

PROTECTED: EVALUATION OF A NEXT GENERATION OXYGEN SYSTEM – ASSESSMENT OF USABILITY, COMFORT AND HUMAN PERFORMANCE

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Background

- Oxygen masks and oxygen systems as integral part of pilots' safety equipment aircraft cockpits
- Every commercial aircraft is equipped with an oxygen system and masks for the flight crew
- Preventive use / emergency situations
- Regulations for supplemental oxygen use:
 - **EASA-OPS:**
The pilot-in-command shall ensure that he/she and flight crew members engaged in performing duties essential to the safe operation of an aircraft in flight use supplemental oxygen continuously whenever the **cabin altitude exceeds 10 000 ft** for a period of **more than 30 minutes** and whenever the cabin altitude exceeds **13 000 ft**. (European Aviation Safety Agency, 2012)
 - **FAA:**
If one pilot of a pressurized aircraft leaves his/her station while the aircraft is **above flight level 350**, the other pilot must wear and use an oxygen mask that is secured and sealed and supplies oxygen at all times, or automatically supplies oxygen whenever the **cabin altitude exceeds 14,000 feet**. Also, while flying **above flight level 410**, one pilot must always wear and use the oxygen mask. (14 CFR 91, 2013)
 - **ICAO Annex 6:**
Specifies the same use requirements for the crew as EU-OPS 1 (ICAO Annex 6, Chapter 3,4, 2013)

Research question

- Problem of non-compliance among pilots:

“The question that comes to mind is; why are otherwise disciplined, compliant, professional pilots choosing to disregard this regulation. There must be compelling reasons for this behavior.”

(Miller, 2014)

- **Reasons**

lack of comfort, impaired communication, vision interference, oxygen depletion, hygiene, problems with stowing and donning the mask *(Miller, 2014)*

