Web3D Standardization Meeting at SIGGRAPH 2019

Web3D Korea Chapter

- **Date** July 29 (Monday), 2019, at 14:00–17:00
- **Place** Hotel Indigo Los Angeles Downtown (SIGGRAPH 2019)

Supported by KSA (Korean Standards Association) and RRA (National Radio Research Agency)

- **Agenda (tentative)**

14:00-14:20	• X3D C/C++/C# binding (Myeong Won Lee, U. of Suwon) • X3D C/C++ binding viewer (Myeong Won Lee) • X3D C# binding Unity viewer (Myeong Won Lee)
14:20-14:40	• X3D Python binding (Myeong Won Lee) • X3D Python binding viewer (Myeong Won Lee)
14:40-15:00	• Cybersickness evaluation using electromyography (Hyun Kyoon Lim, KRISS (Korea Research Institute of Standards and Science)) • Discussion on standardization
15:00-15:20	• ISO TC 184/SC 4/JWG 16 STEP model visualization projects (Soonhung Han, KAIST) • Discussion on standardization

Cybersickness Evaluation Using Electroencephalography (EEG)

Jul. 29. 2019

Hyun Kyoon Lim, Ph.D.,
Principal Research Scientist, Professor


한국표준과학연구원
KRISS
KRISS

KRISS

- National Measurement Institute (standard) in Korea
- Measurement
- Calibration
- Uncertainty

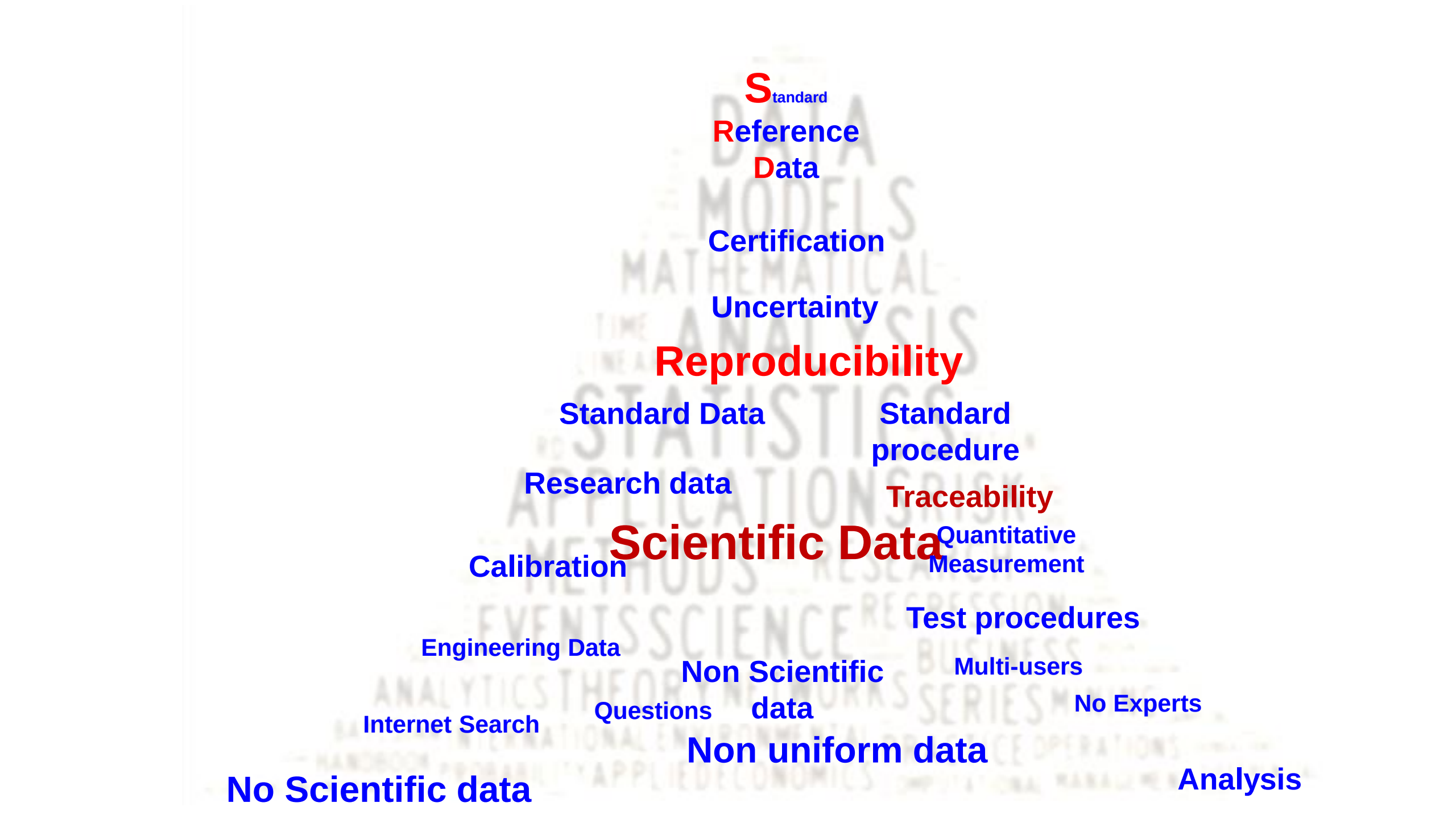

KRISS
KRISS 1975 ~ (KOREA)

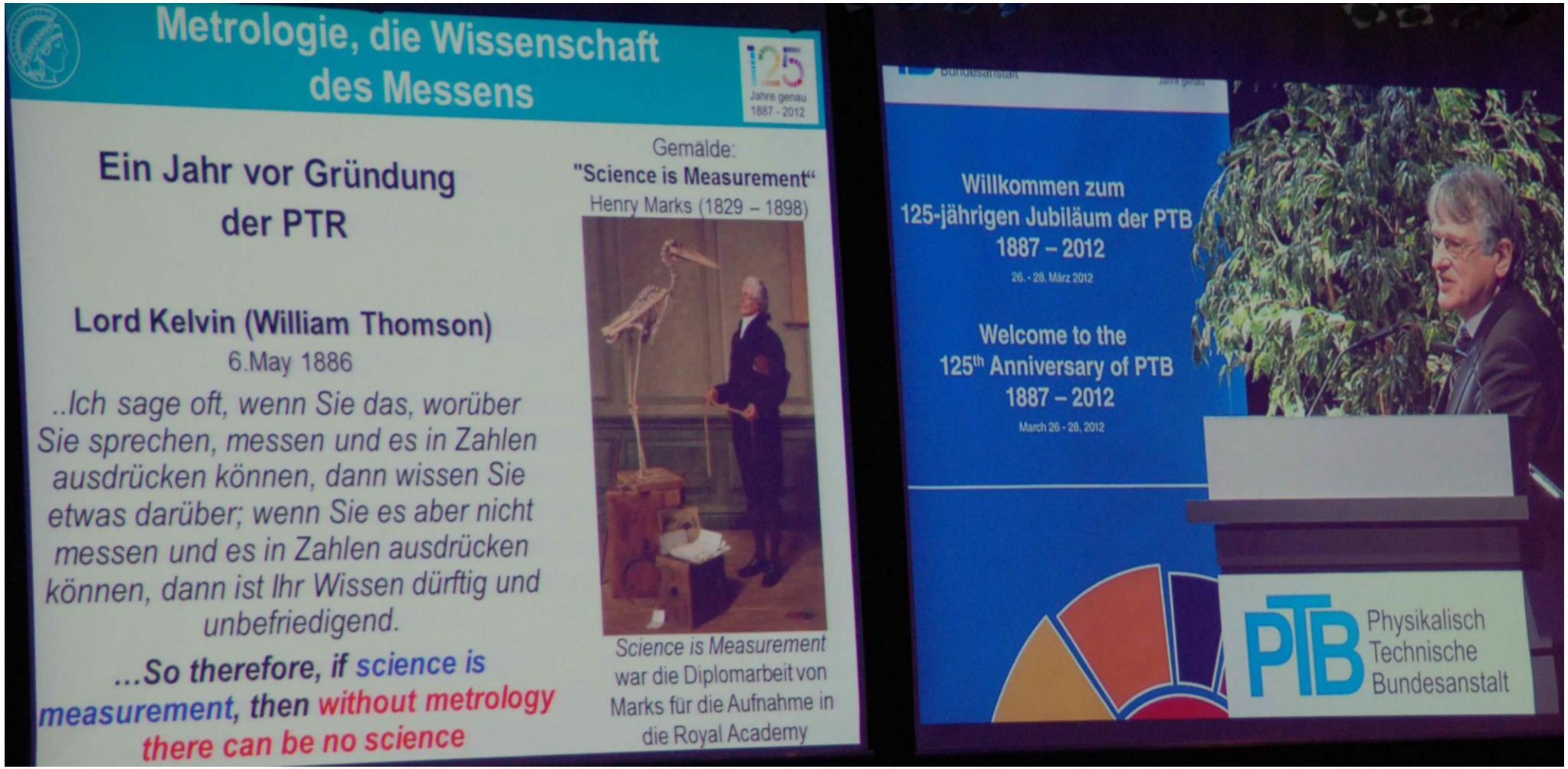

PTB
Physikalisch-Technische Bundesanstalt
Bundesallee 100
PTB 1887 ~(Germay)


NIST 1901 ~ (USA)

