Guided seat memory usage - bus drivers acceptance and experiences

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Abstract In public transport buses, the driver's workplace is equipped with an ergonomic seat that allows the driver to sit in a comfortable position that is beneficial to his health thanks to a wide range of adjustment options. In everyday operations, these adjustment options are often not used properly due to a lack of time and/or instruction. With the help of seat memory systems for simplified adjustment of various seat parameters, the optimum individual seating position can be stored on a memory card and automatically recalled. The question therefore arose as to whether a memory seat would prove its worth in everyday operations and actually contribute to an improved ergonomic sitting posture at the bus driver's workplace. In this project, the body measurements relevant for seat adjustment of 24 bus drivers were determined. Subsequently, the personal ergonomically optimised seat settings of these drivers was defined using joint angles proposed by common guidelines and controlled by using the CUELA measurement system. The resulting backrest tilt, seat tilt, seat height and horizontal seating position were set on a seat with memory function and stored on a memory card, which was handed out to the drivers. The settings and changes to the seat settings during driving (400 regular shifts on urban and rural routes) were recorded for subsequent analysis. Daily and final questionnaires were used to determine the experiences with the memory seat and the personal seating position and posture. The specified personal seat settings were initially rated as relatively negative after the trial period. Presumed reasons were, among others, the change of a seat adjustment that had been used for years, getting used to a new driver's seat model with different cushions, vibration damping and surface textures as well as the fact that the seat height could not be adjusted optimally due to an insufficient adjustment range downwards. The electronic storage of the seat settings was very well received; above all, the experienced timesavings at the beginning of a shift and during driver change was positively emphasised. In comparison with the standard seats used, the memory seats scored just positive. An evaluation of the memory seat system directly after the tests resulted in positive evaluations. The repeated survey a few weeks after the end of the test showed a similar picture. Drivers clearly preferred the memory seat system when they were confronted with the fictitious choice between a standard seat and the memory seat. Results also show the importance of being instructed to an ergonomic seating posture by a physician or trainer, due to the required knowledge of measuring joint angles. Successfully, 50% of the subjects reported a change of their former seat adjustments and sitting habits in favour of a more ergonomic sitting posture.

Keywords: Seat memory, bus driver, joint angles, sitting posture.

1 Introduction

Bus drivers report more about musculoskeletal complaints than other employees [1]. Musculoskeletal disorders also account for up to 40% of premature incapacity to drive. Among other things, this was primarily attributed to the posture adopted during driving. The experience of transport companies has also shown that the driver's seat is not optimally adjusted manually by the driver due to the variety of models and the manageability of the adjustment mechanisms. Furthermore drivers complain about a lack of time for seat adjustments during driver changes during operation. The resulting sitting postures can lead to sometimes considerable musculoskeletal stress.

Seat memory systems have been developed for the simple and quick adjustment of an individually optimised seating position and posture. In the project "Ergonomic testing of a seat memory at the bus driver's workplace [2] it has already been shown that such a seat memory system leads to a better ergonomic posture compared to the previously usual manual seat adjustment by the driver and that a few memorised parameters are sufficient to achieve a considerably improved posture.

At the time of the previous study [2], memory functions were still relatively uncommon in vehicle seats. In the meantime, this function has become a standard feature of some car models. However, especially for public transport, with frequent and quick driver changes, an automatic seat adjustment seems to be particularly appropriate. The follow-up project [3] was therefore intended to test whether a memory function facilitates the setting of an ergonomic seating position for the driver and whether a seat memory function is functional when using today's technology widely used in transportation companies. Furthermore, it was examined which acceptance a given sitting posture experiences and how this affects the driver's sense of comfort.

