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Mitsuo Ueno, *Okayama University*
Takeo Ohta, *Okayama University*
Shingo Nakagiri, *Okayama University*
Takanori Ogawa, *Okayama University*
Shunzo Nakao, *Okayama University*
Toyotake Arisawa, *Okayama University*
Yoshio Mino, *Okayama University*
Ryosei Kodera, *Okayama University*
Susumu Kanazawa, *Okayama University*
Kouichi Oyama, *Okayama University*
Katsumi Nakase, *Okayama University*
Shigeki Koda, *Okayama University*
Hideyasu Aoyama, *Okayama University*

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Abstract

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KEYWORDS: one-man bus, two-man bus, work load, subjective fatigue complaints, auditory task

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COMPARATIVE STUDY OF THE WORK LOAD BETWEEN ONE-MAN BUSES AND TWO-MAN BUSES

Mitsuo UENO, Takeo OHTA, Shingo NAKAGIRI, Takanori OGAWA, Shunzo NAKAO, Toyotake ARISAWA, Yoshio MINO, Ryousei KODERA, Susumu KANAZAWA, Kouichi OYAMA, Katsumi NAKASE, Shigeki KODA and Hideyasu AOYAMA

Department of Hygiene, Okayama University Medical School, Okayama 700, Japan

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Abstract. The differences in physiological and safety conditions of one-man buses and two-man buses were examined from the view point of occupational fatigue. This survey consisted of a work load study which included a time study, study of subsidiary behavior, auditory task, memory test, Galvanic Skin Response (GSR) and physiological function tests and a self-administered questionnaire which involved items concerning safety and subjective fatigue complaints. The visual and postural restrictions in the one-man bus were greater than in the two-man bus. The mental capacity of the one-man bus drivers was found to be less. Greater mental fatigue and stress were observed in the one-man bus. More subjective fatigue complaints were observed in the one-man bus. More cases of near accidents were observed in the one-man bus. From these results it was concluded that the one-man bus caused bus drivers a greater mental and physical work load.

Key words : one-man bus, two-man bus, work load, subjective fatigue complaints, auditory task.

Within the last 10 years, the working conditions of bus drivers have changed rapidly, and where there used to be two-man buses with a conductor, these have largely been replaced by one-man buses without a conductor. Furthermore the development of auto-mobilism in Japan has brought bus drivers more mental and physical strain because they must operate one-man buses under busy, noisy and dusty working conditions.

In spite of these changes, there are relatively few studies (1, 2) which have reported on the safety and health conditions of bus drivers. This study compares the physiological and safety conditions on one-man and two-man buses. The driving of a one-man bus was evaluated from the view point of occupational fatigue. In particular, the extent of the work load in one-man bus operations, actual conditions of fatigue and near accidents were examined.

METHODS

In order to evaluate the extent of the work load in the one-man buses, the authors performed a time study, examination of subsidiary behavior, auditory task, memory test and physiological function tests such as CFF and Threshold for Discrimination of Two Points. A self-administered questionnaire concerning safety and health conditions was given to evaluate the actual conditions of fatigue and near accidents. This study was conducted in 1980.

Work load study (Study 1). This study was designed so that conditions were identical in the one-man bus and the two-man bus.

As the subjects of this study, four drivers were selected from 9 who were engaged in both one-man and two-man bus driving schedules over the same route. They were between 35 and 49 years old, and the length of their career was more than 10 years. They had no particular health difficulties.

The route for this study was set between H city and O town, because both one-man and two-man buses were running on this route. The one-way distance of this course was 59.7 km. This study was conducted in both directions. The same drivers drove each kind of bus every other day. This study was carried out for four days. The time table adopted for this study was as follows:

	H city —— O town		O town —— H city	
One-man bus:	9 : 20	11 : 26	13 : 30	15 : 40
Two-man bus:	9 : 00	11 : 03	13 : 07	15 : 15

The buses were two identical model 1974 Mitsubishi FUSO buses. Duty time, portal-to-portal hours, driving time, break times, and the previous day's conditions were identical for both the one-man and two-man bus drivers.