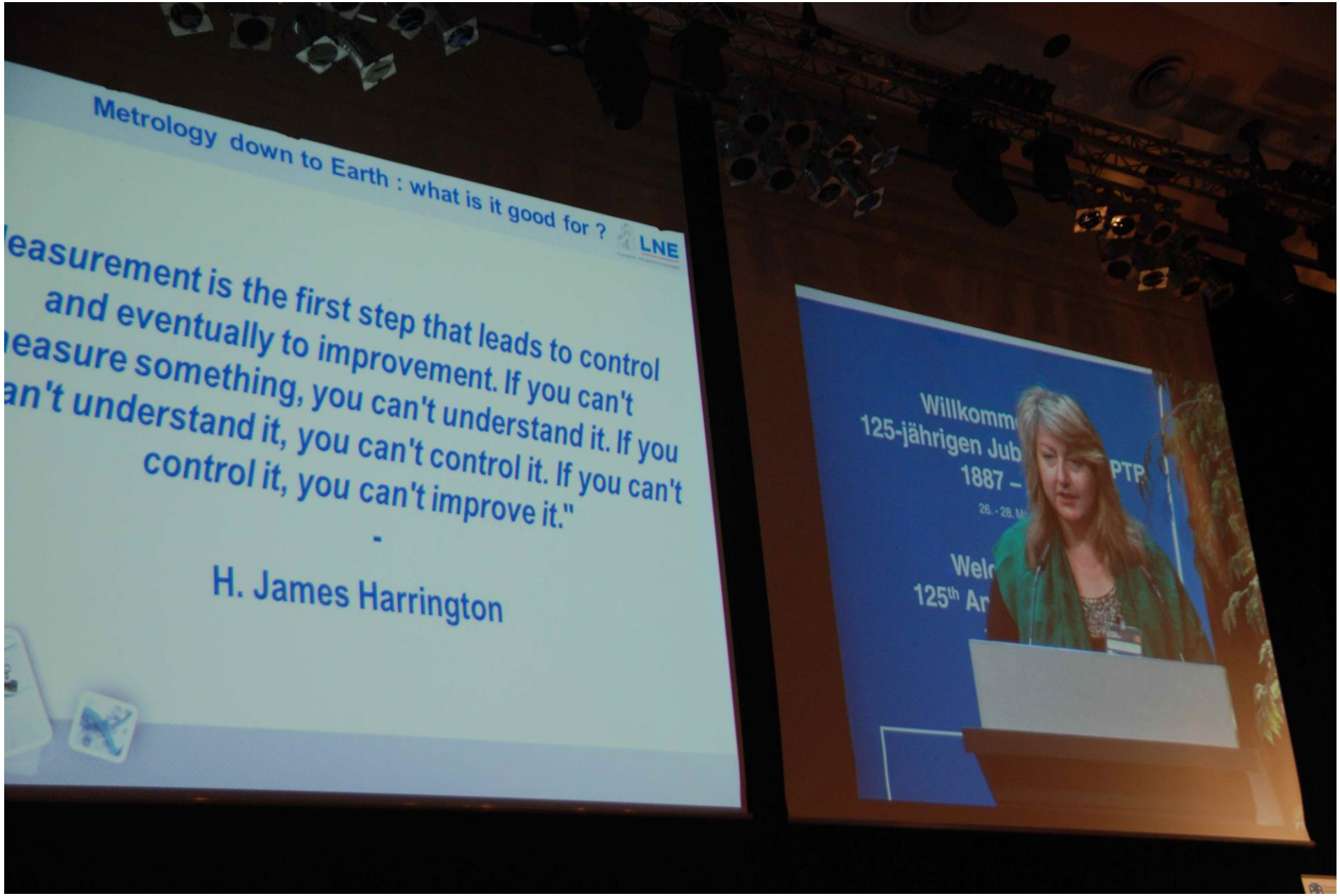

NPL 1900 ~(UK)

Introduction


Standard
Reference
Data
Certification
Uncertainty
Reproducibility
Standard Data
Standard procedure
Research data
Traceability
Scientific Data
Quantitative Measurement
Calibration
Test procedures
Engineering Data
Non Scientific data
Multi-users
Questions
No Experts
Internet Search
Non uniform data
No Scientific data
Analysis



If Science is measurement , then without metrology there can be no science.


Metrology down to Earth : what is it good for ?
LNE
easurement is the first step that leads to control
and eventually to improvement. If you can't
easure something, you can't understand it. If you
an't understand it, you can't control it. If you can't
control it, you can't improve it."
-
H. James Harrington
Willkomm
125-jährigen Jub
1887 –
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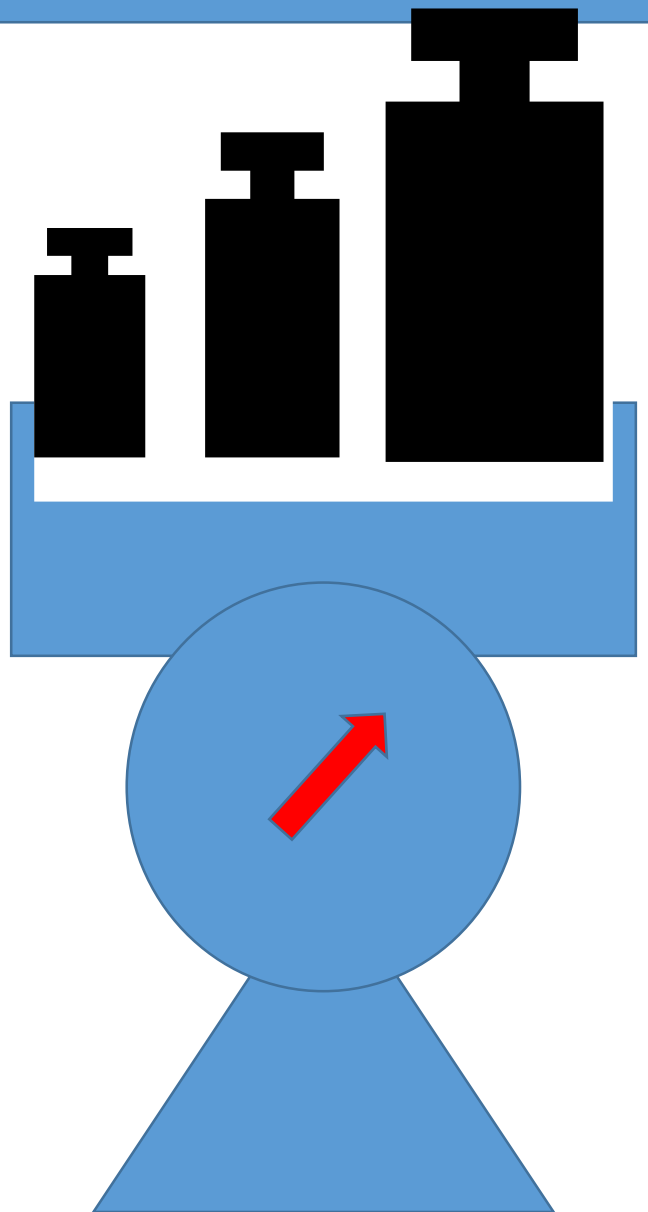
“Measurement is the first step that leads to control and eventually to improvement.

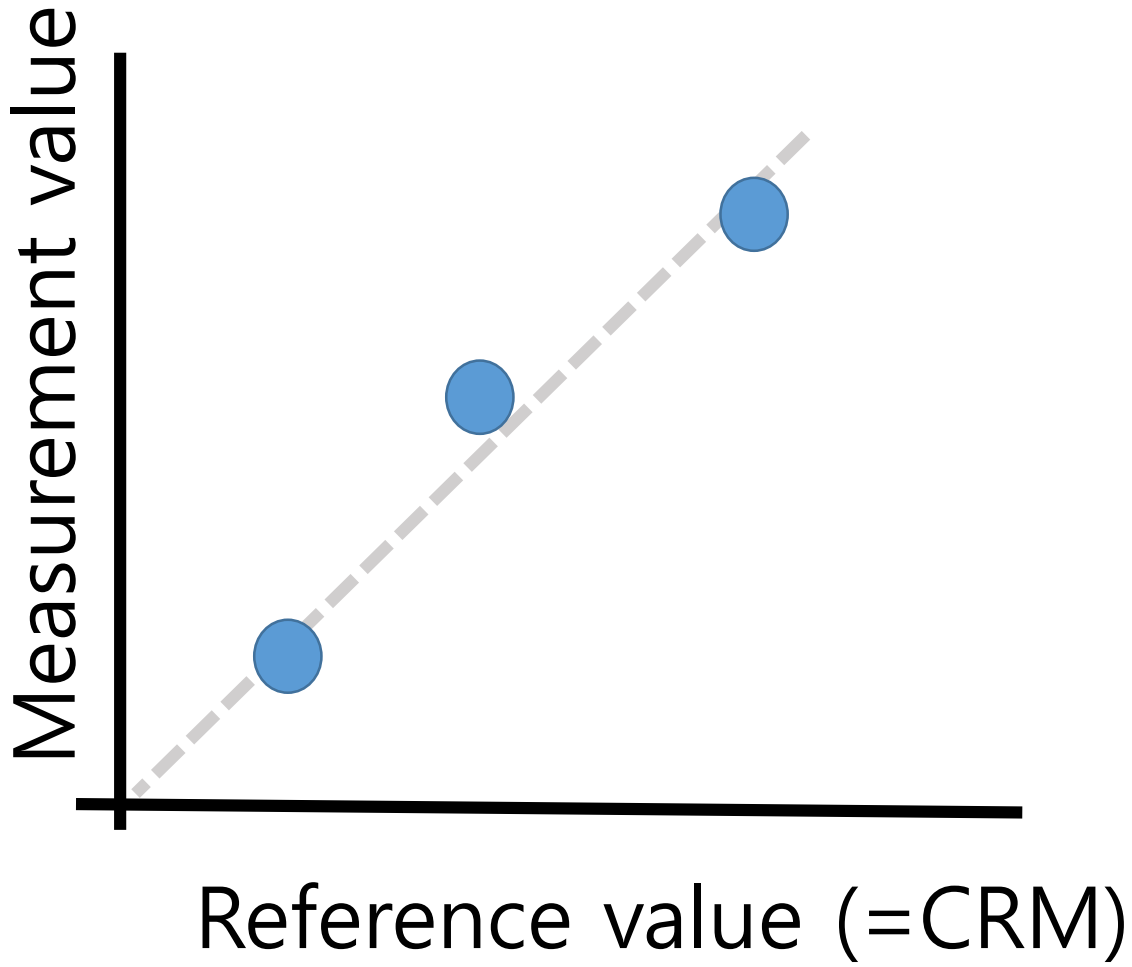
If you can't measure something, you can't understand it.

If you can't; understand >> control >> improve it.

H. James Harrington

Calibration



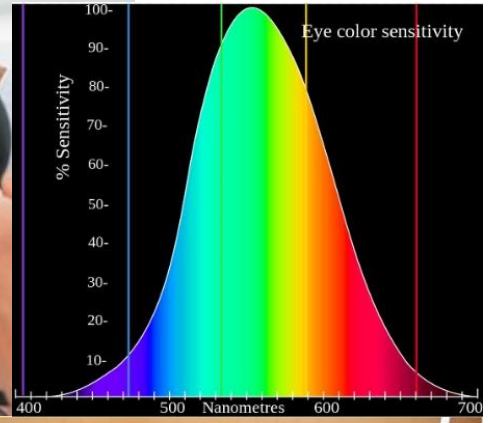


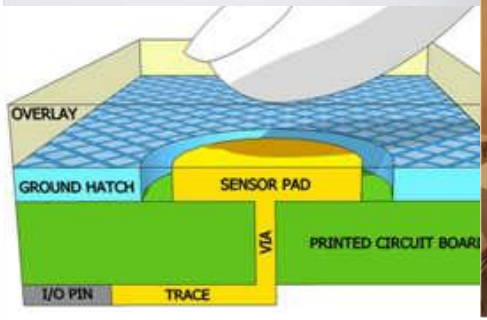
CRM=Certified Reference Material

Hard Metrology

vs.

