Feasibility of an individually tailored virtual reality program for improving upper motor functions and activities of daily living in chronic stroke survivors: A case series

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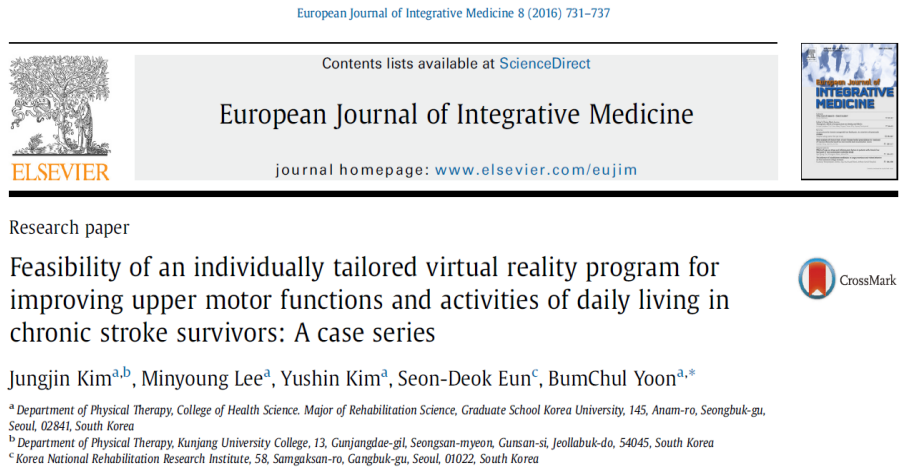

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Research paper

Feasibility of an individually tailored virtual reality program for improving upper motor functions and activities of daily living in chronic stroke survivors: A case series

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Introduction

o Research problem (background of the work)
o Research objective, questions and/or hypotheses

Methods

o Summary of experiment/methodology
o Data used (if any)
o VR/AR equipment

Results (Main findings)

o Summary of the results
o Highlight relevant results from the VR/AR implementation

Conclusions

Introduction

Research Problem (Background information)

- Stroke is one of the leading causes of disability worldwide.
- The interruption of blood supply to the brain occurring during stroke can cause several physical and cognitive impairments that may highly affect patients' participation in activities of daily living (**ADL**) and their quality of life.
- Chronic stroke survivors can make home management difficult.
- To enhance their quality of life, **rehabilitation** plays a key role in the recovery of function for the patients.

Research Objectives & Hypothesis

Objectives:

Pre - ITVRP VS Post - ITVRP

Hypothesis:

Rehabilitation ↑ ∝ Physical Function & ADL ↑

Problems associated with traditional rehabilitation methods:

Require external instruments like treadmill ambulation using harness suspensions.

Manual assistance by physical therapists

Methods are becoming more and more expensive.

Require one-to-one therapist–patient activity.

Simple and repetitive exercises induce boredom in the patients.

Treatment data not collected as simple exercising devices are designed with no sensors.

Problems to be solved with VR system

(RP1) – Does simply equipment and self-exercise (without supervision/unassisted) help stroke survivors on the recovery process?

(RP2) – Can short program on rehabilitation provide significant changes on activities movement for stroke survivors?

(RP3) - Is it a necessity of home-based virtual reality programs developed to adapt individual characteristics of stroke survivors?

Methodology

Info

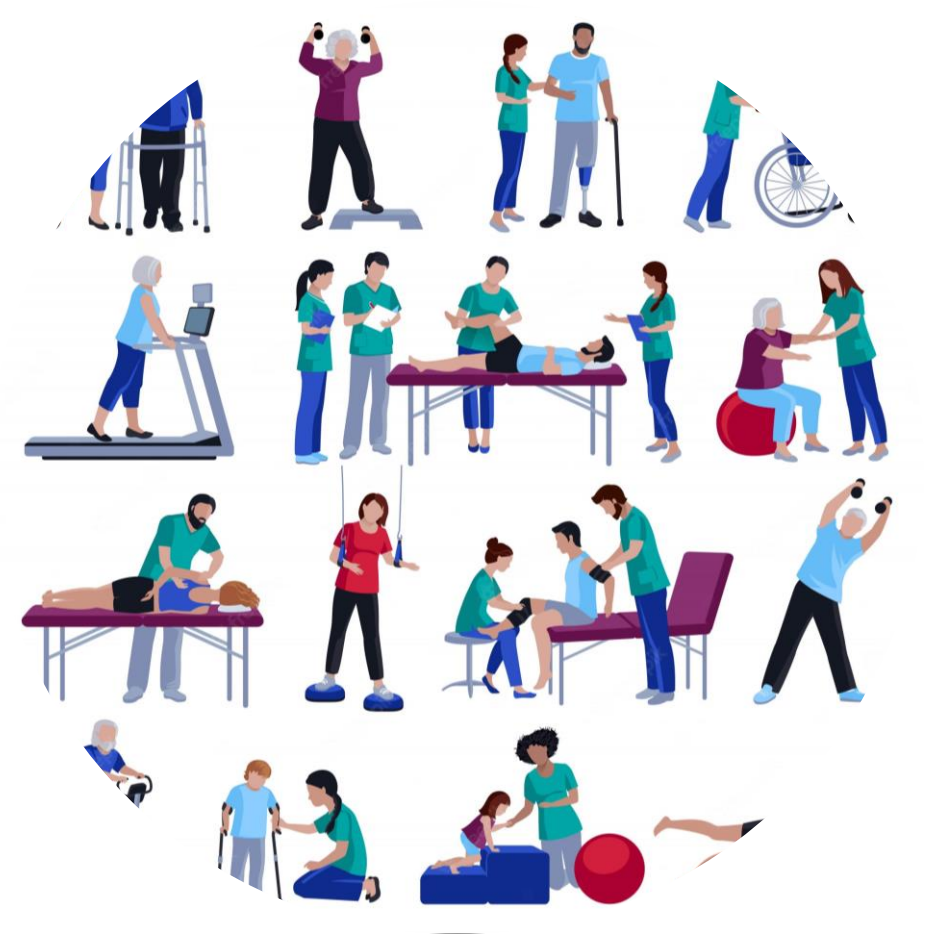
sample size: 15 stroke survivors

Individual Tailored Virtual Reality Program (ITVRP) -> 8 weeks rehabilitation program

Compared results between pre and post ITVRP among 4 different assessments.

