

Disentangling alcohol and sleepiness effects

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Fordonsstrategisk
Forskning och
Innovation

This work was funded by the Swedish Strategic Vehicle Research and Innovation Programme (VINNOVA FFI; Grant No. 2025-04148)





Problem statement

1.19 million

Road Deaths in 2021 (WHO, 2023)

1.5 %

Increase from 2014 to 2024 (ITF, 2025)

20 %

Are alcohol-related (Vissers, 2017)



Solutions

Legal limits and enforcement

For most countries based on BAC
or BrAC

Sweden: 0.2 ‰ BAC (SFS 1951:649)

Europe: ~0.5 ‰

US: ~0.8 ‰

Driver Monitoring System (DMS)

Detect alcohol-related impairment

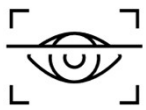
Measurement of alcohol presence **or**



Assessment of behaviour



Camera-Based DMS



Alcohol affects eye movements (Roche & King, 2010)

Eye movements generally slow down when drunk and/or fatigued (Schleicher et al., 2008; Zemblys et al., 2024)

- Indirect measurement of BAC
- + Direct measure of behaviour change (impairment)

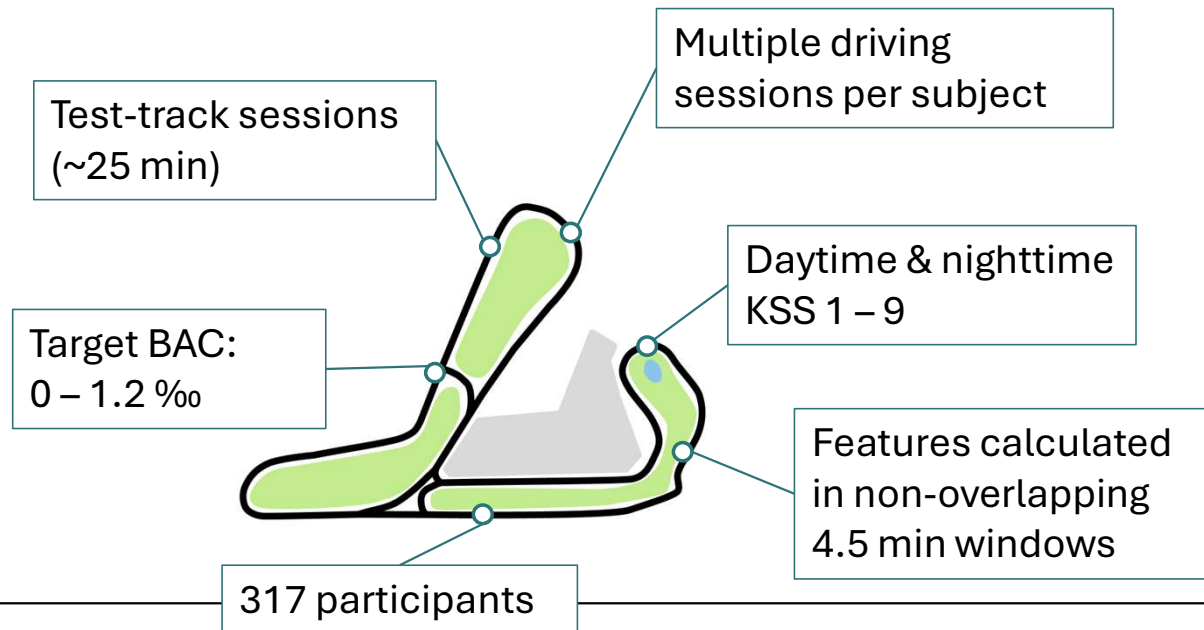


Research questions

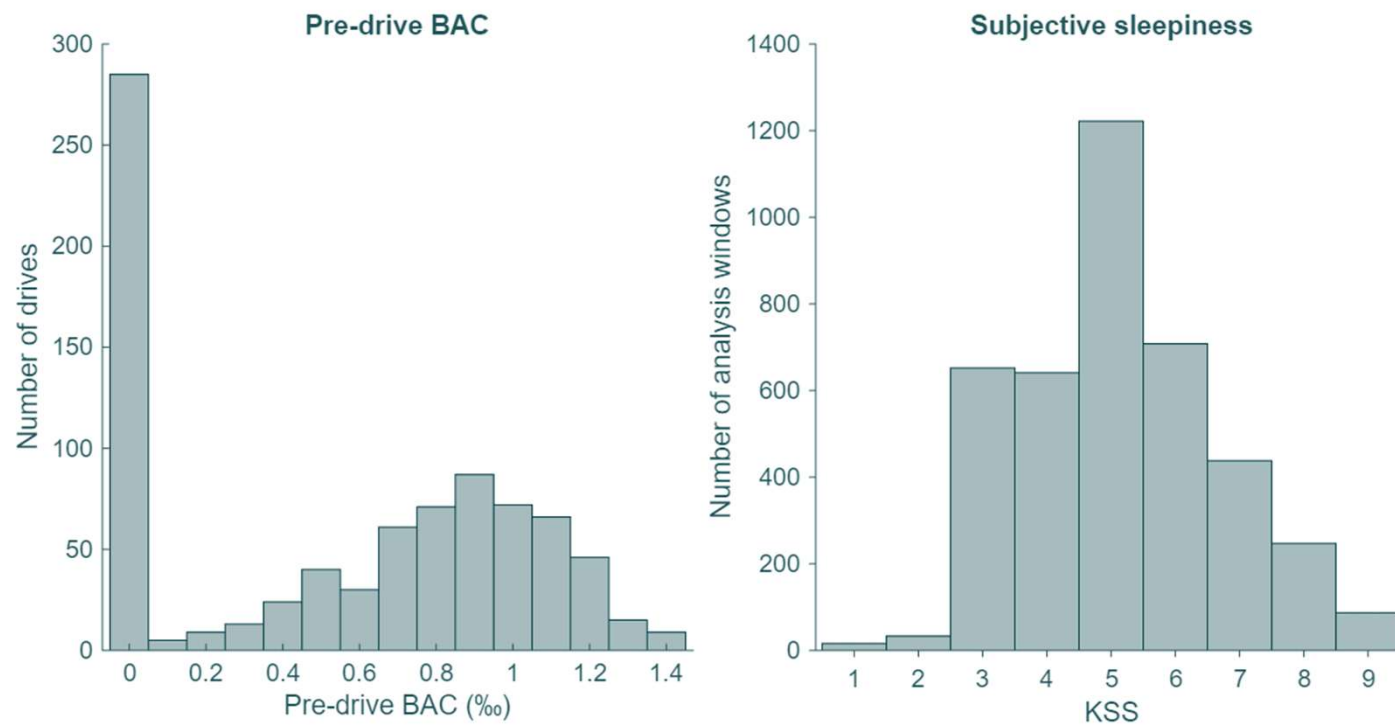
1. Which camera-based features are more associated with BAC?
2. Which features are more associated with sleepiness?
3. Will features differ between ascending and descending phases of the BAC curve?
4. Will such phase differences remain when ascending and descending observations are additionally matched on sleepiness?

Dataset

Repeated test-track drives across alcohol and sleepiness conditions



Distribution of BAC and KSS in the dataset



Feature set



Blink & eyelid

10

Blink duration mean · P05 · P95
Closing speed mean · P05 · P95
Opening speed mean · P05 · P95
PERCLOS percentage of eye closure



Fixations

4

Fixation duration mean · P05 · P95
Long fixations proportion > 500 ms



Saccades

19

Frequency saccades per minute
Duration · amplitude · peak velocity mean · P05 · P95
Velocity/amplitude ratio · curvature mean · P05 · P95
Main sequence slope · R^2 · residual SD



