

Micro- and Macro-Steering Reversal Analysis for Personalized Drowsiness Detection in Heavy Commercial Vehicles



CHALMERS

Sanjana Hassan Ananda Kumar^{1,2*}, David Öst² & Dr. Mats Jonasson¹

¹ Chalmers University of Technology, Sweden & ² Volvo Group, Sweden



BACKGROUND

- Steering behavior has demonstrated considerable potential as an indicator of driver drowsiness (e.g., Altmüller, 2007, Gastaldi, et al., 2014, Thiffault, et al., 2003).
- Steering reversal rate (SRR) is defined as the number of changes in steering direction, per minute, between 1° to 10° angle, referred to as the gap size (Markkula & Engström, 2006).
- Altmüller (2007) identified the optimal value of gap size 6° with reference to PERCLOS^a and video rating fatigue, in a simulated environment.
- Zhang et al., (2016) identified the same value with reference to KSS^b but by conducting an on-road experiment with 36 taxi drivers using a passenger car.
- No previous available research on gap size most sensitive to drowsiness in heavy commercial vehicles.

METHODOLOGY

- Dataset comprised of 40 test drives conducted by 25 drivers, as per the test methods outlined in Council Regulation (EU), 2021/1341, 2021
- Key metrics from the test were steering wheel angle sampled at 10Hz and KSS rating recorded verbally every ten minutes.
- Linear relationship was assumed between SRR and KSS ratings (Zhang et al., 2016 & Altmüller, 2007) determined by Pearson correlation coefficient, r .
- Random effect from the linear mixed model was high with a group variance of 1053.22 and 297.42 for micro- and macro-reversals respectively.
- Personalized model was therefore developed to account for the high group variance.
- Only micro-reversals were used for model development as they showed a stronger correlation.
- A dynamic baseline for each driver was set as the maxima of their reversals. Drop in reversals percentage from the baseline was computed continuously. Based on the drop percentage, the KSS values were calculated.
- If KSS > 7, the model gave out a warning.
- Drop percentages were scaled according to the baseline, making the thresholds personalized to each driver.

a. PERCLOS = percentage of time pupils of eyes are 80% or more occluded over a specified time interval

