A **Co-Creative Approach** to the **Multimodal Assessment** of **Fatigue** in **Post-COVID Syndrome**: Integrating **Virtual Reality** and **Physiological Metrics**

Julia Belger[1,2], Mia Neubauer[1,2], Felix Klotzsche[2], Paul Chojecki[3], Carsten Finke[4], Michael Gaebler[2], Stephan Krohn[4], Mustafa Lafci[3], Jeroen de Mooij[2], Detlef Runde[3], Josefin Joy Sarow[4] & Angelika Thöne-Otto[1,2]

julia.belger@medizin.uni-leipzig.de

[1]*Universitätsklinikum Leipzig, Clinic for Cognitive Neurology, Leipzig Germany*
[2]*Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany*
[3]*Fraunhofer Institute for Telecommunications, Berlin, Germany*
[4]*Charité – Universitätsmedizin Berlin, Germany*

Introduction

Post-COVID Syndrome (PCS): Persistence/new symptoms ≥ 12 weeks after infection [1].

Fatigue and cognitive impairments: Frequent, disabling consequences of PCS; can occur independently [2].

Gap: Assessments mainly rely on subjective reports; **objective measures needed** [3].

Fatigue and cognitive impairments remain difficult to assess objectively.

Patient perspectives are rarely incorporated into study design and validation [4].

Aims

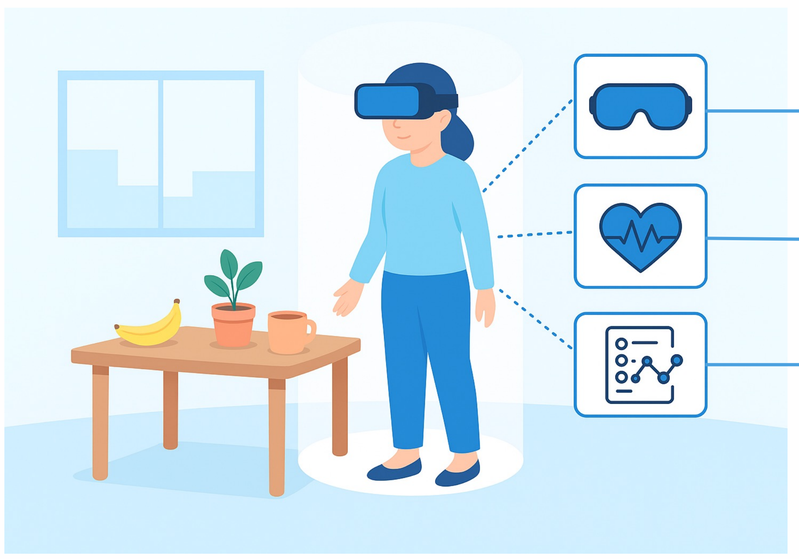
I. Multimodal Assessment:

Objective assessment of fatigue & cognition using a multimodal toolbox; identify subtypes

II. Co-Creation and Participation:

Co-creative development of a patient-centred, clinically feasible study design

Methods



Multimodal Diagnostic Toolbox

Virtual Reality performance:
Mobile immersive Virtual Memory Task

Autonomic health data:
Wearable sensors (ECG, smartwatch, accelerometer)

Digital psychometrics:
Fatigue questionnaires
Neuropsychological assessment

Interviews & Questionnaires

Preferences: Usability & feedback, VR task design with session duration, wearable acceptability

Clinicians (*N* = 13)
Neurology (*n* = 1)
Neuropsychology (*n* = 5)
Speech therapy (*n* = 1)
Occupational therapy (*n* = 1)
Other (*n* = 5)

Patient characteristics	***N* = 10**[1]
Age	42.90 (11.09)
Sex, ♀	7 (70%)
PCFS Score	2.64 (0.47)
ME/CFS Diagnosis, yes	8 (80%)
FSS Score (0-7)	6.18 (0.65)
PEM, yes	9 (90%)
Months since PC diag.	23.33 (10.50)

[1]*Mean* (*SD*); *n* (%)

Results

Are there specific symptoms or health conditions that should be considered?

