Telerehabilitation Based on XR

Takeshi Kurata

ISO/IEC JTC 1/SC 24 HoD of Japan

Deputy Director
Human Augmentation Research Center
AIST, Japan

Outline

- Examples of XR product/service for rehabilitation
- Market report and Review
- Introduction of our new NEDO project
  - Multimodal XR-AI platform development for telerehab and reciprocal care coupling with health guidance

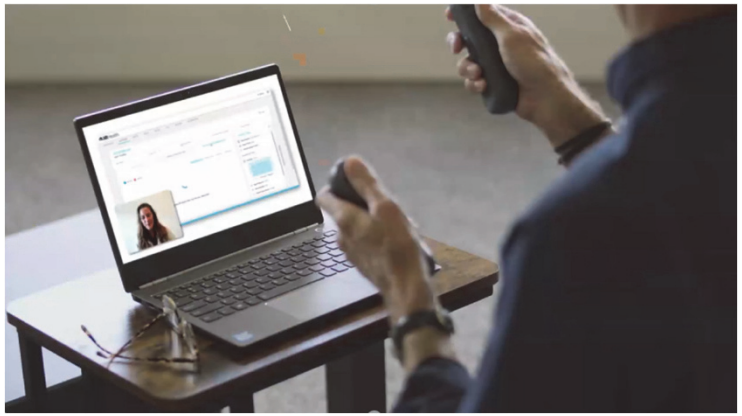
Outline

- Examples of XR product/service for rehabilitation
- Market report and Review
- Introduction of our new NEDO project
  - Multimodal XR-AI platform development for telerehab and reciprocal care coupling with health guidance

Examples of XR product/service for rehabilitation

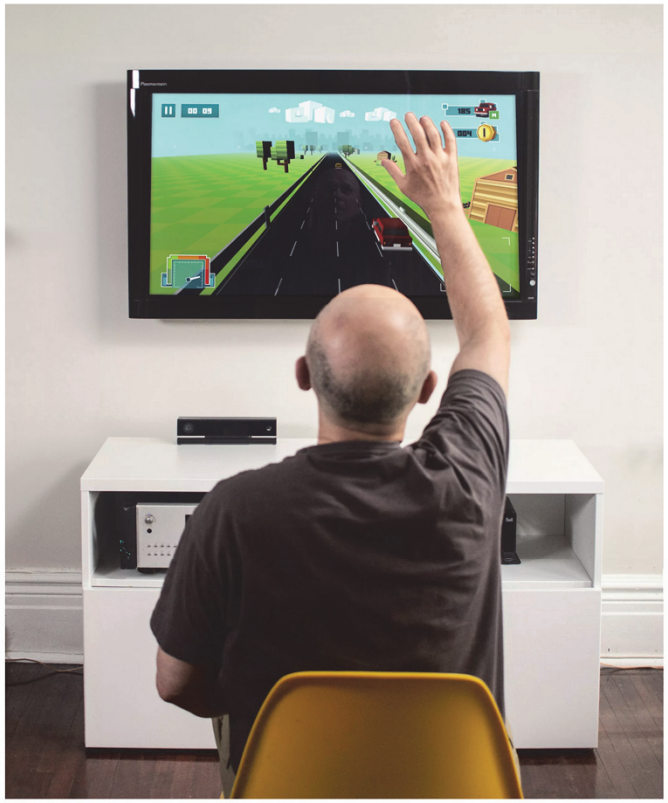
Name	Features	Users	Target body part	Which XR	How to use XR	People involved in XR	Organization	Country	Notes	URL
Physical rehab										
Service/Product										
XRHealth	(1) Assigned physical therapists proposing VR rehab programs for each disease (2) Improving physical functions through VR games (3) FDA-registered medical VR applications	Broad	Broad (physical, neurological or behavioral symptoms)	VR (HMD)	Execution of rehabilitation programs through VR games	User	XRHealth USA INC	USA	Telerehabilitation	https://www.xr.health/
SaeboVR	(1) Designed to engage the client involving daily functional activities through a virtual ADL (activities of daily living) rehabilitation system to help the brain “re-program” itself and form new neural connections (2) Virtual assistant appearing on the screen to educate and facilitate performance by providing real-time feedback (3) FDA-cleared software system	Patients with cognitive or upper limb impairments	Upper limbs	VR (Monitor)	(1) Providing ADL-focused virtual world in which the users incorporates their impaired upper limb to perform simulated self-care tasks that involve picking up, transferring and manipulating virtual objects (2) Using Microsoft Kinect	User	Saebo, Inc	USA	None	https://www.saebo.com/shop/saebovr/
MindMotion GO	(1) Gamified neurorehabilitation therapy platform for medium and light severity impairments able to be deployed in the patient’s home (2) Including rehabilitation exercises for the upper extremity, trunk, and lower extremity; audio-visual feedback and graphic movement representations for patients (3) FDA-cleared system	Stroke survivors at home	Broad(Upper limbs, torso, lower limbs)	VR (Monitor)	(1) Execution of rehabilitation programs through VR games (2) Using Microsoft Kinect and Leap Motion	User	MindMaze SA	Switzerland	Telerehabilitation	https://mindmaze.com/digital-therapies-for-neurorehabilitation/mindmotion-telerehab/ https://www.physiofunction.co.uk/rehabilitation-technology/upper-limb-rehabilitation/mind-motion-go-for-home-use
MindMotion Pro	(1) Designed for acute neurorehabilitation and ideally suited for delivering table-top therapy to patients recovering from upper-limb hemiparesis (2) Gamification of the exercises (levels of difficulty, rewards, real-time feedback) to maintain patient motivation and to increase the amount of practice (3) FDA-cleared system	Acute stroke patients at hospital	Upper limbs (or)	VR (Monitor)	Project a CG depiction of the nonfunctional one hand, which is controlled by the patient’s movement of the working another hand	User	MindMaze SA	Switzerland	None	https://www.mindmaze.com/digital-therapies-for-neurorehabilitation/
mediVR KAGURA	Seated reaching motion improving postural balance and dual-task cognitive processing function	Stroke patients	Upper limbs, torso (core)	VR (HMD)	Execution of rehabilitation programs through VR games: horizontal/vertical/Mito-Komon/vegetables/fruits	User	mediVR inc.	Japan	None	https://www.medivr.jp/
RehaVR	Gives the feeling of walking in a grassland or a place with beautiful scenery to increase motivation	Elderly people who wish to improve their motor skills	Lower limbs	VR (HMD, Foot Pedal Exerciser)	Providing virtual environments with beatiful scenary such as sightseeing spots	User	silvereye Inc.	Japan	None	https://rehavr.com
KiNvis system	Using KiNvis (KiNesthetic illusion induced by visual stimulation) described as the feeling of one’s body moving during sensory input, even though the body is actually in a resting state; cognitive stimulation to the embodied brain system for body ownership, a sense of agency, and kinesthetic perception	Patients with chronic stroke	Upper limbs	VR/AR (Monitor/ HMD)	(1) Providing visual stimulation which is recorded hand moviment in the movement task involving hand opening and closing (2) Applying electrical stimulation while watching the movie during the finger-extension phase.	User	Inter Reha Co.,Ltd.	Japan	None	https://doi.org/10.3389/fnsys.2019.00076 https://www.irc-web.co.jp/kinvis https://keio-rehab.jp/efforts/kinvis/
Prototype/Research										
Phantom motor execution facilitated by ML and AR	Novel plasticity-based, non-invasive treatment for phantom limb pain, in which phantom motor execution is decoded via machine learning, while visualisation of the phantom is accomplished via augmented and virtual reality.	Patients with phantom limb pain	Upper limbs	AR/VR (Monitor)	Preserving the virtual arm in the anatomically correct placement	User	Chalmers University of Technology	Sweden	None	https://doi.org/10.1016/S0140-6736(16)31598-7 https://www.youtube.com/watch?v=ek7JHGC-T4E
Walk Again Project (WAP)	(1) BMI with VR makes the patient’s brain reacquire the notion of walking. (2) By walking in a custom-designed exoskeleton with BMI, patients are eventually able to rekindle their remaining nerves to send signals back to brain, and reactivate some voluntary movement and sensitivity.	Paraplegics	Lower limbs	VR (HMD)	Presenting visually the virtual lower limbs through the HMD and the sense of touching the ground through haptic display attached on forearms	User	Duke University	USA	None	https://qz.com/757516/paraplegics-are-learning-to-walk-again-with-virtual-reality/ https://www.youtube.com/watch?v=pb36O-Yotac
Name	Features	Users	Target symptoms	Type of XR	How to use XR	People involved in XR	Organization	Country	Notes	URL
Mental health/Phobia										
Product/Service										
Immersive simulation system for overcoming fear of heights	Standing on top of a vitrual skyscraper to alleviate fear	People with a fear of heights (acrophobia)	Acrophobia	VR (HMD)	Providing virtual environments on top of a skyscraper	User	CRESCENT,INC	Japan	None	https://www.youtube.com/watch?v=AR-VAImfFXI
Prototype/Research										
RECOVER: Virtual Reality in Rehab	Providing valid contexts for people to practise their communication skills, build confidence interacting with others and generalise their communication skills to various environments	People with communication disorders	Communication disorder	VR (HMD)	Simulating social communication situations that are difficult to create within the clinic in realistic, personally relevant and safe environments (Cooking etc.)	User and other people interacting with the user	The University of Queensland	Australia	Speech pathologists	https://www.uq.edu.au/news/article/2021/03/virtual-reality-help-patients-speak https://www.tandfonline.com/doi/abs/10.1080/09638288.2021.1895333?journalCode=idre20
Bravemind	Supporting exposure therapy, in which a patient with PTS(Post-Traumatic Stress) – guided by a trained therapist – confronts their trauma memories through a retelling of the experience	Veterans with urgently needed options for PTS treatment	PTS and depression	VR (HMD)	Providing 14 different worlds from a crowded Iraqi marketplace to a remote Afghan village, a checkpoint in the desert to a forward operating base in the mountains	User	The University of Southern California Institute for Creative Technologies	USA	None	https://www.soldierstrong.org/bravemind/ https://www.youtube.com/watch?v=dVmxmDFCMIQ