b. KSS= Karolinska Sleepiness Scale

RESULTS

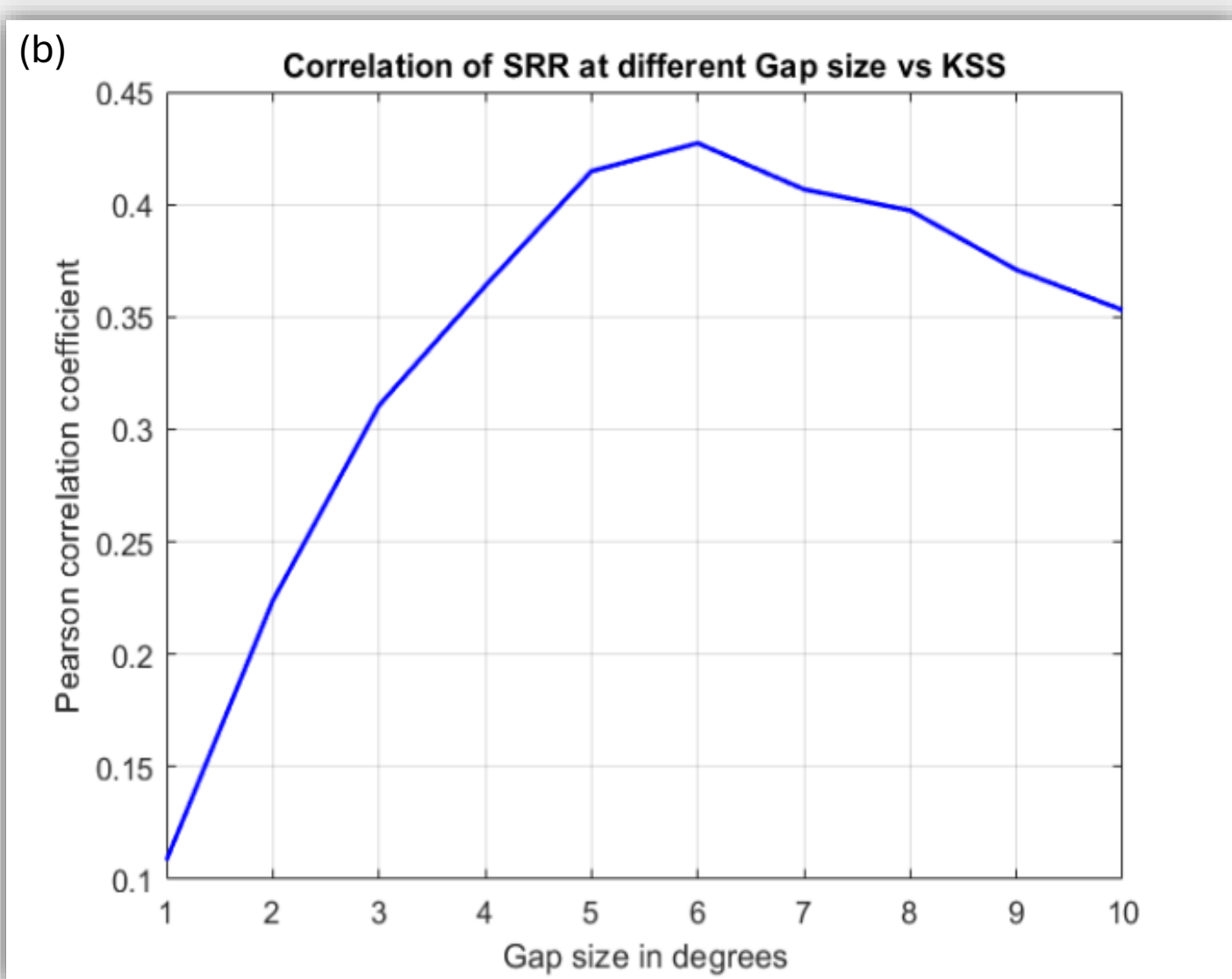
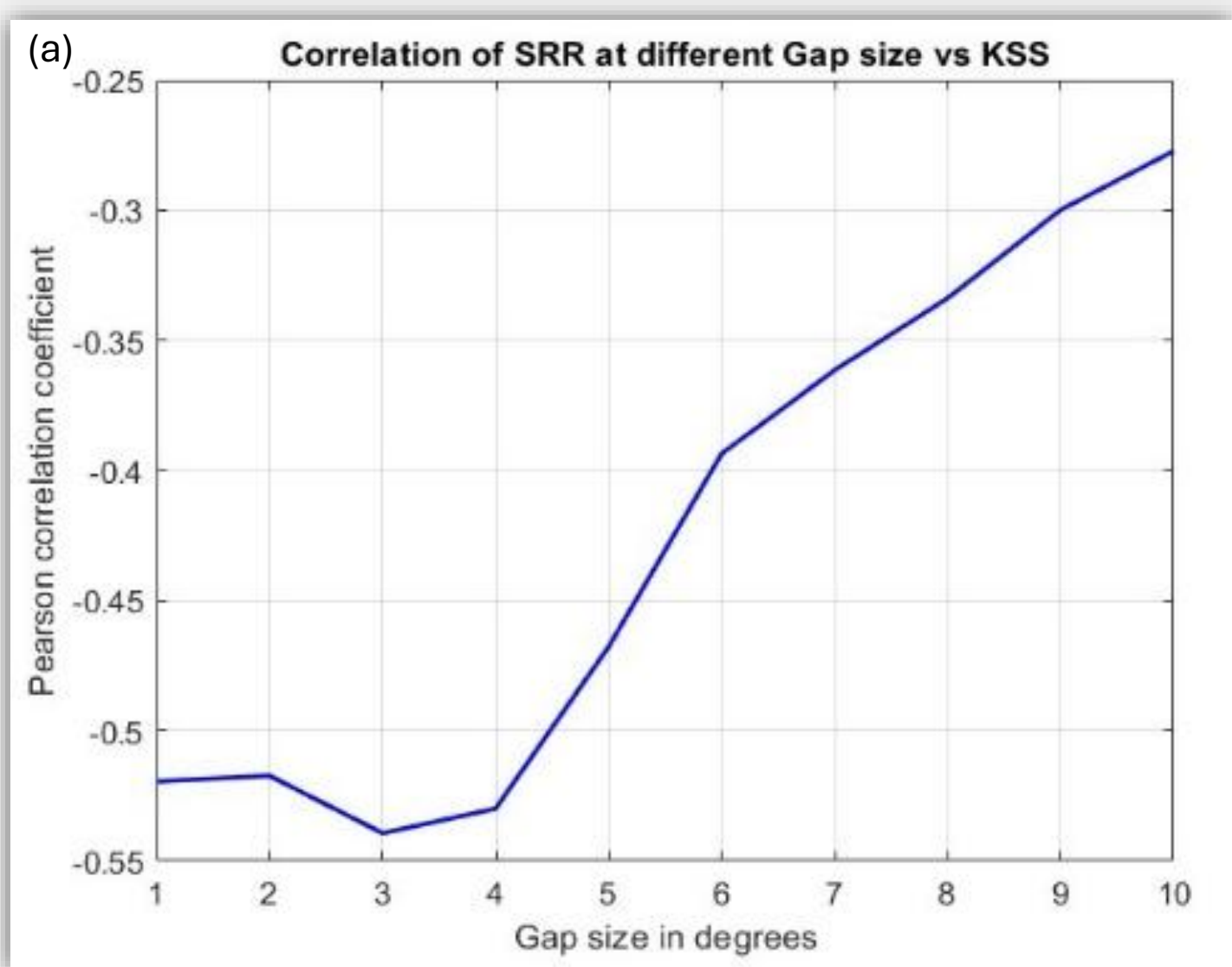