Gaze allocation & scan path

5

Road-centre gaze · downward gaze
percentage of time
Stationary gaze entropy SGE · duration-weighted SGE
Gaze-transition entropy GTE



Continuous eye & gaze movement

6

Sample entropy position · velocity
Eye-velocity spectral measures 0.2–5 Hz relative power
Low-frequency measures power · centroid (0.1–1 Hz)
Spectral entropy eye velocity

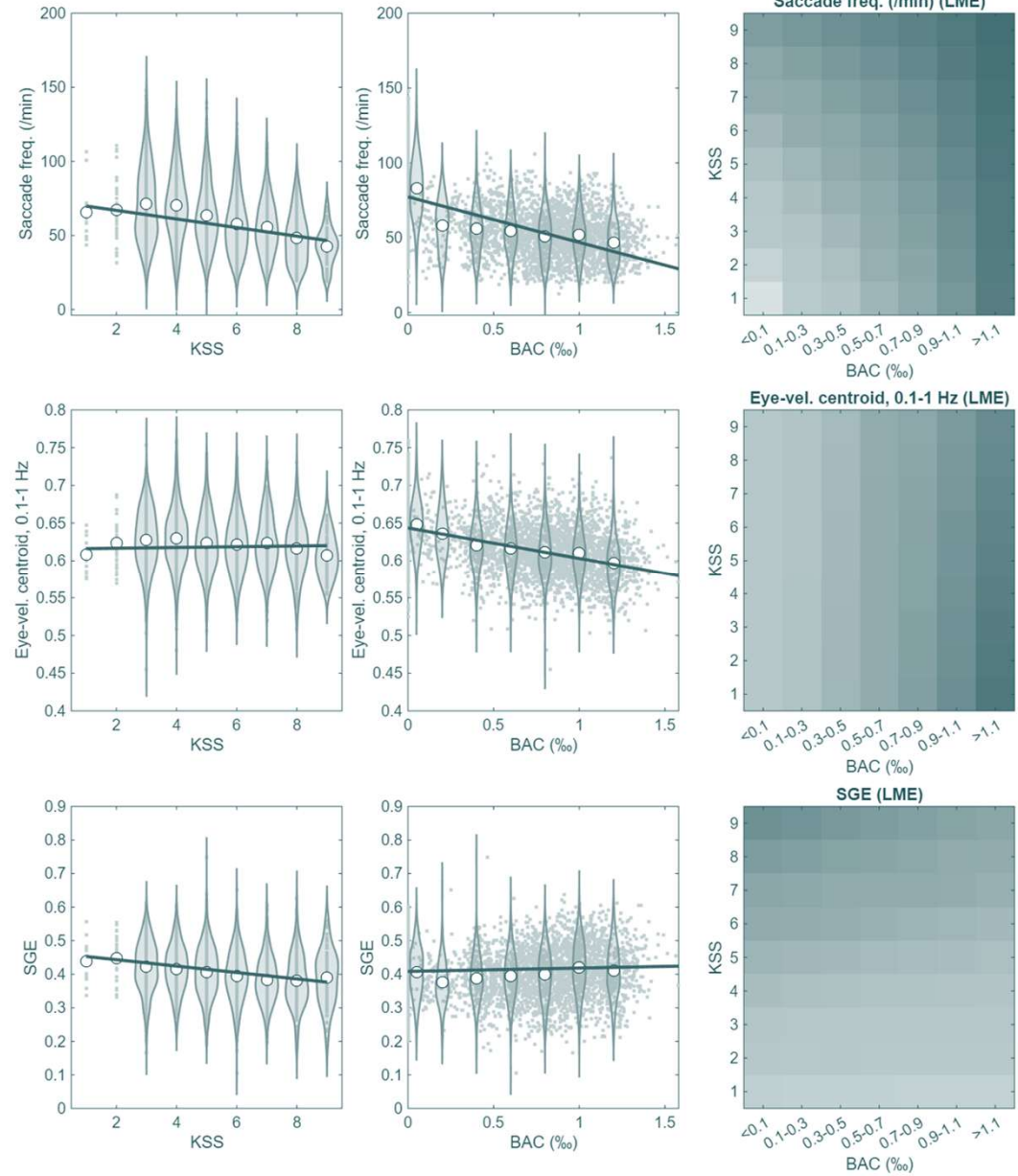


Eye-head movement

8

Eye-head correlations position + velocity · horizontal + vertical
Speed coherence eye-head movement magnitude
Head contribution head-to-gaze speed ratio
Head-active gaze speed RMS · P95

