Sleep quality and (dis)comfort in a minimal space envelope

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ABSTRACT

Sleep facilities in vehicles often have a limited space due to economic and/or operational reasons. Currently no guidelines exist on minimal sleep space envelopes for qualitative, effective and comfortable sleep. This study aims to preliminary investigate the influence of a 2D minimal space envelope on sleep quality, sleep effectiveness and (dis)comfort, in order to work towards such guidelines. Forty-one participants slept in three different conditions: night 1) in their normal bed space, night 2) in a limited space (170 x 70 cm), and night 3) in a minimal space designed by the participant. Night 2 was rated significantly least comfortable and most discomfortable, where night 1 in the own bed was rated as most comfortable and least discomfortable. Sleep quality and sleep effectiveness were rated worst in the limited space (night 2), which had a 30% space reduction relative to an average one person bed. However no significant difference in sleep quality and sleep effectiveness between the own bed (night 1) and the minimal space designed by the participant (night 3) were found, although space on average was reduced by 25%. This indicates that tweaking the dimensions of the reduced sleep space envelope can increase sleep quality, sleep effectiveness and comfort. Further research on minimal space envelope design (non-rectangular and 3D) and its influence on sleep quality and efficiency, and (dis)comfort is needed, in which sleep behaviour, sleeping postures and movement, and anthropometrics should also be taken into account.

KEYWORDS

Posture, Bed, Bunk, Aircraft, Vehicle

Introduction

Sleep facilities in aircrafts, trains, busses, ships, submarines, (autonomous) cars, and other vehicles often have a limited space due to economic and/or operational reasons (Smulders, 2018; Stanglmeier et al., 2020). Providing an effective and comfortable sleep is important for passenger satisfaction (Kluge, Ringbeck, & Spinler, 2020) – also to justify surplus prices (Hugon-Duprat & O'Connell, 2015; Kuo & Jou, 2017) – and crew effectiveness and operational safety – e.g. in operational safety critical environments such as aircraft cabin crews (Avers, King, Nesthus, Thomas, & Banks, 2009; Drury, Ferguson, & Thomas, 2012; Hartzler, 2014), medical staff (Dorrian et al., 2008; Gold et al., 1992; Weinger & Ancoli-Israel, 2002), offshore and maritime workers (Hope, Øverland, Brun, & Matthiesen, 2010; Hystad, Nielsen, & Eid, 2017; Sneddon, Mearns, & Flin, 2013) and military personnel (Good, Brager, Capaldi, & Mysliwiec, 2020; Grandou, Wallace, Fullagar, Duffield, & Burley, 2019; Parker & Parker, 2017). There are minimal standards for sleep facilities in safety critical environments such as aircraft (Simons & Spencer, 2007), but no guidelines exist on minimal sleep space envelopes. Such guidelines could help designers and engineers to design qualitative, effective, comfortable and compact sleep facilities.

This study aims to preliminarily investigate the influence of a 2D minimal space envelope on sleep quality, sleep efficiency and (dis)comfort, in order to work towards such guidelines.

Method

Forty-one participants (see Table 1) were asked to score the experienced sleep quality (by means of the Pittsburgh Sleep Quality Index (PSQI) (Buysse, Reynolds III, Monk, Berman, & Kupfer, 1989)), sleep effectiveness (by means of the Karolinska Sleepiness Scale (KSS) (Åkerstedt & Gillberg, 1990; Kaida et al., 2006), the Samn-Perelli 7-point Fatigue Scale (SPFS) (Samn & Perelli, 1982) and a Rested Scale) and (dis)comfort after a night sleep in three conditions: night 1) in their normal bed space (the bed they sleep in in their house, which was usually between 190-200 cm long and between 90-140 cm wide), night 2) in a limited space (170 x 70 cm), and night 3) in a minimal space designed by the participant (a bed space which is limited, but still rather comfortable, based on own insight and their experiences from nights 1 and 2).

Table 1: Participant demographics (n=41)

		Mean	**SD**
Male (n=12)	Age [Years]	22.8	1.7
	Stature [m]	1.85	0.07
	Weight [Kg]	75.0	7.6
Female (n=29)	Age [Years]	22.9	1.6
	Stature [m]	1.72	0.07
	Weight [Kg]	62.1	8.5

The Wilcoxon test ($p<.05$) for paired examples was used to test for significance in PSQI, KSS, SPFS and (dis)comfort. The measurements of the designed minimal 2D space envelopes are combined into one average square minimal space envelope.

