



## A novel personal protective equipment for filovirus outbreaks: a usability study under simulated field conditions

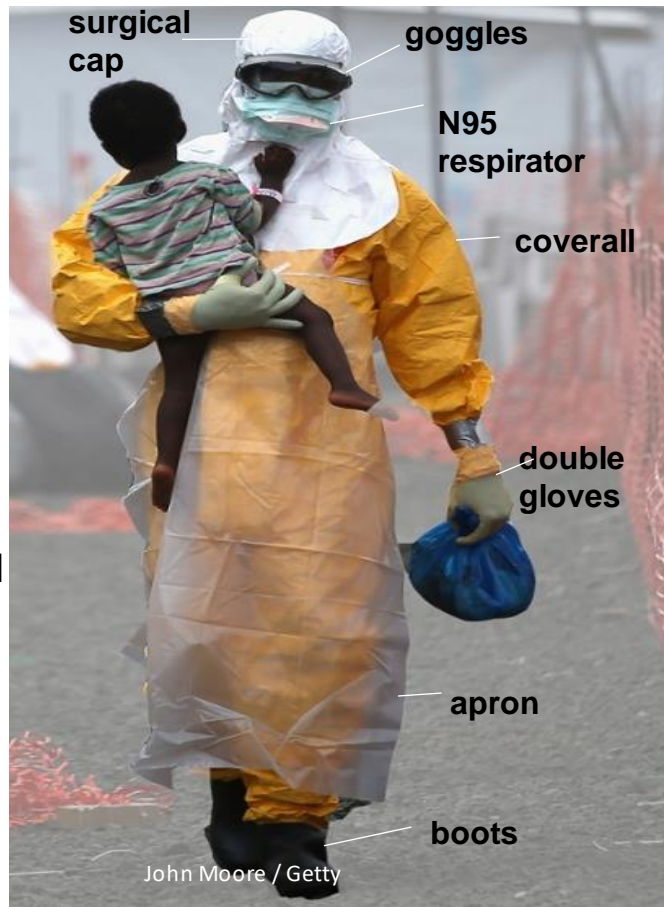
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# Introduction

After the large West African Ebola outbreak in 2013-2015, the “**SmartPPE project**” was formed to address the need for an improved coverall personal protective equipment (PPE) for filovirus front-line workers

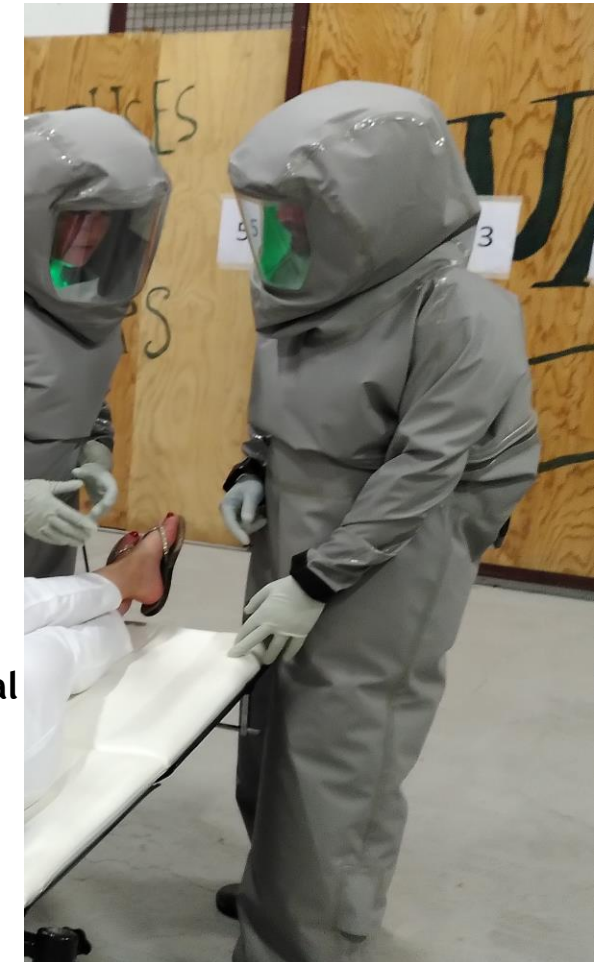
## CURRENT PPE

- Too hot and inappropriate for hot and humid tropical climates
- Doffing of the PPE is time consuming
- Built-up humidity inside the suit (goggles) & reduced vision field
- Poor reusability and too expensive



