Developing just in time adaptive interventions (JITAIs) to counter stress: Promises and pitfalls

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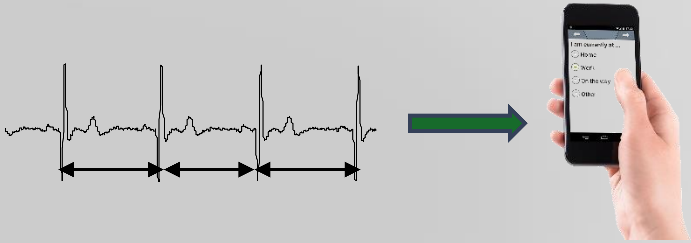

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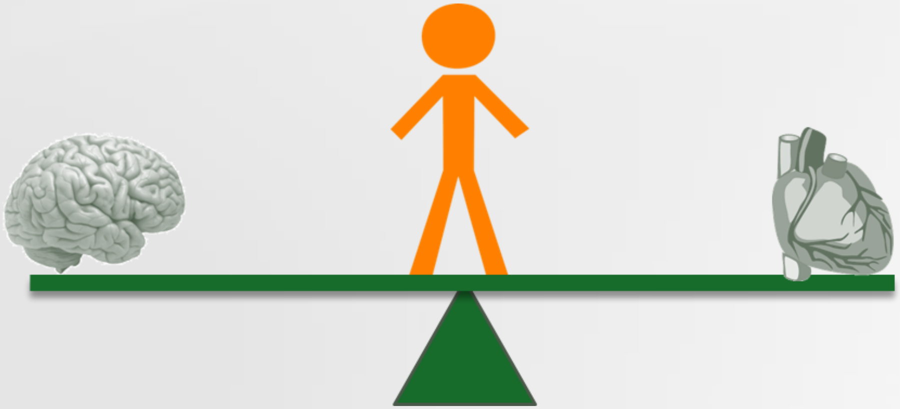
JITAIs: What if…

- .. technical aids and algorithms could detect how we are feeling (or the state of our mental/physical health)?
- ..we were informed about when we are particularly productive/creative or vulnerable?
- ...we received help in our daily lives exactly when we needed it the most?
- **Are JITAIs the solution?**

The promises of JITAIs

- According to data from the European Commission, in 2014, with a global population of 7 billion people, there were already over 5 billion mobile phones;
- 90% of users carry them with them 24 hours a day;
- This results in significant potential for healthcare and prevention, especially for health psychology!



JITAIs: Why useful?

- Customized interventions, not only tailored to differences between individuals (personality, gender, motives, etc.) but within individuals (risky situations or times of day, sensitive external or internal contexts);
- In fact, the superiority of tailored interventions (on an inter-individual level!) to improve health behavior can be questioned. Indeed, such effects are small (e.g., Noar et al., 2007; $r = .074$; max. $r = .12$);
- Do we need the intra-individual level?

JITAIs: Main characteristics

- Direct and time-sensitive response to the individual's needs or goals;
- The content or timing of the intervention is based on dynamically collected data;
- The intervention is controlled/triggered by the system and not by the individual themselves (→ Push-Interventions);
- In principal, the individual/client should be involved in the development of the intervention to make it more powerful!

JITAIs: Key concepts

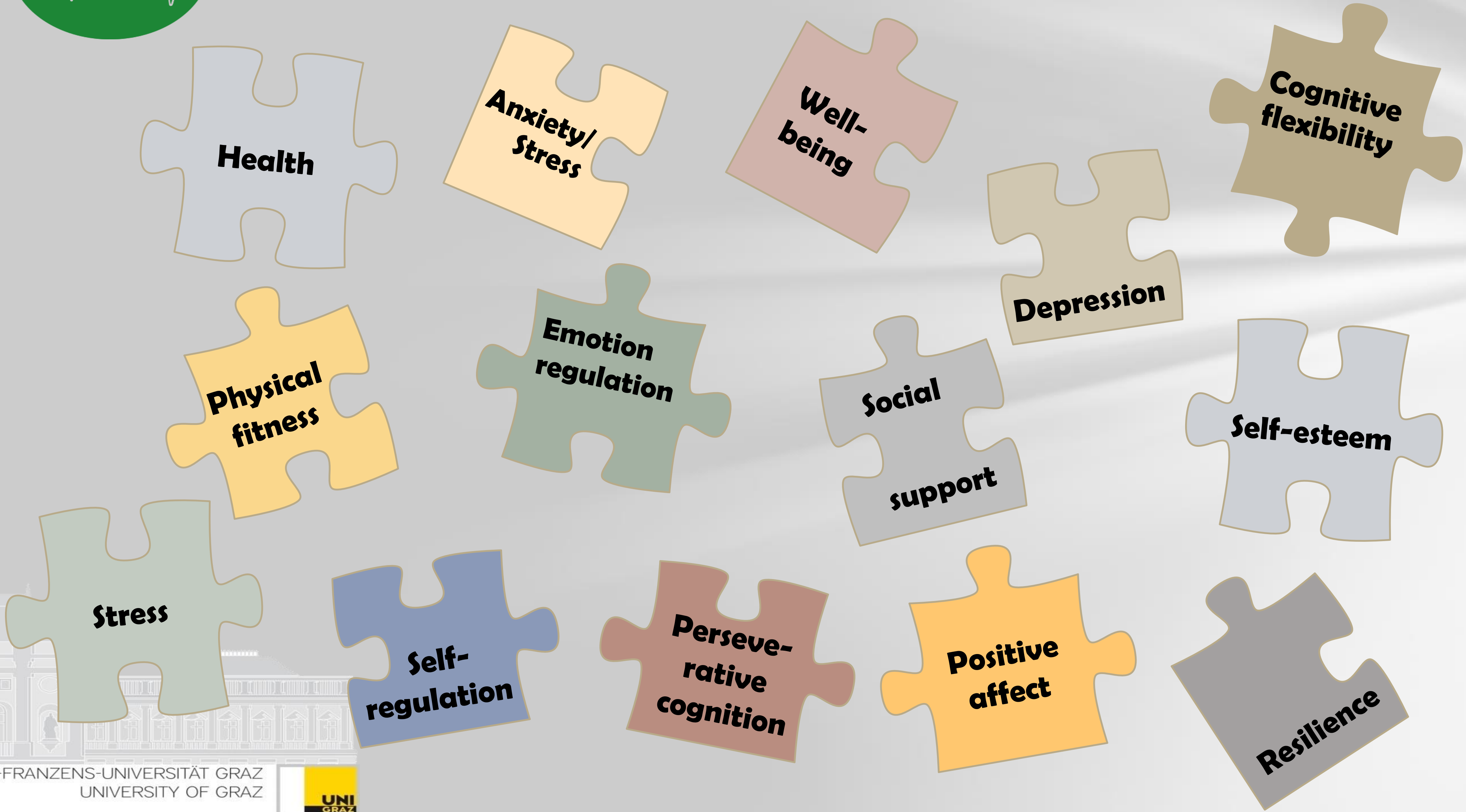
1. **Vulnerability** (when does a person need the intervention?)
2. Opportunity (when does the intervention fit into the daily routine?)
3. Receptivity (when is the person receptive to it?)