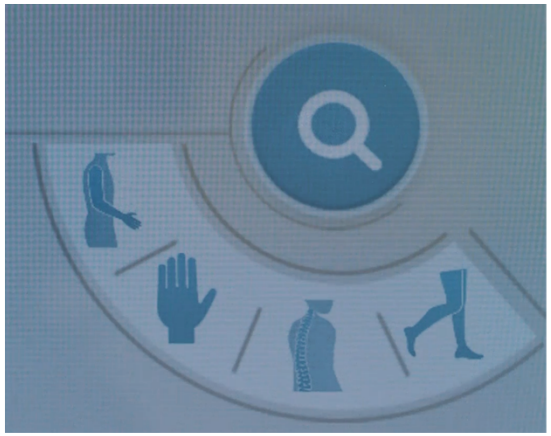
XRHealth			XRHealth USA INC	
Features	Users	Target body part	Which XR	How to use XR
(1) Assigned physical therapists proposing VR rehab programs for each disease (2) Improving physical functions through VR games (3) FDA-registered medical VR applications	Broad	Broad (physical, neurological or behavioral symptoms)	VR (HMD)	Execution of rehabilitation programs through VR games



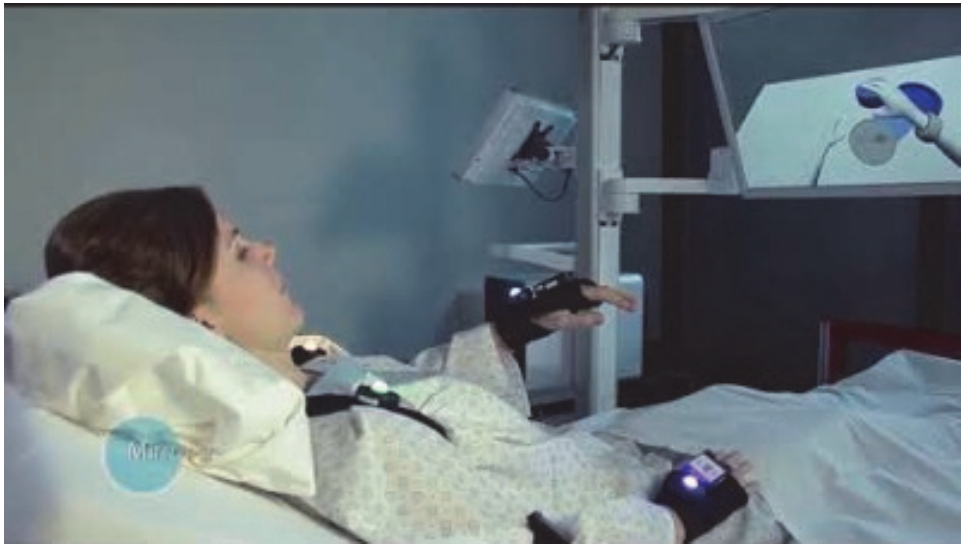
SaeboVR			Saebo, Inc	
Features	Users	Target body part	Which XR	How to use XR
(1) Designed to engage the client involving daily functional activities through a virtual ADL (activities of daily living) rehabilitation system to help the brain “re-program” itself and form new neural connections (2) Virtual assistant appearing on the screen to educate and facilitate performance by providing real-time feedback (3) FDA-cleared software system	Patients with cognitive or upper limb impairments	Upper limbs	VR (Monitor)	(1) Providing ADL-focused virtual world in which the users incorporates their impaired upper limb to perform simulated self-care tasks that involve picking up, transferring and manipulating virtual objects (2) Using Microsoft Kinect

MindMotion GO			MindMaze SA	
Features	Users	Target body part	Which XR	How to use XR
(1) Gamified neurorehabilitation therapy platform for medium and light severity impairments able to be deployed in the patient's home (2) Including rehabilitation exercises for the upper extremity, trunk, and lower extremity; audio-visual feedback and graphic movement representations for patients (3) FDA-cleared system	Stroke survivors at home	Broad(Upper limbs, torso, lower limbs)	VR (Monitor)	(1) Execution of rehabilitation programs through VR games (2) Using Microsoft Kinect and Leap Motion





MindMotion Pro			MindMaze SA	
Features	Users	Target body part	Which XR	How to use XR
(1) Designed for acute neurorehabilitation and ideally suited for delivering table-top therapy to patients recovering from upper-limb hemiparesis (2) Gamification of the exercises (levels of difficulty, rewards, real-time feedback) to maintain patient motivation and to increase the amount of practice (3) FDA-cleared system	Acute stroke patients at hospital	Upper limbs (or)	VR (Monitor)	Project a CG depiction of the nonfunctional one hand, which is controlled by the patient's movement of the working another hand



