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Assessing Car Seat Posture through Comfort and User Experience

Irene Caballero-Bruno [1,2,*], Daniel Töpfer [1], Thomas Wohllebe [1] and Pedro M. Hernández-Castellano [2]

[1] Volkswagen AG, 38436 Wolfsburg, Germany; daniel.toepfer@volkswagen.de (D.T.); thomas.wohllebe@volkswagen.de (T.W.)
[2] Departamento de Ingeniería Mecánica, Universidad de las Palmas de Gran Canaria, 35017 Las Palmas de Gran Canaria, Spain; pedro.hernandez@ulpgc.es
* Correspondence: irene.caballero.bruno@volkswagen.de

Abstract: The vehicular market is undergoing a profound transformation that includes a trend toward fully automated driving. When travelling in automated systems, the main task is no longer driving. Therefore, the interior design of automated vehicles requires a renovation to adapt to new use cases. With this motivation, the use case of sleeping while travelling was chosen for this user study, in which different seat configuration conditions were evaluated. The three preselected seat positions for this research included the upright, reclined and flat seat positions. To the best of our knowledge, this study is the first to examine the comfort of different seat angles in meeting the need to sleep in a moving vehicle. Since the physical experience of the occupants with a high-fidelity seat prototype is essential to evaluate the new interior concept of the vehicle of the future, in this study, the experimental participants were asked about their perception of comfort and overall user experience while travelling by car under close-to-real test conditions. Therefore, the primary objective of this evaluation was to explore different seat configurations and find the most suitable seat position for the use case of sleeping in a car while moving. Our findings suggest that users prefer reclining and flat seats in short-/medium- and long-term use cases, respectively.

Keywords: comfort; user experience; car seat; testing; seat angles

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1. Introduction

The expectation of the release of fully automated vehicles has increased in parallel with the trend of higher automation in the industry. In the near future, as such systems emerge in the general market, a profound evolution of mobility and the transport segment will be needed [1]. Many potential benefits of this new type of vehicle are anticipated, such as increased transport comfort and safety [2]. However, the optimization of mobility through the more efficient use of travel time has given rise to the search for new use cases, which must be analyzed.

In automated driven systems, driving is no longer a core task [3], and travelling can have new side purposes. Currently, the interior design of the car is focused on the driver and the driving tasks, spaces and instruments. This same space can be used for activities other than driving. The search for new vehicle concepts, led by automobile manufacturers, is an intensive and adventurous exploration which involves the creation of designs and models to define the future car interior. Simultaneously, various studies and questionnaires have been carried out to determine the desired uses for the interior of vehicles. One of the most desired activities while travelling is to rest or sleep [4]. To allow sleep activity inside the vehicle, the interior as we know it must undergo a significant transformation.

The process of designing and configuring the current car safety, ergonomic and usability systems has been a long and gradual process where the knowledge develops at the same time as the needs of society and advances in technology. The high criteria when evaluating cars has been created through an ongoing adaptation process and a slow establishment of ever-higher standards. To create systems that adapt to new use cases of high automation in the vehicular field, it is important to study, predict and forecast the new future situation. Thus, in the analysis of this upcoming scenario, it is necessary to imagine and test new interior environments, creating prototypes in a various ways, both visual and physical. The development of technical solutions for such concepts is also required. The literature includes both patents and scientific papers that explore different technical solutions. However, the real, or close-to-real, physical experience of occupants is often not used due to the complexity of building such high-fidelity prototypes. Therefore, until now, the establishment of knowledge in this field has primarily consisted of very limited user experiences and the creation of imaginary scenarios. In addition, participants in user studies and tests in the field of autonomous cars have pre-conceived, inaccurate ideas about what the future will look and feel like based on current cars and expectations [5]. In conclusion, to develop new technological advances, it is important that users are directly involved and have realistic close-to-real experiences [6,7].

In particular, the research that can be found in the literature on seats for sleeping inside cars is quite limited, primarily due to the high level of novelty of the topic. In order to address the issue of sleeping in a new autonomous vehicle environment, multidimensional research is necessary to look at the topic from different perspectives, and to find comparable examples in different fields [8]. Thus, when dealing with seats, a predominant topic in the literature has been comfort and discomfort, especially, the ergonomics of the seats used in different contexts, such as cars, trains, planes, offices, etc.

