Cognitive Psychology in Mechanical Design: Perception of Comfort Across Chair Inclines

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Abstract

This study investigates how changes in backrest angle influence users' perceptions of comfort, balance, and appeal. Six digital chair configurations (85°, 95°, 105°, 115°, 125°, and 135°) were shown to fifty participants, who rated each on a 1-5 scale. Mean ratings showed a rise from the upright position, a peak in the mid-recline range, and a decline at higher angles. Polynomial regression, Wilcoxon tests, and the Coefficient of Variation measures confirmed that these differences were consistent and statistically meaningful. The results identify 105°-115° as the range most positively rated across all variables.

Keywords: Human-centred design; Ergonomics; Backrest inclination; Comfort perception; Mechanical design; Cognitive psychology; Chair geometry; User experience; Seating biomechanics; Postural stability; Aesthetic appeal; Perceived balance; Backrest angle; Statistical modelling; Polynomial regression; Wilcoxon signed-rank test; Coefficient of variation; Correlation analysis; Visual perception; Design optimisation; Product ergonomics; Anthropometrics; Mechanical-psychological interface; Consumer perception.

2. Introduction

Mechanical Engineering is often perceived as the study of machinery and industrial systems. However, the common eye overlooks an equally important branch – human-centered engineering. It prioritises human needs, behaviors – physical and mental – and context in the engineering design process. A simple everyday object like a chair is not only a static structure; it is a system where forces, angles, and human perception intersect. The way a backrest varies in angle can change not just how a body balances, but how the user feels supported and focused.

This paper investigates how the geometric design variable of inclination affects the perception of human comfort, stability, and appeal. Using six digital chair configurations (85°, 95°, 105°, 115°, 125°, and 135°), it analyzes how small angular changes alter the three factors through perception. Previous mechanical and ergonomic studies have already shown that seat and backrest angles influence physical loads on the body. For example, a recline of about 105° produced optimal subjective comfort and reduced spinal pressure [Lyu et al., 2025]. Office-based studies further confirmed that differences in seat and backrest angles can measurably change comfort and work performance [Groenesteijn et al., 2009].

Only a few studies have explored how people perceive mechanical changes in backrest angle or how their feedback can inform better design [Li et al., 2021]. This highlights a gap between mechanical design principles and human perception, as standards such as ISO 9241-5 define ergonomic and postural requirements but offer little insight into how users experience comfort in practice.

By combining user-rating data with statistical methods such as correlation and regression analysis, this study links variations in chair angle to user-perceived comfort and balance. Psychological comfort in this context is inferred from these ratings, which reflect how balanced and supported participants felt when viewing different chair angles. The results show that changes in backrest inclination correspond to consistent changes in perceived comfort, suggesting that psychological comfort arises from physical stability and load distribution rather than personal bias or preference. In this way, the study connects a simple mechanical variable to human perception, showing how even small geometric differences can influence how comfort is experienced.

3. Methodology

3.1 Experimental Design

Six digital chair configurations were set at angles of 85°, 95°, 105°, 115°, 125°, and 135°, and allocated letters A, B, C, D, E, and F with their set angles respectively, so that only the backrest inclination changed while all models had identical seat height, depth, and overall proportion. Each configuration represented a static seated condition in which the body's weight and the reaction forces from the seat and backrest would vary depending on the angle. The selected range included both upright and reclined positions to capture how different inclinations influence perceived comfort and balance. This setup isolated the backrest angle as the single variable being tested.

3.2 Participants and Procedure

Fifty participants voluntarily took part in the study through a Google Form online survey. The survey displayed six chair configurations in increasing angle order (shown in Figure 1). For each configuration, participants rated Comfort, Balance, and Aesthetic Appeal on a 1–5 scale, where 1 represents the lowest score assigned to a factor (e, 1 for comfort = Very uncomfortable) and 5 represents the highest score assigned to a factor (eg,5 for appeal = Very appealing). No personal information, such as name, age, or location, was collected; only numerical ratings were recorded. This method allowed subjective impressions to be expressed as quantitative data that could be compared and analyzed systematically.

