Assessment of cognitive engagement from heart rate dynamics during simulated driving with an in-vehicle information system

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Motivations

Technological innovations are broadening the range of cognitive demands facing the driver

How can we optimally assess cognitive loading in complex environments?

Subjective reports

“how difficult?”, “how stressful?”, “how engaging?”, …

Weaknesses

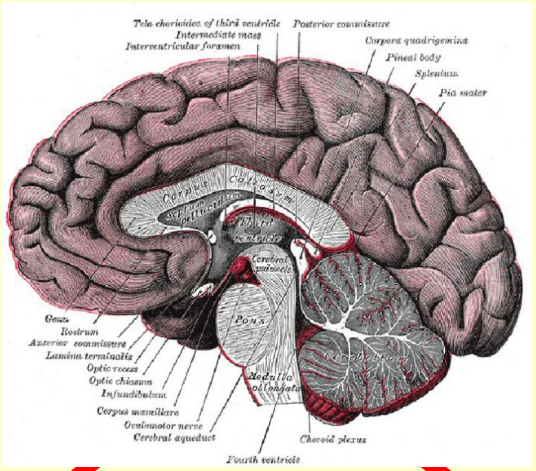
- retrospective (poor reliability over long time spans)
- poor time resolution
- poor specificity

Heart rate dynamics as a marker for cognitive loading

Heart provides metabolic fuel

fuel demand ~ workload

Autonomic nervous system regulation



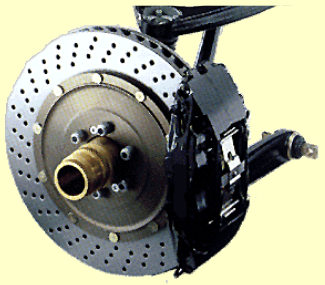
Sympathetic

- co-active
- antagonistic

+

-

Para-sympathetic



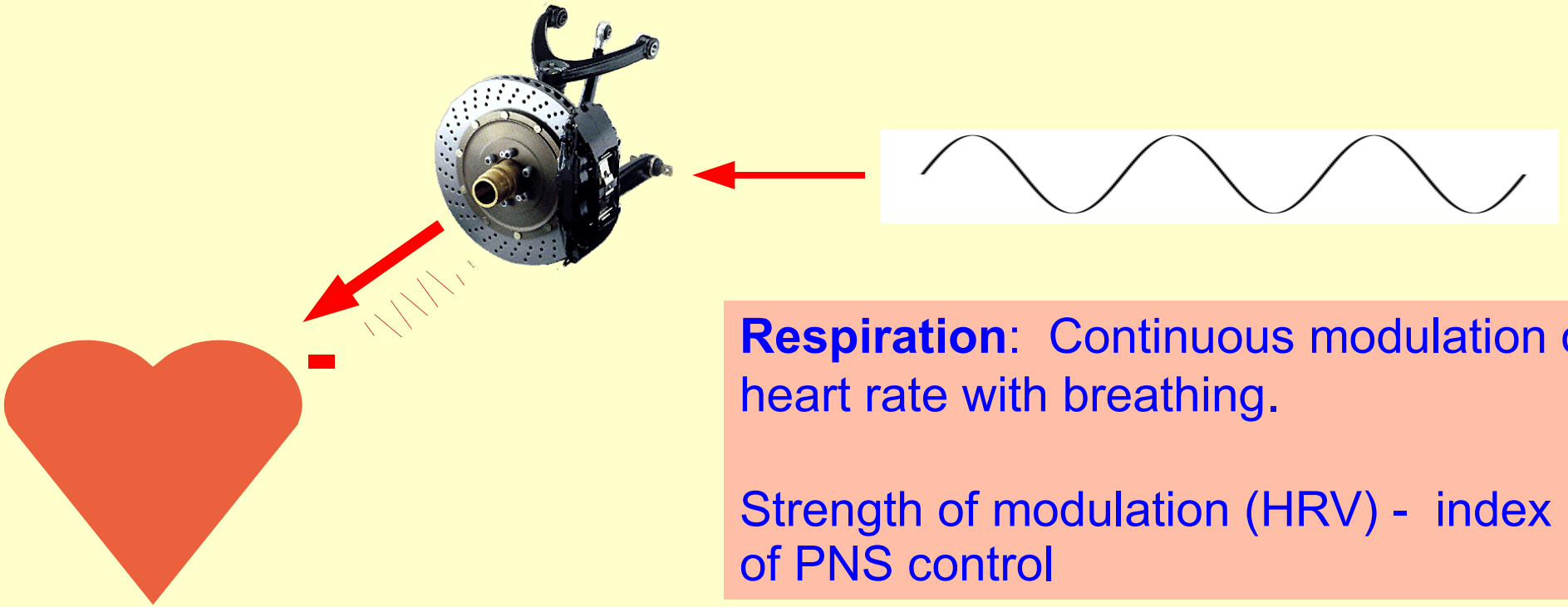
Parasympathetic nervous system (PNS)