Surveys have been a common method of determining comfort factors that affect the user's sleep experience. The authors of [9] focused on non-driving-related tasks and provided a list of requirements for future automated vehicle interior based on an online survey and a small-scale experiment. Regarding the seat, the study determined two related preliminary requirements: the seat should support a flat position facing the driving direction, and the seat should be wider without side supports.

An alternative method of research is to administer a questionnaire of a regular event. For example, the authors of [10] analyzed the factors affecting sleeping comfort for flight crew members. The study aimed to evaluate existing aircraft bunks beds, comparing these experiences with sleeping comfort at home, based on the participants' perceptions and opinions. The main limitation of that study is that it only included crewmembers from three airlines sleeping in bunks on three different aircrafts, limiting the geometries, situations and conditions to those defined by the existing facilities.

The idea of sleeping while travelling has been explored primarily for long-haul transportation industries, such as airplanes. The authors of [11] explored the influence of different seat angles on sleep quality at naptime. The results were consistent with previous studies, and concluded that the quantity and quality of sleep increase as the back angle of the seat increases, as they mainly depend on head stability and autonomic activity. However, the study has several limitations, such as the dissimilarity with the real conditions and characteristics of airplane seats.

Another approach to define the characteristics of the best ideal seat for sleeping in a vehicle is to focus on biomechanical quality. The authors of [12] evaluated biomechanical quality using the interface pressure score based on the effect of different seat pan and backrest angles. These assessments were complemented by subjective evaluations made by the participants when they were asked how adequate the positions were for sleeping. One of the seat configurations was defined as the most suitable because it provided the most favorable pressure properties. However, the pressure evaluation did not correlate with the higher subjective rating in suitability for sleeping. Some limitations of the study included the short duration of the test session, the static scenario and the inclusion of only male participants. Analyzing a scenario closer to reality, i.e., more dynamic, and with a wider range of participants and longer test length, would be beneficial to obtain a more reliable result. Moreover, subjective ratings need to be further explored, as pure pressure data can overlook actual user needs.

One of the main aims of the present study was to develop a replicable framework where user experience, comfort and safety are the main drivers for the design and validation of future vehicle systems. The occupants' physical experience with prototypes becomes an essential part of the development process. This research focuses on seating, specifically to define the most suitable seating position, including seat pan and backrest angles, for sleeping in a moving vehicle environment.

2. Materials and Methods

In this study, different seat configurations were evaluated for the purpose of sleeping. An experimental procedure and method were designed to conduct a user study on the subject's comfort and user experience. Three different seat configurations were applied under a dynamic moving vehicle condition. Subjective questionnaires of the topic were given during a ride using the experimental setup.

2.1. Participants

Ten healthy adults with some previous knowledge on the topic were recruited. Eight men and two women, with a varied range of heights and weights, volunteered for subjective experimental testing. The participants had an average age (±SD) of 42.9 ± 12.0 years, and an average height and weight of 80.9 ± 13.1 kg and 1.83 ± 0.1 m, respectively. According to the authors of [13], the target market for self-driving cars is consumers who are 18 years or older and hold a driver's license. Thus, the sample age, height and weight are representative of a normal population that would use such autonomous vehicle. Participants had no previous experience with the defined seat configuration and test conditions. All participants confirmed that they did not suffer from any conditions that could affect the test results, such as musculoskeletal injuries or other related diseases. Before the experiment, they were informed in detail about the content and procedure of the study, and provided their informed consent.

2.2. Test Conditions

The study was carried out using a tailored prototype seat inside a vehicle. In particular, the seat prototype was mounted in the rear of a Volkswagen T6.1 Multivan. The same seat prototype was used for every condition. The seat was designed to adapt to a wide range of configurations and be suitable for each of the seat configurations tested. In addition to the seat positions, the automatic seat transition was carefully configured for the purpose of the study.

