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Experiences of Upright Sleeping in a Vehicle: The Preferred Back Rest Angle

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ABSTRACT

Taking a nap is a welcome pastime in vehicles such as trains, airplanes, and cars. Flat sleeping cannot always be facilitated because of space and economic constraints, but a larger backrest recline angle is associated with better sleep quality. To define the best and the worst comfort experience and sleep comfort in these settings, and to offer design guidelines to practitioners, six backrest recline angles were compared regarding overall comfort and sleep comfort. The backrest recline angles ranged from 110 to 150 degrees, and 180 degrees was added as a reference. 16 participants were invited to sleep for a duration of 90 min. in each condition. Overall comfort and sleep comfort significantly improve in conditions higher than 120 degrees. Local discomfort is rated relatively low in all angles, but in comparison, people experience high discomfort in the neck, lower back, and lower leg region while in the 110 and 120 degrees condition. It is concluded that in the bigger recline angles the napping comfort experience is higher, with a minimum advised angle of 130 degrees.

Keywords: Napping, Transportation, Back rest recline, Comfort, Discomfort

INTRODUCTION

In many vehicles passengers are sleeping. Groenesteijn et al. (2014) reported that on medium to long distance train trips, the second most time was spent on 'staring or sleeping'. Bouwens et al. (2017) report that the majority of passengers sleep during a flight, while this activity has the lowest comfort score. The likelihood of resting and sleeping during a commute automated vehicle trip is also high (Wilson *et al.*, 2022). Usually this sleeping is a nap, as Faraut et al. (2017) defined a nap as any sleep period with a duration of less than 50% of the average major sleep period of an individual. Discomfort while taking this nap might be caused by the upright sitting position. Studies by Nicholson & Stone (1987), Aeschbach et al. (1994), Hayashi & Abe (2008), and Roach et al. (2018) show that the larger the recline angle of the seat ('flatter'), the better the sleep efficiency. A flat bed is preferred. However, a flat bed is often not possible due to space and economic reasons during mobility. In the previously mentioned studies, sleep efficiency in a range of backrest recline angles was studied. Cabellero-Bruno et al. (2022) tested the comfort experience in 150 and 177 degrees, but for design purposes it is useful to make a comparison of a complete range with smaller increments to give design professionals the tools for choosing the best seat setup for their client's needs. Therefore in this paper, six backrest recline angle conditions with increments of 10°, were studied. Additionally, in many studies on the recline angle of the backrest, the focus lies on sleep efficiency. For academic purposes the influence of the recline angle on sleep comfort and the comfort perception of the nap is underexposed. The research question addressed in this study is: *Based on overall comfort and sleep quality, what is the preferred backrest angle for short naps, comparing 6 backrest angle sleep conditions with a increment of 10° starting at 110°.*

METHOD

To discover what back rest angle is acceptable for an upright sleep, six customized chairs were used of which the backrest could be positioned in five different angles (110°, 120°, 130°, 140°, 150°)(Fig. 1) and an additional 180° bed was added as a reference (a horizontal stretcher). Sleeping was facilitated with a good temperature, dimmed warm lights, blankets (Caddick *et al.*, 2018) and a cushion. The research setup is shown in Fig. 1. Sixteen participants (8 male, 8 female, mean age: 24 ± 3.7) were asked to try and sleep six times for a duration of 90 minutes to facilitate at least one sleep cycle (Carskadon and Dement, 2005), the angle sequence was randomized using the Microsoft Excel randomization function to prevent order effects. Participants were selected prior to the study based on a reduced Morningness-Eveningness questionnaire (rMEQ)(score of 17 or lower, no specific type or evening types were included)(Danielsson, Sakarya and Jansson-Fröjmark, 2019), people were selected who are more likely to sleep during the day. Additionally, people with sleeping disorders, people who find it 'extremely not easy' to nap during the day, and who snore, were excluded. The nap start time was at 13:00 or 15:30. Prior to the test all test participants signed an informed consent and the test procedure was approved by the research ethical committee of the Delft University of Technology (nr. 2679). Questions on sleep comfort were asked after the sleep, and questions on general comfort were asked before and after the sleep (on a scale of 0–10, 0 being no comfort and 10 extreme comfort). Additionally, the participants were asked to give a local posture discomfort (LPD) score for each body part, as described by Anjani et al. (2021). A self-written Python code was used to calculate general descriptive statistics and to calculate significant differences with the Wilcoxon Signed rank test.

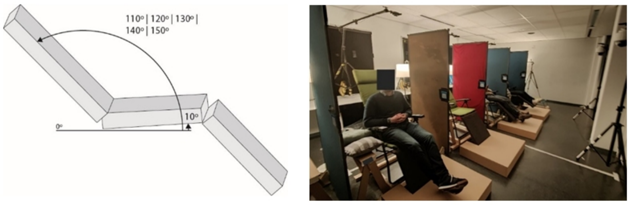

Figure 1: Seat configurations excluding 180° (left) and a research setup impression (right). The leg rest moves parallel to the backrest and the lights were dimmed during the test as they are brighter for the purpose of this picture.

RESULTS AND DISCUSSION

The results show that overall comfort was low (below 6) for 110 and 120 degrees (Fig. 2). Overall comfort was significantly better at 130° and larger angles compared to 110° and from 140° and higher compared to 120° (Table 1). A comparable trend was shown for sleeping comfort (Fig. 3, table 1). When looking at the before and after comparison, the after-sleep general comfort experience is better than before sleep from 140° and upwards, with the exception of 180°.