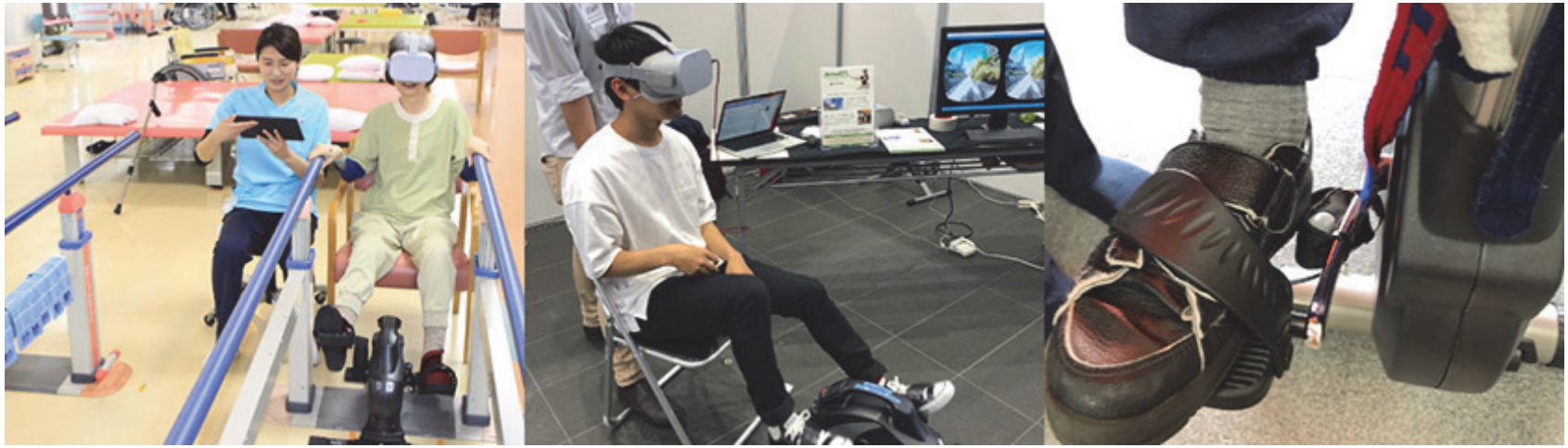
mediVR KAGURA			mediVR inc.	
Features	Users	Target body part	Which XR	How to use XR
Seated reaching motion improving postural balance and dual-task cognitive processing function	Stroke patients	Upper limbs, torso (core)	VR (HMD)	Execution of rehabilitation programs through VR games: horizontal/vertical/Mito-Komon/vegetables/fruits

3. 製品概要

Neuroscience／Behavioral scienceの知見を応用し
リーチング動作を介して脳の運動学習を進め
姿勢制御系の脳の機能統合及び認知機能を改善させるプログラムを
「ゲームにしか見えない」形で開発

座位トレーニングで失調、歩行、上肢機能、認知機能、疼痛が改善

RehaVR			silvereye Inc.	
Features	Users	Target body part	Which XR	How to use XR
Gives the feeling of walking in a grassland or a place with beautiful scenery to increase motivation	Elderly people who wish to improve their motor skills	Lower limbs	VR (HMD, Foot Pedal Exerciser)	Providing virtual environments with beatiful scenary such as sightseeing spots



KiNvis system			Inter Reha Co.,Ltd.	
Features	Users	Target body part	Which XR	How to use XR
Using KiNvis（KiNesthetic illusion induced by visual stimulation) described as the feeling of one's body moving during sensory input, even though the body is actually in a resting state; cognitive stimulation to the embodied brain system for body ownership, a sense of agency, and kinesthetic perception	Patients with chronic stroke	Upper limbs	VR/AR (Monitor/ HMD)	(1) Providing visual stimulation which is recorded hand moviment in the movement task involving hand opening and closing (2) Applying electrical stimulation while watching the movie during the finger-extension phase.

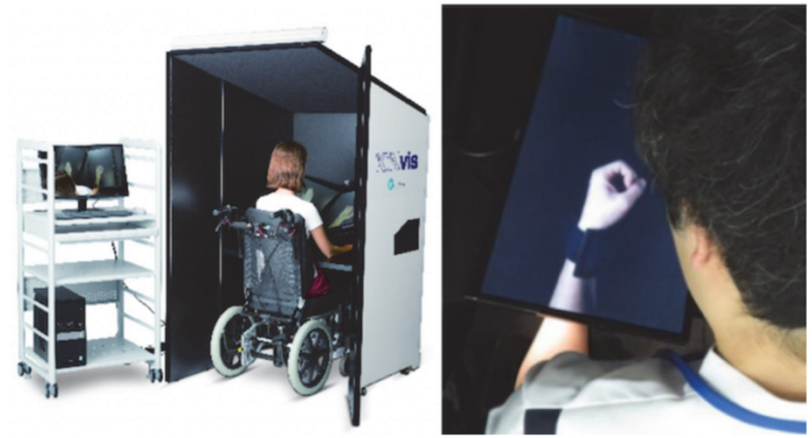


図1

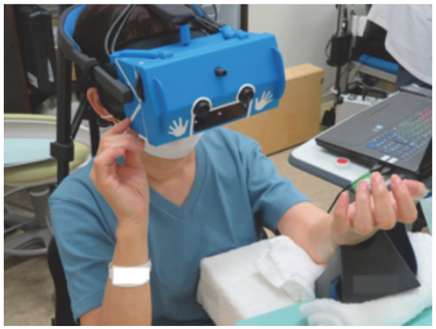
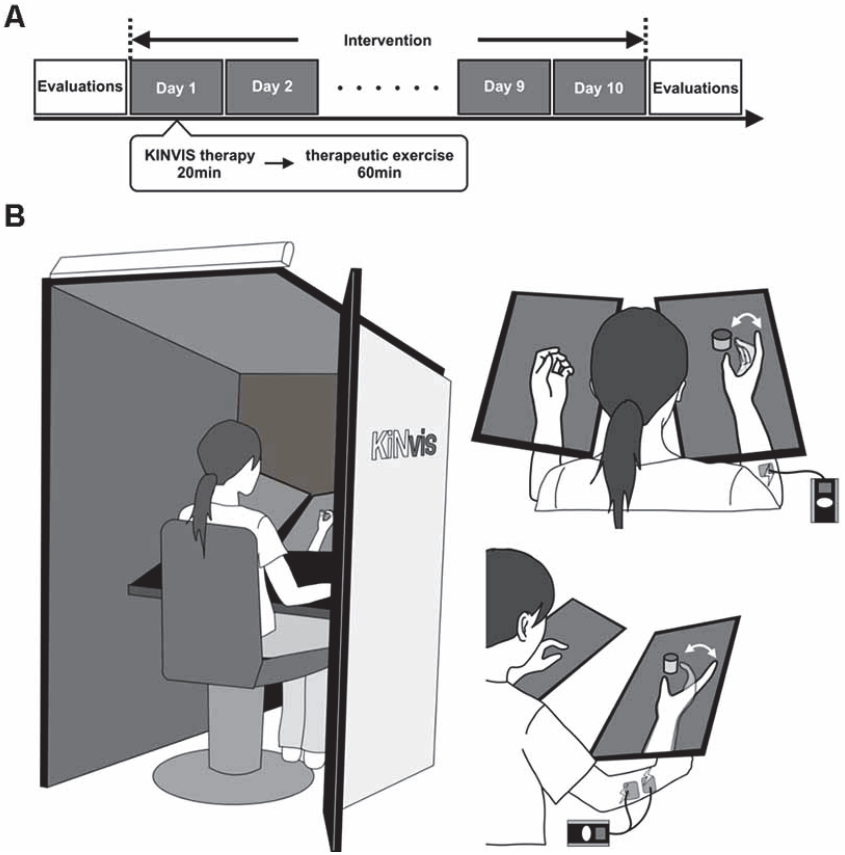
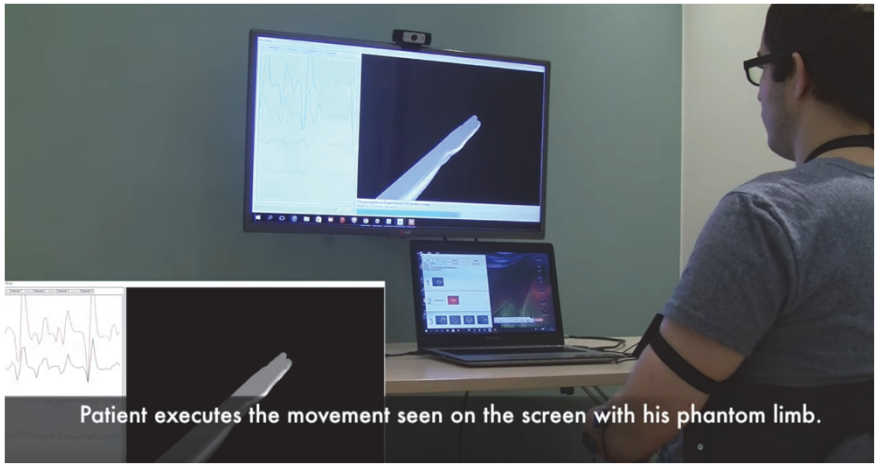