To be representative of a car environment and suitable for every seat configuration, the seat was similar in design to current car seats with minimal geometry or contours and no armrests (Figure 1). The dimensions of the seat included a 900 mm by 645 mm backrest, a 480 mm by 665 mm seat pan, and a 350 mm by 435 mm leg rest. The total flat surface was contained in an area of 1.90 m and 0.66 m. The seat top layer consisted of a layer of 8 to 13 kPa harness foam and a cotton cover over it. The rear of the vehicle, surrounding the prototype seat and the participant, was a free, clean area. The windows in the rear were darkened to help participants focus on the seat, comfort, user experience and sleep use case.

The definition of the conditions included the selection of different seat pan, seat back and leg support angles. The choice of seat angles was made to have three wide-ranging seat configurations and cover a broad range of use cases. The final chosen seat configuration conditions consisted of an upright, reclined and flat position (Figure 2). The back angles of the seat with respect to the vertical were 20° in the upright condition, which is a usual configuration in current cars; 40° in the reclined condition, which is the angle of some car seats under development for future cars [14]; and 87° in the flat position, which is very close to the flat angle of a bed. The seat pan and leg support angles were selected correspondingly to support the body in a natural way for each of seat configurations. The seat pan was positioned at 10°, 20° and 0° with respect to the horizontal, and the leg support was set at 10°, 65° and 90° with respect to the vertical.

(A) (B) (C)

Figure 1. Prototype seat and environment in the upright, reclined and flat seat positions. (**A**) Upright. (**B**) Reclined. (**C**) Flat.

(A) (B) (C)

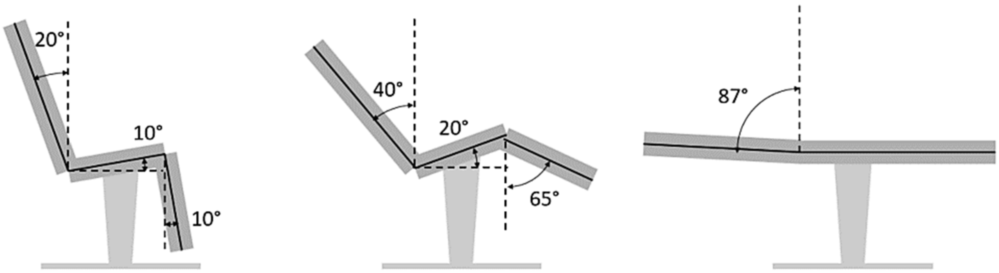


Figure 2. Configuration of seats for the upright, reclined and flat conditions. (**A**) Upright. (**B**) Reclined. (**C**) Flat.

Before each trial drive, the seat was adjusted from the upright position to the designed position (e.g., reclined) in a smooth pre-programmed transition while the participant was sitting correctly. In addition, to maintain safety levels in the reclined and flat positions, the seat included a seven-point seatbelt, which was the result of the combination of a conventional three-point seatbelt and a four-point seatbelt in the opposite direction, with an extra buckle point between the users' upper legs (Figure 3).

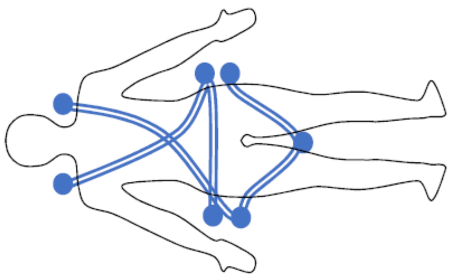


Figure 3. Diagram of the 7-point seatbelt setup on a human body.

2.3. Experimental Procedure

A dynamic user study was conducted to investigate seating comfort under a wide range of seat configurations with the purpose of sleeping while driving. The main hypothesis of the study was that a more reclined back angle would contribute to occupant comfort and be perceived as a preferred configuration for the sleeping use case in a driving scenario. Subjective comfort and user experience were analyzed to answer the following research questions:

- Do seat angles affect perceived comfort in real-world conditions?
- Does the discomfort of different human body areas and restraint systems affect general comfort ratings?
- How does time affect comfort and discomfort ratings?
- How do first impressions of different seatback angles reflect their suitability for sleeping?

