

Anxiety as a source of inattention during highly automated driving: Effects on situation awareness at takeover

Angus McKerral and Kristen Pammer

School of Psychological Sciences, The University of Melbourne

School of Psychological Sciences, University of Newcastle

Supervising an automated vehicle degrades situation awareness at takeover



- L3 automation moves the driver to a supervisory role⁹ causing situation awareness (SA) to degrade at takeover¹
- Two established sources of inattention under automation:
 - non-driving-related task (NDRT) engagement¹⁷
 - passive fatigue from monotonous monitoring⁶
- Prior study found operators who monitored the vehicle lost SA across a long drive⁸
 - offset by NDRT engagement
- Internal states such as anxiety are a candidate third source.
 - Automation research has framed anxiety around acceptance and trust^{10,11,15}

Processing Efficiency Theory: Anxiety costs most in low-demand tasks



Processing Efficiency Theory⁴

- Anxious individuals divert cognitive resources toward worry, environment monitoring, reducing available capacity for task-relevant processing
- In manual driving, anxiety has been shown to both impair and, in some cases, enhance performance depending on task demands¹⁴
- Impairment most likely expressed in low-demand contexts such as passive vehicle monitoring, where SA and takeover performance matter most
- Trait anxiety shown previously to predict self-reported driving lapses after controlling for processing efficiency¹⁶

Working hypothesis

- Anxiety directs attention away from a task that already under-occupies it

Present study: Does anxiety predict the change in SA across an automated drive?



Framing

- A driver is inattentive when information sampling is insufficient to form and maintain a sufficient representation of the situation⁷ (our SA probe measures that representation)
- SA coded to Perceptual Cycle Model categories separates information collection (World Information) from integration (Schema)
- Gap: anxiety is an understudied contributor to attentional disruption under automation
 - no study has tied it to SA across an extended automated drive

Hypotheses

- **H1** Change in anxiety across the drive predicts change in SA
- **H2** Monitoring condition (passive supervision vs NDRT engagement) moderates the relationship
- **H3** Schema-level SA is the most sensitive: NDRTs and anxious rumination should both disrupt integration rather than detection
- Direction left open: relinquishing control may reduce anxiety and free resources, or provoke it and increase attentional competition

Paradigm

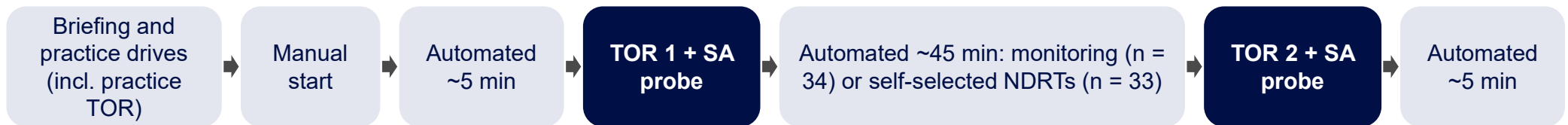


Fig. Construction-zone takeover scenario in the STISIM M300WS simulator with the automation toolbox of Eriksson, de Winter & Stanton³; Level 3 behaviour (SAE J3016).

Measures: Anxiety scales and a verbal SA probe coded to the Perceptual Cycle Model



Anxiety

- STAI-Y2 trait anxiety before the session; STAI-Y1 state anxiety pre- and post-drive¹²
- DCQ-manual before the session; DCQ-AV, with instructions adapted to the automated vehicle, pre- and post-drive²

Situation awareness

- Verbal description of the scene immediately after each takeover request
- Sentence fragments coded to World Information, Action and Schema
 - count scores per probe

Example response:

“I had just braked. I saw what looked like boxes all over both lanes of my side of the road. Um, there was a car that was pulled over to my left that had it's- I think it had its right indicator on so it looked like it was- it could've been turning back in. Um, there wasn't really much traffic on the other side of the road, which means [the ego car] could have gone around but it's double lines and it's dangerous. Um, there was a truck right in front of us, and I assume that's where the boxes came from, like the truck, they flew off the truck or something. And yeah, that's about it.”

