Evaluating aircraft escape path marking in immersive virtual reality

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Acknowledgements

Our research is partially supported by an **FAA** grant

We are grateful to **Cynthia McLean** for her precious feedback and encouragement

Other people involved in this work:

Nicola Zangrando (software development)

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Floor proximity escape path marking

Floor proximity escape path marking is part of the interior emergency marking system of an aircraft (14 CFR 25.812)

Different floor proximity escape path marking systems are in use (point lighting, flood lighting, strip lighting, …)

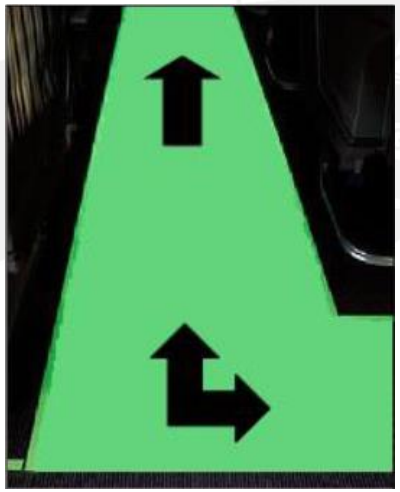
Requirements for path marking systems

The marking system must provide evacuation guidance for passengers when all sources of illumination more than four feet above the floor are obscured (14 CFR 25.812 (e))

Escape path marking systems should be designed in such a way that they do not lead passengers past available exits (AC 25.812-1A)

Path marking design choices

There are multiple design choices for floor proximity escape path marking systems (e.g., active/passive system, light shape, light color, light behavior, …)



Studies on the effectiveness of different proximity escape path marking designs are surprisingly rare (Paskoff et al., 2015, DOT/FAA/AM-15/14)

Our goals

Explore the use of Virtual Reality (VR) for investigating design choices in the context of cabin safety research

Compare the effectiveness of four different design choices for floor proximity escape path marking in an immersive VR evacuation scenario

- Focus on non-floor level overwing exits

Using VR for cabin safety research

VR has become a well-established method in several research fields for safety research

VR advantages:

- Internal validity
- Easy replication
- Safe, controlled simulation of dangerous scenarios
- Cheaper than field studies
- Convenient recording of behavioral and physiological data

The considered VR scenario

Virtual evacuation of an Airbus 320 with immersive VR technology:

- **boarding stage**: participants enter the cabin and reach their seat in the rear of the aircraft
- **taxi/accident stage**: an accident occurs while the aircraft is taxiing from the terminal to the runway
- **evacuation stage**: participants evacuate the aircraft through the available exits with escape path marking being the only visible feature

Study design and procedure

Between-groups design (4 conditions, one for each path marking design)

Procedure:

- Study description, informed consent, demographic questionnaires
- Immersive VR scenario
- Post-task questionnaires and interview

Path marking designs

Four path marking designs based on point lights

Each design is a different combination of light color (green/red) and light behavior (steady/flashing)