ITVRP

- Home-based self-exercise, unsupervised and unassisted.
- Provides effective rehabilitation
- 8 Weeks Program (total 24sessions)：
  - 4 sessions with community
  - 20 sessions self-learning
- 2 movement-based controlled modes:
  - 1)training modes;
  - 2)game mode



VR System used

Equipment:

- A motion-capture sensor
- A HDMI cable
- Computer
- A 50-inch PDP display monitor

How it work:

- Connect HDMI between computer and monitor
- Exercise program will display on the monitor
- The motion-capture sensor captured participant's motion
- A motion capture sensor detects the participants' joint positions automatically and continuously.

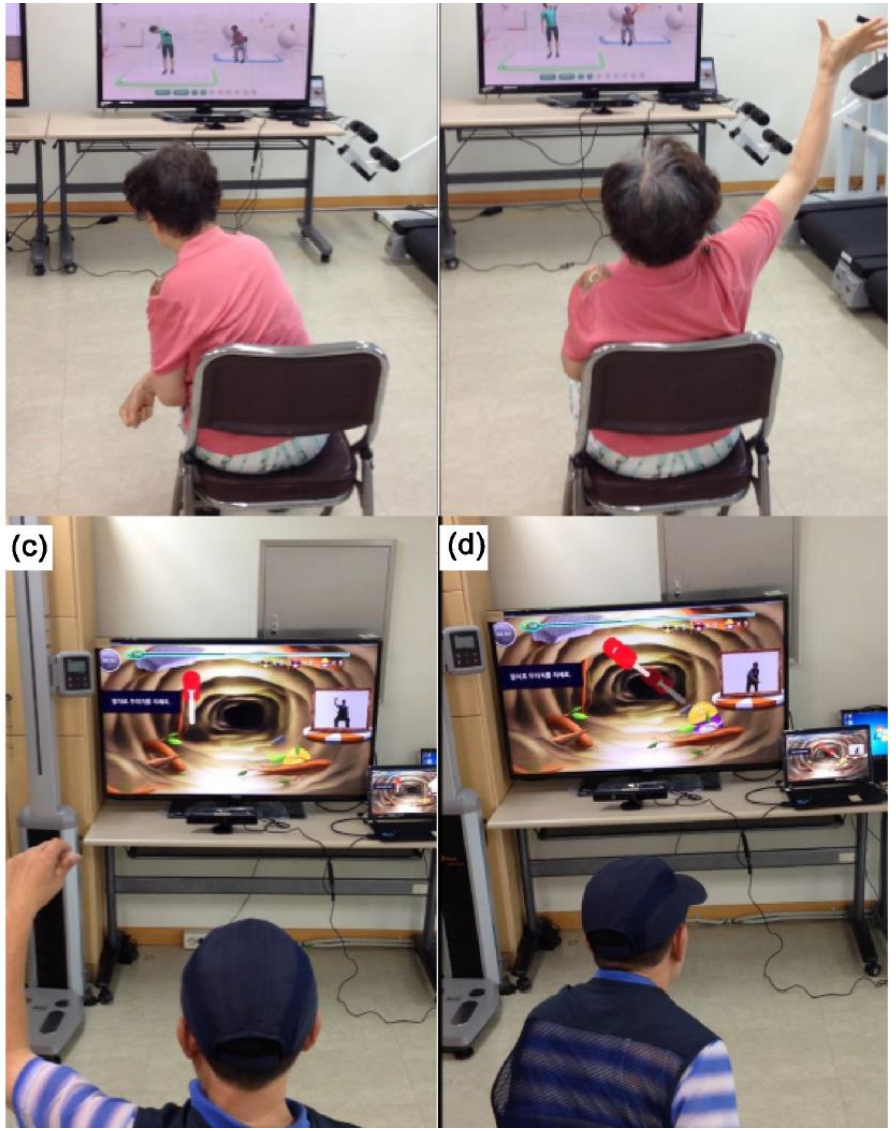


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Table 1
Movement patterns and descriptions of training and game modes.

Contents		Description
Training Mode	Diagonal 1 Shoulder Flexion pattern (D1 Flexion pattern)	The arm begins in an extended position slightly out to the side, about one fist width from the hip, with the wrist stretched and the fingers opened. Then, the arm is lifted to about nose level across the body with the elbow crossing the midline. This pattern often thought of as functional for self-feeding.
	Diagonal 1 Shoulder Extension pattern (D1 Extension pattern)	Reverses D1 Flexion pattern. The arm begins in a lifted position at about nose level across the midline of the body. Then, the arm is extended slightly out to the side, about one fist width from the hip, with the wrist stretched and the fingers opened. This pattern often thought of as fastening a seat belt.
	Diagonal 2 Shoulder Flexion pattern (D2 Flexion pattern)	The arm begins in an extended position about one fist width from the hip across the midline of the body. Then, the arm is lifted at about one fist width from the ipsilateral ear with the wrist stretched and the fingers opened. This pattern often thought of as throwing a wedding bouquet.
	Diagonal 2 Shoulder Extension pattern (D2 Extension pattern)	Reverses D2 Flexion pattern. The arm begins in an extended position about one fist width from the ipsilateral ear with the wrist stretched and the fingers opened. Then, the arm is extended about one fist width from the hip across the body with the elbow crossing the midline. This pattern often thought of as resheathing a sword.
Game Mode	Whack-a-mole game	Play with one hand using the D1 and D2 Flexion and Extension patterns. Moles appear in the following patterns, wherein the participant performs diagonal and spiral arm movements to hit the moles with a hammer in a cave: (1) right up and then left down; (2) right down and then left up; (3) left up and then right down; (4) left down and then right up of the right. If the participant catches a mole with the correct velocity and angle, it disappears, making a pained expression and saying, "ouch!" However, if the participant does not hit it, it disappears after 5 s.
	Nutcracker game	Play with both hands using the D1 and D2 Flexion and Extension patterns. Nuts appear in the same patterns as the whack-a-mole game. The participant makes diagonal and spiral arm movements to crack the nuts with a hammer in the forest. If the participant hits a nut with the correct velocity and angle, it cracks and disappears, making a cracking sound. However, if the participant does not hit it, it disappears after 5 s.
	Jet ski game	Play with the trunk as a warm-up exercise. In this game, which reflects the participants' trunk movement, the participant tries to catch coins to increase their score as they advance in the sea. Coins appear on the left and right sides, prompting the participant to move the trunk laterally.

