Karlsruher Institut für Technologie

PHYSIO-ADPAPTIVE SYSTEMS – A STATE-OF-THE-ART REVIEW AND FUTURE RESEARCH DIRECTIONS

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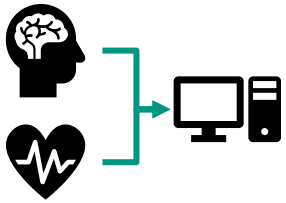
Motivation

IT supported acitivites

A growing number of professional activities are today IT-supported, and this trend will continue in the coming years [1,2].

Interaction between Human and Computer

Today humans and computers interact still in an asymmetrical mouse and keyboard dependent way [3].



In the field of NeuroIS and physio-adaptive systems there are promising approaches towards am more advanced interaction between humans and information systems that consider psychophysiological user states [4,5]. These approaches could help to support desirable states such as flow, which influence well-being and productivity at work [6].

Motivation

Physiological sensors

[7]


[8]

The collection of physiological data is no longer a challenge due to progress in the area of wearables. Ergonomic chest straps are now able to collect heart rate signals with clinical accuracy [9].

Research Gap

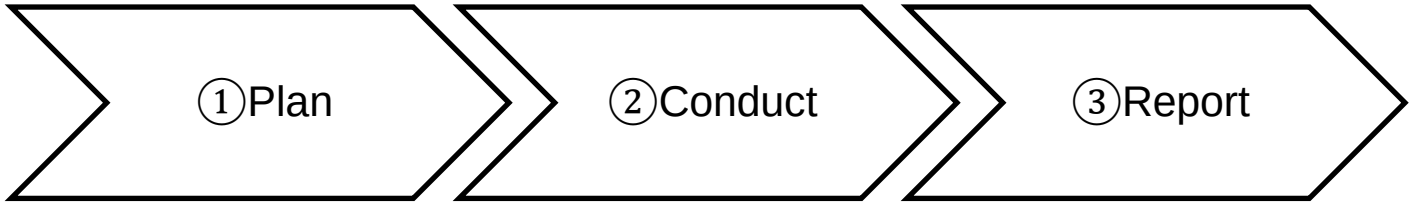
There is a lack of a state-of-the-art overview of physio-adaptive systems for the development of advanced human-machine interfaces based on human physiology.

Research Question

What is the state-of-the art and future research directions of physio-adaptive systems?

Systematic Literature Review

Systematic literature review according to the guidelines from Webster and Watson [10], and Kitchenham [11]:



Classification Process

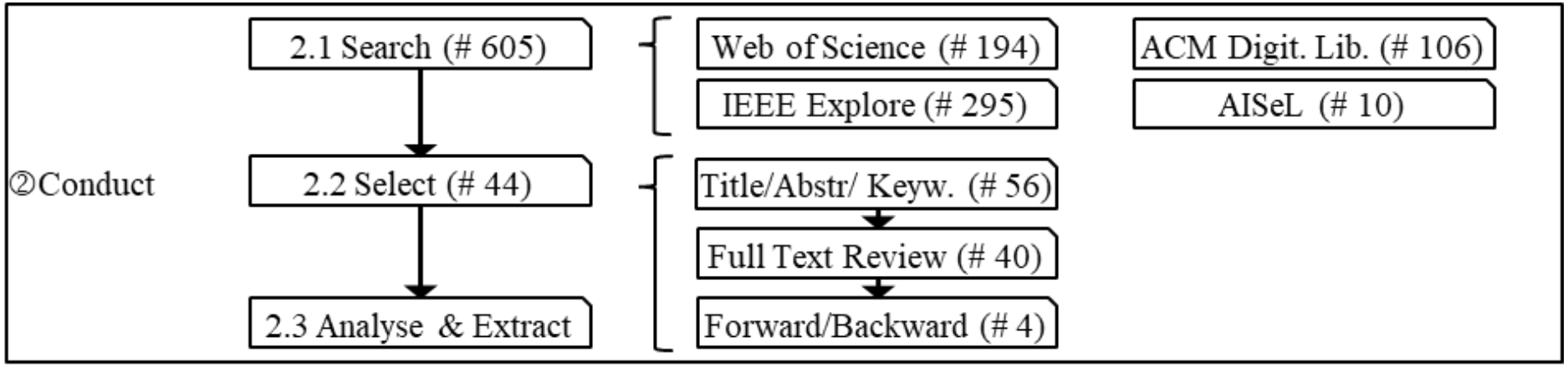
1. Derivation deductively from literature
2. Cross-validation of existing codes or creation of new ones
3. Assignment of codes independently by two researchers and conflict resolution

