



A VISION AND RADAR GUIDANCE SYSTEM (VSN) REDUCES SPRAYER OPERATOR STRESS

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OPERATING A SPRAYER IS STRESSFUL!

- Operating an agricultural sprayer is stressful
 - Work 15 hrs/day in peak season (Dey and Mann, 2010)
 - Steer the sprayer in narrow rows
 - There are other parts of spraying to focus on besides steering

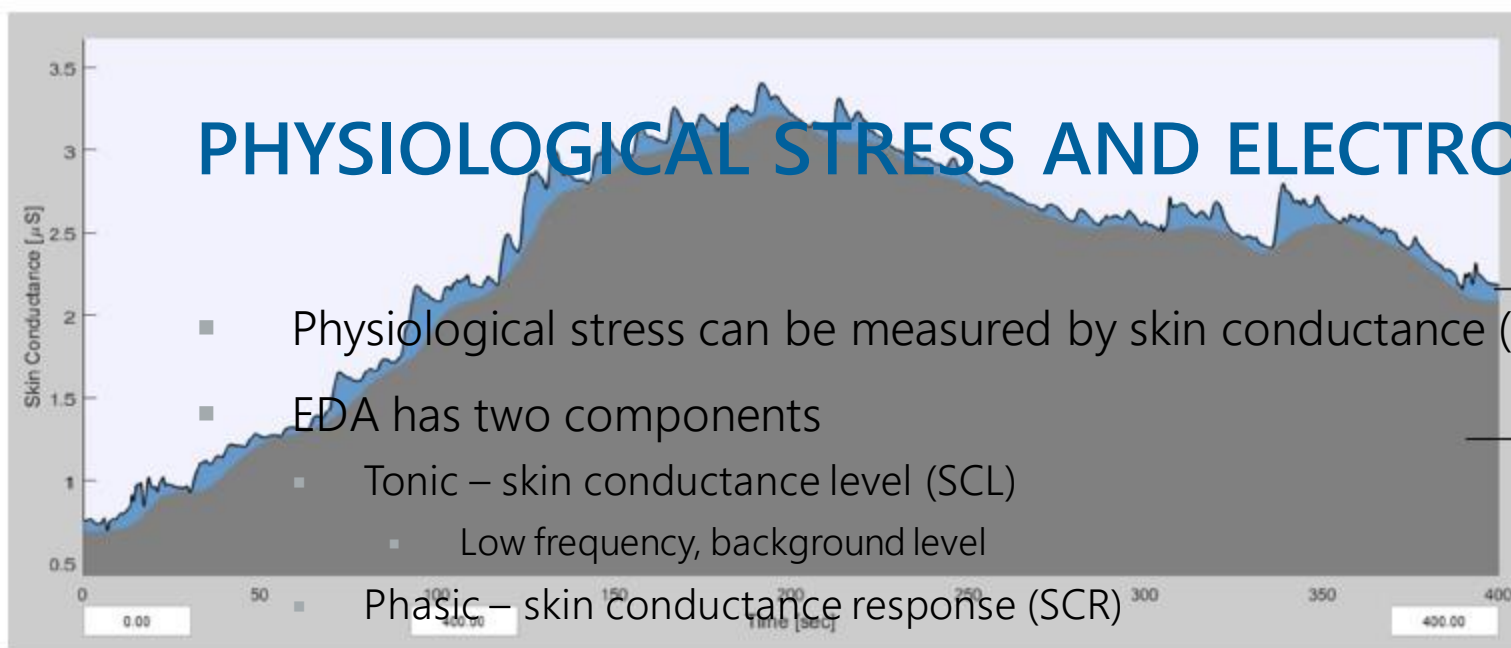


OPERATING A SPRAYER IS STRESSFUL!

- Sprayers commonly use 15-in (38-cm) tires in 30-in (76-cm) rows
 - Speeds of 12–18 mph (20–29 kph) (Burgers et al. 2021)
- Chevy Silverado in parking space has more clearance
 - 13 in (33 cm) on each side
 - Almost double the clearance!

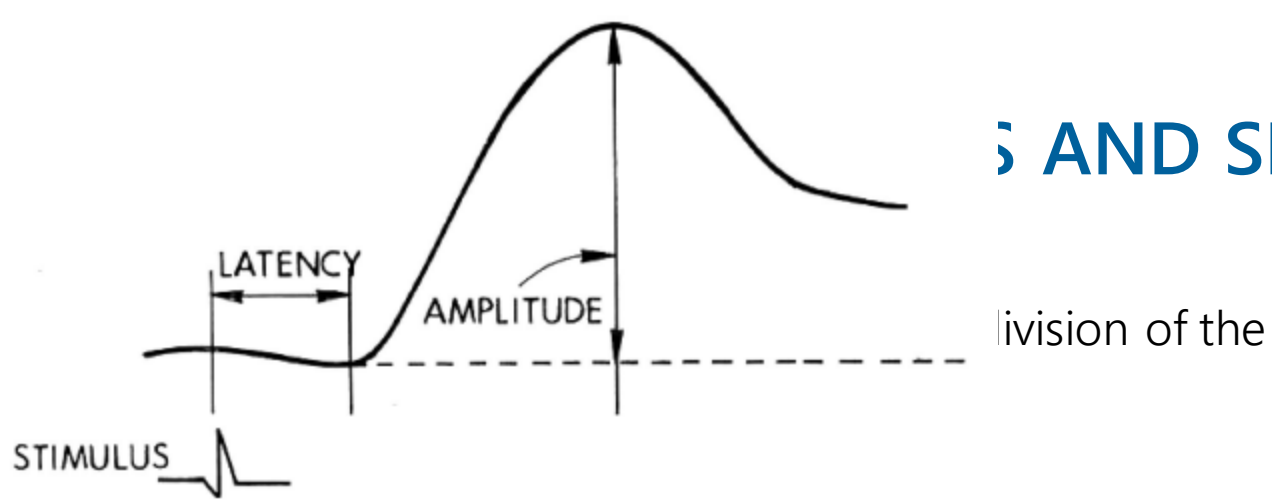


PHYSIOLOGICAL STRESS AND ELECTRODERMAL ACTIVITY



- Physiological stress can be measured by skin conductance (i.e., electrodermal activity, EDA)
- EDA has two components
 - Tonic – skin conductance level (SCL)
 - Low frequency, background level
 - Phasic – skin conductance response (SCR)
 - High frequency, specific stimulus, emotional arousal, can be used to determine stressful events