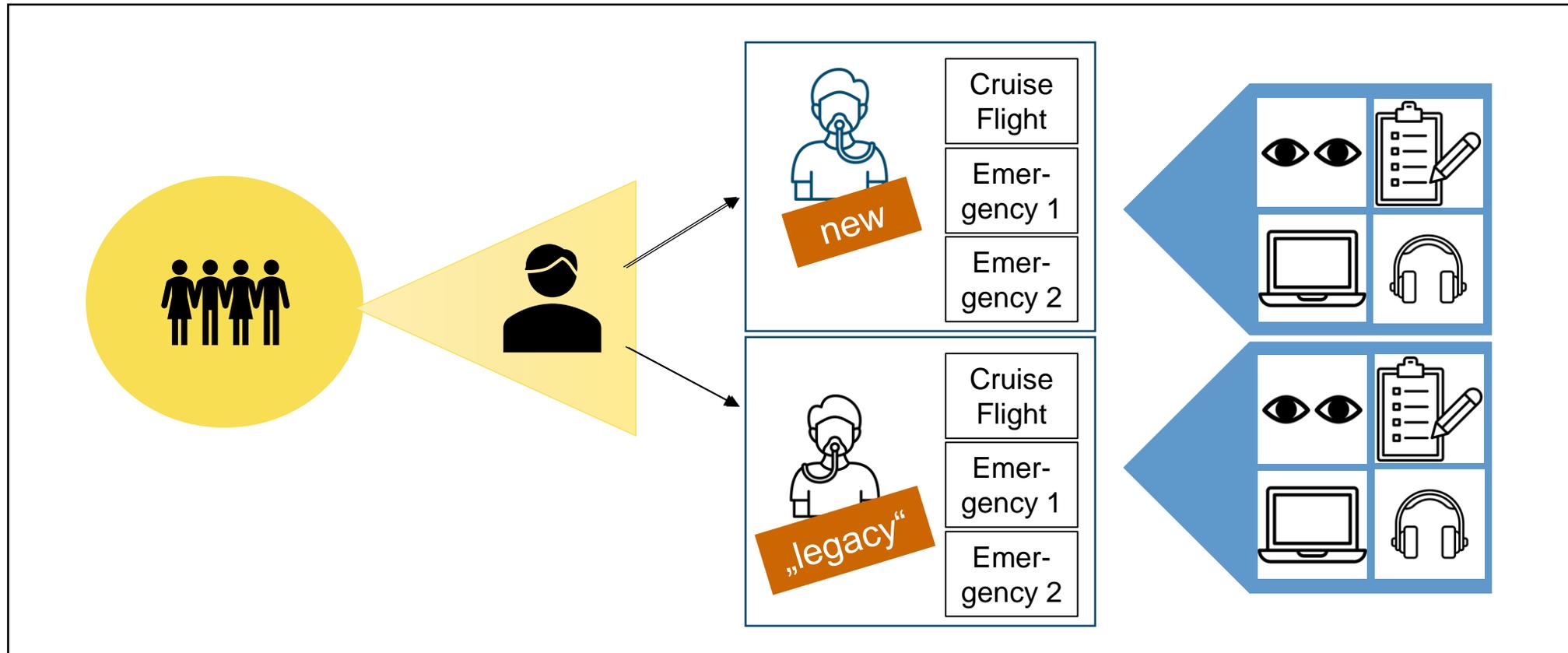
- **Consequence**

Development of a new oxygen system by Safran Aerosystems. Focus: Improvements regarding usability and comfort

- **Objective**

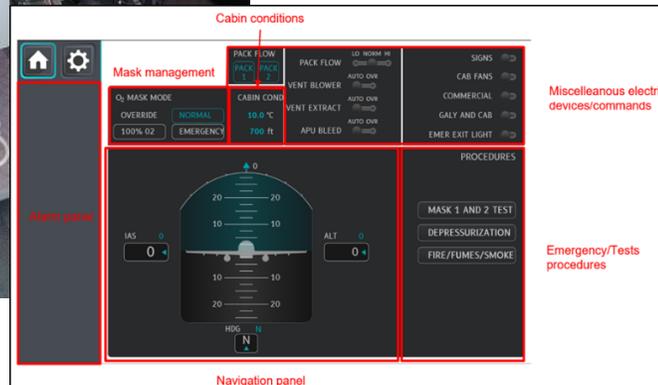
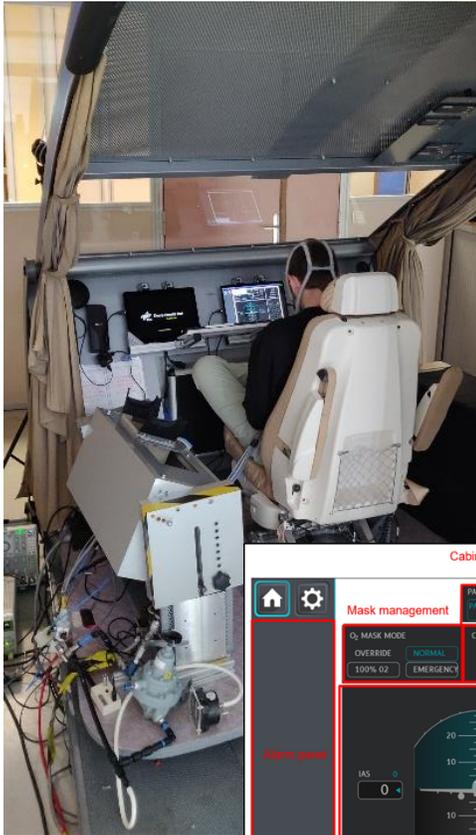
Evaluation of the new oxygen system (mask & human-machine interface, HMI) and comparison with a legacy mask on the basis of subjective data