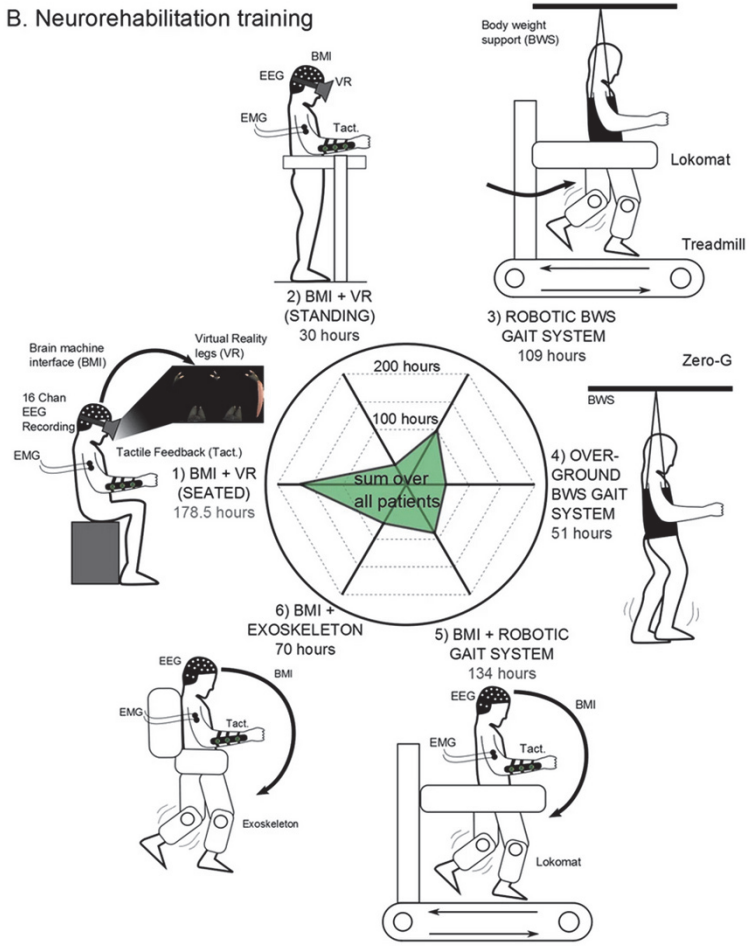
図2



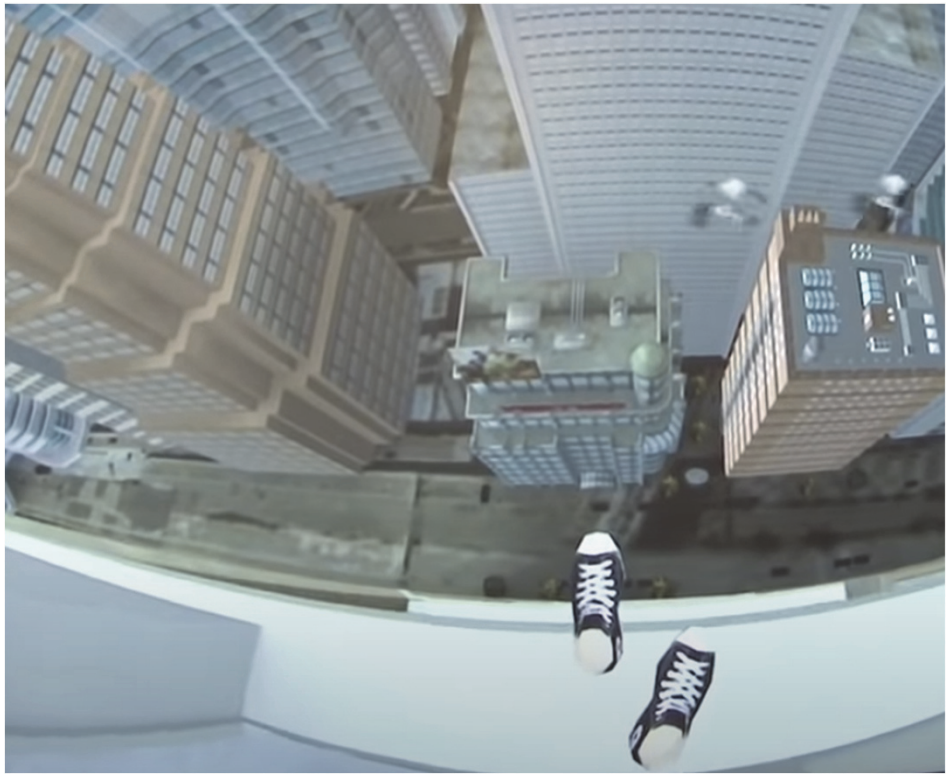
Phantom motor execution facilitated by ML and AR			Chalmers University of Technology	
Features	Users	Target body part	Which XR	How to use XR
Novel plasticity-based, non-invasive treatment for phantom limb pain, in which phantom motor execution is decoded via machine learning, while visualisation of the phantom is accomplished via augmented and virtual reality.	Patients with phantom limb pain	Upper limbs	AR/VR (Monitor)	Preserving the virtual arm in the anatomically correct placement



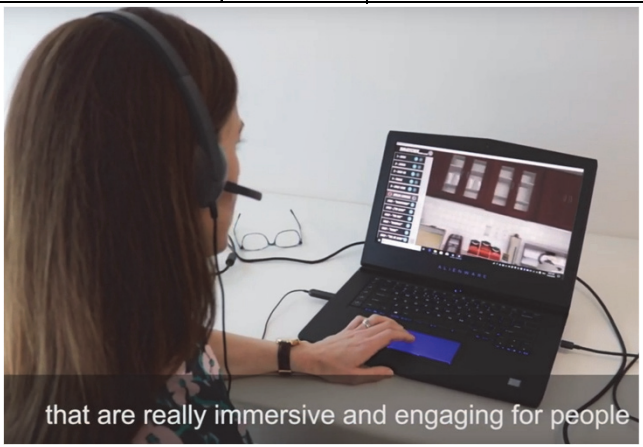
Walk Again Project (WAP)			Duke University	
Features	Users	Target body part	Which XR	How to use XR
(1) BMI with VR makes the patient's brain reacquire the notion of walking. (2) By walking in a custom-designed exoskeleton with BMI, patients are eventually able to rekindle their remaining nerves to send signals back to brain, and reactivate some voluntary movement and sensitivity.	Paraplegics	Lower limbs	VR (HMD)	Presenting visually the virtual lower limbs through the HMD and the sense of touching the ground through haptic display attached on forearms



Immersive simulation system for overcoming fear of heights			CRESCENT,INC	
Features	Users	Target symptoms	Which XR	How to use XR
Standing on top of a vitrual skyscraper to alleviate fear	People with a fear of heights (acrophobia)	Acrophobia	VR (HMD)	Providing virtual environments on top of a skyscraper



RECOVER: Virtual Reality in Rehab			The University of Queensland	
Features	Users	Target symptoms	Which XR	How to use XR
Providing valid contexts for people to practise their communication skills, build confidence interacting with others and generalise their communication skills to various environments	People with communication disorders	Communication disorder	VR (HMD)	Simulating social communication situations that are difficult to create within the clinic in realistic, personally relevant and safe environments (Cooking etc.)