Table 2
Descriptions of individualised strategies embedded in the newly developed ITVRP.

Individualized strategies	Description
Exercise direction setting function	All programs were equipped with both left and right versions, so that all participants could exercise their affected side. Before starting, the participant could choose selected the exercise direction (left/right) on the menu screen. The system could also recognise the participant's 2-handed movements even though the left or right side was selected on the menu screen; this strategy enabled severely affected participants to exercise using both hands.
Movement velocity	Considering stroke survivors have increased spasticity with rapid movements, all movements were designed to take about 5 s from start to finish. There were 2-s intervals between movements.
Movement pattern	Considering that the entire upper body tends to be flexed in stroke survivors, extension pattern movements were designed and conducted, simultaneously moving the shoulder, elbow, wrist, and finger (D1 and D2 Flexion patterns).
Visual feedback	In the D1 and D2 exercise patterns, if the participant's movement was correct, a yellow light flashed around the participant's body on the monitor. In games, if participant successfully hit a target (moles or nuts) with the correct velocity and angle, the targets showed immediate feedback by changing their figures (e.g., making a pained expression or shattering). The accuracy of the participant's movement was scored by a software program; the participant could see their total score at the end of the exercises and games.
Auditory feedback	In the D1 and D2 exercise patterns, if the participant's movement was correct, the participant was praised with comments such as "good job" and "excellent." In contrast, if the participant's movement was incorrect, the participant was encouraged with comments such as "try harder" or "don't despair." In games, if the participant successfully hit a target with the correct velocity and angle, the targets made a sound such as "ouch!" or a cracking sound.

Table 3
Baseline characteristics by participant.

Participant	Age	Sex	Duration	Etiology	Side	NIHSS
P1	69	M	175 weeks	Ischemia	R	4
P2	62	M	55 weeks	Ischemia	R	2
P3	74	M	84 weeks	Ischemia	L	6
P4	68	M	29 weeks	Ischemia	L	2
P5	64	M	56 weeks	Ischemia	R	0
P6	52	M	55 weeks	Hemorrhage	L	1
P7	72	F	78 weeks	Ischemia	R	5
P8	57	M	75 weeks	Hemorrhage	L	3
P9	75	F	39 weeks	Ischemia	R	3
P10	68	M	82 weeks	Ischemia	R	1
P11	64	M	104 weeks	Hemorrhage	L	1
P12	62	F	248 weeks	Hemorrhage	R	7
P13	77	M	53 weeks	Hemorrhage	R	9
P14	53	F	75 weeks	Ischemia	L	1
P15	67	F	19 weeks	Ischemia	R	1

M, male; F, female; R, right side; L, left side; NIHSS, National Institutes of Health Stroke Scale.

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NIH Stroke Scale Score	Stroke Severity
0	No stroke symptoms
1-4	Minor stroke
5-15	Moderate stroke
16-20	Moderate to severe stroke
21-42	Severe stroke

Health Jade Team. (n.d.). NIH stroke scale. Retrieved from HEALTHJADE: https://healthjade.net/nih-stroke-scale/

Data

- Fugl-Meyer assessment (FMA):
  - Assess arm function of the affected side
  - Patients are required to display performance based on the given instruction.
  - Score ranges from 0 to 66
- Box and block test (BBT):
  - Measure unilateral gross manual dexterity before and after the training period.
  - moving 150 blocks, one by one, from one box to another within 60 seconds.
  - Scores: as many blocks as patients can make
- Manual function test (MFT):
  - Developed to examine unilateral upper-limb motor function in stroke patients with paralysis
  - Like FMA, patients are required to complete 8 tasks to see their performance
  - Score ranges from 0 to 32
- Modified Barthel index(MBI)
  - Used to measure performance in activities of daily living (ADL).
  - Assess on 10 personal activities, including feeding, personal toileting, etc
  - Score ranges from 0 to 100

Health Jade Team. (n.d.). Barthel index. Retrieved from HEALTHJADE: https://healthjade.net/barthel-index/

**The higher score indicate better function/ recovery.

Data Used

Data are expressed as mean ± SD

FMA, MFT and BBT data were analyzed by the Shapiro-Wilk test

Paired T-tests were used for FMA

Wilcoxon signed rank test was performed in MFT and BBT

Results

4 DIFFERENT ASSESSMENT MATRICES USED BEFORE & AFTER TRAINING WITH VR:

All 15 participants completed the entire training session and subsequent evaluation