Results

The average comfort and discomfort scores differed significantly ($p < .01$) (see Figure 1). In their normal bed space (night 1) the comfort score was 3.96 (scale 1-5; 5=maximum comfort; SD= 0.73), in a limited space (night 2) 2.59 (SD=0.91) and in their own minimal designed sleep space (night 3) 3.0 (SD=0.90), and in their normal bed space (night 1) the dis-comfort was 1.53 (scale 1-5; 5=maximum discomfort; SD= 0.60), in the limited space (night 2) 2.98 (SD=0.86) and in their own minimal designed sleep space (night 3) 2.4 (SD=0.90).

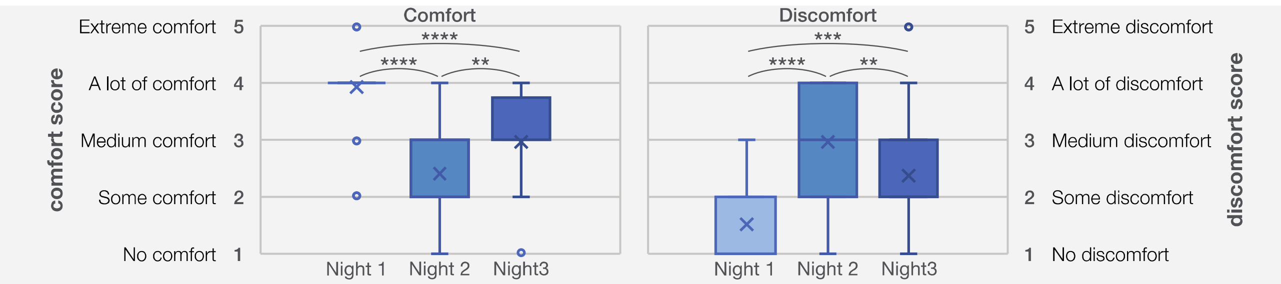

Figure 1: Distribution of comfort and discomfort scores per night (n=41). Higher comfort and lower discomfort scores are considdered better. Significant difference is stated as follows: ** = $p \leq 0.01$, *** = $p \leq 0.001$, **** = $p \leq 0.0001$.

The minimal sleep space designed by the participant varied a lot: the minimal width was 46 cm and the maximum was 140 cm, and the length varied from 100 to 200 cm. The mean designed sleep space was 166 x 78 cm; a reduction of 25% compared to an average one person bed (see Figure 2).

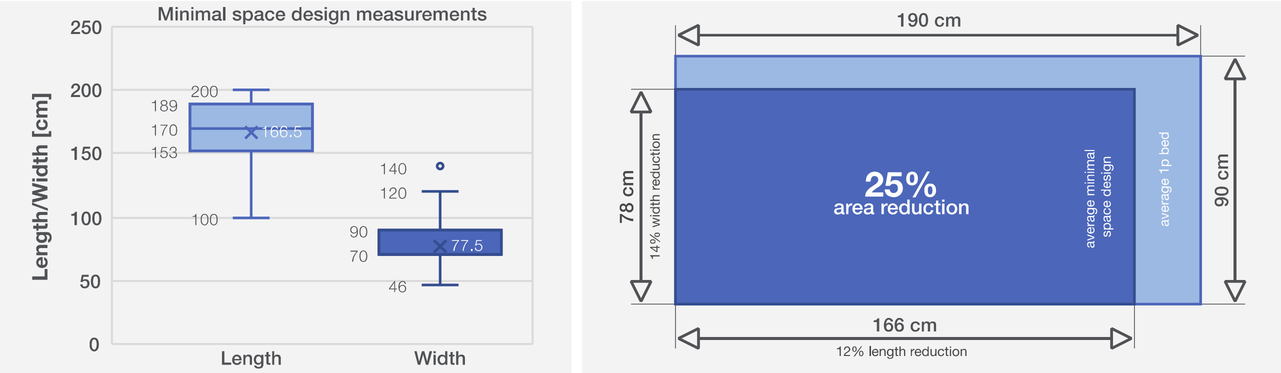

Figure 2: Distribution of minimal space design measurements by the participants for night 3 and a visualisation of the 2D space area reduction from average one person bed (190 x 90 cm) to average minimal bed design by participants (166 x 78 cm) (n=41).

When looking at the impact on sleep quality, night 2 in the limited bed was scored worse on the PSQI score (see Figure 3), the Karolinska Sleepiness Scale (see Figure 4), the Samn-Perelli Fatigue Scale (see Figure 5), and the Rested Scale (see Figure 6) by participants than sleeping in their own bed (night 1) or their own designed sleep space (night 3). No significant difference was found in sleep quality (PSQI) between night 1 and 3. No significant difference in alertness-sleepiness (KSS) was found between pre- and post-night for night 2, where nights 1 and 3 resulted post-night in significant more alertness to pre-night. Fatigue (SPFS) significantly differed for all nights between pre- and post-nights. Participants felt significant more rested post-nights 1 and 3 compared to night 2, where no significant difference was found between nights 1 and 3.