Influences of attention on the PNS:

Detection of sensory events → immediate braking

Extended concentration → consistent baking

Threat → immediate withdrawal of braking



Respiration: Continuous modulation of heart rate with breathing.

Strength of modulation (HRV) - index of PNS control

Subjects and methods

14 volunteers

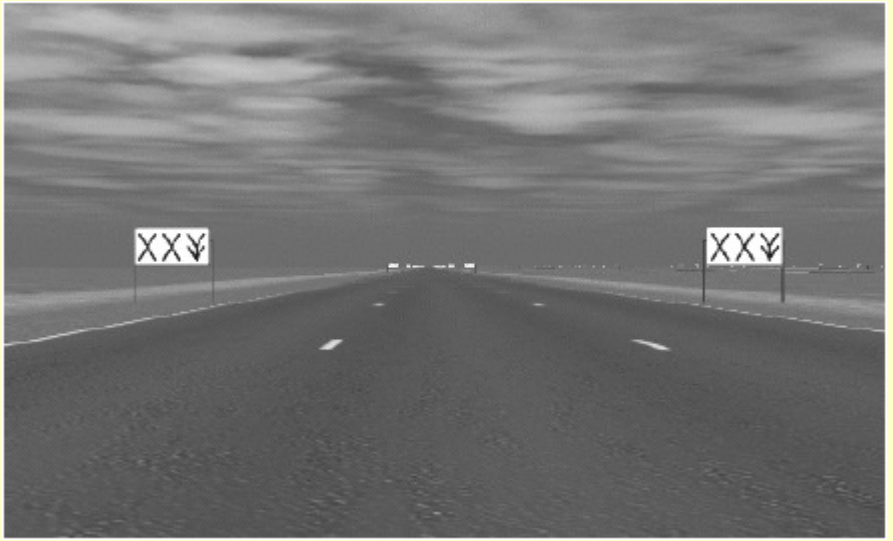
Ages 18 – 41 years

Experienced drivers

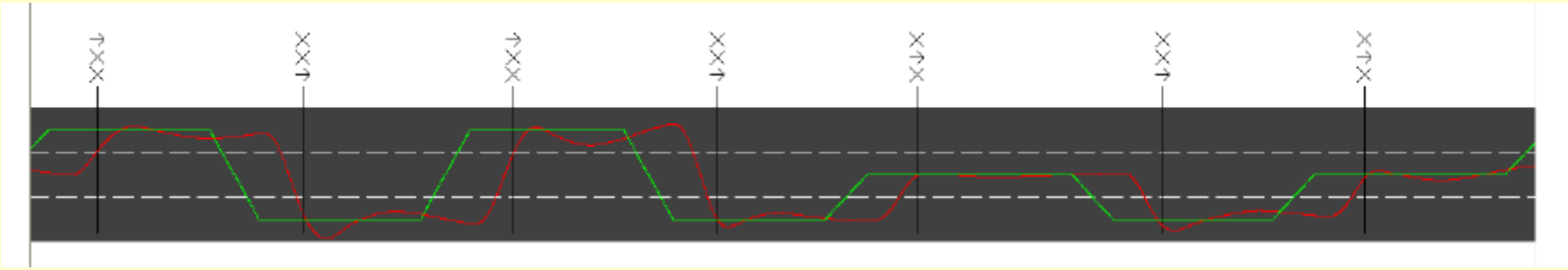
Comfortable in English language (non native speakers)