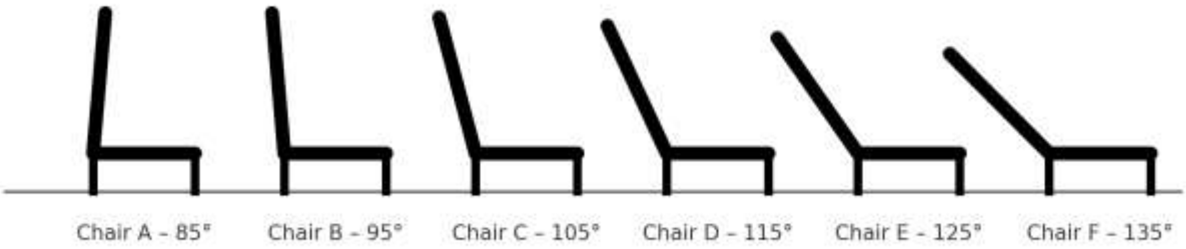

Figure 1

3.3 Mechanical Rationale

Changing the backrest angle affects how a seated person's weight is supported between the seat and the backrest. At lower angles such as 85° and 95°, most of the body weight would act vertically downward, creating a more upright and stable posture. As the angle increases, a larger share of that weight would be directed toward the backrest, reducing vertical pressure but slightly lowering the sense of stability. Each participant's comfort, balance rating represents their perception of how well these forces might be supported at each angle. Since every other visual factor in the chairs remained identical, any difference in ratings reflects the effect of changing the backrest inclination alone.

3.4 Statistical Framework

Measures of Central Tendency (Mean, Median, Mode)

The mean, median, and mode of each angle's ratings were calculated to summarize participant responses. The mean provided the overall trend, the median represented the midpoint of opinion, and the mode showed the most frequently selected score. These three values together offered a complete view of how comfort and balance shifted with changes in inclination.

Standard Deviation

Standard Deviation was calculated for each configuration to understand the consistency of participants' responses. Lower values indicated stronger agreement, while higher values reflected differing opinions and perceptions among participants.

Pearson's Correlation Coefficient

Correlation analysis provided an insight into the relationship between comfort, balance, and appeal ratings. Positive correlations suggested that as comfort increased, balance and visual satisfaction tended to rise as well. The table below (see Figure 2) was used to classify the strength of the positive correlations discovered.

Value of Coefficient	**Relation Between Variables**
0.70-1.00	Very Strong Association
0.50-0.69	Substantial Association
0.30-0.49	Moderate Association
0.10-0.29	Low Association
0.01-0.09	Negligible Association

Figure 2
Source: Alwadael (2010)

Polynomial Regression (Second Degree Curve Fitting)

A second-degree polynomial regression model was applied to analyze how comfort, balance, and aesthetic appeal ratings changed with increasing chair angle. The quadratic model was chosen as the relationship between angle and perception was expected to be non-linear, with the perception of a factor likely rising to a certain point before decreasing. The regression generated a smooth parabolic curve that best fit the average ratings for each configuration. This approach enabled the identification of the approximate angle range that produced the highest comfort values, indicating a balance between upright support and reclined relaxation. The resulting trendline provided a mathematical way to describe how mechanical inclination corresponds to user perception.

Wilcoxon Signed-Rank Test

The Wilcoxon Signed-Rank Test was used to compare comfort ratings between configurations to determine whether the change in perception across these distinct postures was statistically significant. This method was chosen because it provides a reliable comparison between two related groups without assuming a specific data distribution.

Coefficient of Variation (CV)
The coefficient of variation was calculated by dividing the standard deviation by the mean for each set of ratings. It was used to evaluate the relative consistency of participant responses across different backrest angles.

3.5 Assumptions and Limitations

It was assumed that participants viewed chairs under similar conditions, such as screen size, lighting, and posture. The experiment depended fully on visual judgement, so no real seating or force measurement was involved. The results capture participants' visual impressions of comfort and balance, not the physical mechanics of seating or load transfer. Long-term sitting effects, fatigue, and posture adjustments were not considered. Although demographic information was not collected, this ensured anonymity and kept the focus solely on perception. Despite these limitations, the results provide a clear indication of how changes in backrest angle influence user comfort, balance, and appeal.

4 Results and Discussion

Several statistical methods, such as Mean, Median, Mode, Standard Deviation, Pearson's Correlation Coefficient, Polynomial Regression, Wilcoxon Signed-Rank Test, and Coefficient Variation (CV), were calculated to strike a relationship between multiple variables.

