User-Centered Design Metrics and Motivational Aspects for Basic Study Design

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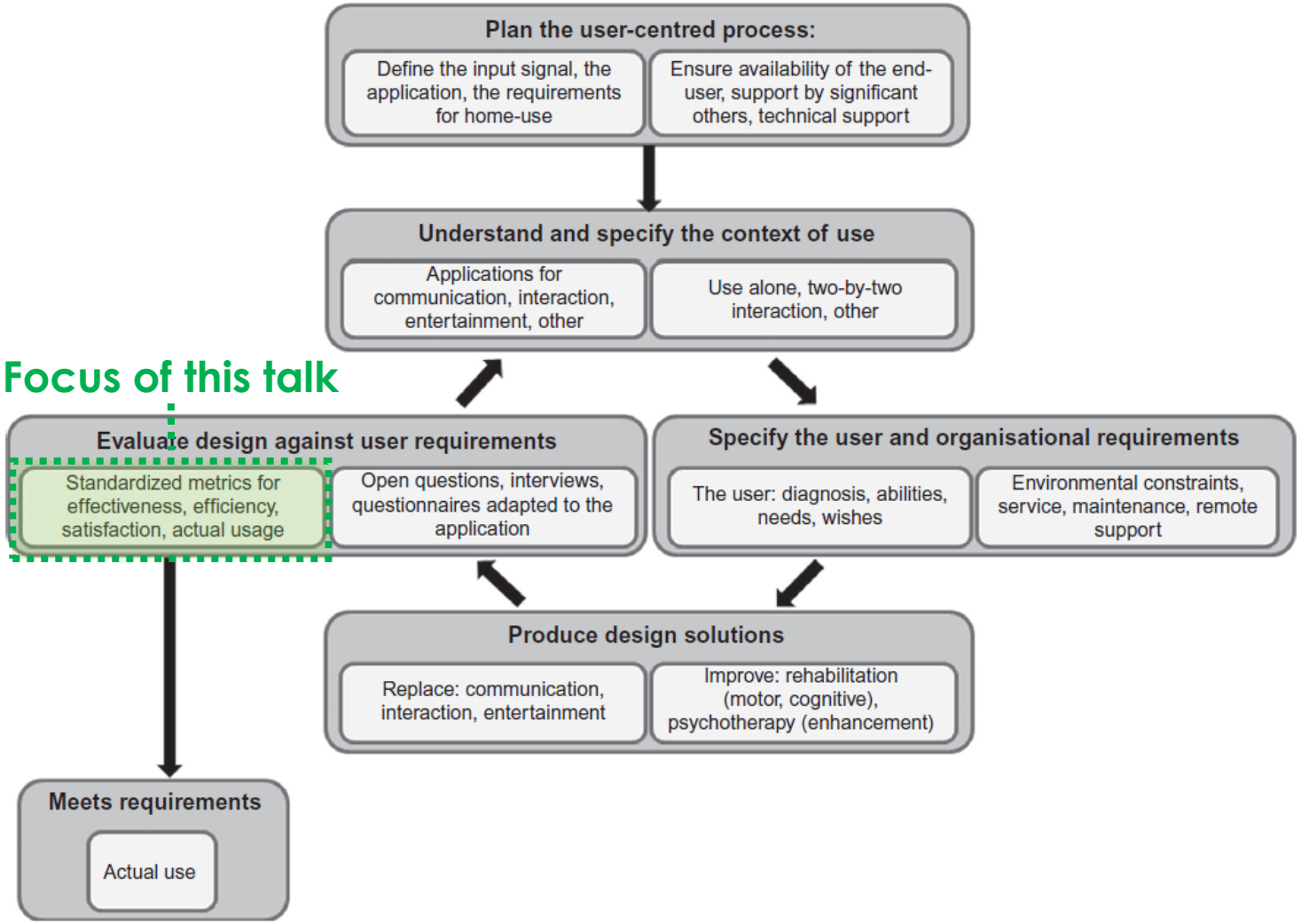
User-Centered Design (UCD): A Step-by-Step Process (as explained by Angela)



Kübler, A., Nijboer, F., & Kleih, S. (2020). Hearing the needs of clinical users. In Ramsey, N. F. & Millán, J. R. (Eds.), *Handbook of Clinical Neurology*. Amsterdam: Elsevier.
Kübler, A., Holz, E. M., Riccio, A., Zickler, C., Kaufmann, T., Kleih, S. C., …, & Mattia, D. (2014). The user-centered design as novel perspective for evaluating the usability of BCI-controlled applications. *PLoS ONE, 9(12),* doi: 10.1371/journal.pone.0112392.