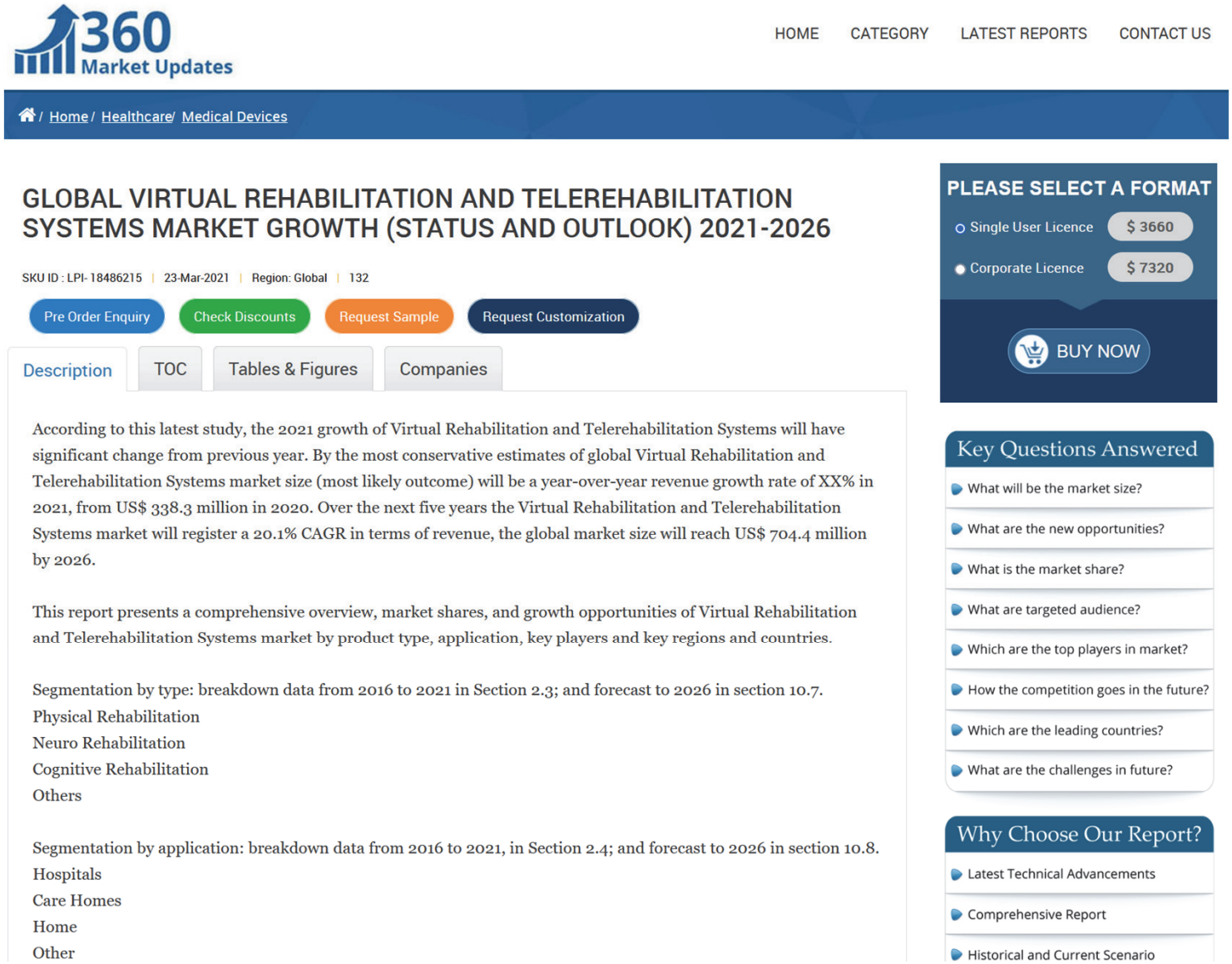


Bravemind			The University of Southern California Institute for Creative Technologies	
Features	Users	Target symptoms	Which XR	How to use XR
Supporting exposure therapy, in which a patient with PTS(Post-Traumatic Stress) – guided by a trained therapist – confronts their trauma memories through a retelling of the experience	Veterans with urgently needed options for PTS treatment	PTS and depression	VR (HMD)	Providing 14 different worlds from a crowded Iraqi marketplace to a remote Afghan village, a checkpoint in the desert to a forward operating base in the mountains

Outline

- Examples of XR product/service for rehabilitation
- Market report and Review
- Introduction of our new NEDO project
  - Multimodal XR-AI platform development for telerehab and reciprocal care coupling with health guidance

Market Report



https://www.360marketupdates.com/global-virtual-rehabilitation-and-telerehabilitation-systems-market-18486215#

Review

Journal of Clinical Medicine

MDPI

Review

Clinical Application of Virtual Reality for Upper Limb Motor Rehabilitation in Stroke: Review of Technologies and Clinical Evidence

Won-Seok Kim [1,*,†], Sungmin Cho [2,†], Jeonghun Ku [3,*], Yuhee Kim [4], Kiwon Lee [4], Han-Jeong Hwang [5] and Nam-Jong Paik [1]

1 Department of Rehabilitation Medicine, Seoul National University College of Medicine, Seoul National University Bundang Hospital, Seongnam-si, Gyeonggi-do 13620, Korea; njpaik@snu.ac.kr
2 Delvine Inc., Seoul 08788, Korea; cho@delvine.co.kr
3 Department of Biomedical Engineering, College of Medicine, Keimyung University, Daegu 42601, Korea
4 Ybrain Research Institute, Seongnam-si, Gyeonggi-do 13449, Korea; yuhee.kim@ybrain.com (Y.K.); kiwon.lee@ybrain.com (K.L.)
5 Department of Electronics and Information, Korea University, Sejong 30019, Korea; hwanghj@korea.ac.kr
* Correspondence: wondol77@gmail.com (W.-S.K.); kujh@kmu.ac.kr (J.K.); Tel.: +82-31-787-7735 (W.-S.K.); +82-53-258-7535 (J.K.)
† These authors contributed equally to this work.

Received: 22 September 2020; Accepted: 19 October 2020; Published: 21 October 2020

Abstract: Neurorehabilitation for stroke is important for upper limb motor recovery. Conventional rehabilitation such as occupational therapy has been used, but novel technologies are expected to open new opportunities for better recovery. Virtual reality (VR) is a technology with a set of informatics that provides interactive environments to patients. VR can enhance neuroplasticity and recovery after a stroke by providing more intensive, repetitive, and engaging training due to several advantages, including: (1) tasks with various difficulty levels for rehabilitation, (2) augmented real-time feedback, (3) more immersive and engaging experiences, (4) more standardized rehabilitation, and (5) safe simulation of real-world activities of daily living. In this comprehensive narrative review of the application of VR in motor rehabilitation after stroke, mainly for the upper limbs, we cover: (1) the technologies used in VR rehabilitation, including sensors; (2) the clinical application of and evidence for VR in stroke rehabilitation; and (3) considerations for VR application in stroke rehabilitation. Meta-analyses for upper limb VR rehabilitation after stroke were identified by an online search of Ovid-MEDLINE, Ovid-EMBASE, the Cochrane Library, and KoreaMed. We expect that this review will provide insights into successful clinical applications or trials of VR for motor rehabilitation after stroke.

Keywords: virtual reality; stroke; rehabilitation; hemiplegia; recovery of function; neuronal plasticity; sensor

https://www.mdpi.com/2077-0383/9/10/3369

Review

Table 2. Commercialized VR systems custom-built for upper limb rehabilitation.