These questions were answered through an experimental evaluation. The study was a moderated in-between designed study with three conditions. The study had repeated measures, and a counter-balanced and randomized design. Participants were welcomed and the instructions were explained. The questionnaire contained 15 questions of varied formats, including multiple-choice, short written responses and fill-in-the-blank answers. The survey was divided into four sections: "Questions before trial drive," which included basic demographic questions; and "Comfort during the trial drive," "Comfort after each seat position," and "Comfort after the complete trial drive," which included comfort questions during and after sitting in the seat, respectively, as well as preference questions. Comfort and discomfort ratings tend to change over time [15]. Therefore, for each condition, the participant rated comfort starting at minute 0, again at minute 10 of the drive and after the drive at minute 15. During the drive, participants were instructed to relax and imagine sleeping during a long-term drive in an autonomous car. Moreover, they were instructed to focus on the seat comfort and their experience. During the drive, questions were orally asked by a moderator, and participants rated the comfort verbally. The moderator transcribed the answers from the subjects. Participants experienced all the three conditions in a randomized order. They had a few minutes between conditions to stand up and take a break before the new condition.

The trial drive was conducted in the dynamic track of Volkswagen Proving Ground in Germany over 2 days. The controlled trial drive was designed to be safe and represent close-to-real dynamic conditions. The purpose of the designated drive condition was to represent a constant smooth drive with an autonomous car on a highway. The driving scenario was selected to offer the closest conditions to the use case while maintaining safety standards. The resulting scenario provided a real feeling of driving, including low speed and accelerations, which are suitable for evaluating comfort and trust [16]. Previous studies [17] have evaluated comfort after 15 min of driving motion, as this has been designated as sufficient time for passengers to settle in a moving car [18]. Therefore, the driving scenario involved a 15 min drive per condition at a constant speed of 30 km/h through a dynamic track that included a series of different curves. As safety was a priority, higher speeds and accelerations were excluded due to concerns in the unusual seating position. Moreover, the accelerations were controlled ($ay \leq 0.2$ g) during the drive. Each round was approximately 1.25 km and took 5 min.

Due to the COVID-19 pandemic, after a robust risk assessment, a special hygiene protocol was established. This procedure, which included measures before and during the test [19], was followed. Before each participant entered the vehicle, the surfaces were disinfected, and the vehicle was aired. During the study, the participants had to wear a special full-body protective suit while travelling inside the vehicle. This was a requirement to minimize the contact with surfaces. Moreover, a medical mask was worn by all passengers, including the participant. These additional measures were necessary at the time of the experiment and could not have been avoided by alternative procedures.

2.4. Sleep Quality and Comfort Rating

The evaluation of comfort was executed through subjective methods. The scale was the result of the modification of two well-known comfort scales: the Borg (1990) [20] CR-10 scale, and the Corlett and Bishop (1976) [21] discomfort scale. These scales assess the degree of discomfort and comfort of the participant with respect to the seat. The resulting general scale (Figure 4) is a seven-point Likert scale that measures the level of general comfort, from −3 (strong discomfort) to +3 (strong comfort). Similar modifications have been performed previously in the literature [22]. An additional four-point Likert scale was used to identified body specific discomfort, from −3 (strong discomfort) to 0 (neutral/no discomfort). Using these scales helped to identify areas of discomfort and track the perception of comfort in the brief sitting experience. The comfort and discomfort scales, as well as the questionnaire, were explained to the participants beforehand. The participants were encouraged to ask for clarification during the test when needed.

Discomfort				Comfort		
Strong	Moderate	Weak	Neutral	Weak	Moderate	Strong
−3	−2	−1	0	1	2	3

Figure 4. General comfort scale.

2.5. Statistical Analysis

The 1.2.5042 version of RStudio [23] and Microsoft Excel were used for the statistically analyzes. Additional tests, namely the Shapiro-Wilk test for normality and Levene's test for the equality of variances, were performed to check the data assumptions: Moreover, other preliminary tests included the identification of outliers.

To describe the effect of the different back and seat angles and the time on the comfort variables, two-way repeated measures ANOVAs were performed. Two within-subject factors were included: time and seat angle. Each factor had three levels. The time factor included minute 0, minute 10 and minute 15; and the seat angle factor included upright, reclined and flat. Furthermore, two-tailed paired t-tests were calculated to identify any effects among pairs of factors.

