School of Physical and Occupational Therapy

EXCELLENCE THROUGH GROWTH

McGill Faculty of Medicine

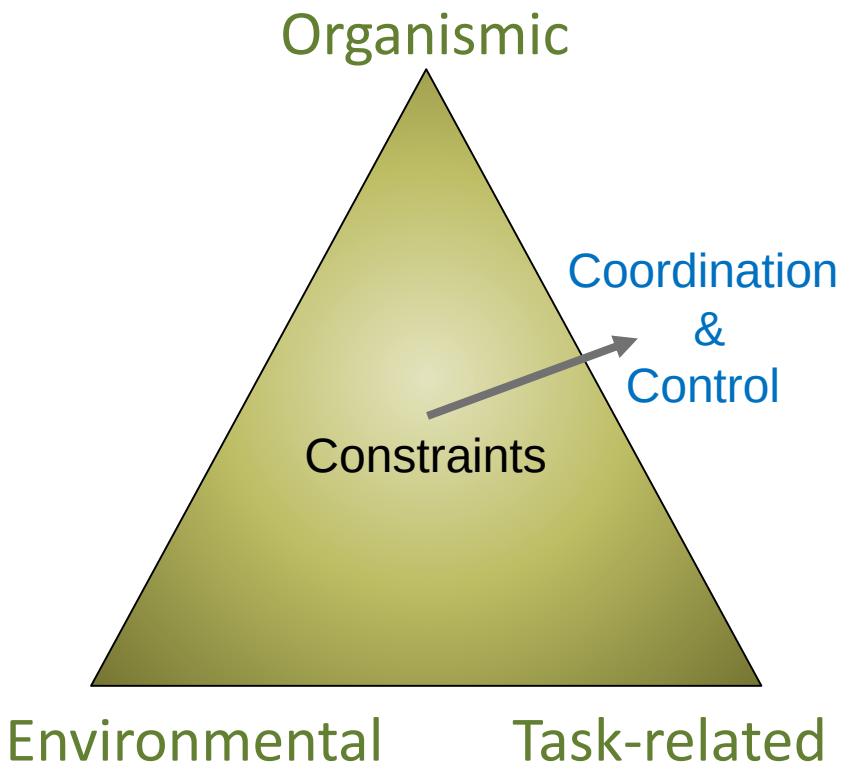
Enhancing motor learning using virtual rehabilitation: New ways to deliver old tricks

Mindy F. Levin, PhD, PT

Canada Research Chair in Motor Recovery and Rehabilitation

Dynamical Approach to Motor Learning

Emphasizes dynamics of change in the movement sequence and its outcome over practice



- Idea that skill learning is reflected in the mastery of redundant degrees of freedom (DFs) – Bernstein (1930's).
- Problem-solving system that uses available constraints and possibilities to discover solutions to a movement problem.
- Acquiring coordination is not hampered by the many interacting variables (i.e., joint DFs) but simplified by them.
- Allows exploitation of the natural properties of the system.
- Emergent rather than reductive approach
- Gives rise to adaptability based on task demands and constraints.

Thelen, 1995; Newell 1996; van Dijk et al. 2016

Ten principles of experience-dependent neural plasticity

Kleim JA and Jones TA. J Speech Lang Hear Res 51:5225, 2008.

1. Use it or Lose It
2. Use it and Improve It
3. Specificity
4. Repetition Matters
5. Intensity Matters
6. Time Matters
7. Salience Matters
8. Age Matters
9. Transference
10. Interference

Motivation

Fun!

McGill

Motivation

- crucial for motor learning

Dopaminergic projections from ventral tegmental area (signaling reward) to primary motor cortex mediate motor skill learning (Hosp et al. 2011)

Behavioral research supports motivational effects (including perceived competence) on motor learning (Krakauer 2006, Kleim 2008, Lewthwaite and Wulf 2012)

Reward improves long-term skill retention

(Abe et al. Curr Biol. 2011)

McGill

Virtual Reality for Rehabilitation

- A computer-based technology that provides the user with opportunities to interact with virtual objects and events that appear, sound, and in some cases feel, similar to those of the real world (Wilson et al. 1997).

Immersion

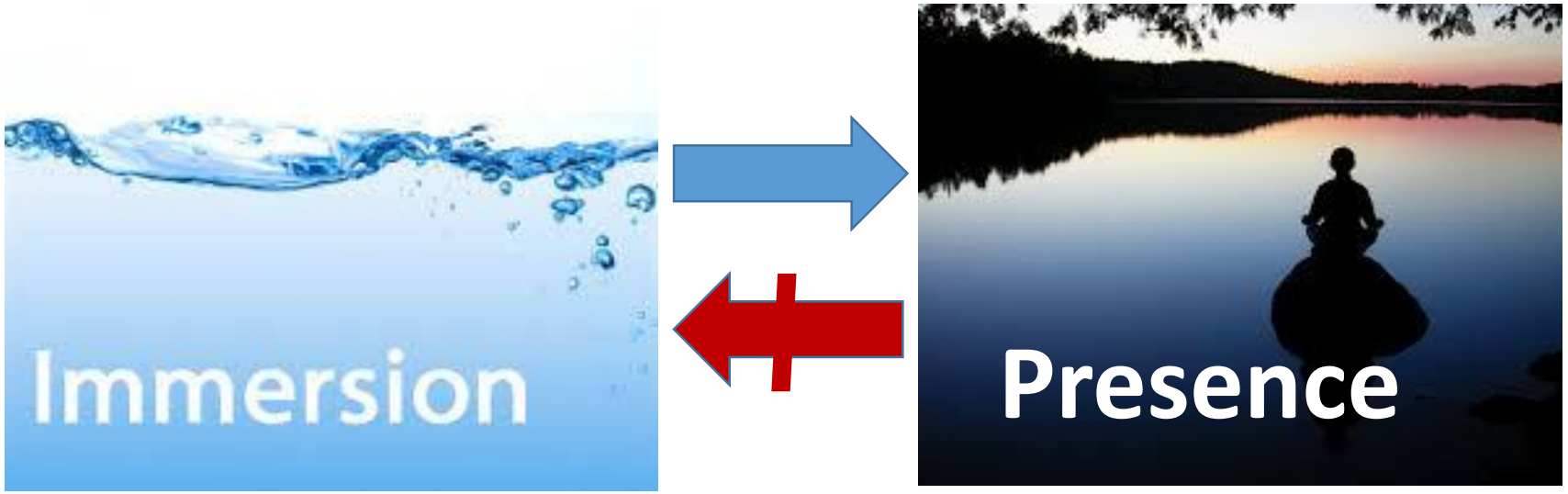
Extent to which technology can deliver an illusion of reality.

Perception of being physically present in a non-physical world. The perception is created by surrounding the user with images, sounds or other stimuli that provide an engrossing total environment.

Presence

State of consciousness of being in a virtual environment.

Subjective experience of being in one place or environment even when being physically situated in another.