Nahum-Shani, I. et al. (2018). Just-in-Time Adaptive Interventions (JITAIs) in mobile health: Key components and design principles for ongoing health behavior support. *Annals of Behavioral Medicine*, 52, 446-462.

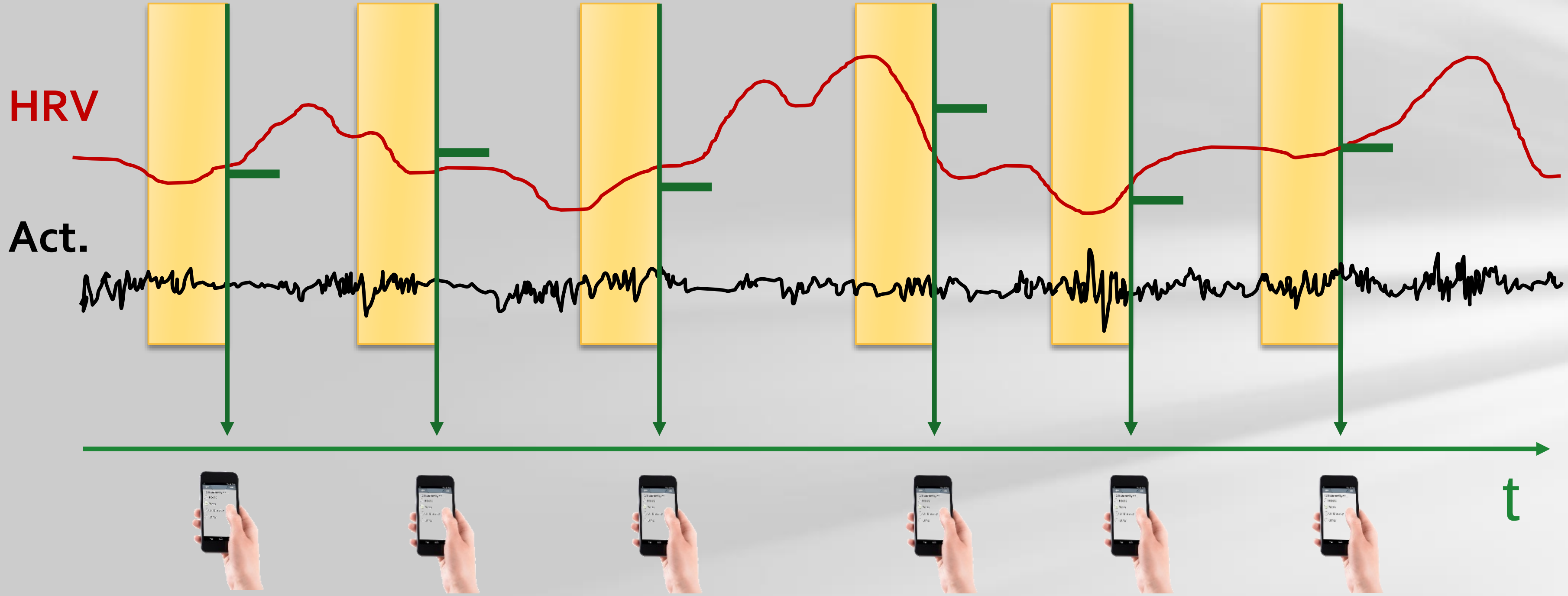
Using HRV to index moments of vulnerability??

HRV: A useful variable for JITAIs?

HRV anybody?


Health
Anxiety/ Stress
Well-being
Cognitive flexibility
Depression
Physical fitness
Emotion regulation
Social support
Self-esteem
Stress
Self-regulation
Perseve-rative cognition
Positive affect
Resilience

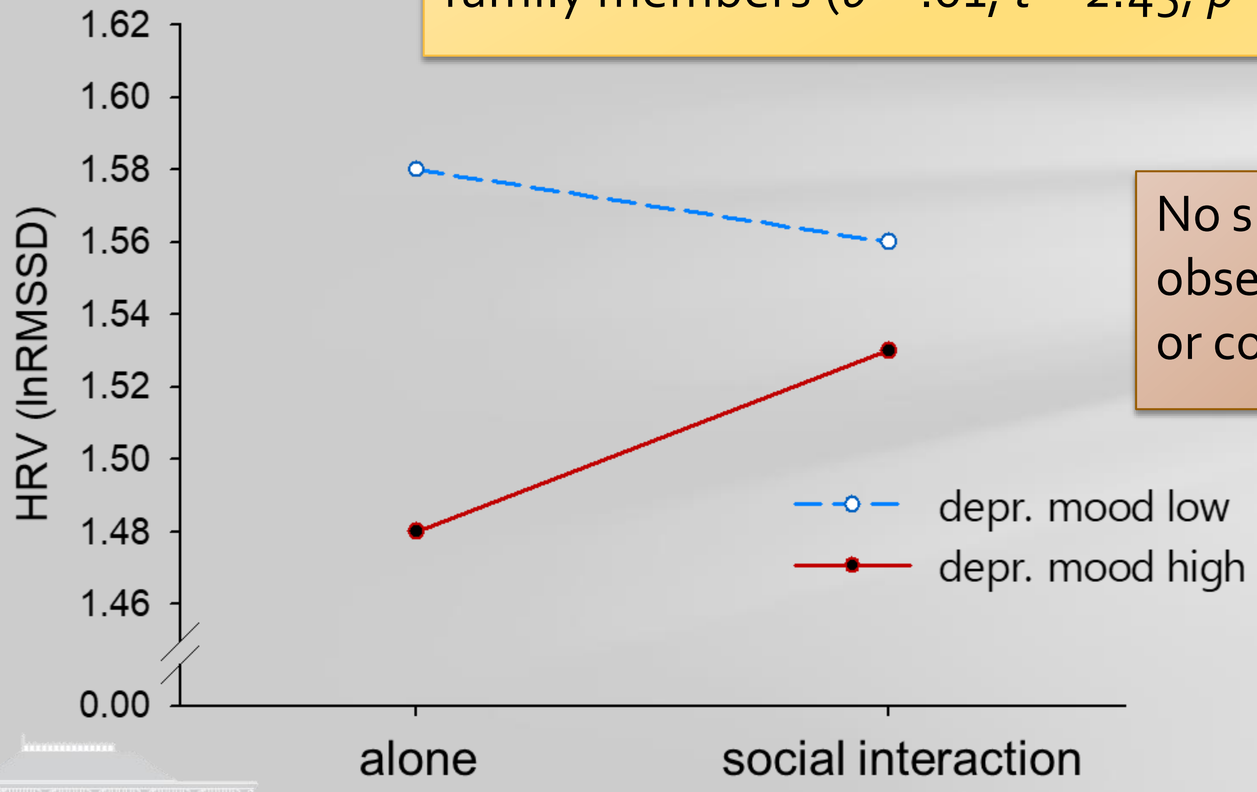
Time sampling: Commonly applied



- Time sampling allows for a more or less random sampling of different situations and/or psychological states, BUT interesting situations/states might be missed by chance!