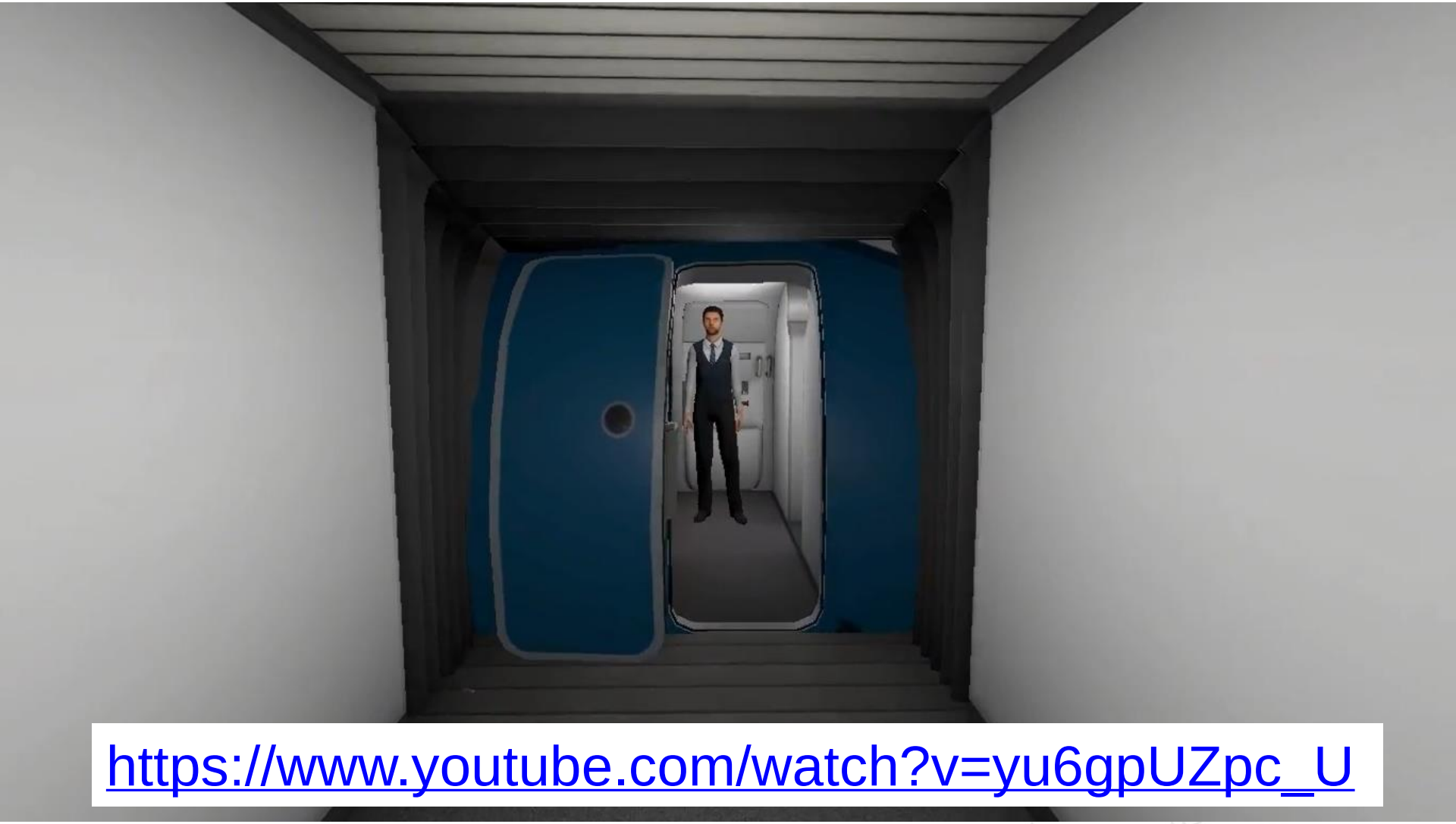
- Green and red are the two colors most commonly associated to emergency exits in western countries (green is more common in Europe, red in USA)
- Past research has found flashing lights to be effective in grabbing attention in the case of emergencies

These designs have not been compared in the aviation domain

Path marking designs

https://www.youtube.com/watch?v=yUqd5MAMzy4

Full scenario example



https://www.youtube.com/watch?v=yu6gpUZpc_U

Participants

Number: 56 (29 M, 27 F), diverse occupations, Italians

Age:
M=27.79 (SD=10.15)

Number of flights in the last two years:
M=2.20 (SD=2.77)

3D app/videogame familiarity (1=not at all, 7=very high):
M=2.41 (SD=1.99)

Flight anxiety (FAS score, range 32-160):
M=54.77 (SD=17.81)

Collected data

Exit choice

Total evacuation time

Walking evacuation time

Perceived level of stress (stressVAS)