2 Materials and Methods

The driver's seat used (Isringhausen, ISRI 6860/880E NTS2, Fig. 1, left) has numerous adjustment possibilities. Only four of them were used in the project (seat tilt, seat length adjustment, backrest tilt, seat height), as these four memorised adjustment options can be considered sufficient [2] for a seat adjustment according to VDV specifications. All other adjustment options were regarded as additional comfort settings and were not considered in this study. The drivers were informed that these adjustment options were deactivated as far as possible. Three different seat settings can be stored and recalled using the external control panel (Fig. 2). The driver's seats were installed in MAN buses (type NL 263, built 2004, Fig. 1). The buses of two depots operated on different routes with different stopping frequencies in the urban area of Berlin.

The subjects consisted of 24 male bus drivers of the participating transportation company. A selection of ten body measurements of the test persons (anthropometric values according to [4] definition DIN 33402 "Human body measurements") was recorded by occupational physicians trained in the use of anthropometric measuring tools. The individual adjustment of the driver's seat was carried out taking into account the requirements of DIN 33402-1 [5]. These are based on the research results of the ika [6] and are intended to achieve an ergonomically favourable seating position with corresponding physiologically less stressful body angles. During the seat adjustment processes the control of the subjects´ postures and joint angles was carried out by using the posture measuring system CUELA [7] (Fig. 1). This measuring system, which is worn on clothing, allowes the measurement of joint angles to the nearest degree without impairing the subject´s work. Various sensors (potentiometers, gyroscopes, inclinometers, rotary sensors) record the angle of the joints of the extremities and the posture of the upper body at a frequency of 50 Hz.

The seat adjustment data were stored on the personal memory card as seat setting 1. If required, an alternative seat position could be stored (seat setting 2). These seat setting data might have been slightly different but still close the range of the recommended values and could be changed by the driver. Seat setting 3 were basic settings for comfortable entry and exit (backrest vertical, seat in maximum rear position). The subjects were informed that the preset seat setting should be regarded as recommendations and that they can be adjusted manually if necessary. In the system, the seat setting selected by the drivers and the manual seat setting changes were stored in log files and evaluated at the end of the trial period.

The participating drivers were asked to fill out questionnaires before and after a shift on a bus with a built-in memory seat. The questionnaires covered present physical complaints before and after the shift, the duration, adjustments made to the seat by the driver and any difficulties that may have arisen with the memory seat system. At the end of the 6-week test period, a final questionnaire was conducted in which the general experience gained with the memory seat system was asked for and an evaluation of the memory seat system was requested. Using a follow-up questionnaire a few weeks after the end of the experiment, the subjects were asked to compare the memory seat with the standard seats again and to make a further personal assessment of the memory seat system.

Fig. 1. Driver's seat (© ISRI), BVG bus (© Berliner Verkehrsbetriebe), CUELA-System (© DGUV)

3 Results

Four buses equipped with the memory seat system were in service at two depots. Twelve drivers from each depot were instructed in the operation of the seat and familiarised with the various functions. The average age of the drivers was 48 years (SD 7.9), body height 176 cm (SD 7.6 cm), weight 89 kg (SD 16.8 kg), driving experience 22.7 years (SD 9.2 years), BMI 30 (SD 4.7). Ten additionally measured body dimensions (forward reach, body seat height, shoulder height when seated, seat surface height, buttocks/knees length, buttocks/knees length, buttocks/legs length, abdominal depth) largely corresponded to values specified in DIN 33402 [8].

With the available adjustment ranges of the seat in the given installation situation, it was not always possible to achieve a sitting posture with all body angles recommended according to DIN 33402-1 [5], which was largely due to insufficient downward adjustability of the seat height. This particularly affected the thigh angle and resulted in deviations of wider joint angles due to the joint angle chain, e.g. knee angle. Some drivers did not want or could not accept the suggested seat adjustment, which mostly concerned the upper body posture or the upper body angle (and thus also the hip angle), since a more upright sitting posture was generally preferred. The low sitting position resulting from the body angle preferences was also repeatedly criticized by the drivers. The reasons often cited were, on the one hand, a reduced visibility of the area directly in front of the vehicle and a low seating position when in contact with the passengers (e.g. at ticket sales/checks, giving information). According to some test participants, a sitting position at least at eye level with the passengers was also considered as psychologically important.