The figure below (see Figure 3) shows the measures of central tendency for comfort. All three statistical methods display a similar pattern – an increase in rating up to Chair C and then a decline. The lowest standard deviation was recorded at 105°, which shows that participants strongly agreed on Chair C being the most comfortable.

Chair	Mean	Median	Mode	Standard Deviation
A (85°)	1.98	2	1	1.18648856
B (95°)	3.5	3	3	1.035098339
C (105°)	4.08	4	4	0.6651683844
D (115°)	3.54	4	4	0.9082389329
E (125°)	3.14	3	2	1.245563556
F (135°)	2.76	2	2	1.422271825

Figure 3

The figure below (see Figure 4) shows the measures of central tendency for balance. However, a different trend is observed – all three descriptive statistics show an increase in rating up to Chair B and then a consistent decline. The lowest standard deviation was recorded at 95°, which shows that participants strongly agreed on Chair B being the most stable.

Chair	Mean	Median	Mode	Standard Deviation
A (85°)	2.86	3	2	1.229069666
B (95°)	4.18	4	5	0.849729849
C (105°)	3.96	4	5	0.9026039428
D (115°)	3.34	3	3	1.022402133
E (125°)	2.84	2.5	2	1.330336769
F (135°)	2.4	2	1	1.456862718

Figure 4

The figure below (see Figure 5) shows the measures of central tendency for appeal. A similar trend is observed relative to the ratings for comfort (see Figure 3), where there is an increase in ratings up to Chair C and then a decline. The lowest standard deviation was recorded at 105 °, which shows that participants strongly agreed on Chair C being the most appealing.

Chair	Mean	Median	Mode	Standard Deviation
A (85°)	2.04	1	1	1.44222051
B (95°)	3.34	3.5	4	1.303214237
C (105°)	3.88	4	4	0.9178501945
D (115°)	3.24	3	4	1.187691982
E (125°)	2.7	2	2	1.432138404
F (135°)	2.12	1	1	1.46580061

Figure 5

After analyzing the measures of central tendency, correlation analysis using Pearson's correlation coefficient was conducted between comfort, balance, and appeal with respect to the angle of the chair. Since all three variables describe aspects of the same geometric experience, examining their association helps determine whether users perceive comfort purely as mechanical balance or also as a visual or emotional response to chair design.

Chair A Correlations	Comfort vs Balance	Balance vs Appeal	Comfort vs Appeal
Pearson's Coefficient (r)	**0.5018502558**	**0.5673701081**	**0.6802808009**

Figure 6: Correlations for Chair A

Chair B Correlations	Comfort vs Balance	Balance vs Appeal	Comfort vs Appeal
Pearson's Coefficient (r)	**0.4292528254**	**0.4780542701**	**0.6581058473**

Figure 7: Correlations for Chair B

Chair C Correlations	Comfort vs Balance	Balance vs Appeal	Comfort vs Appeal
Pearson's Coefficient (r)	**0.1414061914**	**0.2650618109**	**0.2500357536**

Figure 8: Correlations for Chair C

Chair D Correlations	Comfort vs Balance	Balance vs Appeal	Comfort vs Appeal
Pearson's Coefficient (r)	**0.3257093771**	**0.2675601382**	**0.3125431779**

Figure 9: Correlations for Chair D

Chair E Correlations	Comfort vs Balance	Balance vs Appeal	Comfort vs Appeal
Pearson's Coefficient (r)	**0.3910738054**	**0.2782557065**	**0.2563962886**

Figure 10: Correlations for Chair E

Chair F Correlations	Comfort vs Balance	Balance vs Appeal	Comfort vs Appeal
Pearson's Coefficient (r)	**0.4571770283**	**0.5741457101**	**0.6532646302**

Figure 11: Correlations for Chair F

Across all six chair configurations, the correlation values show a consistent pattern in how participants linked comfort, balance, and aesthetic appeal. All correlations were positive, indicating that when one aspect improved, the others tended to increase as well. The strongest relationships appeared for Chairs A, B, and F, where coefficients ranged roughly between 0.45 and 0.68. These values fall in the "substantial association" range (refer to Figure 2), suggesting that users perceive comfort partly through how stable the chair looks and how visually appealing it appears.

Chairs C, D, and E showed weaker correlations, with several values falling between 0.14 and 0.32. This indicates that at mid-range reclines, users judged each factor more independently. For example, a chair could look balanced but still not feel comfortable. The overall trend suggests that comfort is not a lone influence and ratings may be affected by visual impression and perceived stability, although the strength of this relationship varies with the angle.

