth, H., & Barros, K. (2016). <i>PhysiVR: A Novel mobile virtual reality framework for physiological computing</i> . 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (HealthCom), pp. 1-5. Presented at the 2016 IEEE 18th International Conference on e-Health Networking, Applications and Services (HealthCom), doi:10.1109/HealthCom.2016.7749512	EmoCat: Rescuers encourages players to regulate their heartbeats in order to find a cat lost in a forest	Encourages deep breathing in order to lower heart rate, ultimately increasing health	VR, biofeedback	HMD, smartwatch, headphones, gamepad	LG G Watch R, Samsung Galaxy S4 w/ low-cost HMD, PhysVR, Unity	humans	N/A	input: heart rate, gamepad; output: movement, cat's meow	Lower your HR in order to hear a virtual cat meow, so that you can find it and rescue the cat. Deep breathing is encouraged to lower HR through gamification techniques	Proof of concept	Gamification and real-time visual and auditory feedback on internal states help people learn to regulate their internal states.

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Navarro-Haro, M. V., Lopez-del-Hoyo, Y., Campos, D., Uehara, M. M., Hoffman, H. G., Garcia-Palacios, A., Morrongiello, A. M., et al. (2017). Meditation aspects in Virtual Reality Mindfulness: a pilot study evaluation of the feasibility and acceptability of Virtual Reality to facilitate mindfulness practice in people attending a mindfulness conference. <i>PLoS One</i> , <i>12</i> (11), e0181777. doi:10.1371/journal.pone.0181777	VR Dialectical Behavioral Therapy (DBT); mindfulness skills training technique	Regular mindfulness practice benefits people both mentally and physically	VR	HMD	Oculus Rift DK2	people who have trouble focusing attention	44 (28 Female)	input: head movement; output: virtual view	Nature visuals and sounds matched a guided meditation instructor where the participant could follow along and practice focusing and paying attention with minimal distractions and concrete things to focus on.	participants reported significantly less sadness, anger, and anxiety, and reported being significantly more relaxed	VR is a highly controlled world that allows the user to focus on the essentials during meditation and blocks out other distractions. This is good for those who have trouble focusing their attention or more traditional forms of meditation do not work.
Palombini, R., Mueller, F., Floyd, L., Leckrone, M., & Duchwartz, G. (2017). Life Tree: Understanding the Design of Breathing Exercise Games. <i>Proceedings of the Annual Symposium on Computer-Human Interaction in Play, CHI PLAY '17</i> (pp. 18-31). New York, NY, USA: ACM. doi:10.1145/3116626.3116621	Life Tree: a virtual reality (VR) game in which a player controls the growth of a tree by practicing pursed-up breathing.	Regular breathing exercises can be a beneficial part of leading a healthy life.	VR	HMD, microphone	Smartphone + HMD, Breathing headset		32 (16 Female)	input: pursed up breathing; output: virtual tree growth	Inhaling expands tree, and exhaling contracts tree. Sitting (phone accelerometer) will trigger tree to be submerged in water. Leaves are blown on exhalation. Background rhythmic breathing to help players match their breathing.	Overall, participants liked playing Life Tree. They reported that the game was very fun and relaxing and de-stressing. They also thought of it as a novel experience. P17, a female participant said, "It is really good. I feel surprised about that game because I have not experienced such a kind of game before. It really felt special for me."	Design considerations listed: 1. Consider Using Subtle Onboarding to Help Players Engage with the Breathing Exercises; 2. Consider Using Non-Intuitive Breathing Feedback to Support Self-Awareness of Breathing During Gameplay; 3. Consider Using the Object in the Game Environment to Provide Intuitive Breathing Feedback; 4. Consider Using a Minimalist Approach to Designing Naturalistic Visuals to Help Players Focus on their Breathing; 5. Consider the Intimate Placement of Breathing Hardware and how it can Affect Breathing Performance; 6. Consider Designing Breathing Hardware that Helps Players Hear their Own Breathing.
Papa, M., Cochrane, K., & Riecke, B. E. (2015). <i>Hacking Alternatives in 21st Century: Designing a Bio-Responsive Virtual Environment for Stress Reduction, Persuasive Computing, Paradigms for Mental Health, Communications in Computer and Information Science</i> (pp. 34-39). Presented at the International Symposium on Persuasive Computing Paradigms for Mental Health, Springer, Cham. doi:10.1007/978-3-319-29270-4	SOLAR: Immersive virtual environment (VE) that assists novice users to learn the stress reducing practice of mindfulness meditation	Meditation practice is known to reduce stress	soundscapes, biofeedback	EEG, respiration belt	Emvot Epic, Thought Technology ProComp2, Unity, Max MSP	novice meditators	13	input: brain electrical activity, respiration; output: meditation sounds and visuals	When EEG data reveals a state of distraction, the soundscape becomes more salient, increasing its ability to cue users back to their breath with curiosity. Once they achieve focused attention, the interaction paradigm fades out, allowing users to meditate undisturbed.	Participants felt relaxed	The following design principles were applied: 1. thought distracting - distancing from negative thoughts; 2. abstract visual elements - pleasant visual feedback; 3. rewarding system - motivational feedback; 4. Immersive and Natural Restorative Environments - nature elements.