Overview

Evaluation metrics for each aspect of usability (Table 26.2)

Aspects of usability	Transfer to BCI/ applications	Metrics	Assessment	Exemplary studies using these measures
Effectiveness	Accuracy	% correct responses	Each session	Many
Efficiency	Information transfer rate (ITR)	Bits/min	Each session	Many
	Utility metric	Bits/min (bits/min = 0 if effectiveness < 50%)	Each session	Zickler et al. (2013)
	Workload	NASA-TLX	Each session/ task	Riccio et al. (2015)
Satisfaction	General aspects of AT	QUEST 2.0	End of prototype testing	(Rupp et al., 2012; Holz et al., 2013)
	BCI-related aspects	Four items (reliability, learnability, speed, and esthetic design)	End of prototype testing	Zickler et al. (2011, 2013)
	Overall satisfaction	VAS (0 – 10)	Each session	Holz et al. (2015a, b)
	Interview	Semistructured; free	End of prototype testing	Vasilyev et al. (2017)
Usage	Match between product and user	ATD-PA device-initial, sections consumer, professional	End of prototype testing	Holz et al. (2015b)
	Overall usability	System usability scale	End of prototype testing	Pasqualotto et al. (2015) and Zander et al. (2017)
	Use in daily life	Single item	End of prototype testing	

Focus of this talk

See supplements for detailed information.

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BCI SOCIETY

Overview

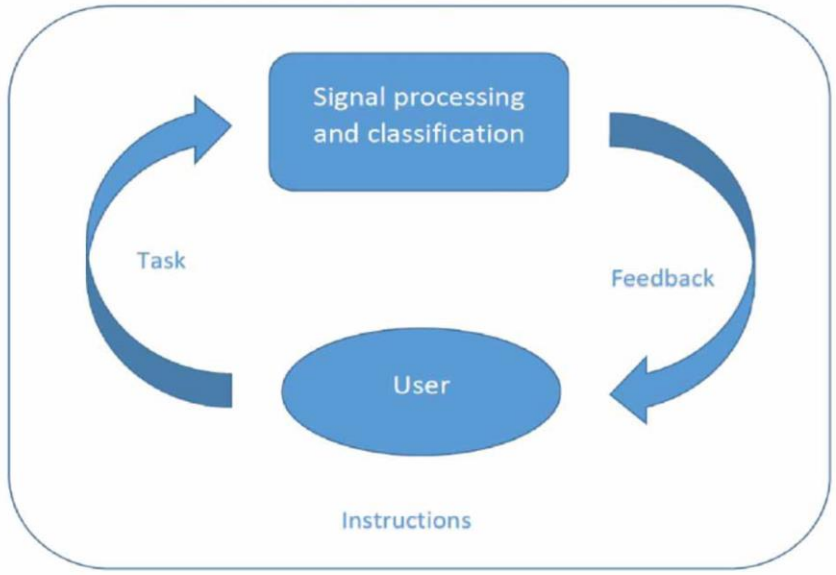

FIGURE 1 | Conventionally, BCI research is focused mostly on the signal processing and algorithms necessary to translate mental patterns into control commands. The user and the context in which he or she is learning to produce mental patterns is, on the other hand, often treated with neglect. We argue that the *tasks* a user has to perform, the *feedback* that informs about the performance, and the *instructions* that enable to perform are equally important and discuss them based on literature from instruction design.

Focus of this talk

Table 1 | Summary of desirable properties of a good instructional design with corresponding suggestions to improve human training protocols for BCI.

