Which design features differentiate expectations in automotive seating comfort? A mixed methods approach

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ABSTRACT

The study built on previous work and earlier findings where it asks the question which seating design elements in particular are effective in differentiating expected automotive seating comfort. Two hypothesis were tested with a mixed methods approach 1) that automotive seats with triangular integrated headrests and angular shape characteristics lead to a holistic evaluation strategy for consumers, and 2) for seats that displayed padded areas which were deemed more comfortable would afford more localised attention hotspots. Twenty seven participants were asked to evaluate 15 automotive seat designs. Participants were asked to evaluate in terms of comfort. The seats were evaluated using a combination of methods and measures: gaze behaviour, subjective emotional responses and mark-up by participants on images followed by card sorting. The cumulative heat map plots across the different designs showed that a considerable amount of visual attention was focused on the *shoulder support* and *the lumbar upper back support areas*. Significant main effects as a function of design on expected automotive seat comfort and emotional response were found.

KEYWORDS

Comfort perception, design attributes, visual evaluation, automotive seating

Introduction

Automotive seat comfort is a key attribute in consumer satisfaction surveys, hence plays a significant role in repurchases and on vehicle loyalty (J.D. Power 2017). The concept of comfort is regarded as a highly subjective and multi-faceted experience, affected by numerous factors and emotions (Helander 2003, Vink, Hallbeck 2012, Vink, Overbeeke et al. 2005). Underlining that in current literature comfort and discomfort are treated as two different constructs, Vink and Hallbeck (2012) provided the definition of comfort as "...pleasant state or relaxed feeling of a human being in reaction to its environment". Helander (2003) demonstrated that sitting comfort not only pertains to physical but also visual characteristics in office chairs. Similarly, de Rouvray et al. (2008) also found that the visual sense is the predominant sense in a user's evaluation in office chairs. Thus, the appearance of a product not only influences the aesthetic value of a product, but also the perceived functional and ergonomic values (Bloch 1995).

Our previous research has shown that the mere appearance of physically identical automotive seats significantly affects perceived comfort (Erol et al. 2014). In this context, Erol et al. (2020) investigated the effects of appearance on comfort impression with 38 automotive seat designs from a premium automotive manufacturer. The study focused on the major descriptors established in the seating comfort literature (Pinkelman 2014); *Sporty, Comfortable, Luxurious* and established a

taxonomy of design attributes that potentially affects comfort perception. The findings indicated that for the descriptors of Comfortable and Sporty with various seat designs lead to a repeated categorization effect where the headrest and integration with the shoulder support was the most significant attribute. It was observed that the family of seats with identical physical dimensions but with differing features (e.g prominence, details) led to very different evaluations. The findings led to the hypothesis that seats with triangular integrated headrests and prominent shoulder support with angular shape characteristics lead to an overall holistic perception of category e.g. sporty, standard etc. In comparison the seats that possessed padded cushions and patterns would afford more localised attention and therefore hotspots for comfort assessment.

As stated by Bloch (1995), designers decide and make choices on characteristics e.g. shape, scale, proportion, materials etc. and create a coherent whole that form products. The amount of change in size and the properties of a feature inferred by the consumer is an important parameter leading to an overall customer preference for any product (Du and MacDonald 2014). Orquin and Loose (2013) specifically have indicated that eye movements during decision making are both controlled by top down and bottom up processes. They have also indicated that fixated information influences decision making more than non-fixated information, where decision makers' trade-off between fixations and working memory. In this perspective one has to bear in mind that, gaze allocation does not have a direct causal effect on preference formation, however it might be informative with regards to assessment strategies for consumer preferences (Orquin and Mueller Loose 2013). Köhler, Falk and Schmitt (2014a) findings suggested that eye tracking as a methodology reveals the "perception clusters" where the consumer when viewing products which mainly depended on the complexity of the studied product. It could be argued that a similar approach could yield areas with distinct elements or containing higher information are effective in comfort evaluation (Köhler, Falk and Schmitt 2014a; Köhler, Falk and Schmitt 2014b).