Table 1. Recommended joint angles [°] and realized percentages of 24 subjects after guided seat adjustment.

N=24	*Knee angle [°]*	*Thigh angle [°]*	*Hip angle [°]*	*Upper body angle [°]*
Recommendation	110-120	0-15	100-115	-20 - -10
< recommended	21%	66%	33%	0%
recommended +/- 2°	71%	33%	58%	96%
> recommended	8%	0%	8%	4%

For the alternative seat setting 2, the optimum areas were left somewhat more frequently. In general, a larger knee angle than recommended was taken, which is probably due to the generally more rearwardly adjusted sitting posture. The thigh angle, on the other hand, was more often within the recommended range (50%). The distribution of the hip angles was almost identical with the distribution in seat setting 1. The most frequent deviation from the optimum range was recorded with the upper body angle. About half of the test persons preferred a less backward inclined, almost vertical posture, of the upper body. This may also be due to compensation of the generally low sitting position in order to achieve a higher head position. In general, the driver's seat for seat setting 2 was moved to a position slightly further backwards and the knee angle was increased while the seat height remained approximately the same. The seat height was generally retained. A change to a lower seat height would not have been technically possible in most cases anyway, since in more than 50% of the cases the lowest setting had already been reached. On average, the backrest inclination was made about 2 degrees steeper. The seat surface inclination, which according to [5] should rise slightly forwards, was set significantly lower in the front (seat setting1 = -2.6°, seat setting 2 = +3.8 degrees), so that the seat surface drops slightly forwards in seat setting 2. Some drivers argued that the force to be applied to the pedals could be achieved more by weight than by muscle power, or that a seat rising to the front would be uncomfortable. On average, the opening angle of the seat has been reduced by about the amount of the change in the backrest tilt. On a total of 24% of all days of use, no subsequent adjustment of the seat position/posture was carried out (Table 2).

Table 2. Questionnaire results regarding physical complaints after the shift [% of n=404 questionnaires]

N=404	*no change*	*better*	*worse*	*N/A*
upper back	73	2	22	4
middle back	84	0	11	4
lower back	83	3	10	4
buttock	88	0	7	4
thigh	80	0	15	4
knee/foot	80	2	14	4

The final questionnaire at the end of the test period was used to determine whether and which of the basic settings of the memory seat (seat setting 1/ 2) were perceived as disturbing or uncomfortable and a comparison should be made between the memory seat and the standard driver seats. Response was 21 out of 24 participants (Table 3).

Table 3. Results of final questionnaire [n=21]

		n
Did sth bother you (regarding seat setting 1/2)?	Yes	13
	No	7
	N/A	1
What did you dislike?	seat height	7
	seat length adjustment	7
	seat tilt	4
	backrest tilt	9
Where did you have complaints?	neck, shoulder, upper back	5
	middle back	3
	mower back	6
	buttock	2
	thigh	3
	knee, lower leg, foot	4
How do you rate the memory seat compared to standard driver seats?	much worse	0
	worse	2
	rather worse	6
	rather better	9
	better	3
	much better	1

A few weeks after the end of the test, the test persons were asked to complete a further questionnaire in order to carry out a reassessment of the memory fit afterwards (Table 4).

Table 4. Results of follow-up questionnaire [n=20]

		n
How do you rate the seat compared to standard driver seats?	much worse	0
	worse	1
	rather worse	8
	rather better	4
	better	6
	much better	1
If you had a choice now, would you choose the tested memory seat?	Yes	13
	No	5
	I do not care	2
Do you now adjust the driver's seat differently than before?	Yes	10
	No	10
	I do not know	0

All adjustment processes were stored in log files. Table 5 shows for each test person the number of shifts driven with a memory seat, the total number different logged seat setting changes, the mean number of different seat positions per shift and the proportion of seat settings stored that corresponded exactly to seat settings 1 or 2. Note, that the percentages unfortunately do not allow conclusions to be drawn about the actual time spent in the respective seat setting.