World Information Action Schema

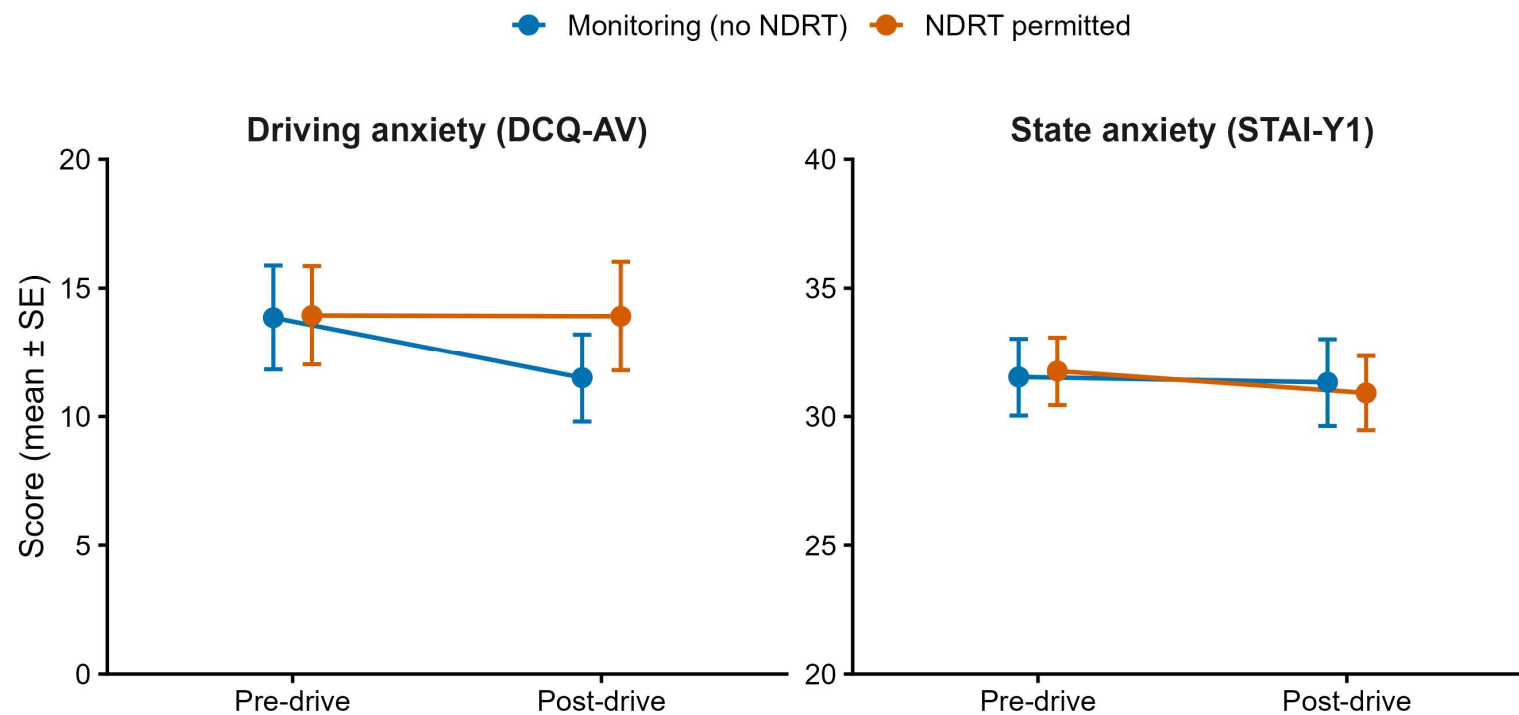
Participants



Condition	n	Age M (SD)	Women	Years licensed M (SD)	Crashes M (SD)	Anxious-driver rating (0–100) M (SD)
No NDRT (monitoring)	34	28.1 (9.19)	82%	10.7 (6.55)	2.03 (2.56)	32.5 (28.0)
NDRT permitted	33	25.1 (7.93)	71%	8.67 (6.55)	2.45 (3.16)	27.9 (23.2)