Papa, M., Ganesel, D., Vidyarthi, J., Kibson, A., & Riecke, B. E. (2016). Sonic Cradle - Immersive interaction design combining breathing and near-to-feedback to foster focused attention on breath. Presented at the 2nd International Conference on Mindfulness, Rome, Italy.	Sonic Cradle - a system that encourages deep diaphragm (abdominal) breathing by providing real-time neuro- and biofeedback generated from EEG and respiration data.	Mindfulness meditation practice is widely recognized for its psycho-logical and physical well-being benefits	soundscapes, biofeedback	EEG, respiration belt, surround-sound	Interaxon Muse, Max MSP, Thought Technology ProComp2	novice meditators	8	input: brain activity, respiration; output: sound	Breathing frequency as well as eventfulness (arousal) and pleasantness (valence) levels of the audio environment are sent from Muse map patch to the game engine Unity 3D. In Unity, the cube of eventfulness is mapped to the waves of the ocean. Higher aroused states result in a more disturbed ocean surface and waves. The color of the sky progresses from grey (at the beginning of the experience) to pitch black (at the end of a session) over the span of eight minutes. A participant's breathing data controls the elevation of the user in the VE in that when the user breathes in, their position in the environment is elevated so they can rise above the ocean surface. Similarly, when the participant exhales, they sink.	Self-reported anxiety and arousal levels decreased, and pleasantness increased	Sounds and physical set-up was relaxing and had minimal distractions that allowed focus on meditation. Biofeedback gave users a sense of their performance and gently guided them back to their breath when distracted. The revisions could include instructions to emphasize reflection on "calmness," which is suggestive of mindfulness practices' focus of inner sensations opposed to a quantification of performance.
Papa, M., Tatar, K., Riecke, B. E., & Pasquier, P. (2017). The Pulse Breath Water System: Exploring Breathing as an Embodied Interaction for Enhancing the Affective Potential of Virtual Reality, Virtual, Augmented and Mixed Reality. <i>Lecture Notes in Computer Science</i> (pp. 163-172). Presented at the International Conference on Virtual, Augmented and Mixed Reality, Springer, Cham. doi:10.1007/978-3-319-57987-0_13	Pulse Breath Water: Immersive virtual environment (VE) with affect estimation in sound	the integrity of our minds and bodies engaged in actions with environments, in a process through which meaning and understanding are generated.	VR	HMD, respiration belt	Oculus Rift DK2, Thought Technology, Max MSP patch, M/M middleware, Unity	humans	24 (16 Female)	input: respiration rate, arousal; output: use position vertically, wave amplitude	Breathing frequency as well as eventfulness (arousal) and pleasantness (valence) levels of the audio environment are sent from Muse map patch to the game engine Unity 3D. In Unity, the cube of eventfulness is mapped to the waves of the ocean. Higher aroused states result in a more disturbed ocean surface and waves. The color of the sky progresses from grey (at the beginning of the experience) to pitch black (at the end of a session) over the span of eight minutes. A participant's breathing data controls the elevation of the user in the VE in that when the user breathes in, their position in the environment is elevated so they can rise above the ocean surface. Similarly, when the participant exhales, they sink.	Relaxed, calm, engaged, breath awareness	Family/First, Engagement After, Tension and Relaxation, at the Same Time, Environmental Context is the Key
Quaresel, D., & Riecke, B. E. (2017). Awestruck: Natural interaction with virtual reality on eliciting awe [pp. 205-206]. <i>IEEE</i> . doi:10.1109/SUDI.2017.7893343	Google Earth VR: Flying interface to explore the Earth, leading to the experience of awe	transformative experiences the feeling of awe is found to alter an individual's perception in positive, lasting manners	VR	HMD, camera	HTC Vive, Senneiser noise-cancelling headphones, Logitech H3 C270 webcam and LEDs casting unidirectional light	humans	16 (6 Female)	input: HTC Vive wands; output: flight in 3D connection with the planet, movement by flying with natural interaction (use of beer/bag chair), nature elements - Earth from space and zooming into famous places or home town	connection with the planet, movement by flying with natural interaction (use of beer/bag chair), nature elements - Earth from space and zooming into famous places or home town	43.8% of the participants experienced goose bumps; if they experienced goose bumps they were more likely to experience awe. Females were more likely to experience goose bumps (but not awe) than males. No differences in flight vs. standing conditions.	interactive VR can induce both subjective and physiological indicators of awe, embodied interfaces must have low cognitive load and inarduous interactions to be successful.
