5. RESULTS

The R package bootES ("bootstrap Effect Sizes") (Daniel & Gerlanc, 2023) was used for the analysis and it was used the 'boot' package to find the bootstrap confidence intervals for both original scale (unstandardized) and normalized across different scales (standardized) effect-size measures appropriate for experimental and survey research. These include effect sizes for mean, mean differences, contrasts, correlations, and differences between correlations. By comparing the bootstrap confidence intervals with the value of the dependent variable alone, statistical significance can be observed easily.

The next sub sections present the results of the pairwise comparison of the three visualization approaches. The following applies to all tables. The first two columns of the result tables represent the two visualization approaches being compared. Third column represent the mean value difference of two groups $\left(\text{Mean}_{\text{Group 2}} - \text{Mean}_{\text{Group 1}}\right)$. Positive values for both the lower and upper confidence interval bounds (CI_{Low} and CI_{High} values) suggest that the visualization in the second column produced significantly higher values than the one in the first column. Conversely, negative values for both CI_{Low} and CI_{High} indicate that the visualization in the first column resulted in significantly higher values than the one in the second column. A statistically significant difference between the two groups is implied when the upper bounds of the bootstrap confidence interval do not enclose zero (Gorte & Degbelo, 2022).

Statistically significant differences between the two groups are highlighted in the tables with light yellow colored background. The bias is the difference between the mean of the resamples and the mean of the original sample. The SE (standard error) is the standard deviation of the resampled means (Kirby & Gerlanc, 2013). The number of resamples used in the analysis was N=5000.

5.1 Efficiency

5.1.1 Overall efficiency

In each task, there were five questions, and the time taken for each question was measured. Overall efficiency was computed by averaging the time taken for each question in the task. Table 6 presents the efficiency results.

Table 6: Bootstrapping results: Influence of the visualization approach on the time needed to solve tasks at different vertical attribute levels.

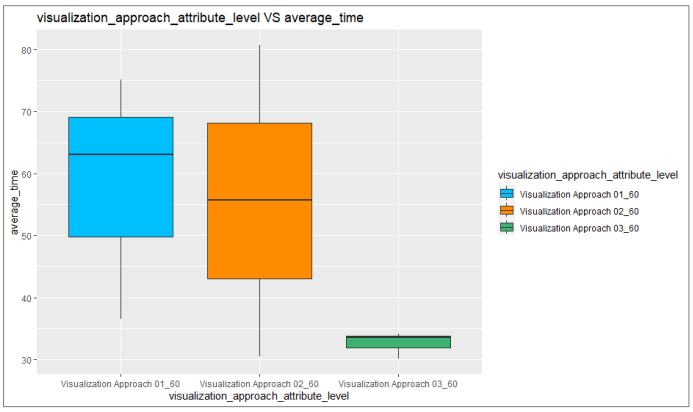
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference (Seconds)	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	-2.683	-32.290	26.923	-0.275	15.067
		90	-1.410	-16.817	16.890	0.083	8.646
		120	38.620	14.347	60.617	-0.150	11.927
		150	0.540	-24.970	33.817	0.033	14.921
		180	-26.213	-68.587	3.677	0.160	18.006
		200	53.187	-15.663	94.673	-0.498	26.722
		Overall	10.340	-6.866	30.913	0.127	9.597
Scrolling Baseline Approach	Zoomable circle packing Approach	60	-25.693	-41.287	-3.977	-0.024	9.332
		90	12.727	-4.870	28.067	-0.003	8.478
		120	45.377	35.303	55.667	-0.098	5.254
		150	6.237	-25.670	38.143	0.269	16.996
		180	-32.430	-79.430	0.807	-0.282	19.493
		200	-8.323	-22.683	6.557	-0.053	7.507
		Overall	-0.351	-15.972	13.251	0.010	7.410
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	-23.010	-48.077	0.813	0.314	11.687
		90	14.137	-10.537	32.650	-0.050	11.261
		120	6.757	-19.130	29.887	-0.162	12.645
		150	5.697	-25.023	23.963	0.066	11.312
		180	-6.217	-35.967	12.427	0.119	12.117
		200	-61.510	-103.397	1.197	-0.116	26.842
		Overall	-10.691	-31.810	4.440	0.064	9.115

The key takeaways are:

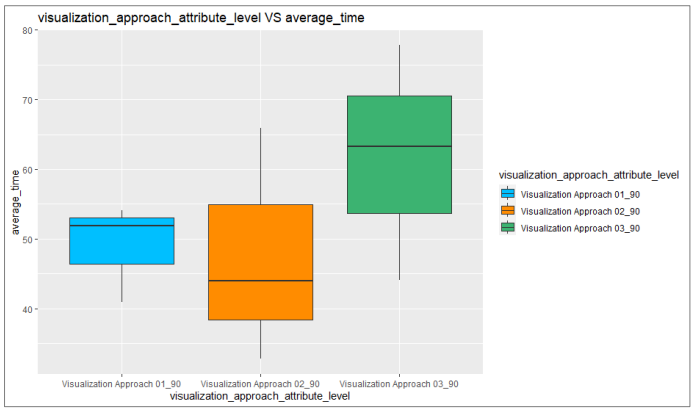
- Scrolling baseline approach vs Spiral-type leaflet markers approach: Each visualization approach had a slight advantage for 60, 90, 150, 180, and 200 vertical attribute levels, but the advantages were not statistically significant. At the 120 vertical attribute level, the scrolling baseline approach had a statistically significant advantage over the spiral-type leaflet markers approach because Participant 07 took more time to complete the task related to spiral-type Leaflet markers.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach was significantly faster at the 60 vertical attribute level. The scrolling baseline approach was significantly faster at the 120 vertical attribute level because Participant 03 took more time on q4 related to the scrolling baseline approach and Participant 15 took more time on q5 related to the zoomable circle packing approach.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: Each visualization approach had a slight advantage for some vertical attribute levels, but the advantages were not statistically significant.