AND SKIN CONDUCTANCE RESPONSE



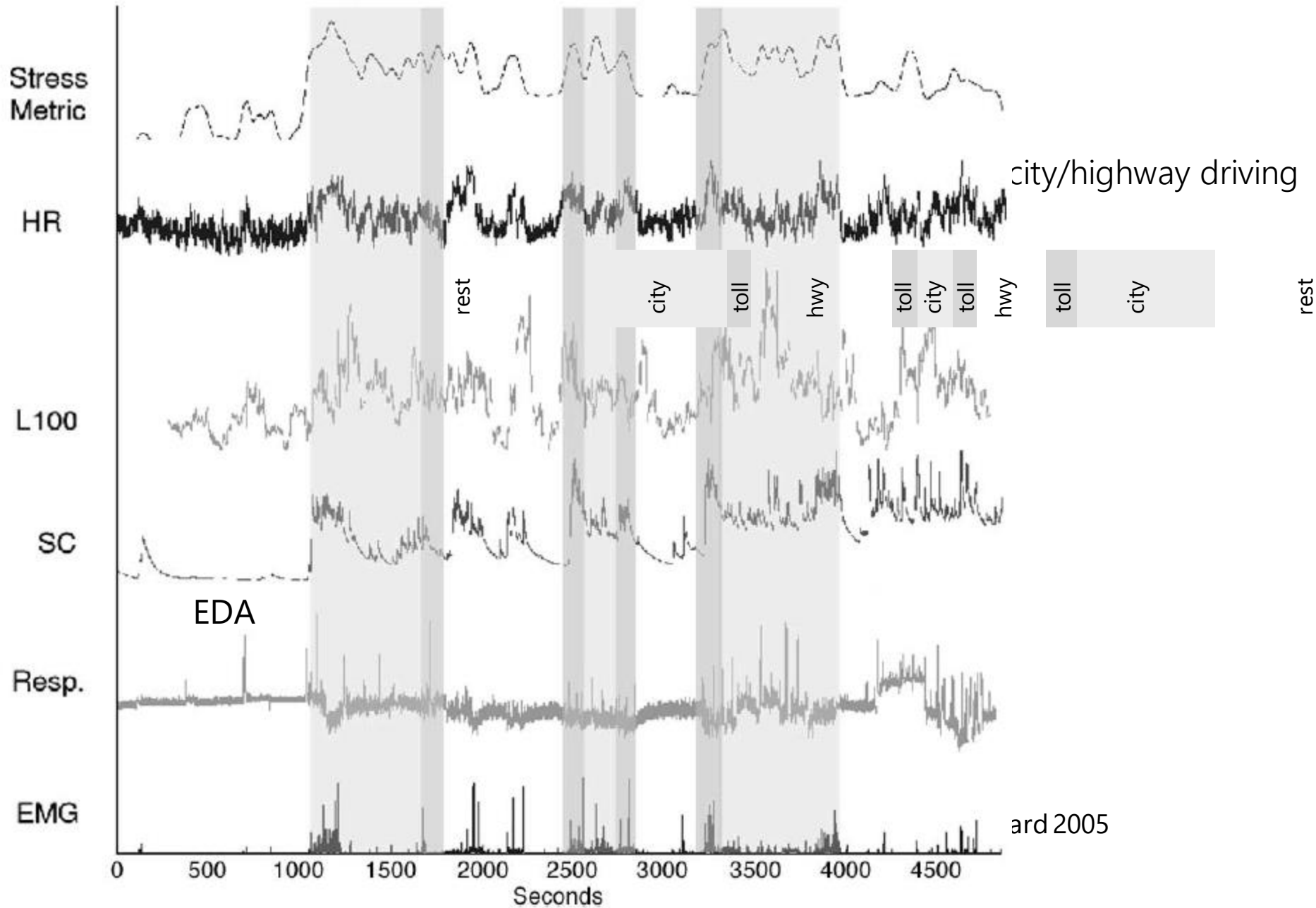
- EVIDENT THROUGH INCREASED SWEAT GLAND ACTIVITY
- Momentary increase in electrical conductivity of skin
 - Skin conductivity can be measured (e.g., wristband)

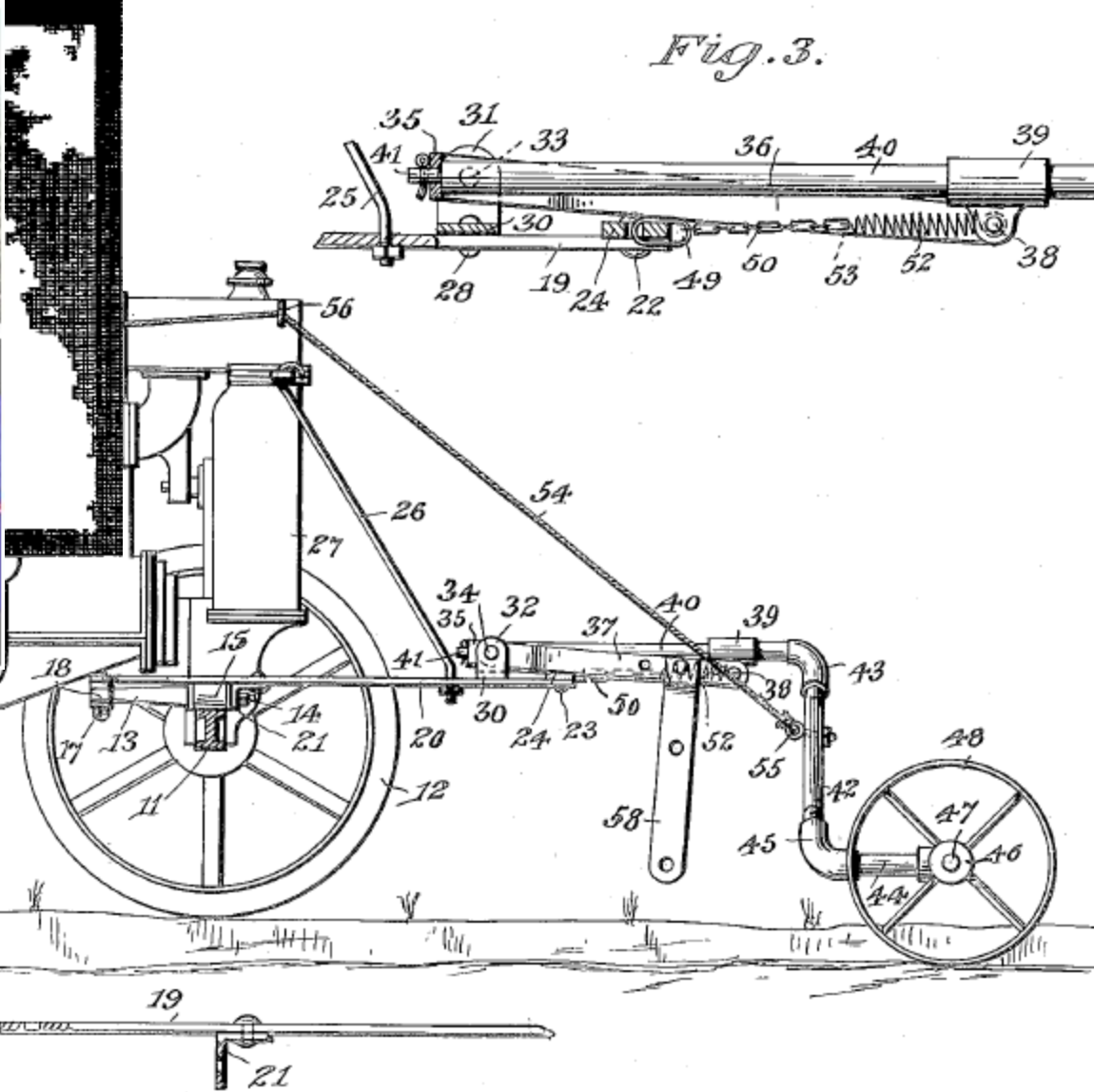
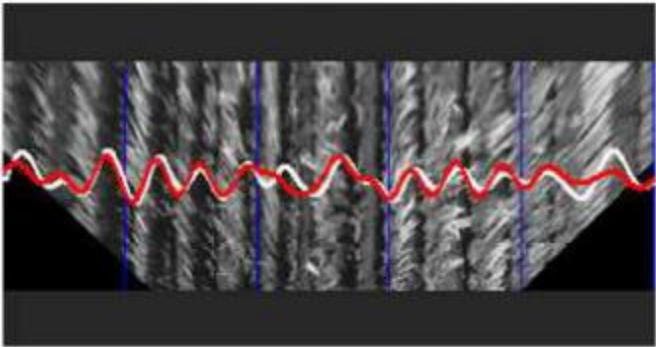


Empatica.com

Dawson et al. 2011

Signals and Stress Metric for Drive R2-1





BY
Wm. H. Kimball
 ATTORNEY.
 INVENTOR,
Fred T. Willrodt

Fig. 4.

Fig. 3.