A study of driving operations was conducted by counting the frequency of various operative motions. Subsidiary behavior related to the foot, leg, arm, hand, eye, head and mouth, including yawning, all of which are considered to be compensatory actions for the static work load (3), were checked. Since the kinds of subsidiary behavior vary according to the habits of each individual, the same examiner checked the subsidiary behavior of the same examinee.

The subsidiary auditory task, which has been used for measuring the spare mental capacity of car drivers (4-6), was loaded randomly for drivers while driving. The subsidiary auditory task has 2 kinds of sound signals which are at 500 Hz and 1000 Hz.

A memory test was conducted both before and after driving to evaluate the degree of mental fatigue. In this test, the examinees memorize four numbers and search a line of 20 numbers for these particular numbers. If the line contains all four numbers, the examinees make a circular mark, and if not, they make an x mark. The examiners measure the time required to complete 20 lines of numbers.

The Galvamic Skin Response (GSR) was adopted for one driver (Driver A) to evaluate the extent of mental stress and fatigue. Two skin resistance electrodes were taped to the ring and little finger of the subject's right hand, and the electric resistance was measured for 20 min in the suburbs of H city using the exosomatic method. Moreover, both the dry-bulb and wet-bulb temperature were measured with a Assman Aspiration Psychrometer.

The physiological functions were also measured using the Critical Flicker Fusion (CFF), Threshold for Discrimination of Two Points and Near Point Distance methods.

The self-administered questionnaire study (Study 2). As the subjects of this study, 25 bus drivers who drove both one-man and two-man buses were selected from 184 bus drivers working at the same corporation as the four drivers mentioned above. The data of this study was analyzed

by means of the person-day method. There were 84 instances of one-man bus driving, and 34 of two-man bus driving, the difference being due to the greater number of one-man routes. The questionnaire contained items concerning safety and a subjective fatigue inventory proposed by the Industrial Fatigue Research Committee of the Japan Association of Industrial Health (1970) (7, 8). The subjects filled out the questionnaire both before and after work for a week.

RESULTS AND DISCUSSION

Study 1. The frequency of foot motions for brake and clutch operations and the frequency of hand motions for operations of devices in the cab were evaluated by counting the number of movements in a five-minute period. The average frequency of brake operations was 36.0 times for the one-man bus and 31.3 times for the two-man bus. For clutch operations it was 12.8 times for the one-man bus and 11.7 times for the two-man bus. As for the operations by hand, the frequency was 14.8 times for the one-man bus and 4.8 times for the two-man bus. Of these driving motions, the difference in frequency between the one-man bus and the two-man bus was greatest in the case of hand operations. However, the traffic condtions such as density and accidents were almost identical between the one-man bus and the two-man bus, as might be expected from the matching of the driving time, schedules and routes. These results reveal that the drivers in the one-man bus must operate many devices and switches in the cab because of the absence of a conductor.

The frequency of subsidiary behavior while driving is shown in Fig. 1. The frequency of subsidiary behavior in the one-man bus was observed to be statistically higher than in the two-man bus by the paired t test ($p < 0.05$), and on the return journey this tendency became particularly clear in all cases. Among four subjects