Fig 1. Pearson correlation coefficient between SRR & KSS

(a) negative correlation – micro-reversals (gap size <1° to 10°), (b) positive correlation – macro-reversals (gap size > 1° to 10°)

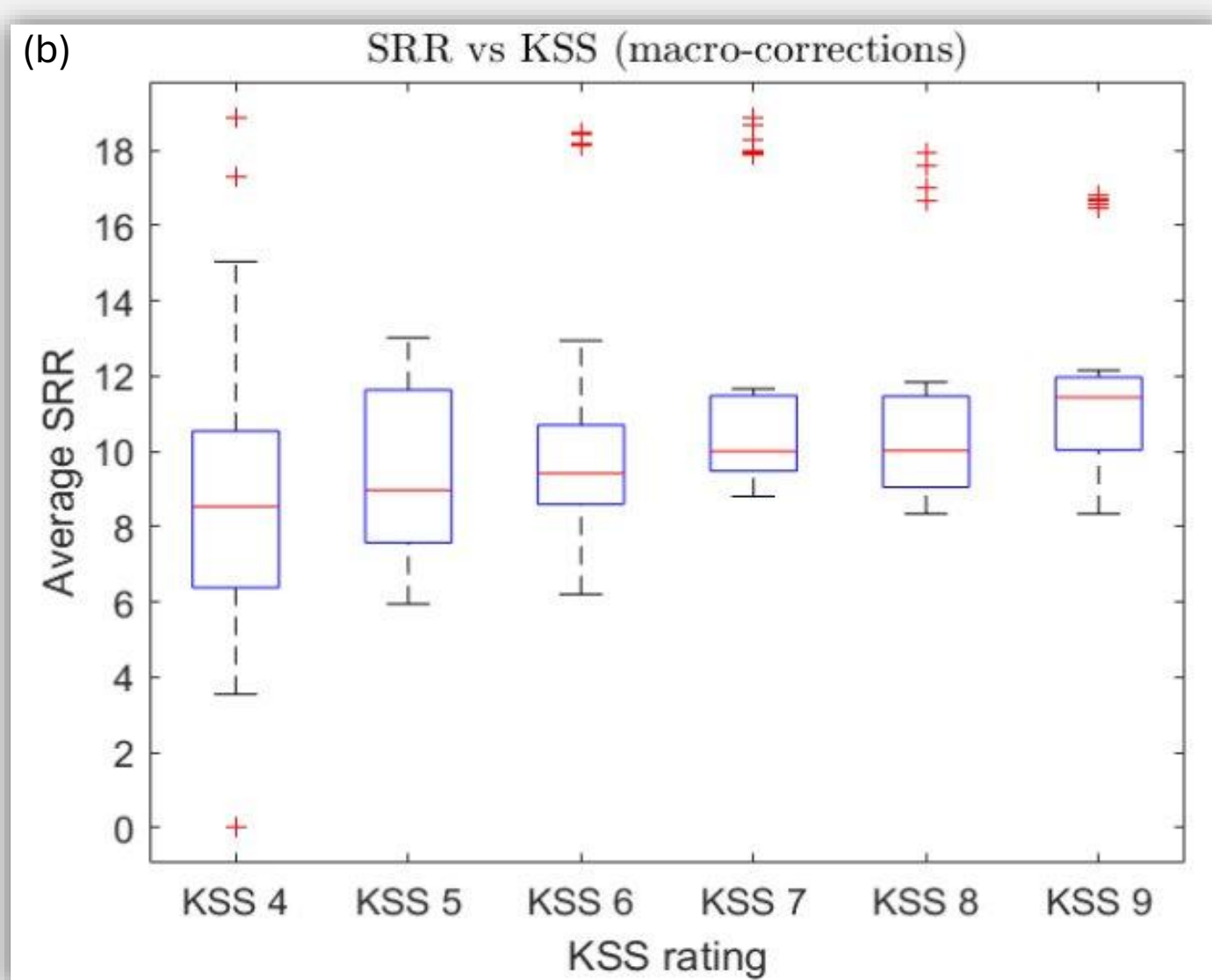
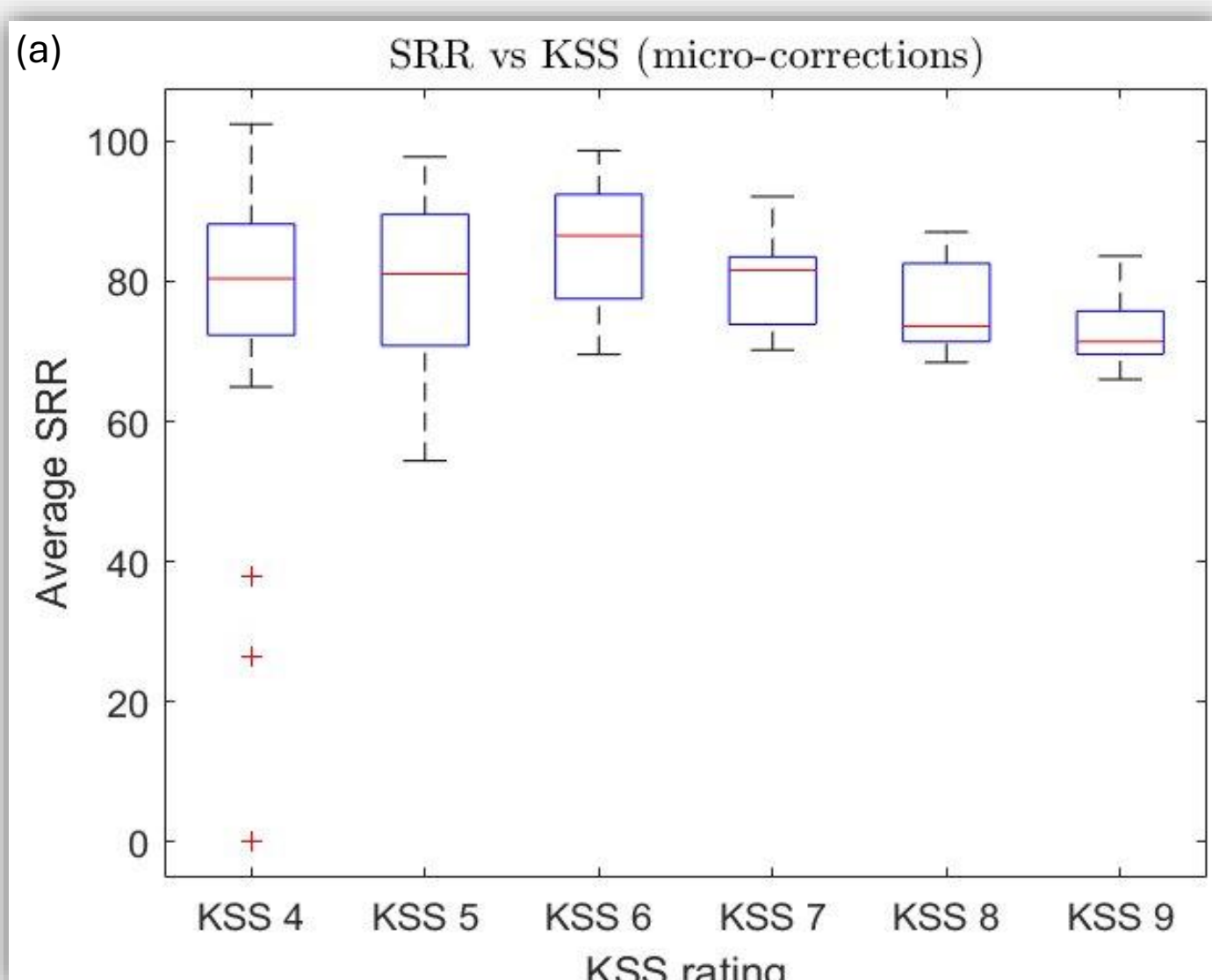