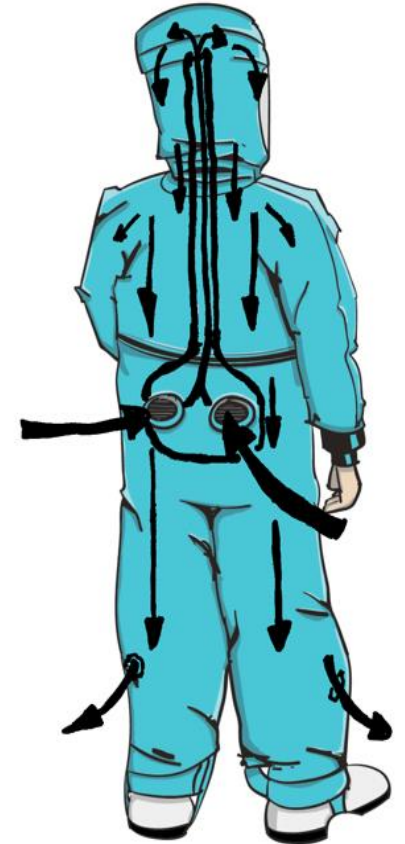
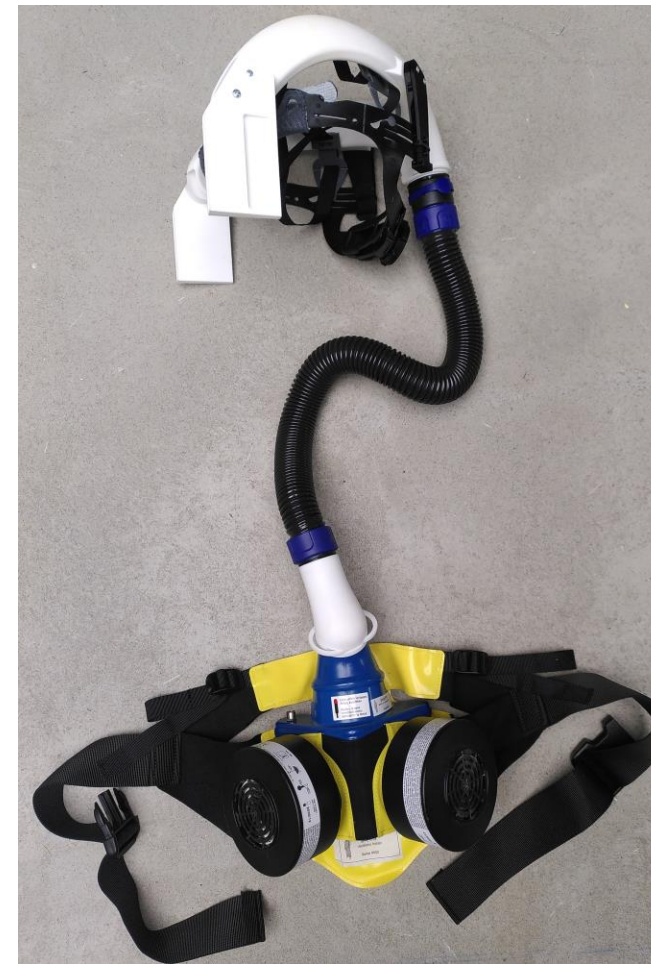
## SmartPPE

- One-piece suit
- Personal cooling system
- Positive pressure
- Large face shield
- No protective mask
- Immediate, watertight seal
- Fully reusable





The aim was to assess user's perceptions on the comfort/functionality of the developed prototype suit in a usability study before closure of the final product design.



Front and back views showing face shield, watertight zippers, rubber seals and internal suspenders

Ventilator and Air System, and movement of the air around the suit.

# Methods

## OVERALL OBJECTIVE

To assess the **usability** (ease-of-use, user comfort, work-place-functionality, and **doffing-safety**) of the smartPPE compared to the current PPE through user testing in a simulated field environment.

## ASSESSMENTS

4 **guided testing sessions** representing clinical and non-clinical field tasks, performed by each participant in both Smart and Standard PPE in random order.

## DATA COLLECTION

- Measurements (Vital signs, visibility and hearing, ambient temperature & humidity, CO<sub>2</sub> and temperature inside the suit)
- Session observations
- User feedback questionnaires

## TEST USERS

N=10 (medical-/non-medical profile, different levels of front-line PPE experience)

## STUDY SITE

**Simulated set-up (high indoor humidity/high temperature)** at UNHRD)/ WHO INITIATE<sup>2</sup> campus, Brindisi, Italy, 26<sup>th</sup> May to 3<sup>rd</sup> June 2023

## ETHICS

Test users signed informed consent; study protocol approved by MSF Ethical Review Board



LH / MSF



<https://www.sciencedirect.com/science/article/pii/S0196655318308411>



# Sessions 1-4, Performed twice by each test user: in current and smart PPE, with guided donning and doffing

## Session 1 Movement & getting to know the suit

Activity 1 Moving & interaction with objects

Activity 2 Visual range

## Session 2 Medical Activities

Activity 1 Simulated medical acts

Activity 2 Conversation

## Session 3 Heavy physical work

Activity 1 Water Sanitation and Hygiene Activities

Activity 2 Sand shoveling

(Session 3 involved continuing activities for as long as participants were comfortable to do so, to a maximum of 1.5hr)

## Session 4 Trouble shooting

Activity 1 Incident with glove

Activity 2 Incident with liquid spillage

Activity 3 Incident with faulty ventilation (SmartPPE only)