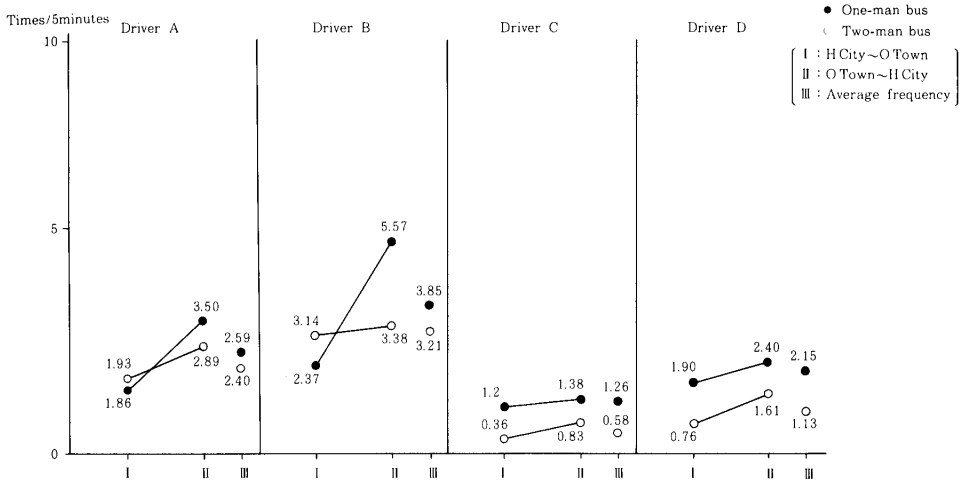

Fig. 1. Frequency of subsidiary behavior during driving

two patterns were found in the frequency of subsidiary behavior, one of which was the pattern as shown by drivers A and B, and the other was that shown by drivers C and D. In all cases the frequency of subsidiary behavior increased on the return trip ($p < 0.05$), but the differences between the two patterns would seem to be related not only to the increase in general fatigue on the way back, but also to the biorhythm of the subjects. It was considered that the visual and postural restrictions in the one-man bus were greater than in the two-man bus because of the many operative motions and confirmative safety movements necessary in the former.

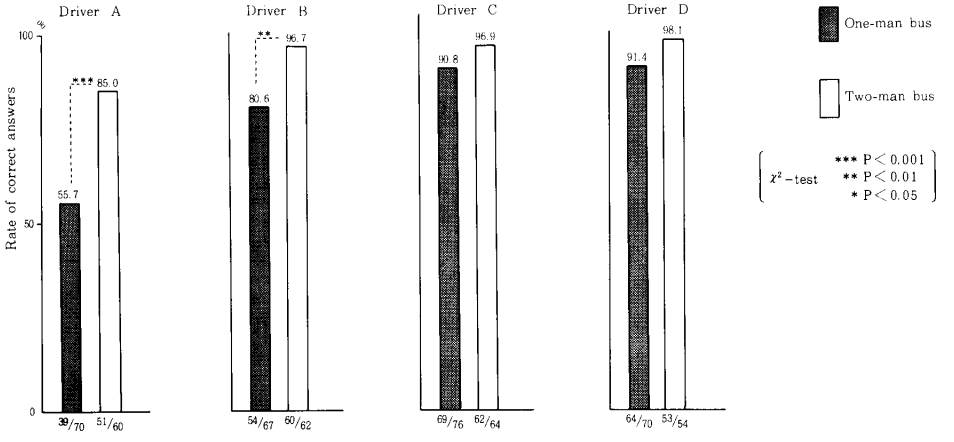

Fig. 2. Rate of correct answers in the subsidiary auditory task while driving

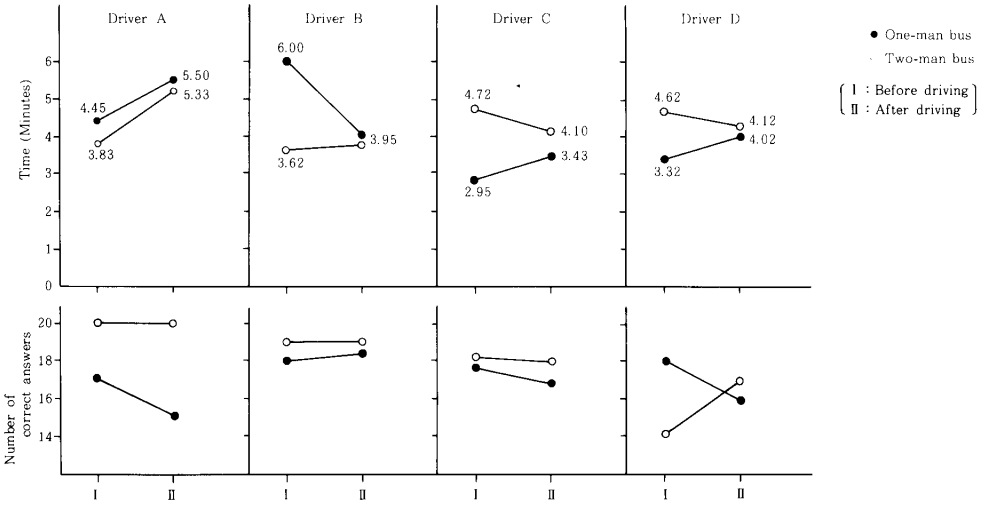

Fig. 3. Number of correct answers and time required before and after driving in the memory

The rate of correct answers in the subsidiary auditory task in the one-man bus was lower than in the two-man bus in all cases as shown in Fig. 2. From this result it is suggested that the mental capacity in the one-man bus is less than in the case of the two-man bus.