Detailed participant activity

Post-task interview data

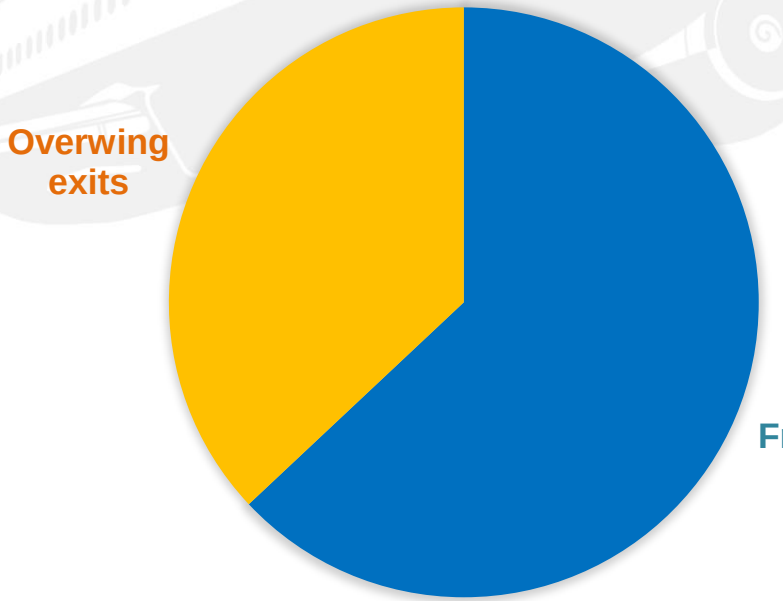
Lab set-up

Ocuus Rift DK2 HMD
+ headphones

Xbox 360 controller

Results: overall exit choice

36 participants (63%) escaped from front exits
20 participants (37%) escaped from overwing exits



Results: overall exit choice

Evacuation from front exits

- Consistent with affiliation theory (Sime, 1985): in case of emergency, people tend to seek familiar persons **or places**
- Inconsistent with the analysis of aviation accidents conducted by (Galea et al., 2006)

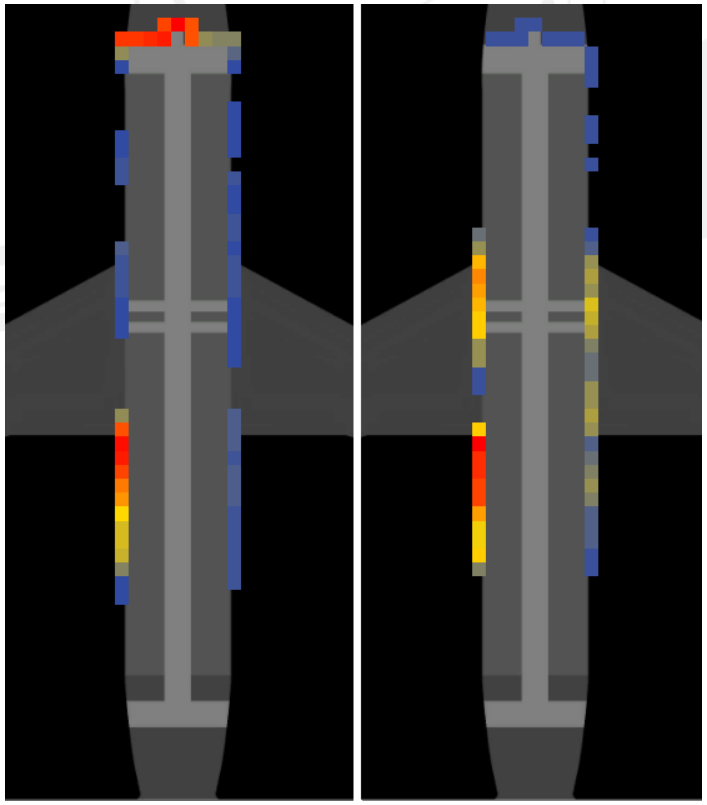
Subjective justification for exit choice:

- Looked for familiar entry door (22 participants, front exits)
- Followed the lights (21 participants, front exits)
- Previous knowledge (12 participants, wing exits)
- Lights under test could indicate possible exit (8 participants, wing exits)

Results: overall behavior

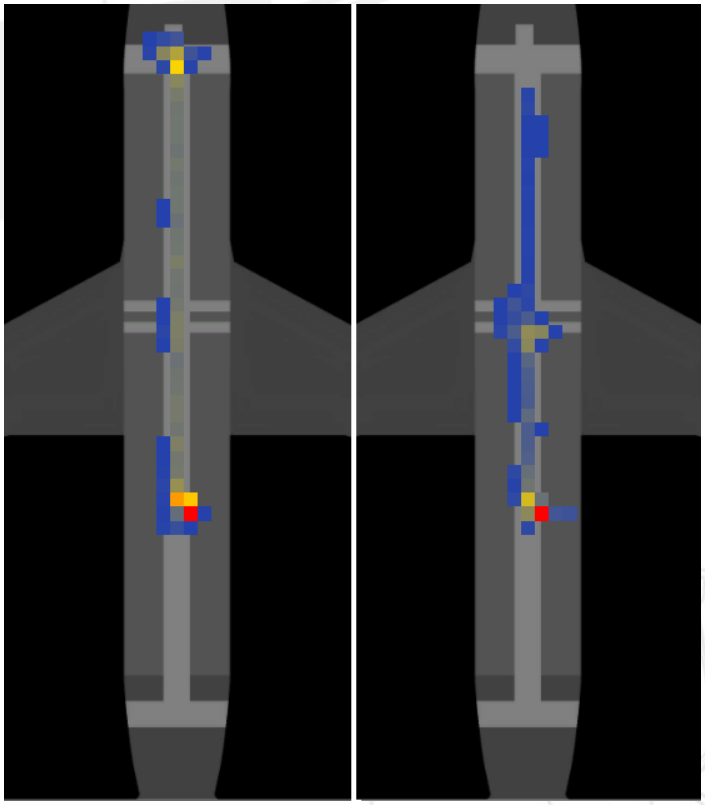
Participants who escaped from front exits did not look for other exits and did not slow down near wing exits