All Images LH / ER / MSF

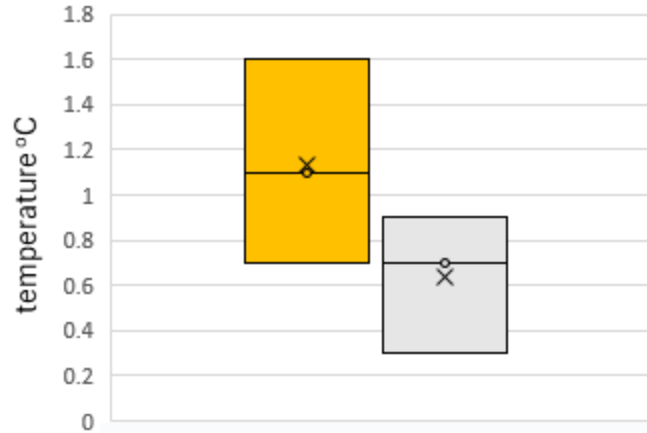
## Test user characteristics

Participants	N=11*
Biometrics	Mean (min, max)   % (n/N)
Female	27.3% (3/11)
Age	41.8 years (28, 53)
Height	177.3 cm (155.0, 193.0)
Weight	75.5 Kg (45.0, 95.0)
Head circumference	58.8 cm (55.0, 62.0)
Chest circumference	100.4 cm (79.0, 118.0)
<b>Previous experience with MSF</b>	<b>90.9% (10/11)</b>
<b>Front-line profession in filovirus outbreak context</b>	
WATSAN	45.5 (5/11)
Medical	45.5 (5/11)
Unrelated	9.0 (1/11)
<b>Previous experience with cover-all PPE</b>	
never	27.3 (3/11)
1-2months	36.4 (4/11)
≥ 12 months	9.1 (1/11)
≥ 24 months	18.2 (2/11)
<b>Size smart PPE suit attributed</b>	
small	9.0 (1/11)
medium	63.6 (7/11)
large	27.3 (3/11)

\*N=11 people  
for **10 test user spots**  
(1 replacement )

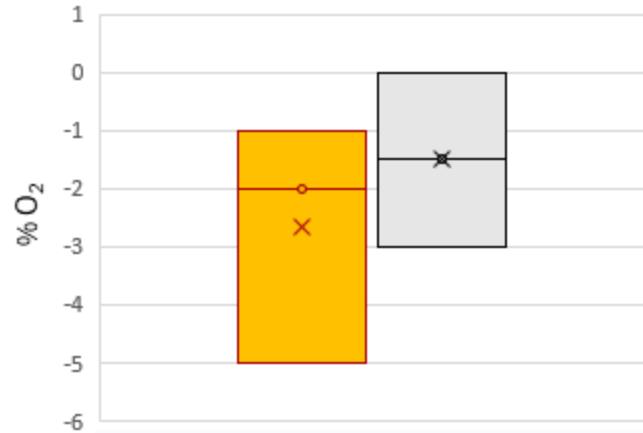
# VITALS (combined, sessions 1-3)

### Increased body temperature



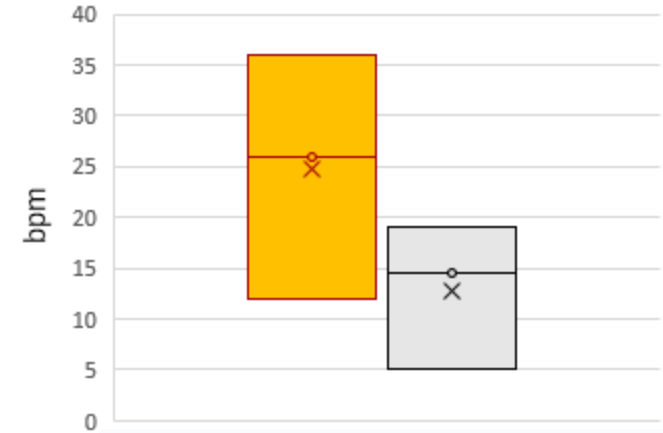
Median increase:  
**1.1°C** [IQR: 0.7–1.6] vs **0.7°C** [0.3–0.9]  
 (p<0.001)

### Reduction of O2



Median decrease:  
**-2%** [-5 to -1] vs **-1.5%** [-3 to 0]  
 (p=0.027)