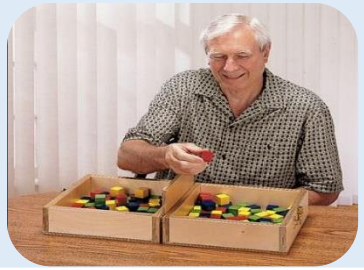
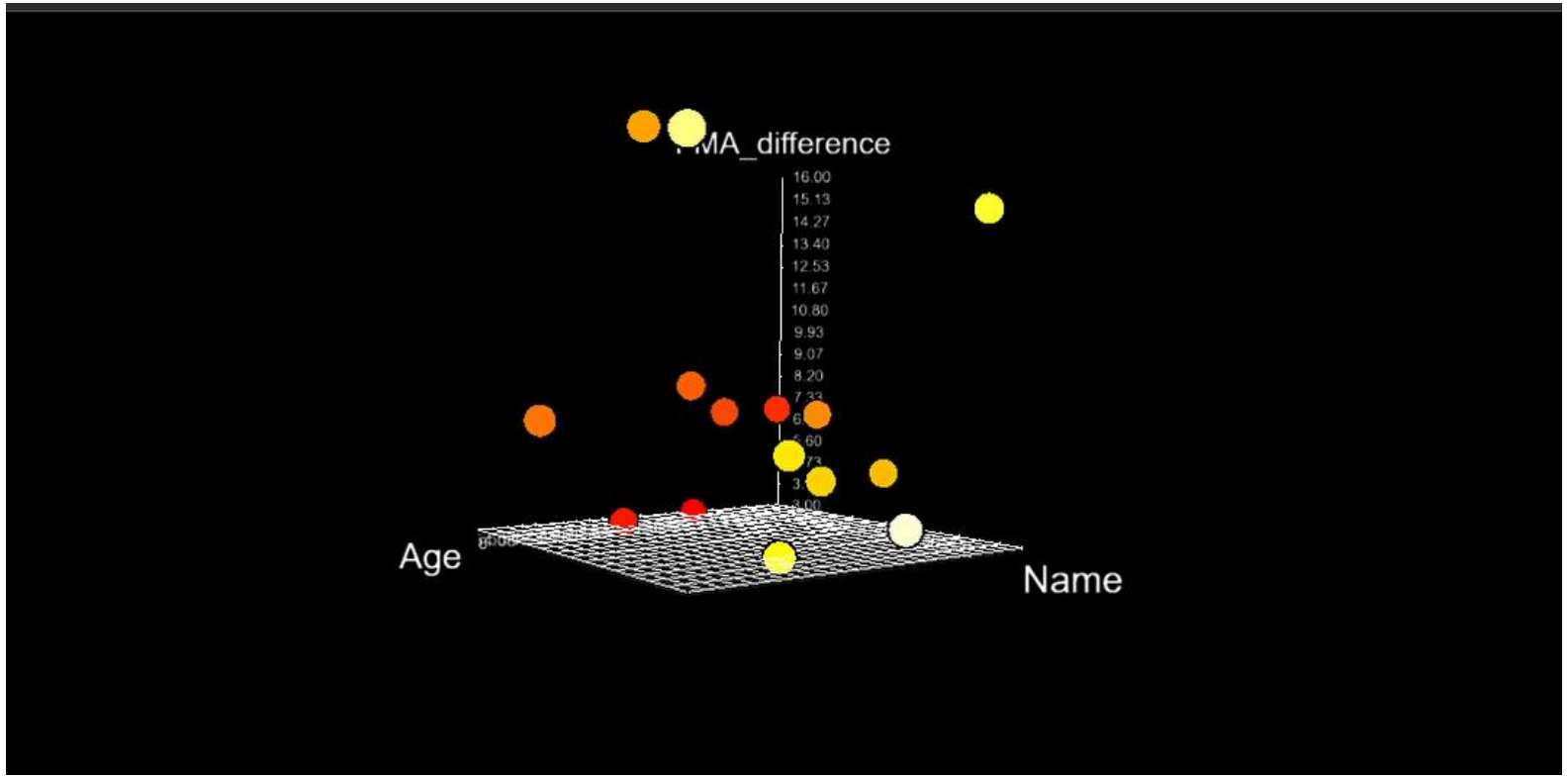
	FUGL-MEYER ASSESSMENT	MANUAL FUNCTION TEST	BOX AND BLOCK TEST	MODIFIED BARTHEL INDEX
				
What is it?	FMA is a stroke-specific, performance-based impairment index. To assess motor functioning, balance, sensation and joint functioning in patients with post-stroke hemiplegia.	MFT includes 8 tasks in the following categories: arm motions, grasp and pinch, and arm and hand activities.	Single task where participants need to move as many blocks as possible from one section of the box to the other for 60 s using their affected side.	MBI includes 10 personal activities: feeding, personal toileting, bathing, getting on and off a toilet, controlling bladder, controlling bowel, moving from wheelchair to bed and returning, walking on level surface and ascending and descending stairs.
How to give points?	0 to 66, 0=severe impairment, 66= maximum ability of upper limb function	0 to 30, 0= severe impairment, 30= maximum ability of upper limb function	0 to unlimited, as per participant ability	0 to 100, 0=severe impairment, 100=maximum ability of activities of daily living
What does it determine?	Disease severity, describe motor recovery, and to plan and assess treatment	Disease severity, upper body reflexes and range of motion	Determine severity, unilateral gross manual dexterity before and after the training period.	Disease severity, ability to conduct personal daily life activities without support
Time taken?	30-35min or upto 1 hr	30-35min or upto 1 hr	1 minute	2 to 3 hrs including observation

Image sources:FMA,MFT-Youtube/Occupational Therapist Veronica Rowe performs the assessment at Emory University
BBT-totalpatientcare.com.au
MBI-dreamstime.com
Theory reference: Selected Research paper

SCATTERPLOT OF PATIENT'S NAME, THEIR AGE & FUGL-MEYER ASSESSMENT-DIFFERENCE SEEN(using scatterplot3js)