BAC and KSS dominant features



Alcohol and sleepiness overlap DMS

Most eyelid, fixation, and saccade features were associated with both BAC and KSS.

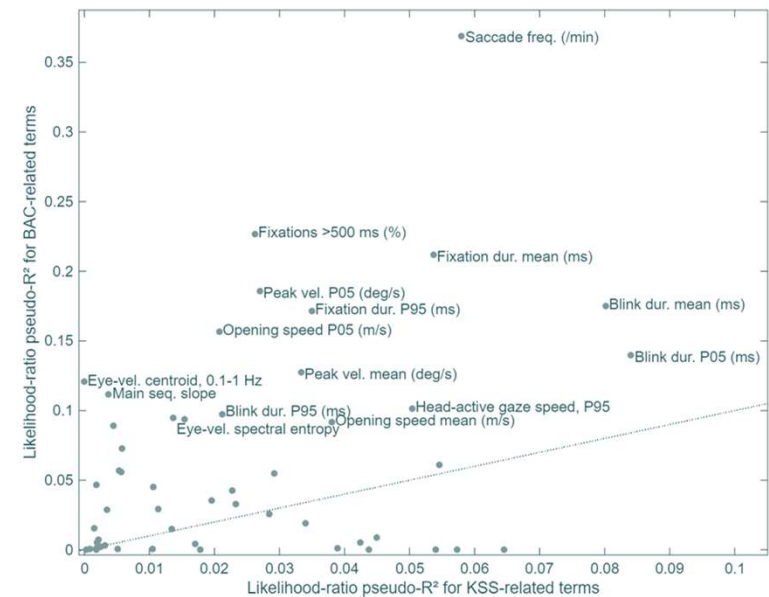
BAC-dominant features:

- blink duration and eyelid speed
- saccade frequency, amplitude, and velocity
- some eye-velocity spectral features

