

Development of a Drowsiness Assessment and Prediction System (DAPS) for Commercial Vehicle Drivers : A Basic Study on Arousal Level Assessment Methods

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This study presents a preliminary investigation conducted as part of the development of a Drowsiness Assessment and Prediction System (DAPS) for commercial vehicle drivers. DAPS is a system designed to reduce drowsy-driving accidents by continuously assessing a driver's arousal level not only before departure but also throughout driving operations. The concept is based on “dynamic roll-call inspections,” in which driver alertness is objectively evaluated at multiple points related to driving operations, such as before departure, during breaks, loading and unloading activities, and waiting periods. The study focused on identifying indicators that can estimate driver arousal levels. Previous research has reported that sleepiness reduces attention and working memory capacity, while also affecting speech characteristics such as fundamental frequency, vocal intensity, and articulation ability. Based on these findings, the authors hypothesized that changes in working memory capacity and speech characteristics could be used as indicators for assessing arousal level.

To examine this hypothesis, an overnight human-subject experiment was conducted with four licensed drivers (two males and two females, average age 37.25 years). Participants completed repeated assessments from late afternoon until the following morning. Before each assessment session, subjective sleepiness was measured using the Karolinska Sleepiness Scale (KSS). Participants then performed two tests: a recall span test, designed to evaluate working memory capacity, and a reading-aloud test, designed to evaluate vocal characteristics. Between assessment sessions, participants performed a truck-driving game. A scheduled nap period was included in the experimental protocol.

In the recall span test, recall span performance tended to decrease under conditions of high sleepiness (Table 1). This suggests that reduced arousal may be associated with a decline in working memory capacity. However, one participant did not show a clear relationship between sleepiness and recall span performance.

In the reading-aloud test, the fundamental frequency of speech tended to be lower during sleepy states ($KSS \geq 7$) than during alert states ($KSS \leq 3$) (Table 2). Statistical analysis showed a significant difference when the entire experimental dataset was analyzed collectively. However, the difference did not reach statistical significance in the analysis that accounted for repeated measurements within participants. Nevertheless, the same trend was observed, and the p-value was close to the 5% significance level, suggesting an association between arousal level and fundamental frequency.

Overall, the findings suggest that both working memory capacity and speech characteristics have potential as indicators of driver arousal level. The authors conclude that these measures may contribute to future drowsiness assessment systems and propose further investigation of speech characteristics that change with declining arousal, with the aim of applying them to practical dynamic roll-call inspection systems.

Table 1 Time-Course Changes in Recall Span

Exp. No.	Subject No.							
	1		2		3		4	
	KSS	Average recall span	KSS	Average recall span	KSS	Average recall span	KSS	Average recall span
1	4	8.00	2	7.33	3	7.33	2	9.33
2	3	6.67	2	6.67	3	6.67	3	10.67
3	3	7.33	4	7.33	3	7.33	5	10.67
4	4	6.00	6	7.33	3	8.00	8	8.00
5	8	6.00	7	6.67	3	6.00	4	8.67
6	8	6.67	7	6.67	3	6.67	4	10.00
7	7	8.00	4	7.33	7	6.67	2	14.67

Red: Maximum value of sleepiness scale (KSS) / Blue: Minimum average recall span

Table 2 Changes in Average Fundamental Frequency across Arousal Levels (KSS)

Subject No.	Exp. No.	Average fundamental frequency [Hz]	Exp. No.	Average fundamental frequency [Hz]
		KSS ≤ 3		KSS ≥ 7
1	2	292.85	5	272.19
2	2	98.64	5	97.69
3	1	193.90	7	176.26
4	1	144.60	4	130.68