Human Factor Test Campaign



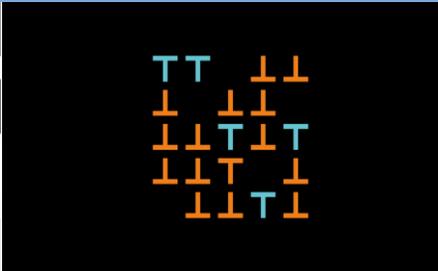
Experimental setting

New Mask



Legacy Mask



| Method | Illustration | | | | | | | | | | | | | | | | | |
|--|---|--|---------------|---------------|--|--|-------|-------|--|--|---------------|---------------|--|--|-------|-------|--|--|
| <p>Observation</p>  |  | | | | | | | | | | | | | | | | | |
| <p>Questionnaire Usability & Comfort</p>  | <p>Comfort (Cruise Flight I)</p> <p>The following questions concern your comfort experience with the mask you are currently wearing. Please enter your rating on a 5-point scale. First assess a characteristic (e.g. 1 = light to 5 = heavy) and then the degree of comfort for this characteristic (1 = very uncomfortable to 5 = very comfortable).</p> <p>Please rate the comfort of the mask:</p> <p>The weight of the mask is ...</p> <p style="text-align: center;">light heavy</p> <p style="text-align: center;">○ ○ ○ ○ ○</p> <p>...and this is what I perceive as ...</p> <p style="text-align: center;">very uncomfortable neutral very comfortable</p> <p style="text-align: center;">○ ○ ○ ○ ○</p> <p>The smell of the mask is ...</p> <p style="text-align: center;">weak strong</p> <p style="text-align: center;">○ ○ ○ ○ ○</p> <p style="text-align: center;">very uncomfortable neutral very comfortable</p> | | | | | | | | | | | | | | | | | |
| <p>Cognitive Performance Deary-Liewald-Tasks & Visual Search Task</p>  | <table border="0" style="width: 100%;"> <tr> <td style="width: 50%;">On the screen</td> <td style="width: 50%;">On the screen</td> </tr> <tr> <td style="text-align: center;"> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> </td> <td style="text-align: center;"> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> </td> </tr> <tr> <td style="text-align: center;">Press</td> <td style="text-align: center;">Press</td> </tr> <tr> <td style="text-align: center;"> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> </td> <td style="text-align: center;"> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> </td> </tr> <tr> <td style="text-align: center;">On the screen</td> <td style="text-align: center;">On the screen</td> </tr> <tr> <td style="text-align: center;"> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> </td> <td style="text-align: center;"> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> </td> </tr> <tr> <td style="text-align: center;">Press</td> <td style="text-align: center;">Press</td> </tr> <tr> <td style="text-align: center;"> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> </td> <td style="text-align: center;"> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> </td> </tr> </table>  | | On the screen | On the screen | <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> | Press | Press | <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> | On the screen | On the screen | <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> | Press | Press | <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> <input type="checkbox"/> | <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input checked="" type="checkbox"/> |
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| <p>Acoustic Side Task (2-back)</p>  |  | | | | | | | | | | | | | | | | | |

HFTC – Sample



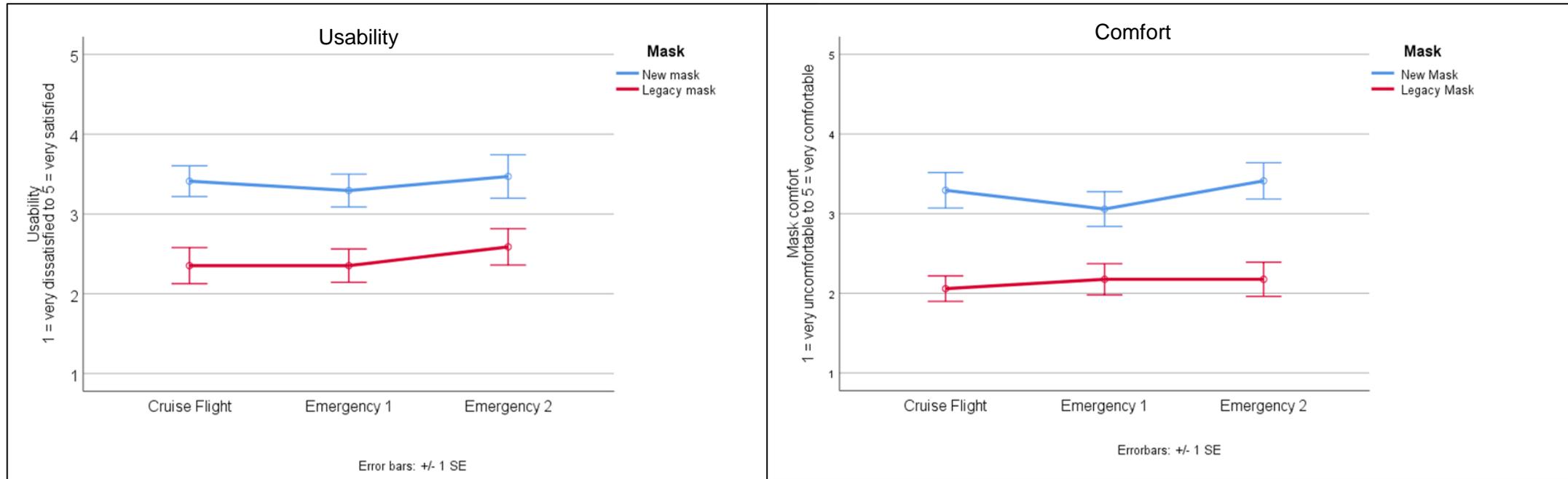
- The sample consisted of $N = 20$ pilots, 70% CPL, 30% ATPL-holders of French nationality
- Gender: 19 were male, 1 female
- Age: 21–33 years ($M = 26.8$ years, $SD = 4.0$ years)
- Height: 168 cm–190 cm ($M = 178.5$ cm, $SD = 6.1$ cm)
- Weight: 60 kg–90 kg ($M = 72.8$ kg, $SD = 10$ kg)
- Head circumference: 55 cm–63 cm ($M = 57.7$ cm, $SD = 2.0$ cm)
- Only three of the subjects did not have any experience with wearing an oxygen mask so far, the other had experience in simulator and/or aircraft
- Compensation: 200 € after experiment