Dual task study design

Primary task:
Simulated driving with Lane Change Test (LCT)



Outcome: Steering tracking accuracy



Dual task study design

Secondary tasks:
Operation of an in-vehicle information system ("Breeze") to perform an identical task under 3 different conditions

IVIS components

Display screen

Audio speaker

Steering wheel mounted information system controller

Dual task study design

Task: Use the controller to access an email and follow the instructions in the email to initiate a telephone call

Trial conditions (modalities)

1. **Audio (A)**

   Interaction with system through audio feedback

   (computer synthesized voice)

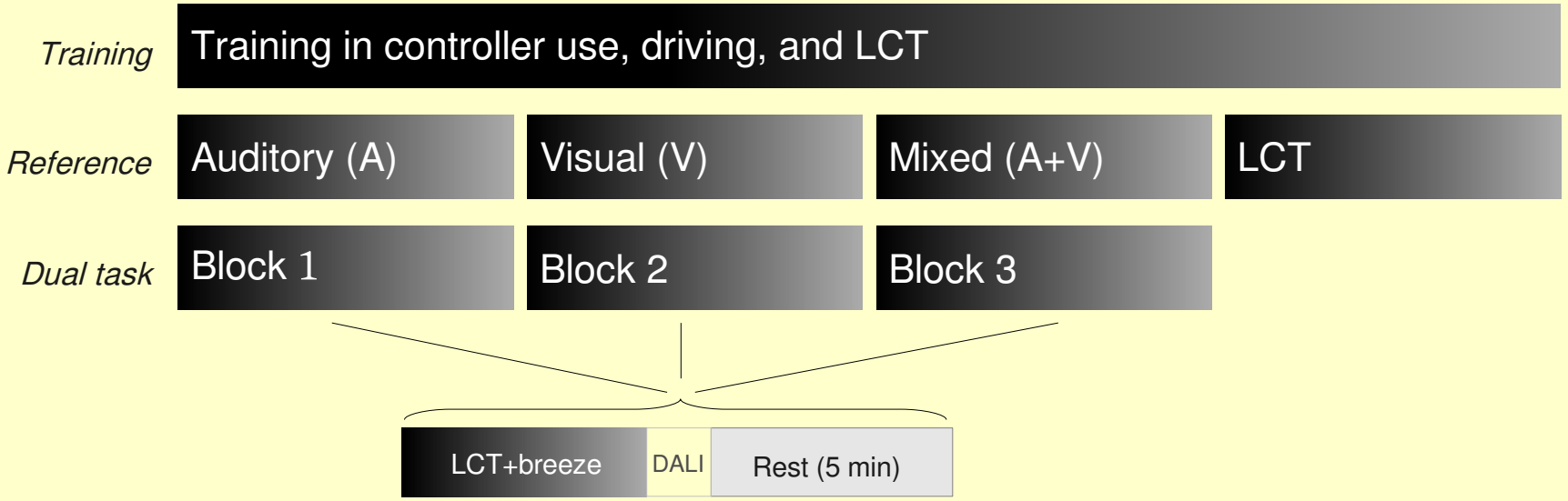
2. **Visual (V)**

   Visual interaction through the display screen

3. **Audio and Visual (AV)**

   Simultaneous presentation of both modalities

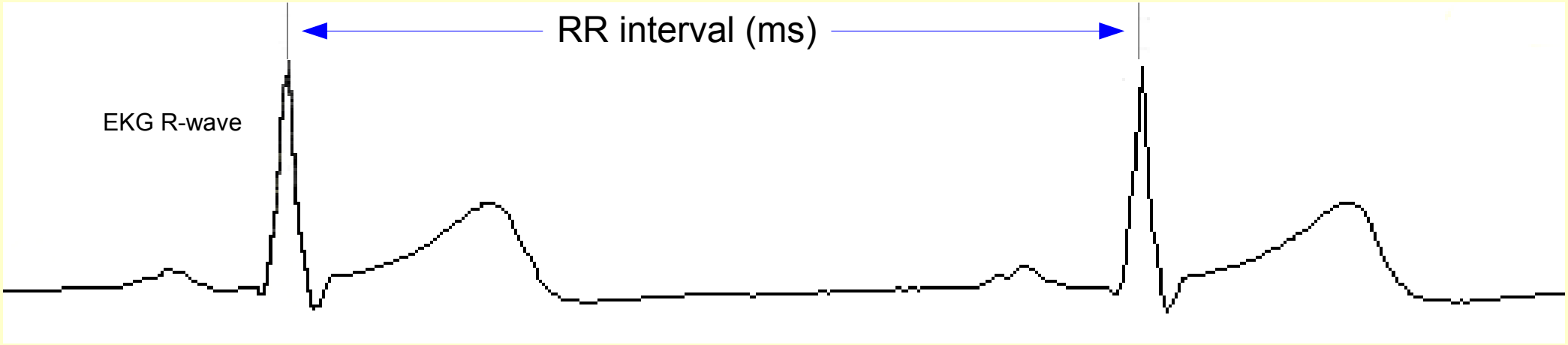
3 phases of the experiment:



Ordering of modality-trials was randomized across subjects

Duration of each dual-task block was determined by the time needed to complete the secondary task

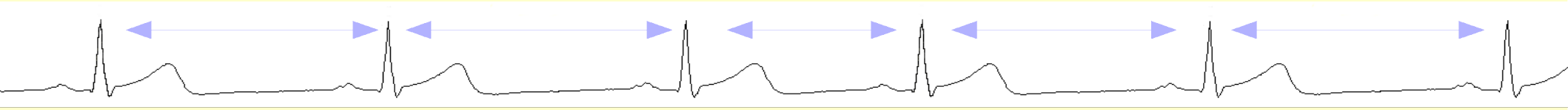
Currency:
Instantaneous heart rate (RR interval)



Outcome measures:

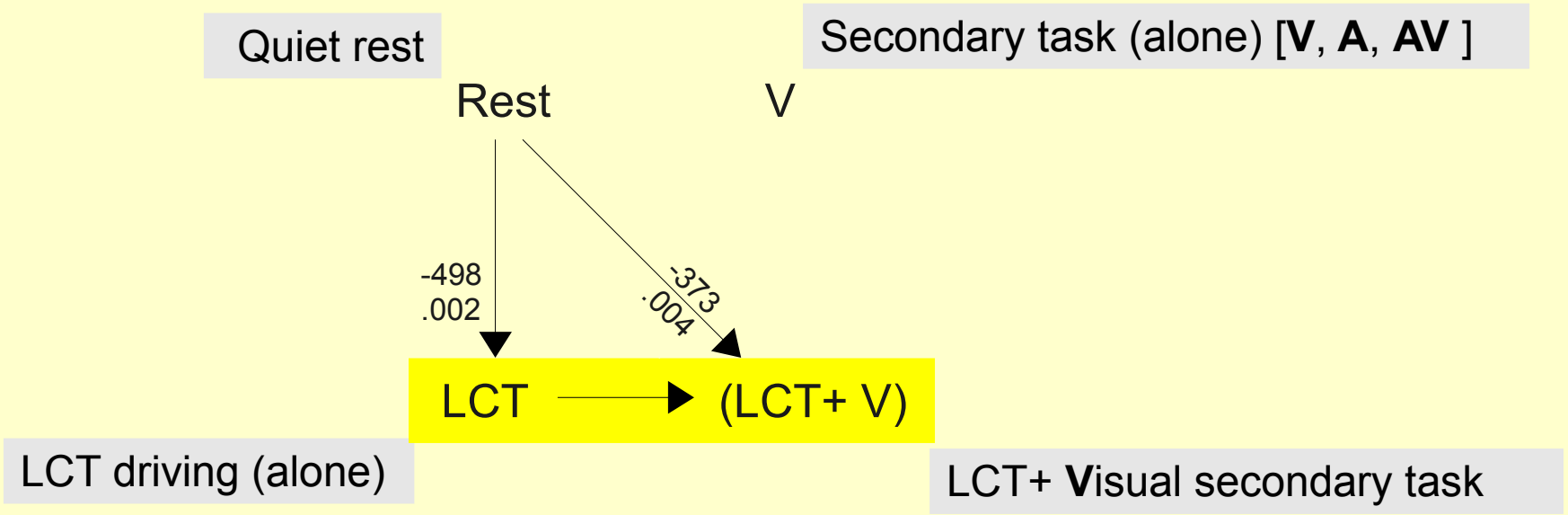
1) Average RR interval

2) Beat-to-beat variability of RR intervals ($RMSSD_5$)



Results presentation:

Map of statistical contrasts* between trials:



Arrows point to:

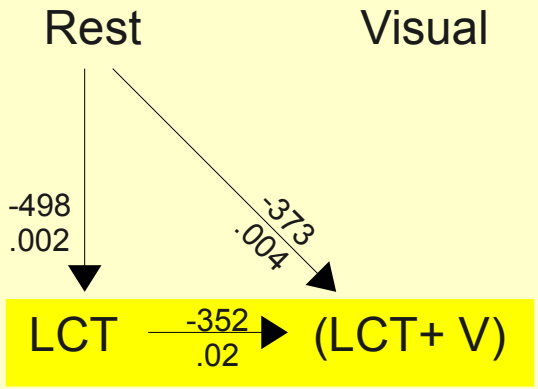
Increased heart rate