Fig 2. Steering reversal rate vs KSS rating - (a) micro-reversals at 3° (b) macro-reversals at 6°

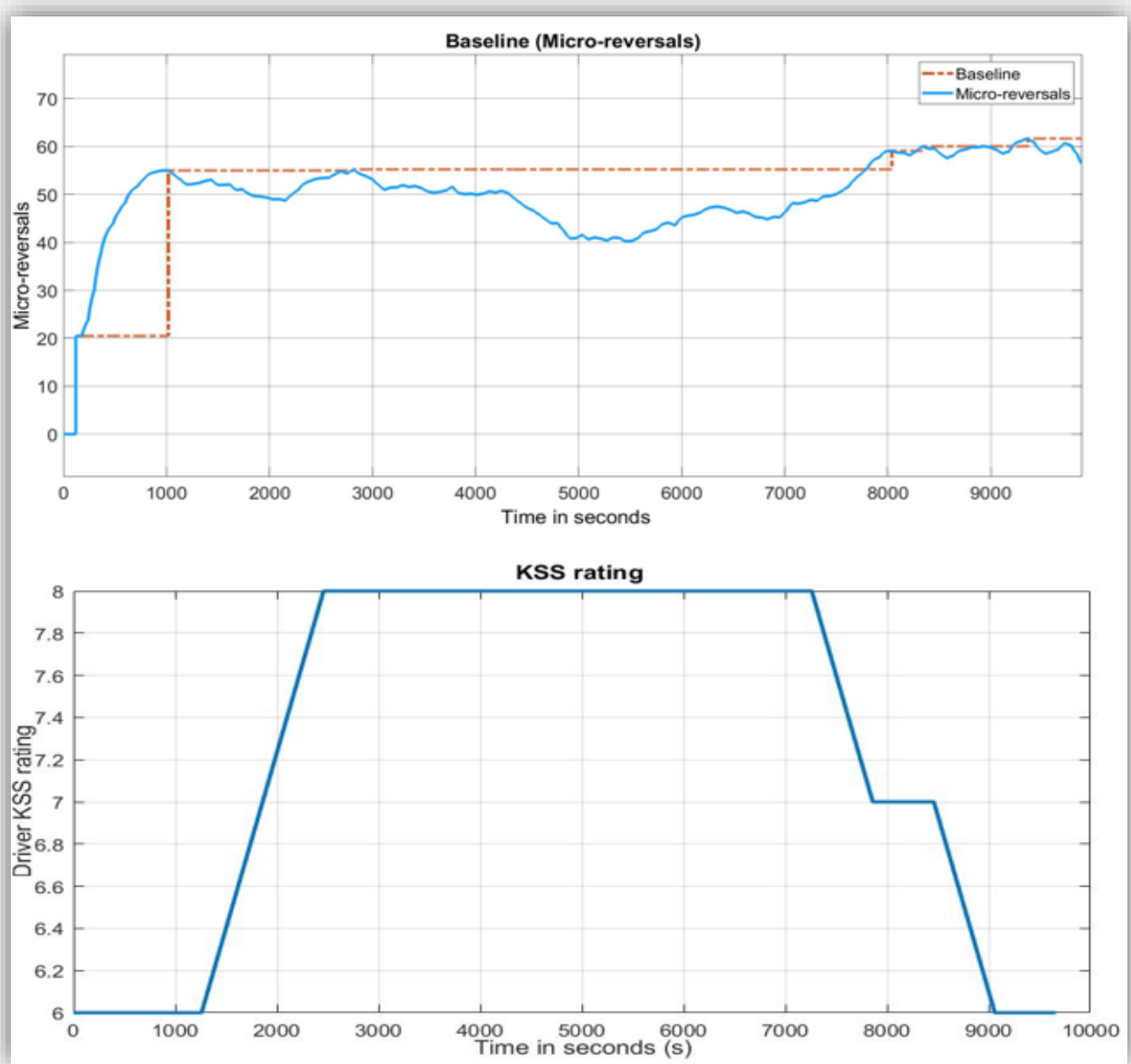


Fig. 3. Variation of baseline of micro-reversals with reference to KSS rating.

- <3° is the most sensitive gap size to KSS for micro-reversals.
- >6° is the most sensitive gap size to KSS for macro-reversals.

in %	Personalized model	Generic model
Average sensitivity per driver	58,64	71,64
Average false warning per driver	4	60
Average sensitivity per drive	58,75	72,08
Average false warning per drive	2,5	37,5