In the memory test (Fig. 3), all drivers except driver B gave fewer correct answers and required more time in the one-man bus. As for the two-man bus, there was no change in the number of correct answers for three of the drivers, and a reduction in time was observed for two of the drivers. Thus, greater mental fatigue was observed in the one-man bus.

Fig. 4 shows the changes in GSR (Galvanic Skin Response) while driving. At the initial point (0 min), the value of the one-man bus was lower than that of the two-man bus. The dry-bulb and wet-bulb temperatures were respectively 19 ℃ and 16 ℃ in both the one-man and two-man buses. Accordingly, it seems that the drivers of the one-man buses received greater mental stress up to the time the GSR values were measured. In the one-man bus, the value of electric resistance decreased steadily with the advance of time. On the other hand, the electric resistance in the two-man bus dipped sharply in the middle of the time course, but increased again in the latter part of the course. It is reported that the GSR is closely related to changes in emotion and traffic conditions (9, 10). Therefore, the marked decrease of the GSR value in the one-man bus suggests that the extent of mental stress is greater in the one-man bus than in the two-man bus.

The changes in CFF, Threshold for Discrimination of Two Points and Near Point Distance were observed before and after driving as shown in Fig. 5. In the case of driver B, The Near Point Distance was found to be above 10 cm in the one-man bus, but the other drivers didn't show such clear changes. The Threshold for Discrimination of Two Points showed a tendency to increase in the

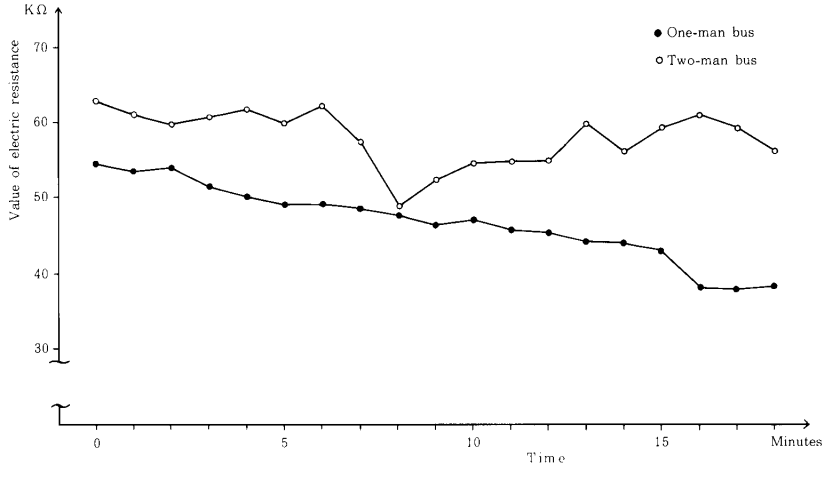

Fig. 4. Changes in GSR while driving

one-man bus, however, after a break, the distance shortened in three of the drivers. As for CFF, no particular findings were observed among the four drivers.