Level	Properties of a good instructional design	Corresponding suggestions for BCI training protocols
Feedback	- Non-evaluative and supportive feedback (Hattie and Timperley, 2007; Shute, 2008) - Feedback that conducts to a feeling of competence (Ryan and Deci, 2000)	Provide positive feedback (feedback only indicating when the user did right) only for beginners, and disconfirmatory feedback for advanced users
	- Clear and meaningful feedback (Hattie and Timperley, 2007)	Start with a subject-independent classifier for users with poor initial performances
	- Explanatory and specific feedback (Hattie and Timperley, 2007; Shute, 2008) (Moreno and Mayer, 2007) - Feedback that signals a gap between current and desired performances (Hattie and Timperley, 2007; Shute, 2008)	Provide more information about what was right or wrong about the EEG patterns produced by the user: - Provide as feedback the value of a few (less than seven) relevant EEG features - Provide as feedback some measure of quality of the mental imagery
	- Multimodal feedback (Ainsworth, 2006) (Merrill, 2007)	Provide a multimodal feedback (e.g., visual + haptic), with the same granularity and specificity for each modality, with some redundancy between them
	- Engaging feedback and environment (Ryan and Deci, 2000)	Represent the feedback as an interaction with a game element (e.g., a 3D car)
Instructions	- Goals should be clearly defined (Hattie and Timperley, 2007; Shute, 2008)	Expose the real goal of BCI training, i.e., to produce clear, specific and stable EEG patterns
	- The meaning of the feedback should be explained (Ainsworth, 2006)	Explain what the BCI feedback means, particularly for non-intuitive feedback such as the classifier output.
	- Prior knowledge should be activated (Merrill, 2007; Moreno and Mayer, 2007) - The skill to be learned should be demonstrated (Merrill, 2007)	- Instruct the users to remember situations in which they used the task they will imagine - Demonstrate successful BCI use and BCI feedback during correct task performance
Tasks	- Progressive and adaptative tasks (Ainsworth, 2006; Merrill, 2007) - Tasks that are challenging but still achievable (Hattie and Timperley, 2007; Shute, 2008)	Use adaptive BCI training protocols with increasing difficulty (e.g., progressively increasing the number of mental tasks to be mastered)
	- Need for autonomy and work at the user's own pace (Ryan and Deci, 2000; Shute, 2008) (Moreno and Mayer, 2007)	Include more training sessions with free and/or self-paced BCI use
	- Motivation and positive emotions promote learning (Ryan and Deci, 2000; Um et al., 2012)	Using positive emotion-inducing training tasks e.g., including gaming mechanisms
	- Need for variability over tasks and problems (Sweller et al., 1998; Ainsworth, 2006)	Include variety in the mental tasks to be performed, e.g., change in speed or duration of the mental imagery
	- Adapt the training procedure to the student (Hattie and Timperley, 2007; Shute, 2008)	Matching BCI training protocols to users' characteristics

It should be noted that such suggestions are only based on theory, and will need to be formally validated.

See supplements for detailed information.

Chavarriaga, R., Fried-Oken, M., Kleih, S., Lotte, F., & Scherer, R. (2017). Heading for new shores! Overcoming pitfalls in BCI design. *Brain-Computer Interfaces, 4,* doi: 10.1080/2326263X.2016.1263916.
Lotte, F., Larrue, F. & Mühl, C. (2013). Flaws in current human training protocols for spontaneous Brain-Computer Interfaces: lessons learned from instructional design. *Frontiers in Human Neuroscience, 7,* doi: 10.3389/fnhum.2013.00568.

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Example

SCIENTIFIC REPORTS

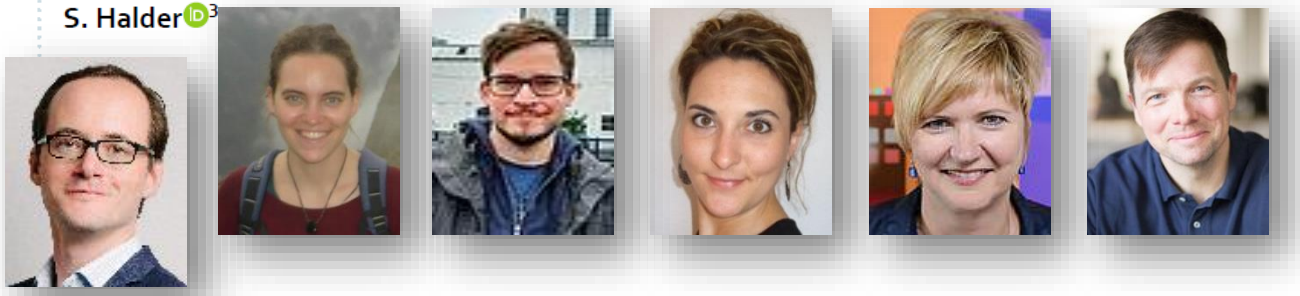
nature research

Check for updates

OPEN

Stimulus modality influences session-to-session transfer of training effects in auditory and tactile streaming-based P300 brain–computer interfaces

P. Ziebell[1✉], J. Stümpfig[1], M. Eidel[1], S. C. Kleih[1], A. Kübler[1], M. E. Latoschik[2] & S. Halder[3]



Ziebell, P., Stümpfig, J., Eidel, M., Kleih, S. C., Kübler, A., Latoschik, M. E., & Halder, S. (2020). Stimulus modality influences session-to-session transfer of training effects in auditory and tactile streaming-based P300 brain–computer interfaces. *Scientific Reports, 10(1),* doi: 10.1038/s41598-020-67887-6.