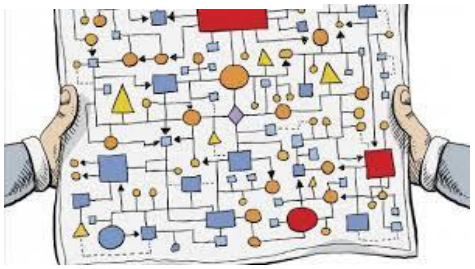


Slater & Wilber, 1997, Witmer & Singer, 1998

Immersion is multi-modal

Wendy Powell 2017

Full Immersion



Cybersickness

Luque-Moreno et al 2015

+

- Increased heart rate (Maron et al. 2016)
- Altered kinematics in reaching tasks (Powell et al. 2015)
- Reduced postural stability (Treleavan et al. 2015)

Solution

Incomplete immersion*

**potential for sensory conflict*

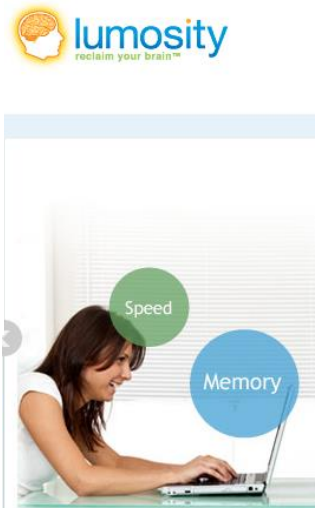
- Fewer side effects
- Better outcomes (Buttussi & Chittaro 2017; La Priore et al. 2003)

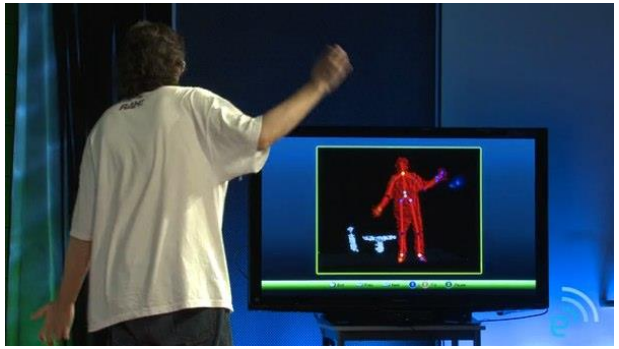
Attributes of virtual rehabilitation

Caveat

Virtual rehabilitation is not equivalent to video-game applications for cognition, brain fitness and physical fitness

- Brain Age (Nintendo DS) www.touchgenerations.com
- Lumosity (www.lumosity.org) – visual attention & working memory (Scanlon et al. 2007)
- MindFit – attention, working memory, sensorimotor control (Korczyn et al. 2007)
- Nintento Wii
- Sony Eye Toy
- Microsoft Kinect

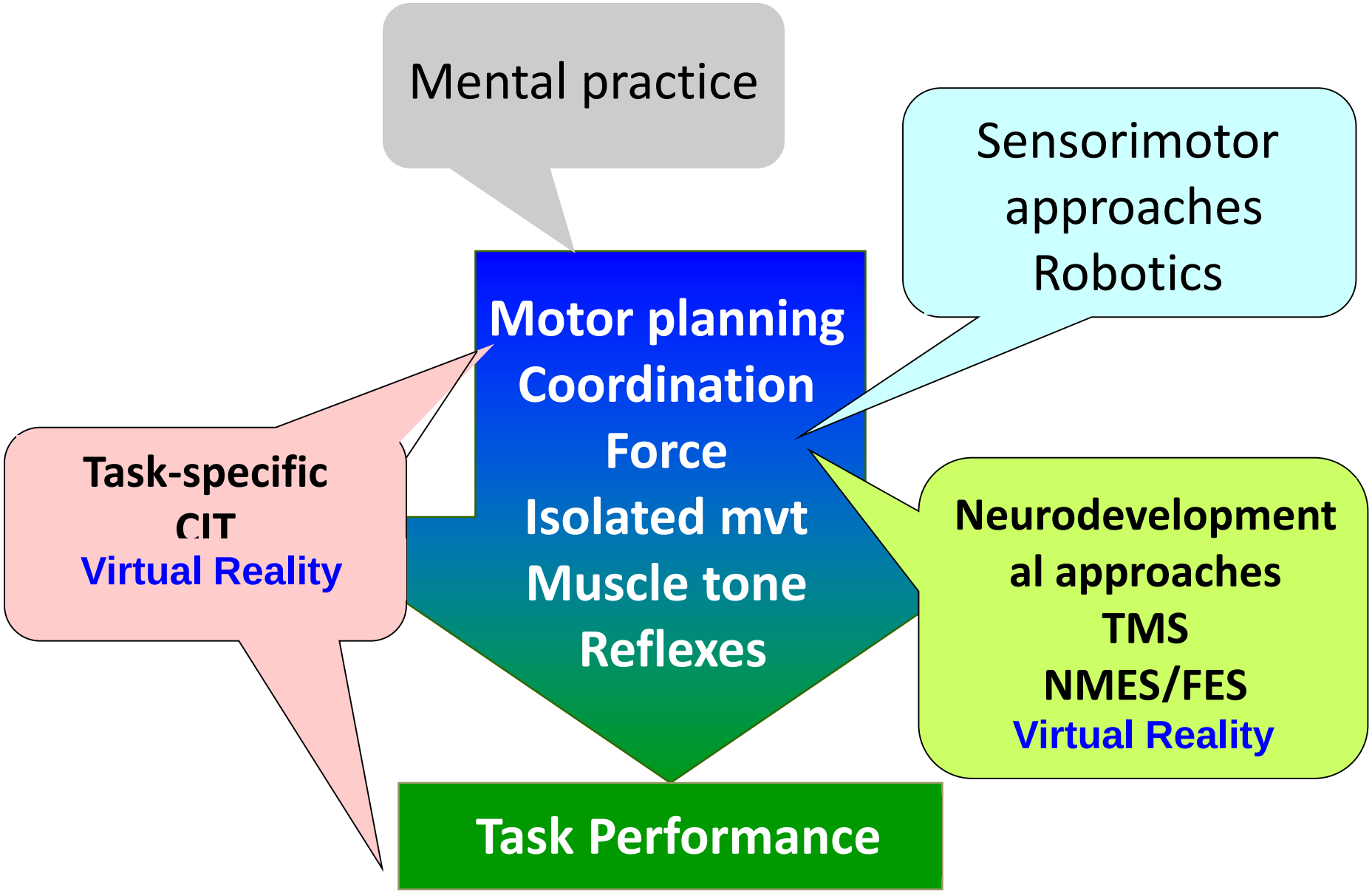




Virtual rehabilitation – more than just play

VR applications	Video games
Rich, controllable multi-modal stimulation	Rich, multi-modal stimulation
Intrinsic (task-related) feedback - salient	Intrinsic (movement-related) feedback - unfocused
Programmable extrinsic feedback	Fixed extrinsic feedback
Learning by problem-solving – cognitive and motor	Not focused on learning, but gains in skills are assumed
Motivation and arousal	Motivation and arousal
Individualized activities	**X**
Individualized progression of level of difficulty	Progression of difficulty according to skill level

Interventions for sensorimotor rehabilitation



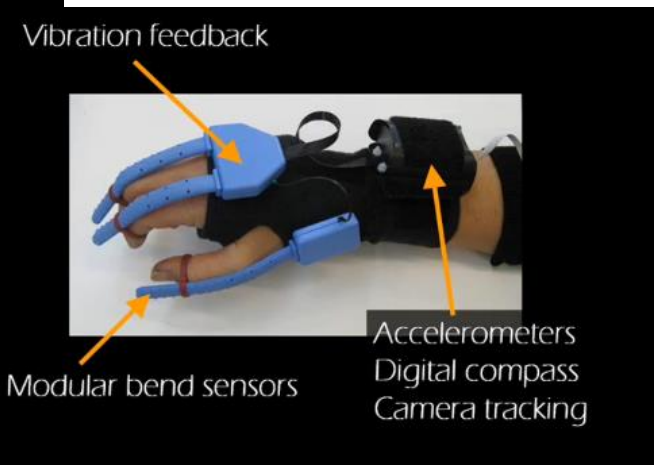
Types of virtual rehabilitation applications