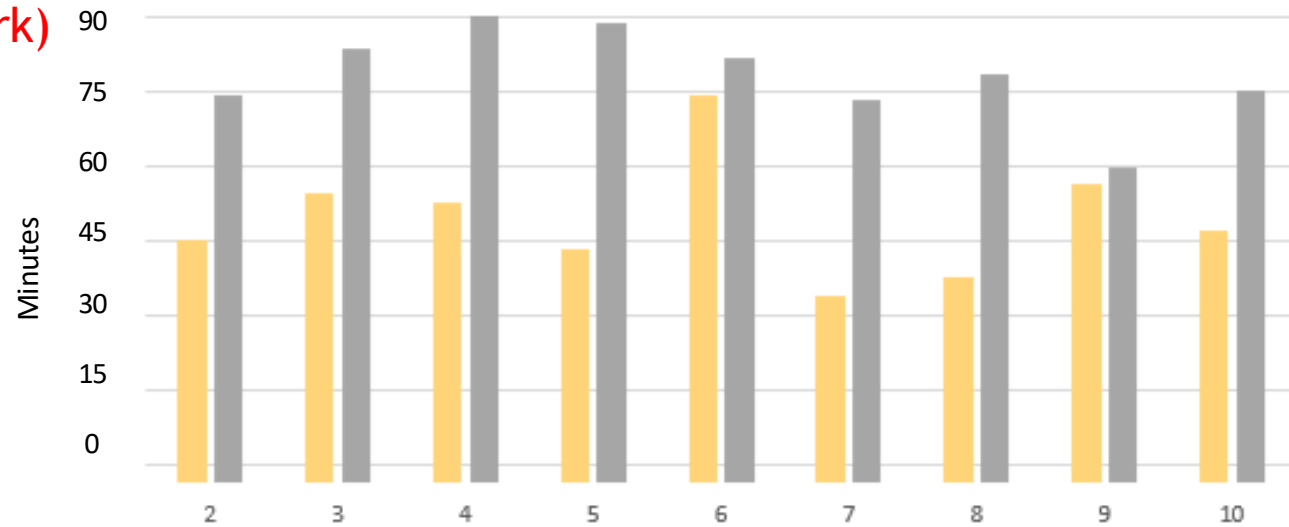
### Increase of heart rate



Median increase:  
**26 bpm** [IQR: 12–36] vs **14.5 bpm** [5–19]  
 (p=0.001)

# TIME IN SUIT Session 3 (heavy physical work)

Median duration  
 Standard PPE: 49.5 min [IQR:45–56]  
 smartPPE : 80.0 min [75–84]  
 (p=0.002)



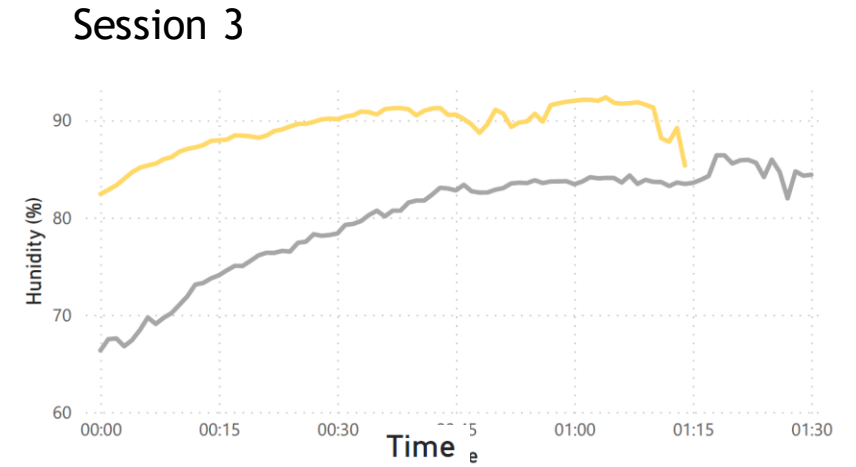
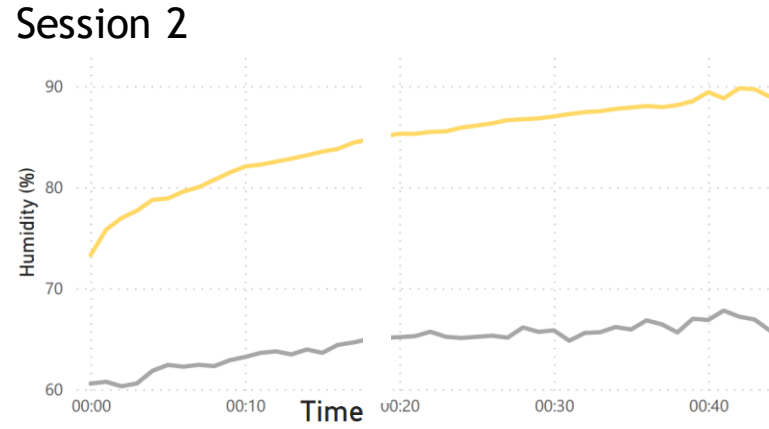
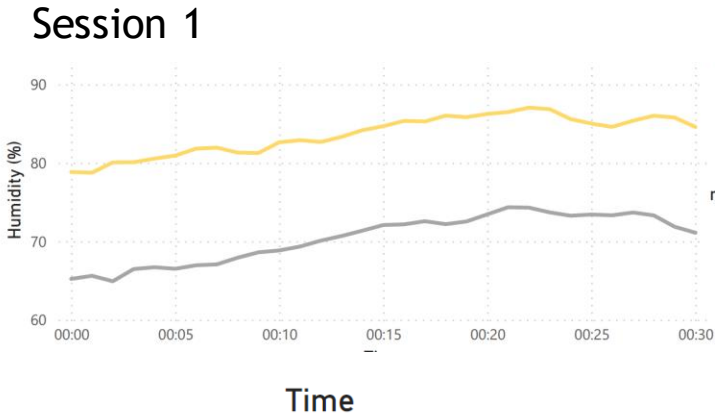
■ current  
 ■ smart