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Task, Feedback, and Instructions

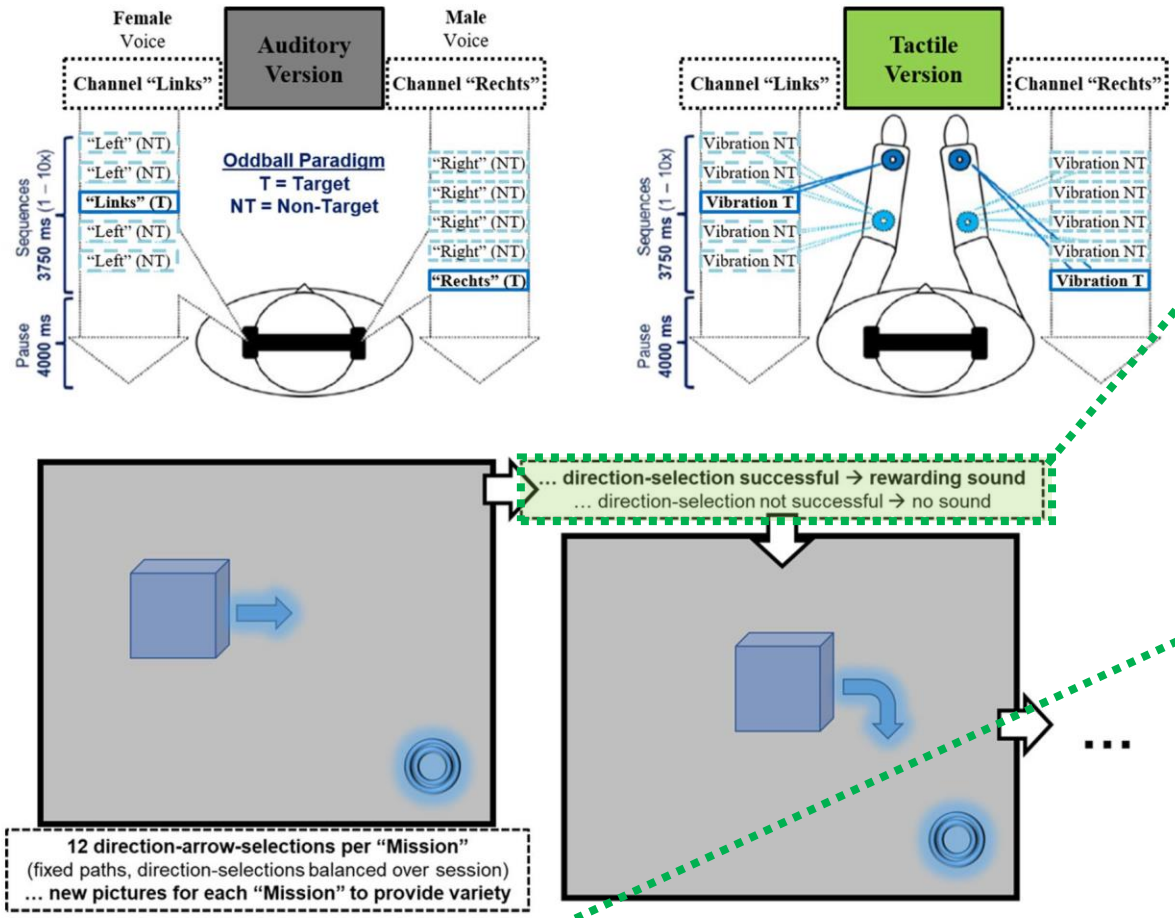
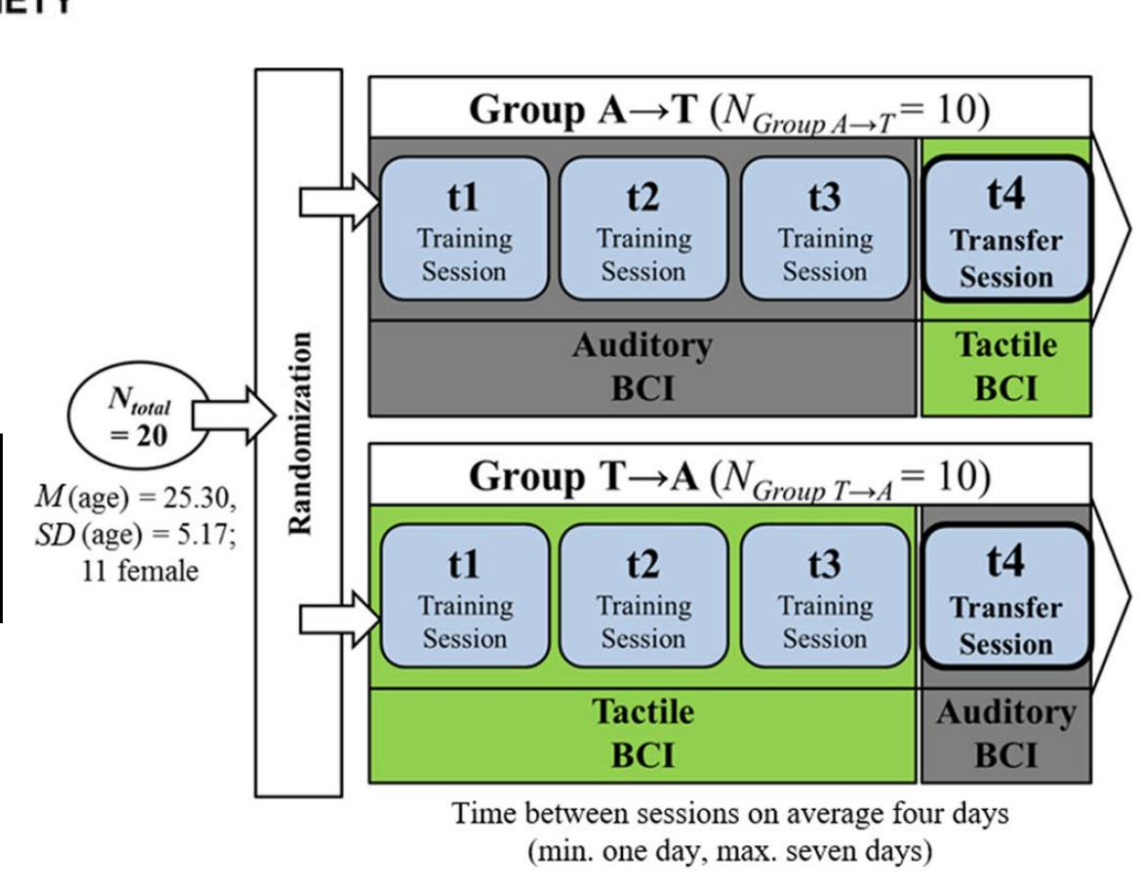