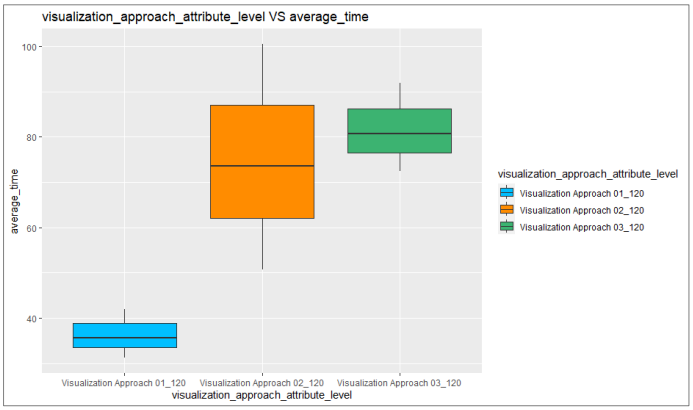
Figure 13 illustrates the graphical representation of overall efficiency of each visualization approaches at different vertical attribute levels.



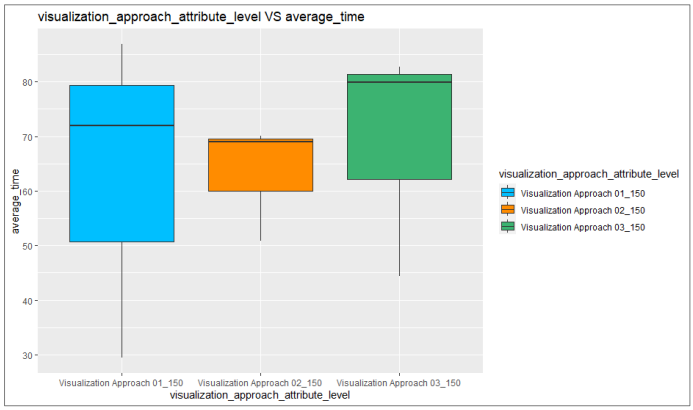
(a) 60 vertical attribute level



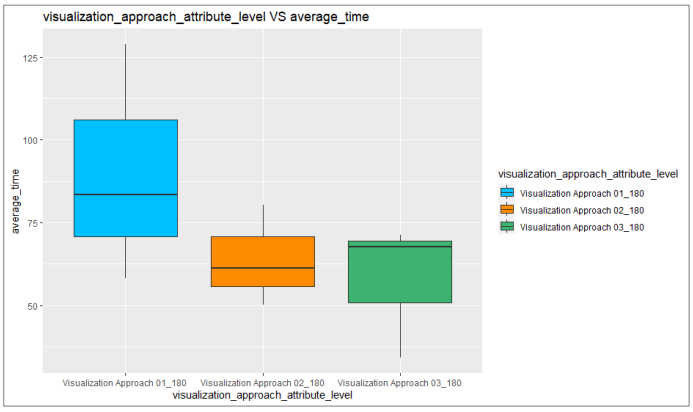
(b) 90 vertical attribute level



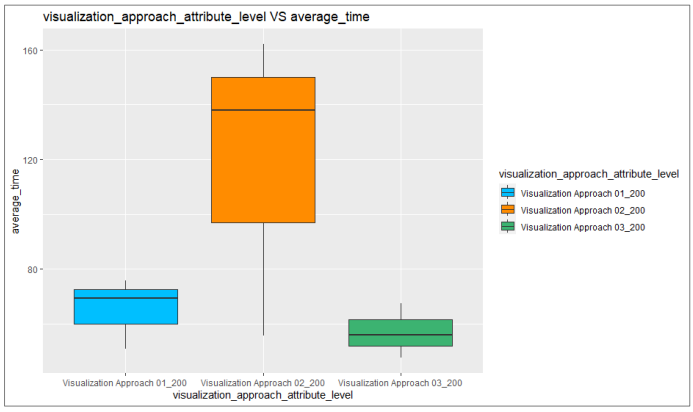
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 13: Boxplots indicating the overall efficiency of each visualization approaches at different vertical attribute levels.

5.1.2 Efficiency for counting vertical attributes

In each task, there was a special question (q4) for counting the vertical attributes in the given attribute category. Efficiency for counting the vertical attributes was computed by considering the time taken for this question (q4). Table 7 presents the efficiency results for q4.

Table 7: Bootstrapping results: Influence of the visualization approach on the time needed to complete q4 at different vertical attribute levels.