- Teacher-animation
- Problem-solving scenarios
- Game-like
- Immersive, multi-modal, augmented reality

McGill

Teacher-animation

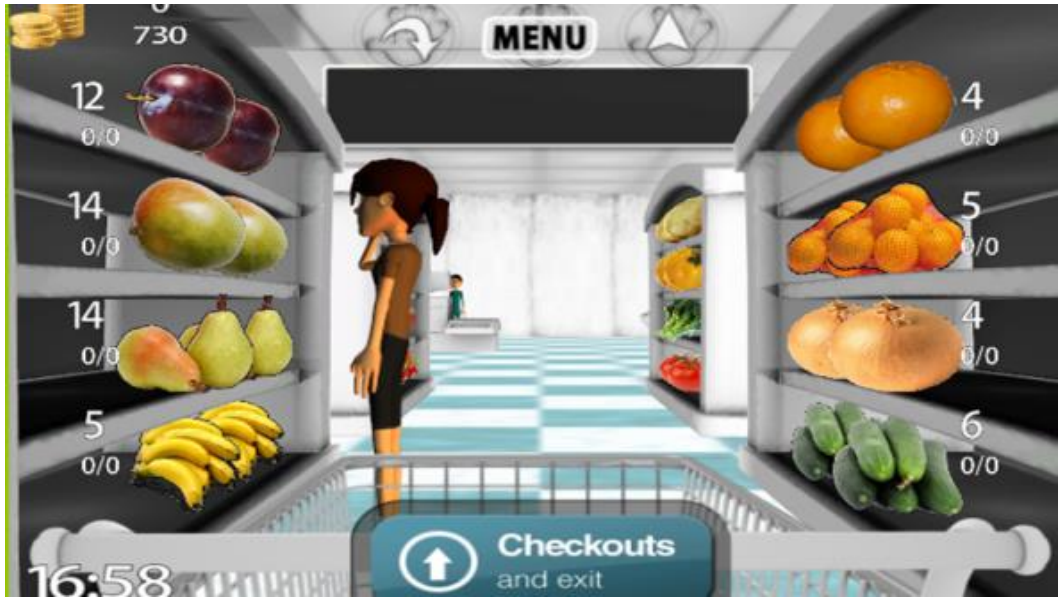
YouGrabber ETH Zürich



Exercise prescription

- Home program compliance

Problem-solving

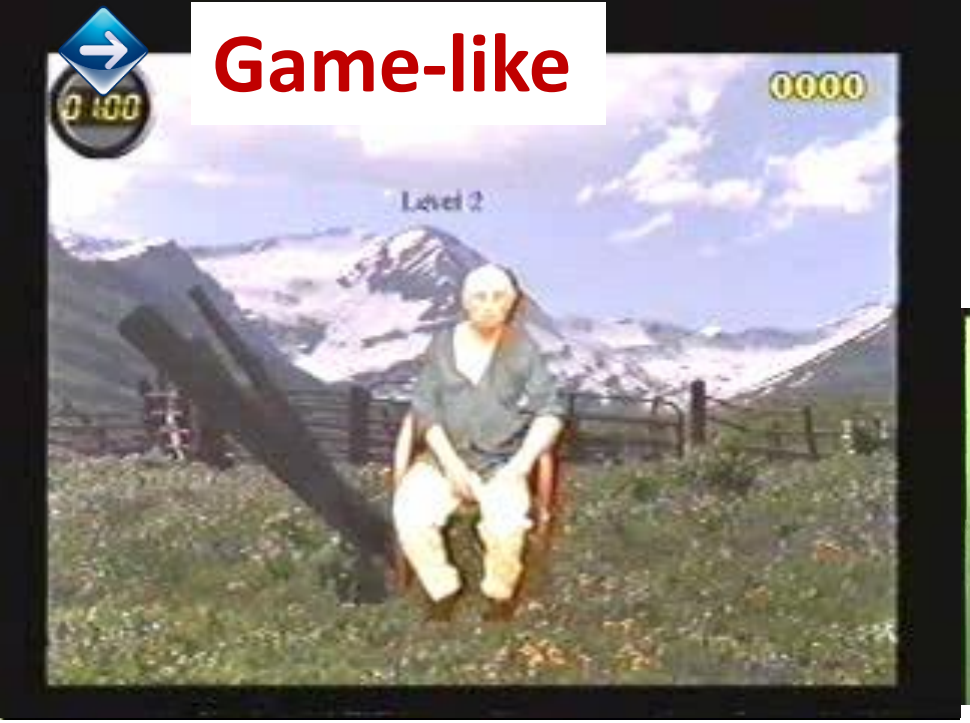


Scenarios that involve tasks that can be used to identify and provide metrics about users' cognitive and motor abilities