Figure 1. Top: Streaming-based P300 BCIs with auditory stimulation (top left) and tactile stimulation (top right). Bottom: "Star Wars Mission" task, where participants had to move objects (symbolized by a cube) towards a goal (ring) along predetermined direction arrows before various backgrounds. The objects and backgrounds that have been used in this study are not shown in this figure due to trademarking issues. Direction arrows were varied but always clearly pointed towards either left or right.

Motivational Aspects

Ziebell, P., Stümpfig, J., Eidel, M., Kleih, S. C., Kübler, A., Latoschik, M. E., & Halder, S. (2020). Stimulus modality influences session-to-session transfer of training effects in auditory and tactile streaming-based P300 brain–computer interfaces. *Scientific Reports, 10(1),* doi: 10.1038/s41598-020-67887-6.

Training Protocol



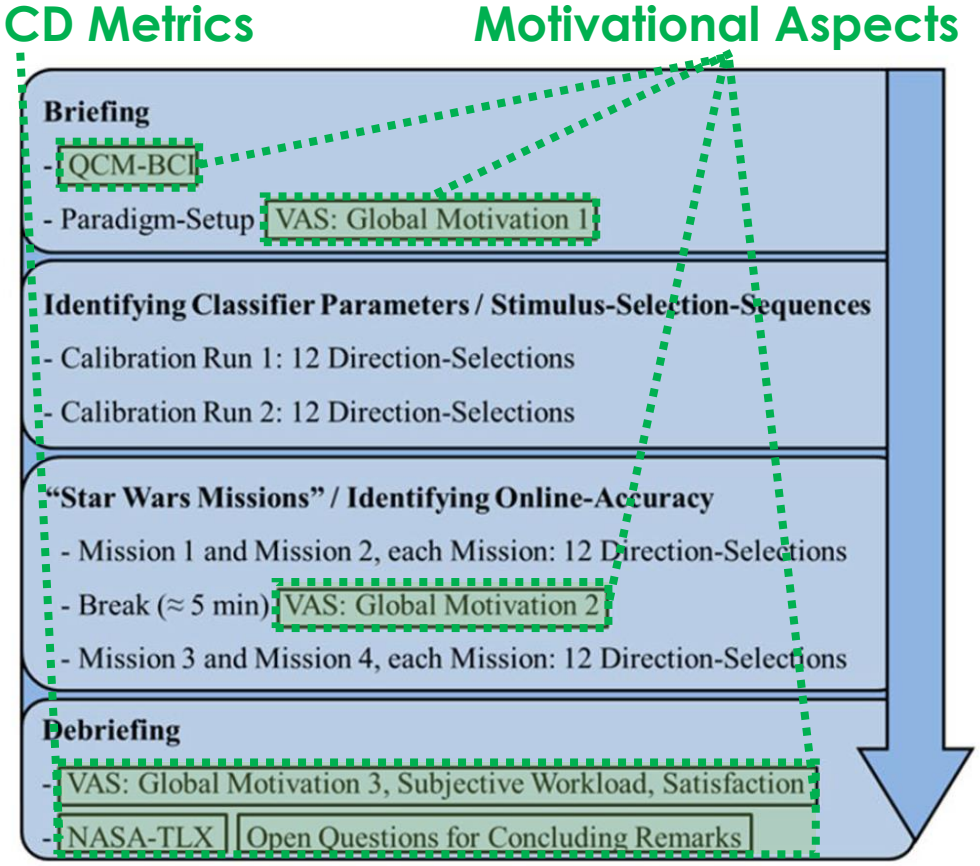


Figure 2. Left: Training overview. Right: Session overview including questionnaires (QCM-BCI, NASA-TLX, VAS).

Ziebell, P., Stümpfig, J., Eidel, M., Kleih, S. C., Kübler, A., Latoschik, M. E., & Halder, S. (2020). Stimulus modality influences session-to-session transfer of training effects in auditory and tactile streaming-based P300 brain–computer interfaces. *Scientific Reports, 10(1),* doi: 10.1038/s41598-020-67887-6.

Objective UCD Metrics

Online-Accuracy (UCD effectiveness) and ITR (UCD efficiency) can provide valuable complementary information...

..., same goes for depiction of individual profiles (e.g. dropouts could be prevented).