Method

Search String

(physiol* OR psychophysiol*) *AND*
(adaptive-system* OR “adaptive-automation” OR adaptive-interface* OR “adaptive-computing” OR biocybernetic* OR “bio-feedback”)

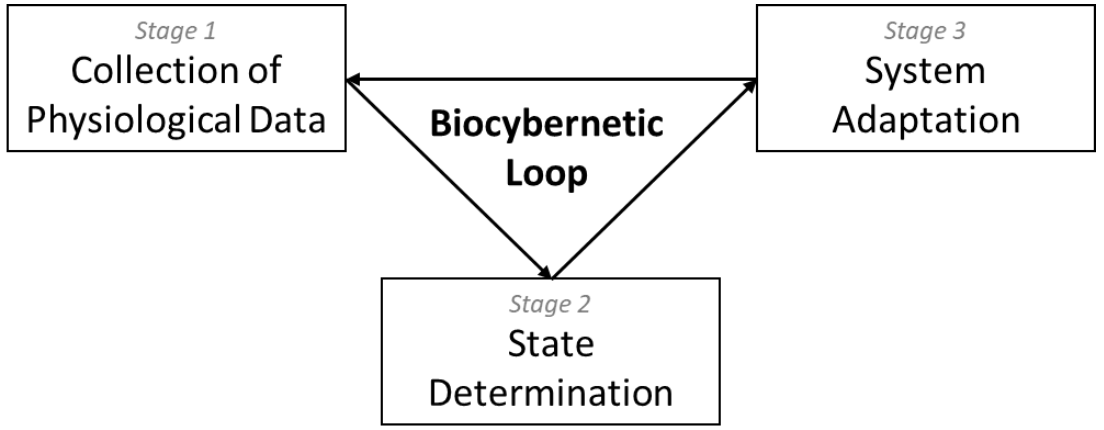
Hit Statistics



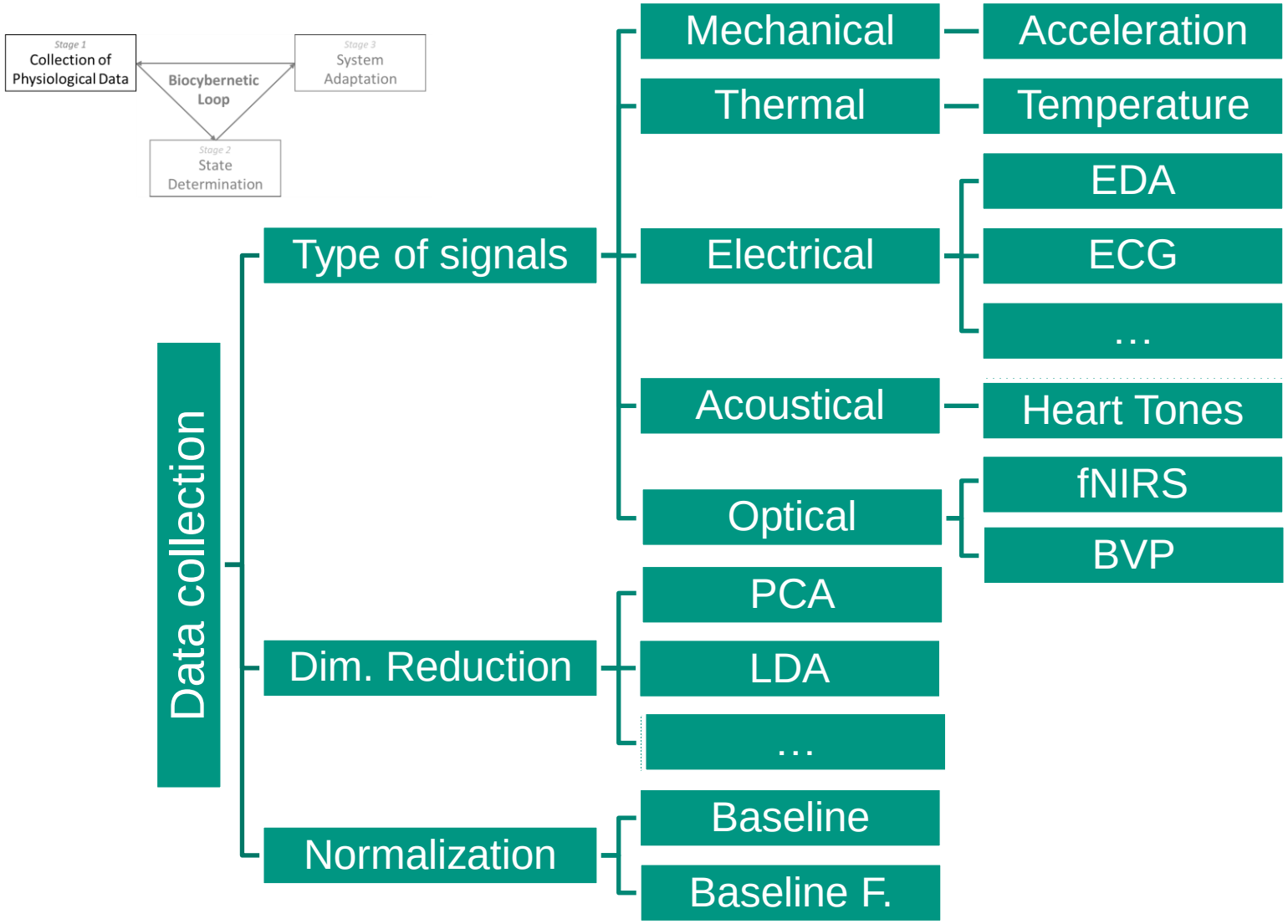
Definition and Conceptual Framework

Physio-adaptive systems define a class of information systems that refer to an innovative mode where system interaction is reached by monitoring, analyzing, and responding to hidden psychophysiological user activity in real-time. [5]

At the core of these systems lies the so-called biocybernetic loop [5]:



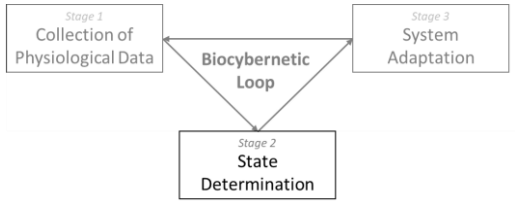
1 – Data Collection

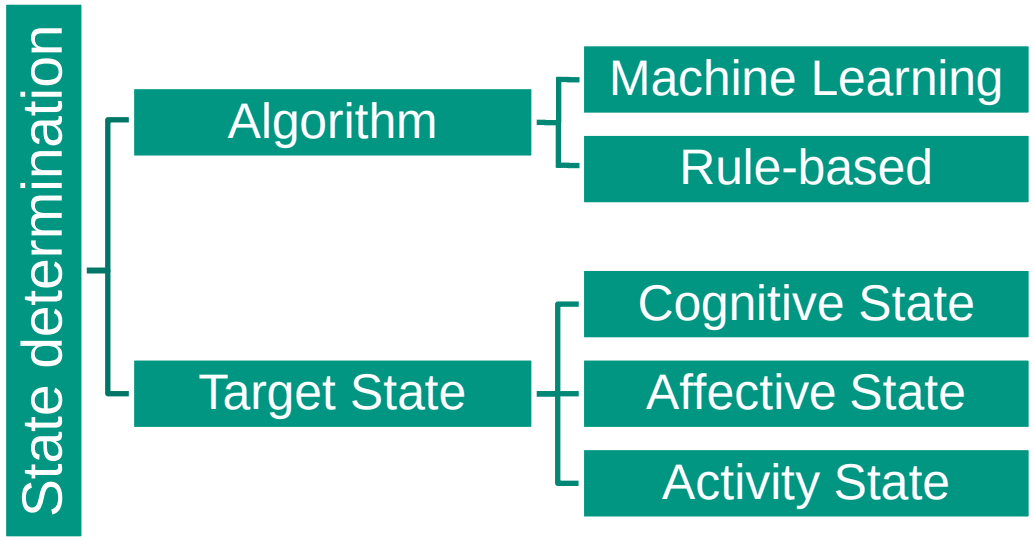


The Data Collection Stage was according to [5] subdivided into the subcategories:

- Type of signals
- Dimensionality Reduction
- Normalization

2 – State Determination

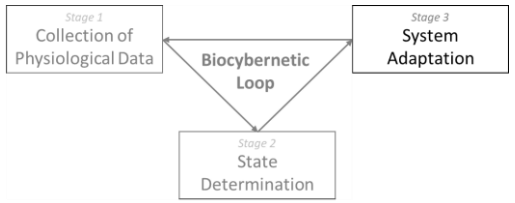


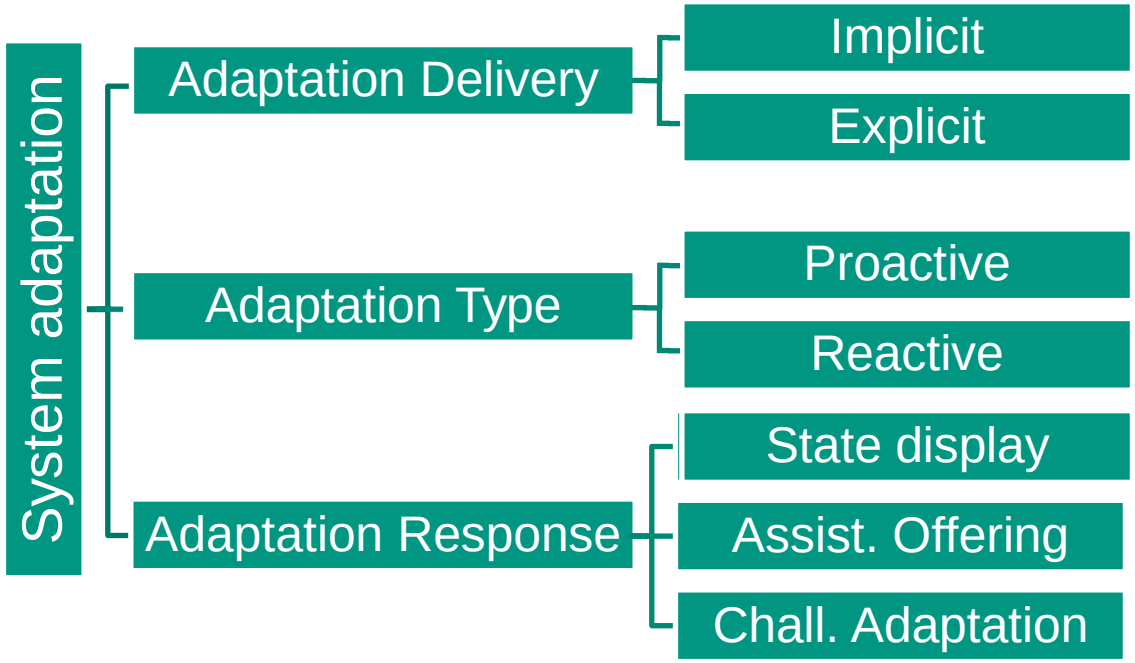


The State Determination stage was according to [5] subdivided into the subcategories:

- Algorithm
- Target State

3 – System Adaptation



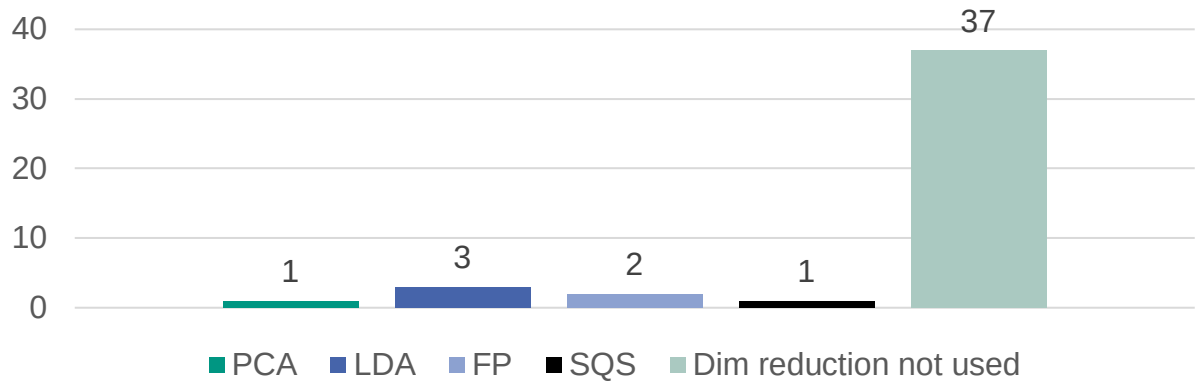


The System adaptation stage was according to [5] subdivided into the subcategories:

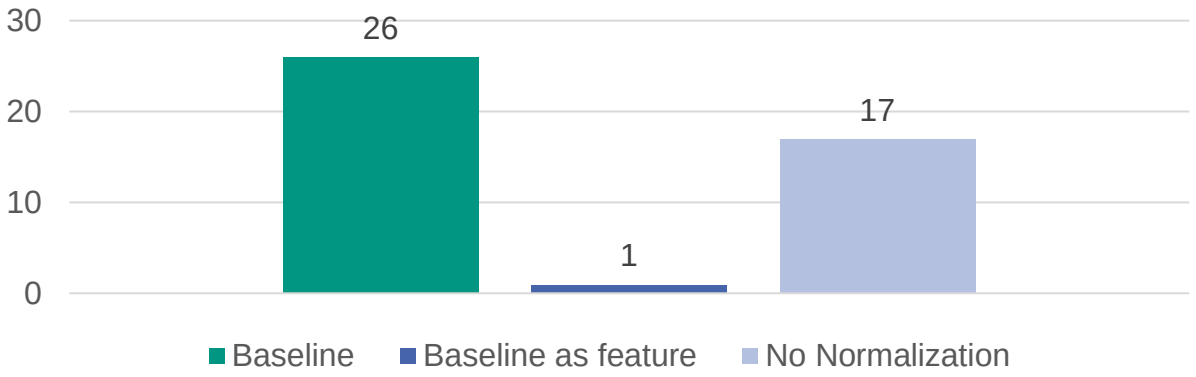
- Adapatation Delivery
- Adapatation Type
- Adaptation response