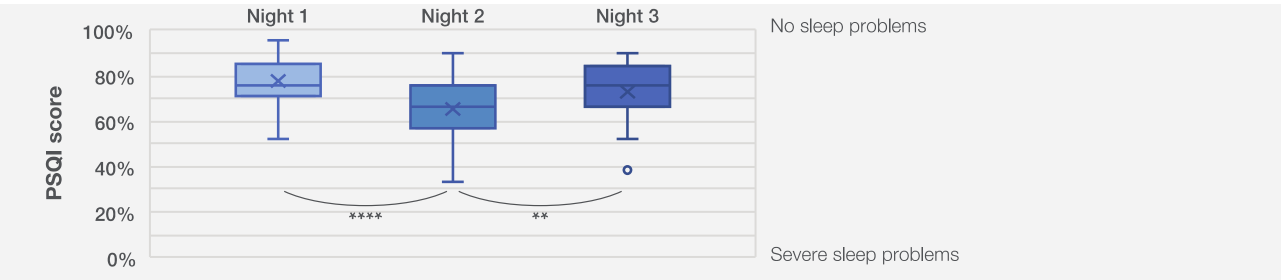

Figure 3: Distribution of PSQI scores per night (n=41). Higher PSQI scores are considdered better. Significant difference is stated as follows: * = p ≤ 0.05, ** = p ≤ 0.01, **** = p ≤ 0.0001.

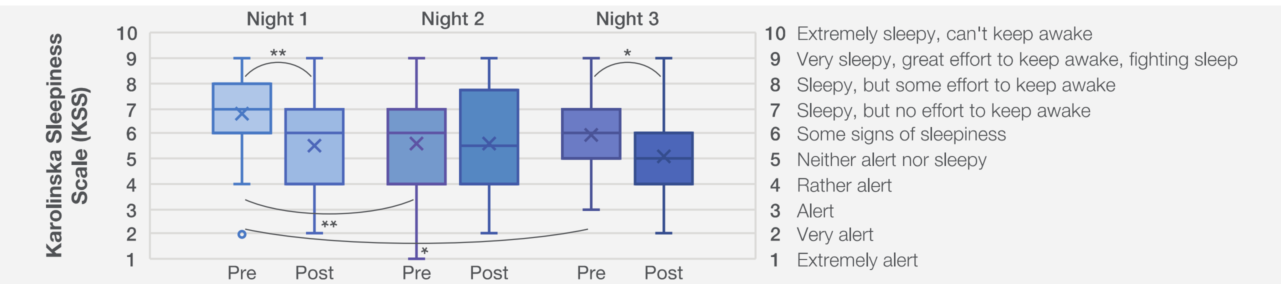

Figure 4: Distribution of KSS alertness/sleepiness scores per pre- and post-night (n=41). Lower post- than pre-night KSS scores are considdered better. Significant difference is stated as follows: * = p ≤ 0.05, ** = p ≤ 0.01.

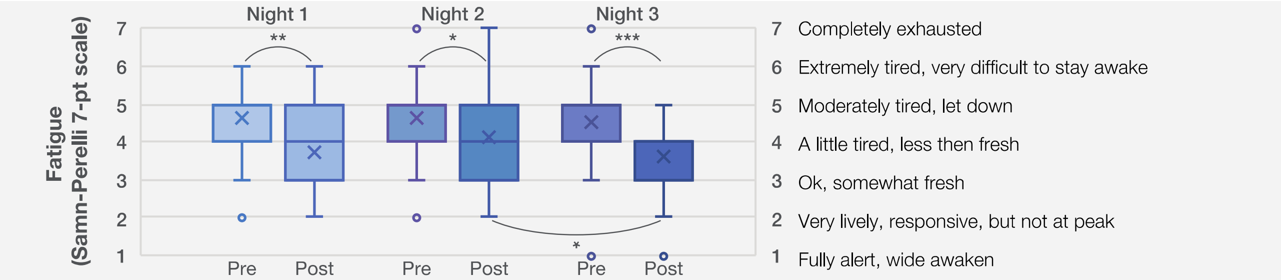

Figure 5: Distribution of SPFS scores per pre- and post- night (n=41). Lower post- than pre-night fatigue scores are considdered better. Significant difference is stated as follows: * = p ≤ 0.05, ** = p ≤ 0.01, *** = p ≤ 0.001.