Soft Metrology

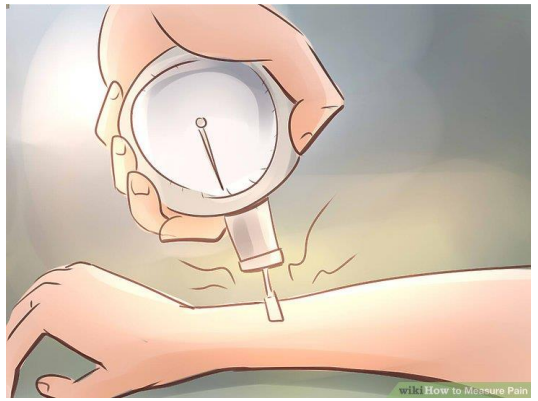




XVIII IMEKO WORLD CONGRESS (2006)

Hard Metrology

Soft Metrology



Hard Metrology

Soft Metrology

Background

- Promising technologies in many fields:

  VR (Since 1990)
- In the medical field, VR have been studied

  for various medical application

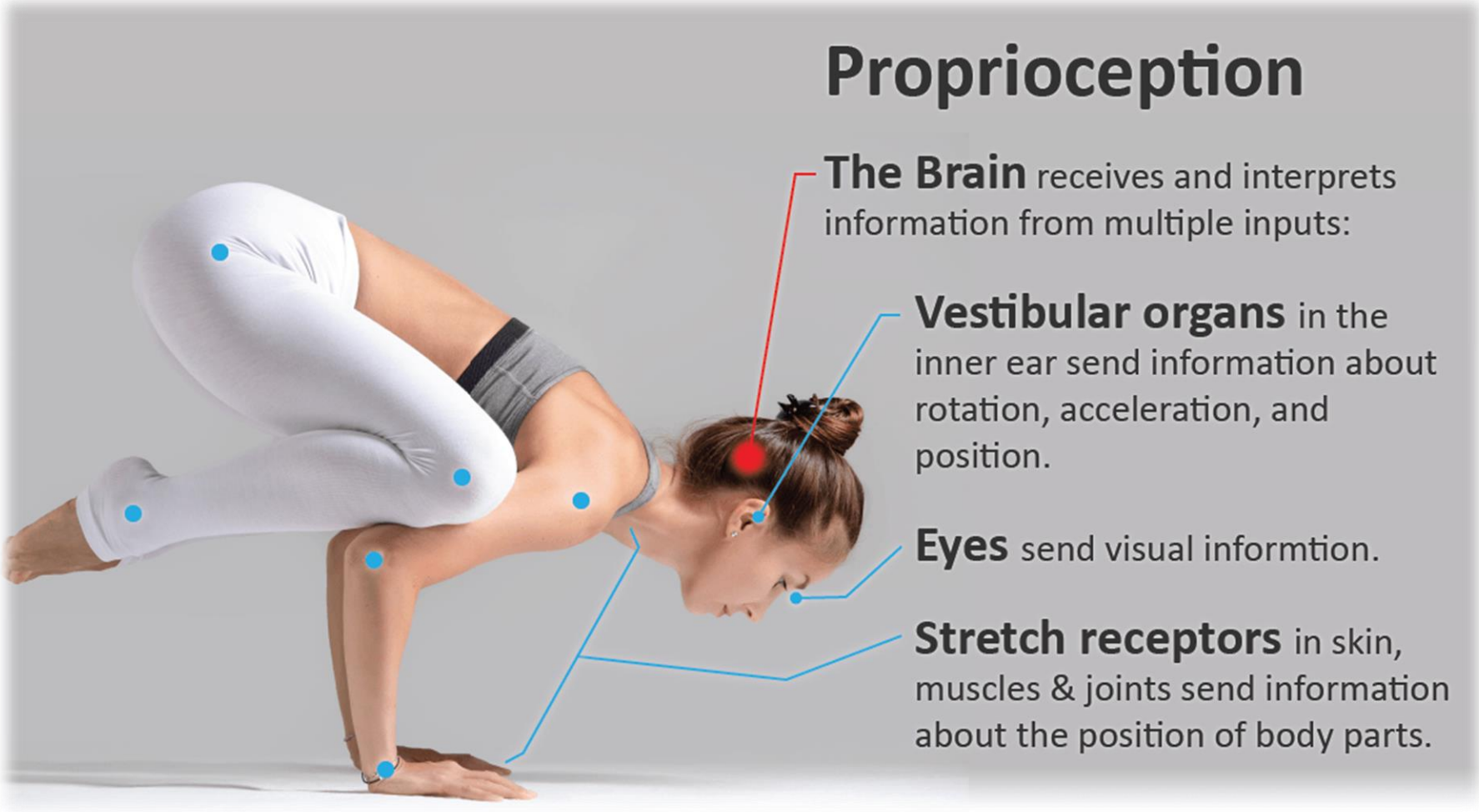
  including anxiety, phobia, chronic pain, etc..
- User immersion is one of the main issues.
- Cybersickness is also an issue in user immersion.

Background (cont.)

- Cybersickness can cause discomfort to the users with various symptoms.
- There are a number of factors that contribute to cybersickness.
- Most previous studies considered insufficient variables.
- It becomes more important to measure the degree of cybersickness objectively and quantitatively.

Motion sickness ← Sensory mismatch theory

- The information such as vestibular organs, vision, proprioception, etc. are synchronized. Changes in the external environment due to their body movements and movements are similarly perceived.



Sensory mismatch theory

- Motion perception is caused only by visual stimulation without involvement of the vestibular system, resulting in motion sickness due to mismatch between sensory information (vestibular organ and vision).

Cybersickness

Simulator sickness

Gaming sickness

Cinema sickness

- Rotational speed
- Speed of movement
- Motion axes
- Rotation range
- Navigation control
- Background complexity
- VR fidelity

} Optical flow

- Age
- Gender
- Prior experience
- MS susceptibility
- Duration

Content → Hardware → Human factors

- Display types
- Rendering modes
- Head tracking
- Field of view(FOV)
- Latency
- Flicker

Cybersickness

- Rotational speed
- Speed of movement
- Motion axes
- Rotation range
- Navigation control
- Background complexity
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} Optical flow

- Age
- Gender
- Prior experience
- MS susceptibility
- Duration

Cybersickness

Content → Hardware → Human factors → Objective measurements → Subjective measurements

- Display types
- Rendering modes
- Head tracking
- Field of view(FOV)
- Latency
- Flicker

- EEG
- fMRI
- ECG
- Postural sway
- EGG
- GSR

- SSQ
- FMS
- Nausea scale

- The purpose of this study is to develop objective measurement method for cybersickness and to investigate the effect of the potential factors that can cause cybersickness on the contents (movement, rotation) while measuring EEG.

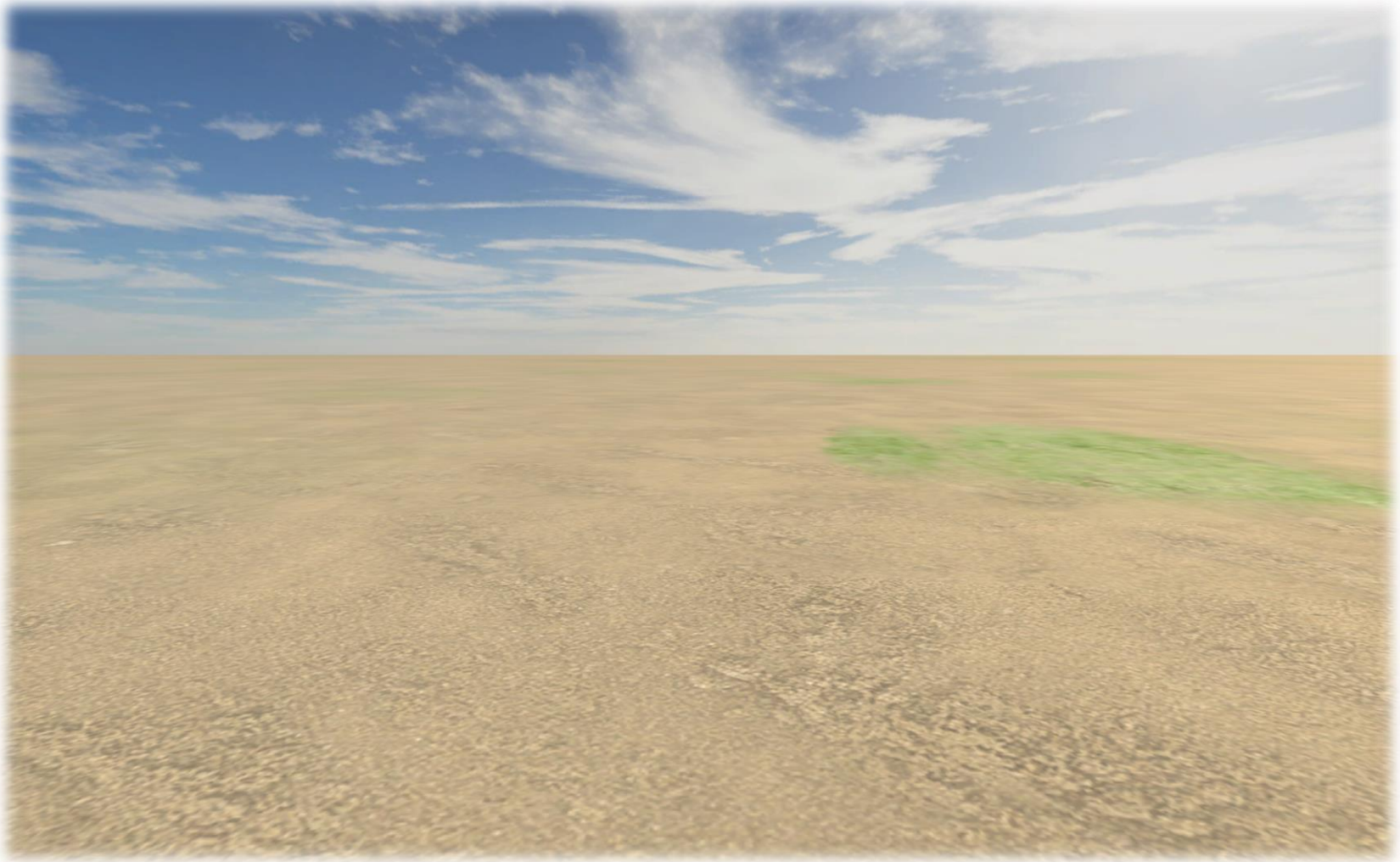
EEG

Method

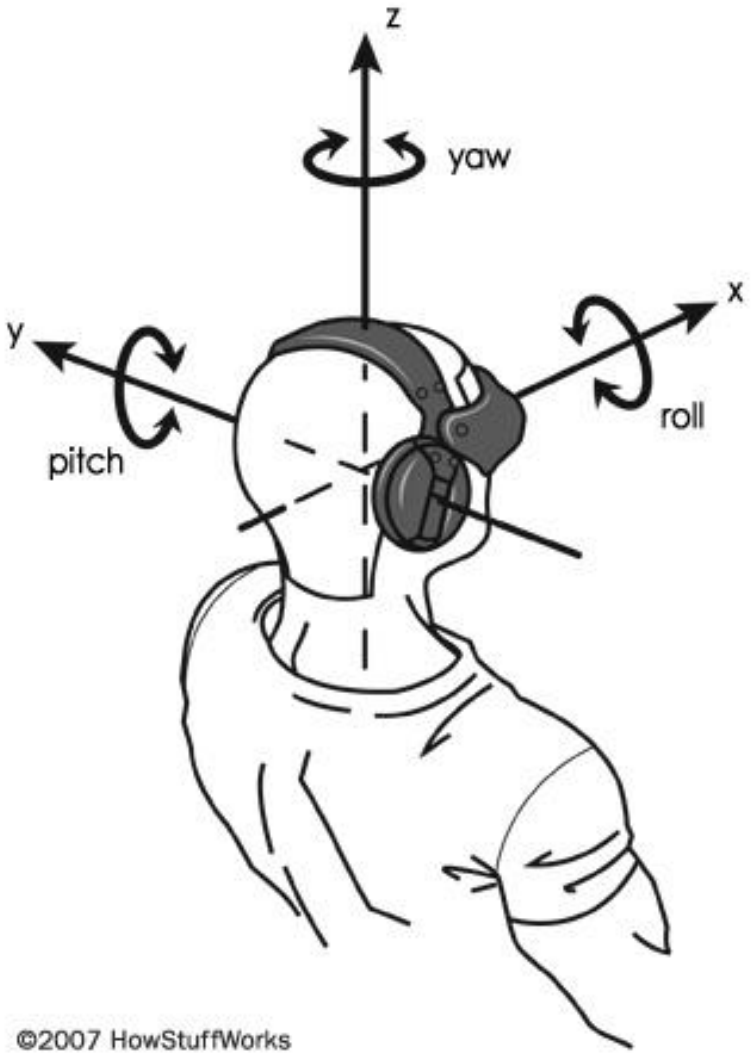
- Participants
  - 10 healthy male participants (26.4±2.72 years)
  - The participants participated in the experiment twice between 1 to 6 days
- Experiment environment
  - Monitor
    - 23-inch flat panel monitor (Resolution: 1920x1080 pixels)
    - 49-inch curve monitor (Resolution: 3840x1080 pixels)