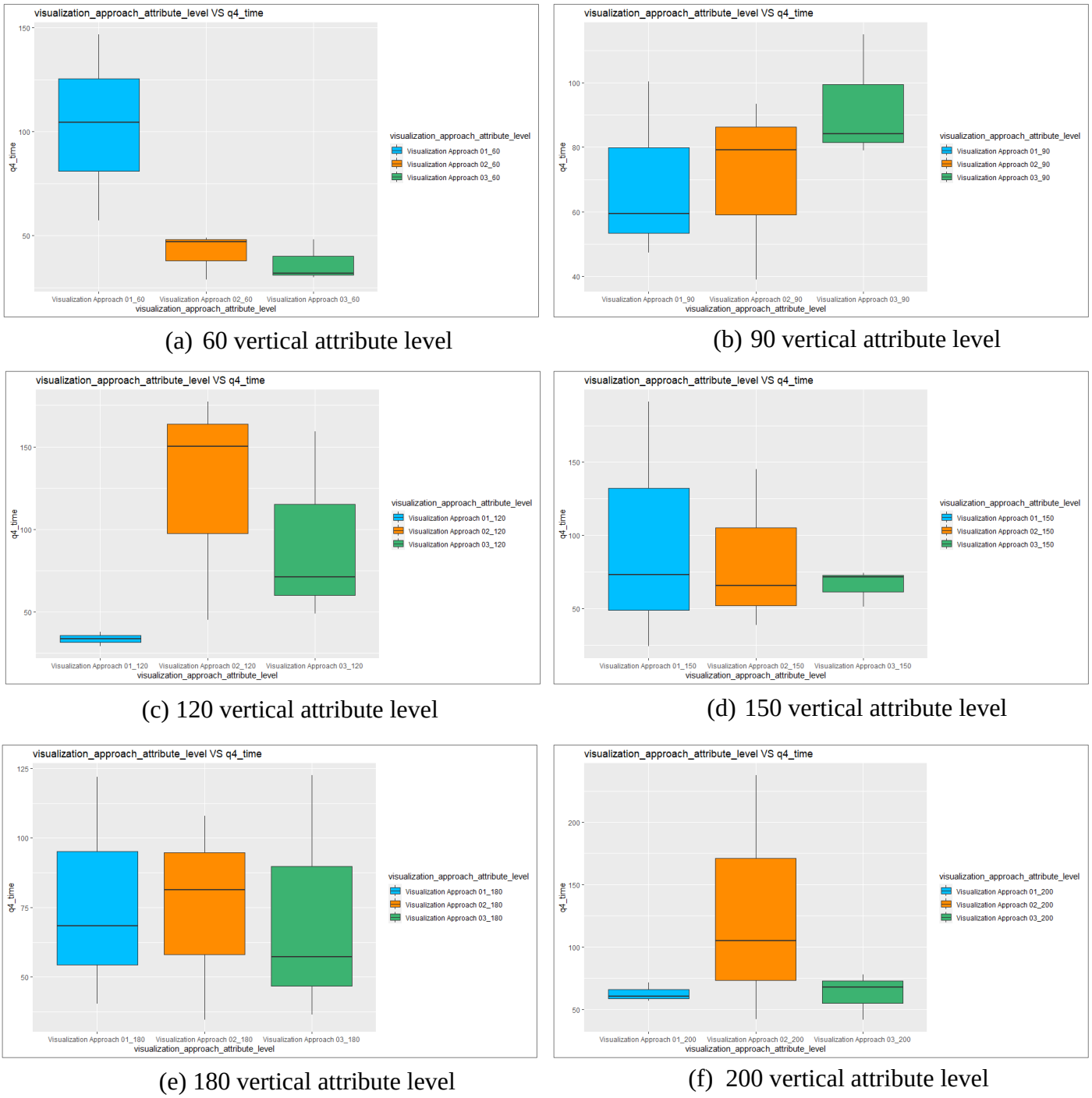
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference (Seconds)	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	-61.117	-104.263	-21.597	-0.311	21.683
		90	1.493	-43.597	32.463	0.133	18.559
		120	90.450	10.087	135.850	0.506	32.837
		150	-13.160	-113.333	68.927	-0.651	47.576
		180	-2.197	-62.740	40.530	0.329	26.072
		200	65.287	-17.407	174.713	0.443	47.583
		Overall	13.459	-17.043	48.075	0.191	16.781
Scrolling Baseline Approach	Zoomable circle packing Approach	60	-66.107	-109.897	-24.837	0.106	21.460
		90	23.620	-9.307	49.807	-0.036	15.958
		120	59.510	20.003	125.463	-0.065	27.158
		150	-30.657	-132.437	31.767	-0.289	41.331
		180	-4.833	-60.667	45.567	0.680	28.980
		200	-0.397	.24,707	14.463	-0.002	9.563
		Overall	-3.144	-30.245	19.832	0.156	12.800
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	-4.990	-17.127	8.440	0.122	7.000
		90	22.127	-6.237	55.297	0.172	16.126
		120	-30.940	-104.160	69.977	0.077	42.771
		150	-17.497	-86.267	23.917	-0.365	26.732
		180	-2.637	-48.793	56.627	-0.265	26.905
		200	-65.683	-183.753	8.203	0.712	47.834
		Overall	-16.603	-50.055	11.101	-0.162	15.432

The key takeaways are:

- Scrolling baseline approach vs Spiral-type leaflet markers approach: The spiral-type leaflet markers approach was significantly faster at the 60 vertical attribute level and significantly slower at the 120 vertical attribute level. For other vertical attribute levels, each visualization approach had a slight advantage, but the advantages were not statistically significant.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach was significantly faster at the 60 vertical attribute level, while the scrolling baseline approach was significantly faster at the 120 vertical attribute level. For other vertical attribute levels, each visualization approach had a slight advantage, but the advantages were not statistically significant.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: Each visualization approach had a slight advantage for some vertical attribute levels, but the advantages were not statistically significant.

Figure 14 illustrates the graphical representation of efficiency of q4 for three visualization approaches at different vertical attribute levels.



(a) 60 vertical attribute level

(b) 90 vertical attribute level

(c) 120 vertical attribute level

(d) 150 vertical attribute level

(e) 180 vertical attribute level

(f) 200 vertical attribute level

Figure 14: Boxplots indicating the efficiency of q4 for three visualization approaches at different vertical attribute levels.

5.1.3 Efficiency for identifying the attribute categories of vertical context

In each task, question (q5) was specially included for identifying the attributes categories of vertical context. Efficiency for counting the vertical attributes was computed by considering the time taken for this question (q5). Table 8 presents the efficiency results for q5.

Table 8: Bootstrapping results: Influence of the visualization approach on the time needed to complete q5 at different vertical attribute levels.

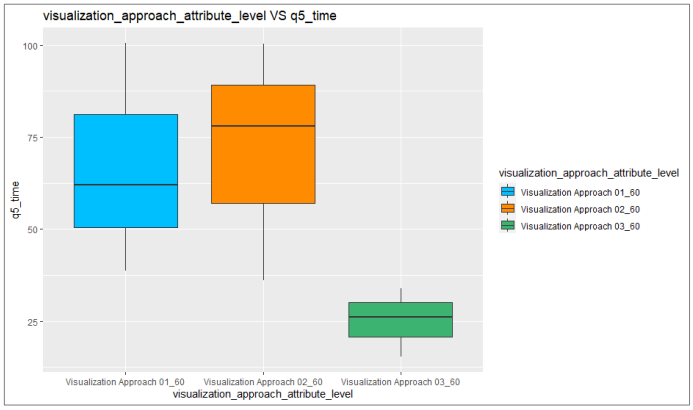
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference (Seconds)	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	4.390	-43.810	38.940	-0.216	21.069
		90	-19.683	-71.607	13.353	0.386	20.940
		120	0.810	-18.143	15.647	-0.164	8.802
		150	-19.260	-71.100	22.403	0.307	23.693
		180	-30.757	-68.097	-10.867	0.115	14.191
		200	30.750	-22.077	62.990	0.432	21.098
		Overall	-5.625	-23.941	12.248	0.099	9.312
Scrolling Baseline Approach	Zoomable circle packing Approach	60	-41.932	-77.850	-17.743	0.038	15.109
		90	-32.127	-81.123	6.213	-0.562	22.410
		120	40.610	24.437	76.537	0.009	11.106
		150	4.283	-49.803	37.653	0.010	22.875
		180	-10.447	-50.437	14.367	-0.394	16.541
		200	3.440	-35.667	39.017	0.367	18.890
		Overall	-6.032	-24.251	11.157	0.018	8.902
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	-46.313	-74.120	-10.923	0.273	15.891
		90	-12.443	-31.720	12.263	0.050	11.582
		120	39.800	15.010	72.403	0.246	14.022
		150	23.543	-18.663	59.430	0.057	20.003
		180	20.280	1.797	36.190	0.044	9.174
		200	-27.310	-72.247	22.020	-0.287	25.107
		Overall	-0.407	-18.547	16.377	-0.080	9.026