Boo, J., S. Genova, B., Frey, J., & Hachet, M. (2017). Inner Garden: Connecting Inner Spaces to a Mixed Reality Sandbox for Mindfulness. <i>Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA '17</i> (pp. 1459-1470). New York, NY, USA: ACM. doi:10.1145/3092683.3092743	Inner Garden: augmented sandbox to support mindfulness practices	Inspire self-motivation and curiosity	AR, VR	HMD, projector, respiration belt, HR monitor	www, Unity, OpenVibe, ASUS short-throw projector, Kinect v1, Mio Fuse smartwatch, Oculus Rift DK2	humans	12 Females	input: sculpting sand, breathing, HR; output: garden appearance	oscillating breathing patterns are mapped to the water level which creates waves, and the wind strength (creating gusts of wind); Cardiac coherence was used to indicate garden health. When in good health, the amount of sand reduces, flora's growth speed is increased and sounds caused by the fauna are more present. Note that there is no obvious "unhealthy" state; fauna might hide, but trees will not start dying as a result of a low CC score. The following design considerations were used: balance distraction and guidance, keep it minimalist, be non-judgmental and non-striving, promote acceptance and autonomy, use tangible interaction, choose the right reality.	They tested the system with meditation practitioners of different levels of experience (from initiated to daily meditators), which found the design engaging while also being well suited for mindfulness. Preliminary quantitative results seem to indicate that the system fosters a calm and mindful state on the users.	Different mediums used for greater accessibility: AR for tangible experience and "Tying It Out" VR for more immersive and personal experience and a chance to go deeper. Nature elements and biofeedback set the stage for a relaxing and invigorating experience.
van Rooij, M., Lobel, A., Harris, O., Smil, N., & Granic, I. (2016). DEEP: A Biofeedback Virtual Reality Game for Children at Risk for Anxiety. <i>Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA '16</i> (pp. 1388-1397). New York, NY, USA: ACM. doi:10.1145/2851581.2851629	DEEP: a virtual reality (VR) game that simulates players in a beautiful underwater fantasy world in which they can move around freely and explore at their leisure	provide an immersive and relaxing experience in order to decrease anxiety	VR	HMD, variable resistor/stretch sensor	Oculus DK2	children at risk for anxiety	86 (42 Female)	input: respiration; output: expanding and contracting circle	Large circle -> inhalation peak, small circle -> exhalation peak; lung capacity <+50% -> gravity applied; inhaling -> upward movement, exhaling -> downward movement	the pilot study demonstrated that playing DEEP reduces state-levels of anxiety in children and thus confirmed its potential as an intervention for anxiety	Dynamical Systems Theory (DST): real-time in-game information to dynamically adjust the game environment to individual learning trajectories. Use of natural imagery and sound to help increase relaxation. Immersive environment decreases outside distractions.
Sakanokita, M., Nishimura, T., & Alexandrova, T. (2015). Enhancing values through virtuality for intelligent artifacts that influence human attitude and behavior. <i>MultiMedia Tools and Applications, Dordrecht</i> (74(24)), 11537-11568. doi:10.1007/s11042-014-2250-5	MikuMikuDance: AR trading card game	Supports telepresence, socialness	AR, tangibles	Projectors, motion capture, web camera	Kinect, OpenNI, Skype	gamers	N/A	input: body movement, trading cards; output: virtual character movement, augmented card projection	Real and digital combined to provide presence and keep the tactile feel of traditional trading card games. Virtual avatars are customizable for personal element.	Proof of concept	Customizable game helps to engage user. Use of cameras and projection can help users feel like they are playing with a real person, thus increasing social connection.