Due to the small number of participants in this study, effect sizes were calculated using Cohen's d formula for paired comparisons. This provided an indication of the size of the difference in each dependable variable, even if the effect was not statistically significant. The effect sizes were interpreted as very small if $d < 0.2$, small if $d \geq 0.20$, moderate if $d \geq 0.40$, large if $d \geq 0.80$ and very large if $d \geq 1.2$ [24,25]. Lastly, to answer some of the research questions, Spearman's correlation was performed to compare the means pairs of variables, such as body part discomfort and general comfort.

3. Results

3.1. Seat Comfort

An initial analysis through observation yielded notable results. The general comfort ratings obtained during the dynamic experiment were mostly positive in all conditions and times of measuring. Table 1 details a summary of the mean values and standard deviations from the analyzed data. The means for general comfort, for any seat position during any time (0 min, 10 min, 15 min) of measuring, were between 1.2, slightly over a "weak" comfort, and 2.0, a "moderate" comfort. This outcome shows that there were no major points of short-term discomfort during the driving and sitting experience. However, discomfort-specific ratings showed that some parts of the seat produced more intense discomfort in certain conditions. For example, the legs and feet area was rated more negatively in the upright and reclined positions, whereas the head region was the most negatively evaluated by participants in the flat condition.

The first remarkable observation that can be detected when graphically plotting the results is the different behavior of the comfort ratings of the conditions with time (Figure 5). Throughout the three measuring times, 0 min, 10 min and 15 min, the comfort ratings changed differently depending on the conditions. In the case of the flat position, the mean ratings improved over time, from minute 0 at 1.2 to the end of the drive (minute 15) at 1.9. Meanwhile, while in the reclined condition, the means remained mostly stable for the duration of the study. Lastly, in the upright position condition, the general comfort mean declined with time.

Table 1. Measures for the comfort and discomfort perceptions for the upright, reclined and flat conditions.

Variables			Upright (20°)	Reclined (40°)	Flat (87°)
	Time	**Body Part**	**M (±SD)**	**M (±SD)**	**M (±SD)**
Overall comfort (−3 = strong discomfort, +3 = strong comfort)	0′		2.0 (±0.9)	1.6 (±1.1)	1.2 (±1.4)
	10′		1.6 (±1.0)	1.8 (±0.7)	2.0 (±0.4)
	15′		1.2 (±1.5)	1.7 (±0.8)	1.9 (±1.4)
Discomfort (−3 = strong discomfort, 0 = no discomfort)	0′	Head/Neck	0.0 (±0.0)	−0.4 (±0.9)	−0.6 (±0.7)
		Back	−0.4 (±0.5)	−1.1 (±1.0)	−0.7 (±0.6)
		Buttocks	−0.1 (±0.3)	−0.4 (±0.7)	−0.2 (±0.4)
		Legs/Feet	−0.7 (±0.8)	−0.9 (±0.8)	−0.4 (±0.5)
	10′	Head/Neck	−0.2 (±0.4)	−0.4 (±0.7)	−0.7 (±1.0)
		Back	−0.6 (±0.7)	−0.8 (±0.7)	−0.8 (±0.9)
		Buttocks	−0.1 (±0.5)	−0.4 (±0.7)	−0.3 (±0.6)
		Legs/Feet	−0.8 (±0.7)	−1.0 (±0.8)	−0.2 (±0.4)
	15′	Head/Neck	−0.2 (±0.4)	−0.4 (±0.5)	−0.8 (±0.7)
		Back	−0.4 (±0.5)	−0.7 (±0.6)	−0.7 (±0.8)
		Buttocks	−0.4 (±0.7)	−0.4 (±0.7)	−0.3 (±0.6)
		Legs/Feet	−0.8 (±0.7)	−0.9 (±0.7)	−0.3 (±0.6)