Aim of the study

The main aim of this study was to understand which seating design elements (e.g. head rest, backrest) were important in determining perceived seating comfort assessed on the basis of images. It was hypothesised that structuring or virtually disassembling the seat into its subcomponents had a potential to reveal which segments of an automotive seat bear the highest importance when the consumers' is evaluating comfort based on visual information. In an attempt to answer this question, the study was conducted using a mixed methods approach.

Methods

An unobtrusive eye tracker capable of recording the position of the eyes at a sampling rate of 300 Hz was used in order to assess the participants' gaze behaviour for the implicit measures (Tobii TX300, Tobii, Sweden). A total of 27 participants (13 male, 14 female; convenience sample) took part in the study and were asked to evaluate a high resolution monochrome image set of automotive seats from a premium automotive manufacturer.

Experiment Protocol

Participants were asked to sit at a distance of 65 cm from the monitor and to move as little as possible with the aid of a chin rest. The images were presented on a 23" Tobii TX300, 1920 x 1080 pixel monitor in a controlled usability lab environment. The seat image size on screen was approximately 22 x 14.5 cm. Fifteen seat images were displayed for 10 seconds each and the participants were asked to" look for comfort" for each of the stimuli. The image display sequence was randomized for every recording. After the initial eye tracking capture session, each seat image were re-displayed on the screen individually for the explicit measures; ratings with emotional response scales and scale items. For each stimuli, participants were asked to use Self-Assessment

Manikin (SAM) scale (Bradley and Lang 1994) to rate their emotional response to the different designs using the valence and arousal dimensions on a 9-point scale. They were also asked to rate perceived "comfortable" item for each stimulus using a Likert scale ranging from; 1: Not at all to 7: Extremely. After each rating carried out, they were asked to utilise an iPad to mark-up & annotate on the seat image. The participants were asked to indicate the features that they thought to be the most effective in the assessment whilst looking for comfort. During the mark-up, they were motivated to draw on features or areas in any way they like (free interaction) to highlight the features. Finally, participants were asked to rank order the seats from most to least comfortable or according to their "comfort preference". Each of the 15 seat images was printed on 12 x10 cm cardboard card and participants were given as much time as they needed to rank order the seats. The whole procedure of data collection and sorting exercises took approximately 1hr to complete.

Results

Out of the 27 participants, 3 female participants were omitted form the eye tracking analysis, where there was a cut off of minimum 75% capture rate for the gaze data. The recordings of 24 (13 male, 11 female) participants were analysed. Three participant recordings were not captured effectively for the duration of exposure of the 15 seat images, where weighted gaze samples of percentages were lesser than the advised recording capture for both eyes.

Determination of areas of interest (AOI)

Gaze behaviour and fixation count/duration in predefined square Areas of interest (AOI), i.e. headrest, shoulder support, back/lumbar, seat pan were analysed. Automotive seats tend to be divided into several regions based on both occupants' support and stylistic requirements. The rationale in the selection of the AOI regions took in to consideration the body-parts supported by each partition of the seats (see figure 1) and the relative body discomfort mapping scales used for physiological assessment based on the literature studies (Mergl et al. 2006).



Figure 1: Pre-determined Areas of Interest (AOI) for statistical analyses between the seat designs.

Heat map analysis

The cumulative heat map of each plate for all 24 subjects on the 15 seat images are presented in the Appendix. These cumulative heat map plots on the 15 stimuli seat images shows that when viewing seat designs, a significant amount of attention was focused on the 1) shoulder support partition, 2) back-lumbar support partition (see figure 2; red indication of higher counts) of the seat design attributes. The heat map plots in this study also suggest that when the participants were asked to "look for comfort", the comparison and attention on the 15 stimulus presented in three quarter (¾) views was mostly focused on the central axis of the seats that can be observed from the cumulative heat map plots (see Appendix).





Figure 2: A4 RS4 Sport seat design (left) and cumulative heat map plot (right).

AOI analysis of eye tracking metrics

In order to assess if the eye tracking capture data was fit for statistical analysis, the metrics for the whole seat image area which consisted of all the gaze data for each seat was subjected to scrutiny with SPSS. There were no statistically significant differences for the gaze metrics of fixation counts (FC) and fixation durations (FD) amongst the 15 seat stimuli over the 9.6 seconds of exposure. This meant that the eye tracking capture was homogenous for all seats and the data was sound for further statistical testing of AOIs.