Study 2. Fig. 6 shows the distribution of the increase in the number of subjective fatigue complaints after work. More statistically significant differences were

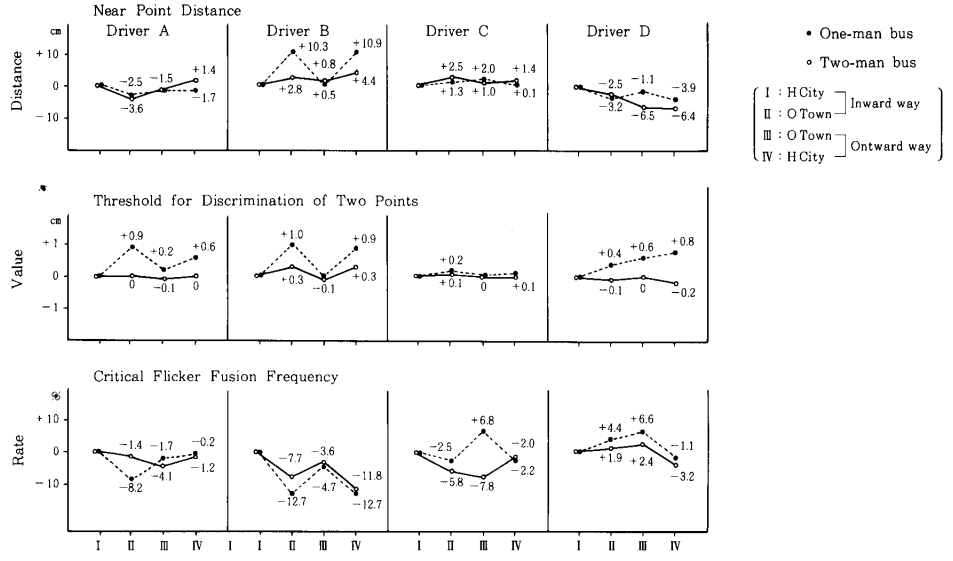

Fig. 5. Changes in Critical Flicker Fusion Frequency, Threshold for Discrimination of Two Points and Near Point Distance before and after driving (0 means the standard value of initial test point)

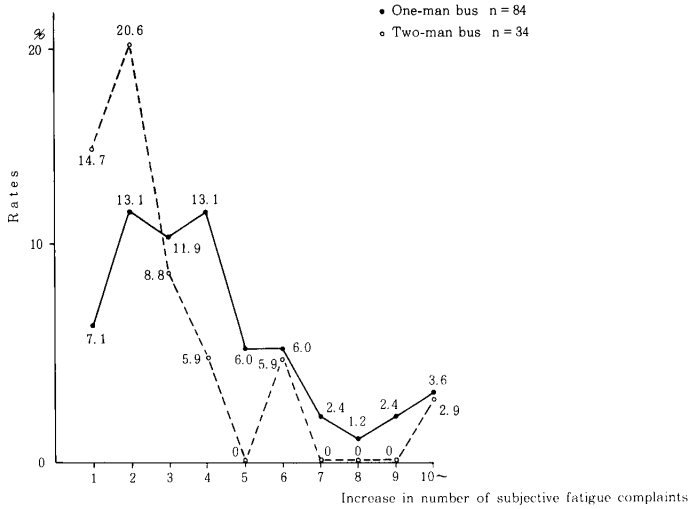

Fig. 6. Distribution of the increase in number of subjective fatigue complaints after work