OBSERVED AREAS



FRONT WING

TIME SPENT



FRONT WING

Results: overall behavior

25 participants (45%) looked towards the rear of the aircraft at the beginning of the evacuation to see if they could escape from that direction

- 12 out of those 25 participants (48%) then escaped from wing exits

23 participants (41%) looked in the direction of wing exits while they were near them

- 20 out of those 23 participants then escaped from wing exits

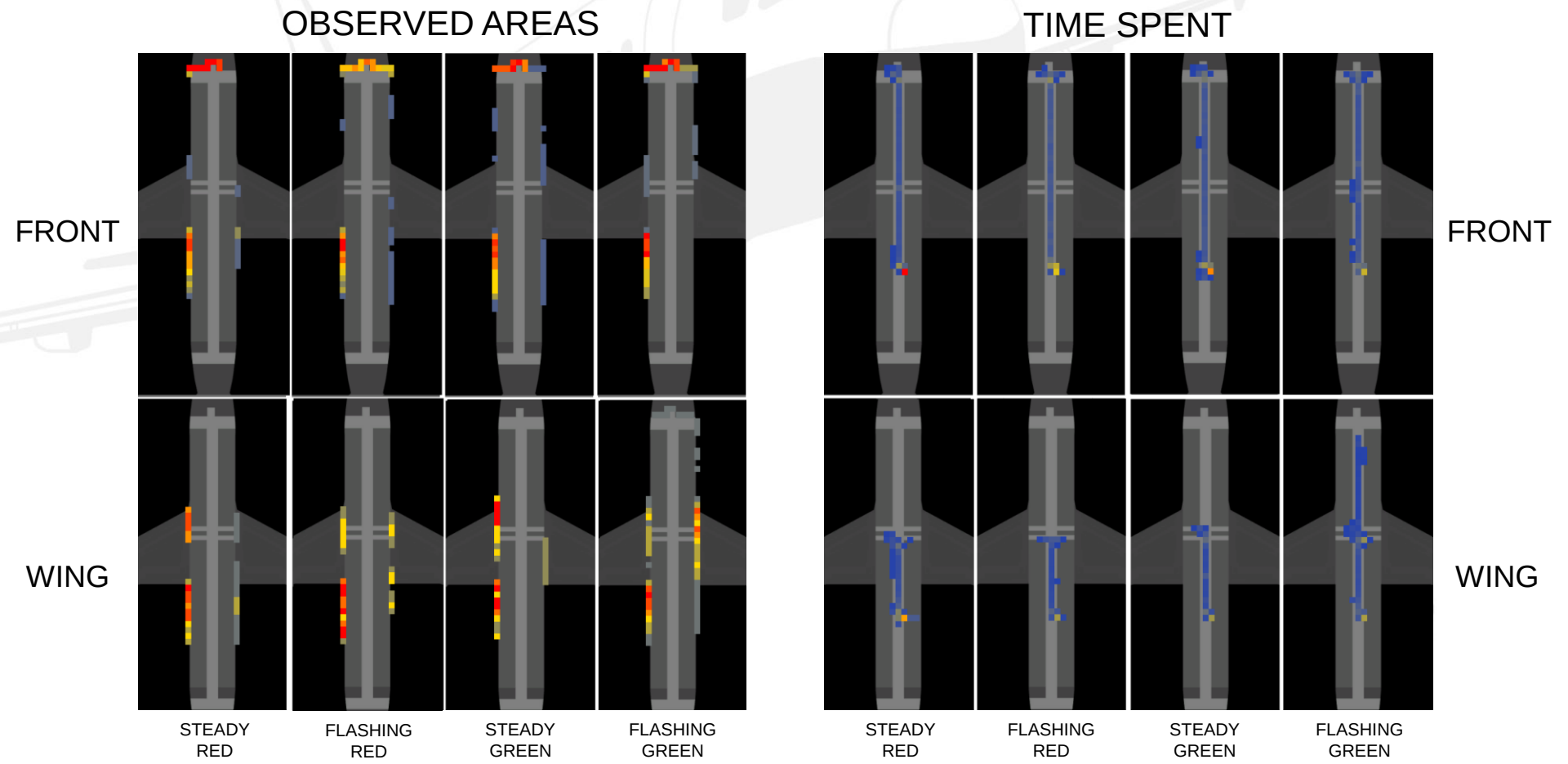