McGill

University of Haifa

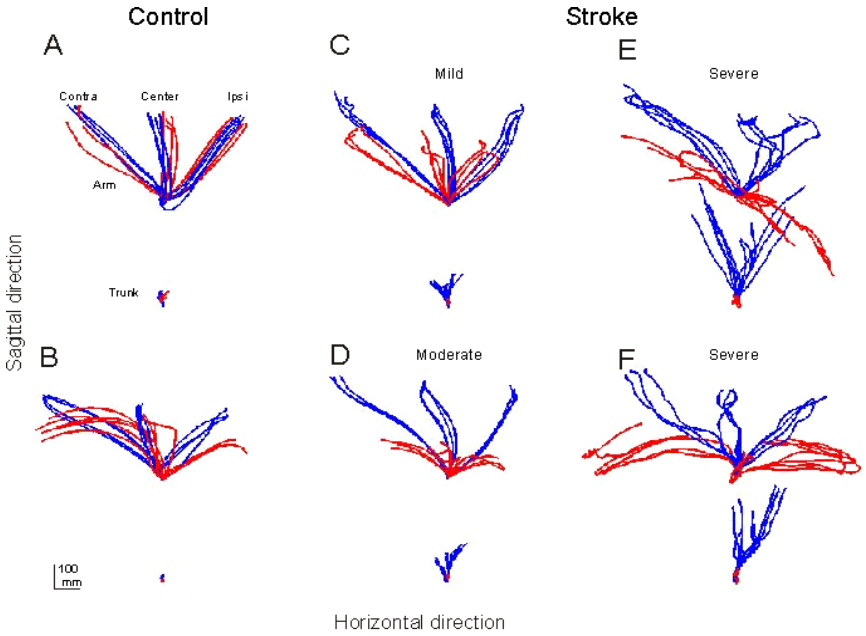
Game-like



Video-capture VR environments

GestureTek HEALTH

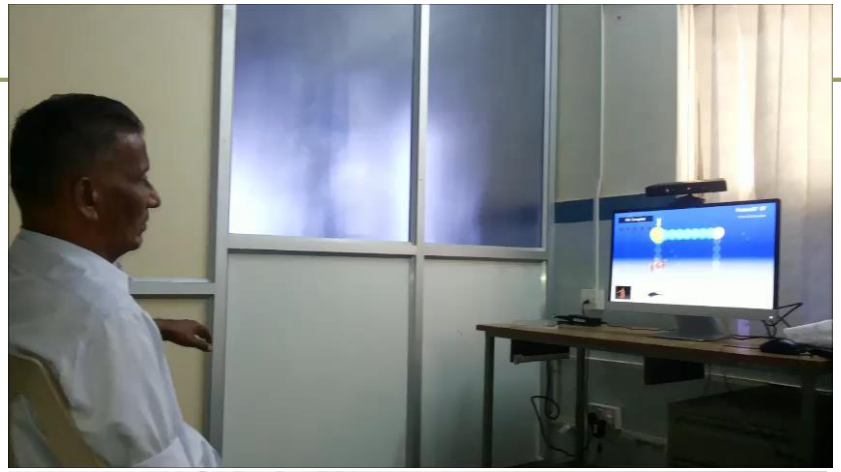
Caveat – movements made in 2D VR

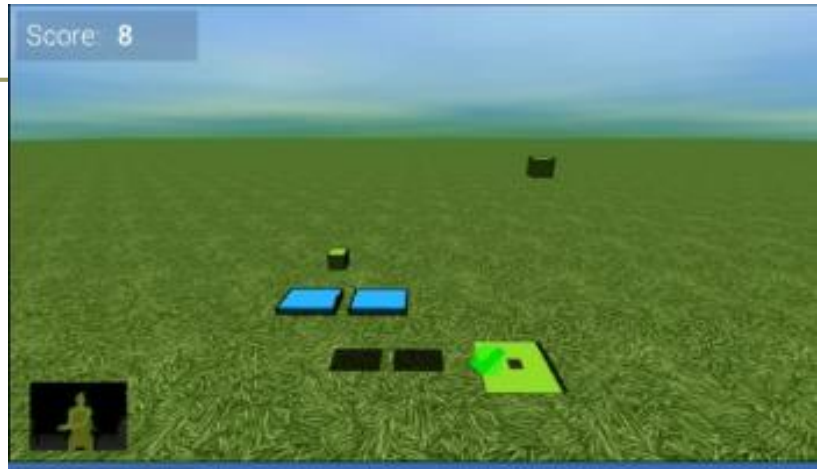


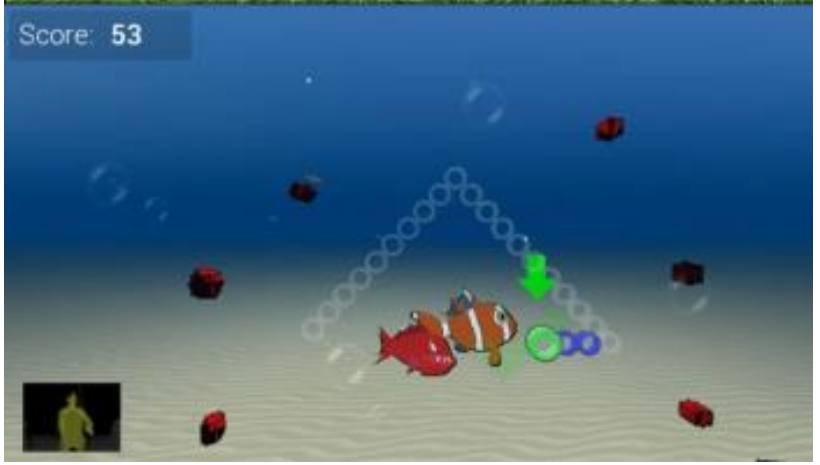
Liebermann et al. TNSRE, 2012

Game-like

Jintronix Rehabilitation System.







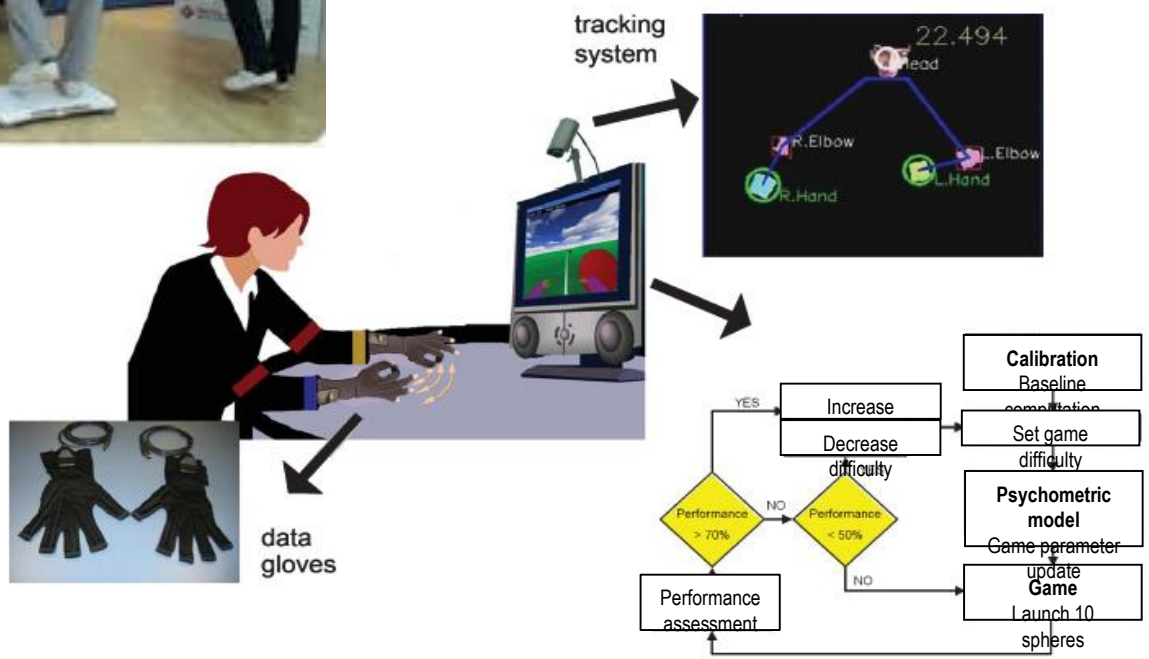
JINTRONIX

Montreal, Quebec

Game-like

Fall prevention / balance training

Reaching training



Personalized Training Module (PTM)