Decreased heart rate variability

* Linear Mixed Effects models with adjustment for trial duration

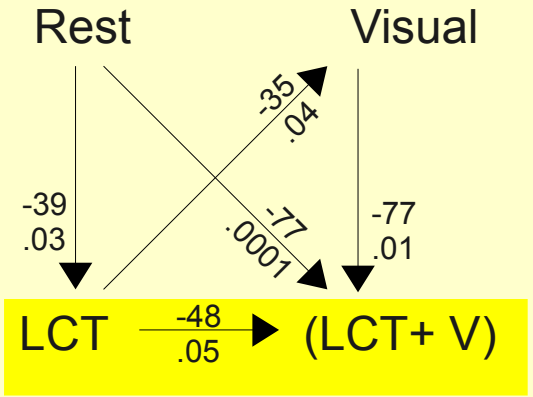
Visual modality (V)

Heart rate (R-R intervals)



increased heart rate

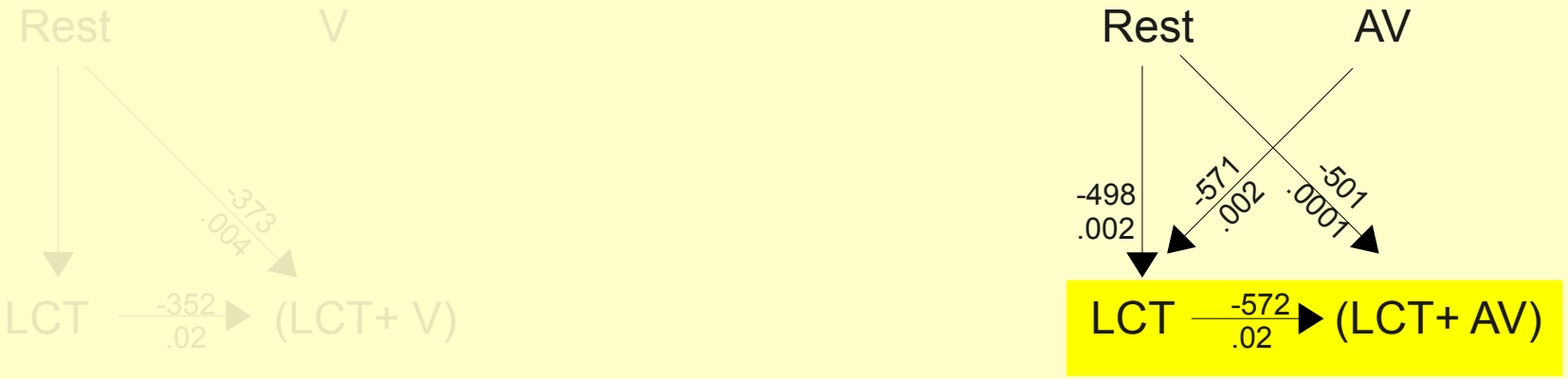
Heart rate variability ($RMSSD_5$ R-R)