Results – Data Collection

Dimensionality Reduction



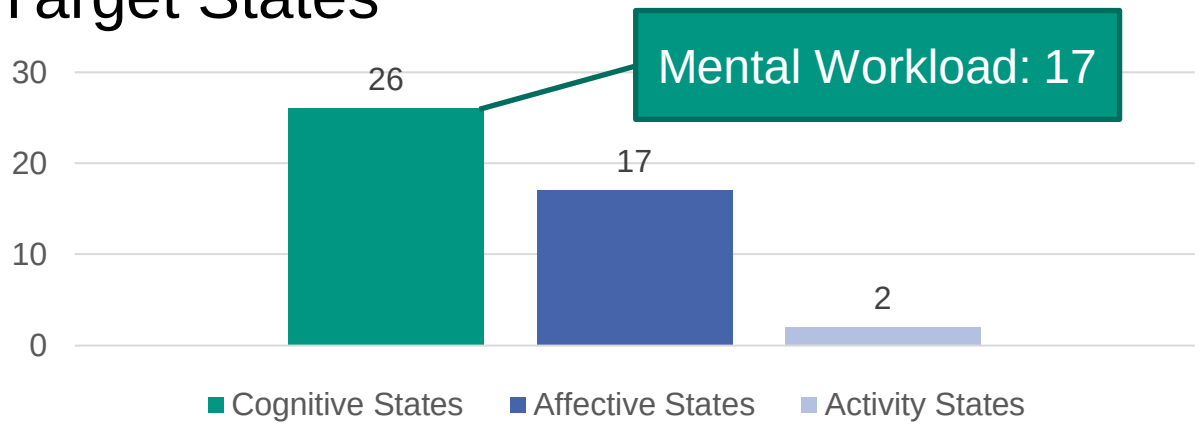
Normalization



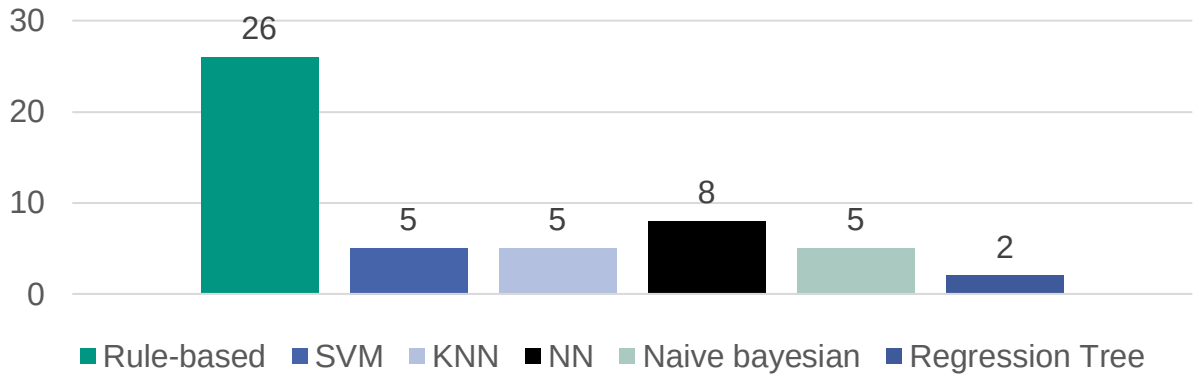
- The type of the collected physiological data is diverse through the literature.
- The majority of the studies do not use dimensionality reduction, although it is considered promising in the literature.
- The evaluation of a baseline in general and the use of the baseline as a feature are so far scarcely addressed in literature, although the baseline could contain interesting information especially as a feature for machine learning approaches.