Immersive multi-modal

Dual task performance within a functional VE

Jewish Rehabilitation Hospital Montreal

McGill

Immersive

Pain management

Snow world – Hunter Hoffman

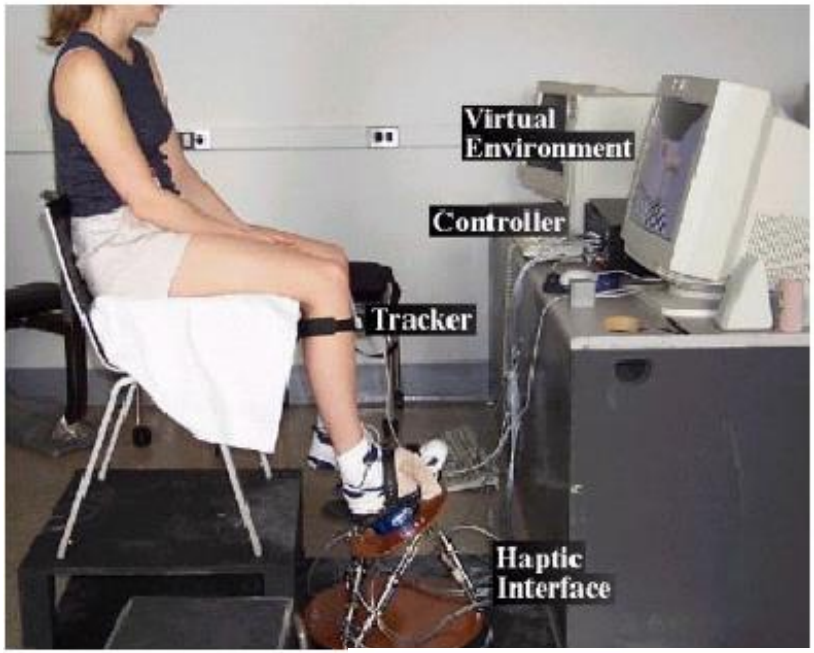
Immersive

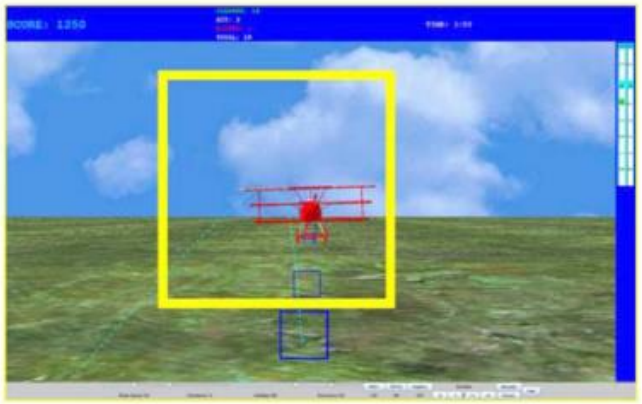
Anxiety, fear, PTSD

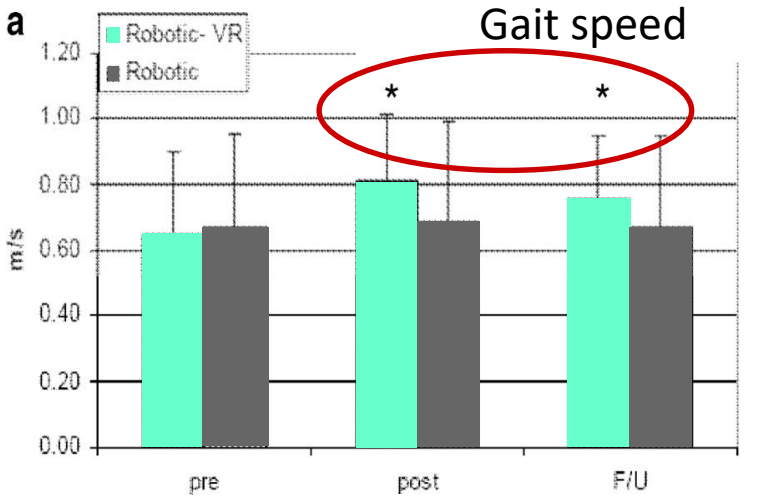
Type of Practice

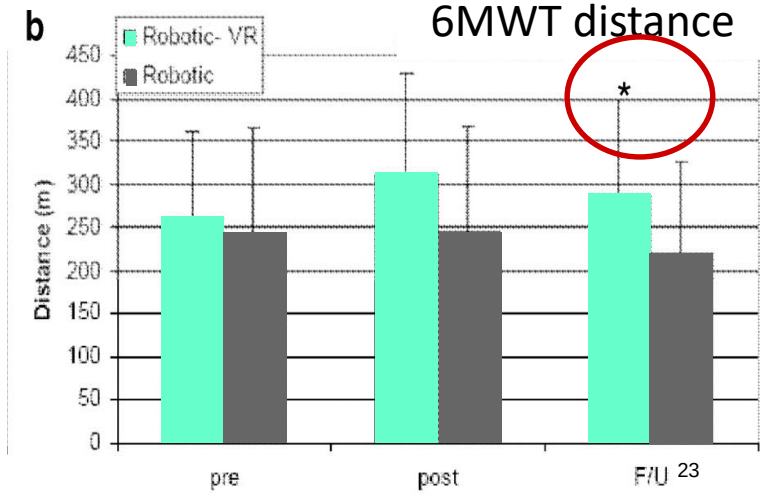
Task-related practice in VR vs non-specific practice