Chi square goodness of fit tests revealed significant main effects of seat design for fixation counts (FC) for the *headrest* AOI (χ 2 (14) = 57.23, p< .0001), *shoulder-upper back* AOI (χ 2 (14) = 33.8, p< .005) and *seat pan* AOI (χ 2 (14) = 31.12, p< .005). Hence the *seat back-lumbar support* AOIs had the highest FC counts across all the seat designs. The Chi square goodness of fit test did not yield any significant main effects for the fixation durations (FD). There was no significant effect for the number of fixation counts (FC) for the *lumbar support-side bolsters* AOI hence did not differ across the different seat designs. However it has to be reported that the highest mean FC were in this AOI across the seat designs. A mixed linear model analysis of the FC were carried out as this approach does permit the ANOVA analysis with the missing values for AOI data.

The number of fixation counts (FC) for the *headrest* AOI differed across the different seat designs and the effects were found to be statistically significant ($F_{(1,14)}$ =2.93, p <.001). Post-hoc multiple comparison analyses showed that for the main effects the fixation count for showed that the mean difference for the *A7 Standard* was significantly higher than *A5 Comfort*, *A5 RS5 Comfort*, *A5 standard*, *A6 comfort*, *A6 sport*, *A8 standard*, and *TT standard* seat designs (p < .0033, Bonferroni correction applied).

The number of fixation counts (FC) for the *shoulder-upper back AOI* differed across the different seat designs and this effect was found to be statistically significant ($F_{(1,14)} = 2.69,p < .005$). Post-hoc analyses (Bonferroni) showed that the fixation count mean difference was significantly higher for the *TTRS sport* seat than *A5 comfort*, *A5 RS5 Comfort*, *A8 sport*, *A8 standard and A8 comfort* seat designs (p< .01).

The number of fixation counts (FC) for the *seat pan AOI* differed across the different seat designs and this effect was found to be statistically significant ($F_{(1,14)}$ = 2.9, p < .001). The post-hoc multiple comparison tests held for the 15 seats pairwise analyses showed that *A4RS4* sport seat received significantly *lower* fixations in comparison to *RS6 seat design*, *A5 standard* seat (p<0.003) and *A6 comfort* seat pan designs.

Affective response: Self-assessment Manikin & Comfort rating

The results of the 27 participants were analysed for affective SAM responses (see table 1). The non-parametric Friedman 2-way ANOVA tests revealed significant differences across the different seat

designs along the valence dimension (χ^2 (14) =50.1, p<0.01). Post-hoc pairwise analysis indicated *A6 sport* seat design was rated significantly lower than two other seats in the set. Hence the *RS6 Sport* seat with the integrated headrest, prominent shoulder support and quilt design was significantly rated higher than *A8 sport*, *A6sport*, *TTRS sport*, *A5 standard*, *A8standard*, *A8 Comfort* in participants' responses.

Table 1: The most and the least mean values for the valence and arousal dimensions and corresponding seat designs

Affective Response	Highest	Lowest
Valence	RS6 Sport seat	A6 Sport seat
(1:Least – 9:Most)	(Mean=6.40,SD=1.59)	(Mean=4.33,SD=1.9).
Arousal (1:Least – 9:Most)	RS6 Sport seat (Mean=5.70,SD=2.12)	A6 Sport seat (Mean=3.78,SD=1.84)

The arousal dimension was also significant (χ^2 (14) =66.6, p<.01), with post-hoc analysis again indicating the particular seat design rated as significantly higher than the others in the set. In this case, the *A5/RS5Sport* seat and *RS6 Sport* (p<.01) with *integrated head rest -shoulder support* area appeared to be the main driver for this effect when considering *RS6 Sport* having also the highest valence rating. For the "comfortable" scale item, non-parametric test (χ^2 (14) =36.3, p<.01) was significant, where the post-hoc pairwise analysis indicated the *RS6 Sport* seat was again found significantly more comfortable than the *A6 sport* seat design (p<.05) (see table 2)

Table 2: The most and the least mean values for the valence and arousal dimensions and corresponding seat designs

Item Response	Highest	Lowest
Comfortable	RS6 Sport seat	A6 Sport seat
(1: Not at all – 7: Extremely)	(Mean=5.26,SD=1.29)	(Mean= 3.89,SD=1.34).