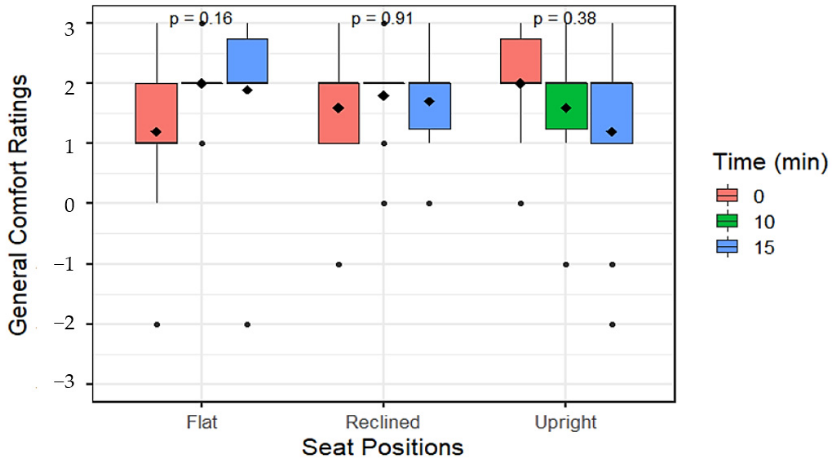


Figure 5. Boxplot with general comfort ratings for the flat, reclined and upright seat conditions over time. The diamond shapes indicate the mean and circles indicate outliers.

When visually observing the discomfort of different body areas (Figure 6), it can be detected that of the region of highest discomfort was the back area for all the seat positions. Moreover, another discomfort area was the lower part of the body in the reclined position. On the other hand, as the seat position grew more reclined, the discomfort seemed to be located higher on the body. Regarding the time of the rating, we could not find a correlation visually.

ANOVA significant tests also support the previous claim that general comfort ratings were significantly different depending on the condition and time of the comfort rating. This differing behavior was revealed by the indication of a significant effect on the interaction (Table 2). Moreover, ANOVAs did not indicate any other significant differences except in the legs and feet area, where the seat position was shown to affect leg discomfort ratings.

Further analyses, for example, paired comparison, showed additional significant results. For instance, between the upright and reclined positions, there was a significant difference in terms of back discomfort, where discomfort was consistently greater in the reclined condition. Paired comparisons between upright and flat conditions revealed that discomfort was significantly higher for the variables head and legs/feet in the flat and upright position, respectively. Finally, the paired comparison between the reclined and flat positions found no significant effect, except in the leg factor, and the reclined position received consistently higher discomfort ratings. The results concerning Cohen's d effect sizes, indicating large or very large sizes of effect, were according to the significant test results.

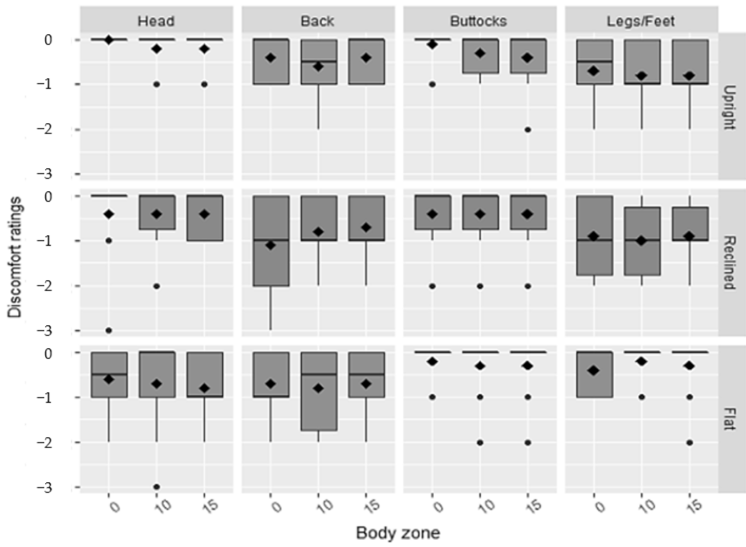


Figure 6. Boxplot with different body part comfort ratings for the upright, reclined and flat seat conditions over time. The diamond shapes indicate the mean and circles indicate outliers.

Table 2. ANOVA and *t*-test paired comparison for dependent variables related to comfort and relax level in the seat for the upright (Up), reclined (Rc) and flat (Fl) conditions. * Symbol indicates a significant effect ($p < 0.05$).