Mirelman et al., Stroke; 40(1):169-74, 2009







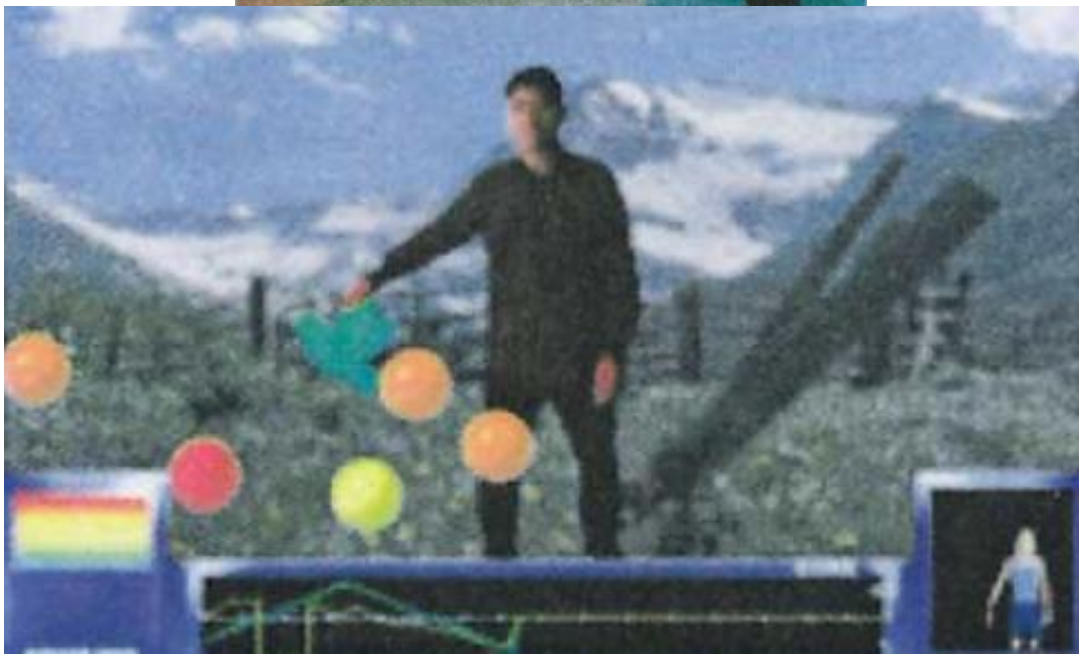


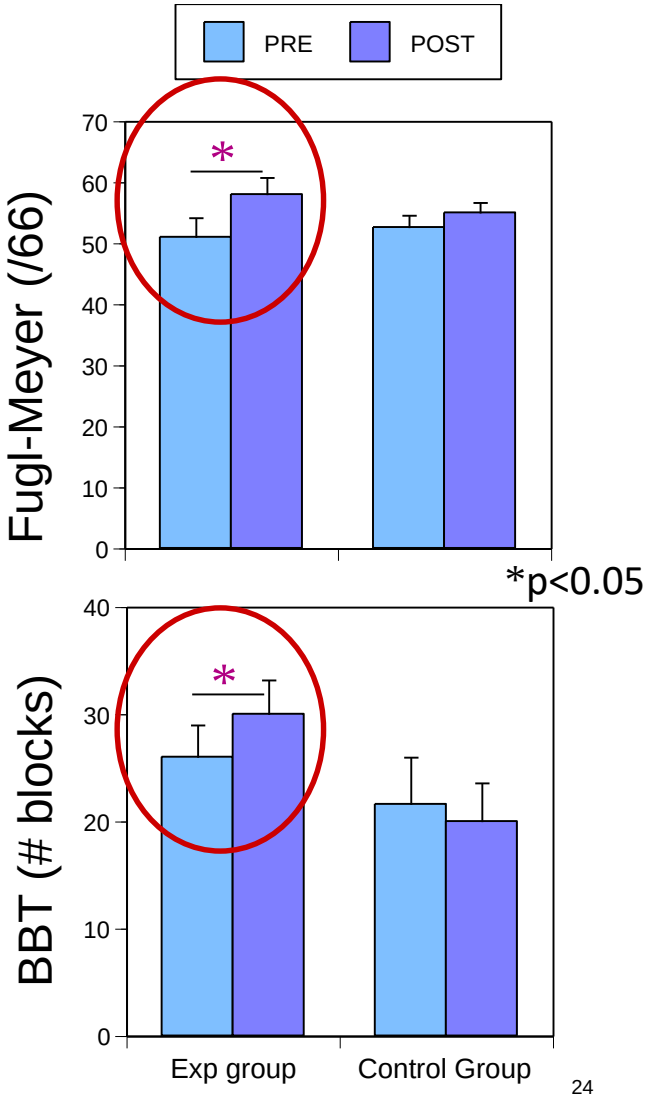
*p<0.05

Differential (variable) practice

Jang et al., APMR, 86:2218-23, 2005

Chronic stroke (n=5 per group), practice in VR compared to no treatment, 60 mins/day, 5 x/wk, 4 wks





Feedback: Internal vs external focus of attention

Internal focus: attention is directed at the movements composing the motor action

External focus: attention is directed at the effect of the movement: goal

Feedback – Knowledge of Results (KR)

- **Positive feedback** - movement is both temporally and spatially successful (high pitched 'ping' sound, target turns green)

- **Negative feedback** - movement is not rapid and/or precise enough (buzzer sound, color of the target does not change)

Feedback – Knowledge of Performance (KP)

- **Excessive trunk motion** – 3rd sound emitted ('whoosh'), target turns red (even if the subject's movement was accurate and precise enough)

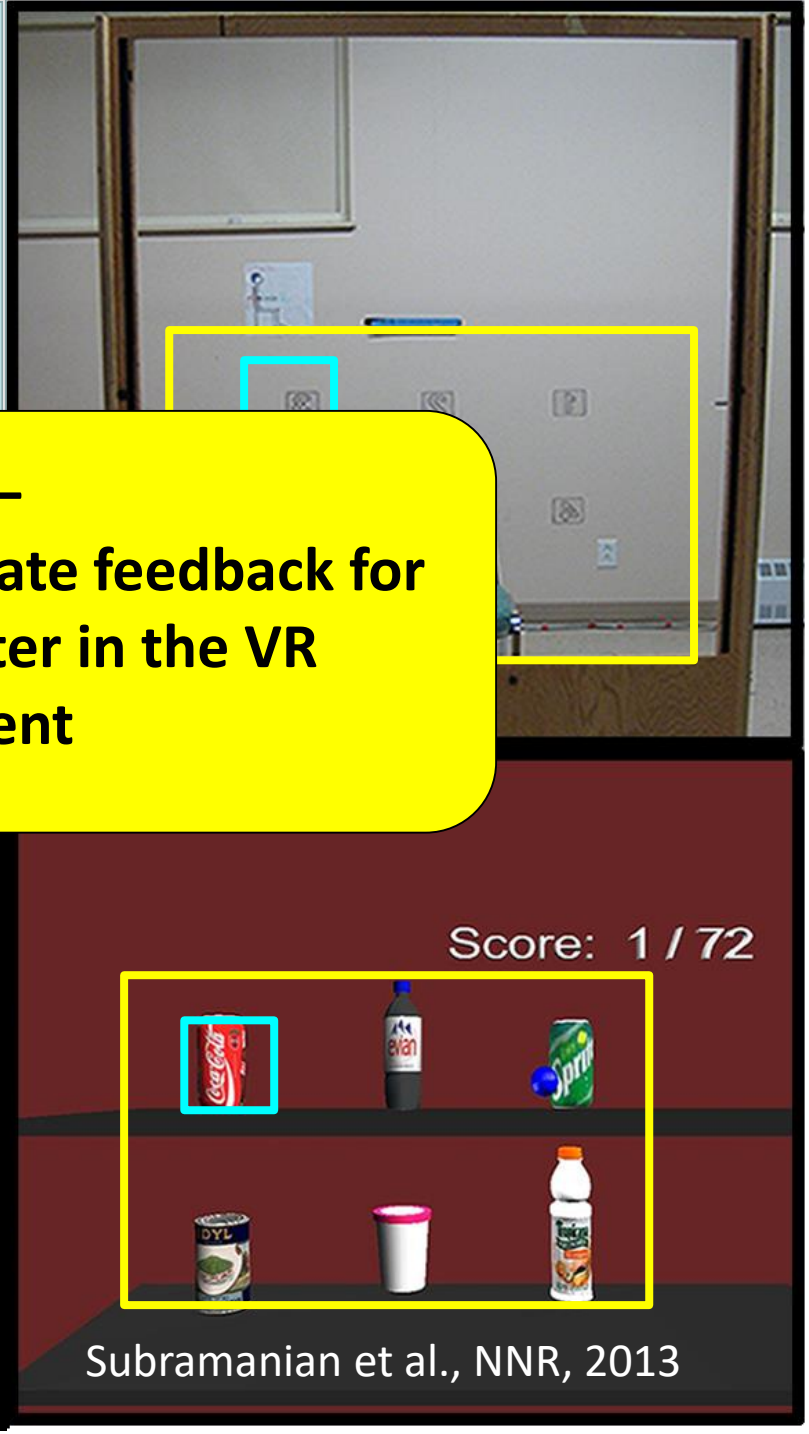
- Default value for permissible trunk displacement tolerance adjustable (i.e. 5 cm)

Training Environment Features

- Same task dimensions and visual array
- Same feedback conditions:
- terminal KR – movement precision & speed (auditory & visual) – success (ping); failure (buzzer)
-concurrent negative KP – trunk movement (auditory)
terminal KR – change in target appearance when successful; conte

-32 participants v
severity and ranc
VE

Results –
patients could incorporate feedback for motor learning better in the VR environment



Subramanian et al., NNR, 2013

Feedback delivery schedule

Continuous (after every trial)

Summary (after a fixed number of trials, general information about all trials)

Average (average information about a fixed number of trials)

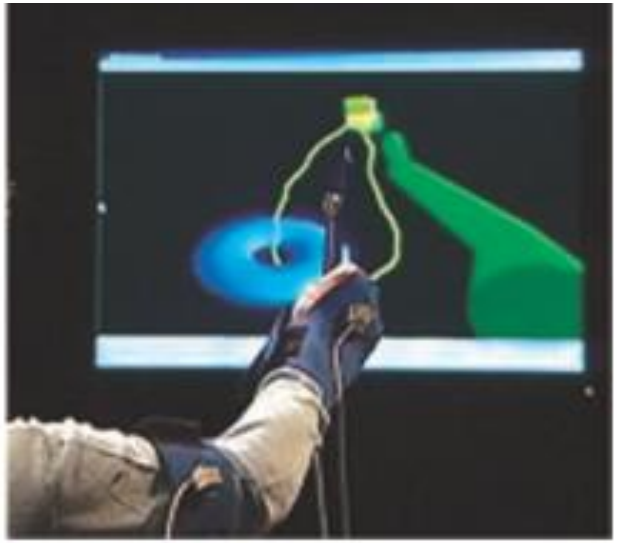
Faded (initially after very trial, then after several trials)