Interaction depressive symptoms x social interactions

The interaction between depression and social contact was only significant for interactions with the partner, friends, or family members (b = .01, t = 2.45, p = .015).



No significant interaction, however, was observed for interactions with strangers or colleagues (b = .002, t = .26, p = .795).

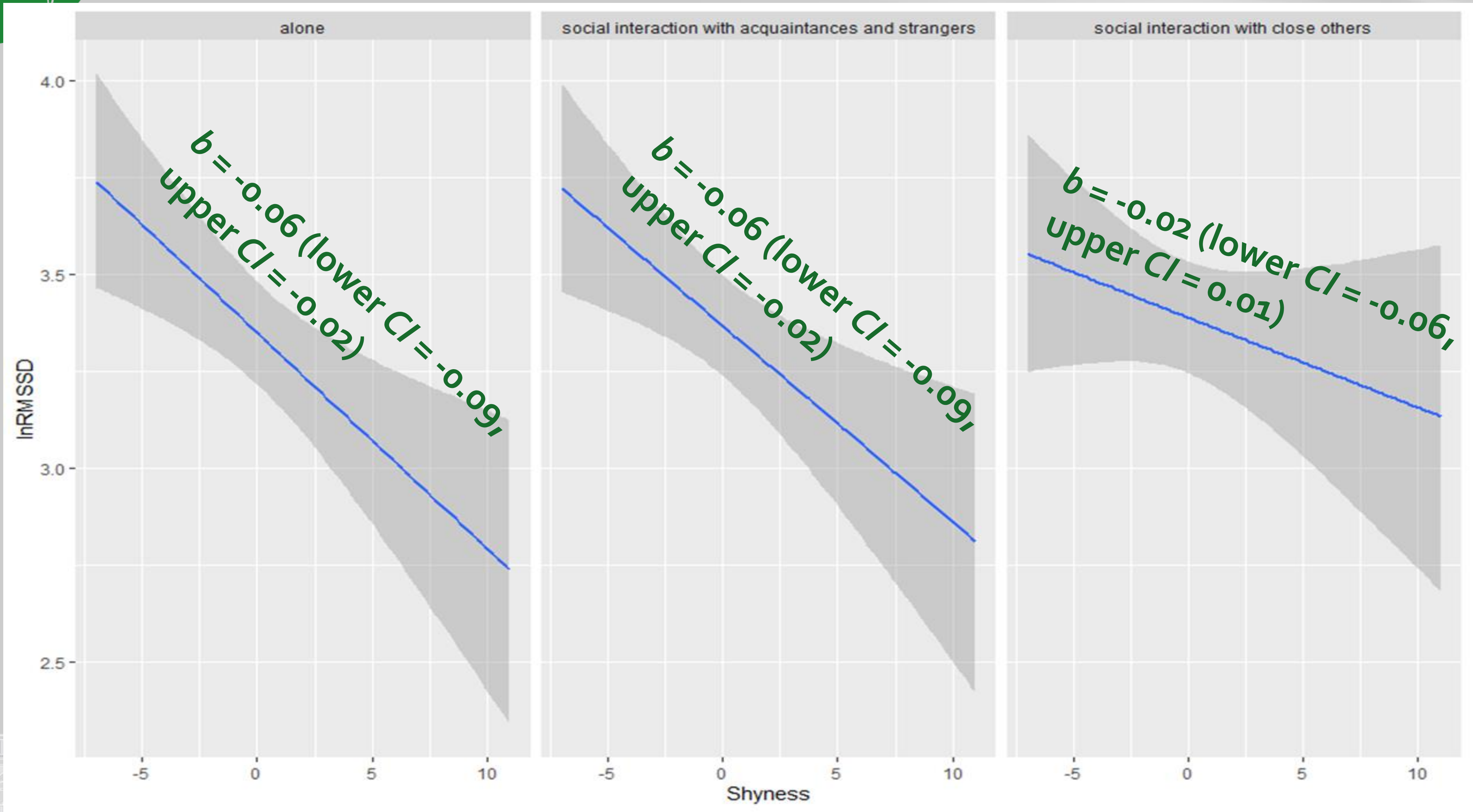
Schwerdtfeger, A. & Friedrich-Mai, P. (2009). *Health Psychol.*, *28*, 501-509.

Social interactions: Conclusions

Social interactions with close others appear to mitigate the negative effects on the cardiovascular system in depressed individuals and reactivate the vagal brake. Findings are compatible with clinical investigations (Frasure-Smith et al., 2000; Liu et al., 2017).

"I thought I'd never laugh again. Then I saw your jacket."

Replication with shyness



Schwerdtfeger, A. R. et al. (2020). *Biol. Psychol.*, *152*, 107864.

Real-life interactions matter more!

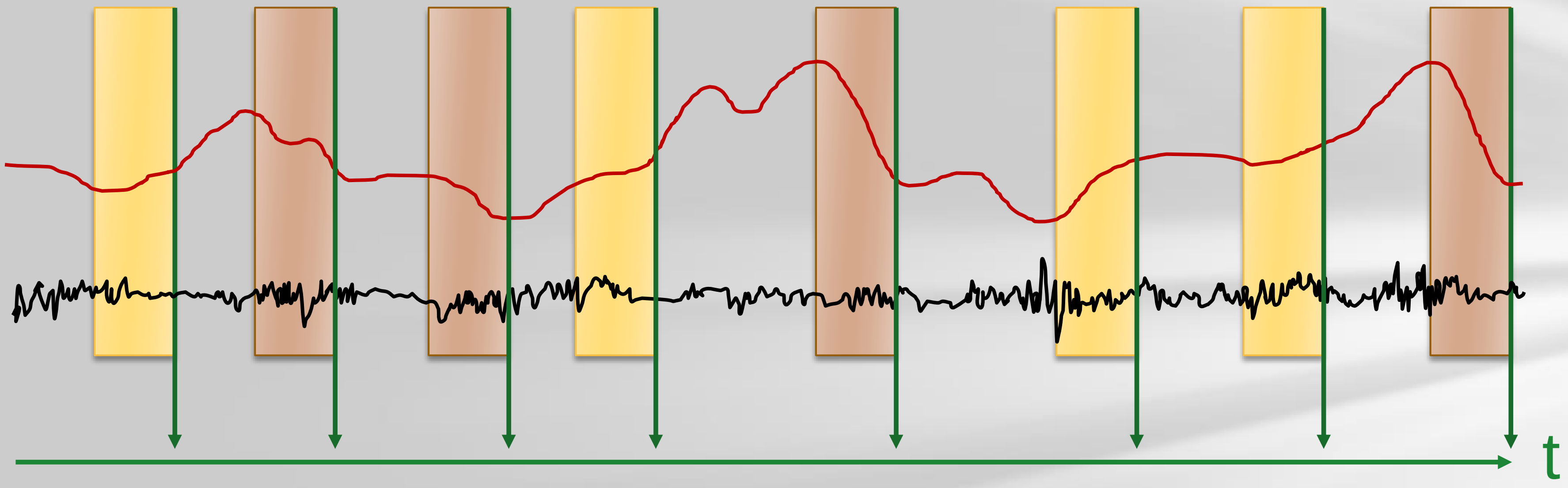
- Stronger and more reliable effects for real-life interactions (Bayes factor: 356), as compared to computer-mediated interactions (Bayes factor: 3.33);
- „Cues-Filtered-Out"-hypothis (Walther, 2011): In computer-mediated interactions, important communication channels are missing, hence the positive effects cannot be achieved.