Dependent Variables		Main Effect of Condition						Paired Comparisons (Seat Position Factor)		
		Two Way Repeated Measures ANOVA						*t*-Test		
		Seat Position		Time		Interaction		Up vs. Rc	Up vs. Fl	Rc vs. Fl
		F	*p*	F	*p*	F	*p*		*p*	
COMFORT	General	0.04	0.961	0.94	0.377	3.11	0.045 *	0.721	0.754	1
	Head	4.51	0.050	0.42	0.662	0.26	0.899	0.738	0.001 *	0.143
	Back	2.20	0.140	0.38	0.686	1.99	0.170	0.038 *	0.138	0.533
	Buttocks	0.72	0.502	0.42	0.662	0.88	0.483	0.213	0.651	0.416
	Legs	3.91	0.039 *	<0.01	1	0.39	0.813	0.411	0.008 *	<0.001 *

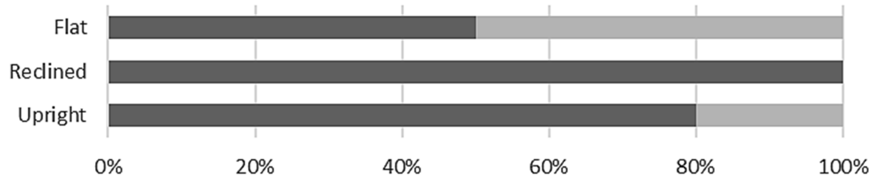
Regarding the discomfort in different body parts and correlation with general comfort ratings, there was only a clear effect in the case of the legs/feet and back areas. The discomfort ratings in the head and the buttocks areas showed no correlation with the overall comfort ratings.

3.2. Seatbelt Discomfort

The participants were asked to evaluate seatbelt discomfort (Figure 7). The restraint system created discomfort mostly in the flat position. The presence of seatbelt discomfort showed no direct relationship with the overall comfort ratings. Thus, the restraint system impact on user experience and comfort should be further explored in future research.

3.3. Relax Levels

Additional results include the relax levels after each condition. The question "How relaxed did you feel while experiencing the seat?" was rated on a seven-point Likert scale (Figure 8). The position with highest relax level was the flat condition, followed by the reclined position and the upright position. When further analyzed, we found significant differences between the upright position and both the reclined and flat conditions.



	Upright	Reclined	Flat
No	80%	100%	50%
Yes	20%	0%	50%

Figure 7. Seatbelt discomfort, answer to the question "Did you perceive discomfort caused by the seatbelt?"

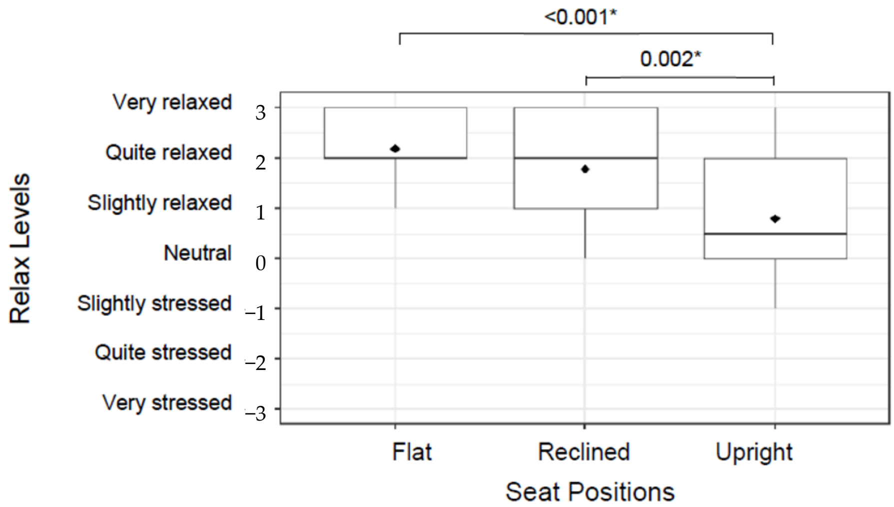
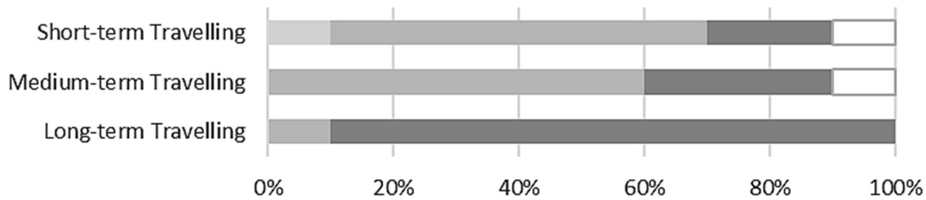


Figure 8. Relax levels from the question "How relaxed did you feel while experiencing the seat?" * symbol indicates a significant effect ($p < 0.05$). The diamond shapes indicate the mean.