To visualise how perceptions changed, the mean comfort, balance, and appeal ratings were plotted against backrest angles.

A second-degree polynomial trendline was fitted to each set of mean ratings to show the curved relationship between angle and perception, as illustrated in the figures below. All three regressions produced strong fits, indicating that the relationships were non-linear.

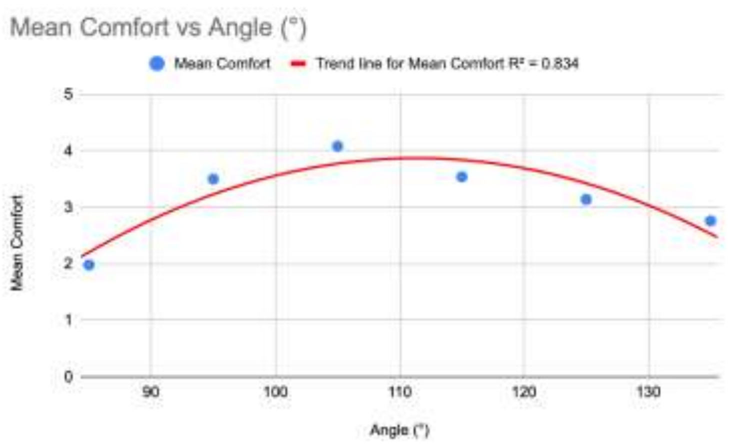

Figure 12: Mean Comfort Ratings vs Angle of Chair

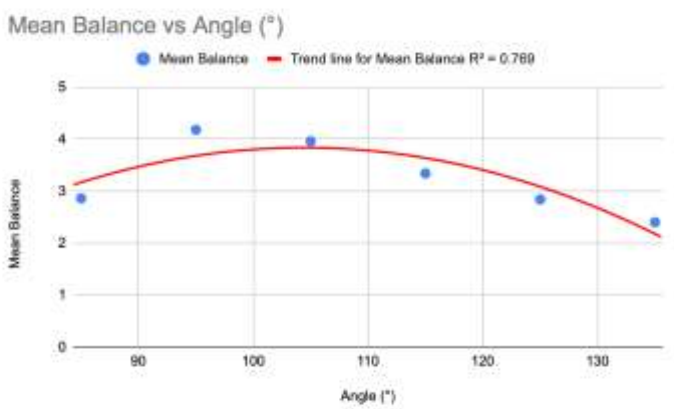

Figure 13: Mean Balance Ratings vs Angle of Chair

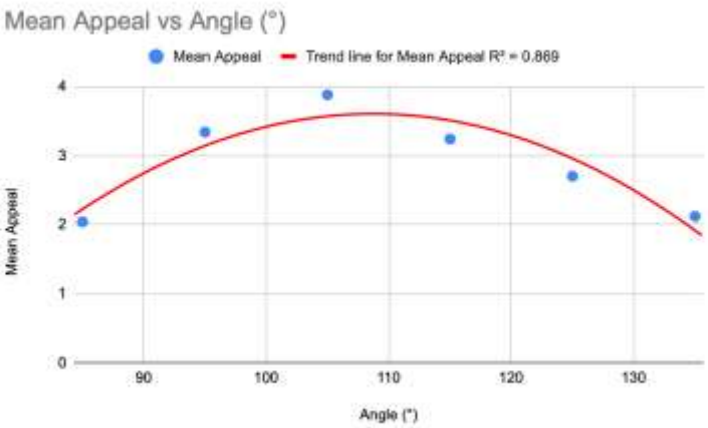

Figure 14: Mean Appeal Ratings vs Angle of Chair

Across all three comparisons, the curves showed the same rise and fall pattern with peak ratings occurring in the mid-recline region between approximately 100° and 110°. The regression models showed strong fits for comfort ($R^2 = 0.834$), balance ($R^2 = 0.769$), and appeal ($R^2 = 0.869$), confirming that participant preference was highest in this region and declined at both the upright and most reclined angles.

To examine whether the differences in ratings were statistically meaningful, the Wilcoxon Signed-Rank Test was used in two key comparisons: 85° vs 115° and 115° vs 135°. These pairs represented the largest observed change in comfort from upright to mid-recline, and from mid-recline to reclined configuration.