GUIDANCE

Os (Willrodt, 1924)

rcy, 1987)

Willrodt, 1924

Reid and Searcy, 1987

English et al. 2014

RAVEN VSN GUIDANCE

- VSN® guidance (Raven Industries)
 - VSN introduced in 2019
 - Stereo vision steering
 - VSN Full Canopy introduced in 2020
 - Radar sensor steering
 - VSN does not rely on GPS for steering accuracy and precision



HYPOTHESIS

- Because we know
 - Operating a sprayer manually is stressful!
 - Guidance systems have been shown to relieve fatigue
 - Our customers tell us VSN guidance system anecdotally reduces fatigue
- **Hypothesis:** Compared to manual driving, VSN guidance will reduce the number of stressful events an operator experiences



steering wheel
modified from
Croplife.com

SUBJECTS AND DATA

- Human subjects research protocol was approved by the SDSU Institutional Review Board (IRB)
- Four male subjects
 - Professional sprayer operators
 - 3 co-op applicators
 - 1 farmer (S3)
- Sprayers
 - 3 front boom
 - 1 rear boom (S2)

| Subject | Spraying experience (years) | Region | Sprayer | Crop |
|---------|-----------------------------|-----------------------|----------------------|---------------------------------|
| S1 | 12 | West Central Illinois | Miller Nitro 7310 | Soybeans (VSN) |
| S2 | 7 | Central Indiana | Case IH Patriot 4440 | Soybeans (VSN) |
| S3 | 2 | Northwest Iowa | NH Guardian SP370 | Tasseled corn (VSN Full Canopy) |
| S4 | 6 | North Central Iowa | Miller Nitro 7370 | Tasseled corn (VSN Full Canopy) |

SUBJECTS AND DATA

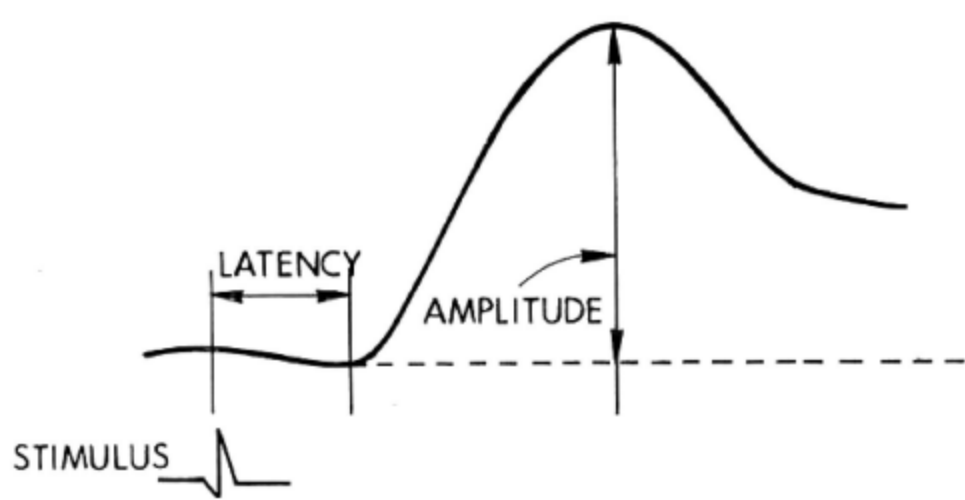
- Human subjects research protocol was approved by the SDSU Institutional Review Board (IRB)
- Four male subjects
- Drove manually and with VSN in same field between tank fills
- Six guidance-planted fields
 - Soybeans and tasseled corn
- Wore wristband (Empatica E4) to measure EDA

| Subject | Spraying experience (years) | Region | Sprayer | Crop |
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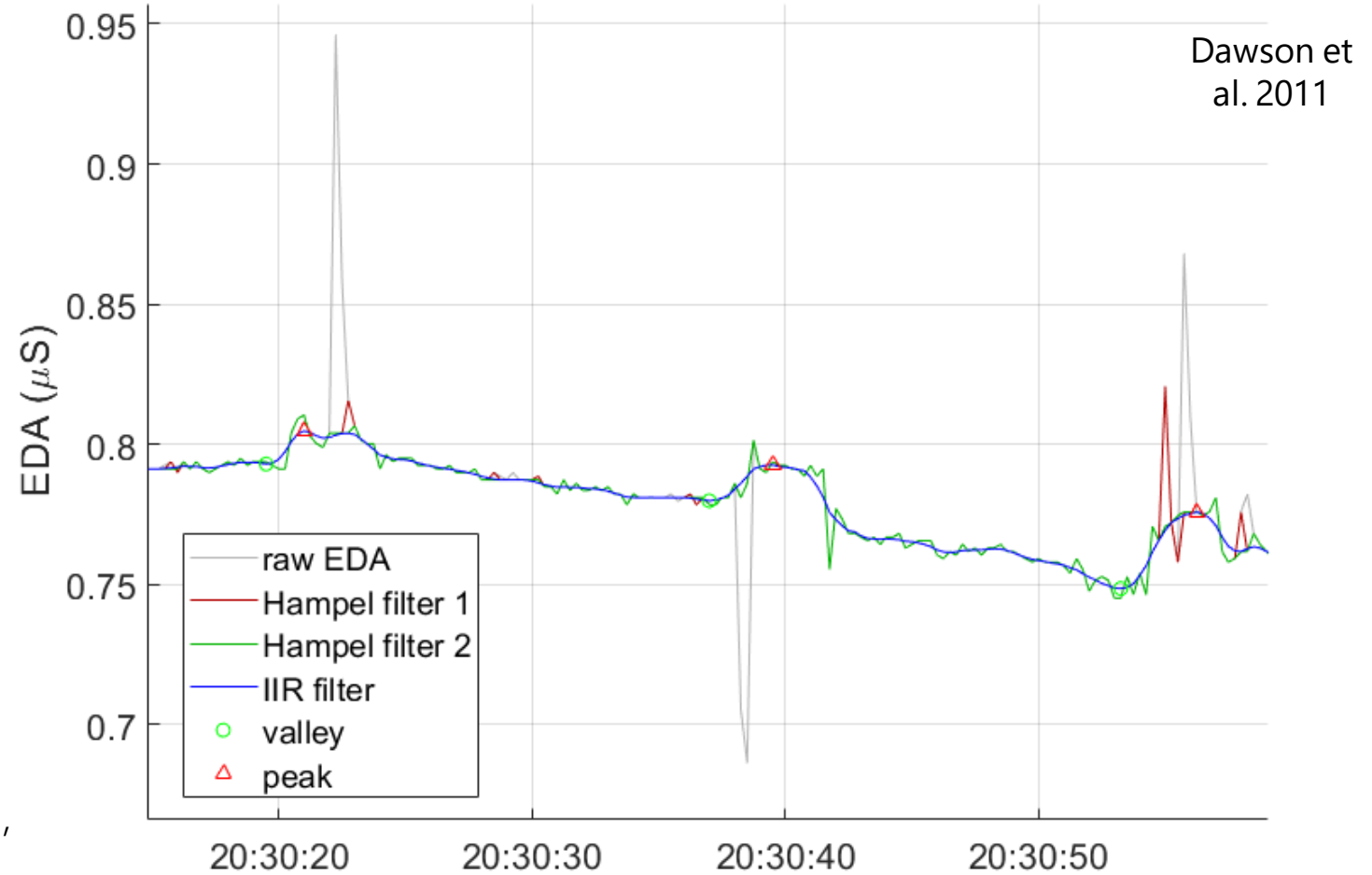


Empatica.com

L EVENTS FROM EDA



- Infinite impulse response filter (IIR) (Kleckner et al. 2017)
 - Window of 1 s
- Data passed EDA quality check
 - i.e., EDA QA, Kleckner et al. 2017
- Found EDA peaks and valleys
- Identified stressful events
 - Minimum valley–peak magnitude threshold of $0.01 \mu\text{S}$ (Lajante et al. 2012)
 - Time to peak 1–3 s (Dawson et al. 2011, Lajante et al. 2012)