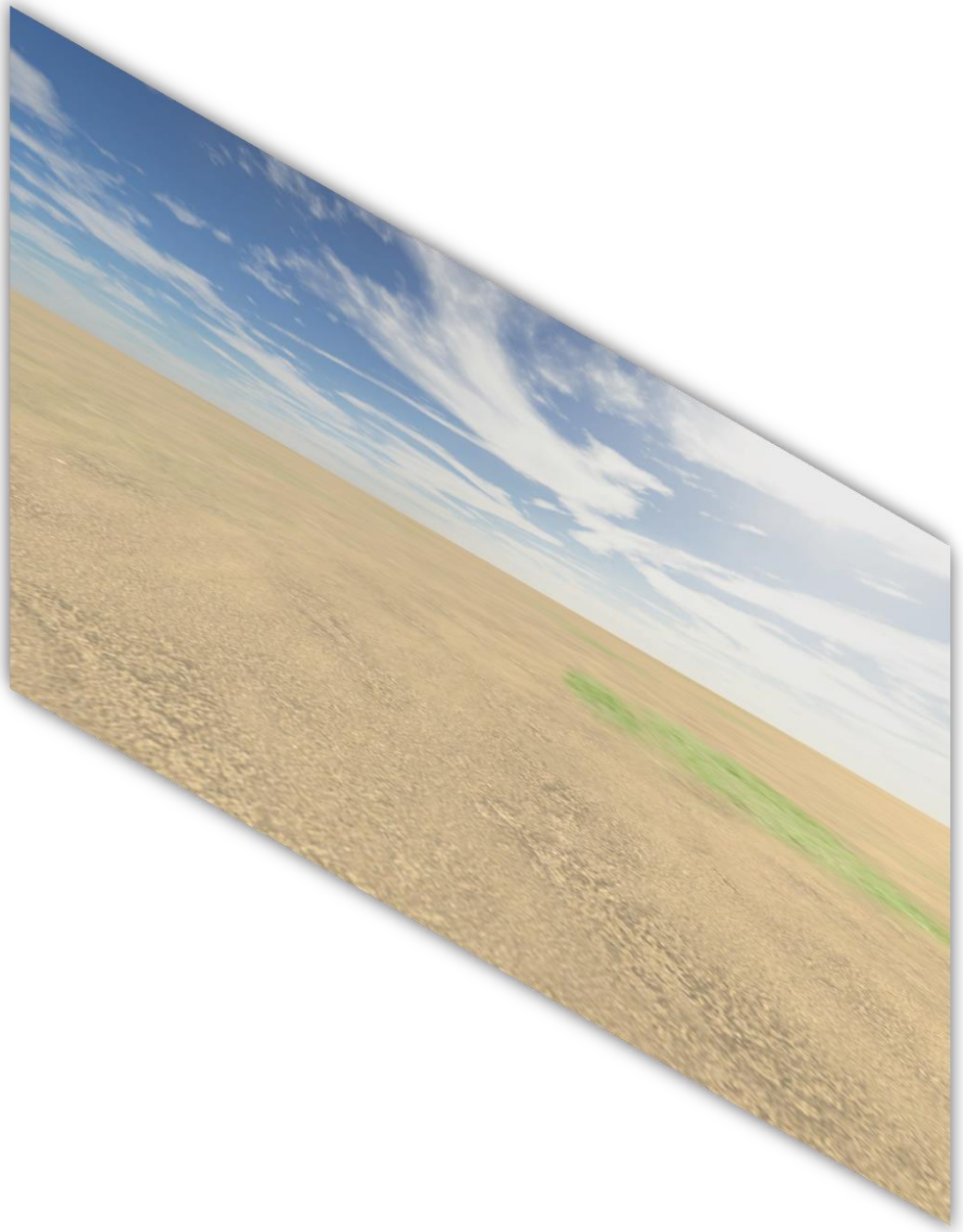
- Display types (23-inch flat panel monitor vs 49-inch curve monitor)

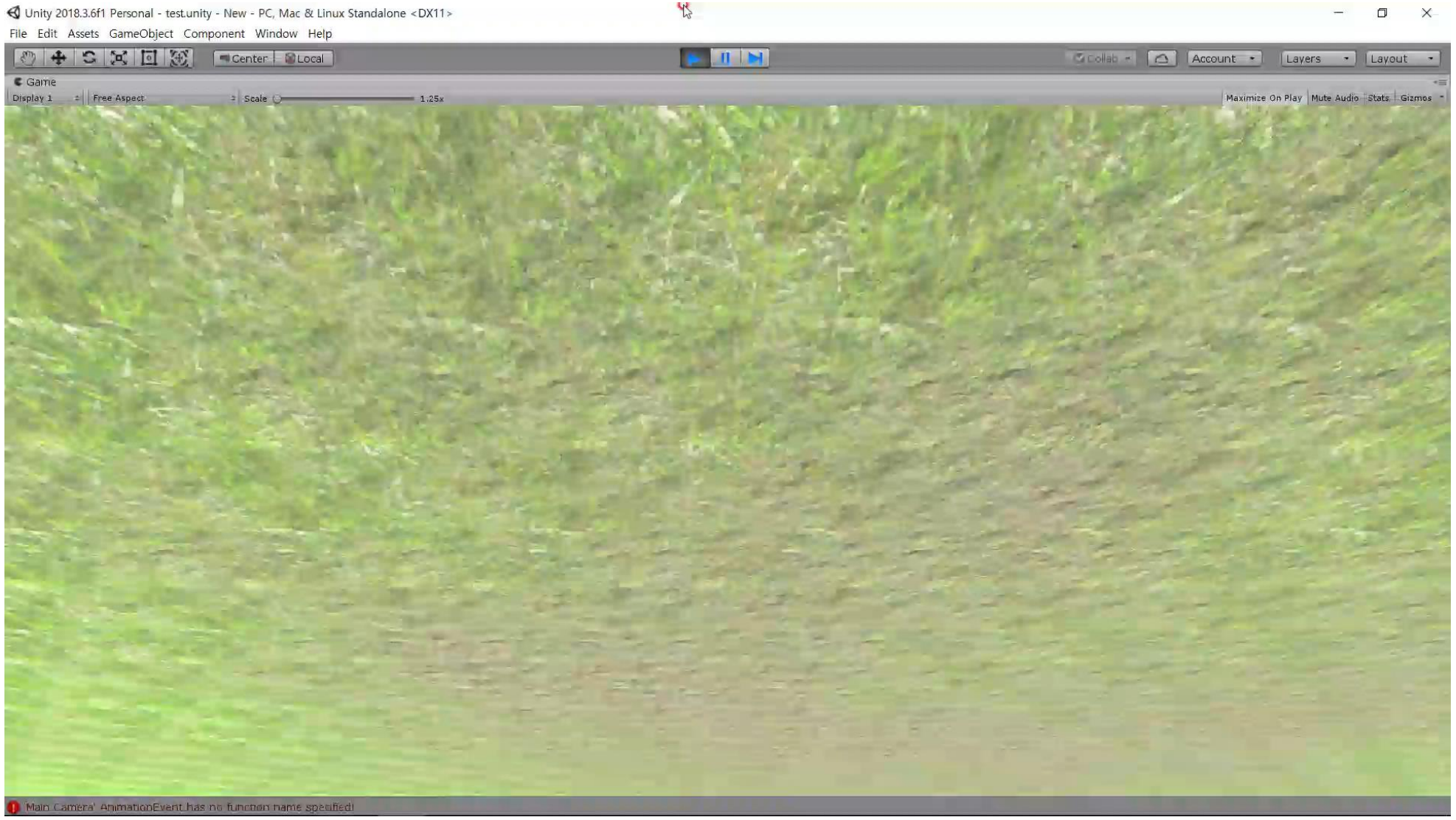
- Content (Scene design)



- Content (Motion axes)



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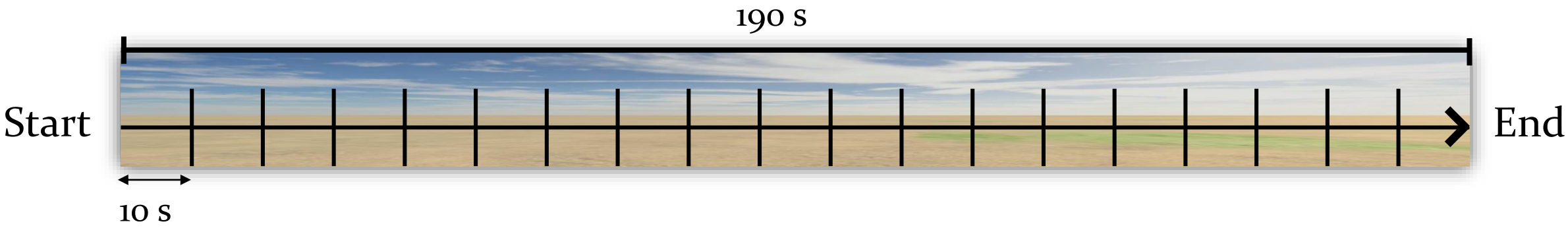
- Content (Optical flow)
  - Movement direction
    (Stop, Forward & Backward, Leftward & Rightward, Upward & Downward)
  - Rotation direction (Roll, Pitch, Yaw)
  - Speed
    - Movement: 2 m/s ~ 20 m/s
    - Rotation: 15 °/s ~ 123 °/s



Movement: +1 m/s
Rotation: +6 °/s

- Motion sickness susceptibility questionnaire (MSSQ)

1. Your CHILDHOOD Experience Only (before 12 years of age)

As a child (before age 12), how often you **Felt Sick or Nauseated** (tick boxes):

	Not Applicable - Never Travelled	**Never Felt Sick**	**Rarely Felt Sick**	**Sometimes Felt Sick**	**Frequently Felt Sick**
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

- Motion sickness susceptibility questionnaire (MSSQ)

1. Your Experience over the LAST 10 YEARS (approximately)

Over the LAST 10 YEARS, how often you **Felt Sick or Nauseated** (tick boxes):

	Not Applicable - Never Travelled	**Never Felt Sick**	**Rarely Felt Sick**	**Sometimes Felt Sick**	**Frequently Felt Sick**
Cars					
Buses or Coaches					
Trains					
Aircraft					
Small Boats					
Ships, e.g. Channel Ferries					
Swings in playgrounds					
Roundabouts in playgrounds					
Big Dippers, Funfair Rides					
	t	0	1	2	3

- Simulator sickness questionnaire (SSQ)
  - 4 major motion sickness
    - Nausea
    - Eyestrain
    - Dizziness
    - Headache

※ Subjects answered the degree of four major motion sickness symptoms verbally (0-4 scores)

Fast motion sickness (FMS)

※ Subjects answered the degree of cybersickness verbally (0-20 scores)

- Experimental procedure

- If you feel cybersickness in watching the content, press the button immediately.
- If you experience severe cybersickness, you can stop the experiment in the middle.