Table 5. Number of shifts using a bus with seat memory system, number of logged settings during test period, mean number of logged setting changes per shift, percentage of seat settings 1 and 2.

Subj.	*No. shifts*	*No. logged settings*	*Mean set./shift*	*Set.1 [%]*	*Set.2 [%]*	*Subj.*	*No. shifts*	*No. logged settings*	*Mean set./shift*	*Set.1 [%]*	*Set.2 [%]*
1	14	327	23	16	1	13	26	295	11	8	3
2	-	-		-	-	14	12	102	9	12	3
3	5	79	16	9	8	15	17	170	10	34	4
4	28	876	31	41	5	16	15	83	6	14	0
5	6	118	20	14	0	17	15	220	15	20	7
6	10	234	23	4	4	18	26	1021	39	7	0
7	30	1400	47	10	0	19	9	217	24	27	1
8	18	311	17	7	5	20	22	315	14	6	1
9	4	-		-	-	21	-	-		-	-
10	25	183	7	29	7	22	25	174	7	14	0
11	27	501	19	26	9	23	25	186	7	34	34
12	22	710	32	6	2	24	15	85	6	14	1

The log files were used to calculate the distribution of stored seat positions and settings. Besides seat tilt, backrest tilt and seat position, the „opening angle" of the seat was calculated, as an indicator for the hip angle, by using the values of backrest tilt and seat tilt. The sum of the deviations less than or equal to 4° or 4 mm respectively, which can still be interpreted as within the scope of recommended values, is 73% (seat tilt), 89% (seat height), 71% (seat position) and 68% (seat opening angle) (see Table 5). Although the original setting was changed quite frequently, those changes were only minor for the most part.

Table 6 shows the values for all test persons of all logged seat variables (seat tilt, seat height, seat position and the calculated values for the seat opening angle).

Table 6. Values [%] of all stored seat settings (N=7607) during the test period (396 shifts), deviations from seat setting 1 in classes of ≤1°, >1°≤4° and >4°.

	≤1°	*>1°≤4°*	*>4°*
seat tilt	41	32	27
seat height	72	17	11
seat position	52	19	29
seat opening angle	40	28	32

The seat setting 1, developed together with the drivers, was therefore accepted to a large extent and changed only slightly.

4 Discussion

The 24 bus drivers who took part in the field tests almost completely covered the percentile ranges of the 18 to 65 year old male population in Germany specified in DIN standard 33402 with their body dimensions. The distributions regarding the abdominal depth and the body weight show a clear right shift towards higher values. In view of the low-movement activity profile of a bus driver this is not a surprising result and a representative sample can be assumed for the anthropometry of the subjects.

The desired driver seat adjustment was based on the VDV234 guidelines, which recommend an optimal posture for seated driving from an occupational medicine point of view in low-floor buses. However, it was not always possible to achieve all recommended body angles without exception. This was based on the one hand on the seats spatial position in the buses and on the other hand on the subjective sensations of the drivers, who were partly unable and/or unwilling to accept the recommended body posture and joint angles. The former largely concerned the seat height, which would have had to be adjusted significantly lower several times in order to achieve the required thigh and knee angle. An extended adjustment range towards a lower seat position would have been necessary. For five subjects only, the minimum adjustable seat height was changed upwards at all. This also explains the low correspondence (33%) of the required thigh angle (Table 1) with the actual thigh angle in seat position 1. 66% of the subjects had a larger than required thigh angle in setting 1. The apparently high acceptance of the seat height must be relativized under these conditions. The required lower seating position also stands in contrast to the opinion repeatedly expressed by the drivers that the lower seating position restricts the view to areas directly in front of the vehicle and also has an unfavourable effect on contact with the passengers. The knee angle of the stored seat setting 1 corresponded in 71% of the cases to the VDV recommendation of 110°-120°. 21% of the subjects requested a slightly smaller knee angle. The required upper body angle of -10° to -20° was set and accepted by almost all subjects (96%) in sitting position 1. A larger percentage deviation had to be realized with regard to the hip angle (agreement in 58% of the cases of seat setting 1) (VDV recommendation 100°-115°). 33% of the subjects demanded a more upright posture with a smaller hip angle. This is reflected by the number deviations of more than four degrees for seat opening angle (32%, Table 6) as well.