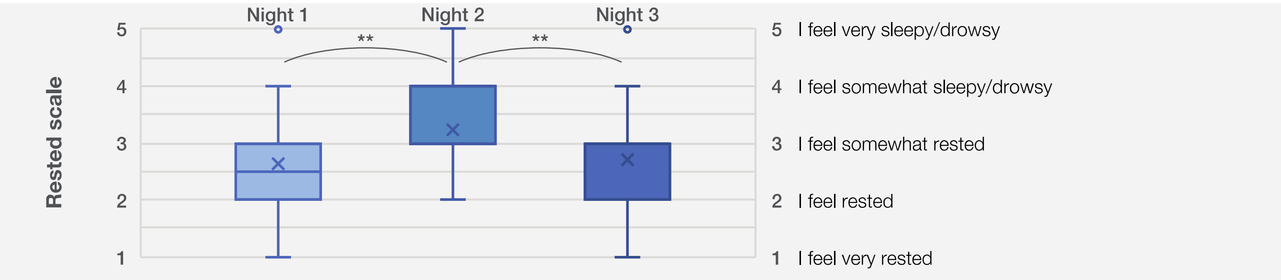

Figure 6: Distribution of rested after night scores per night (n=41). Lower rested scores are considdered better. Significant difference is stated as follows: ** = p ≤ 0.01.

Discussion

This study shows that reducing the sleep space envelope influences (dis)comfort, sleep quality and sleep effectiveness. Participants were able to sleep in all three conditions, but sleep quality (PSQI), sleep effectiveness (KSS, SPFS and Rested scales) and comfort were rated lowest, and discomfort rated highest in the limited space of 170 x 70 cm (night 2). The lack of significant difference in alertness-sleepiness (KSS) between pre- and post-night 2, and the significant higher post-night fatigue (SPFS) and significant lower 'rested' score for night 2 compared to night 3 indicate a limited recovery and thus limited effectiveness of the night 2 sleep. The minimal space designed by the participants (night 3) also showed significant lower comfort and significant increased discomfort than the own bed (night 1) (although to a significant lesser extent than night 2), but the sleeping quality (PSQI) and sleep effectiveness (KSS, SPFS and Rested scale) scores were not significantly different between night 1 and 3, despite the space envelope reduction. What stands out is the minor difference in space envelope reduction between night 2 and 3 (30% versus 25% reduction compared to an average one person bed of 190 x 90 cm), while night 3 scored significant better on (dis)comfort, sleep quality (PSQI) and sleep effectiveness (SPFS and Rested scales) than night 2. This makes the space reduction in the average minimal space designed by the participants of 166 x 78 cm for night 3 possibly more acceptable for the benefit of space reduction while limiting the negative impact on comfort, sleep quality and sleep efficiency. These results also show that tweaking the dimensions can significantly improve the comfort, sleep quality and sleep effectiveness with still a quite similar reduction in space envelope.

This study was conducted with a limited population size (n=41) and limited variation in age (range of 20-28y). As older age groups have different sleep behaviour than younger age groups (De Koninck, Lorrain, & Gagnon, 1992; Luca et al., 2015), generalising the data of this study should be done with care. In future research, older populations should also be included. This study was also limited as only 2D rectangular spaces were used, whereas non-rectangular and 3D shaped spaces could have resulted in more space reduction (e.g. combining multiple beds next to each other with non-rectangular spaces and/or stacking on top of each other could create possibilities to have more passengers sleep comfortably in a minimal space envelope) with the same comfort and sleep quality. Different minimal sleep space designs, movement patterns during sleep and anthropometrics, and their relation to sleep quality and (dis)comfort need to be investigated further.

There could be an order influence, as the conditions were sequential, but this was on purpose: by experiencing the reduced space (night 2) compared to their normal bed (night 1), participants were made aware of the consequences of space reduction in both length and width, allowing them to make a motivated redesign based on their own experience for night 3. However, as night 2 generally resulted in a reduced recovery, it could have influenced the PSQI, KSS, Samn-Perelli 7-pt fatigue scale and rested scores of night 2 and sequential night 3. This study is also only based on subjective data, as sleep quality was self-reported. Further research might include objective polysomnography (PSG) to measure sleep quality and sleep efficiency.

Conclusion

Sleeping in a limited space is possible (as shown in this experiment), however the quality of sleep and comfort are significantly lower and discomfort significantly higher in the limited space. Tweaking the 2D dimensions of the reduced space can limit the negative impact on sleep quality and (dis)comfort.

Further research on minimal space envelope design (non-rectangular and 3D) and its influence on sleep quality and efficiency (preferably with PSG), and comfort are needed, where also sleep behaviour (Smulders & Vink, 2020), sleeping postures and movement, and anthropometrics should be taken into account.

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