The key takeaways are:

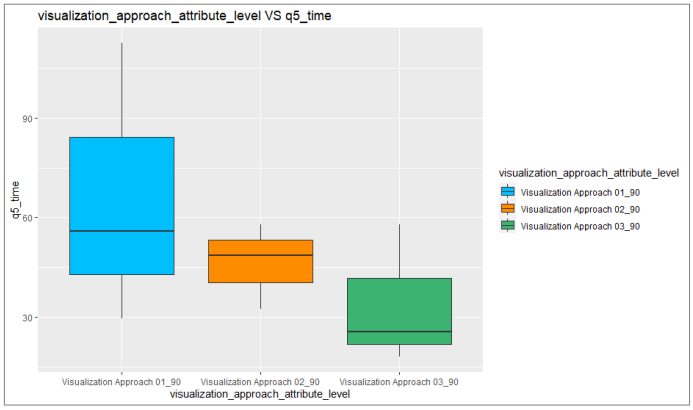
- Scrolling baseline approach vs Spiral-type leaflet markers approach: The spiral-type Leaflet markers method demonstrated significantly higher speed specifically at the 180 vertical attribute. While for other vertical attribute levels, each visualization approach exhibited a slight advantage, these advantages did not reach statistical significance.
- Scrolling baseline approach vs Zoomable circle packing approach: The speed of the zoomable circle packing method showed a significant increase at the 60 vertical attribute level, whereas it exhibited a notable decrease at the 120 vertical attribute level. For other vertical attribute levels, each visualization approach held a slight advantage, but these advantages did not reach statistical significance.
- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The Spiral-type leaflet markers approach demonstrated significantly faster performance at the 120

and 180 vertical attribute levels, while the Zoomable circle packing approach exhibited significantly higher efficiency at the 60 vertical attribute level. Although each visualization approach held a slight advantage for certain vertical attribute levels, these advantages did not reach statistical significance.

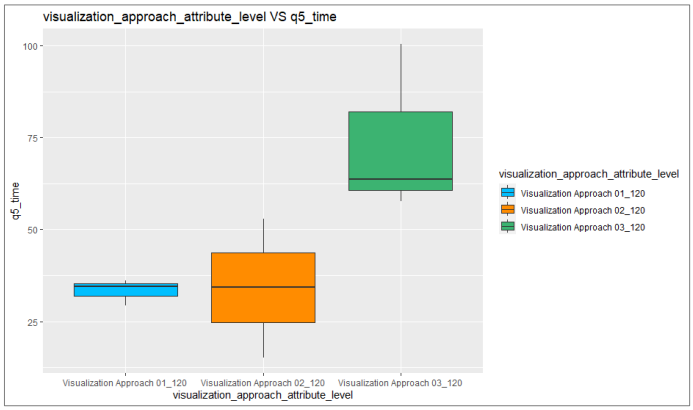
Figure 15 illustrates the graphical representation of the efficiency of q5 for three visualization approaches at various vertical attribute levels.



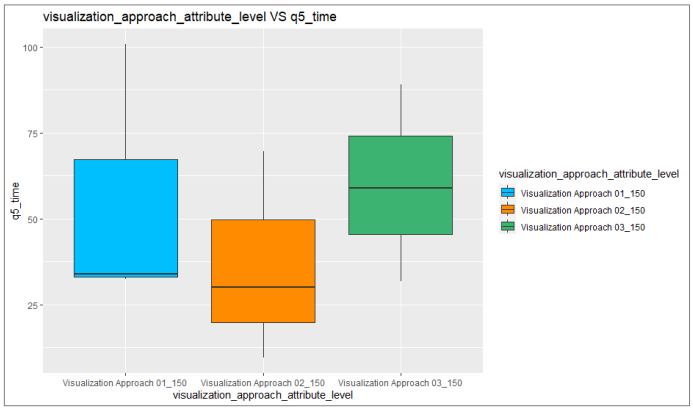
(a) 60 vertical attribute level



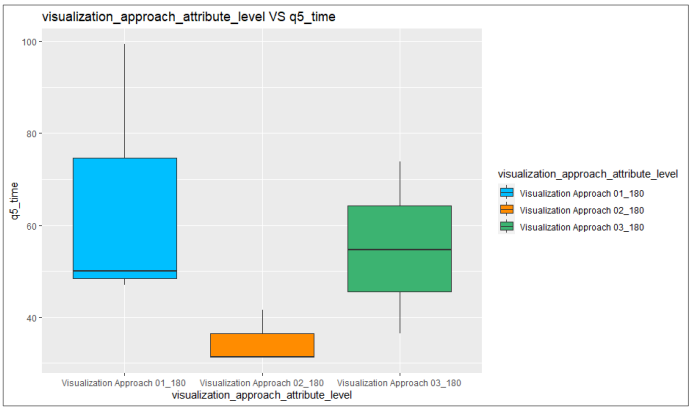
(b) 90 vertical attribute level



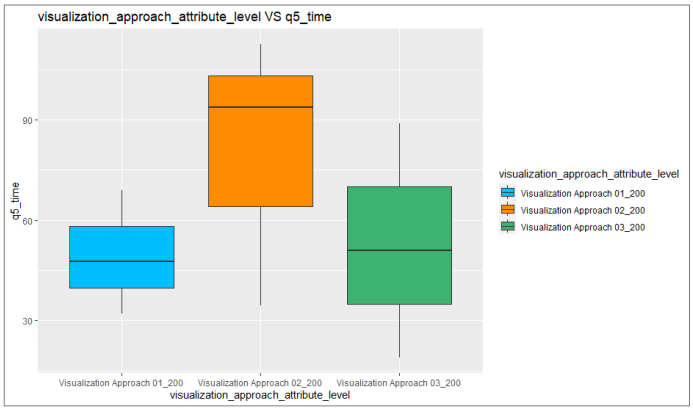
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 15: Boxplots indicating the efficiency of q5 for three visualization approaches at different vertical attribute levels.