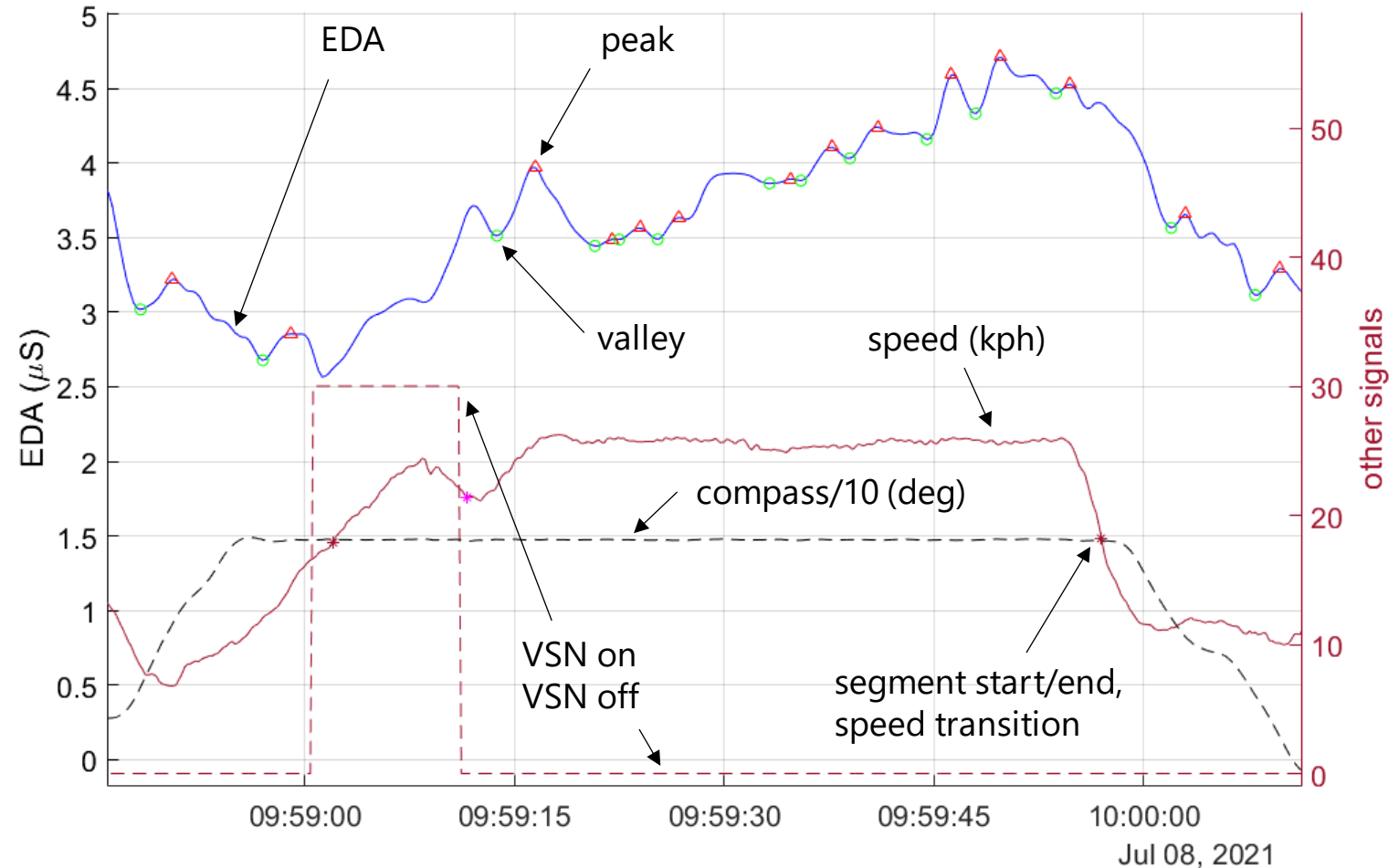
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Jul 29, 2021

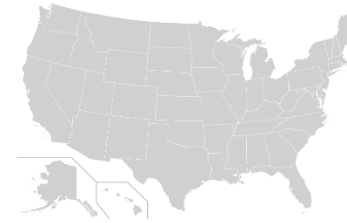
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RELATED STRESSFUL EVENTS TO POSITION AND PASS ACTIVITY

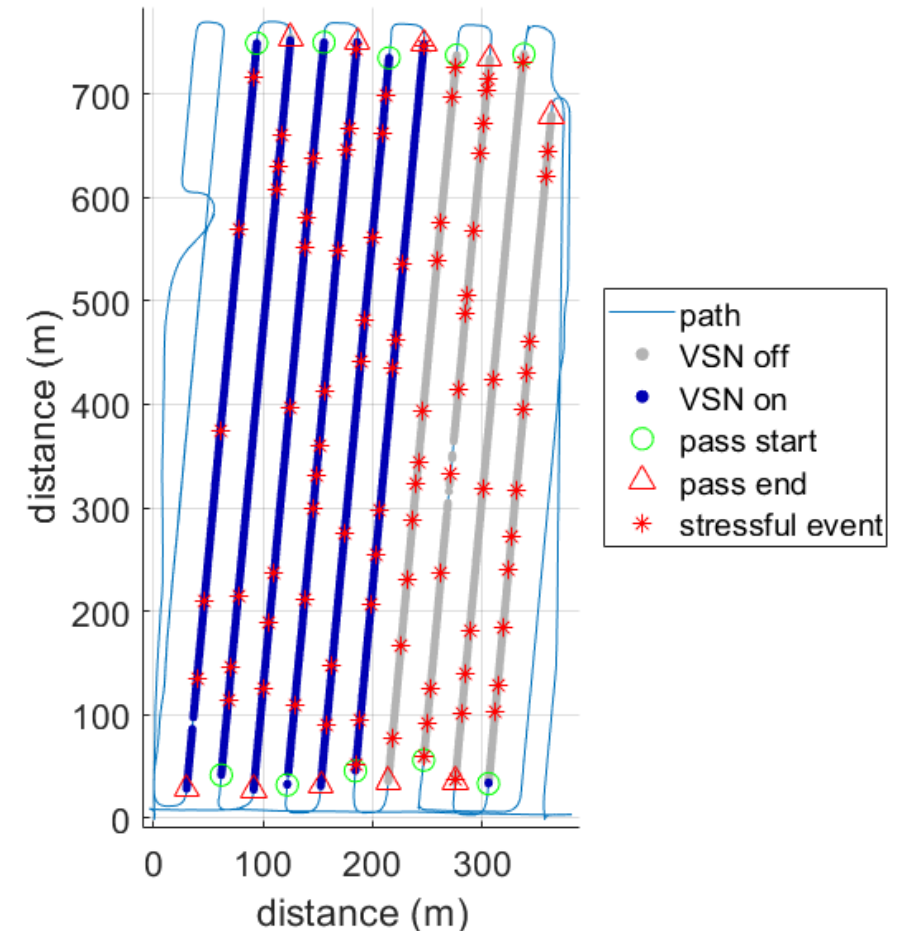
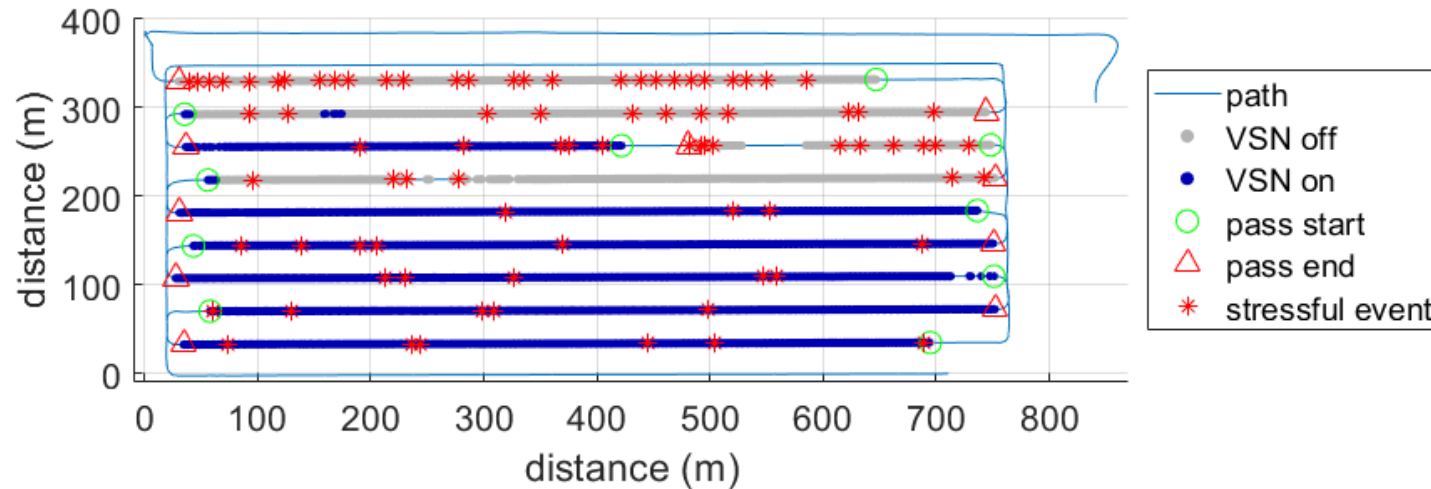
- Collected machine data from CAN logs (RS1™, Raven Industries)
- EDA and machine data were aligned by time
- Calculated per pass
 - Number of stressful events
 - Average machine speed
 - Duration
 - Length
 - Average compass angle
 - Average steering type