Results: exit choice by marking design

No effect of marking design on the choice of exit (Kruskal-Wallis test, $\chi^2=1.22$, $p=0.75$)

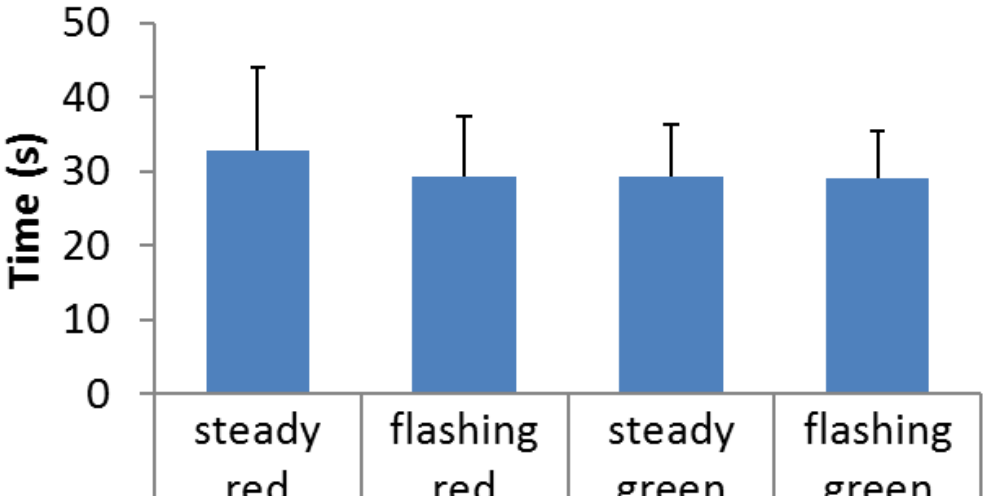
	Wing exits	Front exits
steady red	6	8
flashing red	4	10
steady green	4	10
flashing green	6	8

Results: behavior by marking design

Participants' behavior in the four path marking conditions was very similar



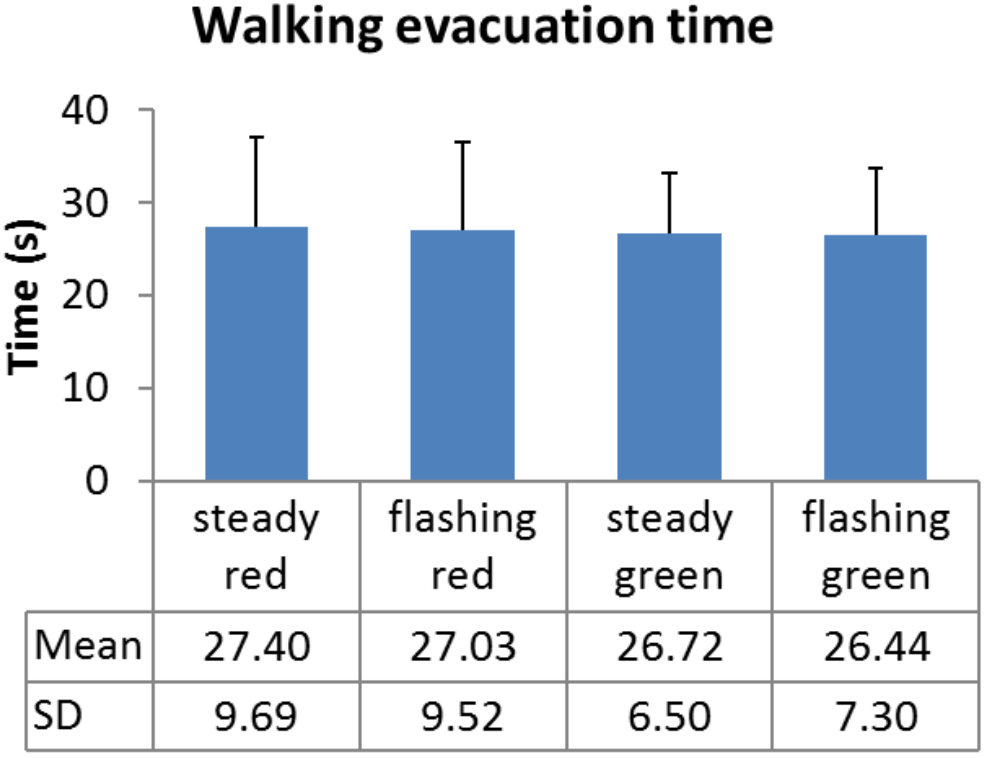
Results: total evacuation time by marking design