Test user

# HUMIDITY inside the suit

Median 12.6 % [8.8–19.6] higher humidity in Standard PPE

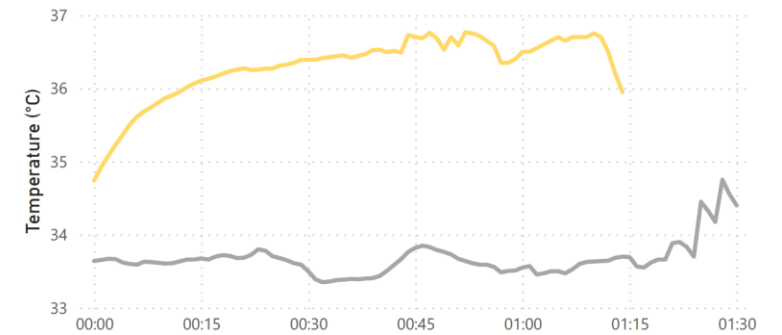
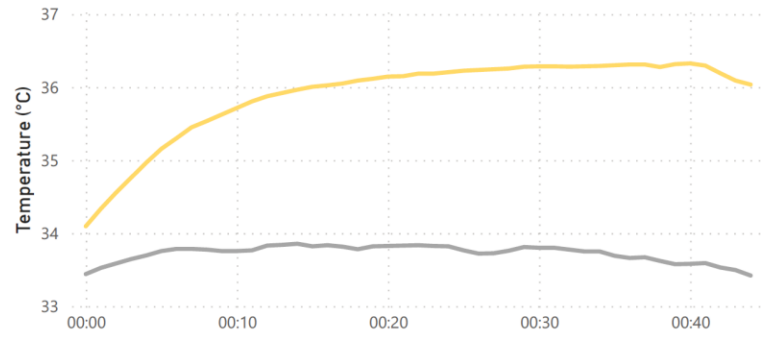
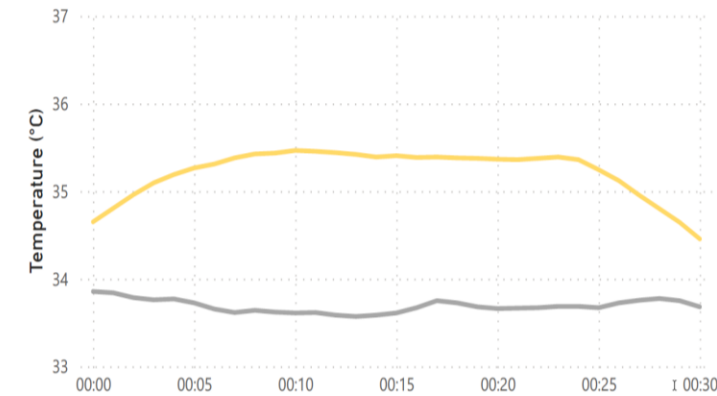
Mean room humidity: 70%  
Mean room temperature: 30°C



● Current ● Smart

# TEMPERATURE inside the suit

Median 2.3°C [IQR 1.8–3.0] higher temperature in Standard PPE



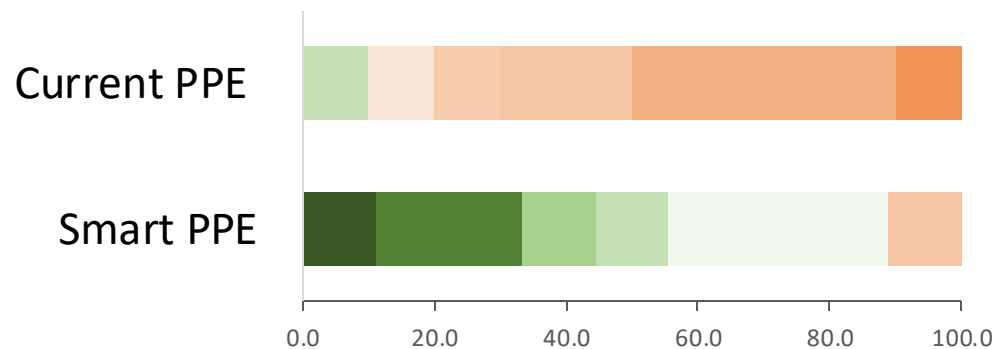
● Current ● Smart



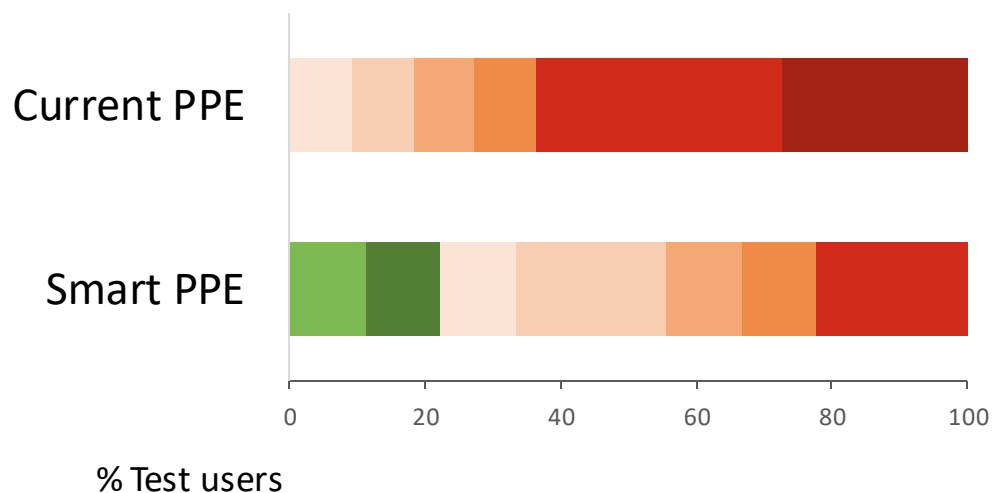
# PERCEIVED PHYSICAL EXERTION (Borg Scale rating)