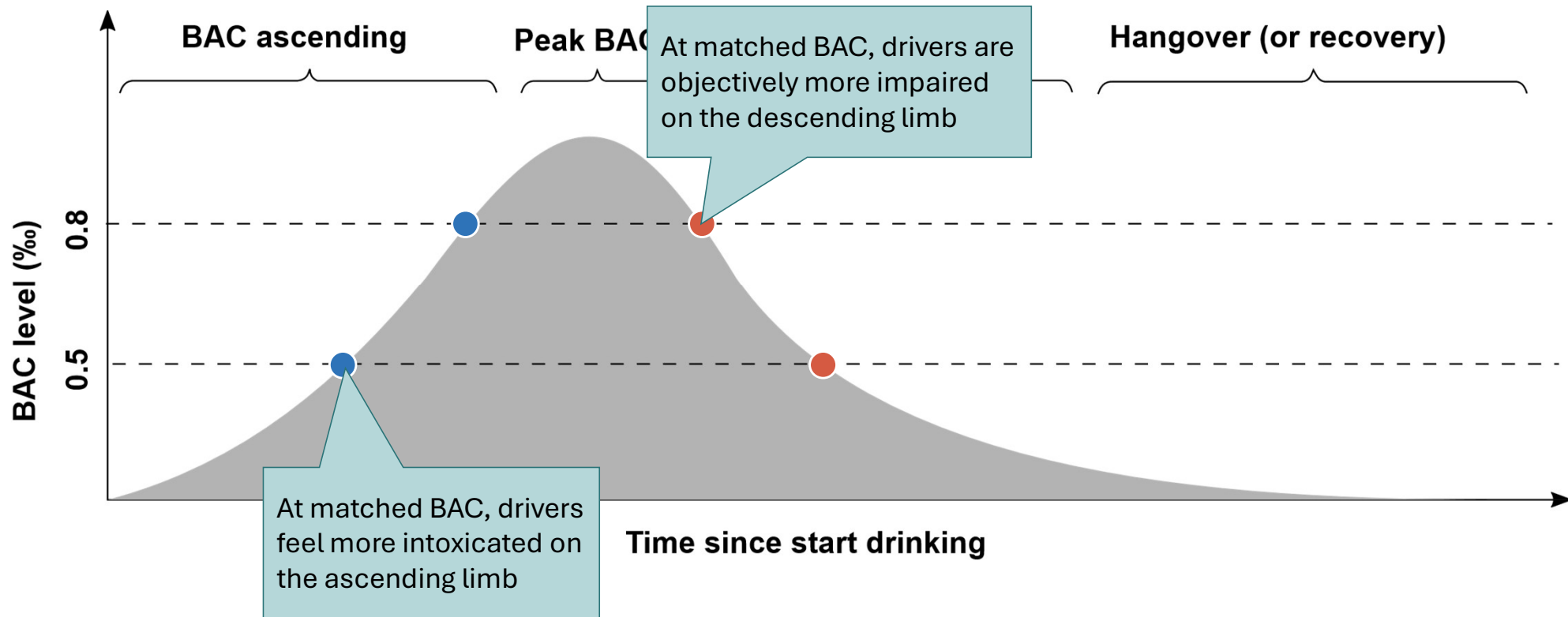
KSS-dominant features:

- gaze entropy and road-centre gaze
- eye-head correlations and coherence

BAC $\times$ KSS interactions were small compared with the separate BAC and KSS contributions.



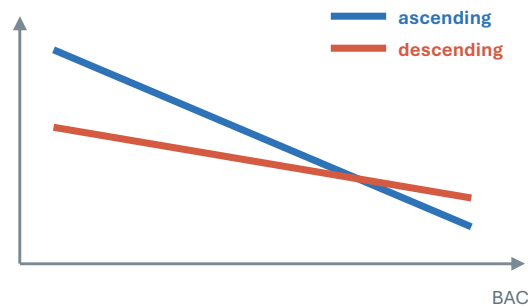
BAC phases and the relation to impairment



BAC phase changes both slopes and feature levels

Slope difference

Linear mixed-effects model



Question: Does the feature-BAC relationship differ by phase?

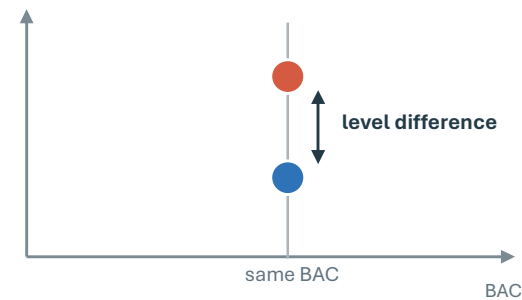
The BAC $\times$ Phase interaction compares the two slopes across BAC.

Linear mixed-effects model results

- BAC slopes were usually steeper during ascending BAC.
- Seven features showed significant phase-dependent BAC associations.
- Most significant interactions reflected **attenuation during descending BAC**, rather than reversal of effect direction.

Level difference

Matched pair analysis



Question: At similar BAC, are feature values different between phases?

Within-participant matching compares values at the same part of the BAC scale.