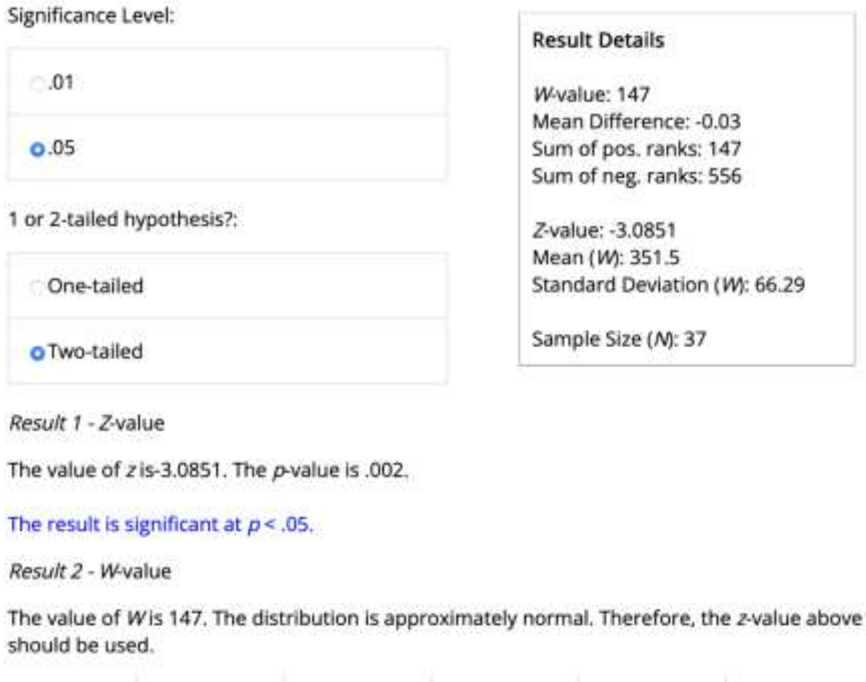

Figure 15: Comparison between 85° and 115° for the Wilcoxon Signed-Rank Test

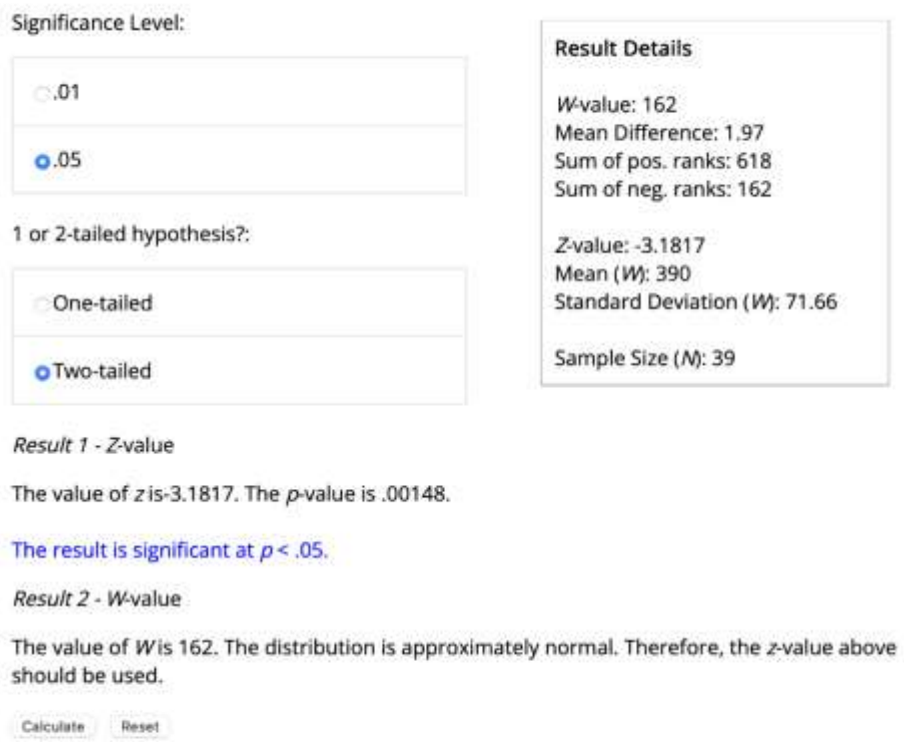

Figure 16: Comparison between 115° and 135° for the Wilcoxon Signed-Rank Test

The comparison between 85° and 115° produced a z-value of −3.0851 with a p-value of .002, indicating a significant increase in comfort at the mid-recline angle. The comparison between 115° and 135° also showed a significant result (z = −3.1817, p = .00148), confirming a meaningful drop in comfort at higher recline angles. These findings demonstrate that changes in backrest angle led to statistically reliable differences in how comfortable participants perceived each configuration to be.