- EEG analysis

- We analyzed the last 10 seconds of a scene (3 min and 10 sec).

  - Physiological signals are already reacting before subjective judgment.

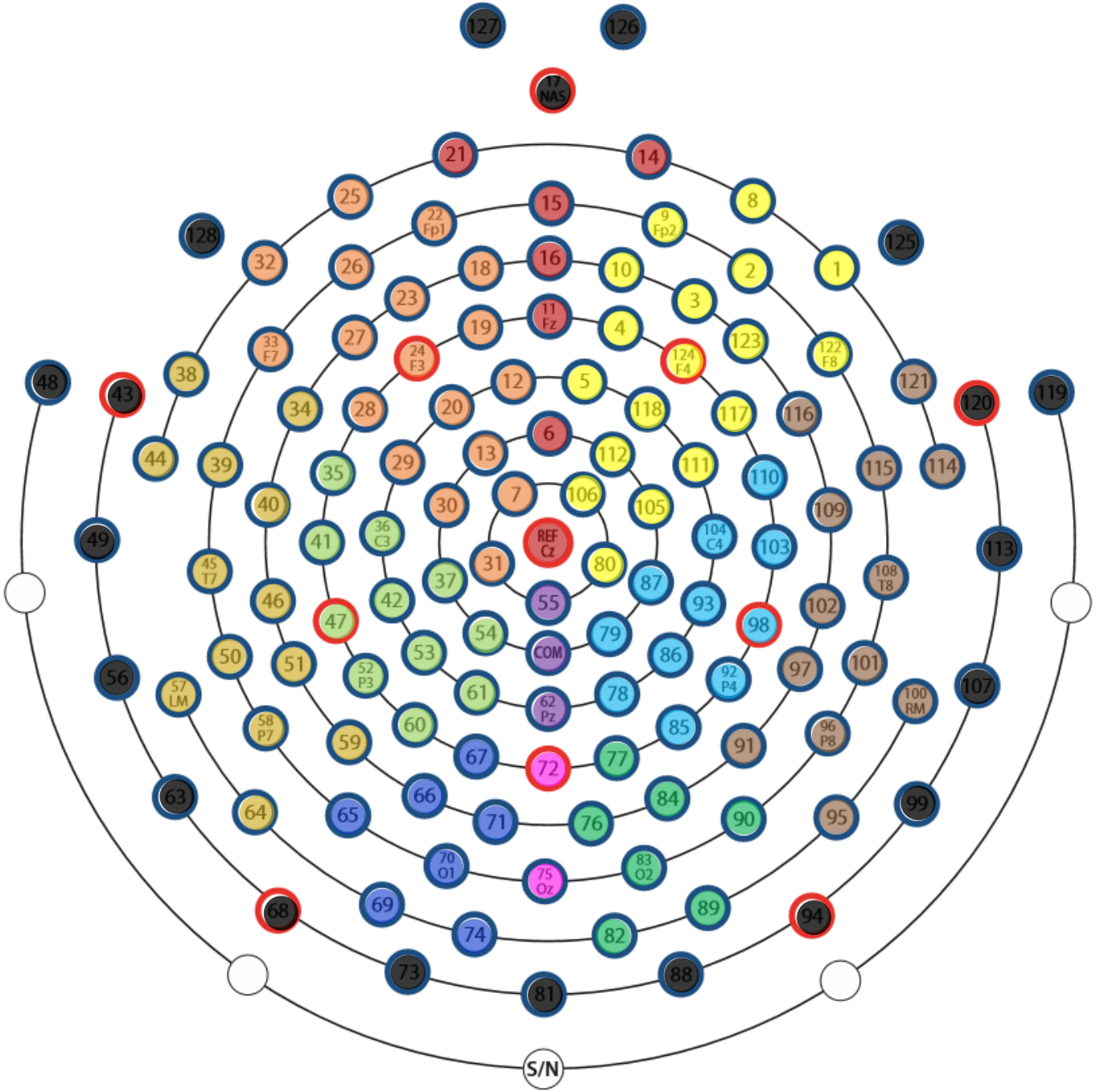
  → The most severe part of the experience.

- EEG

  - Compared the power value of 11 areas with 128 electrodes.

    - Frontal cortex (Left, Middle, Right)
    - Parietal cortex (Left, Middle, Right)
    - Temporal cortex (Left, Right)
    - Occipital cortex (Left, Middle, Right)
    - Compared with fMRI studies
    - 20 electrodes (black) are not included in the analysis because they contain more noise, such as muscle movements, than brain waves.

- EEG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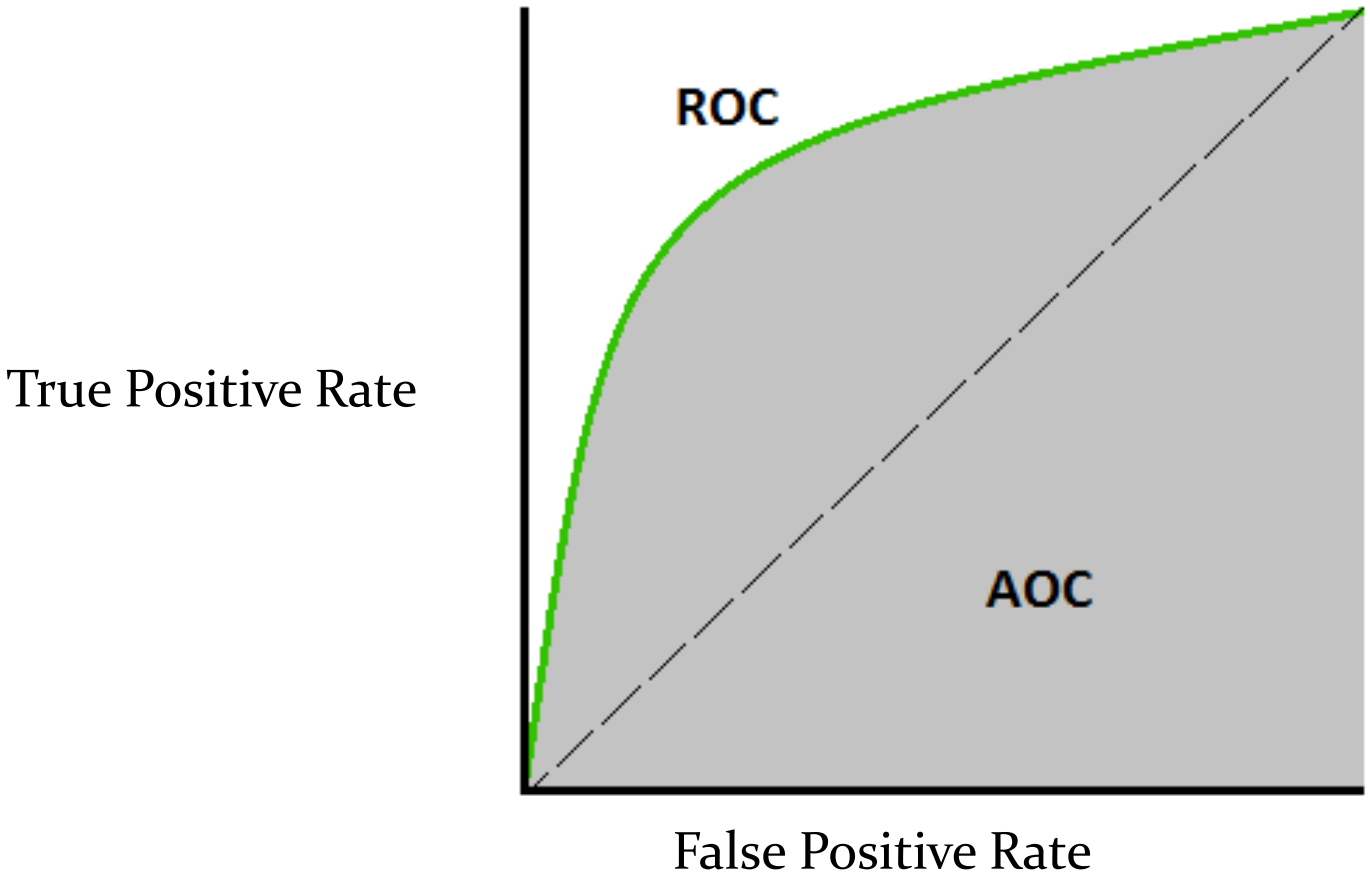
88
81
S/N

- Brain activation is inversely related to Alpha Power.

- Delta Power, a statistically significant difference in many EEG prior studies.