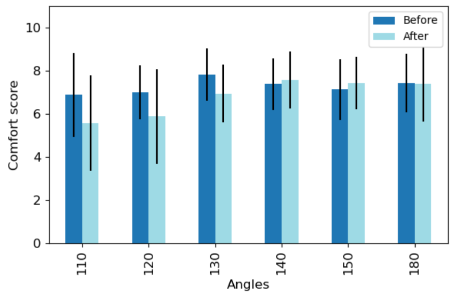

Figure 2: Mean overall comfort score before and after sleep.

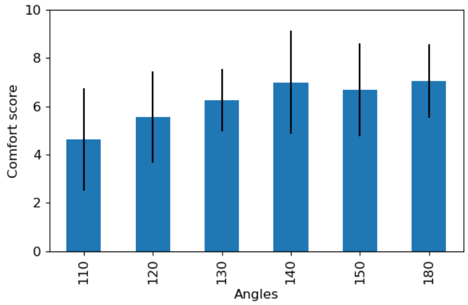

Figure 3: Mean sleep comfort score.

Table 1. Wilcoxon signed-rank test p-values. Sign. values (<.05) are highlighted in green.

	Overall Comfort (after)	Sleep Comfort
110–120	.645	.065
110–130	.037	.005
110–140	.01	.007
110–150	.007	.006
110–180	.006	.002
120–130	.119	.258
120–140	.016	.091

(Continued)

Table 1. Continued

	Overall Comfort (after)	Sleep Comfort
120–150	.012	.032
120–180	.019	.031
130–140	.029	.167
130–150	.097	.199
130–180	.320	.044
140–150	.685	.582
140–180	.779	.972
150–180	.917	.437

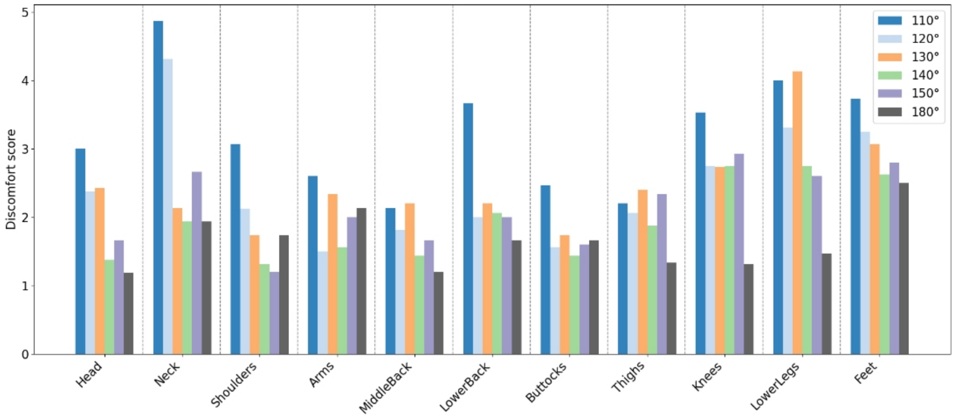

Figure 4: Local postural discomfort (1=no discomfort, 10=extreme discomfort).

As shown in Fig. 4, overall the LPD score is low (below 5), but if the angles are compared a pronounced higher discomfort score is given for the neck at 110/120 degrees and lower leg region and feet at 110/120/130 degrees, and for the lower back region in 110 degrees.

The results show a general improvement trend in the comfort scores as the backrest recline angle increases. This is in line with previous findings. But interestingly this increase flattens from 140° and higher, suggesting an optimum. Curious is the outcome for 180° as all literature suggests flat sleeping is preferred. A possible explanation might be that the comfort of the 180° condition is compared with the participant's home situation. In this case, the used 'stretcher' will be perceived as relatively uncomfortable to their own bed.

As a limitation of this study, the comfort score is not compared to the sleep quality. Therefore, this study only gives a representation of the subjective experience of the participants. Which is also a valuable insight e.g. comfort is an important determinant for choosing to travel by night train (Kantelaar *et al.*, 2022) or the willingness to fly with a certain airline (Vink *et al.*, 2012).

This study used a 'simple' garden seat design, this might partially explain the lower back support discomfort. Therefore in future research using a different seat design might have an influence on the outcomes. Additionally, the sitting comfort in a seat is also influenced by the sitting posture (Smulders and Vink, 2021). This study did not take the sleeping posture into account. For further seat design improvements common upright sleeping postures should be clarified to define where seat support is necessary as sleeping requires different supports (Smulders *et al.*, 2019).

The mean age of the participants was low, further research should consider this as napping habits and ease of movement might be different between age groups. We know napping frequency increases with age (Milner and Cote, 2009) and sleep movements decrease in older adults (Skarpsno *et al.*, 2017). The first might influence the ease with which people fall asleep as they are more used to sleeping during the day, and secondly, as older people move less during sleep this can increase discomfort.

The participants in this test were selected based on their ease of falling asleep during the day to test their sleep comfort. When interpreting the results, this should be taken into account. The selected group might experience the seat angle differently than others who have more trouble sleeping, as they spend more time awake in the seat.

This research gave inspiration for further testing of upright sleeping in a car seat, mapping sleeping postures in different backrest angles, measuring posture movements during sleep, and connecting sleep comfort to sleeping quality. Future research on sleep in dynamic situations is needed to further define attention points for sleeping environments in the context of traveling.

CONCLUSION

A conclusive statement based on sleep quality is hard to give, but in terms of comfort, a backrest angle of 120 degrees or less seems to be unacceptable for a nap. Also, more participants experience a good nap for 130 degrees and more. Suggesting that for a short napping situation, a minimum of a 130 degree recline or more is preferred. To improve sleep comfort in 110 and 120 degree recline; neck, lower back, and lower leg supports are the main attention points.

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