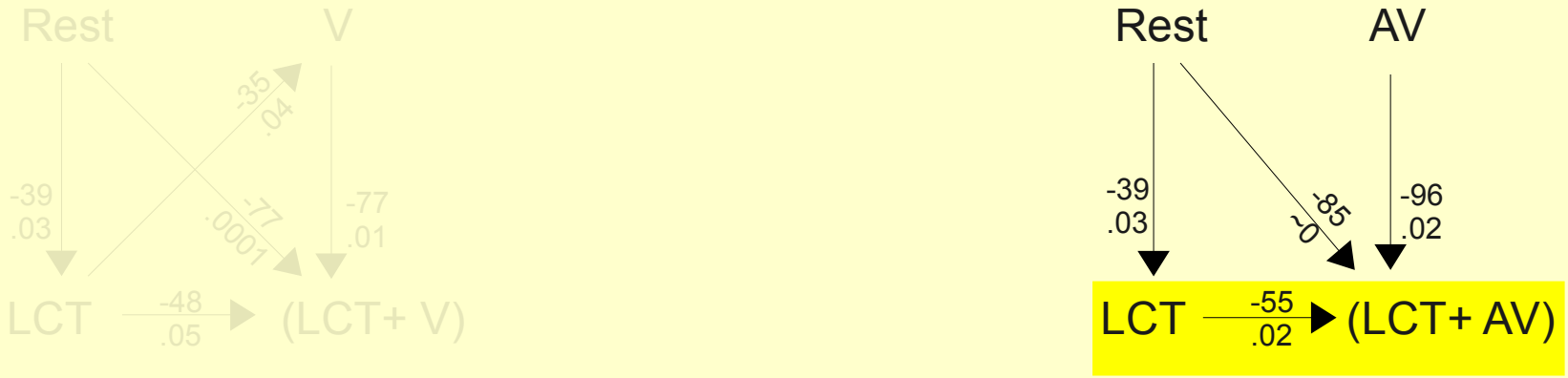
decreased HRV

Audio + Visual modalities (**AV**)

Heart rate (R-R intervals)