User Participatory Mark-up/annotation Approach

The mark-ups were subjected to frequency count analysis; i.e. how many times they had been marked was reported on the basis of the pre-defined AOIs of the eye tracking for comparison. The initial frequency counts interpreted from the mark-up results for the *shoulder-upper back support* area subjected to chi square tests ($\chi^2(14) = 22.7$, p = .08) in combination with eye tracking results appeared to act as the main differentiator between the seat designs.

Certain participants also provided comments, where A4RS4 Sport and TTRS Sport seat which have similar integrated headrest and shoulder support area received comments on how "alien" and "futuristic" it looked. However there were divided opinions expressed as to indicate the "cut-outs" in the back were not received well. RS6 Sport seat and RS7 Sport received comments on how the headrest looked sculpted and the quilt insert design as being a major attribute when they were evaluating the seats. A6 sport and the A7 Standard seat received comments on how plain-dull the seats looked on the back support. Hence A7 Standard was also commented on how "blocky" headrest appeared and out of sync with the design.

Rank order statistics

The rank order data of the seats have also been subjected to non-parametric Friedman tests. The comfort preference ranking amongst the seat designs varied significantly (χ^2 (14)=51.33, p<.001). For the total sample of participants, A5 RS5 Comfort (Mean = 10.33, SD= 2.97) and the A5 RS5 Sport seat (Mean = 10.19, SD= 3.89) were ranked the highest. The A7 standard (Mean = 5.81, SD=4.1) seat was the lowest out of the 15 designs. Hence post hoc pairwise comparisons revealed that both A5 RS5 Comfort and A5 RS5 Sport seats were significantly ranked higher than A7 standard (p<.05), A6 Sport (p<.05) and A8 comfort seats (p<.05) with bonferroni correction applied.

Discussion

The main aim of this study was to understand which seating design elements (e.g. head rest, backrest) were important in the assessment of the perceived seating comfort on the basis of seat images. The utilisation of the eye tracking was sought as an asset to analyse and determine the importance of the seat features. The cumulative heat map plots revealed that when viewing seat designs, a significant amount of attention was focused on the *shoulder support – upper back* area. Orquin and Loose (2013), argued that attention is directed towards information with a greater utility or importance to their decision termed as the "utility effect". It can be argued that in this study *headrest-shoulder upper back support* areas possess these effects in the visual comfort assessment (Orquin & Loose 2013, 190-206). The heat map plots in this study also suggested that the comparison and comfort evaluation within the sequentially presented fifteen stimuli was mostly focused on the central axis of the seats, hence this was not something expected and is a novel finding in automotive seat research. As displayed by the cumulative visual scan paths it can be argued that, the generic scan paths and the peripheral vision around this axis offered an efficient means of search for comfort cues.

In order to test for hypotheses posited in the beginning of the study, AOI analysis was carried out across the different seat designs with fixation Counts (FC) and fixation duration (FD) metrics. The fixations counts yielded significant differences. *A7 Standard* had significantly higher fixations on the headrest AOI than 7 other seat designs. This could be interpreted in conjunction with the comments and mark-ups as particularly indicative of the shape of the headrest and the backrest design were incongruent and led to questioning of the comfort at that particular area. Some subjective comments in the mark-up/annotation task revealed that explicitly the *A6 sport seat* headrest were found "blocky".

As argued by Du and Macdonald (2016) the number of fixations (FC) necessary to complete a task is related to the information density of the area. Hence the analyses revealed an overall significant main effect of seat design (features) for the *head rest*, *shoulder support* and *seat pan* AOIs. Behe et al. (2015) argued that understanding which elements first capture and then hold visual attention aids in assessing the role of product display elements in consumer choice. Based on the findings in this study, it can be argued that the cut outs and extensive shoulder supports are particularly counter intuitive for the comfort perception for a number of participants who have commented as "not liking", "constricting", "alien" and too "futuristic" looks. Extreme sporty seat designs having features such as the cut out holes in the back of the seat may have influenced the results on fixations and attitudes where most advanced yet acceptable (MAYA) effect can be deemed affective in this sense (Hekkert, Snelders and Van Wieringen 2003). The acceptability showed variation as per participants' comments differing in a bipolar fashion; like or not like. This is in contrast to Lee et al. (2018) findings in sitting pressure mapping experiments, as they found no significant relationship to emotional responses in shoulder –upper back support area and "hugging" feeling.