- Receiver operating characteristic (ROC) Curve

  : Performance evaluation of Binary classifier system



- Receiver operating characteristic (ROC) Curve

: Performance evaluation of Binary classifier system

Total Population	Prediction of model is Positive	Prediction of model is Negative
The correct answer is Positive	True Positive	False Negative
The correct answer is Negative	False Positive	True Negative

$$\text{The y-axis of ROC Curve: True Positive Rate} = \frac{\sum \textit{The number of True Positive}}{\sum \textit{The number of The correct answer is Positive}}$$

- Receiver operating characteristic (ROC) Curve

: Performance evaluation of Binary classifier system

Total Population	Prediction of model is Positive	Prediction of model is Negative
The correct answer is Positive	True Positive	False Negative
The correct answer is Negative	False Positive	True Negative

$$\text{The x-axis of ROC Curve: False Positive Rate} = \frac{\sum \textit{The number of False Positive}}{\sum \textit{The number of The correct answer is Negative}}$$

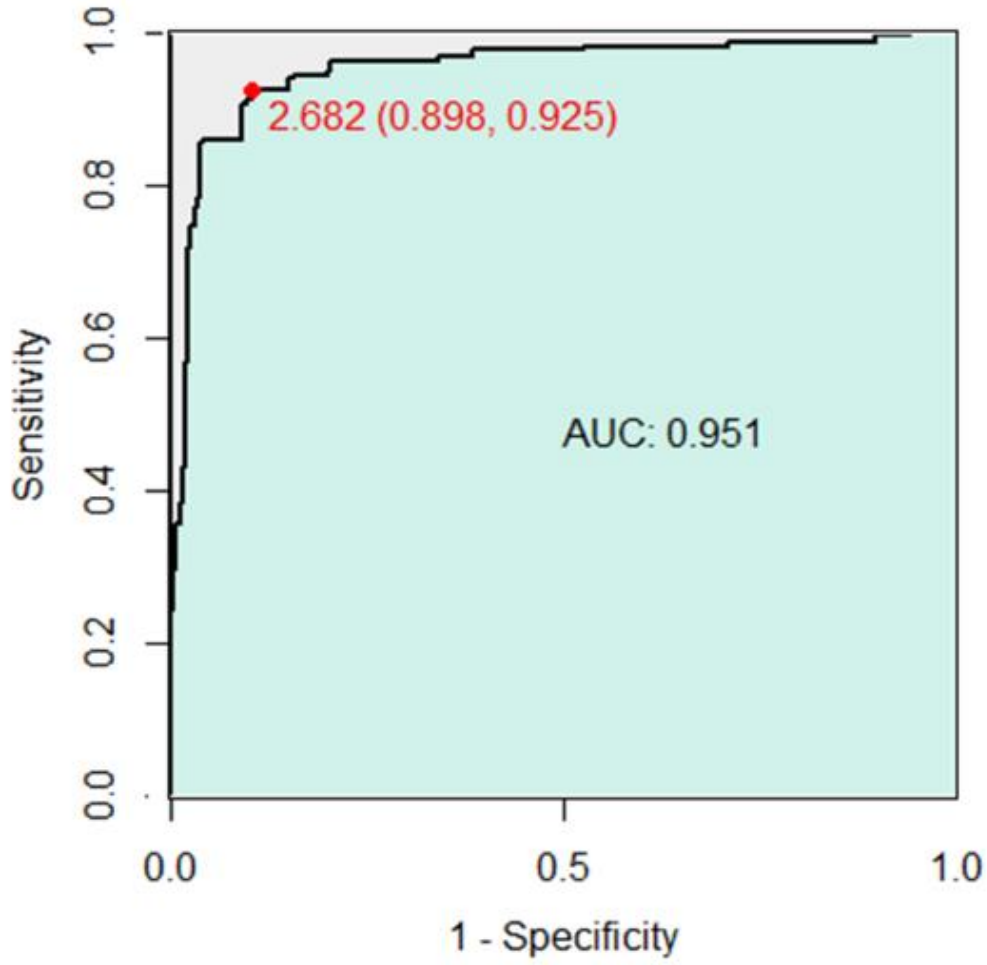
Results

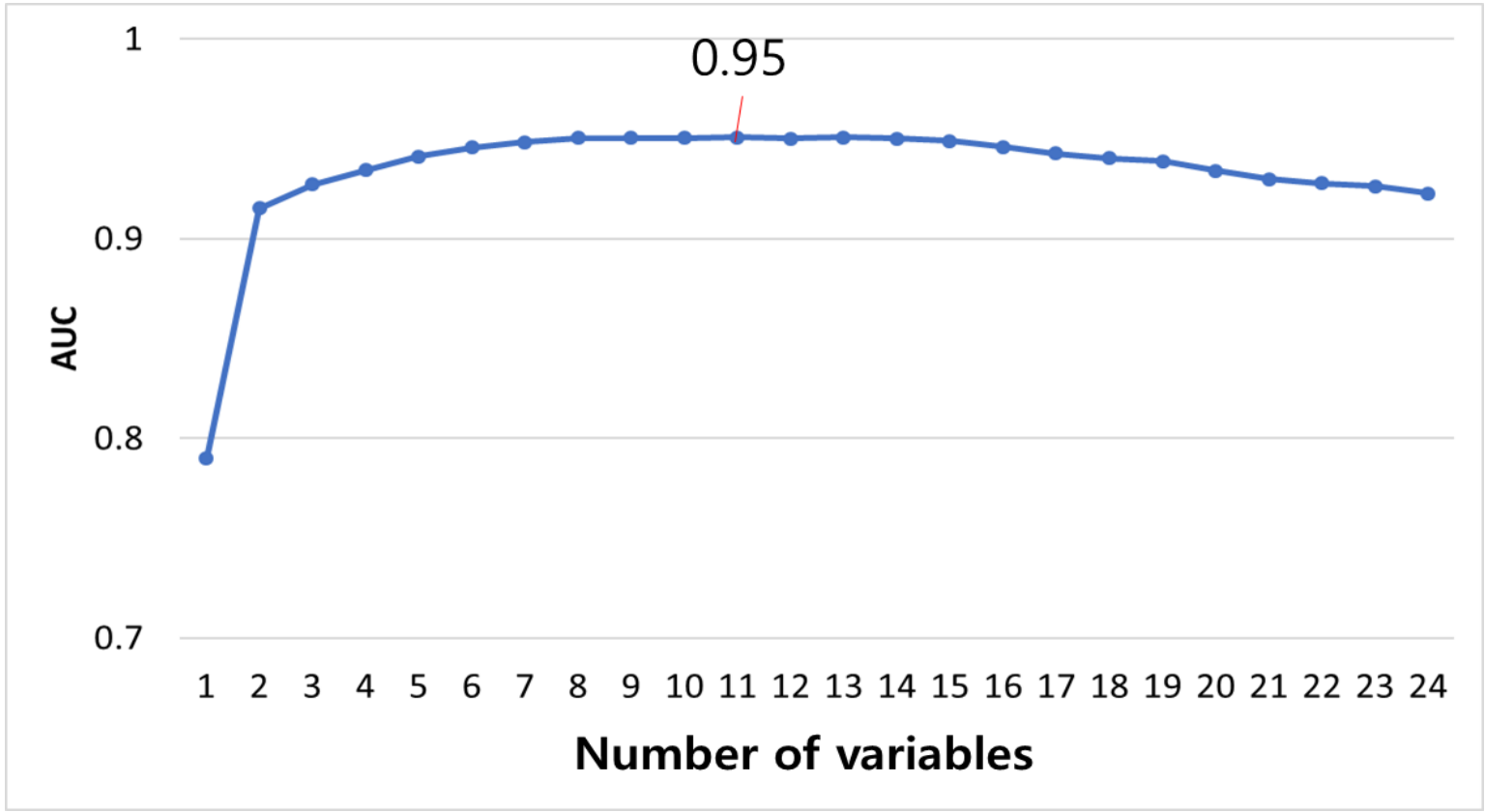
$$M_P = 1.4 - 53.8 * P_{D.MF} + 14.6 * P_{D.LP} - 20.5 * P_{D.MP}$$

$$+79.9 * P_{D.RP} - 11.3 * P_{D.MO} + 30.3 * P_{A.LF} - 50.8 * P_{A.MF}$$

$$+41.0 * P_{A.RF} - 42.1 * P_{A.LP} + 61.6 * P_{A.RP} - 36.2 * P_{A.MO}$$

$P_{D.MF}$, Delta power in the middle frontal lobe;
$P_{D.LP}$, Delta power in the left parietal lobe;
$P_{D.MP}$, Delta power in the middle parietal lobe;
$P_{D.RP}$, Delta power in the right parietal lobe;
$P_{D.MO}$, Delta power in the middle occipital lobe;
$P_{A.LF}$, Alpha power in left frontal lobe;
$P_{A.MF}$, Alpha power in the middle frontal lobe;
$P_{A.RF}$, Alpha power in the right frontal lobe;
$P_{A.LP}$, Alpha power in the left parietal lobe;
$P_{A.RP}$, Alpha power in the right parietal lobe;
$P_{A.MO}$, Alpha power in the middle occipital lobe





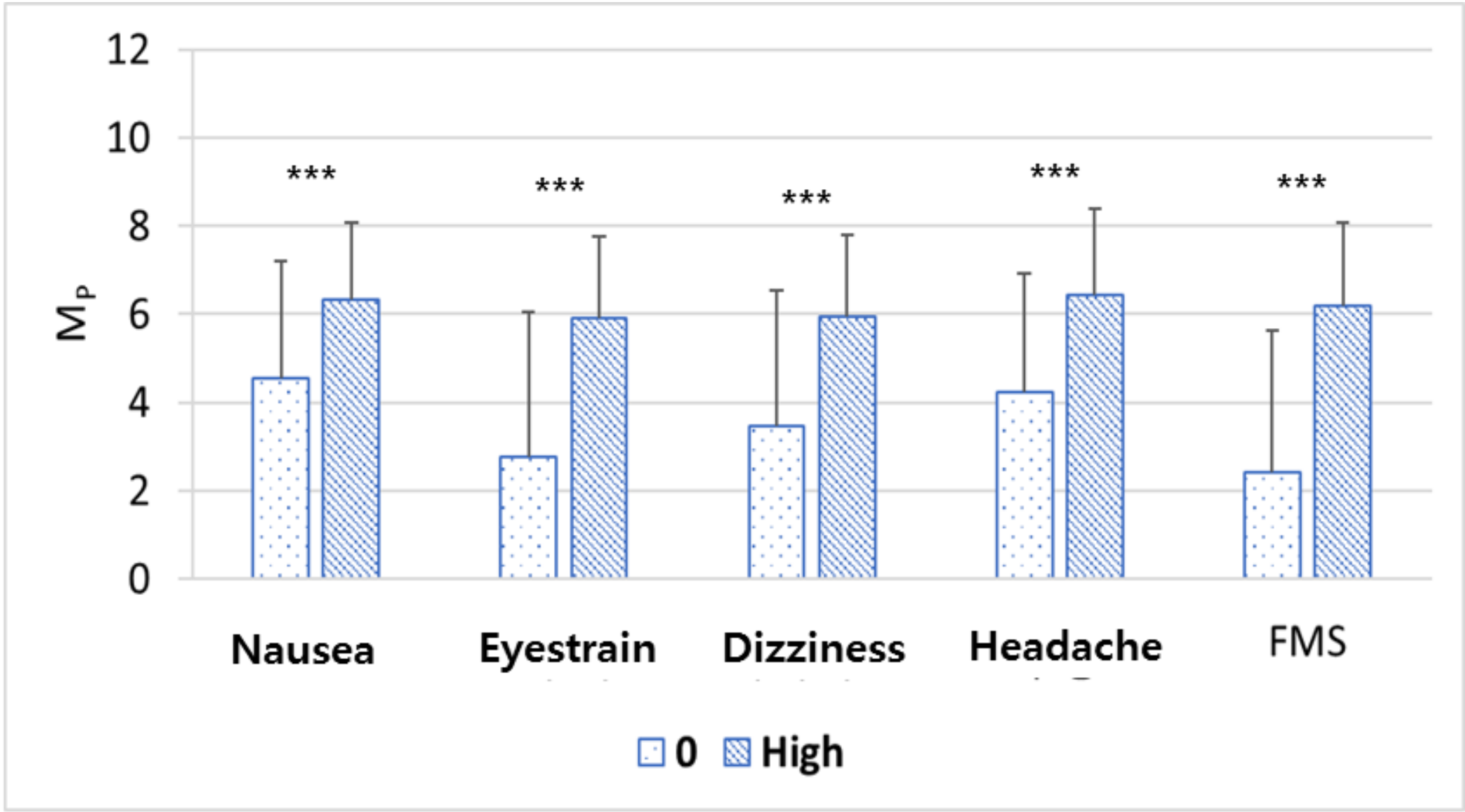
- AUC change according to the number of variables in multiple regression model, the 11 variables have the highest AUC (AUC = 0.95).