VR System	VR Type	Sensor Type	Body Part	Company	Country
Riablo Premium	NI	IMU sensor	Arm	CoRehab	Italy
SaeboVR	NI	Motion-sensing camera (depth sensing, body tracking)	Arm	Saebo	USA
Doctor Kinetic	NI	Motion-sensing camera (depth sensing, body tracking)	Arm	Doctor Kinetic	Netherlands
IREX	NI	Motion sensing with webcam	Arm	GestureTek Health	Canada
Virtual Rehab	NI	Motion-sensing camera (depth sensing, body tracking, and hand tracking)	Arm, hand	Evolv	Spain
XR Health	I	HMD, controller	Arm	XR Health	USA
iWall	NI	Motion-sensing camera (depth sensing, body tracking), touch screen	Arm, hand	CSE Entertainment	Finland
Nirvana	NI	wall or floor touch sensing	Arm, hand	BTS Bioengineering	USA
Myro	NI	Touch screen, touchable objects on screen	Arm, hand	Tyromotion	USA
DIEGO	NI	Hand suspended type	Arm	Tyromotion	USA
AMADEO	NI	Position and force sensor in hand rehab robot	Finger	Tyromotion	USA
Pablo	NI	IMU sensor	Arm, hand	Tyromotion	USA
EsoGLOVE	NI	Hand exoskeleton	Arm, hand, finger	Roceso Technologies	Singapore
Bimeo PRO	NI	IMU sensor for body, IMU sensor in objects	Arm, hand	Kinestica	Slovenia

Table 2. *Cont.*

VR System	VR Type	Sensor Type	Body Part	Company	Country
HandTutor	NI	Data glove	Hand, finger	Meditouch	Israel
Playball	NI	IMU sensor in ball	Hand	Tonkey	Italy
Anika	NI	Data glove	Hand, finger	ZARYA	Russia
Gloreha Workstation plus	NI	Hand exoskeleton, Optical sensor	Hand, finger	Gloreha	Italy
Icone	NI	Machine holding and moving handle	Arm	Heaxel	Italy
ExoRehab X	NI	Arm exoskeleton	Arm	HoustonBionic	Turkey
Hand of Hope	NI	Hand exoskeleton	Hand, finger	Rehab-Robotics Company	Hong Kong
SaeboRejoyce	NI	3D movable handle	Arm, hand	Saebo	USA
MindMotion Pro	NI	Colored object 3D tracking	Arm, hand	MindMaze	Switzerland
YouGrabber	NI	Data glove, infrared tracking camera	Arm, hand, finger	YouRehab	Switzerland
Rapel Smart Glove	NI	Data glove, IMU sensor	Arm, hand, finger	Neofect	South Korea
Smartboard	NI	2D handling board	Arm	Neofect	South Korea
MusicGlove	NI	Finger-to-finger contact	Finger	FlintRehab	USA
FitMi	NI	Puck with multiple sensors for movement tracking	Arm, hand	FlintRehab	USA
SensoRehab	NI	Data glove	Hand, finger	SensoMed	Russia
Rewellio	I	HMD, controller	Arm	Rewellio Inc.	USA

Abbreviations: I, immersive; NI, non-immersive; IMU, inertial measurement unit; HMD, head-mounted display; VR, virtual reality.

https://www.mdpi.com/2077-0383/9/10/3369

Outline

- Examples of XR product/service for rehabilitation
- Market report and Review
- Introduction of our new NEDO project
  - Multimodal XR-AI platform development for telerehab and reciprocal care coupling with health guidance

Multimodal XR-AI platform development for telerehab and reciprocal care coupling with health guidance (2021.7-2025.2)

XR-AI: XR powered by AI (**éksrèɪ**)

遠隔リハビリのための多感覚XR-AI技術基盤構築と保健指導との互恵ケア連携

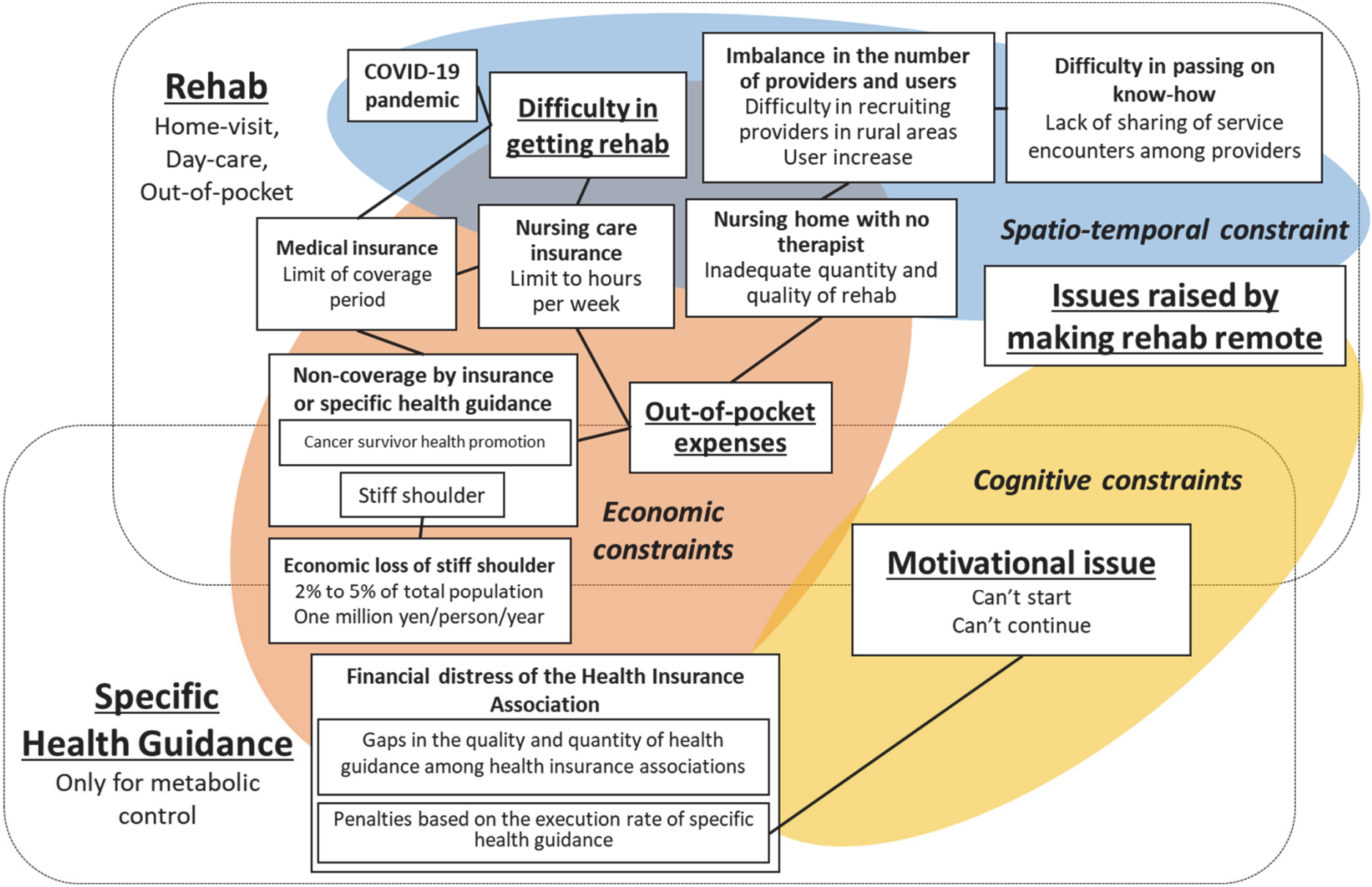
Contractors: AIST, Kyoto University, The university of Tokyo,
Seiko Epson Corp., EveRehab, Inc.