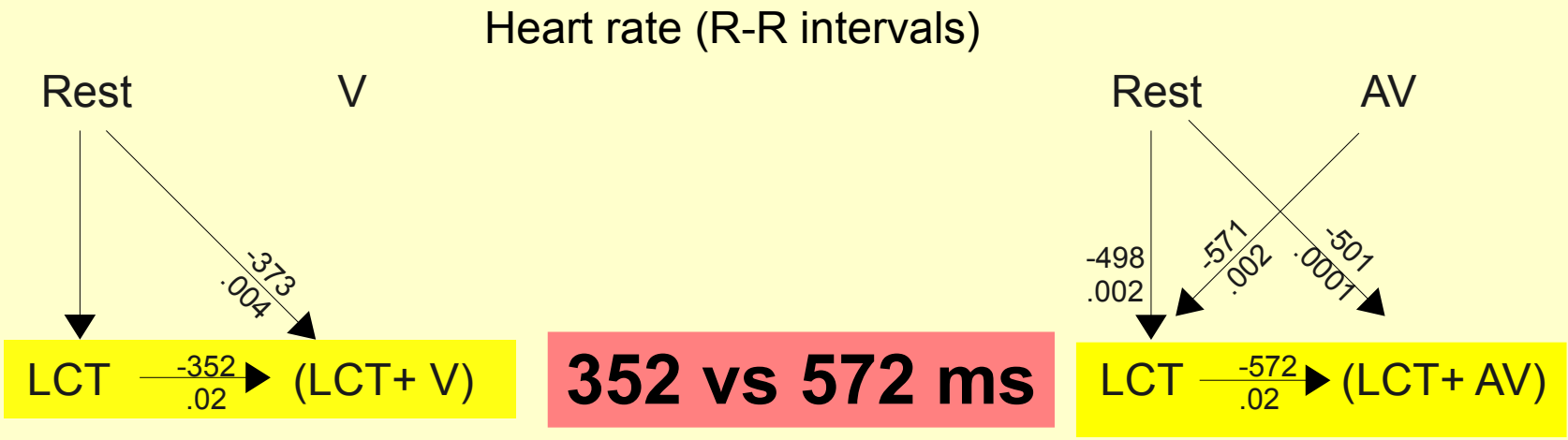


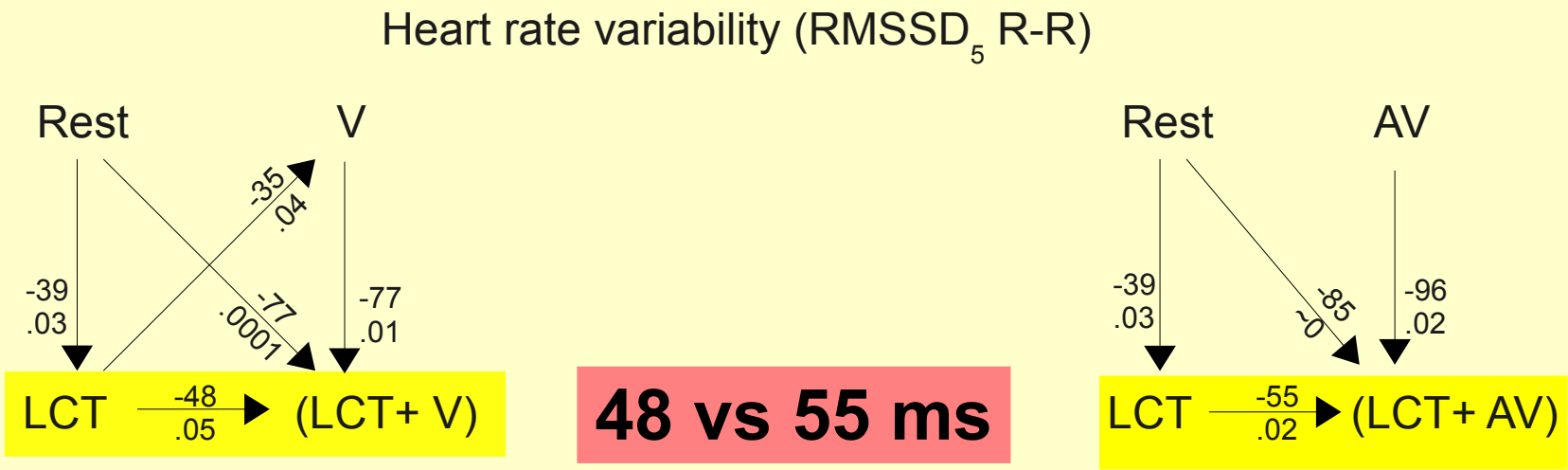
Heart rate variability ($RMSSD_5$ R-R)