Experimental design

| Outside | Demonstrator | | | | | | | | Outside | Extra Room | Outs. | |
|--|--|---|---|--|---|---|---|--|---|--|---|--|
| Welcome, Preliminaries, bio-data & well-being, fam. with mask  | DL task, VS task, acoustic task (baseline, no mask)  | DL task, VS task Mask on   | Cruise flight, acoustic task    | Quest. usability & comfort, DL task, VS task   | Emergency 1 event, acoustic task    | Quest. usab. & conf.  | Emergency 2 event, acoustic task    | Question. usab. & conf.  | Break (outside demonstrator) Up to 30 minutes ↔ | Legacy Mask Baseline Cruise Flight Emergency 1 Emergency 2  | Question. comparison masks  | Open questions, money, goodbye ?!   |
| 10 min. | 10 min. | 5 min. | 20 min. | 10 min. | 10 min. | 5 min. | 10 min. | 5 min. | ↔ | 65 min. | 5 min. | 5 min. |

(≈175 minutes maximum)

Results – Usability & Comfort



- Overall, subjects were more satisfied with the **usability** of the new mask ($F_{(1; 16)} = 18.56, p < .01, \eta p^2 = .54$) and there was no significant effect of the flight situation ($F_{(2; 32)} = 1.24, n. s.$)
- **Overall mask comfort** was higher for the new mask ($F_{(1; 16)} = 34.79, p < .001, \eta p^2 = .68$); again, there was no significant effect of the flight situation ($F_{(2; 32)} = 0.90; n. s.$)

Results – Usability (paired t-tests)



| | New Mask (M/SD) | Legacy Mask (M/SD) | Effect (t) |
|------------------------------------|--------------------|-----------------------|------------|
| Donning the mask | 4.05 (0.98) | 4.26 (0.87) | -0.83 |
| Understanding ATC | 4.14 (0.83) | 3.04 (1.02) | 4.58** |
| Speaking | 2.85 (0.96) | 1.89 (0.88) | 3.90** |
| Nonverbal communication | 2.68 (1.08) | 2.63 (1.09) | 0.22 |
| Unobstructed view | 3.00 (0.88) | 3.37 (0.97) | -1.46 |