- 6-no exertion
- 7
- 8
- 9-very light
- 10
- 11-light
- 12
- 13-somewhat hard
- 14
- 15
- 16
- 17-very hard
- 18
- 19-extremely hard
- 20-maximal exertion

## Session 2: Clinical activities



## Session 3: Heavy physical activities



### Median exertion-scores [IQR]

current PPE **15.5** [14–16]

smartPPE **8.5** [7–11]

(p<0.01)

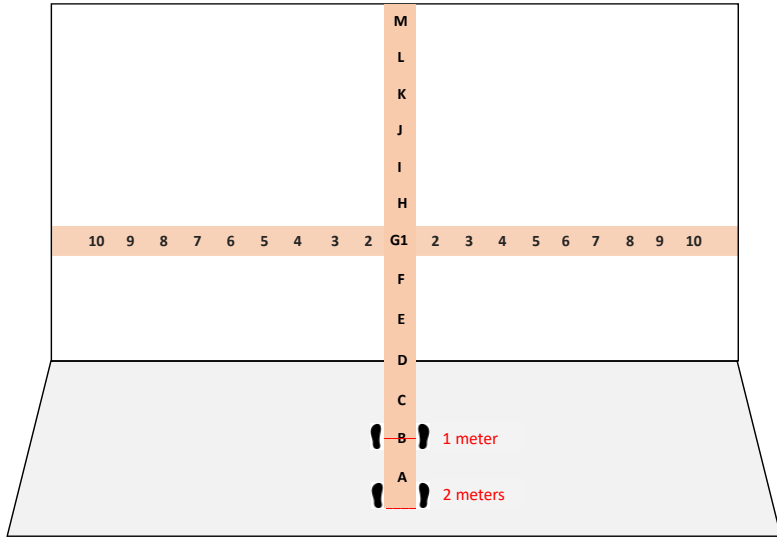
current PPE **18** [17–20]

smartPPE **14** [13–17]

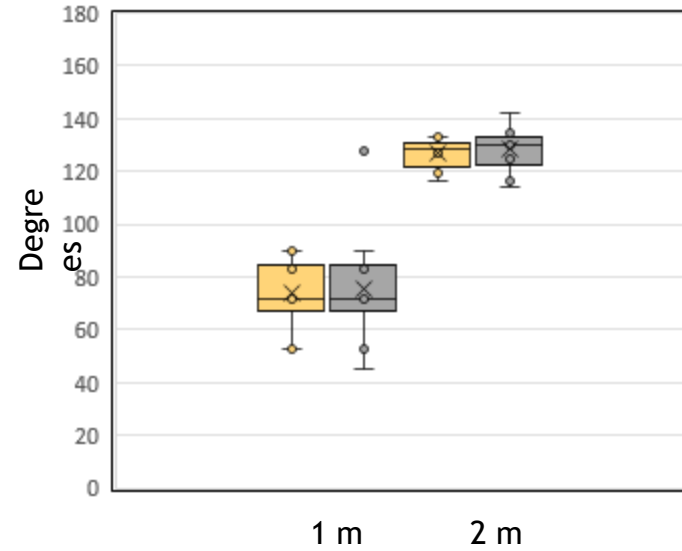
(p=0.035)

% Test users

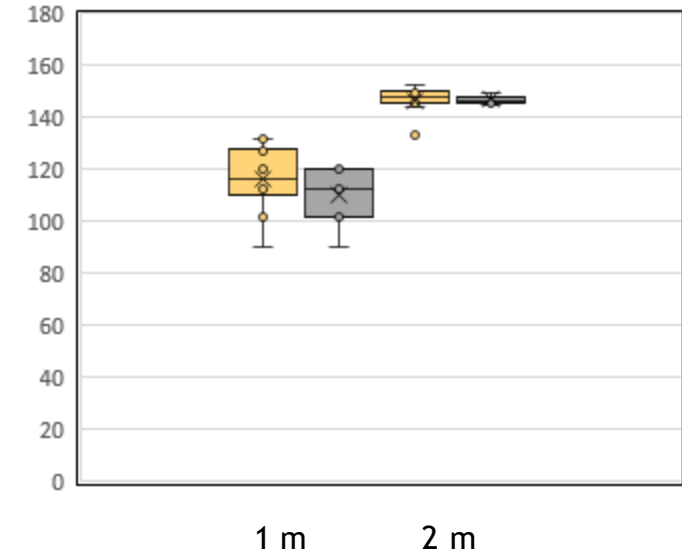
# PERIPHERAL VISION



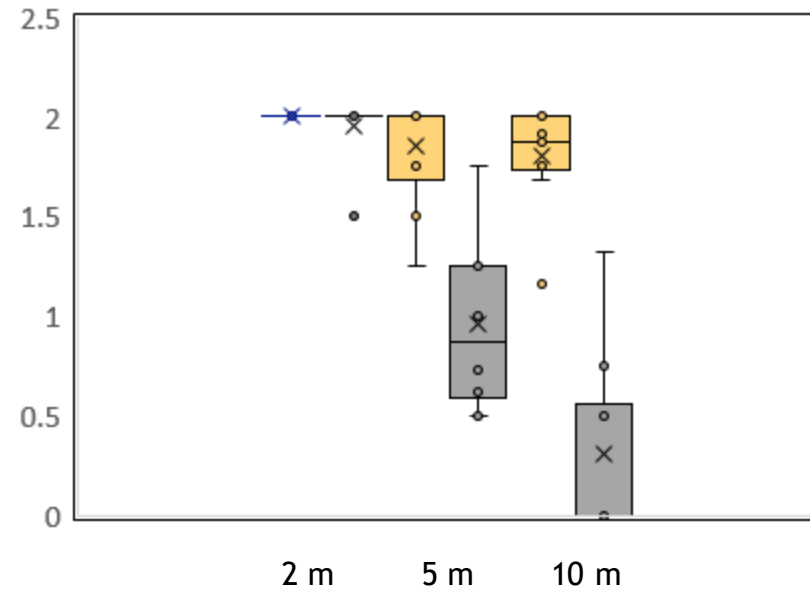
## Vertical vision (ABC)