Seaborn, K. A. (2015). <i>Mixed Reality Gaming for Older Powered Chair Users: A Human Factors Model of Well-being and Engagement</i> (Ph.D.). Canada: University of Toronto (Canada). Retrieved from https://search.proquest.com/proxy.lib.usa/docview/16339867/2943403/1626554/4P034	Powered to Play (PTP): capture-the-flag game that is an accessible, social mixed reality game for co-located mobile play in everyday spaces	Promotes accessible social gaming	MIR	Smartphone	Android & iOS, Javascript framework (Appocaster/Tamam), Google Maps API	powered chair users	13 (8 Female)	input: physical movement; output: capture flag for points	Based on the following design recommendations: 1. multiple people with various skills and abilities can play; 2. intergenerational gaming; 3. opportunities to meet and collaborate with new people/would a common goal; 4. fair playing field; 5. challenge and strategy; 6. Accessible and easy to use equipment and interface design; 7. outdoor play space; 8. opportunities to improve skills and abilities.	participants found the game to be fun, social, and accessible, and engaged with the game in a variety of ways. Participants experienced high leveled engagement.	observer commentary identified three complementary factors that arose as a result of the inclusive, social game design and everyday setting: intergenerational play for multiscale inclusivity and enrichment; mixed ability play that harnesses and supports the abilities of those with and without motor impairments and other disabilities; and community engagement through integration or enactment at public, open community sites.
Shaw, C. D., Gromala, D., & Seay, A. F. (2007). The meditation chamber: Enacting autonomic senses. <i>Proc. of ENACTIVE'07</i> .	Meditation Chamber: bio-interactive, therapeutic, virtual environment	help users lower their stress levels through meditation and muscle relaxation	VR	HMD, GSR, respiration belt, blood volume pulse sensor	VRX-3D (Interactive Imaging Systems), Thought Technologies ProComp+ SVE Toolkit	novice meditators	411	input: skin conductance, heart rate, respiration; output: virtual sunset, jellyfish movement, audio	Visual and audio cues were used to create, guide, and maintain a user's guided relaxation and meditation	GSR levels decreased, breathing patterns were steadier and deeper, self-rated relaxation levels increased, and subjective comments were mostly positive.	Visuals and sound provided real-time feedback on performance, allowing the user to adjust their internal states. Use of abstract and natural imagery provided a means to focus on that is pleasant and relaxing and decreased external distractions. Few instructions allowed for playful interaction and unstructured learning.
Vinvarini, J. (2012). <i>Sonic Cradle: Evoking Mindfulness through Immersive Interaction Design</i> (M.S. Thesis). Surrey, BC, Canada: Simon Fraser University. Retrieved from https://lib.usa/doi/10.2581/582852	Sonic Cradle: an immersive, interactive soundscape designed for novice meditator to explore their breathing	introduces a relaxing HCI paradigm to foster for novice meditator to explore their breathing	immersive soundscapes, biofeedback	respiration physiological sensor, surround-sound	Max MSP, Thought Technology ProComp2	novice meditators	39 (15 Female)	input: breathing from abdomen and chest; hold breath to add sounds, breath quickly to subtract sounds	Mindfulness practice -> Sonic Cradle Interaction Calm focused attention -> focus on respiratory control through sound interaction Wandering mind -> Wandering mind sounds change Meta-awareness -> Automatic breathing as attention is brought back to sounds and user wonders how their breathing controls it	Relaxation, clarity of mind, reduced thinking, emptiness	Playful/non-invasive made experience inviting. Dark room with only soundscape decreased distractions and allowed focus on breathing and present mind -> Wandering mind sounds were meditative in nature - neutral or calm yet still energetic enough to keep attention. Easy to learn mapping to explore breath. Auditory feedback on performance.
Wietlauf, A., & Butz, A. (2010). ColourVision: Controlling Light Patterns Through Postures. <i>Proceedings of the 10th International Conference on Smart Graphics, SG'10</i> (pp. 281-284). Berlin, Heidelberg: Springer. Retrieved from http://dl.acm.org/citation.cfm?id=1894345.1894384	ColourVision: people use their posture to change the color of a room, reflected as their current mood	people experience the psychological effects of different colors	Immersive room installation	Camera, RGB lights	C++ video analysis software, DMX converter	humans	N/A	input: posture in chair; output: room colour	The implemented body interface controls the room through posture. Red, for example, is activated through an open, active seating position. Green is the color for introverted reflectiveness as generated if a person takes a thoughtful, closed position. A person, sitting on the chair in a stretched, relaxed position plunges the room into a cool blue as the color for calmness.	Different emotional color impressions were reported from the participants. Asked about their emotional state when exposed longer to one color, for example red, the participants reported an increased level of "nervousness." An intensive exposure in a relaxed posture to the color blue was described as "peaceful."	Playful interactions with the body interface were perceived positively. Users were curious to try out different postures to see how that affected the colour. Users also reflected on their own emotions by perceiving the colour if it reflected their internal states visualized and, in turn, the visuals affect the user's internal states - feedback loop