MAPPED STRESSORS IN FIELD



- Calculated distances from GPS coordinates and haversine formula (Daidzic, 2017)
- Used fields with both manual and VSN passes
 - Not headlands
 - Not passes on the edge of the field
 - Distance > 150 m



MAPPED STRESSORS ANIMATION: SUBJECT 3

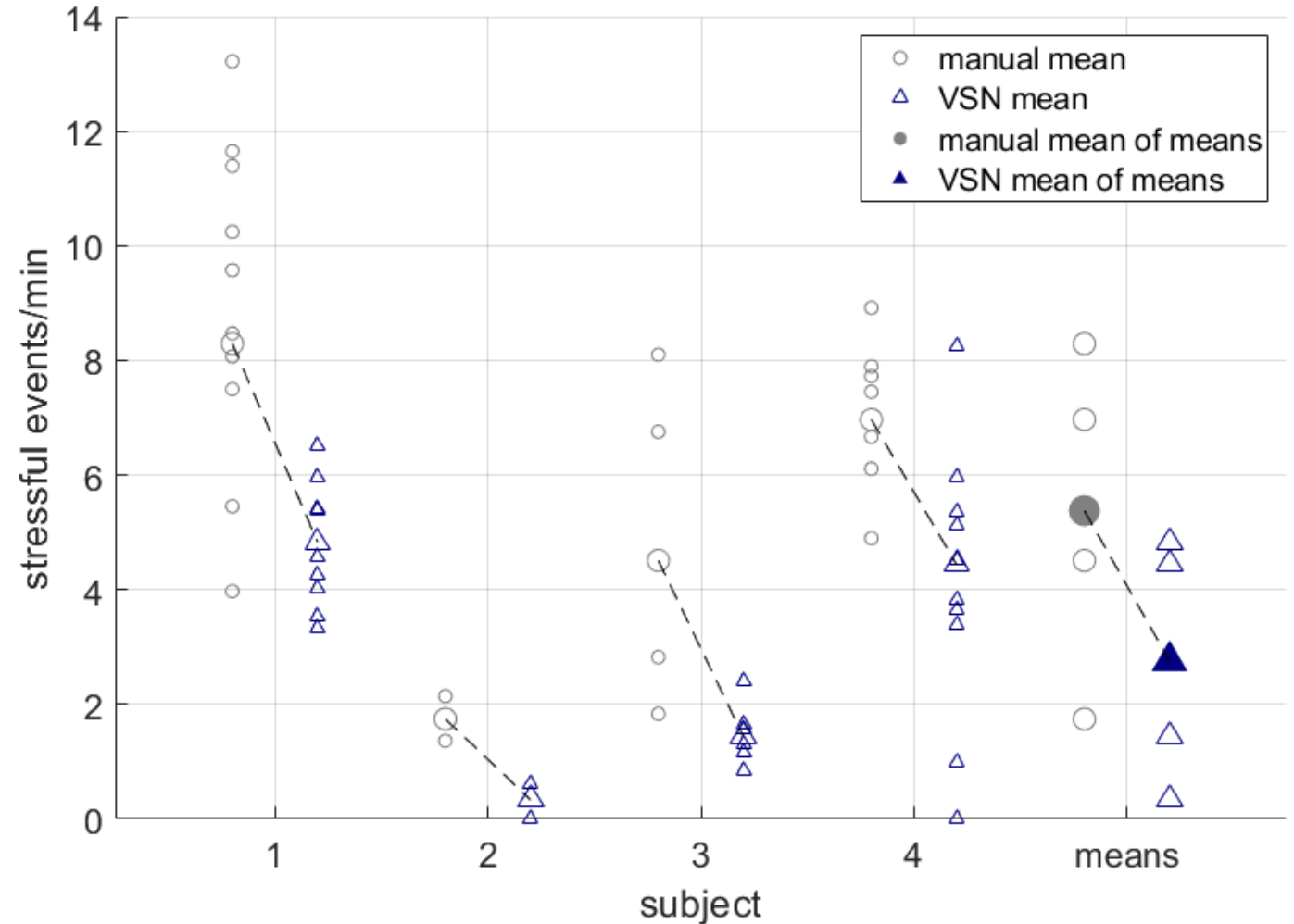


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RAVEN

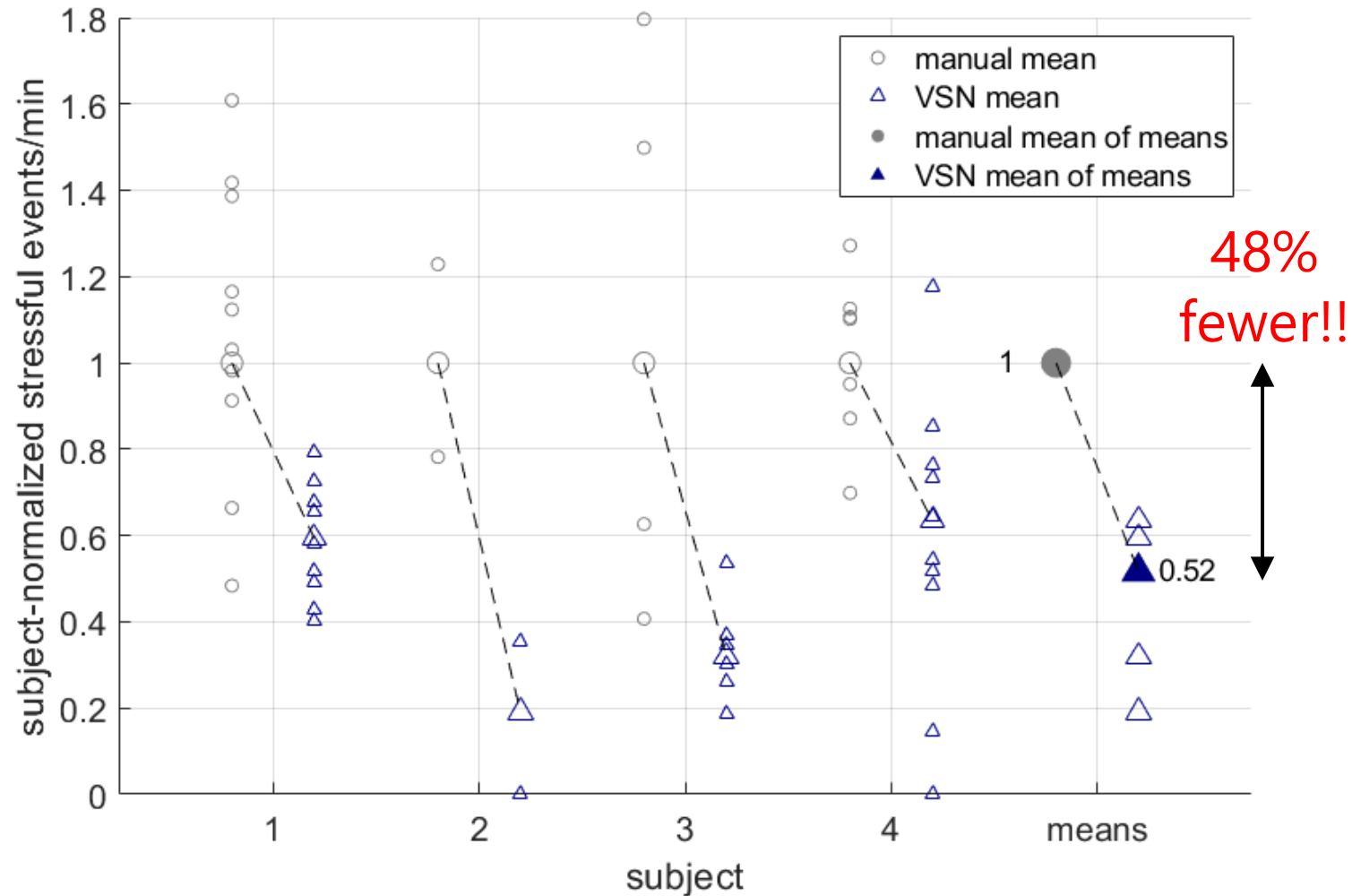
VSN REDUCED NUMBER OF STRESSFUL EVENTS

- Analyzed 51 passes
 - 23 manual
 - 28 VSN