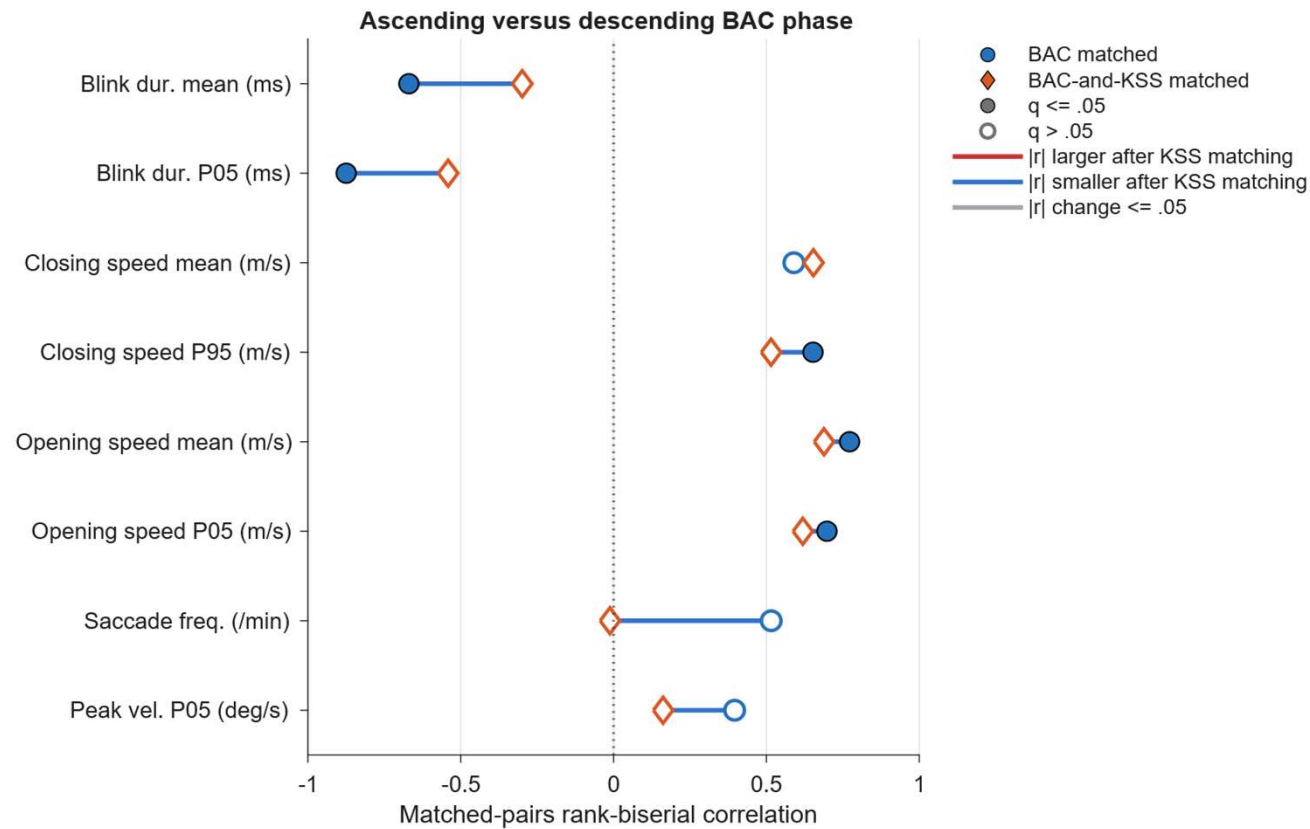
BAC-matched comparisons

- 108 pairs from 26 participants.
- At similar BAC, descending-phase observations showed longer and slower blinks

BAC-and-KSS-matched comparisons

- 48 pairs from 22 participants.
- No feature remained significant after FDR correction.

What changes after matching on sleepiness?



Summary and conclusions

- Breathalyzers measures BAC (presence). Driver monitoring add information about functional state.
- Alcohol and sleepiness overlap, making it difficult for a DMS to separate the two states.
- Some features indicate greater impairment in the descending phase of the BAC curve.
- Sleepiness contributes to this larger impairment in the descending phase.

The background is a solid teal color with a subtle, wavy pattern of thin, concentric lines that create a sense of depth and movement, resembling a topographical map or a liquid surface.

vti

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