- Headache
- Morning > afternoon
- Breaks required
- Seating & retreat options
- Fatigue/PEM
- Postural difficulties
- Anxiety

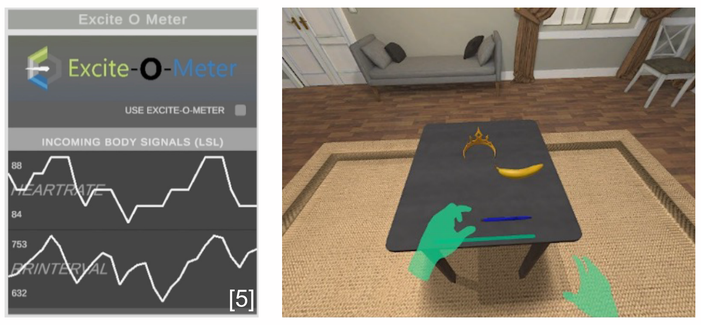
- Headache
- Fluctuating performance
- Breaks required
- Sensory sensitivity
- Simple language
- Slow speech rate
- Low information density

What feedback do you expect after the study?

- Feasibility outcomes
- Fatigue severity
- VR performance course
- Autonomic parameters
- Sleep and activity patterns

- Personal feedback
- Detailed report
- Key results presentation
- Digital dashboard

Co-creation feedback directly impacted the study design.



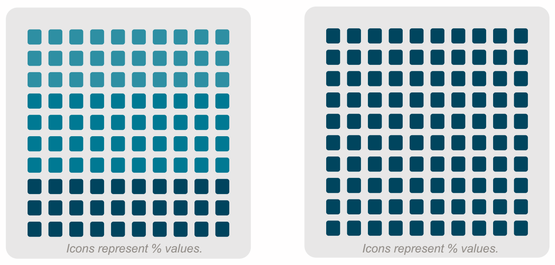
Appointment 1 — 24 h — Appointment 2 — 24 h

- Wearable choice
- Parameter choice
- Performance feedback
- Reduced study duration (2x 24h)

- Reduction of task trials
- Focus on relevant elements
- Well-being assessment during VR task
- Break option

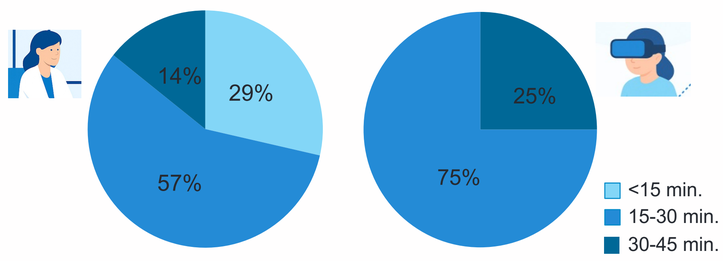
How do you rate wearing a smartwatch for 3 days?

70% Feasible — **100% Highly feasible**



Clinicians — **PCS patients**

What should be the max. time in VR?



Outlook and Impact

The co-creative approach systematically optimized the design of the diagnostic toolbox and the study design by involving clinicians and patients. This enhanced acceptability, reduced participant burden, and improved overall clinical applicability.
Next steps include empirical validation of the toolbox, identification of differential indicators of fatigue and cognition, and structured feedback sessions with all users, supported by digital dashboards.

Key advantages of co-creation for PCS studies and beyond:

- Early identification of barriers
- Identification of overlooked needs
- Human-centered design process
- Direct implementation of feedback
- Improved usability and accessibility
- Increased adherence and motivation
- Enhanced trust and therapeutic alliance
- Strengthened translational impact

Gefördert durch:
Bundesministerium für Forschung, Technologie und Raumfahrt

[1] Paterson, C., et al. (2022). What are the long-term holistic health consequences of COVID-19 among survivors? An umbrella systematic review. *Journal of Medical Virology, 94*(12), 5653–5668.
[2] Hartung et al. (2022). Fatigue and cognitive impairment after COVID-19: A prospective multicentre study. *EClinicalMedicine*, *53*, 101651.
[3] Machado, M., Kang, N., Tai, F., Sambhi, R., Berk, M., Carvalho, A., Chada, L., Merola, J., Piguet, V., & Alavi, A. (2020). Measuring fatigue: a meta-review. *International Journal of Dermatology*, 60.
[4] Benson T. (2023). Why it is hard to use PROMs and PREMs in routine health and care. *BMJ open quality*, *12*(4), e002516.
[5] Quintero, L., Munoz, J. E., Mooij, J. D., & Gaebler, M. (2021). Excite-O-Meter: Software Framework to Integrate Heart Activity in Virtual Reality. *2021 IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, 357–366.

EPSILON
https://www.epsilon-projekt.de/en