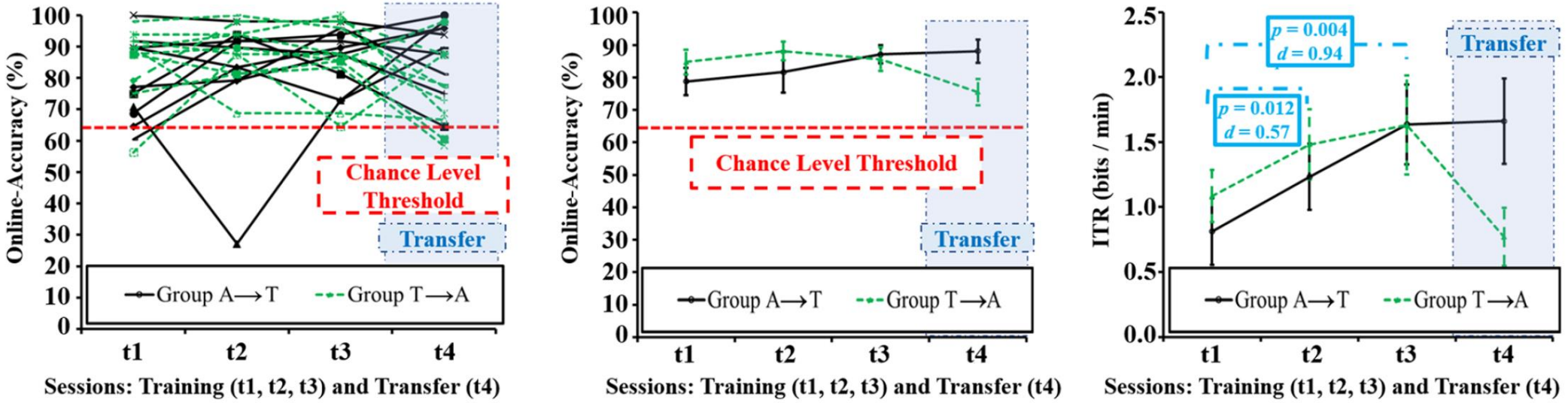


Figure 4. Objective measures for effectiveness (Online-Accuracy) and efficiency (Information Transfer Rate, ITR). Graphs on the left show individual online-accuracies, graphs in the center and on the right show average profiles for online-accuracy and ITR, with error bars marking standard errors of the means and significant p-values (after Bonferroni–Holm correction). Red dotted horizontal line at online-accuracy level of 63.59% indicates the chance level for a two-class BCI with 48 trials and a significance level of $\alpha = 0.05$[29].

Ziebell, P., Stümpfig, J., Eidel, M., Kleih, S. C., Kübler, A., Latoschik, M. E., & Halder, S. (2020). Stimulus modality influences session-to-session transfer of training effects in auditory and tactile streaming-based P300 brain–computer interfaces. *Scientific Reports, 10(1),* doi: 10.1038/s41598-020-67887-6.

Subjective UCD Metrics

NASA-TLX (UCD efficiency) and VAS (UCD efficiency, UCD satisfaction) can provide valuable complementary information…

…, same goes for non-significant trends.

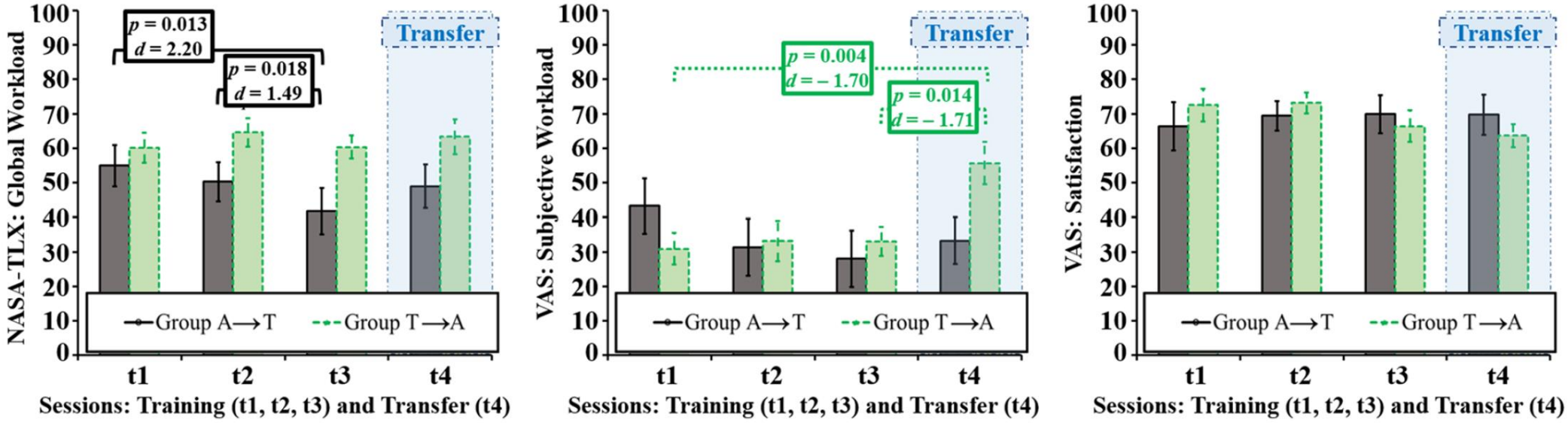


Figure 5. Subjective measures for efficiency (NASA-Task Load Index, NASA-TLX: Global Workload; Visual Analogue Scales, VAS: Subjective Workload) and satisfaction (VAS: Satisfaction). Graphs show average profiles with error bars marking standard errors of the means and significant p-values (after Bonferroni–Holm correction).