Note. Usability scales ranged from 1 = difficult to 5 = easy;
** $p < .01$

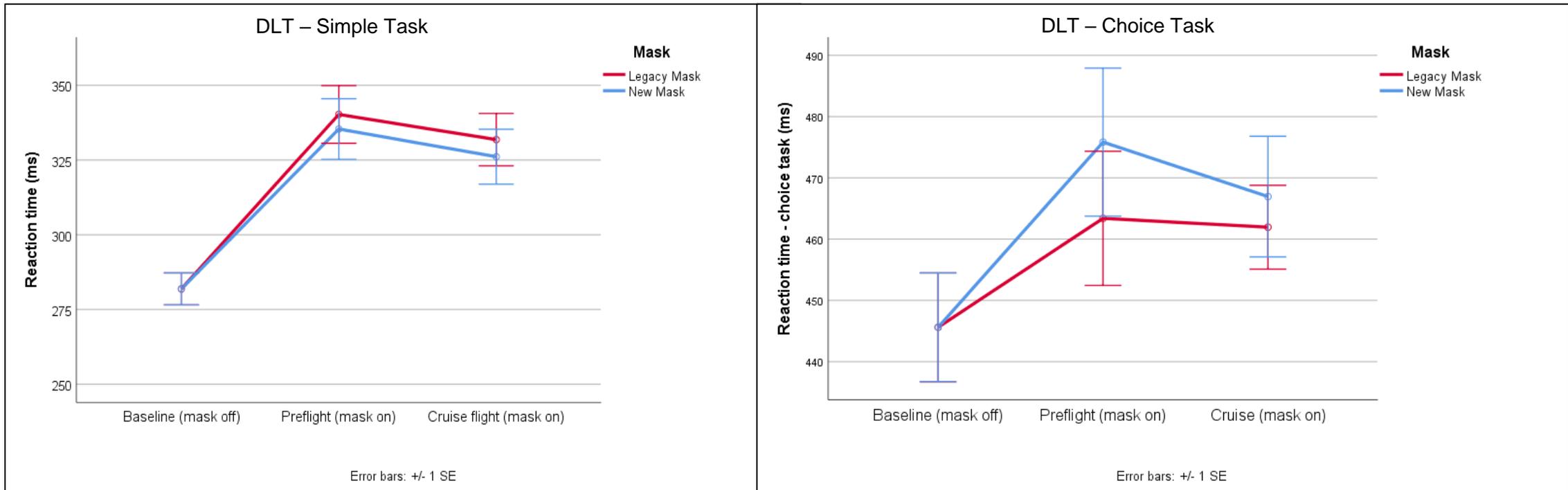
Results – Comfort (paired t-tests)



| | | New Mask (M/SD) | Legacy Mask (M/SD) | Effect (t) |
|-----------------------------------|-------------------------------------|--------------------|--------------------------|------------|
| Pressure on the face | Sensation 1 = weak to 5 = strong | 3.17 (0.85) | 4.52 (0.62) | -5.66** |
| | Evaluation | 2.85 (0.65) | 1.80 (0.78) | 4.58** |
| Temperature under the mask | Sensation 1 = cold to 5 = warm | 3.24 (0.58) | 3.28 (0.55) | -0.38 |
| | Evaluation | 3.54 (0.82) | 3.26 (0.63) | 1.57 |
| Oxygen supply | Sensation 1 = weak to 5 = strong | 3.00 (0.91) | 3.59 (0.91) | -2.30* |
| | Evaluation | 3.37 (0.92) | 3.37 (0.77) | 0.00 |