Similar pattern in **AV** trial 2° task interference

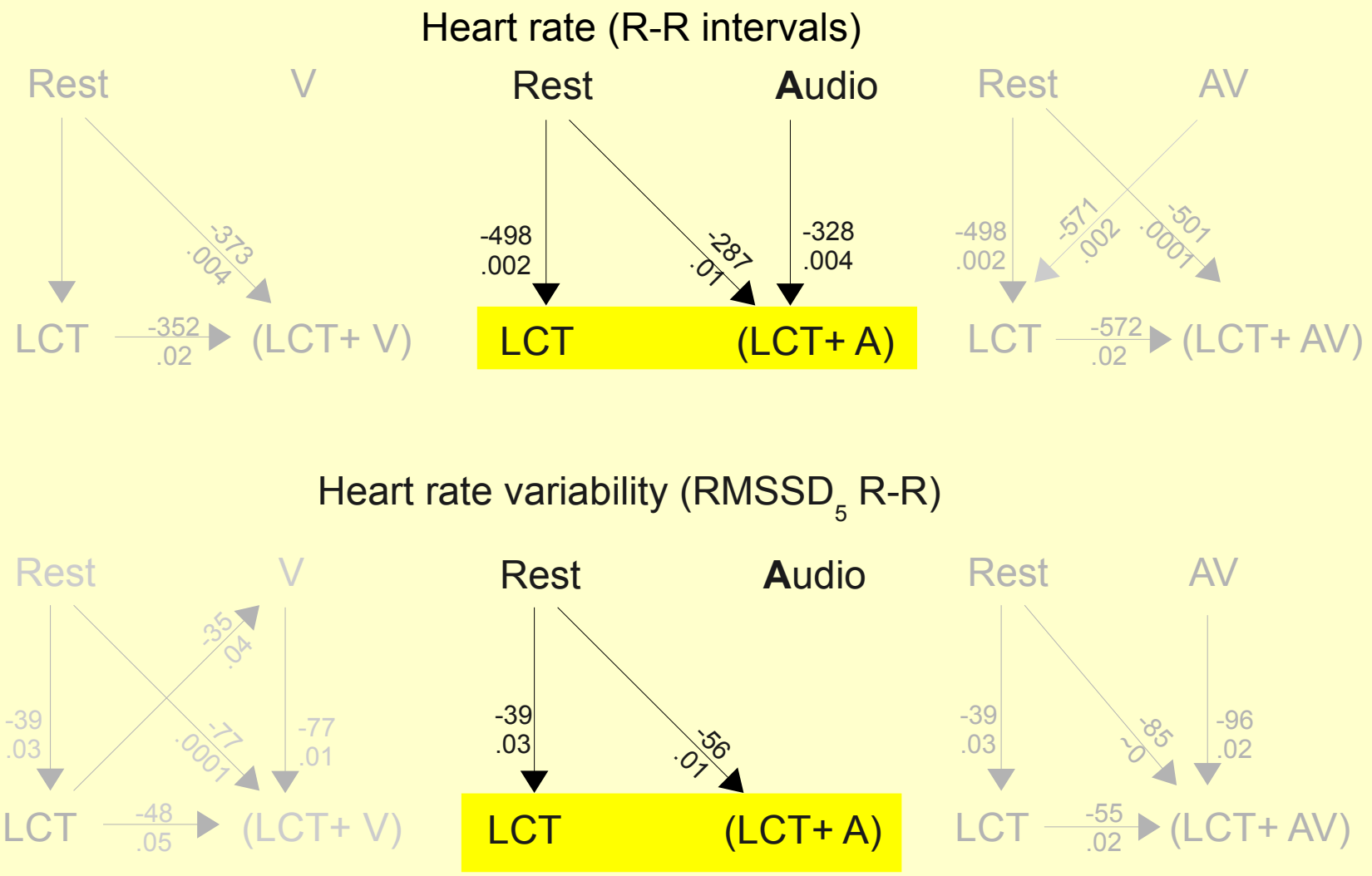
Audio + Visual modalities (AV)





But more pronounced

Audio modality (A)



Audio: No interaction between 1° and 2° tasks

Summary

No 2° task interference from auditory information

Summary

No 2° task interference from auditory information

Visual attention interaction ~ Cardiac engagement

Summary

No 2° task interference from auditory information

Visual attention interaction ~ Cardiac engagement

Simultaneous Auditory + Visual attention ~ Highest amount cardiovascular engagement

Conclusions

Different modes of information processing can be differentiated by heart rate dynamics

Reliable estimates can be made within short (< 3 minute) time windows.

Caveat: Generalizability?

Thank you

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