How many variables necessary?

The number of variables	Variables	AUC
1	$P_{D.MF}$	0.79
2	$P_{D.MF}$, $P_{D.RP}$	0.92
3	$P_{D.MF}$, $P_{D.RP}$, $P_{A.MO}$	0.93
4	$P_{D.MF}$, $P_{D.MP}$, $P_{D.RP}$, $P_{A.MO}$	0.93
5	$P_{D.MF}$, $P_{D.RP}$, $P_{D.LO}$; $P_{A.RP}$, $P_{A.LO}$	0.94
6	$P_{D.LP}$, $P_{D.RP}$, $P_{D.LO}$, $P_{A.LF}$, $P_{A.RF}$, $P_{A.LO}$	0.95
7	$P_{D.RF}$, $P_{D.LP}$, $P_{D.RP}$, $P_{D.LO}$, $P_{A.LF}$, $P_{A.RP}$, $P_{A.LO}$	0.95

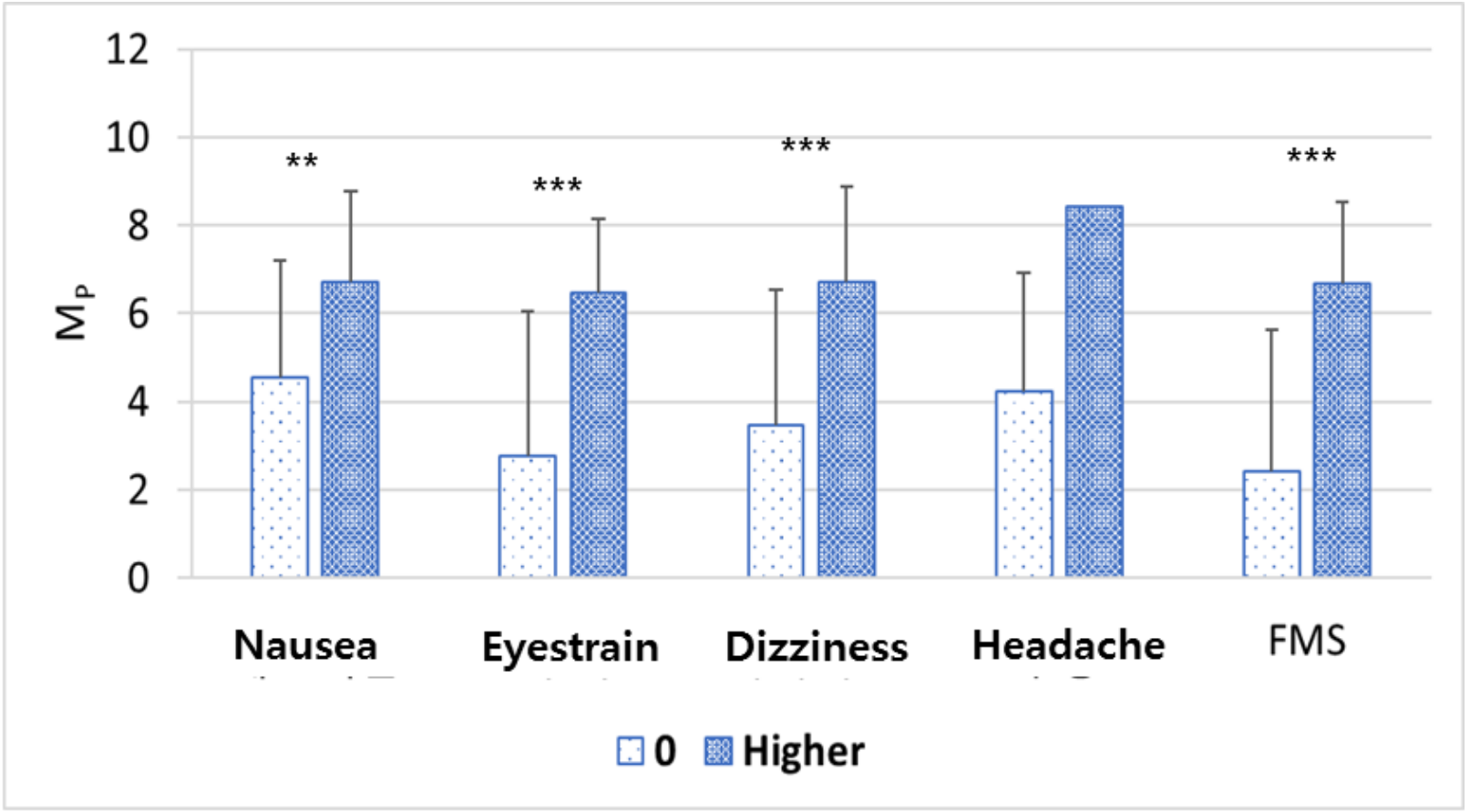
The corresponding variable according to the number of variables and AUC

o score versus High



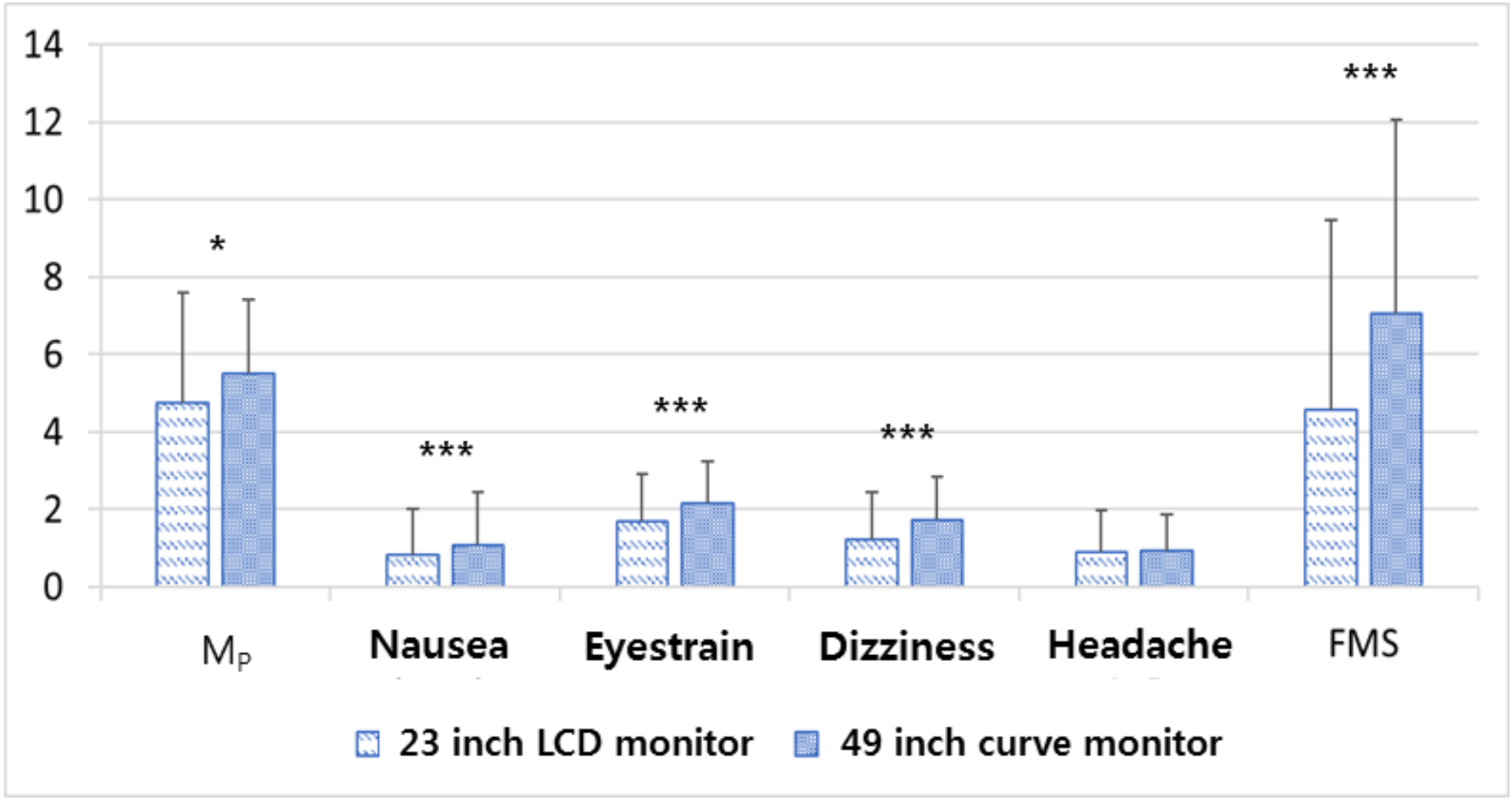
Note: High: 3~4 score (SSQ), 10~20 score (FMS)
* p<.05; ** p<.01; *** p<.001.

o score versus Higher



Note: Higher: 4 score (SSQ), 15~20 score (FMS)
* p<.05; ** p<.01; *** p<.001.