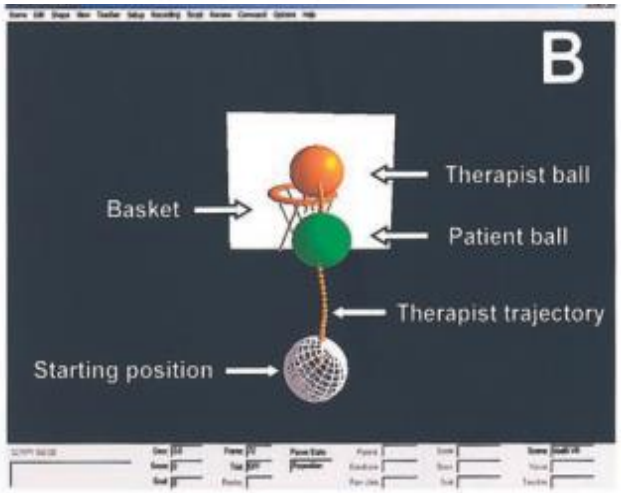
Faded feedback →

- More opportunity to find own motor solution
- Better retention of learned skills

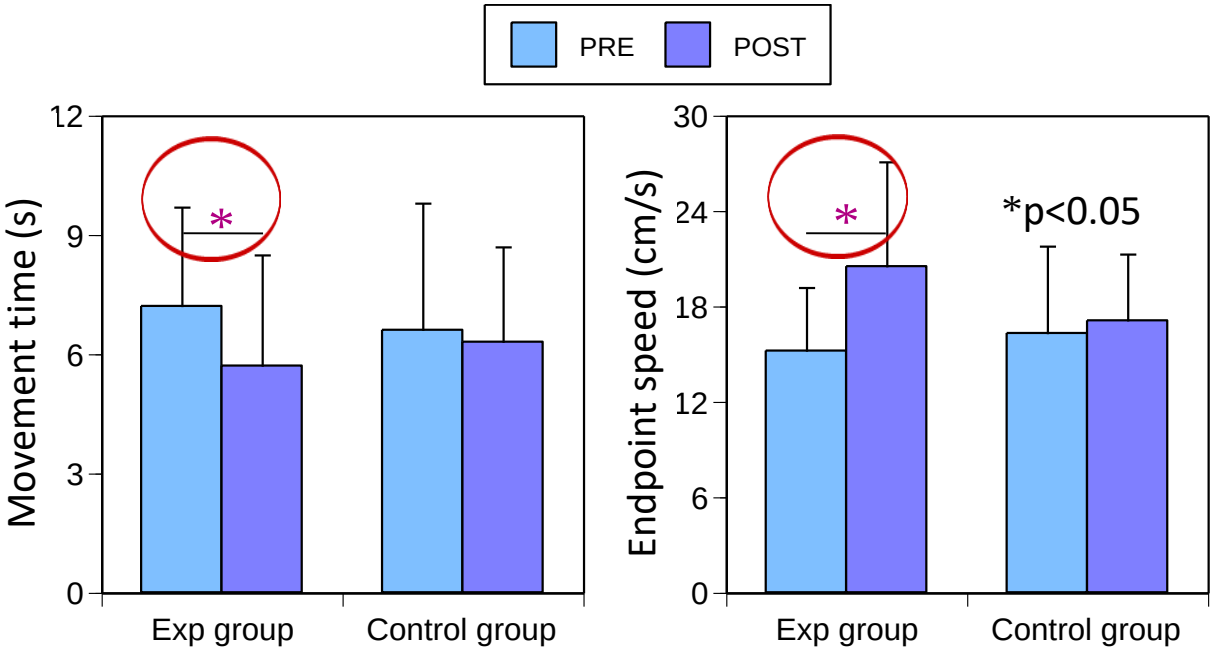
(Hebert et al., 1998, Cirstea et al., 2006)

Continuous feedback





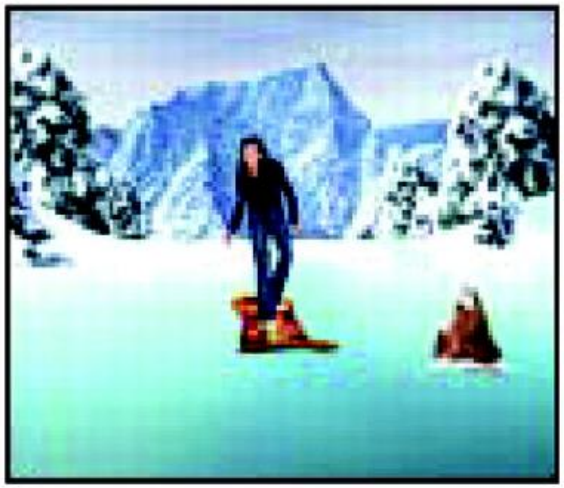
Control: Conventional progressive therapy, n=20
Feedback: VR group, n=27 Verbal KP (arm movement) and visual KR (arm vs. teacher trajectory)
Chronic stroke; 60 mins/day; 5 days/wk; 4 wks



FMA: VE 5.1pts; PE 4.3pts

Piron et al., NNR; 24(6):501-8, 2010

Faded feedback

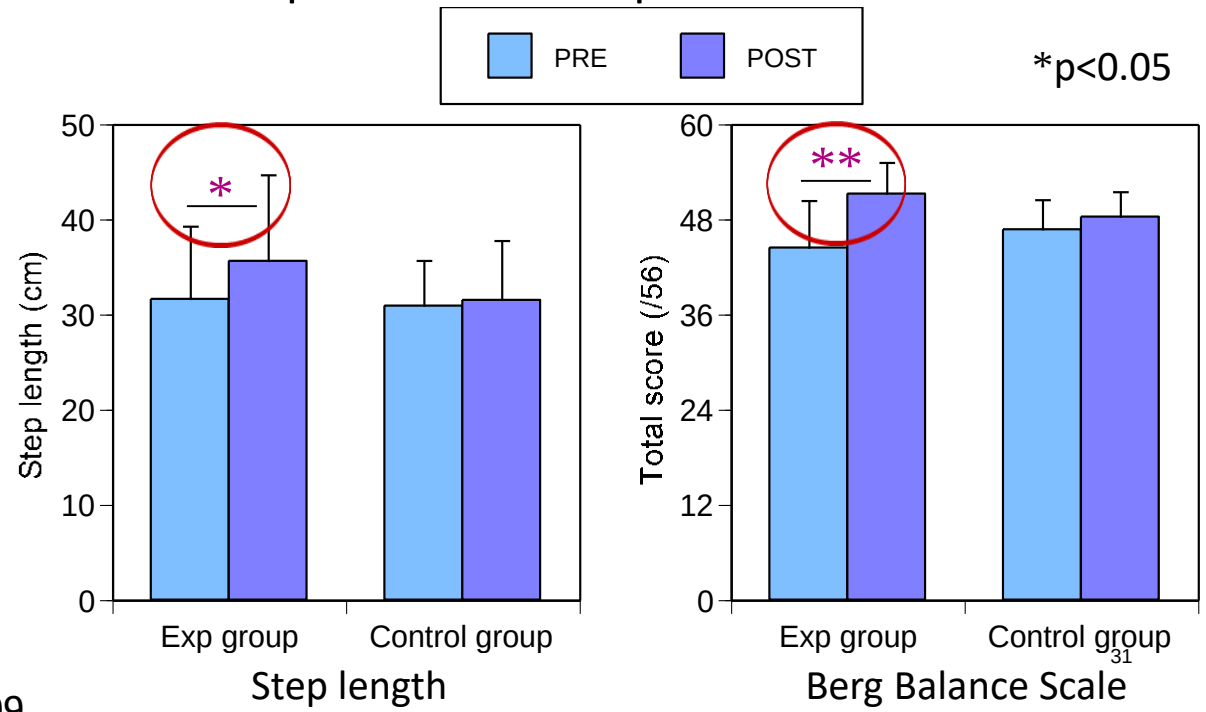


Kim JH et al., AJPMR;88:693–701, 2009

Conventional Tx Group (n=12) 40 min/day, 4 days/wk, 4 wks.