Web: https://unit.aist.go.jp/harc/nedo-xrai-healthcare/

This presentation is based on a project, JPNP21501015-0, commissioned by the New Energy an Technology Development Organization (NEDO) in Japan.

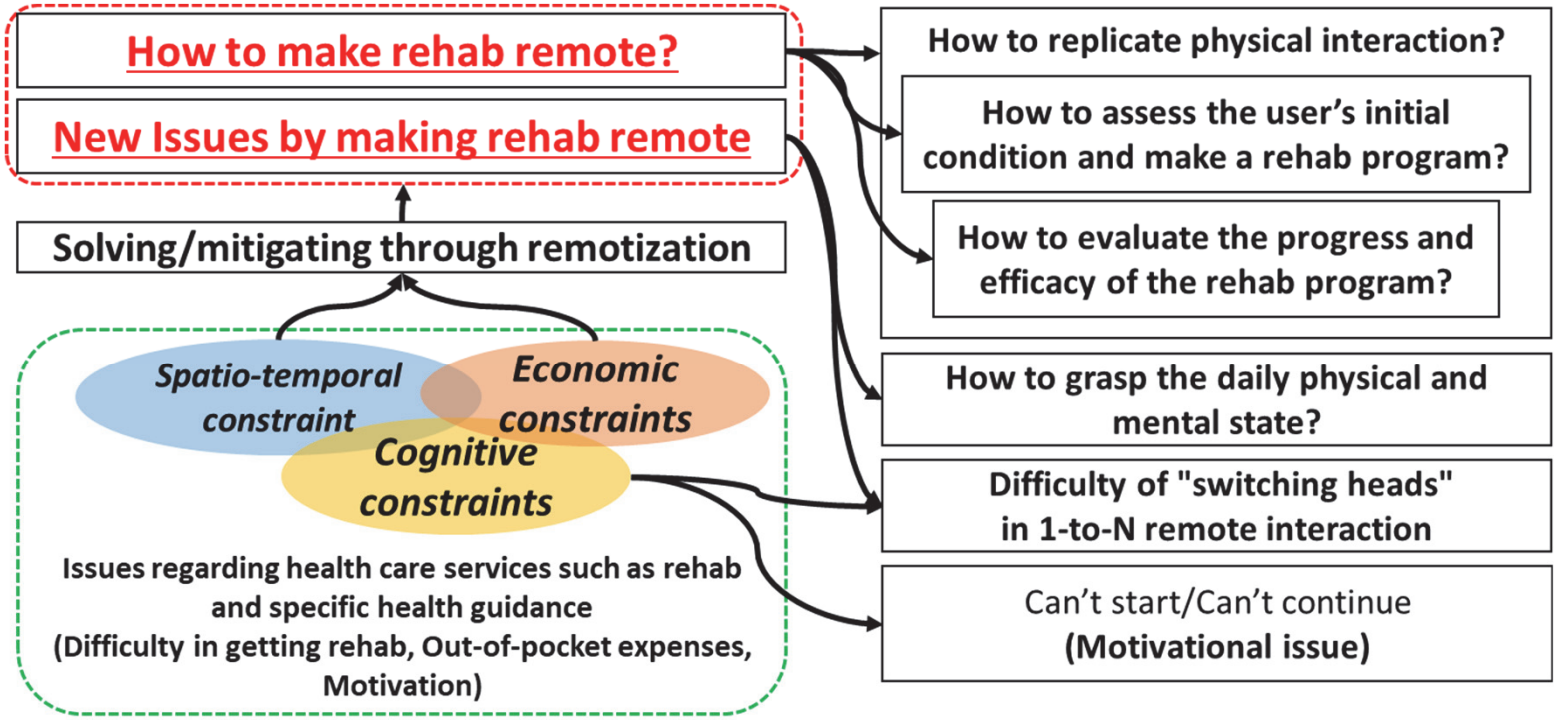
NEDO: National research and development agency that creates innovation by promoting technological development necessary for realization of a sustainable society

Background


Rehab
Home-visit,
Day-care,
Out-of-pocket
COVID-19 pandemic
Difficulty in getting rehab
Imbalance in the number of providers and users
Difficulty in recruiting providers in rural areas
User increase
Difficulty in passing on know-how
Lack of sharing of service encounters among providers
Spatio-temporal constraint
Medical insurance
Limit of coverage period
Nursing care insurance
Limit to hours per week
Nursing home with no therapist
Inadequate quantity and quality of rehab
Issues raised by making rehab remote
Non-coverage by insurance or specific health guidance
Cancer survivor health promotion
Stiff shoulder
Out-of-pocket expenses
Economic constraints
Cognitive constraints
Economic loss of stiff shoulder
2% to 5% of total population
One million yen/person/year
Motivational issue
Can't start
Can't continue
Specific Health Guidance
Only for metabolic control
Financial distress of the Health Insurance Association
Gaps in the quality and quantity of health guidance among health insurance associations
Penalties based on the execution rate of specific health guidance

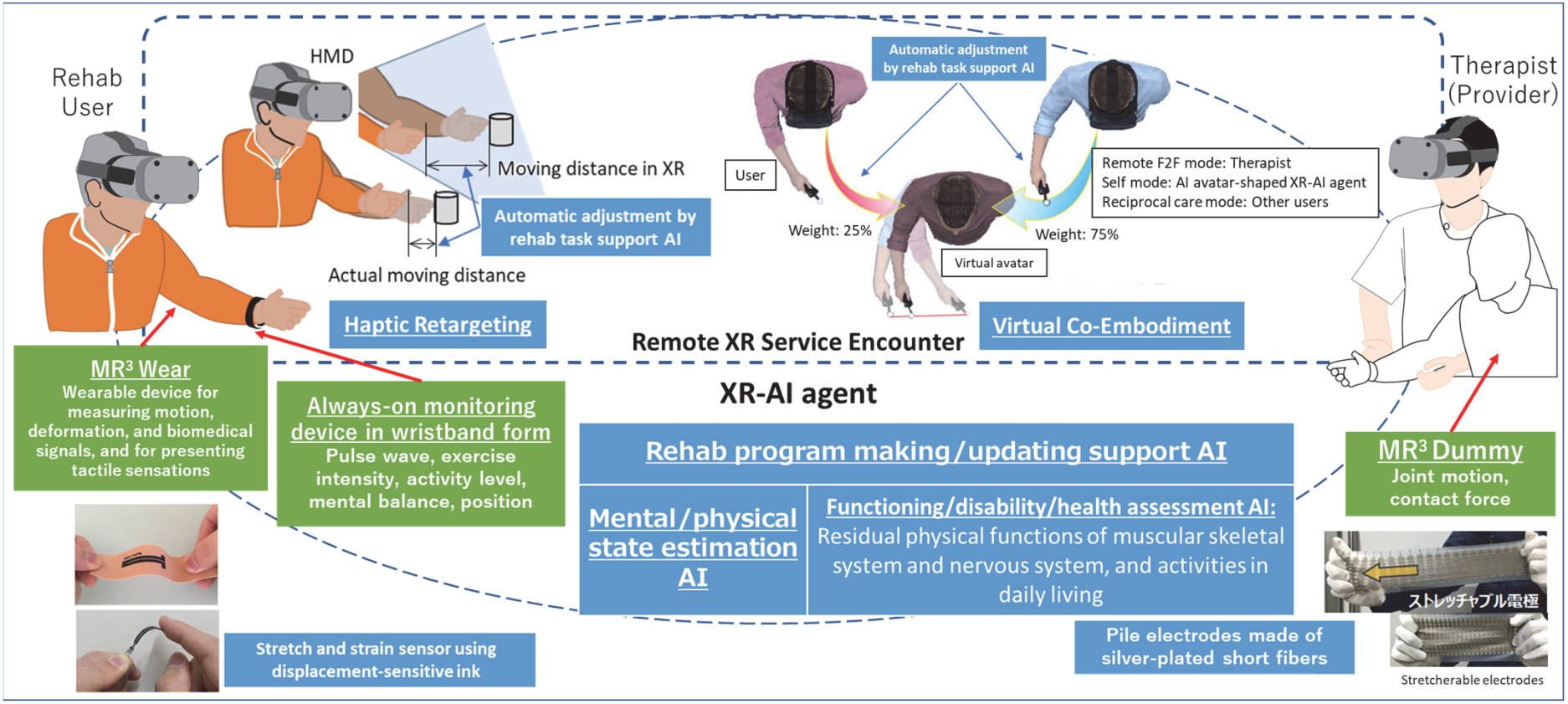
Multimodal XR-AI platform development for telerehab and reciprocal care coupling with health guidance

Purpose Solve and mitigate issues regarding health care service by alleviating spatio-temporal, economic, and cognitive constraints.