5.2 Effectiveness

5.2.1 Overall effectiveness

Table 9 displays the overall effectiveness outcomes, where a higher score indicates a greater number of correctly answered questions. Each task consisted of five questions, and participants received effectiveness scores of 100, 80, 60, 40, or 20 based on the number of questions answered correctly (five, four, three, two, or one respectively). Those who did not answer all five questions correctly received a score of zero.

Table 9: Bootstrapping results: Influence of the visualization approach on the overall effectiveness at different vertical attribute levels.

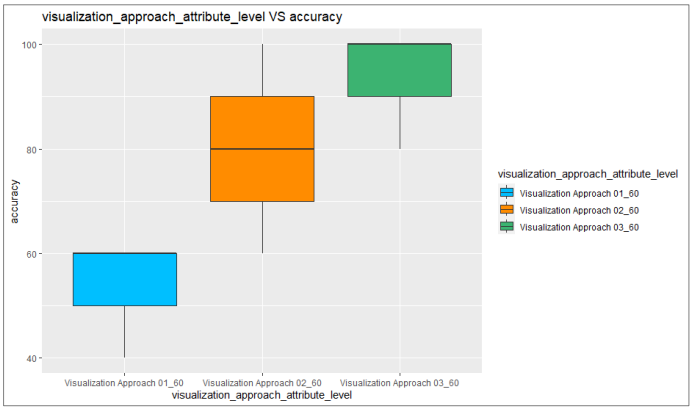
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference	CI_{Low}	CI_{High}	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	26.667	0.000	40.000	-0.085	10.969
		90	20.000	0.000	33.333	-0.101	9.410
		120	-33.333	-60.000	-26.667	0.005	7.769
		150	-40.000	-60.000	-26.667	0.219	9.574
		180	-6.667	-40.000	6.667	-0.029	12.332
		200	-13.333	-33.333	6.667	-0.080	12.063
		Overall	-7.778	-20.000	3.333	-0.044	6.092
Scrolling Baseline Approach	Zoomable circle packing Approach	60	40.000	20.000	46.667	0.119	7.765
		90	13.333	0.000	20.000	-0.037	5.524
		120	-6.667	-33.333	6.667	0.073	10.753
		150	-6.667	-20.000	-6.667	-0.080	5.406
		180	20.000	0.000	26.667	-0.040	7.758
		200	-20.000	-40.000	0.000	0.185	12.294
		Overall	6.667	-5.556	16.667	0.005	5.739
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	13.333	-13.333	26.667	-0.001	10.988
		90	-6.667	-33.333	6.667	-0.203	10.914
		120	26.667	0.000	40.000	0.011	11.002
		150	33.333	6.667	46.667	-0.028	10.954
		180	26.667	6.667	46.667	0.263	12.420
		200	-6.667	-20.000	13.333	0.077	7.789
		Overall	16.667	-22.222	38.889	-0.121	15.423

The key takeaways are:

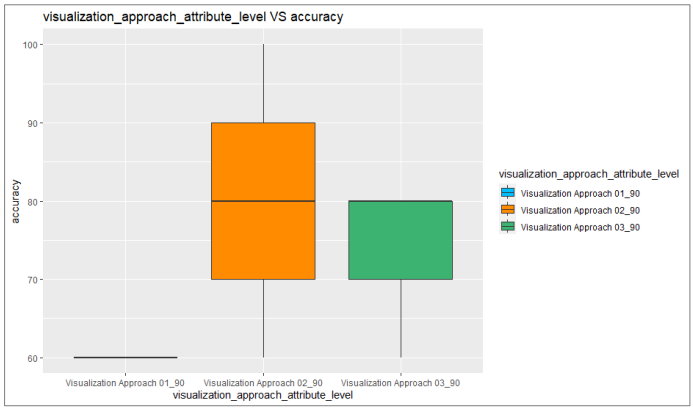
- Scrolling baseline approach vs Spiral-type leaflet markers approach: The spiral-type leaflet markers approach significantly improved result accuracy at the 60 and 90 vertical attribute levels, distinguishing itself from other methods. Likewise, the scrolling baseline approach demonstrated enhanced accuracy at the 120 and 150 vertical attribute levels, exhibiting a significant difference from other approaches.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach demonstrated a significant advantage at the 60, 90, and 180 vertical attribute levels. In contrast, the Scrolling baseline approach showed a significant advantage only at the 150 vertical attribute level.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing approach showed a significant advantage at the 120, 150, and 180 vertical attribute levels, as well as overall.

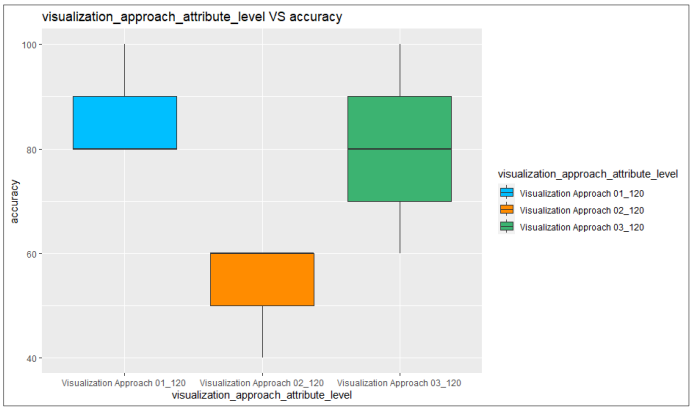
Figure 16 illustrates the graphical representation of overall effectiveness of each visualization approaches at different vertical attribute levels.