	steady red	flashing red	steady green	flashing green
Mean	32.74	29.39	29.34	28.98
SD	11.37	8.06	7.07	6.59

No statistically significant differences among the four marking designs (ANOVA, $F(3,52)=0.61$, $p=0.62$)

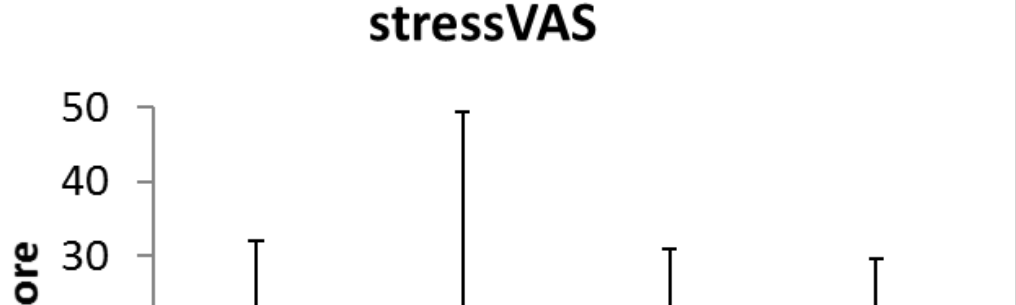
Results: walking evacuation time by marking design



	steady red	flashing red	steady green	flashing green
Mean	27.40	27.03	26.72	26.44
SD	9.69	9.52	6.50	7.30

No statistically significant differences among the four marking designs (ANOVA, $F(3,52)=0.03$, $p=0.99$)

Results: stressVAS by marking design



	steady red	flashing red	steady green	flashing green
Mean	6.50	17.79	7.43	2.71
SD	25.54	31.56	23.48	26.89

No statistically significant differences among the four marking designs (ANOVA, $F(3,52)=0.75$, $p=0.53$)

Results: qualitative observations on marking design

Almost all participants were able to correctly identify the color

Interpretation of color did not significantly differ among the four marking design conditions

- Most participants interpreted lights either as exit availability or path to follow

Several interviewed participants did not remember that the lights were flashing

Results: correlations

Statistically significant correlations between:

- participant's frequency of flying and exit choice (participants who fly more were more likely to evacuate from overwing exits)
- gender and total evacuation time (women were slower in starting to move towards exits)
- familiarity with 3D video games and total evacuation time (participants who were more familiar were faster in evacuating)
- exit choice and evacuation time (participants who escaped from overwing exits were faster)
- FAS (Flight Anxiety questionnaire) and stressVAS values (participants with higher level of flight anxiety had higher subjective stress levels during the virtual evacuation)

Conclusions

The path marking designs we studied were only partially successful in helping participants to find overwing exits

Participants showed similar evacuation performance and behavior with all path marking designs

Participants' behavior in immersive VR shows similarities to human behavior in real emergency evacuations

Future work

The use of VR technologies makes it possible to easily investigate alternative marking designs and alternative scenarios

Possible future work

- Light strips leading towards exits
- Smoke in the cabin
- Social influence
- Effect of pre-flight training
- Effect of cabin crew intervention

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