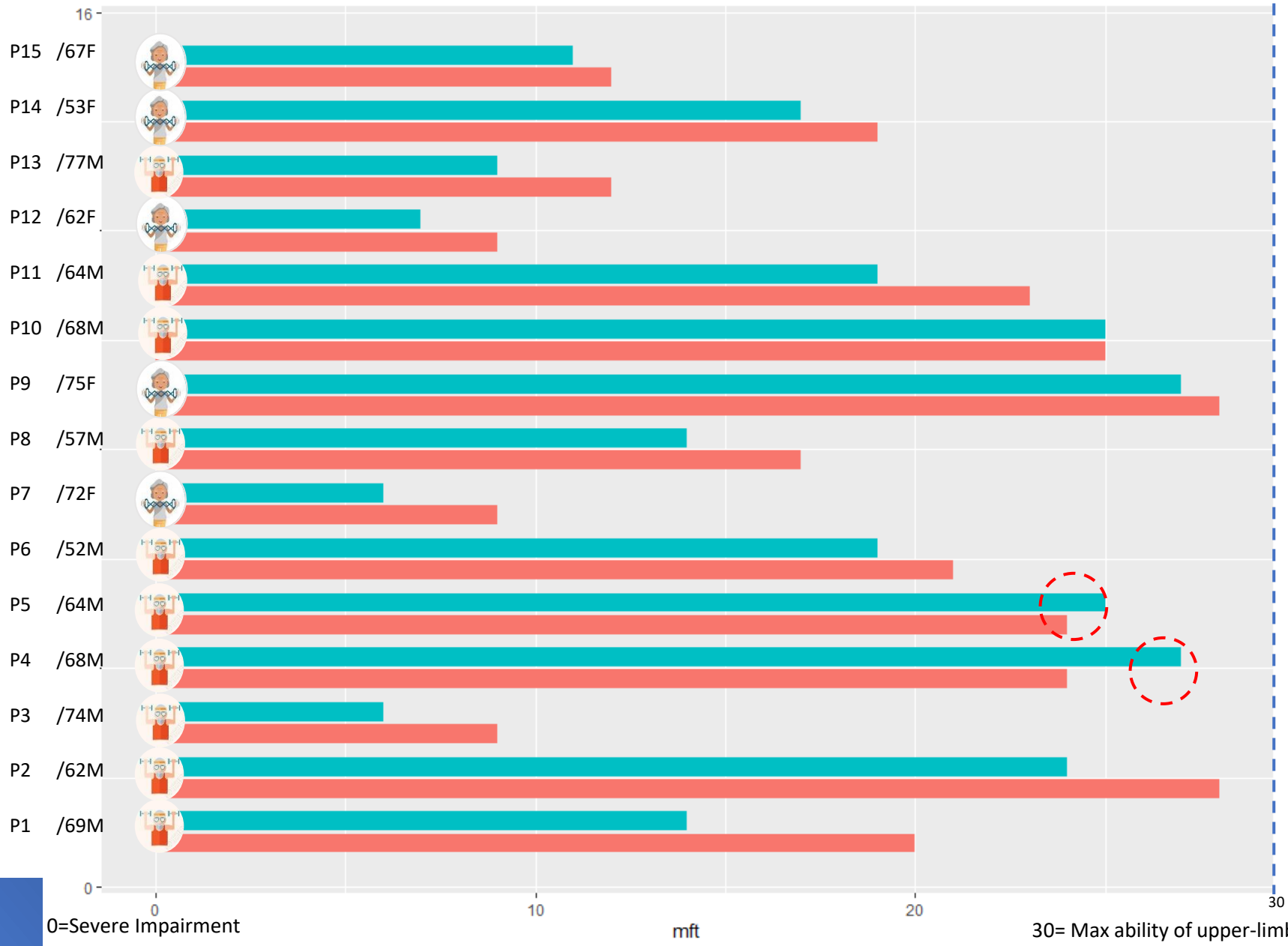


Video source: R studio work based on data from research paper

FMA observations:

- All 15 patients showed an improvement in FMA test.
- Most improvement was shown by participants aged 52-65 yrs old.
- Difference in pre-VR training and post-VR training was seen to range from 3 to 16 units.

R bar PLOT RESULT FOR MANUAL FUNCTION TEST RESULTS WITH DIFFERENCE SEEN(using ggplot2)