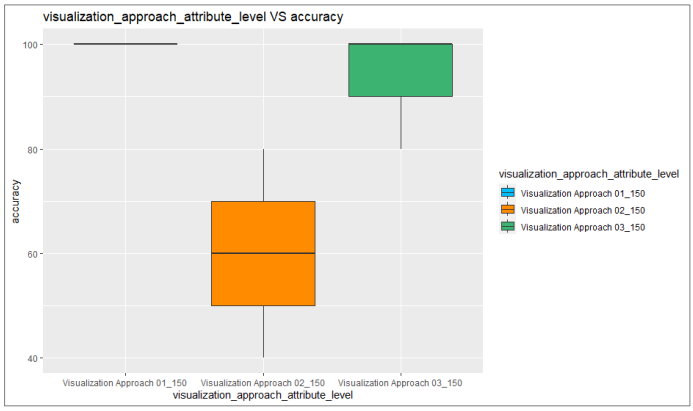
(a) 60 vertical attribute level



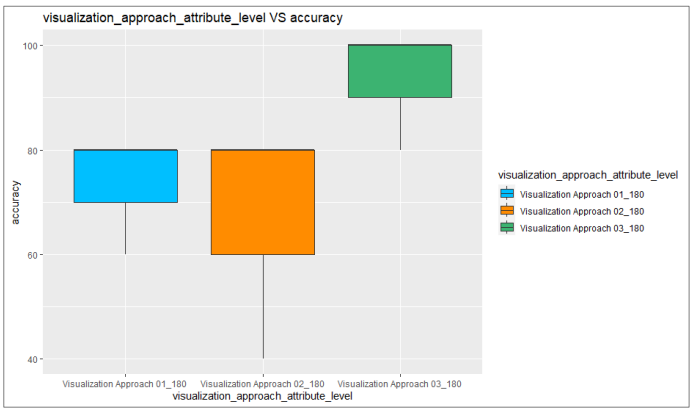
(b) 90 vertical attribute level



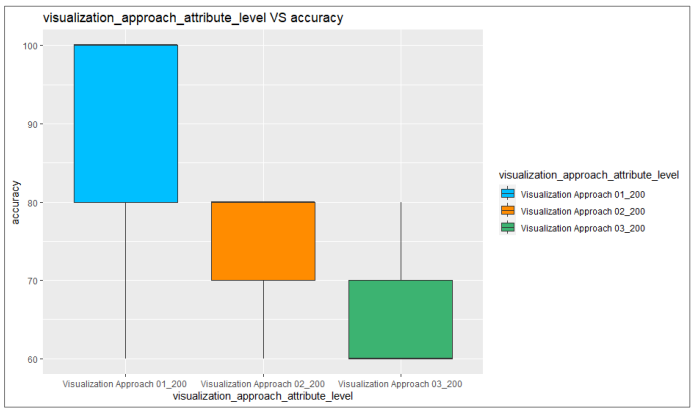
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 16: Boxplots indicating the overall effectiveness of each visualization approaches at different vertical attribute levels.

5.2.2 Effectiveness for counting vertical attributes

Each task included a specific question (q4) designed for counting vertical attributes within the given attribute category. Table 10 represents the accuracy score for q4, with participants receiving an effectiveness score of 100 if they answered correctly. Those who did not provide the correct answer received a score of zero.

Table 10: Bootstrapping results: Influence of the visualization approach on the effectiveness of q4 at different vertical attribute levels.

Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	33.333	-66.667	66.667	-0.287	38.442
		90	66.667	0.000	66.667	0.773	26.824
		120	-66.667	-100.000	-33.333	-0.120	27.385
		150	*****				
		180	33.333	-66.667	66.667	0.313	38.221
		200	*****				
		Overall	-22.222	-55.556	11.111	-0.431	16.112
Scrolling Baseline Approach	Zoomable circle packing Approach	60	33.333	-66.667	66.667	-1.013	38.709
		90	*****				
		120	0.000	-100.000	33.333	-0.220	38.228
		150					*****
		180	66.667	0.000	100.000	-0.493	27.486
		200	*****				
		Overall	16.667	-16.667	44.444	0.143	15.683
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	0.000	-100.000	33.333	0.860	38.537
		90	33.333	0.000	66.667	-0.387	27.031
		120	66.667	0.000	100.000	0.240	27.529
		150	*****				
		180	33.333	0.000	66.667	0.640	27.059
		200	*****				
		Overall	38.889	5.556	66.667	0.030	15.249

***** Since all the values within the each group were identical, it was not possible to calculate the confidence intervals.

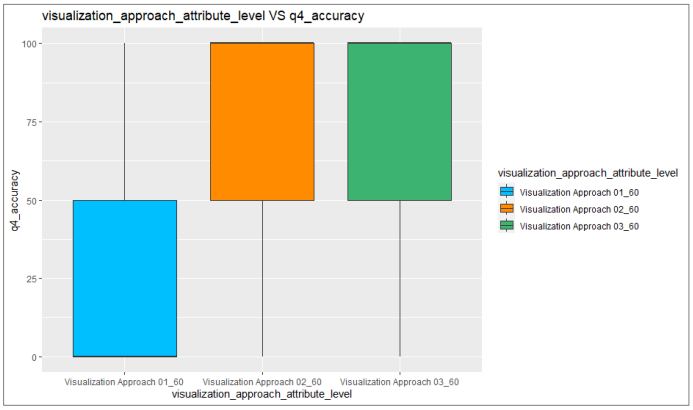
The key takeaways are:

- Scrolling baseline approach vs Spiral-type leaflet markers approach: The scrolling baseline approach significantly enhanced result accuracy at the 120, 150, and 200 vertical attribute levels, setting it apart from other method. Similarly, the spiral-type leaflet markers approach showed improved accuracy at the 90 vertical attribute level, demonstrating a significant difference from other approach.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach demonstrated a significant advantage at the 90, and 180 vertical

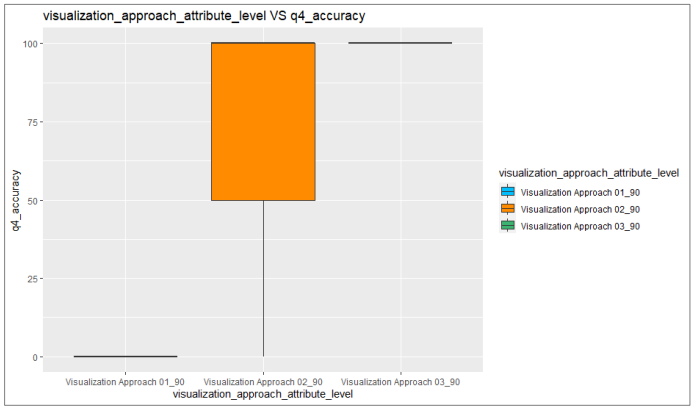
attribute levels. In contrast, the Scrolling baseline approach showed a significant advantage only at the 200 vertical attribute level.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing approach showed a significant advantage at the 90, 120, 150, and 180 vertical attribute levels, as well as overall.