The importance of safety perception

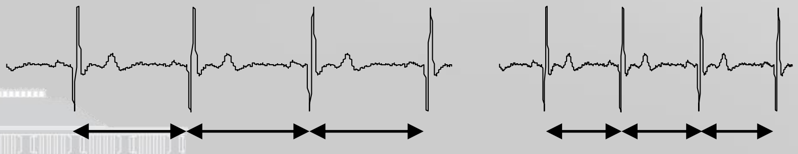
- More recent research suggests that salutogenic effects of social interactions might be attributed to a general feeling of safety (Schwerdtfeger et al., 2022);
- Hence, higher safety ratings were associated with higher HRV and lower heart rate, and lower safety ratings with lower HRV and higher heart rate. This finding could be replicated (Schwerdtfeger & Rominger, submitted);
- When safety is missing, a stressful state is entered (i.e., stress is dishinhibited; e.g., Brosschot et al., 2018).

Schwerdtfeger, A. R., Paul, L. & Rominger, C. (2022). Momentary feelings of safety are associated with attenuated cardiac activity in daily life: Preliminary evidence from an ecological momentary assessment study. *International Journal of Psychophysiology*, *182*, 231-239.

Interactive psychophysiological assessment



Brown et al. (2018, 2020), Verkuil et al. (2016): additional HRV reductions (**AddHRVr**; based on the concept of additional heart rate; Myrtek, 2004)



- What are you doing right now?
- How is your self-esteem?
- How do you feel? (worried, stressed, depressed, …)
- Are you interacting with others?
- …

If physiological triggers, in principal, work, then brief, unobtrusive interventions (like slow breathing) could be justified!

But how do we arrive at physiological triggers??

How to derive a trigger setting?

Using HRV as a trigger for vulnerability

- HRV strongly fuctuates within individuals, depending on various physiological and contextual conditions (e.g., bodily movement, respiration/speaking patterns, food consumption, smoking, etc.);
- At present, we are not able to take into account most of these variables. Instead, we focus on the most promignent confounder, that is bodily movement;
- Of note, the dynamics in HRV strongly differ between individuals, thus an algorithm to detect decreases in HRV needs to be adjusted for each individual (a calibration procedure is necessary!)

$$Expected\ RMSSDij = B0_{\mathrm{i}} + B1_{\mathrm{i}} * Acceleration\ _{ij}$$

$B0_i$ = RMSSD value while no acceleration is present

$B1_i$ = change in RMSSD due to acceleration

Threshold = Actual RMSSD + 0.5 $\times$ *SD* $\text{RMSSD}_{\text{calibration}}$

How to derive a trigger setting?

- A single episode (one segment; 1 minute) of AddHRVr might not be psychosocially relevant or robust;
- the number of segments (e.g., 7) in a specific time frame (e.g., 10 minutes) needs to be specified!
  - Hence, we need to decide on a **window length** (how many segments should be analyzed at all?) and RMSSD **window threshold** (how often in these segments should HRV decreases occur to trigger a prompt?);
- Moreover, we are not yet sure how long the trigger should be set silent (silence mode) and how strong HRV decreases should be pronounced (magnitude of change) to signal pychosocial states!
- **AddHRVr: Many, many unknown parameters! Let's start with some simulations…**

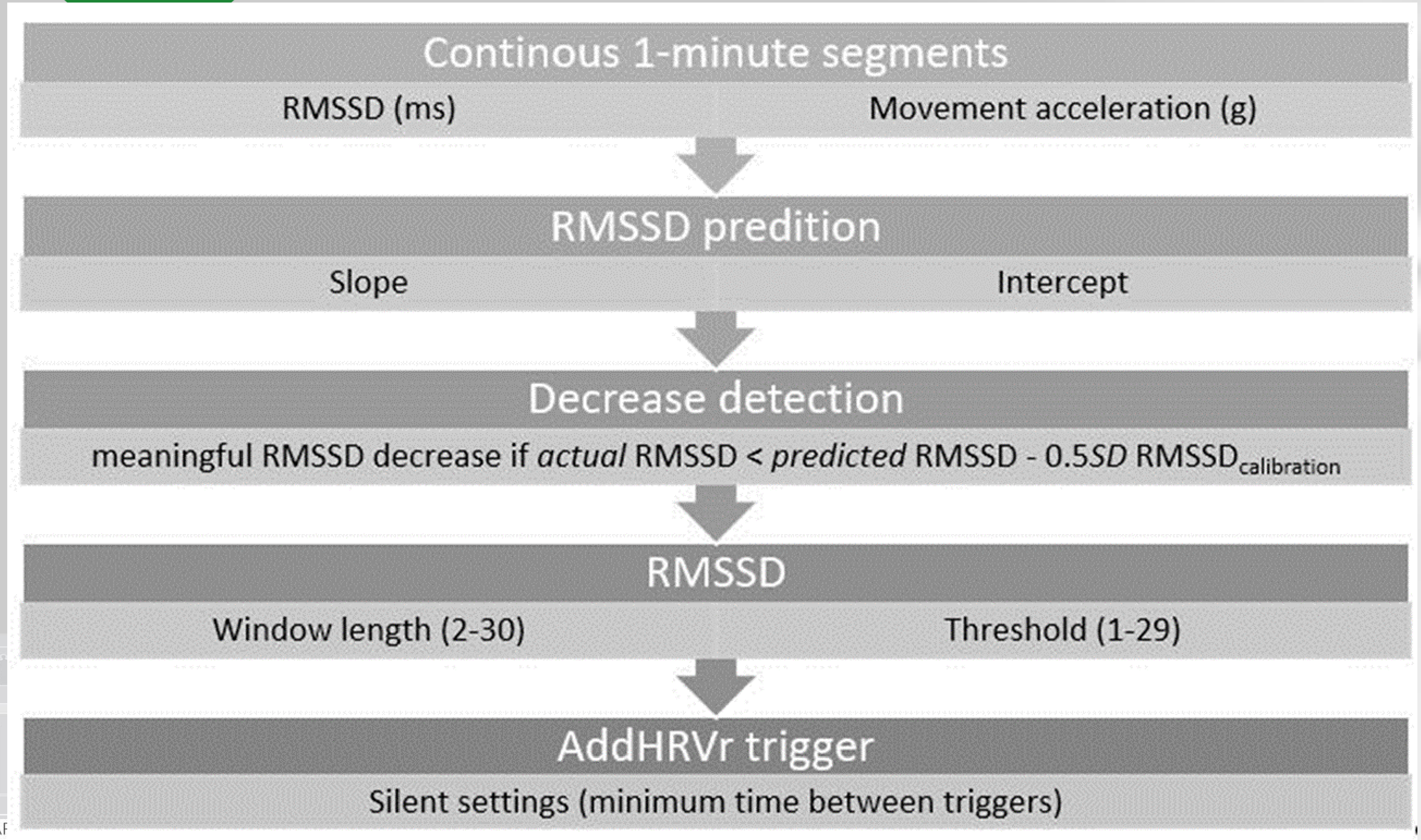
Schwerdtfeger, A. R., & Rominger, C. (2021). Feelings from the heart: Developing HRV decrease- trigger algorithms via multilevel hyperplane simulation to detect psychosocially meaningful episodes in everyday life. *Psychophysiology, 58*(11), e13914. doi: 10.1111/psyp.13914