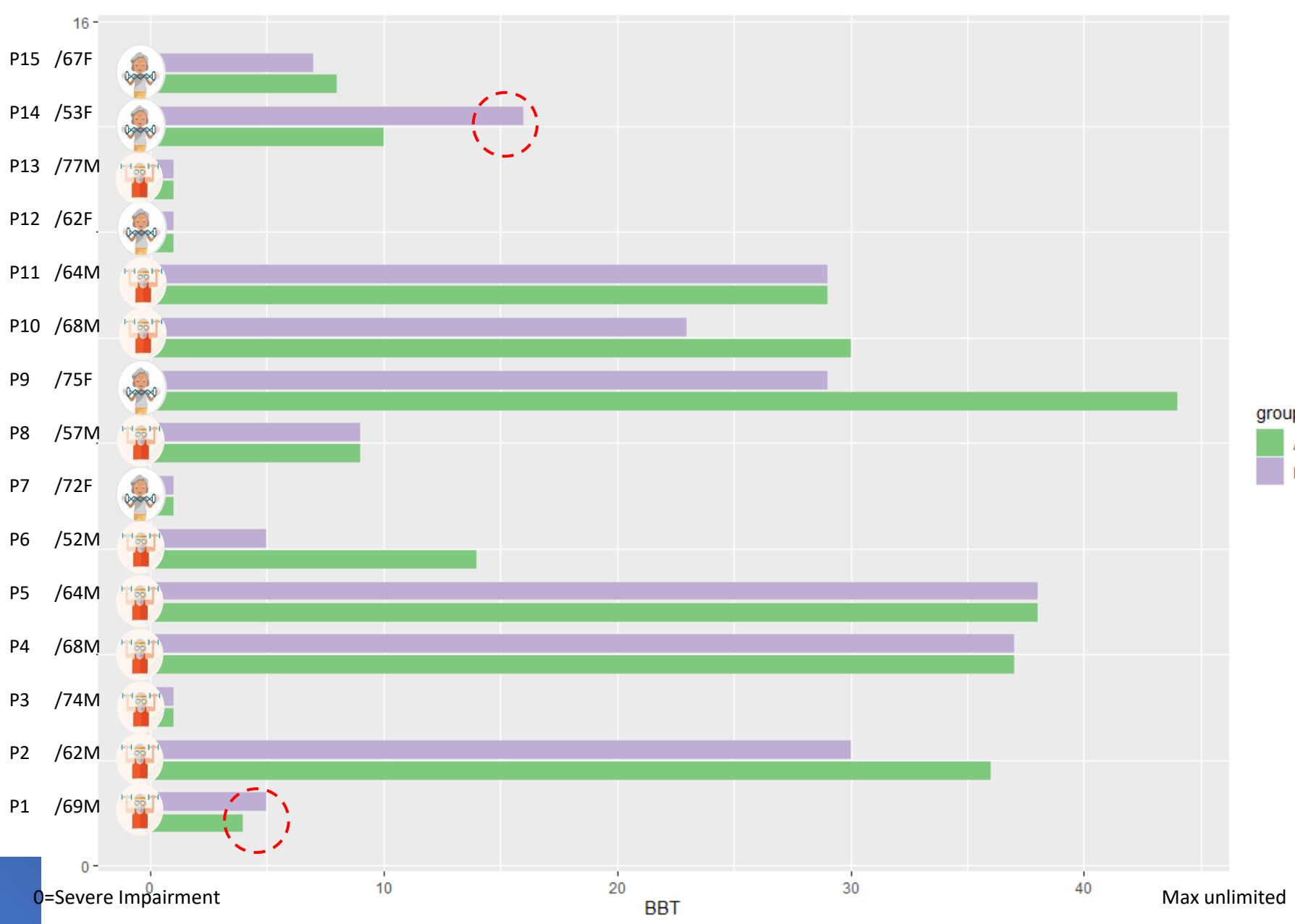
0=Severe Impairment

30= Max ability of upper-limb function

MFT observations:

- In the present study, FMA and MFT scores improved significantly compared to baseline.
- Patient 10 showed no improvement/decline in condition
- Only 2 participants experienced negative outcomes

R bar PLOT RESULT FOR BBT RESULTS WITH DIFFERENCE SEEN(ggplot2)



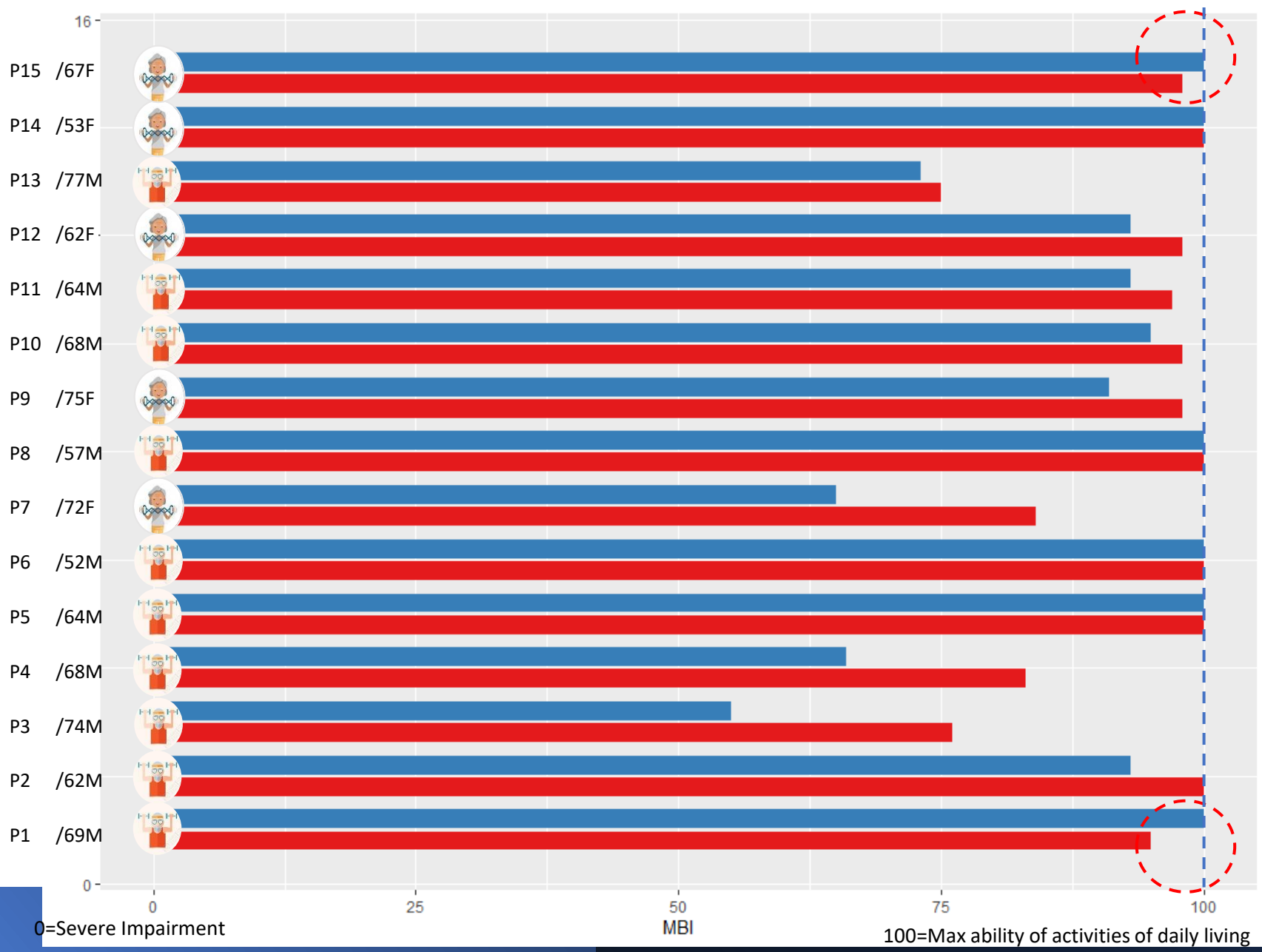
0=Severe Impairment

Max unlimited

BBT observations:

- BBT score improved by approximately 23%, although the difference was not significant;
- Participants P2, P6, P9, P10, P13, and P15 reported improvements.
- Almost half of the participants showed no change in performance.
- P1 and P14 showed a serious decline in their muscle strength and ability.