Table 1. Results - Sensitivity and false warning percentages

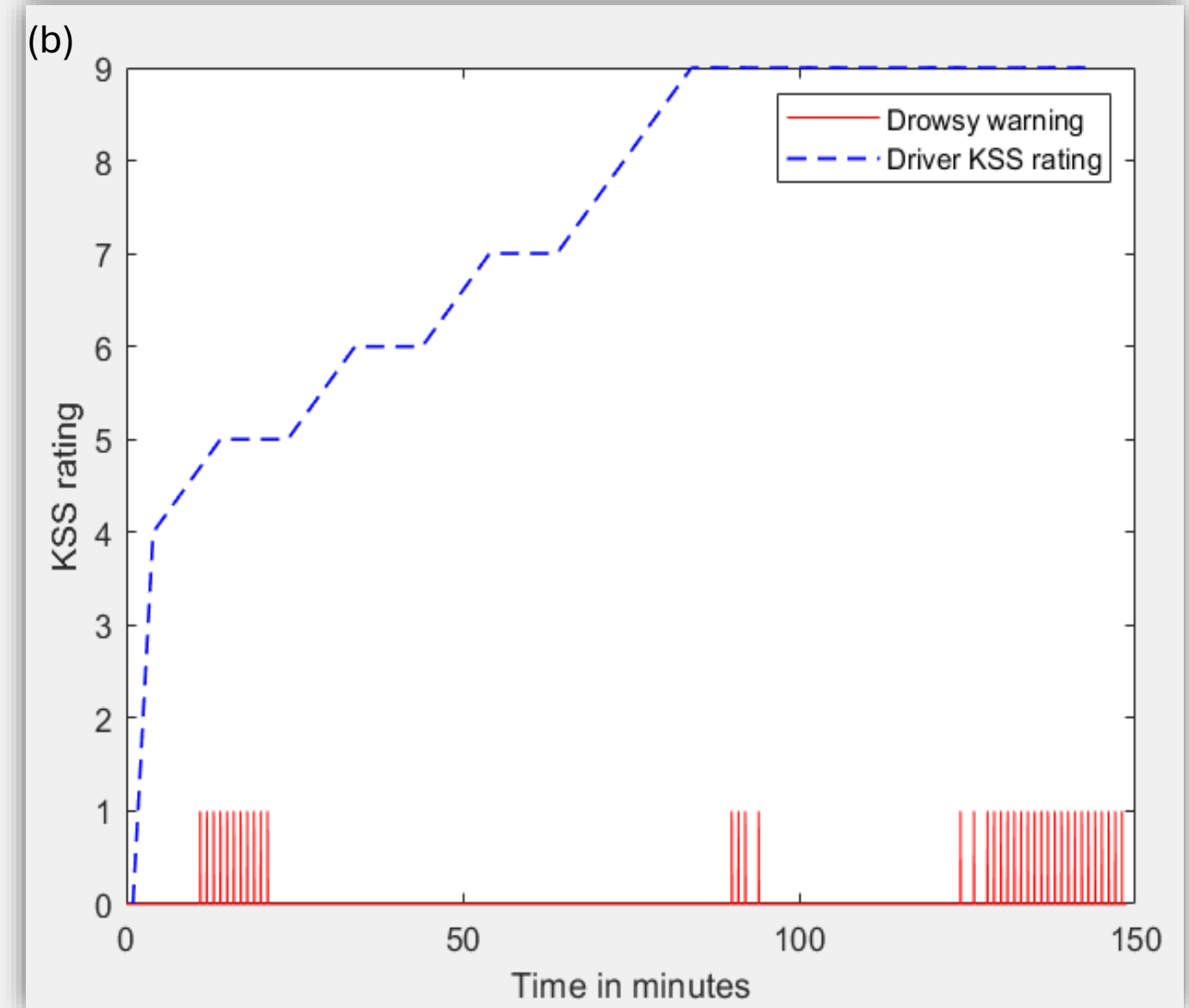
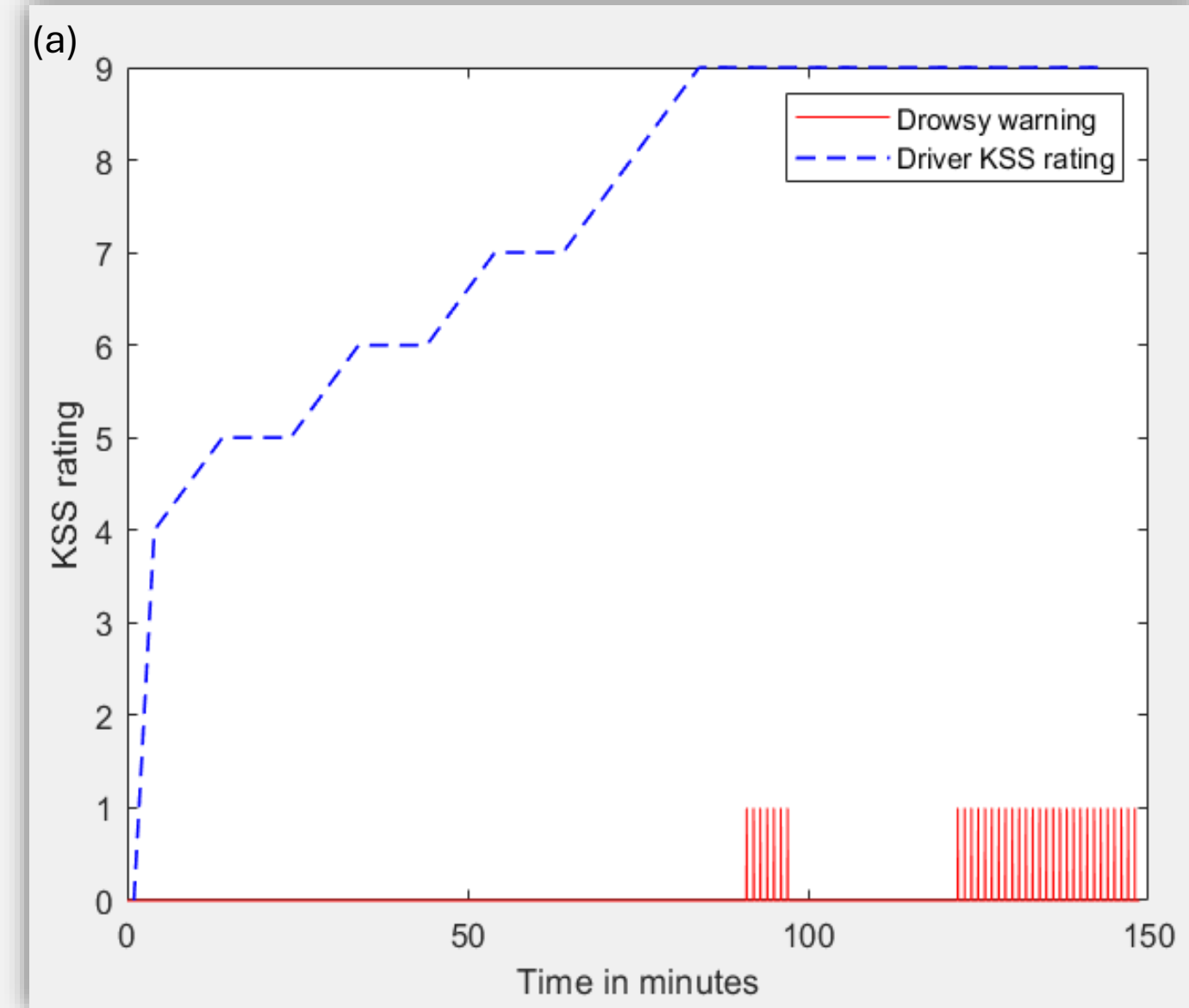


Fig 4. Drowsiness detection and warning for a sample test drive - (a) Personalized model (b) Generic model

DISCUSSIONS & CONCLUSIONS

- Change in median value is more distinct in micro-reversals from KSS 6 to KSS 8 as in Fig.2 (a), which is the critical window to detect drowsiness.
- Significant change in macro-reversals from KSS 8 to KSS 9, that is past the critical window.
- Median of micro-reversals is lower for KSS 4 and 5 compared to that of KSS 6 in Fig 2 (a). Could be either due to lack of data of drivers below KSS 6 or increase in initial vehicle speed till target value of 65kmph (Melman et al., 2018).
- Speed was constant thereafter, bringing only the underlying outcomes of drowsiness to prominence.
- Steering reversal behaviour studied might be applicable only to this demography (Grahn et al., 2024).
- Future work should investigate the effects of changing demographic factors to assess the universal applicability of the parameters identified.
- Gap size used to derive these metrics might also vary between individuals.
- Future work would be to investigate whether gap-size can be likewise personalized.

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