How to derive a trigger setting? Simulations!

- Dataset on HRV (RMSSD) and social interactions across 3 days (Schwerdtfeger, Rominger & Obser, 2020);
- Perceived quality of social interactions; four items assessing perceived closeness, valence of the relationship, warmth, and supportive value. Generalizability Theory Analysis (GTA; Brenan, 2001) revealed satisfactory within-person reliability (R_{KR} = .71) and excellent between-person reliability (R_C = .94), thus suggesting reliable assessment of both within-person changes and interindividual differences;
- ECG and bodily movement via the ECGMove 4 (movisens).

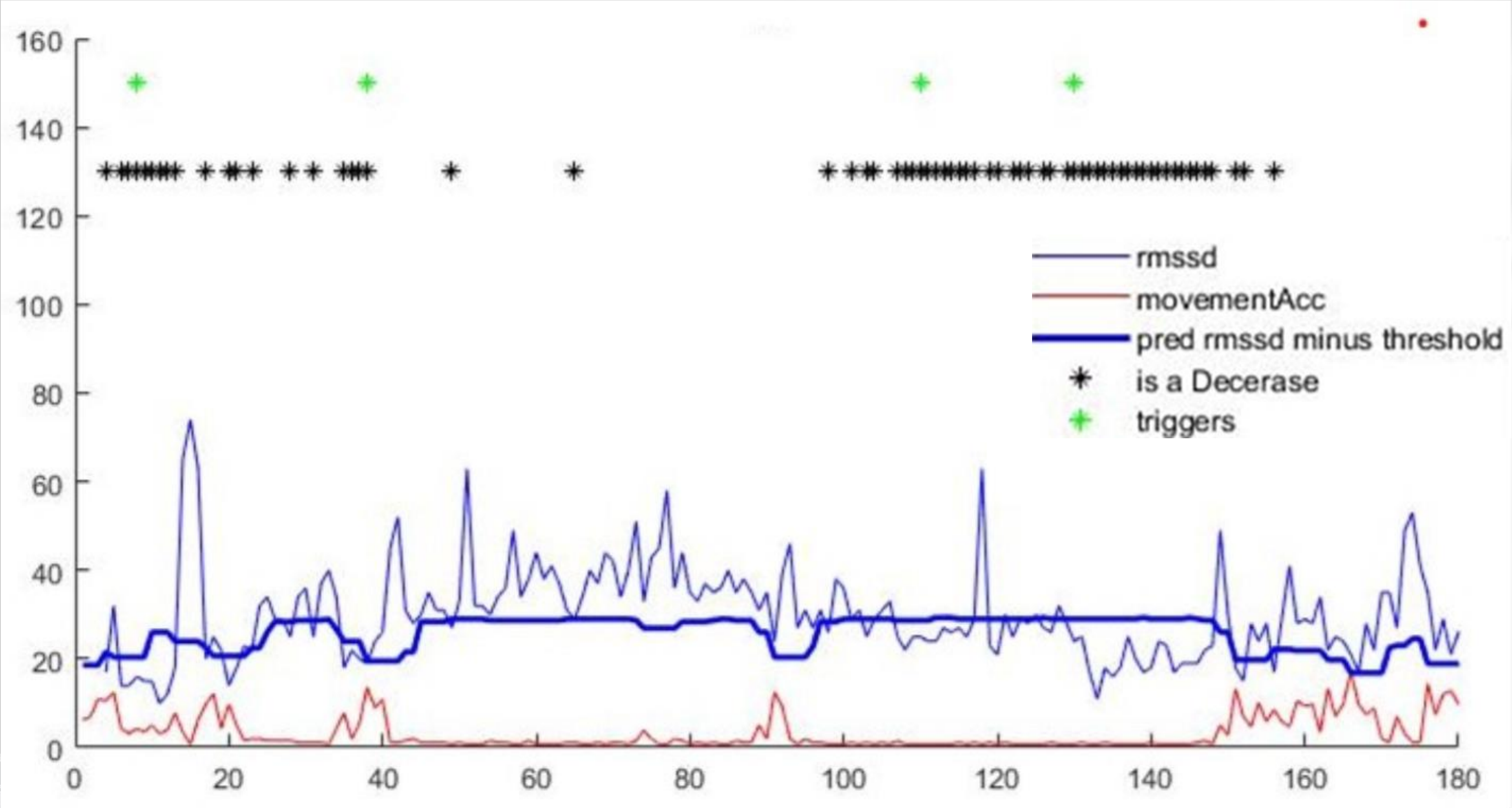
Schwerdtfeger, A. R., & Rominger, C. (2021). Feelings from the heart: Developing HRV decrease- trigger algorithms via multilevel hyperplane simulation to detect psychosocially meaningful episodes in everyday life. *Psychophysiology*, *58*(11), e13914. doi: 10.1111/psyp.13914

Step 1: Simulation of individual AddHRVr triggers for each person



The regression is calculated with data of the first 12 hours of recording (e.g., Brown et al., 2020). Calculations are done via Matlab-