Results – State Determination

Target States



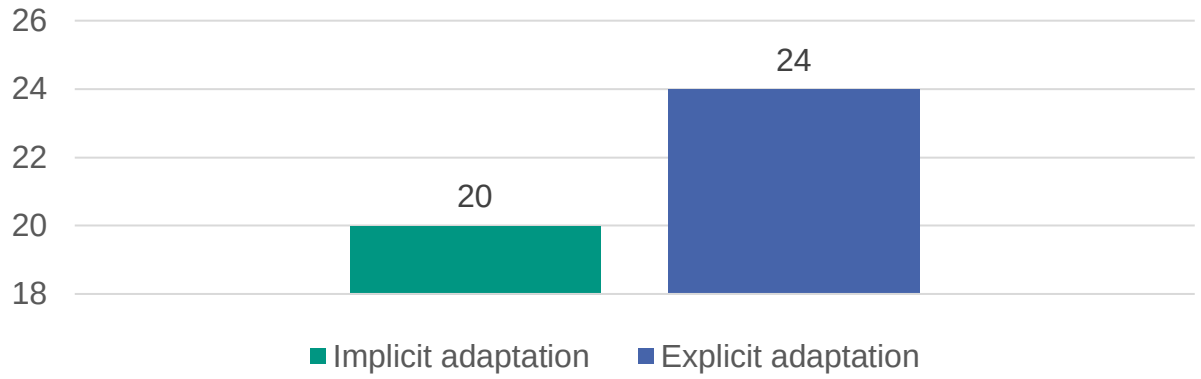
Algorithm



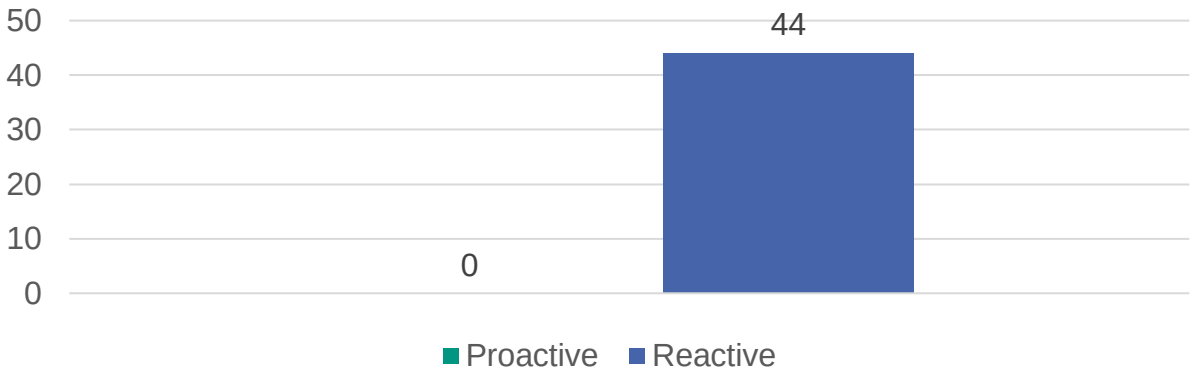
- Multidimensional state adaptation scarcely explored. Only 8 articles tried to adapt more than one user state.
- Cognitive states beyond mental workload scarcely researched. Most physio-adaptive systems in our SLR that target cognitive states target mental workload as unit of analysis.
- Lack of investigation of the suitability of decision trees for state determination.