R bar PLOT RESULT FOR MBI RESULTS WITH DIFFERENCE SEEN(ggplot2)



0=Severe Impairment

100=Max ability of activities of daily living

MBI observations:

- MBI scores increased significantly post-intervention by approx 7%.
- Given that there was no room for further improvement for 6 of the participants, since they already had a score of 100 in the MBI, the actual effect of the ITVRP in improving ADL performance might potentially be greater than that suggested by the results
- 2 patients showed a decline in their ability to conduct daily activities smoothly.

SUMMARY OF RESULTS

- A **questionnaire** was also used to investigate satisfaction and safety of the ITVRP- Twelve participants **(80%) : level of difficulty** of the ITVRP was suitable for their motor function. 11 participants **(73.3%) agreed that this ITVRP would improve** motor functions and ADL performance and would be feasible for chronic stroke survivors.
- **No adverse events were reported**. Participant (P7) reported dizziness and de-conditioning during week 3 of the intervention. However, her symptom and de-conditioning recovered after resting for 10 min.

Measure	Participants														
	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12	P13	P14	P15
	69M	62M	74M	68M	64M	52M	72F	57M	75F	68M	64M	62F	77M	53F	67F
FUGL-MEYER ASSESSMENT(66=max ability of upper limb function)															
Pre	39	54	14	53	51	44	17	33	61	59	47	12	21	35	34
Post	42	57	21	60	59	51	24	49	66	64	53	15	35	50	38
MANUAL FUNCTION TEST(30=max ability of upper limb function)															
Pre	14	24	6	27	25	19	6	14	27	25	19	7	9	17	11
Post	20	28	9	24	24	21	9	17	28	25	23	9	12	19	12
BOX AND BLOCK TEST(maximum is unlimited)															
Pre	5	30	0	37	38	5	0	9	29	23	29	0	0	16	7
Post	4	36	0	37	38	14	0	9	44	30	29	0	1	10	8
MODIFIED BARTHEL INDEX (100=Max ability of activities of daily living)															
Pre	100	93	55	66	100	100	65	100	91	95	93	93	73	100	100
Post	95	100	76	83	100	100	84	100	98	98	97	98	75	100	98

INCREASE

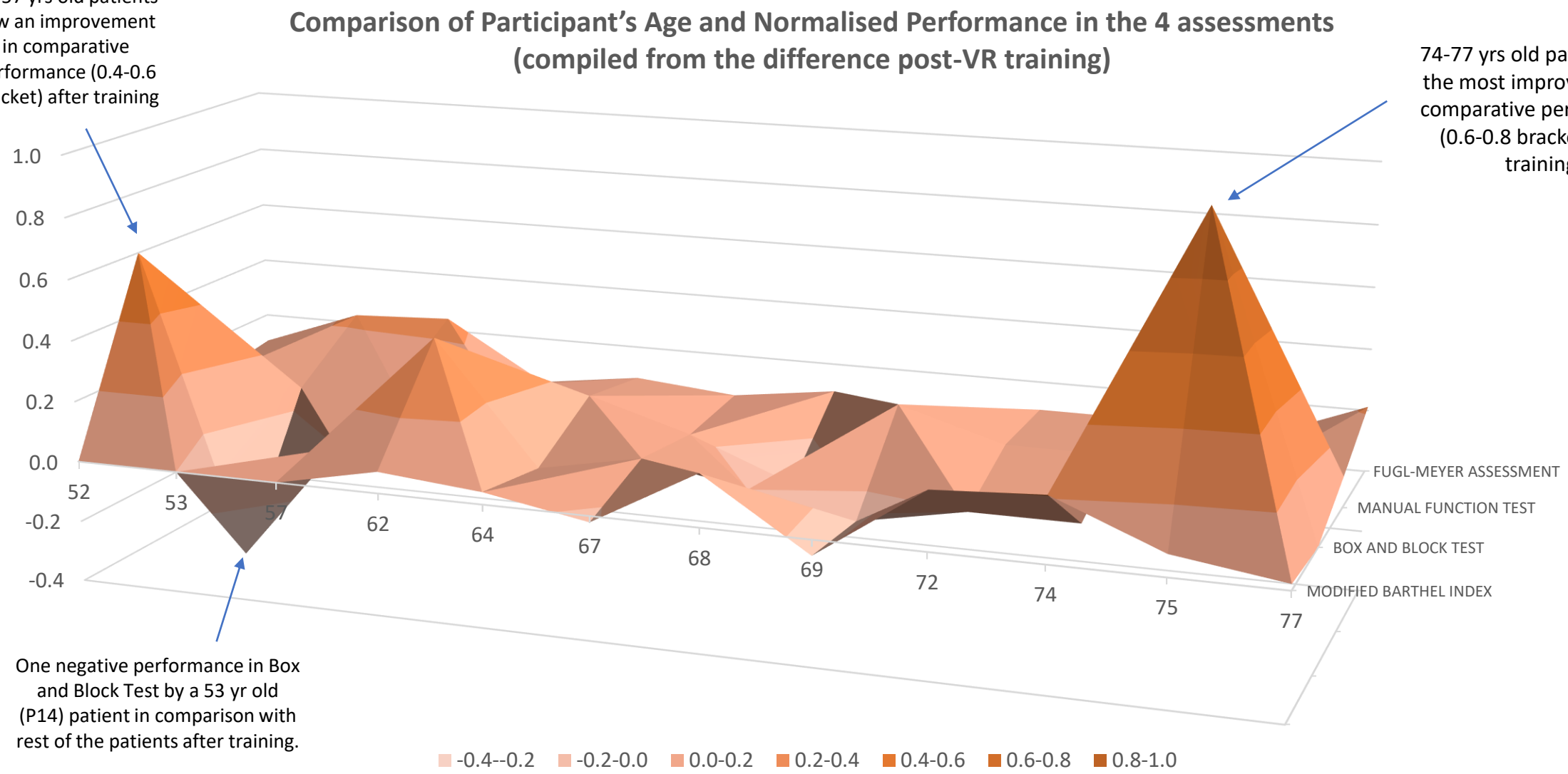
DECREASE

NEUTRAL

CONCLUSIONS FROM THE RESEARCH PAPER

52-57 yrs old patients saw an improvement in comparative performance (0.4-0.6 bracket) after training

74-77 yrs old patients saw the most improvement in comparative performance (0.6-0.8 bracket) after training



One negative performance in Box and Block Test by a 53 yr old (P14) patient in comparison with rest of the patients after training.