Step 2: Illustration



Schwerdtfeger, A. R., & Rominger, C. (2021). Feelings from the heart: Developing HRV decrease- trigger algorithms via multilevel hyperplane simulation to detect psychosocially meaningful episodes in everyday life. *Psychophysiology*, *58*(11), e13914. doi: 10.1111/psyp.13914

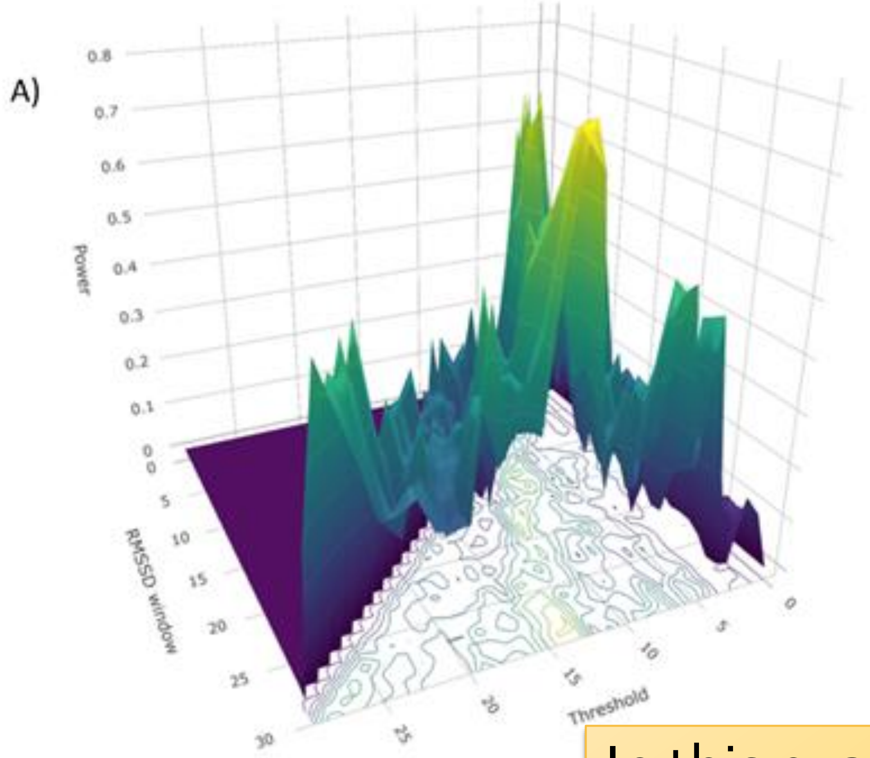
Step 2: Simulation of the AddHRVr trigger's sensitivity to psychosocial states

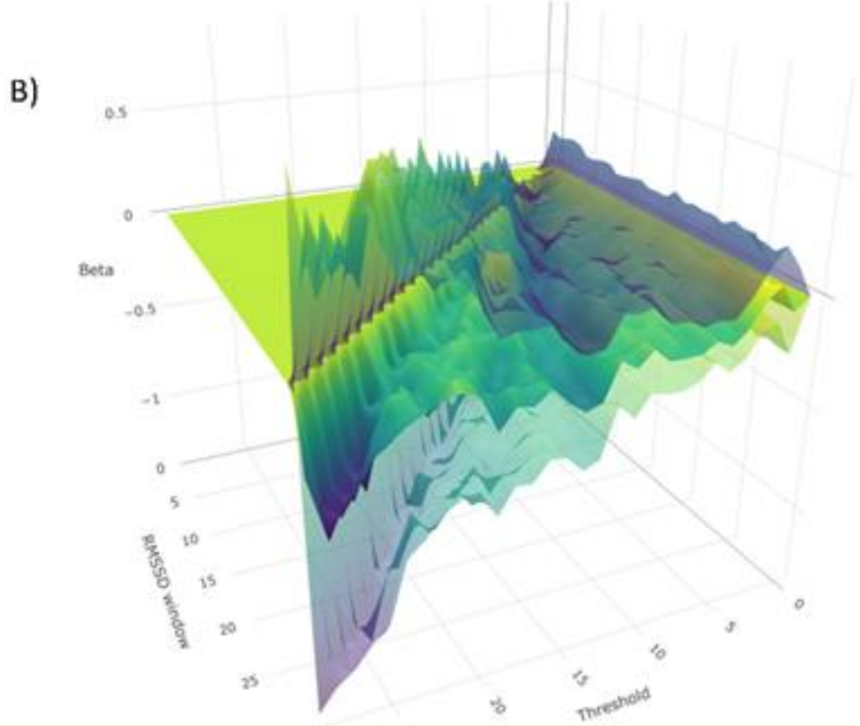
- The predictive utility of an AddHRVr trigger relative to a random prompt is determined via calculating associations with the quality of social interactions assessed at the subsequent prompt following the AddHRVr trigger within 20 min;
- a reliable difference between psychosocial states associated with periods of no change in HRV and AddHRVr triggered prompts would suggest psychosocial sensitivity of the algorithm settings;
- Simulations are done via mixed effects modeling in R (lmer) with 1,000 bootstrap simulations for each pairing to calculate power.

Results: Step 2

Power estimates

Unstandardized effect sizes





In this example, 13 HRV reductions within 29 segments predict low quality of social interactions in the subsequent prompt.

Conclusion and further developments

- This simulation approach constitutes a first step towards the development of psychosocially sensitive HRV decrease triggers;
- **Trigger refinements:** Adjusting the magnitude of AddHRVr; static algorithm – dynamic algorithm?, accounting for the silent setting, accounting for body position and respiration, developing HRV increase triggers (AddHRVi) to index resilient episodes;
- **Trigger specificity:** Different AddHRVr algorithms for different psychosocial concepts?
- **Validation of algorithm settings:** Within-person, between-person, **real-time mode (automatic triggering in daily life)**.

The real-time application of an additional HRV reduction algorithm to detect negative psychosocial states when they occur (and to intervene thereafter): Are we ready yet?

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Rominger, C., & Schwerdtfeger, A. R. (in press). The real-time application of an additional HRV reduction algorithm to detect negative psychosocial states in real-time: Are we ready yet? *Zeitschrift für Psychologie*.