The log files of the memory seat systems, in which each seat adjustment was recorded during shifts, indicated that the seat adjustment system was used extensively, which also corresponds to the information provided by the subjects (daily questionnaires). On average, 17 seat adjustments were registered per shift (MIN 7, MAX 47). This is proof that once the seat adjustment has been adjusted, it was not permanently used but preferred "active sitting" with several different seat settings. Of all stored seat settings during driving, 4% to 41% of each driver's seat position corresponded to seat setting 1. On average, seat setting 1 was taken in 17% of all seat settings and was thus remarkably more accepted than seat setting 2 (MW 5%, Min 0%, Max 34%), which was preferred by drivers during the seat adjustment procedure. The results of all stored seat configurations (Table 5) show that the preset settings with deviations of up to 4° or 4mm account for 70% (seat opening angle), 73% (seat surface inclination), 88% (seat height) and 70% (seat position), i.e. were generally accepted as far as possible and changed only slightly. The results of the follow-up survey a few weeks after the end of the test also show a relatively high acceptance of the suggested seating position, since 50% of the test persons stated that they would now adjust their conventional standard seat differently than before the test series. This can also be interpreted as an indication that drivers in public bus services should be offered training in seat adjustment for an ergonomic sitting posture, possibly at intervals of several years. Such time-consuming and personnel-intensive training can, however, be substituted, as shown in this study, by a driver seat system with memory function. The time required to use a seat memory system is then limited to the procedure for individual seat adjustment. In order to simplify such a procedure, it would be very useful if the seat adjustment could be determined based on the drivers' anthropometric data solely. However, the correlation matrices of the anthropometric data and the corresponding seat positions and posture/joint angles suggested that simple correlations between body dimensions and seat positions are not useful [3].

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5 References

1. Ell, W., 1995, Arbeitszeitverkürzung zur Belastungsreduzierung bei älteren Mitarbeitern im öffentlichen Personennahverkehr, In: Karazman R. et al (Hg.) Betriebliche Gesundheitsförderung für älter werdende Arbeitnehmer, Gamburg: Verlag für Gesundheitsförderung G. Conrad, 160-170
2. Ellegast, R., Knipfer, Chr., 2001, Ergonomische Prüfung eines Sitzmemorys am Busfahrerarbeitsplatz (Projekt 4086), Untersuchungsbericht Nr. 199922881, DGUV
3. Brütting, M., Böser, Chr., Knipfer, Chr., Ellegast, R., 2012, Sitzmemory am Busfahrerarbeitsplatz, IFA Report 3/2012, DGUV
4. DIN 33402-1, 2008, Ergonomie - Körpermaße des Menschen – Teil 1: Begriffe, Messverfahren, Beuth Verlag, Berlin
5. VDV Schrift 234, 1996, Fahrerarbeitsplatz im Niederflur-Linienbus, VDV, Kamekestr. 37-39, 50672 Köln
6. Marx, M., 1996, Optimierung des Fahrerarbeitsplatzes im Niederflur-Linienbus, Schriftenreihe Automobiltechnik des Instituts für Kraftfahrwesen Aachen
7. Ellegast, R., Hermanns, I., Schiefer, C., 2010, Feldmesssystem CUELA zur Langzeiterfassung und -analyse von Bewegungen an Arbeitsplätzen, Zeitschrift für Arbeitswissenschaft, 2, 101-110
8. DIN 33402-2, 2005, Ergonomie – Körpermaße des Menschen – Teil 2: Werte, Beuth Verlag, Berlin