## Lateral vision (123)



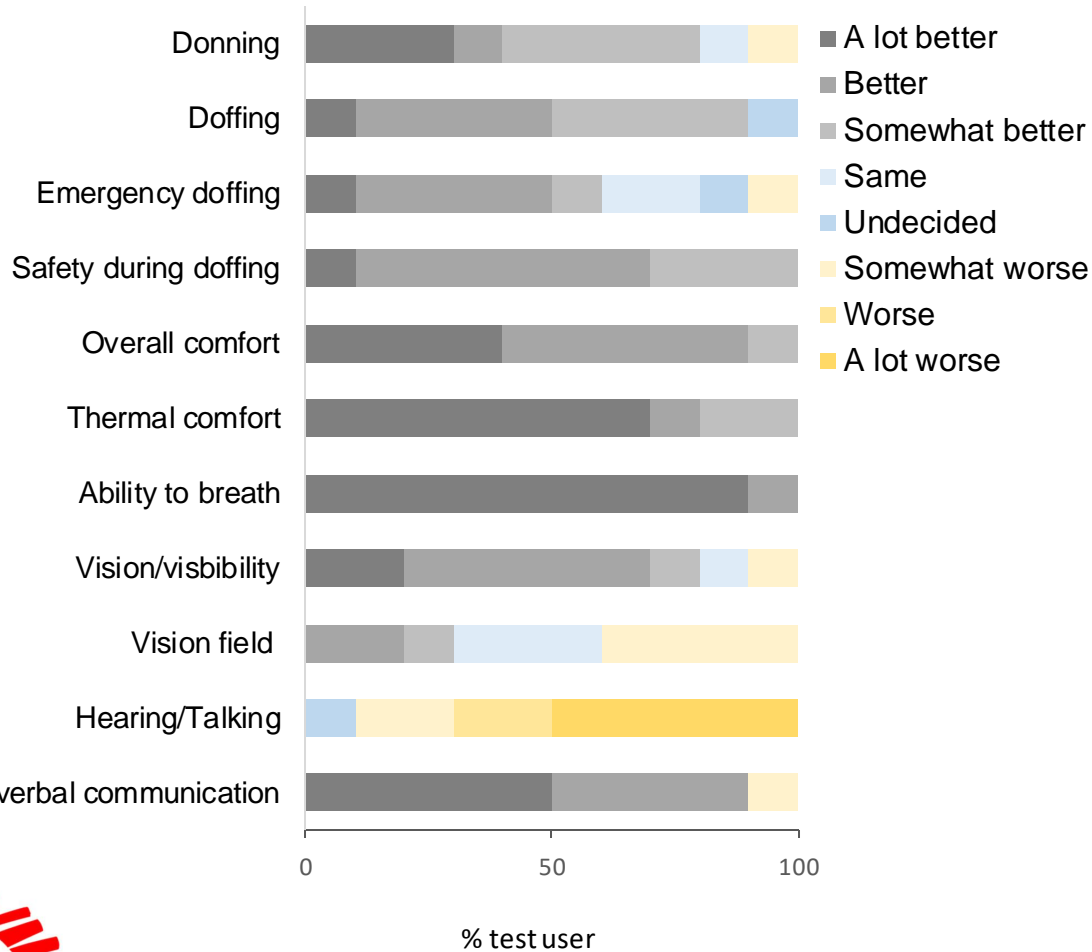
# HEARING SCORES



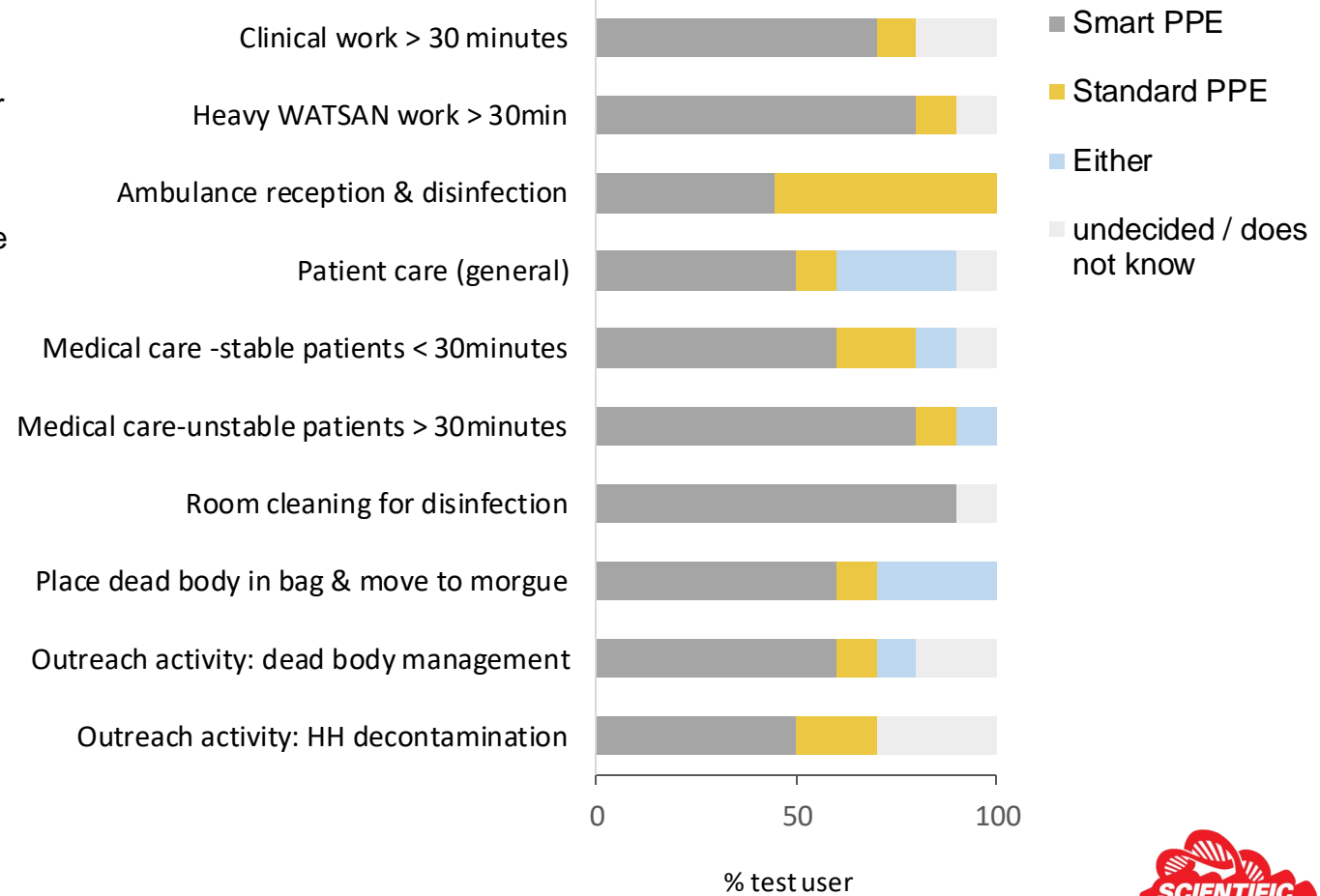
■ current  
■ smart

# COMPARATIVE TEST USER RATINGS

## Preference comparison smartPPE versus current PPE



## Taks-specific PPE preference (envisioned)



# RESULTS - RECOMMENDATIONS/FEEDBACK

## HEADGEAR

**Headgear:** add a chin strap to better secure the helmet

**Visor clipping:** use a different colour clip/tap for better visualisation

## VENTILATION

**Noise:** add a filter to reduce the noise; place the arrival of the air far from ears

**Ventilation fixation:** add a security (lock /screw)

**Ventilation incident:** add a zipper near the head to ease breathing in case of ventilation problem

**Battery:** add an indicator/monitor showing battery charge

## VISION

**Peripheral vision:** move tabs few centimetres to the back to allow a wider view

## BODY FIT

**Size:** smaller size

**Arms:** more tissue in the armpit for improving the movement

**Pants:**

- Have shorter legs
- Have the cord outside to improve the access to the cord system for tighten and untighten the legs
- Add air valves at the pants

**Suspenders:** add a chest strap strip between the suspenders

## MOBILITY

**Ventilation alarm:** solve the obstruction to airflow when bending



## LIMITATIONS

- **Simulated conditions** instead of field conditions and **absence of stress** related to a haemorrhagic fever epidemics
- SmartPPE **donning and doffing protocols adapted** several times during the study
- **Limited diversity** of participants as they came from Europe and North America and were mostly men while most filovirus epidemics takes place in Africa where health care workers are mostly locals

## CONCLUSIONS

- Improved personal protective equipment for front-line health workers in hemorrhagic fever outbreak context is urgently needed. The Smart PPE development project addressed this gap.
- Test users confirmed the usability of smartPPE and favoured it especially for **perceived lessened physical effort and exhaustion during activities, doffing-safety, longer-interval clinical or physical work, and improved non-verbal interactions**, whereas hearing was challenged by the ventilation

## NEXT STEPS

- Adjustments are currently underway before design freeze.
- Stakeholder commitment will be crucial to ensure production at scale.

# Acknowledgements and Thanks

## SmartPPE Project

The logo for EPFL (École Polytechnique Fédérale de Lausanne) is displayed in a bold, red, sans-serif font.

**ERNST GÖHNER  
STIFTUNG**

The logo for HUG (Hôpitaux Universitaires Genève) features the letters 'HUG' in a stylized, multi-colored font (green, blue, and teal) to the left of the text 'Hôpitaux Universitaires Genève' in a smaller, black, sans-serif font.

## Usability Study

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