Real-time study: Outline

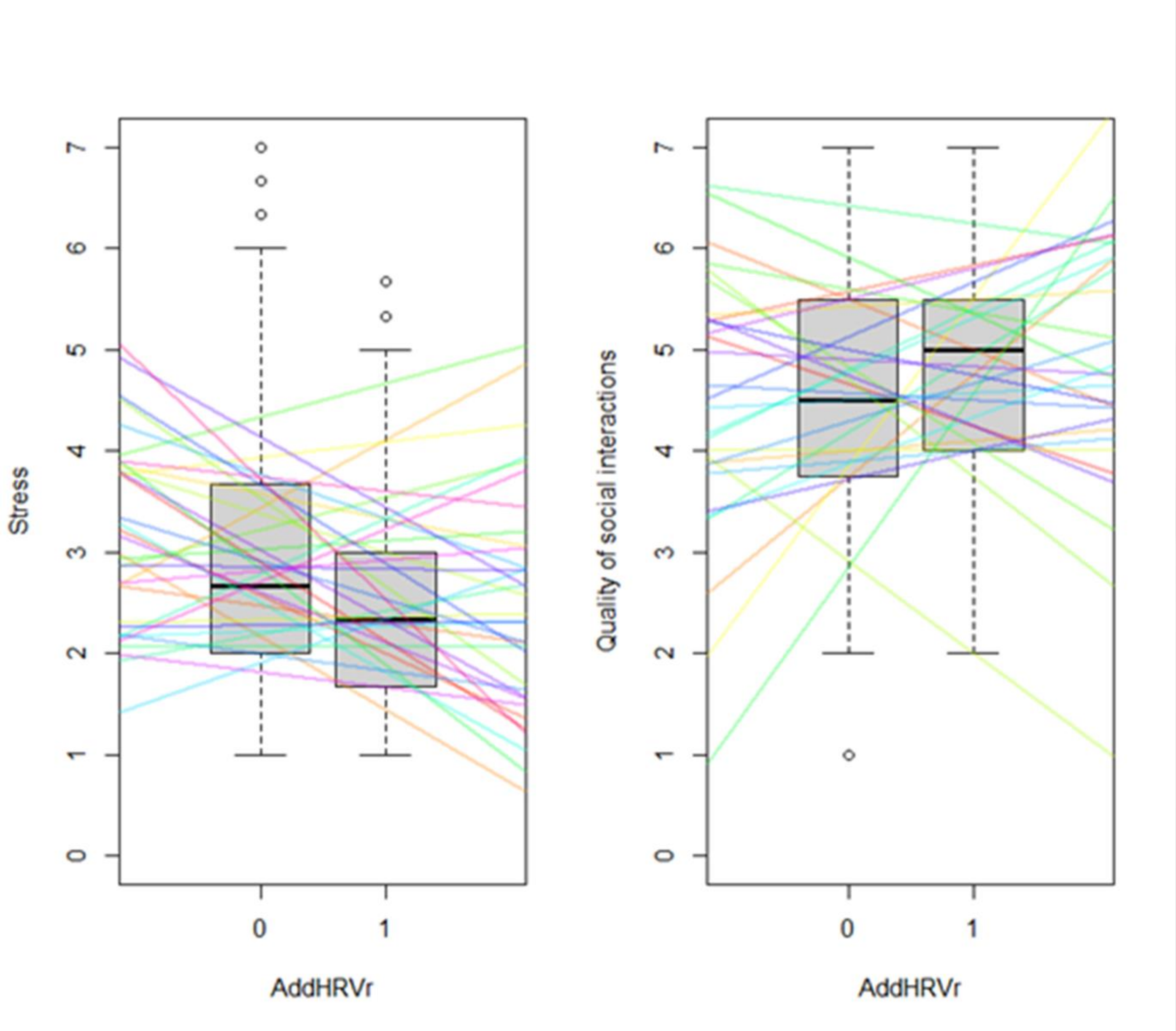
- N = 36 participants completed an ecological momentary assessment throughout five consecutive days;
- HRV (RMSSD), bodily movement, perceived stress, rumination and quality of social interactions were rated with each prompt;
- Prompts were either delivered contingent with automatically detected non-metabolic reductions in HRV or randomly to allow comparisons between psychological states with and without physiological precursors;
- Multilevel models were analyzed predicting psychosocial states by AddHRVr (vs. random) triggers. Trigger settings were taken from Schwerdtfeger and Rominger (2021).

Real-time study: Results

AddHRVr triggers were not significantly associated with the quality of social interactions [$b = 0.09$, $t(575) = 0.99$, $p = .321$], stress [$b = 0.08$, $t(1{,}087) = 1.25$, $p = .213$], and perseverative cognition [$b = 0.041$, $t(1{,}078) = 0.66$, $p = .508$], respectively.

Disappointing!!

Real-time study: Again, simulations…



Why did the triggers not work as expected? → Simulations.

Surprisingly, only about 27% of physiologically triggered episodes could be retrieved by simulations.

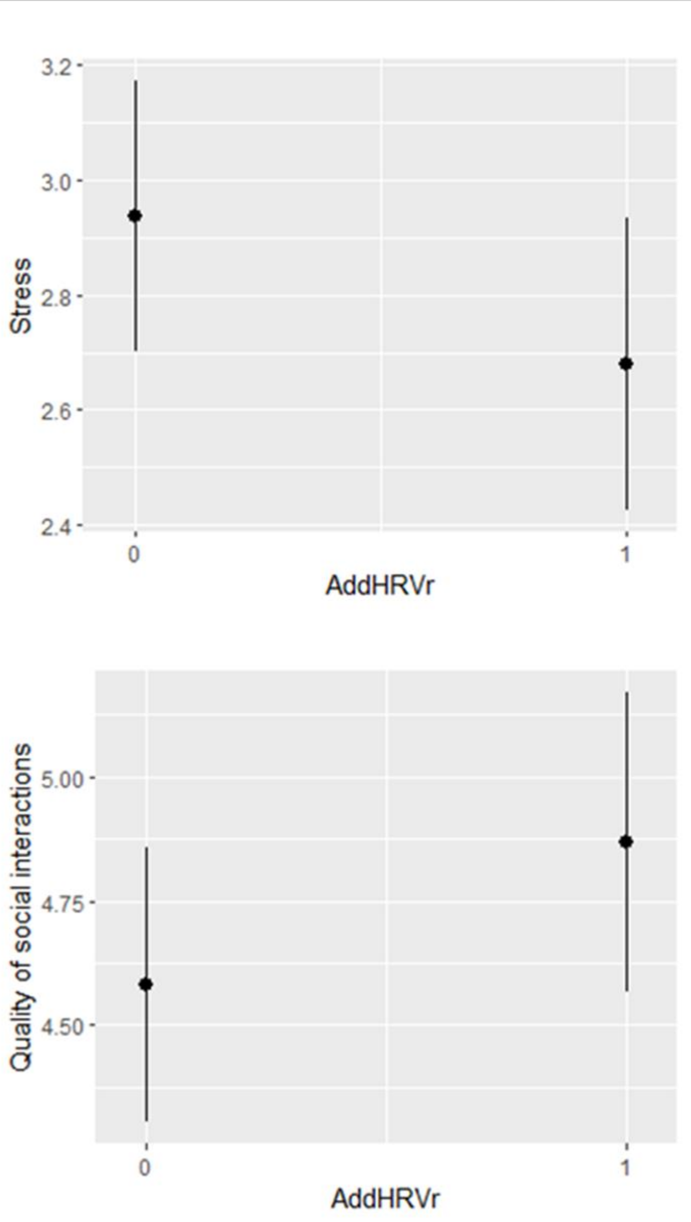
The pattern of findings was even reversed with a tendency toward lower stress ($p = .036$) and higher quality of social interactions ($p = .079$).