The Coefficient of Variation (CV) was calculated for comfort, balance, and appeal across all six angles to compare the consistency of participant responses. CV expresses how much ratings varied relative to their mean, allowing clearer identification of angles where participants agreed most strongly.

Chair	Angle (°)	Mean (Comfort)	Standard Deviation (Comfort)	CV
A	85	1.98	1.18648856	0.5992366463
B	95	3.5	1.035098339	0.2957423826
C	105	4.08	0.6651683844	0.1630314668
D	115	3.54	0.9082389329	0.2565646703
E	125	3.14	1.245563556	0.3966762916
F	135	2.76	1.422271825	0.5153158785

Figure 17: Coefficient of Variation (CV) for Comfort

Chair	Angle (°)	Mean (Balance)	Standard Deviation (Balance)	CV
A	85	2.86	1.229069666	0.4297446386
B	95	4.18	0.849729849	0.2032846529
C	105	3.96	0.9026039428	0.2279302886
D	115	3.34	1.022402133	0.3061084232
E	125	2.84	1.330336769	0.4684284397
F	135	2.4	1.456862718	0.6070261326

Figure 18: Coefficient of Variation (CV) for Balance / Stability

Chair	Angle (°)	Mean (Appeal)	Standard Deviation (Appeal)	CV
A	85	2.04	1.44222051	0.7069708383
B	95	3.34	1.303214237	0.3901839032
C	105	3.88	0.9178501945	0.2365593285
D	115	3.24	1.187691982	0.3665715995
E	125	2.7	1.432138404	0.5304216311
F	135	2.12	1.46580061	0.6914153821

Figure 18: Coefficient of Variation (CV) for Appeal

Across comfort, balance, and appeal, the lowest CV values appeared in the mid-recline range, showing that participants were most consistent at these angles. At 105° and 115°, variation was noticeably lower than at the upright 85° and the deep 135° positions. Higher CV values at the extremes indicate disagreement between participants in how the angles were perceived. In summary, CV reinforces earlier findings by showing that the mid-recline configurations not only received higher ratings but were also judged more consistently across participants.

5 Discussions

The results from the analyses showed a consistent trend throughout: participant perception ratings were highest rn the mid-recline range. Comfort, balance, and appeal all increased as the angle increased from the upright position and reached their highest values between 105° and 115°. Going past 115°, ratings declined again, showing that both extreme upright and deep-recline positions were viewed less favourably.

The statistical tools used support this pattern from several different perspectives. Polynomial regression curves showed a strong fit for all three variables, confirming that the trends of increase and decrease were systematic. The Wilcoxon test demonstrated that the differences between the straight, mid-recline, and deep-recline conditions were statistically significant rather than coincidental. Coefficient of variation (CV) values were lowest in the mid-range, indicating that participants agreed more strongly at these angles than at the extremes. Correlation values also showed a moderate-substantial relationship between comfort, balance, and appeal, suggesting that these perceptions were linked but not identical.

Together, these results show that user comfort follows a predictable geometric pattern. When the angle moves toward the mid-recline region, the chair appears more stable and visually balanced, and this is reflected in higher and more consistent ratings. This suggests that early design decisions in chair development can rely on simple perceptual responses to identify favourable geometric configurations before moving to more detailed mechanical or ergonomic evaluations.

6 Conclusion

This study examined how changes in backrest inclination influence the way users perceive comfort, balance, and aesthetic appeal. Across all statistical measures, the results showed a consistent pattern: ratings increased from the upright 85° position, reached their highest values in the mid-recline range between 105° and 115°, and declined again at the deepest angle of 135°. The similarity of this trend across the mean ratings, regression curves, Wilcoxon comparisons, and CV values indicates that these differences were stable and meaningful rather than random. Overall, the findings suggest that moderate recline angles offer a favourable combination of perceived support and visual stability, making this region a useful geometric guideline in early-stage chair design.

7 Appendix and References