Driving anxiety fell in the monitoring condition only



Summed situation awareness declined in the NDRT condition only



- NDRT permitted: significant decline
- Monitoring: no meaningful change.
- Reverses the pattern in McKerral, Pammer & Gauld (2023)⁸, where the monitoring condition declined
- Possible explanation: the higher baseline arousal associated with anxiety may partly buffer the passive fatigue that otherwise impairs supervisors

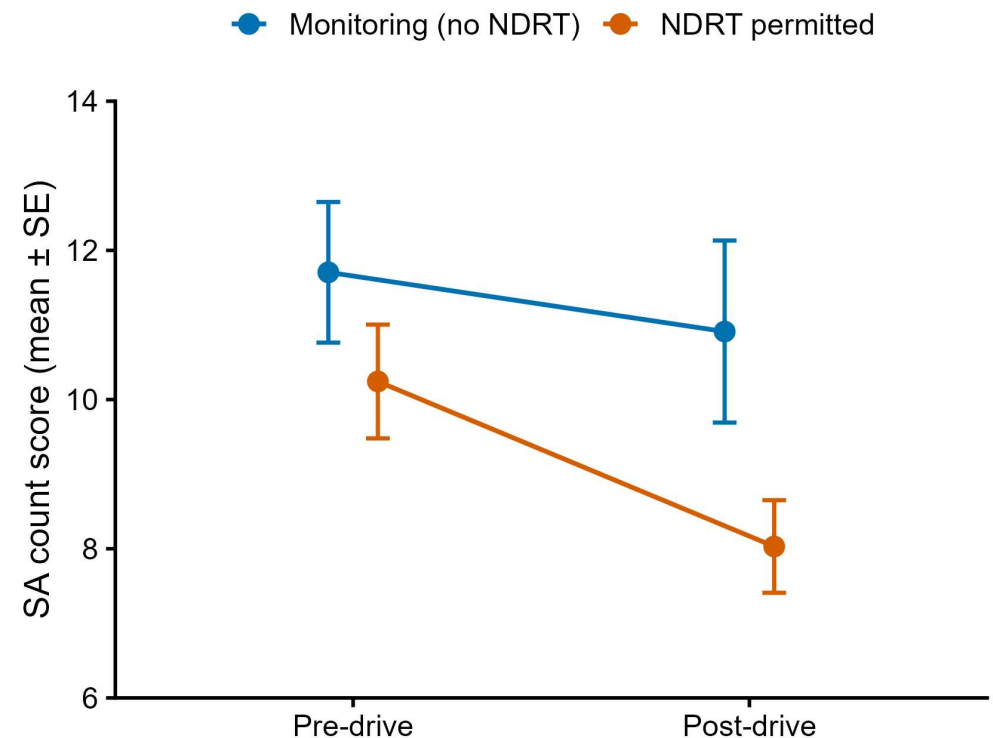


Fig. Summed SA count score, mean ± SE, n = 67.

State-anxiety *change* predicted SA-change, regardless of condition



- SA change $\sim$ STAI-Y1 change + condition: $R^2 = .173$, $F(2, 64) = 6.67$, $p = .002$
- STAI-Y1 change $\beta = -0.387$, $p = .001$; condition $p = .139$
- Operators whose state-anxiety fell across the drive maintained SA at the second takeover; those whose anxiety rose lost SA