Furthermore in terms of *valence* and *arousal* responses, particularly one seat design *RS6 Sport* seat was significantly rated higher than the *A6 sport seat* design. The same significant outcome for the

basic overall comfort evaluation for the same pair of seats indicated that a pleasing and exciting design created a positive emotional attitude, which arguably affects the comfort evaluation in the same positive way. This outcome was congruent with the hypothesised conceptual model in earlier studies (Erol et al. 2016). In terms of design features, the *RS6 Sport* seat had particularly softer design features, quilt inlays in the *seat back-lumbar support* and *seat pan* area in comparison to the *A6 sport seat* design which only has flat flute designs and a blocky head restraint design. Specifically as per the subjective comments the participants to perceive the *A6 sport seat* more flat, firm and "not much of a great design". It is important to note that these two seats belong to the same car segment and shows the significance of the design differentiation.

At the end of the protocol, when participants were asked to do a preference ranking, the results yielded a significant difference where *A5 RS5 Comfort* and *A5 RS5 Sport* seat were ranked higher than *A7 standard*, *A6 Sport* and *A8 comfort* seats which displayed less prominent bolsters and separate headrests. As per ranking results, it can be argued that the backrest shape with prominent shoulder support- integrated headrest guided a *categorisation effect*; primarily in terms of a "design" element hierarchy. It can be further argued that significant evidence accumulation and comparison took place in headrest-shoulder upper back support area when making a trade-off decision.

It is important to point out, given the exploratory nature of the present study, that there were a number of limitations in the interpretation of the eye tracking data. For future studies, it can be argued that rather than a priori AOI determination (pre-set areas kept constant throughout fifteen seat designs), as proposed by Köhler et al (2014b) AOIs can be assigned relevant to the "perception clusters" post data collection. This might enable better comparison of the highest heat map count areas for further analysis of corresponding design features. The findings from this study indicates that consumers looking at a seat did not look at every single part of the product rather to a specific group of areas. Hence the "clusters of perception" corresponded to certain design features when "looking for comfort" which may also have led to "anticipation of discomfort" e.g. *A6 Sport seat* headrest design.

Conclusion

The present study has found significant main effects as a function of design on expected automotive seat comfort and emotional response. Eye tracking may pose a potential to identify the components utilised in comparing the designs, however the mixed method approach is vital in determining the importance of the attributes with regards to comfort. In this context, the quantitative data and qualitative responses together enabled the identification of the design features that differentiated the seats in terms of comfort evaluation. The eye tracking results and the mark-up task led to the conclusion that the *shoulder support area* and *the lumbar upper back support areas* receive the most attention. Furthermore, individual ratings identified two clear results for the "best" and the "worst" design within the seat sample used, which indicates *RS6 sport* seat design with its prominent shoulder supports and quilt inserts lead to higher expectations of comfort when individually assessed. In contrast ranking results yielded a categorisation behaviour, where the perceived sportiness of a seat lead to a trade off in comfort preference, indicating that the global versus local attention to design cues are in effect. For future studies in order to determine how much importance is associated with the particular design features identified in this study, the controlled manipulation of the features as individual parameters is necessary.

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Appendix. Fifteen stimuli utilised in the study

A4 RS4 Sport	RS7 Sport	RS6 Sport
A5 RS5 Sport	TTRS Sport	TT Standard
A8 Standard	A8 Comfort	A8 Sport
33		
A6 Comfort	A5 Standard	A5 comfort
A5 RS5 Comfort	A6 Sport	A7 Standard

Cumulative heat map plots for each of the stimulus (N=24)

A4 RS4 Sport	RS7 Sport	RS6 Sport
A5 RS5 Sport	TTRS Sport	TT Standard
A8 Standard	A8 Comfort	A8 Sport
A6 Comfort	A5 Standard	A5 comfort
A5 RS5 Comfort	A6 Sport	A7 Standard