- Stressful events/minute were significantly dependent on both response variables (ANOVA, $p < 0.05$)
 - Steering type
 - Subject
- VSN had fewer stressful events/min than manual
 - 2.8 versus 5.4 events/min ($p < 0.001$)



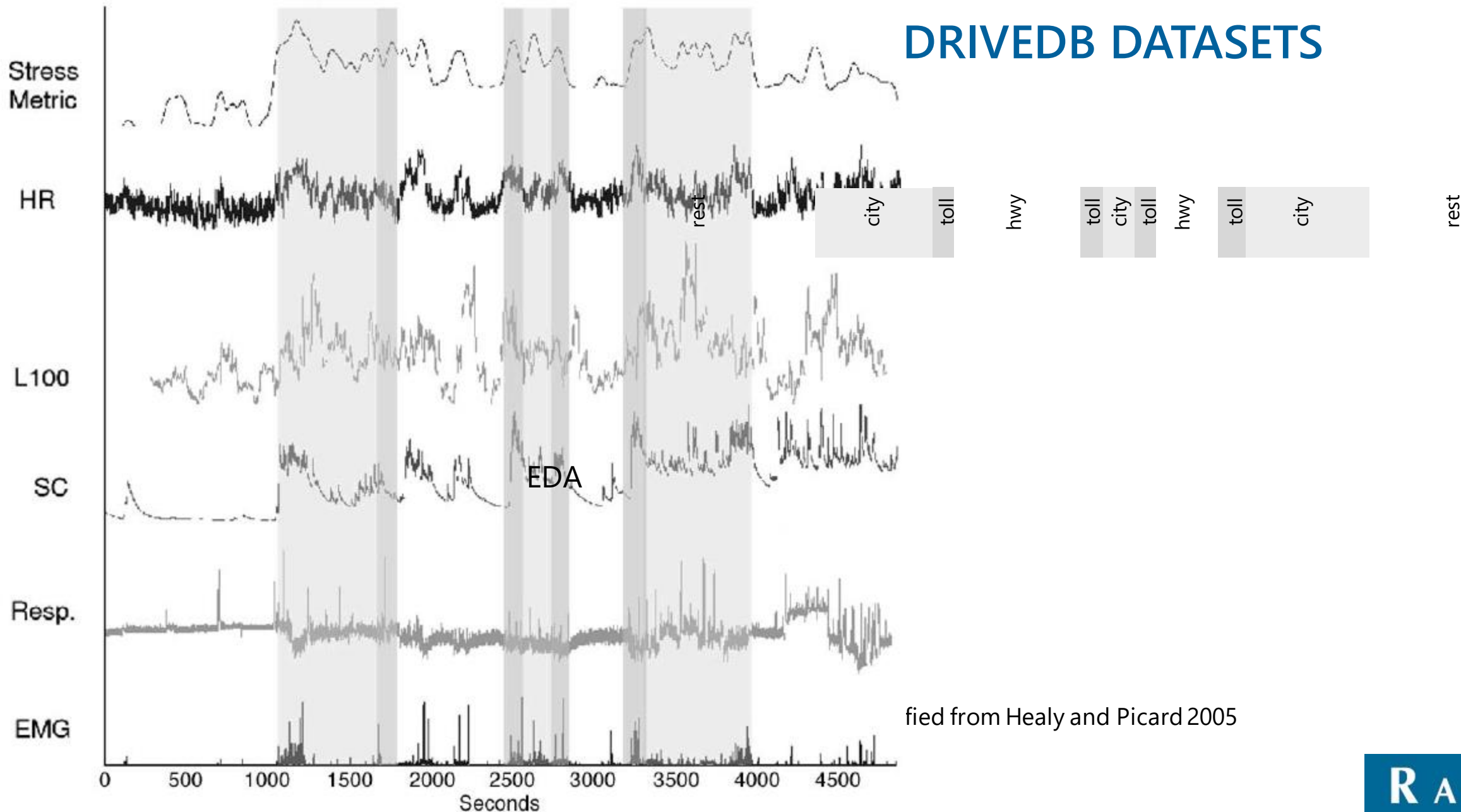
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- Stressful events/minute were significantly dependent on both response variables (ANOVA, $p < 0.05$)
 - Steering type
 - Subject
- VSN had 48% fewer stressful events/min than manual
 - Range 37–81% fewer