3.4. Preferred Position for Sleeping

When participants were asked about preferred position for sleeping (Figure 9), results varied according to the use case. The flat position was the was favored by most subjects (90%) for sleeping during long-term travel. In contrast, the reclined position was selected by 60% of subjects for both short- and medium-term travel.



	Long-term Travelling	Medium-term Travelling	Short-term Travelling
Upright	0%	0%	10%
Reclined	10%	60%	60%
Flat	90%	30%	20%
NA	0%	10%	10%

Figure 9. Preference of seat configuration for sleeping during long-, medium- and short-term travel.

4. Discussion

The study methodology, with a close-to-real dynamic condition, resulted in some significant outcomes, indicating that both seat base and backrest angles affect comfort perception. For the sleeping use case, it was also concluded that users are drawn to choosing a flatter position than the current one in series production cars. This outcome agrees with findings of some previous studies [11,26,27].

On the other hand, the results of the general comfort rating obtained in the study showed an unexpected behavior. Comfort ratings were expected to worsen with time [28], and this was the case for the upright position. However, the flat position had an opposite effect on comfort. This phenomenon can be explained by many comfort perception models, such as the Cappetti and Naddeo comfort/discomfort perception model [29]. In the mentioned model, the resulting comfort is the result of several factors, such as environment, and psychosocial and cognitive factors, rather than strictly physical qualities. In previous similar models, one of the inherited components of comfort perception is expectation or previous experience [30]. One hypothesis could be that the participants had experience with normal car seats and their angles. In contrast, it is expected that participants did not have similar experiences travelling in a lying position inside a car in a dynamic scenario. Therefore, the initial more negative comfort rating of the flat condition could have been caused by the difference in seat expectations in a moving vehicle. Once the participants experienced the seat in the moving car for 5 min, the expectation was readjusted to a more positive opinion.

The analysis of discomfort in different body areas indicates that some of the discomfort originated from seat comfort limitations, whereas other discomfort was inherently specific to seat position. The seat design was based on the design of an automotive seat. Although the intention was to acclimate to the specific scenario and use case, in some cases, the seat prototype was insufficient to truly represent a comfortable futuristic reclined seat. Consequently, this resulted in some localized discomfort in the reclined and flat positions, for example, in the legs/feet and head areas.

Other study limitations were the low number of participants and short duration of the experiment. The constant low speed and accelerations due to safety standards also limited the evaluation of specific driving-related discomforts. These aspects explain the relatively low number of significant results. Another major limitation was the low number of female participants. Gender-based differences in comfort and higher pressure sensitivity have been reported [31,32] and thus must be taken into account when performing comfort user studies. Furthermore, an additional special COVID-19 protocol, which included full bodysuits, protective facemasks and reduced control of the in-vehicle environment temperatures due to constant airing, may have affected the comfort ratings [33,34] and, ultimately, the results.

5. Conclusions

To the best of our knowledge, the present study is the first to examine the comfort of different seat angles in meeting the desire to sleep in automated vehicles, based on the effect of comfort perception in close-to-real conditions. It includes a combination of tests in real conditions with methodical subjective ratings to provide the most favorable conditions and understand how user opinions can change in the short term.

The primary objective of this study was to explore different seat configurations suitable in the use case of sleeping inside a moving car. The close-to-real dynamic scenario was of particular importance in this paper to fill the corresponding gap of knowledge of comparable research in the literature [11,12,22]. The present study suggests that users prefer flat and reclining seat configurations for long- and short/medium-term use, respectively.

This work provides the basis for further studies on long-term comfort, safety and vehicle movement effects on comfort related to sleep. Future research should focus on overcoming the limitations of the present study and exploring the matter more deeply. On the one hand, future works should include pressure distribution, EEG or other objective measurements to complement subjective data. Seat prototype comfort limitations should be identified and improved, with special consideration given to the reclined and flat positions. On the other hand, a longer-term study in which different types of car occupants can sleep in close-to-real conditions would be ideal for a deep and reliable conclusion.

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