Results – System Adaptation

Adaptation Delivery



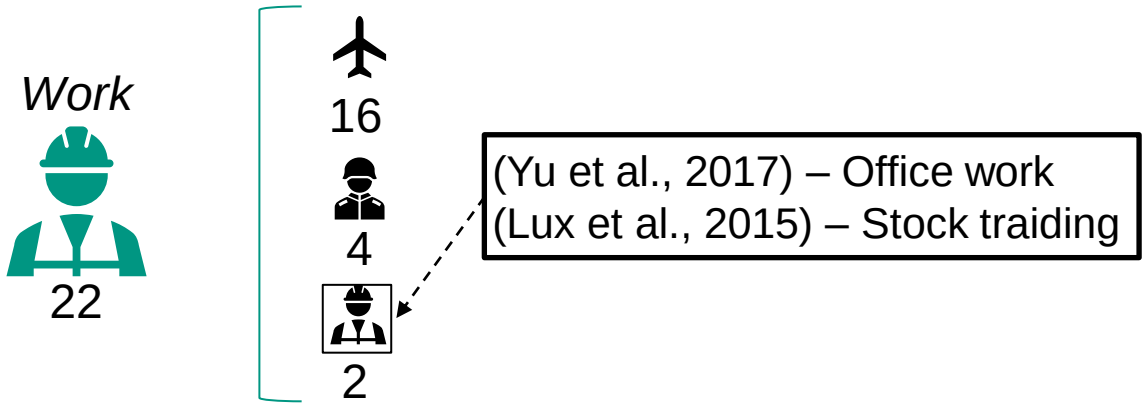
Adaptation Type



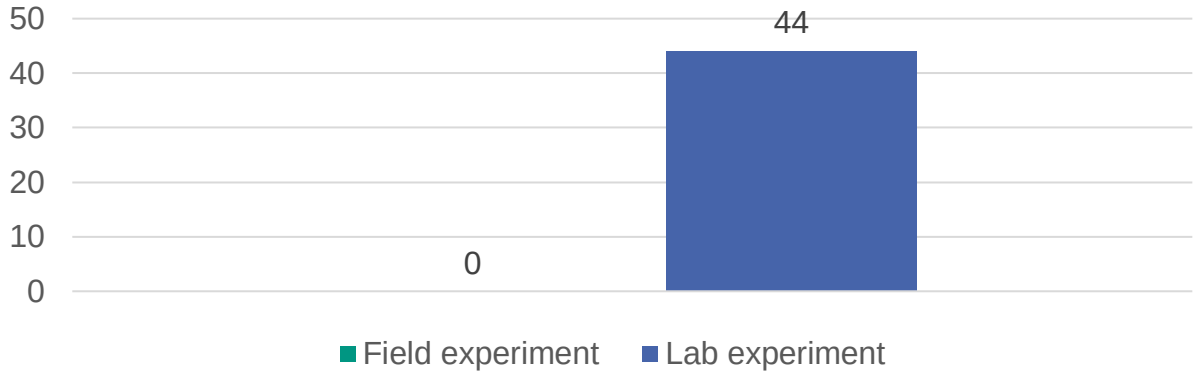
- Implicit, i.e. unconscious, and explicit, i.e. conscious, adaptations of the physio-adaptive systems were balanced in the literature investigated.
- All physio-adaptive systems in the literature used a reactive paradigm for adaptation. None of the systems responded proactively to changes in the user's state.

Results – Context and experimental type

Context



Experimental Type



- Half of the studies investigated physio-adaptive systems in the work context, but only 2 focused civil work, whereas the other 20 studies investigated military and aviation work.
- 15 studies were conducted in the gaming context and 3 in the health context.
- Lack of field studies concerning physio-adaptive systems. Our analysis of the literature on physio-adaptive systems revealed that none of the articles found in the SLR tested a physio-adaptive system in the field.

THANK YOU!

References

[1] Forrester Research Inc (2017). *Midyear Global Tech Market Outlook For 2017 To 2018*. URL: https://www.forrester.com/report/Midyear+Global+Tech+Market+Outlook+For+2017+To+2018/-/E-RES140272.

[2] van der Meulen, R. and W. Bamiduro (2018). *Gartner Says Global IT Spending to Grow 6.2 Percent in 2018*. URL: https://www.gartner.com/en/newsroom/press-releases/2018-04-09-gartner-says-global-it-spending-to-grow-6-percent-in-2018.

[3] Hettinger, L. J., P. Branco, L. M. Encarnacao and P. Bonato (2003). "Neuroadaptive technologies: Applying neuroergonomics to the design of advanced interfaces" *Theoretical Issues in Ergonomics Science* 4 (1-2), 220–237.

[4] Riedl, R. and P.-M. Léger (2016). *Fundamentals of NeuroIS*. *Information Systems and the Brain.* 1st ed. 2016. Berlin, Heidelberg: Springer.

[5] Fairclough, S. H. (2009). "Fundamentals of physiological computing" *Interacting with Computers* 21 (1-2), 133–145.

[6] Csikszentmihalyi, M. (1990). *Flow*. *The psychology of optimal experience.* New York: Harper and Row.

[7] Image by Polar Inc., https://polar.com.

[8] Image by Equivital Inc, https://equivital.com.

[9] Rahel Gilgen-Ammann, Theresa Schweizer, and Thomas Wyss. 2019. RR interval signal quality of a heart rate monitor and an ECG Holter at rest and during exercise. *European journal of applied physiology* 119, 7, 1525–1532. DOI: https://doi.org/10.1007/s00421-019-04142-5.

[10] Webster, J. and R.T. Watson (2002). "Analysing the past to prepare for the future: Writing a literature review" *MIS Quarterly* 26 (2), xiii–xxiii.

[11] Kitchenham, B. and S. Charters (2007). "Guidelines for performing Systematic Literature Reviews in Software Engineering".