TABLE 1. RATES OF SUBJECTIVE FEELING OF FATIGUE BEFORE AND AFTER WORK

Category	Item	One-man bus		Two-man bus	
		Before work	After work	Before work	After work
I Dull-drowsy component	Feeling heavy in the head	26.2%	31.0%	20.6%	26.5%
	Feeling tired in the whole body	16.7	32.1*	35.3	35.3
	Feeling tired in the legs	14.3	34.5**	35.3	32.4
	Yawning	39.3	45.2	26.5	35.3
	Feeling hot headed or muddled	34.5	33.3	20.6	29.4
	Becoming drowsy	53.6	48.8	41.2	41.2
	Feeling eye strain	31.0	71.4***	41.2	67.6*
	Becoming rigid or clumsy in movements	13.1	8.3	5.9	5.9
	Feeling unsteady while standing	7.1	4.8	2.9	2.9
	Wanting to lie down	21.4	48.8*	23.5	29.4
II Component of difficulty in concentration	Having difficulty in thinking	8.3	14.3	20.6	11.8
	Becoming weary of talking	11.9	13.1	8.8	0
	Becoming nervous	7.1	16.7	14.7	14.7
	Inability to concentrate	6.0	17.9*	26.5	14.7
	Inability to show interest in things	11.9	17.9	5.9	8.8
	Becoming forgetful	15.5	23.8	14.7	17.6
	Lacking self-confidence	6.0	7.1	11.8	14.7
	Anxiety about things	21.4	21.4	11.8	17.6
	Inability to straighten up posture	3.6	9.5	11.8	14.7
	Lacking patience	7.1	23.8**	23.5	17.6
III Component of physical disorder	Having headache	16.7	19.0	14.7	17.6
	Feeling stiff in the shoulders	52.4	76.2*	55.9	64.7
	Feeling pain in the lower back	45.2	65.5**	47.1	50.0
	Feeling constrained in breathing	2.4	4.8	2.9	4.2
	Feeling thirsty	23.8	25.0	29.4	26.5
	Having a husky voice	9.5	8.3	0	5.9
	Experiencing dizziness	3.6	8.3	11.8	11.8
	Having eyelid spasm	16.7	34.5*	8.8	17.6
	Have tremor in the limbs	2.4	4.8	2.9	2.9
	Feeling ill	7.1	8.3	2.9	5.9
Number of cases		84	84	34	34

(χ^2 − test *** $p < 0.001$; ** $p < 0.01$; * $p < 0.05$; Fisher's direct probability method : $n \leqq 5$)

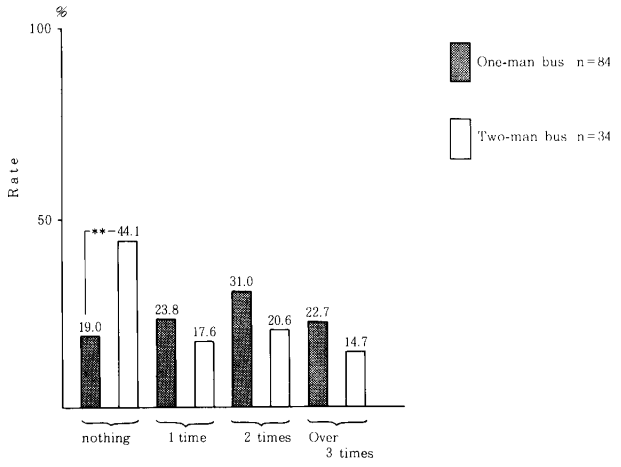

Fig. 7. Distribution of the number of near accidents per working day

TABLE 2. CAUSES OF NEAR ACCIDENTS WHILE DRIVING

	One-man bus	Two-man bus
Bad weather	11.9%	5.9%
Curves	17.9	17.6
Signals	8.3	8.8
Car accidents	4.8	0
Too many passengers	10.7	2.9
High speed	6.0	0
Hurrying	34.5**	11.8
Urination and evacuation	6.0	0
Sudden illness	0	0
Drowsiness	6.0	2.9
Mishandling	2.4	0
Bad vision	8.3	2.9
Near accidents within cars	7.1	5.9
Distraction when taking fares	9.5	0
Opening and shutting of doors	14.3**	0
Lights of on-coming cars	2.4	0
Dangerous driving of on-coming cars	7.1	8.8
Danger of rear-end collisions	14.3	2.9
Road work	9.5	17.6
Skidding in rain or snow	2.4	2.9
Breakdown of cars	35.7	26.5
Loss of control through wind or pot holes	4.4	0
Others	1.2	2.9
Number of cases	84	34

(χ^2-test *** $p < 0.001$
** $p < 0.01$
* $p < 0.05$
Fisher's direct probability method : $n \leqq 5$)

observed in the cases involving four or more complaints after work, in the one-man bus than in the two-man bus ($p < 0.05$). More of the thirty items of a subjective feeling of fatigue increased in the one-man bus than in the two-man bus (Table 1). In the one-man bus more cases of near accidents were observed than in the two-man bus (Fig. 7). Concerning causes of near accidents, shown in Table 2, items such as "Hurrying" and "Opening and shutting of doors" had statistically higher rates in the one-man bus than in the two-man bus. Among 23 items, the rates of 16 items in the one-man bus were higher than in the two-man bus.

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