Keywords Digital health, 1-to-N interaction, Reciprocal care (0-to-N interaction) , Multimodal measurement and intervention

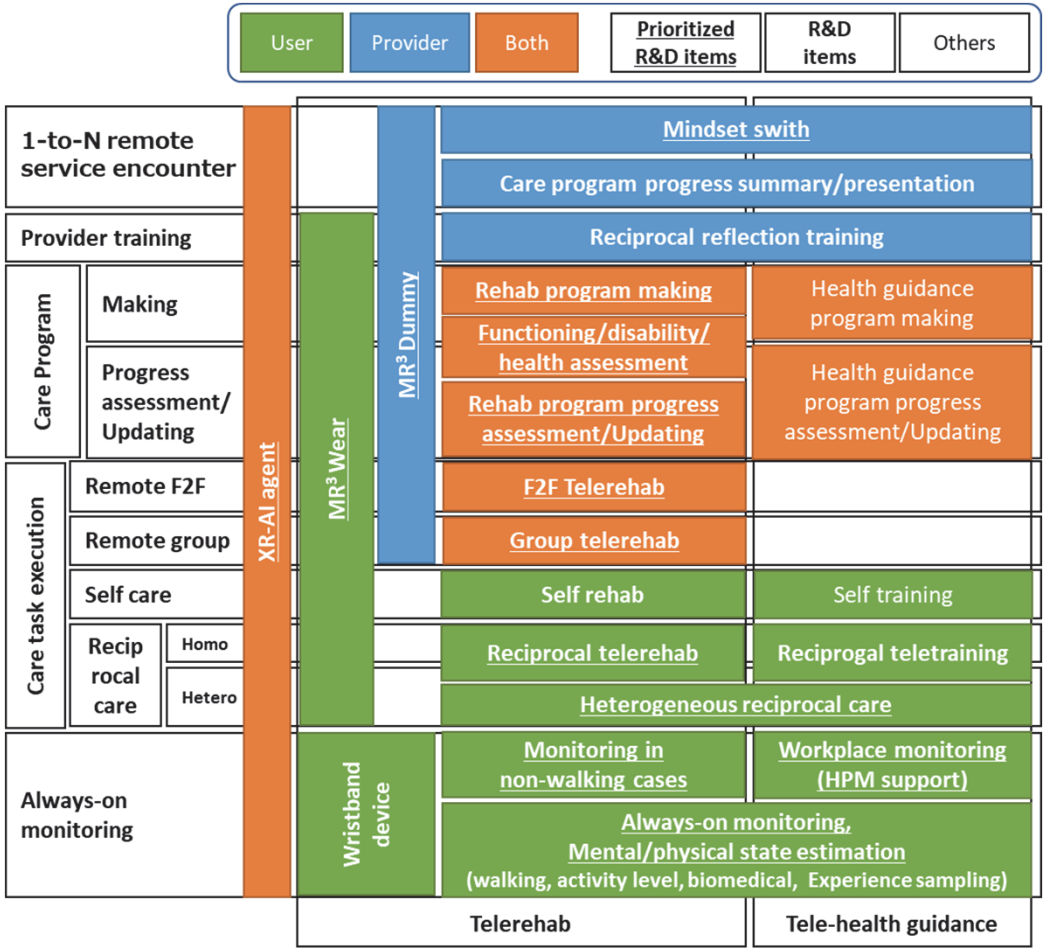
Approaches We develop an XR-AI system to estimate mental and physical states through daily measurements, to support the creation and updating of care programs based on detailed assessments of physical functions using MR³ devices, and to appropriately convert and present the obtained states and care task execution status to remote parties and oneself.



MR³: MultiModal Mixed Reality for Remote Rehab (**ém άə kjú:b**)

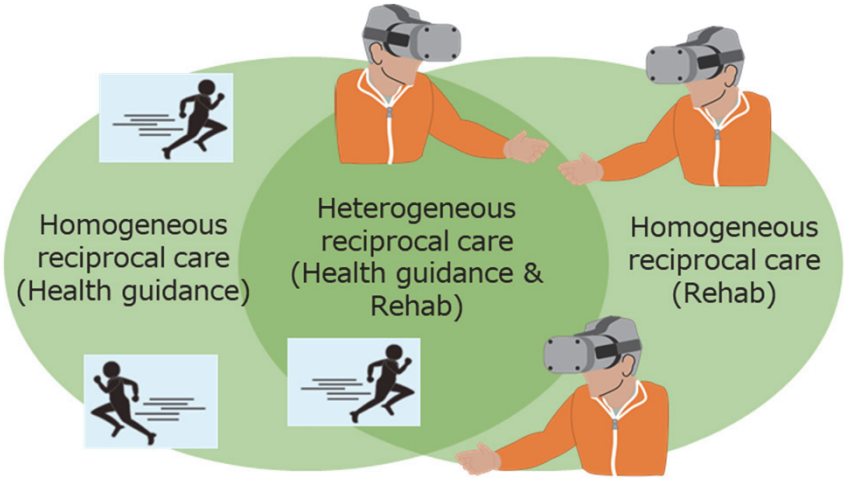
Expected outputs

- Multimodal XR-AI platform development for telerehab
- Designing 1-to-N and 0-to-N telehealth services

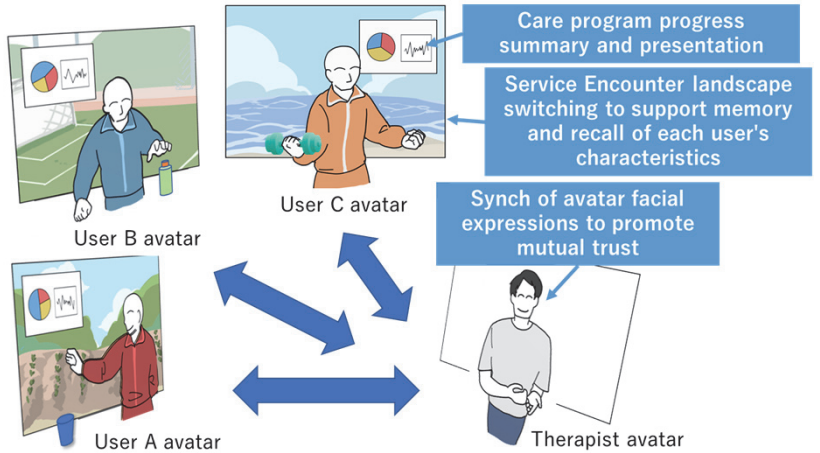


Multimodal XR-AI platform modules for telehealthcare services

HPM: Health and Productivity Management



0-to-N remote interaction (Reciprocal care for homo/hetero communities)



1-to-N remote interaction (Mindset switch)