Figure 2. Simple slopes of separate regressions within each participant with AddHRVr trigger (0=random prompt, 1=triggered prompt) as predictor.

Real-time study: Looking for moderators

- Indeed, effects were heterogeneous, thus calling for moderators;
- This yielded an inconsistent pattern for each psychosocial concept under study (gender, slope and intercept of the regression, and threshold for RMSSD);
- Even more, raw RMSSD showed independent effects of AddHRVr-triggers!

Comparing Simulations with Real-Time Triggers



Surprisingly, simulations revealed that indeed lower HRV was predictive of more stress and lower quality of social interactions!!!

SHOCKING!!

Figure 3. Independent effects of lnRMSSD (group mean centered) and AddHRVr (0=random prompt, 1=AddHRVr triggered prompt) on perceived stress and quality of social interactions.

Conclusions

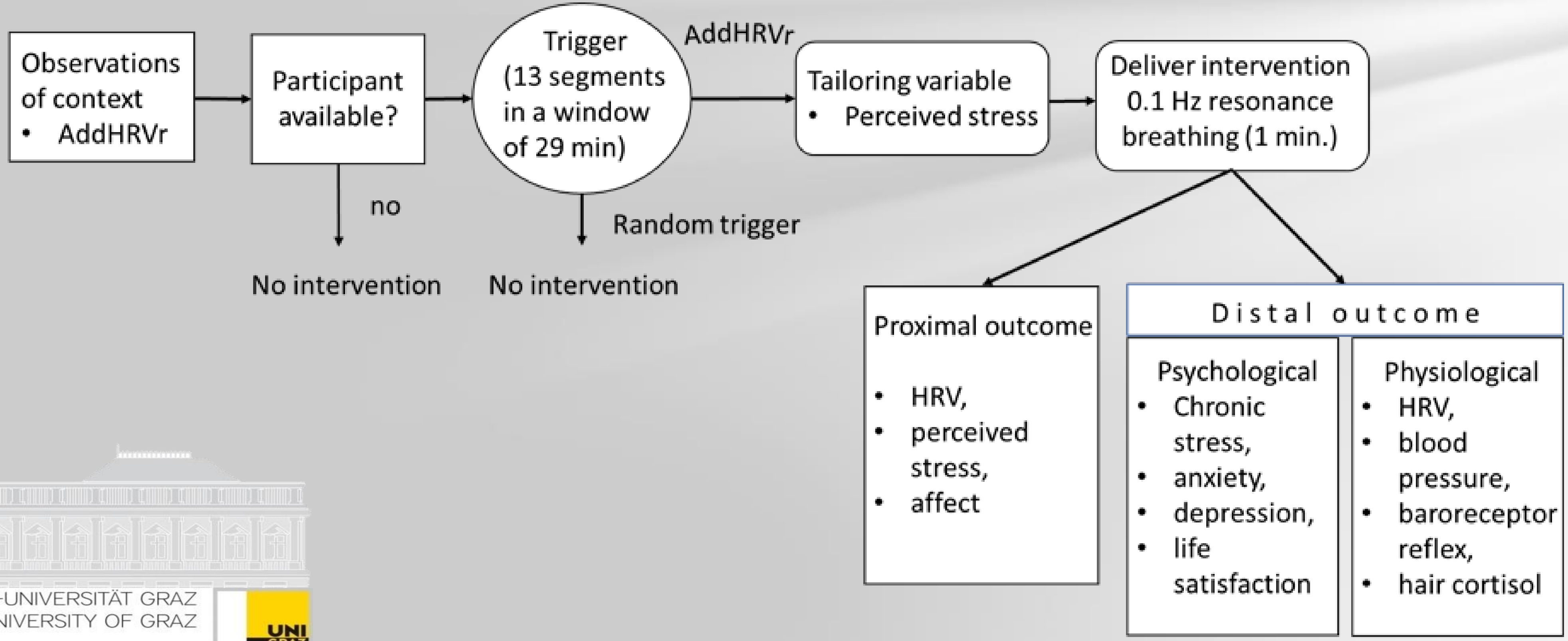
- Can we predict adverse psychological states in real-time by transient changes in HRV? The present study suggests a reluctant "obviously not";
- Although the AddHRVr trigger reliably detected episodes of non-metabolic reductions in RMSSD, such episodes were obviously not associated with compromised social interactions, elevated rumination, or perceived stress;
- The simulated and corrected AddHRVr triggers even predicted the reversed pattern. The finding is astounding in light of previous research relating lower HRV to rumination (Ottaviani, 2018), stress (Kim et al., 2018) or low quality-social interactions (Shahrestani et al., 2015), among others.

Recommendations

- Applying the AddHRVr algorithm in the field to trigger JITAIs for eHealth and mHealth interventions seems premature;
- We need to better align simulation approaches with real-life (exactly the same variables and instructions, same silent settings,..);
- We need to examine the impact of other algorithm settings carefully (static/dynamic triggers, strength of the HRV decrease, calibration procedure, ...);
- Researchers are advised to simulate and apply the algorithm in large and diverse samples in the field and evaluate its robustness in different samples before going real-life.

Future directions

For now, we advocate for a two-stage assessment strategy to use AddHRVr as a sensitive trigger to ask for psychological states to ensure specificity. If both measurement modalities align (**AddHRVr plus elevated stress!**), powerful interventions could be applied.



And Finally…

The road to JITAIs by means of HRV remains attractive, but it is hampered by several roadblocks and unresolved potholes. But someday, we shall arrive…

References:

- Rominger, C., & Schwerdtfeger, A. R. (in press). The real-time application of an additional HRV reduction algorithm to detect negative psychosocial states in real-time: Are we ready yet? *Zeitschrift für Psychologie*.
- Rominger, C., & Schwerdtfeger, A. R. (2022). Feelings from the heart part II: Simulation and validation of static and dynamic HRV decrease-trigger algorithms to detect stress in firefighters. *Sensors*, *22*, 2925.
- Schwerdtfeger, A. R., & Rominger, C. (2021). Feelings from the heart: Developing HRV decrease-trigger algorithms via multilevel hyperplane simulation to detect psychosocially meaningful episodes in everyday life. *Psychophysiology*, *58*, e13914.

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Thank you for your attention!!

Data and code is available via OSF:
https://osf.io/fmt5u/
https://osf.io/6mgbt/

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