Conclusions & Limitations

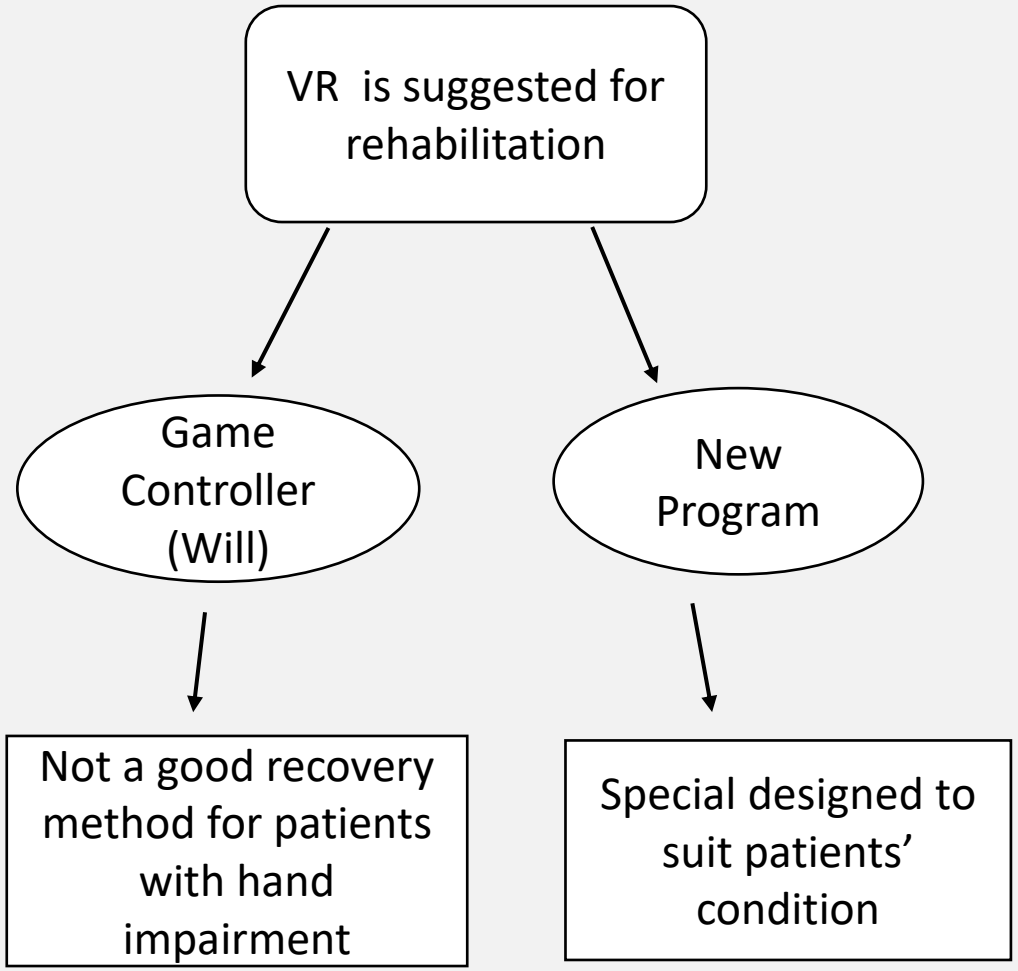
Conclusions

- ITVRP - positively affected upper-limb motor functions (esp. daily life activities)
- Level of difficulty of ITVRP was suitable
- Repetitive and precise exercises used
- ITVRP increased psychological confidence -visual feedback mechanism continuously motivates participants
- Used for virtually any community health center or facility, low-cost and simple devices.

Limitations

- Limited clinical implications, Small sample size (n=15)
- All ITVRP sessions had participant in sedentary position, did not include any locomotor training.
- Changes in brain activities(cortical reorganization) before and after ITVRP intervention not measured
- Lack of control group to investigate the differences in ITVRP and conventional therapy.
- Lasted 8-weeks. no long-term follow-up evaluation(min 6 months required for long term effects)
- ITVRP did not involve haptics

Why VR used in this research?



Our Perspective:

PRO:

1. Good try (1st to apply proprioceptive neuromuscular facilitation concept)
2. Provide more convenience method of rehabilitation
   - reduce transport needs
   - reduce time consumption
   - reduce location problem
   - reduce loneliness
3. Allow elderly to experience new technology.

Con:

1. Patients might addict to the rehabilitation program
2. Technical issue might happen
3. Lack of haptics exercise

Technical lesson learned

Simple equipment used:

- A notebook computer
  - used for install and run the program
- A motion-capture sensor
  - Captured 20 body segments of the participant
  - Low resolution: 640 x 481 pixels at 30Hz (RGB camera) & 320 x 240 pixels at 30Hz (infrared depth-finding camera)
- 50-inch PDP display monitor

Critical:

- Minor adverse effects that may stem from the equipment used and prolonged exposure to a screen while doing different exercises and movements.
- Only one motion capture sensor connected to the main computer

Did the use of VR technology make a difference?

Yes & Could GO BETTER!!

Most difference seen was in 74-77 year old participants. Proves that VR training was helpful!

1 participant did get nauseous, maybe VR wasn't that Individually Tailored? Perhaps use customised games code apart from avatars/adjusting calibration?

Research only restricted to upper limb movement. Perhaps use both AR/VR to see a change?

Ability to manually lift objects was not exercised. Muscle recovery gets impacted with weight training! Should be included in VR?

More modern equipment and interventions like cognitive mapping for post stroke therapy are now being utilised.

Are we ready for **Bio-feedback based new VR exercise games** for post stroke recovery?

Q&A

Thank you for your listening