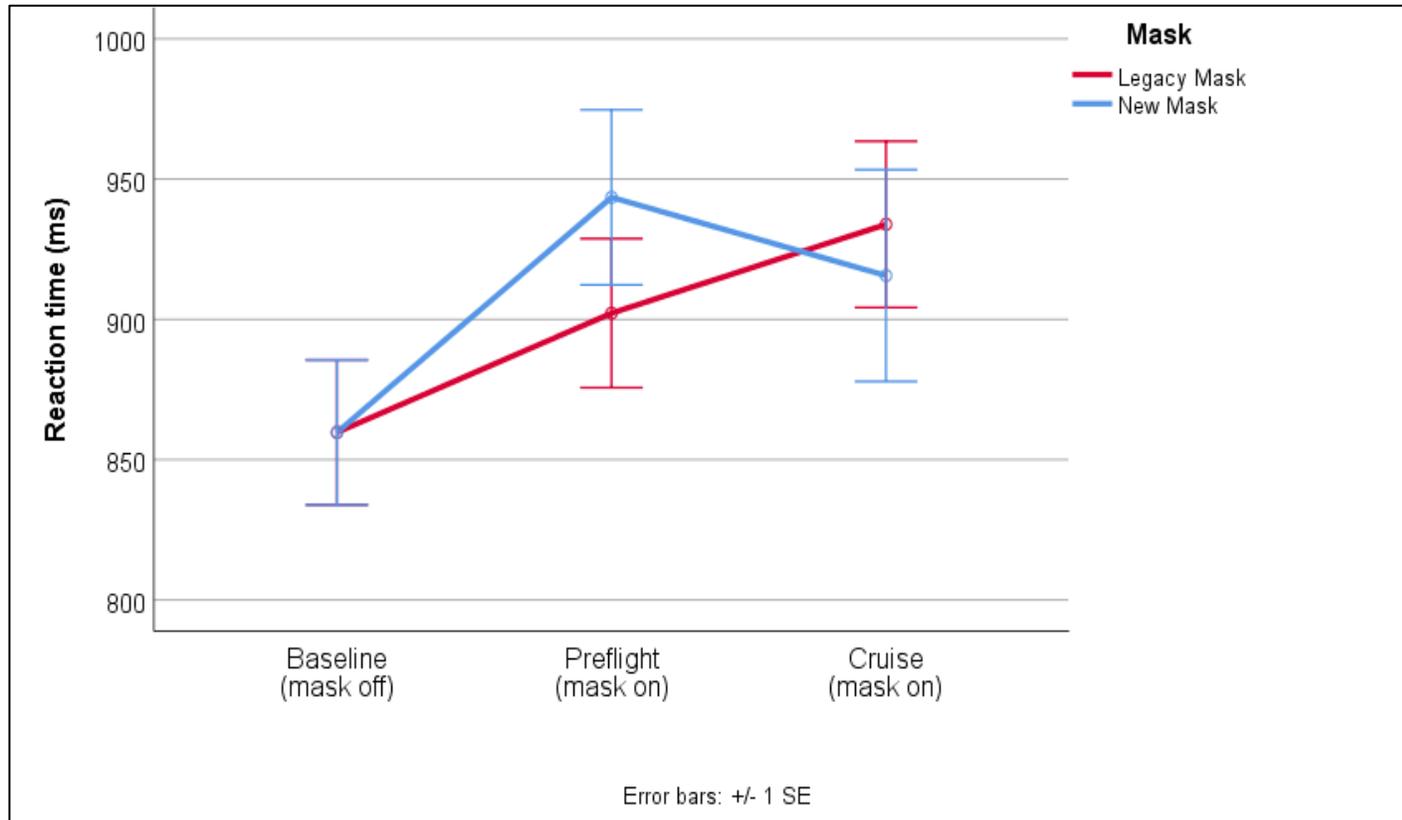
Note. Evaluation scales ranged from 1 = very uncomfortable to 5 = very comfortable;
 ** $p < .01$, * $p < .05$.

Results – Cognitive Performance (Deary-Liewald Tasks)