Signals and Stress Metric for Drive R2-1

DRIVEDB DATASETS

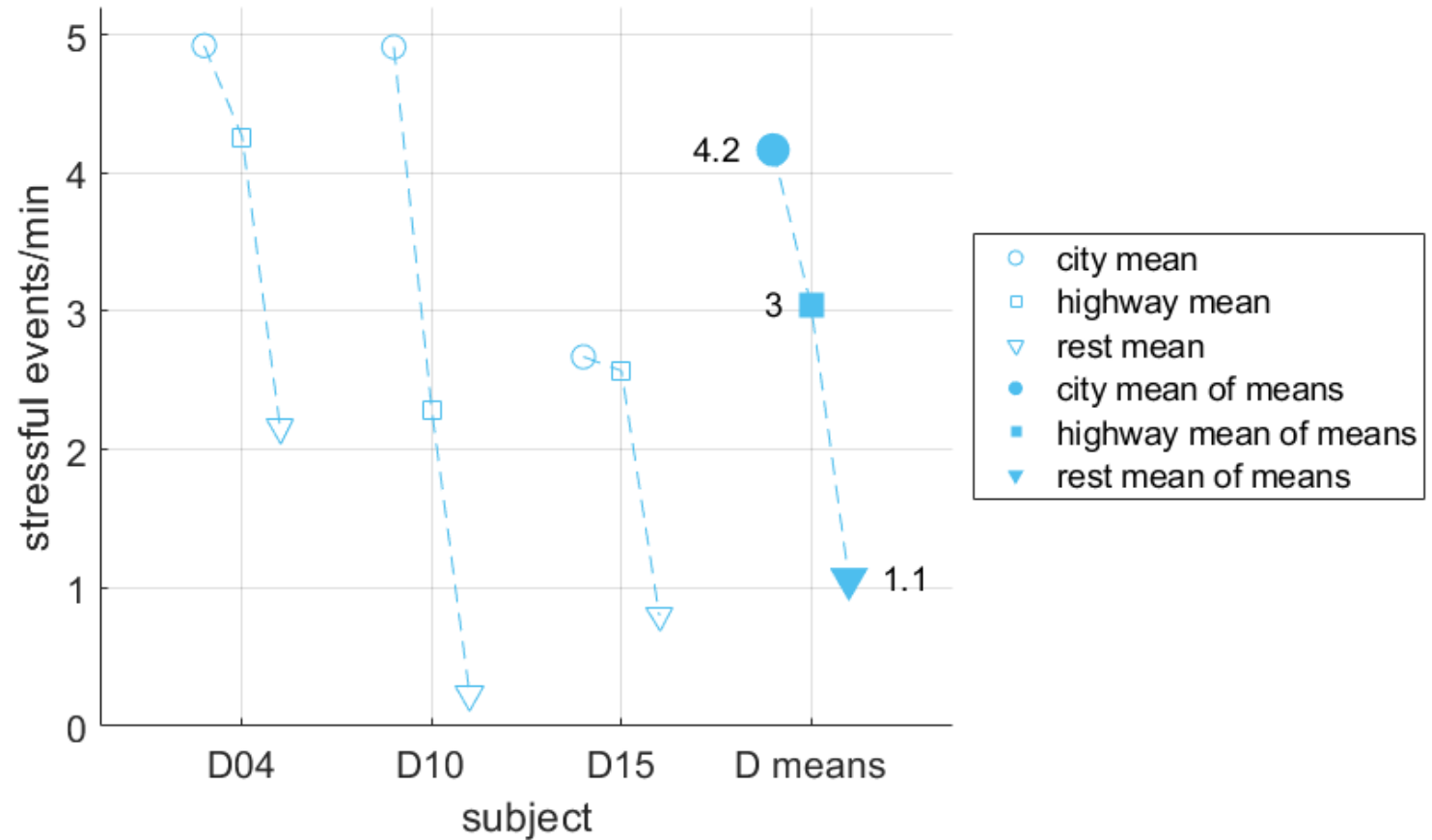


Adapted from Healy and Picard 2005



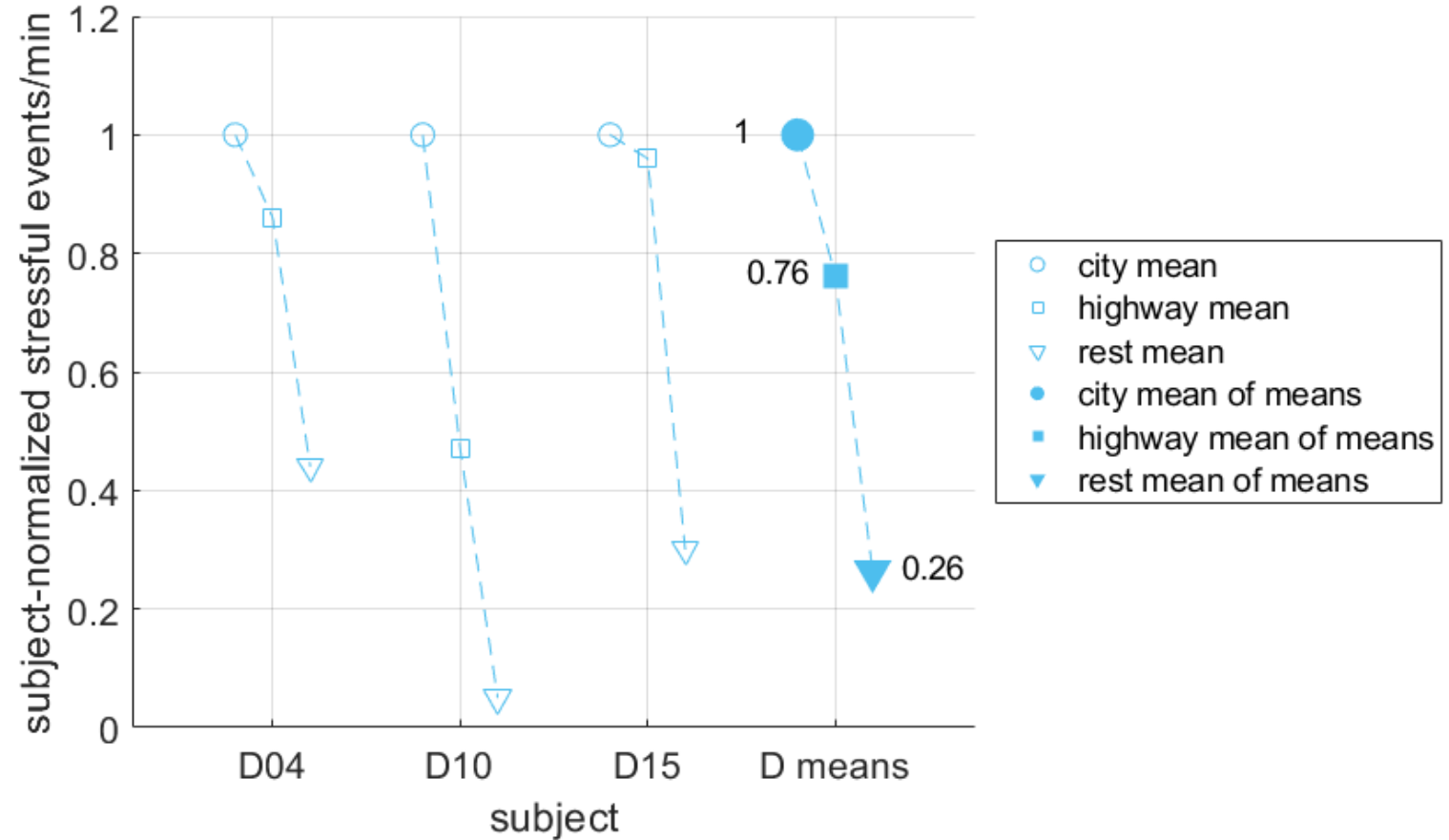
CONTEXT: DRIVEDB DATASETS STRESSFUL EVENTS

- Highway driving had 24% fewer stressful events than city driving
 - 3.0 versus 4.2 events/min