Experimental Group (n=12) Conventional Tx + 30 min VR/session

Feedback: KR (game score) and KP (body movements). Initially provided > 90% of the time and reduced as performance improved.



Practice Intensity

- High intensity practice → better outcomes.

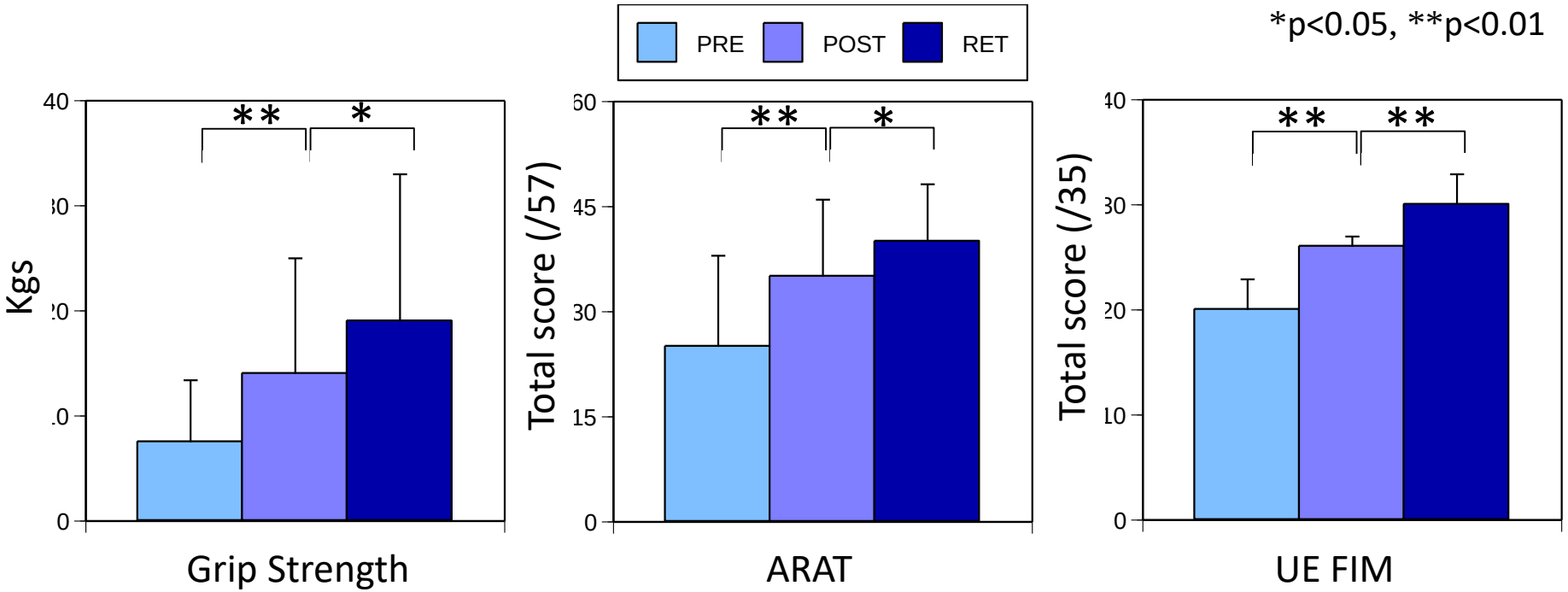
Intensity =

- Duration, active time in therapy
- Number of repetitions

Lohse et al., 2014

Practice Intensity

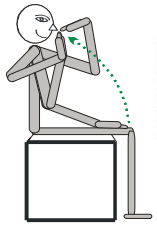
Waddell et al., AJOT, 68(4):444-53, 2014

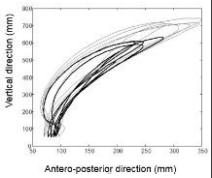


- High intensity practice (single cohort study, 60 mins per day, 289 ± 35 repetitions) per session for 12 sessions, inpatient hospital setting (n=15; 1 month retention test)

Motor learning principles that can be addressed in VR

Redundancy





Task practice with attention to motor compensations
Multiple repetitions of different movements.
Feedback - explicit to implicit learning focus
Continuous to faded – search for task solution

Affordances & Environment

Tasks should be varied in their level of problem-solving to challenge different cognitive and meta-cognitive abilities.
Task practice – task-oriented
Feedback - focus of attention – external (feedback on task goal)

Task Difficulty

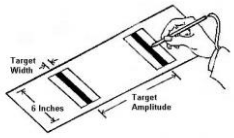
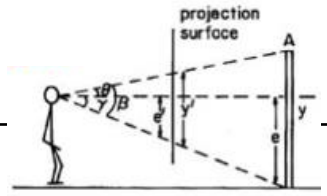


Figure 1. The serial tapping task used by Fitts (1954).

Intensity of practice – high
Progression of task difficulty according to Fitts' Law
Feedback: precision & speed
-explicitly mapped to patient performance and progression through difficulty levels.

Perception



Perceivable properties of environment contain information about actions
Visual techniques can enhance virtual presence
Feedback – haptic, on object contact to reinforce perception

Current learning in virtual reality

More research is needed on effectiveness of manipulating type, frequency and delivery schedule of feedback on motor learning

- Possibility to exploit learning by observation of avatars of moving limbs (mirror neuron system; *Rizzolatti and Craighero 2004*). Translation between perception of action and action execution – drives functional reorganization

- Ability to manipulate extrinsic feedback *(Verschure et al. 2003)*

- Opportunity to explore the environment by varied practice – learning by problem-solving and taking advantage of the system's redundancy *(Bernstein 1967)*

- Use of environments that increase motivation and arousal *(Green and Bavelier 2008)*

McGill

Acknowledgments

- Sandeep Subramanian
- Eliane Magdalon
- Christiane Lourenco
- Luiz Alberto Knaut
- Melanie Banina
- Marika Demers
- Ruth Dannenbaum
- Rhona Guberek
- Christian Beaudoin, Valeri Goussev
- Anatol Feldman

CIHR IRSC

Canada Foundation for Innovation
Fondation canadienne pour l'innovation

FONDATION DES MALADIES DU CŒUR | HEART & STROKE FOUNDATION
À la conquête de solutions.™
Finding answers. For life.™

CRIR
Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain

International Society for Virtual Rehabilitation

http://www.isvr.org/

ISVR

12th International Conference on
Disability, Virtual Reality & Associated Technologies

In collaboration with *Interactive Technologies and Games*

University of Nottingham, England - September 4-6, 2018

SHORT PAPER SUBMISSION DEADLINE: MAY 31, 2018

www.icdvrat.org

ICVR 2019
INTERNATIONAL CONFERENCE ON VIRTUAL REHABILITATION
HAIFA, JULY 2019

www.isvr.org

ArtAbilitation
helping through art

artabilitation.expositus.com

LAVAL VIRTUAL 13

www.laval-virtual.org