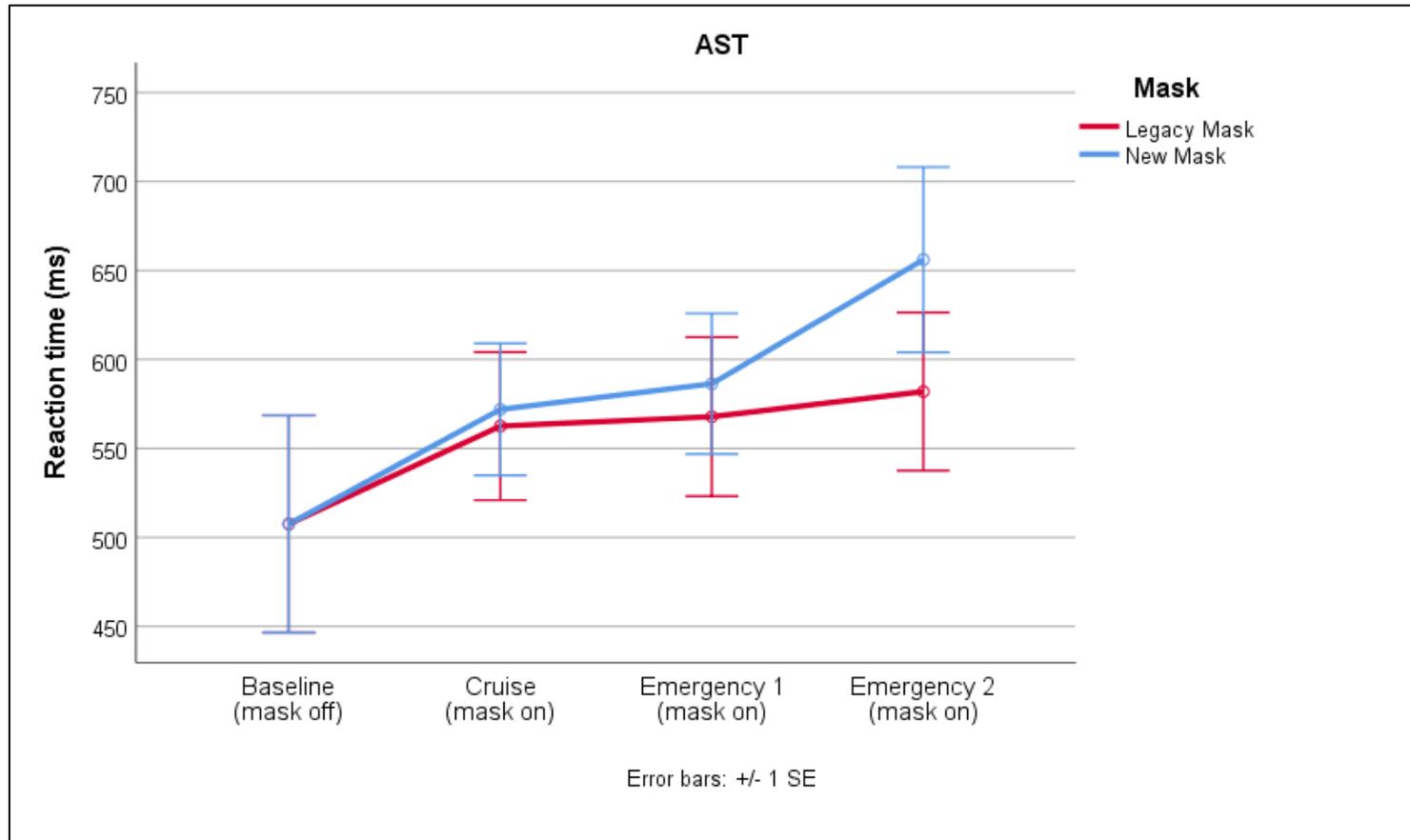
- Results with the new mask did not differ significantly from results with the legacy mask, but reaction times increased in both tasks when the mask was worn compared to the baseline (ST: $F_{(2, 34)} = 40.65, p < .001, \eta p^2 = .70$; CT: $F_{(2, 34)} = 7.75, p < .01, \eta p^2 = .31$)
- In the choice task, reaction times tended to be slower with the new mask, especially during Preflight (n. s.).

Results – Cognitive Performance (Visual Search Task)



- There was no significant effect of the mask ($F_{(1, 17)} = 0.16$, n. s.) and no interaction with the flight situation ($F_{(2, 34)} = 1.45$, n. s.).
- Reaction times in the **VST** increased significantly during Preflight and Cruise flight compared to the baseline ($F_{(2, 34)} = 5.09$, $p < .05$, $\eta_p^2 = .23$).

Results – Cognitive Performance (Acoustic Side Task)



- There was no significant effect of the mask ($F_{(1, 16)} = 1.30$, n. s.) and no interaction with the flight situation ($F_{(3, 48)} = 1.76$, n. s.).
- Reaction times for the new mask increased significantly over time compared to the legacy mask ($F_{(1.4, 48)} = 3.09$, $p < .05$, $\eta_p^2 = .16$).

Summary



- New Mask is altogether rated as more usable and comfortable in all flight situations, but room for improvement was identified
- Cognitive performance with New Mask deteriorated a little during Preflight (orientation?!) and over time (oxygen supply?!)
- Air pressure of New Mask's harness was too low; with peculiar shapes of faces there seemed to be problems with the fit of the face piece of the New Mask (slipping to an uncomfortable position)

Conclusion

- Stable experimental environment, reliable methods for the assessment of usability, comfort and human performance and a representative sample enabled high external and ecological validity of results
- Comprehensive data set was obtained enabling us to perform more thorough and in-depth analyses
- The multi-aspect assessment of critical ergonomics showed very specific issues which have to be analyzed in further detail and should result in further improvements of the new oxygen system before it is made ready for the market.



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- Topic:** PROTECTeD: Evaluation of a next generation oxygen system – assessment of usability, comfort and human performance.
First results from human subject tests conducted in cooperation with Safran Aerosystems
- Date:** 28th September 2022
- Author:** Dr. Julia Maier
- Institute:** Institute for Aerospace Medicine, Aviation and Space Psychology
Hamburg/Cologne, Germany
- Pictures:** DLR, Safran Aerosystems, freepik.com