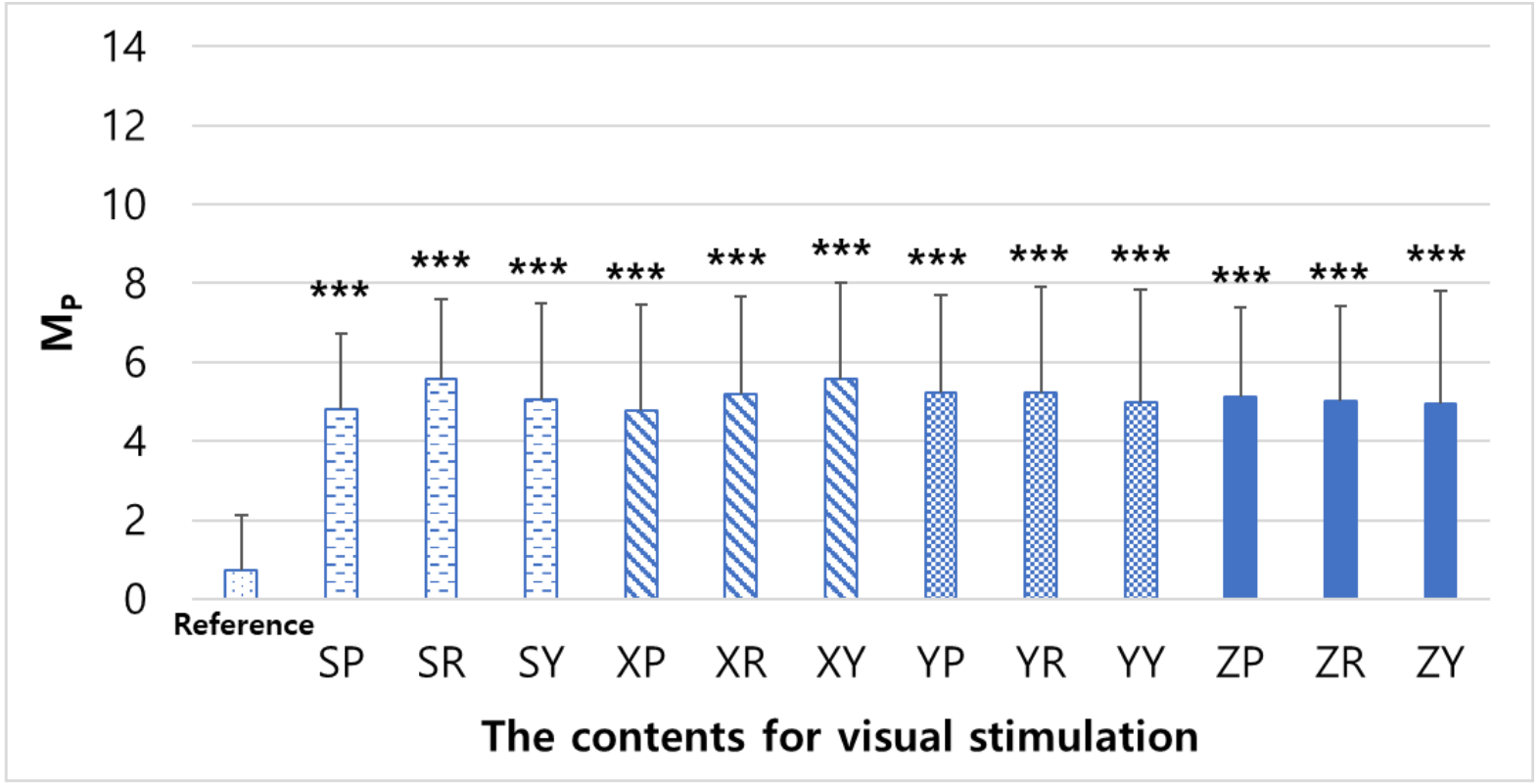
Comparison of questionnaire score and M_P value according to display type



* p<.05; ** p<.01; *** p<.001.

M_P values according to the type of movement and rotation

SP, Pitch rotation in stop state;
SR, Roll rotation in stop state;
SY, Yaw rotation in stop state;
XP, Pitch rotation in forward and backward motion;
XR, Roll rotation in forward and backward motion;
XY, Yaw rotation in forward and backward motion;
YP, Pitch rotation in left and right motion;
YR, Roll rotation in left and right motion;
YY, Yaw rotation in left and right motion;
ZP, Pitch rotation in up and down motion;
ZR, Roll rotation in up and down motion;
ZY, Yaw rotation with up and down motion.



* p<.05; ** p<.01; *** p<.001.

Conclusion

&

Homework

- We confirmed an objective response to cybersickness with high accuracy (95.1%, AUC = 0.95).
- We confirmed that there are specific sites (the frontal lobe, the parietal lobe, and the middle occipital lobe).
- This method and results will be a good reference for future research on cybersickness.

- Do we have standardized contents for the visual stimulation?
- Is MSSQ enough for the normalization or consideration?
- What vital signal could be the best tool to measure the cybersickness objectively?

References

1. Berntsen, K., R.C. Palacios, and E. Herranz. *Virtual reality and its uses: a systematic literature review.* in *Proceedings of the Fourth International Conference on Technological Ecosystems for Enhancing Multiculturality.* 2016. ACM.
2. Ferrer-Garcia, M., J. Gutiérrez-Maldonado, and G. Riva, *Virtual reality based treatments in eating disorders and obesity: a review.* Journal of Contemporary Psychotherapy, 2013. **43**(4): p. 207-221.
3. Parsons, T.D., et al., *Virtual reality in paediatric rehabilitation: a review.* Developmental neurorehabilitation, 2009. **12**(4): p. 224-238.
4. Wiederhold, B.K., *The potential for virtual reality to improve health care.* The Virtual Reality Medical Center, 2006.
5. Cornick, J.E. and J. Blascovich, *Are Virtual Environments the New Frontier in Obesity Management?* Social and Personality Psychology Compass, 2014. **8**(11): p. 650-658.
6. Llobera, J., et al., *Virtual reality for assessment of patients suffering chronic pain: a case study.* Experimental brain research, 2013. **225**(1): p. 105-117.
7. McCann, R.A., et al., *Virtual reality exposure therapy for the treatment of anxiety disorders: an evaluation of research quality.* Journal of anxiety disorders, 2014. **28**(6): p. 625-631.
8. Medling, B., *Virtual Reality Utilization in Health Care: It's Virtually Done.* Biomedical instrumentation & technology, 2005: p. 16.
9. Muhlberger, A., G. Wiedemann, and P. Pauli, *Efficacy of a one-session virtual reality exposure treatment for fear of flying.* Psychotherapy Research, 2003. **13**(3): p. 323-336.
10. Riener, R. and M. Harders, *Virtual reality in medicine.* 2012: Springer Science & Business Media.
11. Riva, G., et al. *NeuroVR: an open source virtual reality platform for clinical psychology and behavioral neurosciences.* in *MMVR.* 2007.
12. Rothbaum, B.O., et al., *A controlled study of virtual reality exposure therapy for the fear of flying.* Journal of consulting and Clinical Psychology, 2000. **68**(6): p. 1020.
13. Wiederhold, M.D. and B.K. Wiederhold, *Virtual reality and interactive simulation for pain distraction.* 2007, Blackwell Publishing Inc Malden, USA.
14. Larson, E.B., et al., *Tolerance of a virtual reality intervention for attention remediation in persons with severe TBI.* Brain Injury, 2011. **25**(3): p. 274-281.
15. McCauley, M.E. and T.J. Sharkey, *Cybersickness: Perception of self-motion in virtual environments.* Presence: Teleoperators & Virtual Environments, 1992. **1**(3): p. 311-318.
16. Rebenitsch, L. and C. Owen, *Review on cybersickness in applications and visual displays.* Virtual Reality, 2016. **20**(2): p. 101-125.
17. Chang, E., et al., *An Integrated Model of Cybersickness: Understanding User's Discomfort in Virtual Reality.* Journal of KIISE, 2018. **45**(3): p. 251-279.
18. So, R.H. and W. Lo. *Cybersickness: an experimental study to isolate the effects of rotational scene oscillations.* in *Proceedings IEEE Virtual Reality (Cat. No. 99CB36316).* 1999. IEEE.
19. Lo, W. and R.H. So, *Cybersickness in the presence of scene rotational movements along different axes.* Applied ergonomics, 2001. **32**(1): p. 1-14.
20. Bonato, F., et al., *Vection change exacerbates simulator sickness in virtual environments.* 2008. **17**(3): p. 283-292.
21. Chen, W., J. Chen, and R.H.Y. So, *Visually induced motion sickness: effects of translational visual motion along different axes.* Contemporary Ergonomics and Human Factors, 2011: p. 281-287.
22. Lubeck, A.J., J.E. Bos, and J.F.J.D. Stins, *Motion in images is essential to cause motion sickness symptoms, but not to increase postural sway.* 2015. **38**: p. 55-61.
23. Gavgani, A.M., D.M. Hodgson, and E.J.P.o. Nalivaiko, *Effects of visual flow direction on signs and symptoms of cybersickness.* 2017. **12**(8): p. e0182790.
24. Bhandari, J., P. MacNeilage, and E. Folmer. *Teleportation without Spatial Disorientation Using Optical Flow Cues.* in *Proceedings of Graphics Interface.* 2018.
25. Dascal, J., et al., *Virtual reality and medical inpatients: a systematic review of randomized, controlled trials.* Innovations in clinical neuroscience, 2017. **14**(1-2): p. 14.
26. Freina, L. and M. Ott. *A literature review on immersive virtual reality in education: state of the art and perspectives.* in *The International Scientific Conference eLearning and Software for Education.* 2015. " Carol I" National Defence University.
27. Valmaggia, L.R., et al., *Virtual reality in the psychological treatment for mental health problems: an systematic review of recent evidence.* Psychiatry Research, 2016. **236**: p. 189-195.
28. Weech, S., S. Kenny, and M. Barnett-Cowan, *Presence and Cybersickness in Virtual Reality Are Negatively Related: A Review.* Front Psychol, 2019. **10**: p. 158.
29. Bonato, F., A. Bubka, and S. Palmisano, *Combined pitch and roll and cybersickness in a virtual environment.* Aviation, space, and environmental medicine, 2009. **80**(11): p. 941-945.
30. Chardonnet, J.-R., M.A. Mirzaei, and F. Merienne. *Visually induced motion sickness estimation and prediction in virtual reality using frequency components analysis of postural sway signal.* in *International Conference on Artificial Reality and Telexistence Eurographics Symposium on Virtual Environments.* 2015.
31. Chen, D., et al., *Visually induced motion sickness after watching scenes oscillating at different frequencies and amplitudes.* Ergonomics & Human Factors. Blackpool, UK, 2012: p. 253-260.
32. Duh, H.B.-L., D.E. Parker, and T.A. Furness. *An "independent visual background" reduced balance disturbance envoked by visual scene motion: implication for alleviating simulator sickness.* in *Proceedings of the SIGCHI conference on human factors in computing systems.* 2001. ACM.
33. Keshavarz, B. and H. Hecht, *Axis rotation and visually induced motion sickness: the role of combined roll, pitch, and yaw motion.* Aviation, space, and environmental medicine, 2011. **82**(11): p. 1023-1029.
34. Kolasinski, E.M., *Simulator Sickness in Virtual Environments.* 1995, Army research Inst for the behavioral and social sciences Alexandria VA.
35. Liu, C.-L. and S.-T. Uang. *A study of sickness induced within a 3D virtual store and combated with fuzzy control in the elderly.* in *2012 9th International Conference on Fuzzy Systems and Knowledge Discovery.* 2012. IEEE.
36. So, R.H., A. Ho, and W. Lo, *A metric to quantify virtual scene movement for the study of cybersickness: Definition, implementation, and verification.* Presence: Teleoperators & Virtual Environments, 2001. **10**(2): p. 193-215.
37. So, R.H. and W. Lo. *Cybersickness with virtual reality training applications: a claustrophobia phenomenon with head-mounted displays.* in *Proceeding of the 1st world congress on ergonomics for global quality and productivity, Hong Kong.* 1998.
38. So, R.H., W. Lo, and A.T. Ho, *Effects of navigation speed on motion sickness caused by an immersive virtual environment.* Human factors, 2001. **43**(3): p. 452-461.
39. Dennison, M.S., A.Z. Wisti, and M. D'Zmura, *Use of physiological signals to predict cybersickness.* Displays, 2016. **44**: p. 42-52.
40. Gavgani, A.M., et al., *Profiling subjective symptoms and autonomic changes associated with cybersickness.* Autonomic Neuroscience, 2017. **203**: p. 41-50.
41. Kim, Y.Y., et al., *Characteristic changes in the physiological components of cybersickness.* Psychophysiology, 2005. **42**(5): p. 616-625.
42. LaCount, L., et al. *Dynamic cardiovagal response to motion sickness: a point-process heart rate variability study.* in *2009 36th Annual Computers in Cardiology Conference (CinC).* 2009. IEEE.