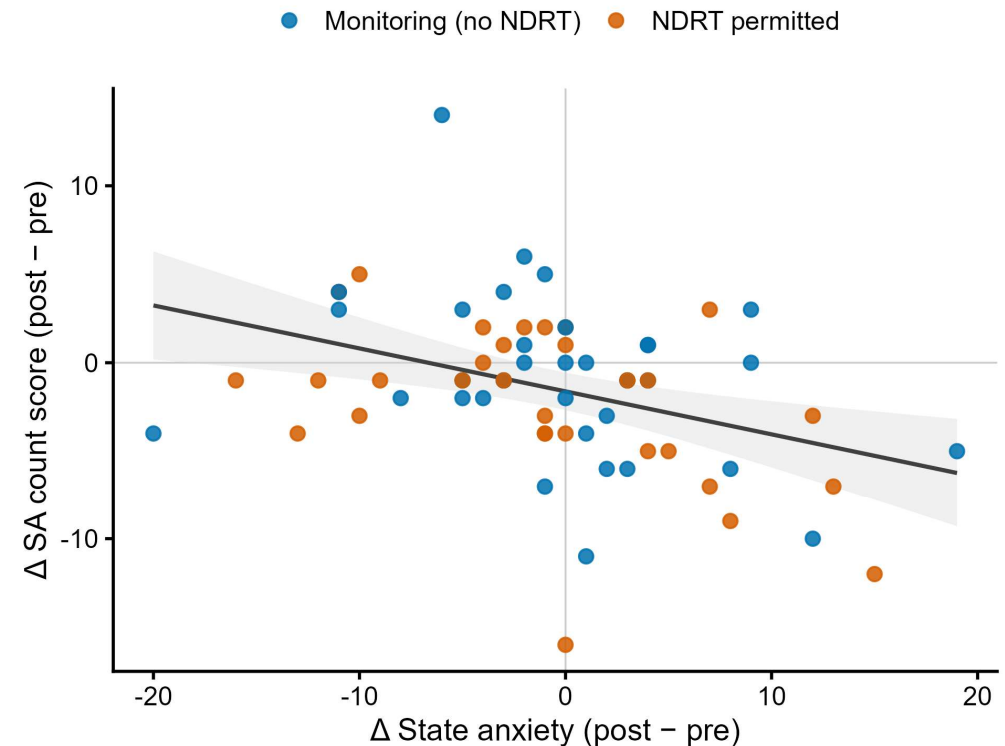


Fig. Δ SA count vs Δ STAI-Y1, both post – pre; OLS line with 95% band; $n = 67$.

State-anxiety is an internal source of inattention under automation



Interpreting results

- State-anxiety change predicted SA change independent of NDRT condition: an internal source of inattention alongside the external one, consistent with Processing Efficiency Theory
- Earlier work with this paradigm located the SA loss in Schema, the integration category⁸ (confirmation pending further analysis)
- An internal source has no observable task artefact, so it is harder for a vehicle system to detect than an NDRT

Design implications

- Active monitoring reduced driving-specific anxiety: exposure with calibrated expectations, to be weighed against passive fatigue⁶
- Warning interfaces that reduce out-of-the-loop anxiety support re-engagement at takeover⁵
- Anxiety-aware, adaptive human-machine interfaces

Limitations and next steps



Limitations

- Self-selected, sub-clinical sample spanning a spectrum of driving anxiety and demographics
- Direction of causation: the SA probe itself may raise state anxiety¹³
- No eye tracking, so any effect of anxiety on visual sampling is untested

Next

- Glance coding of the driver-facing video, test whether more anxious drivers monitor the roadway more relative to their NDRTs (planned)
- Real-time physiological monitoring of anxiety to adapt takeover alert timing and modality
- Whether treating driving anxiety improves SA and takeover, in subclinical and clinical samples

Thank you

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THE UNIVERSITY OF
MELBOURNE

Angus McKerral | angus.mckerral@unimelb.edu.au
School of Psychological Sciences, The University of Melbourne

The University of Melbourne (Australian University) PRV12150/CRICOS
00116K

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