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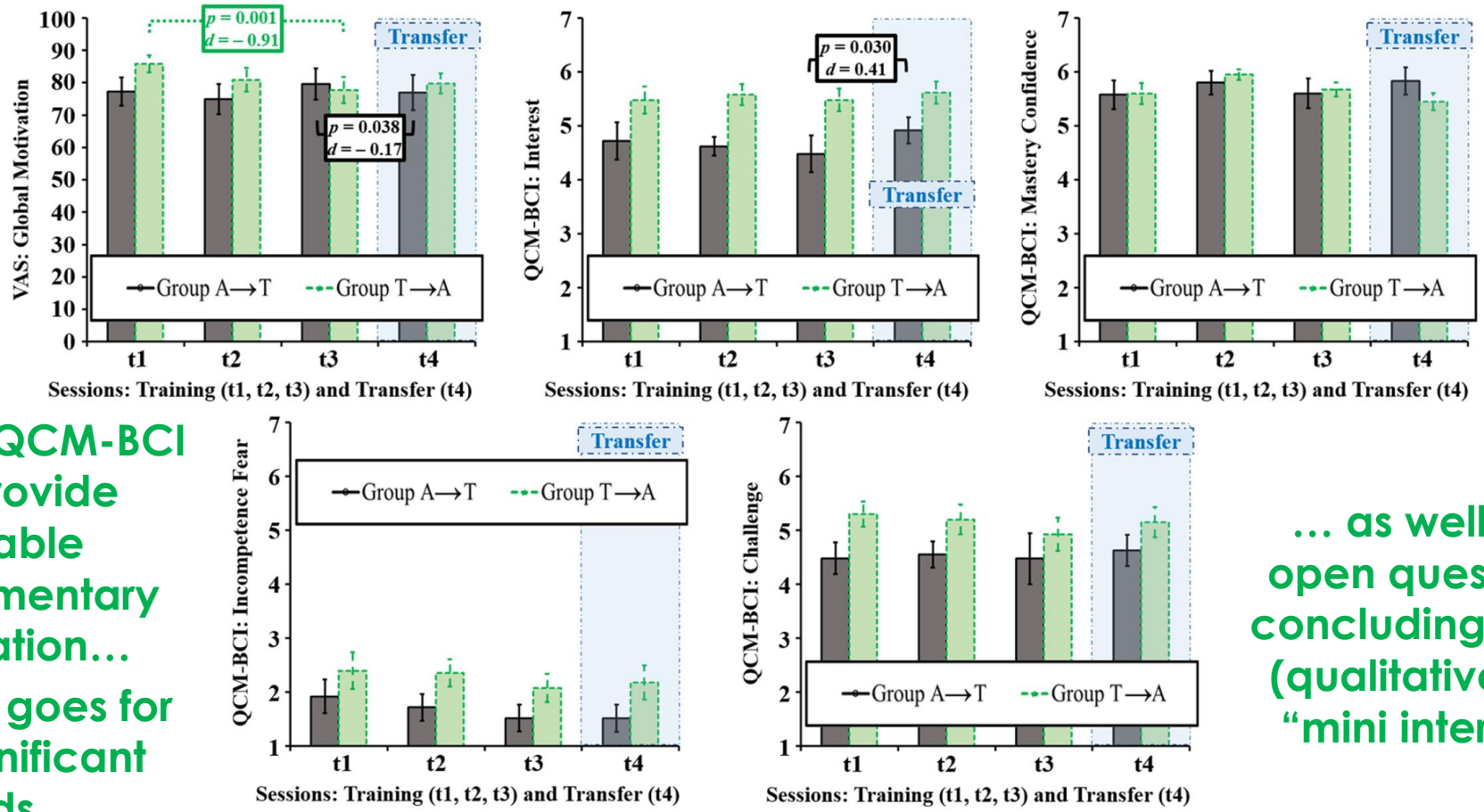
Motivational Aspects



VAS and QCM-BCI can provide valuable complementary information…

…, same goes for non-significant trends…

… as well as the open questions for concluding remarks (qualitative data / "mini interview").

Figure 6. Subjective measures for motivation (Visual Analogue Scales, VAS: Global Motivation; Questionnaire for Current Motivation in Learning and Performance Situations BCI-version, QCM-BCI: Interest, Mastery Confidence, Incompetence Fear, Challenge). Graphs show average profiles with error bars marking standard errors of the means and significant p-values (after Bonferroni–Holm correction).

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- User-Centered Design Metrics
- Motivational Aspects
- Study Design: Methods
- Study Design: Results
- **Q & A**

Thank You!

See supplements for detailed information.

See also poster 2-D-11: „Introducing Tactile P300 Brain-Computer Interfaces to a Locked-In Syndrome Patient with Amyotrophic Lateral Sclerosis“

See also poster 3-D-12: „Moving Closer to Application: ALS Patients Control a Virtual Wheelchair Using a Tactile Brain-Computer Interface “