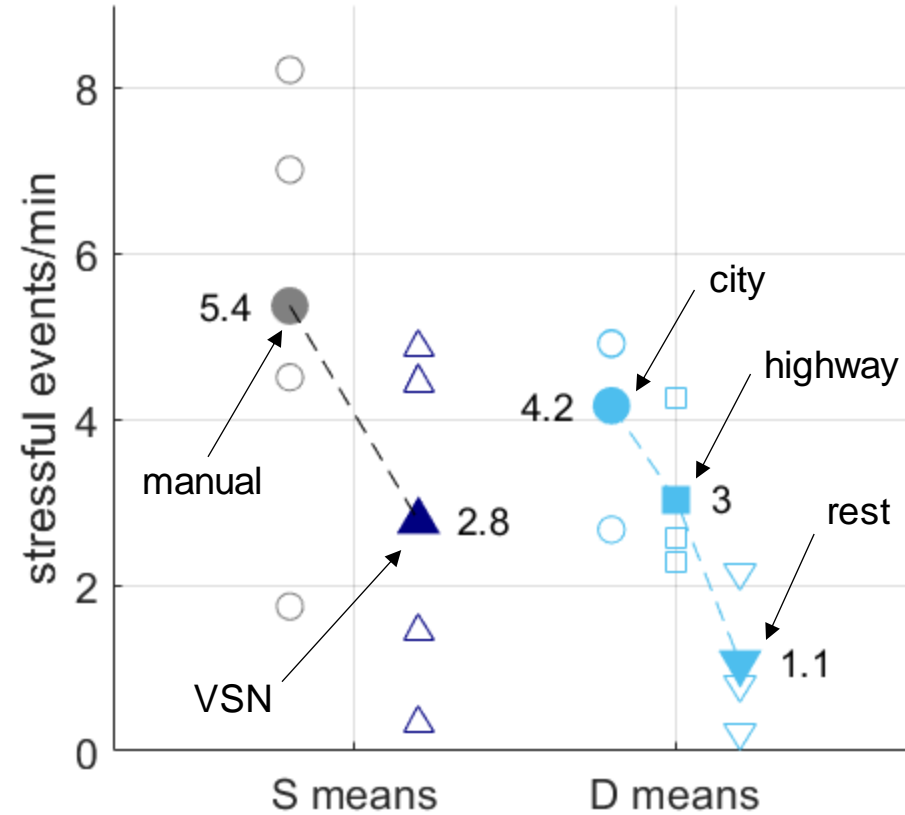
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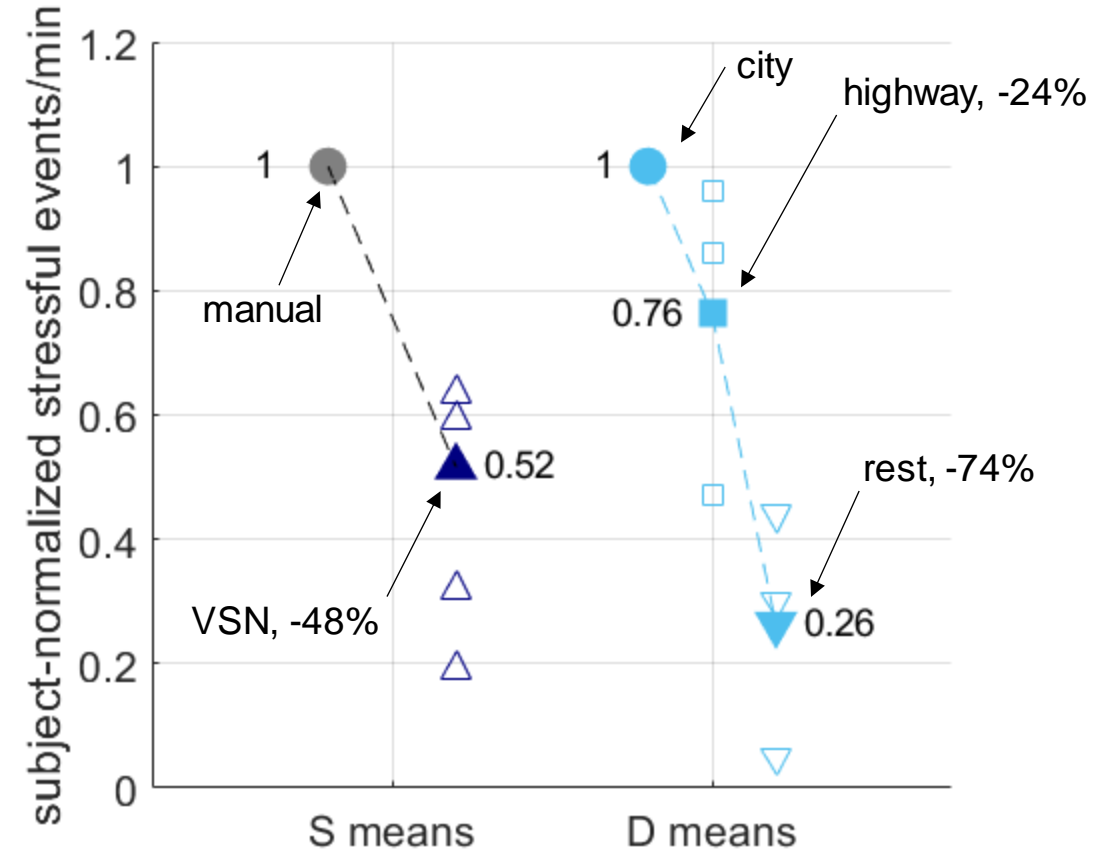
CONTEXT: VSN VS. DRIVEDB STRESSFUL EVENTS

- Number of stressful events/min was similar in VSN study and Drivedb data
- VSN had fewer stressful events/min than Boston highway driving



CONTEXT: VSN VS. DRIVEDB STRESSFUL EVENTS

- VSN/manual had larger stress reduction than highway/city
 - VSN/manual = 48% reduction
 - Highway/city = 24% reduction
 - Rest/city = 74% reduction

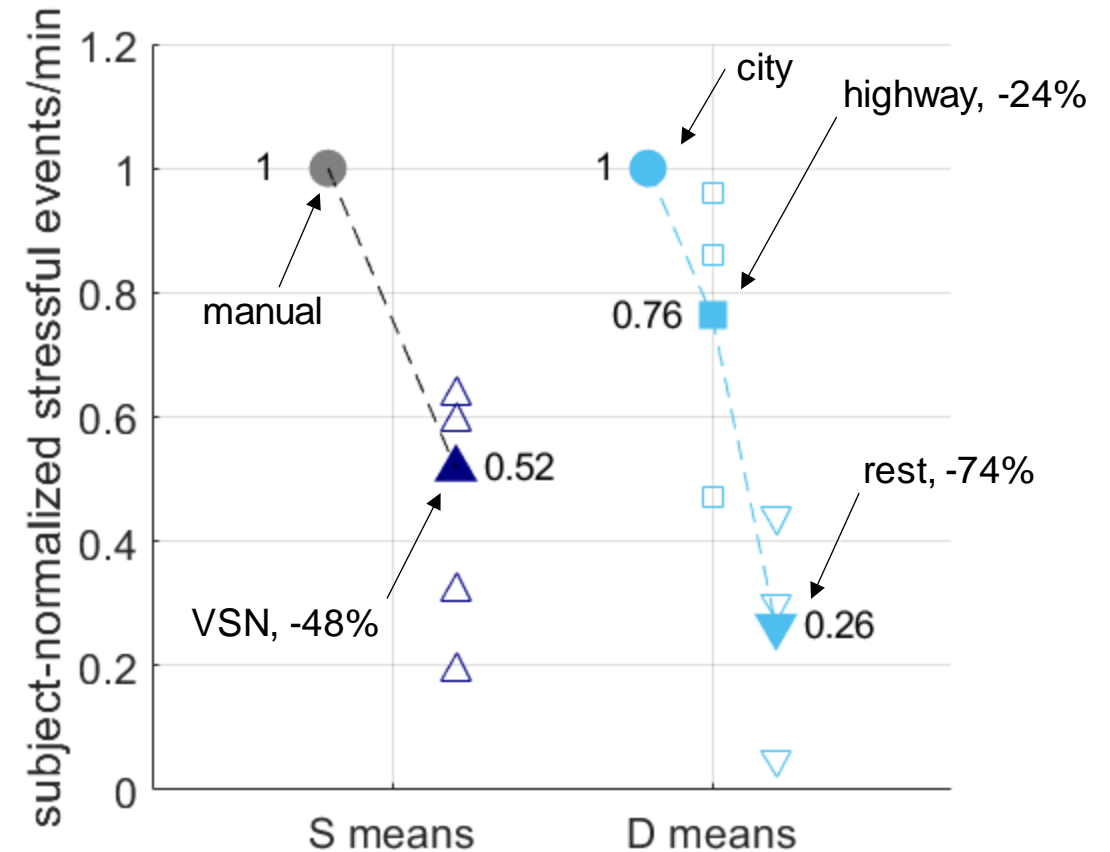


LIMITATIONS

- Sample size
 - 4 operators, 6 fields, 4 sprayers
 - 3 front boom, 1 rear boom
 - 2 VSN, 2 VSN Full Canopy
 - Differences between
 - Vision and radar (and GPS) guidance
 - Front boom and rear boom sprayers
 - Crop types
 - Male and female operators
 - Operator experience

CONCLUSIONS

- VSN reduces operator stress
 - 48% reduction relative to manual!
 - This is more than the reduction from city to highway automobile driving
- Automatic guidance system (VSN) could have a dramatic positive effect on the health of sprayer operators
 - especially when accumulated over workdays and season



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