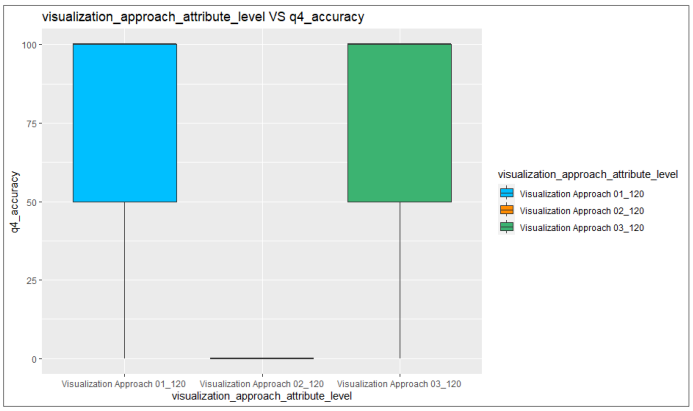
Figure 17 illustrates the graphical representation of effectiveness of q4 for three visualization approaches at different vertical attribute levels.



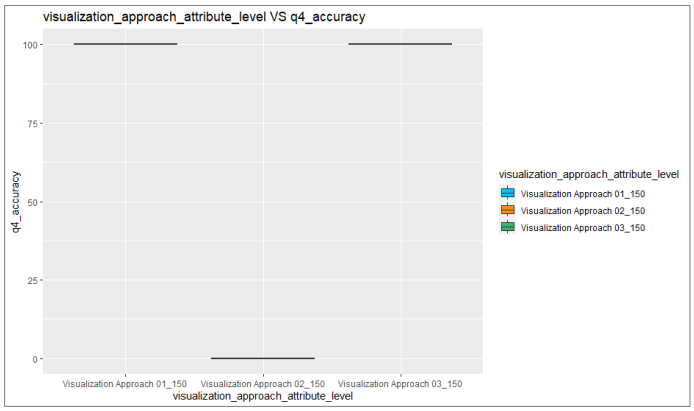
(a) 60 vertical attribute level



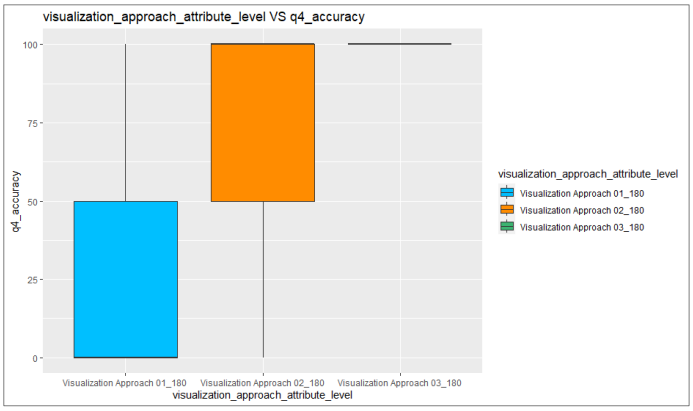
(b) 90 vertical attribute level



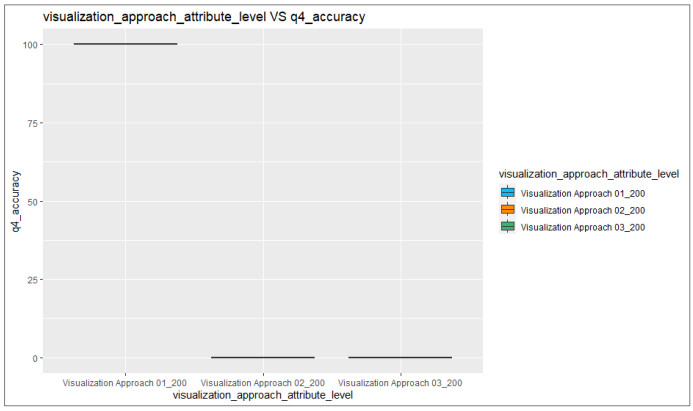
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 17: Boxplots indicating the effectiveness of q4 for three visualization approaches at different vertical attribute levels.

5.2.3 Effectiveness for identifying the attribute categories of vertical context

Each task included a specific question (q5) designed for identifying the attributes categories of vertical context. Table 11 represents the accuracy score for q5, with participants receiving an effectiveness score of 100 if they answered correctly. Those who did not provide the correct answer received a score of zero.

Table 11: Bootstrapping results: Influence of the visualization approach on the effectiveness of q5 at different vertical attribute levels.

Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	33.333	-66.667	66.667	-0.293	38.629
		90	66.667	0.000	100.000	-0.133	27.514
		120	-33.333	-100.000	0.000	0.007	27.389
		150	-66.667	-100.000	-33.333	-0.287	27.151
		180	-33.333	-100.000	0.000	0.607	27.154
		200	33.333	0.000	66.667	0.593	27.374
		Overall	0.000	-38.889	27.778	0.246	16.160
Scrolling Baseline Approach	Zoomable circle packing Approach	60	66.667	0.000	100.000	0.087	27.259
		90	33.333	-66.667	66.667	0.567	38.381
		120	-33.333	-100.000	0.000	0.707	27.074
		150	*****				
		180	66.667	0.000	100.000	-0.253	26.867
		200	-33.333	-100.000	33.333	-0.587	38.609
		Overall	16.667	-16.667	38.889	-0.316	15.156
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	33.333	0.000	66.667	0.513	27.246
		90	-33.333	-100.000	0.000	0.387	27.260
		120	0.000	-100.000	33.333	0.113	38.106
		150	66.667	0.000	100.000	-0.247	27.412
		180	*****				
		200	-66.667	-100.000	-33.333	0.067	27.033
		Overall	16.667	-22.222	38.889	-0.121	15.423

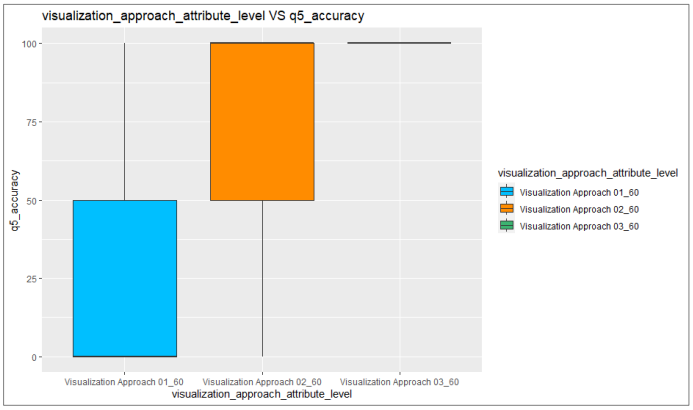
***** Since all the values within the each group were identical, it was not possible to calculate the confidence intervals.

The key takeaways are:

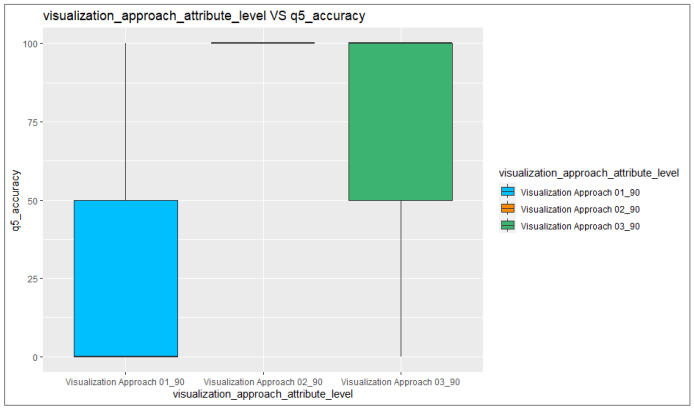
- Scrolling baseline approach vs Spiral-type leaflet markers approach: The scrolling baseline approach significantly enhanced result accuracy at the 150 vertical attribute level, setting it apart from other method. Similarly, the spiral-type leaflet markers approach showed improved accuracy at the 90, 200 vertical attribute level, demonstrating a significant difference from other approach.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing method exhibited a significant advantage at the 60 and 180 vertical attribute levels. While both approaches displayed a slight advantage at certain vertical attribute levels, it is important to note that this advantage was not statistically significant.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing method demonstrated significant advantage particularly in relation to the vertical attributes at levels 60, 150, and 180. On the other hand, the spiral-type leaflet markers approach displayed a significant advantage solely at the 200 vertical attribute level.

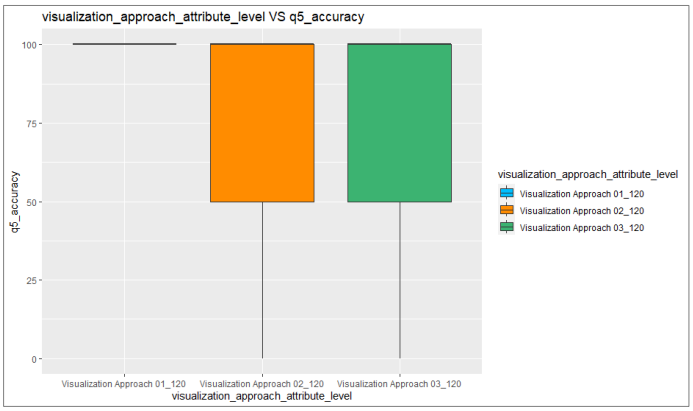
Figure 18 illustrates the graphical representation of effectiveness of q5 for three visualization approaches at different vertical attribute levels.



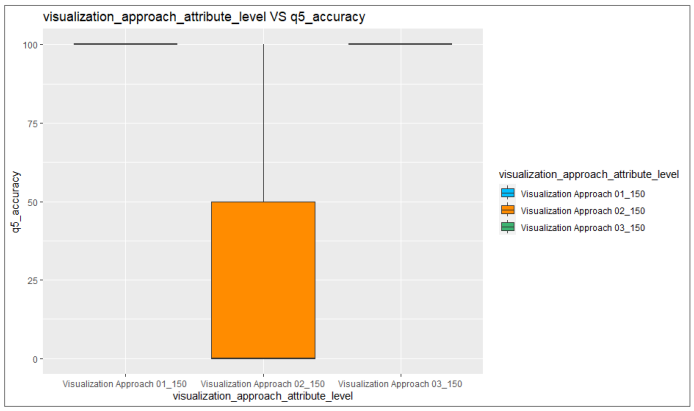
(a) 60 vertical attribute level



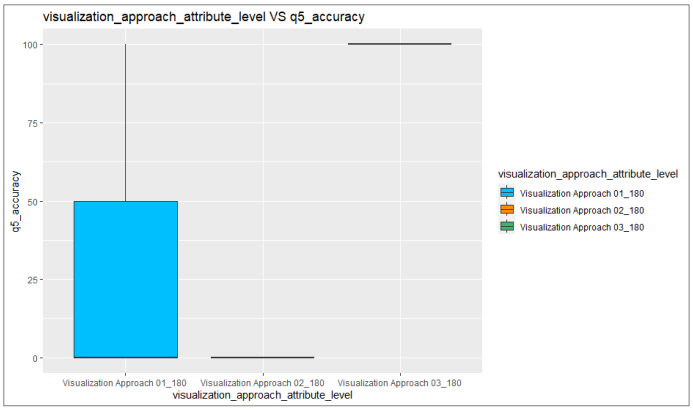
(b) 90 vertical attribute level



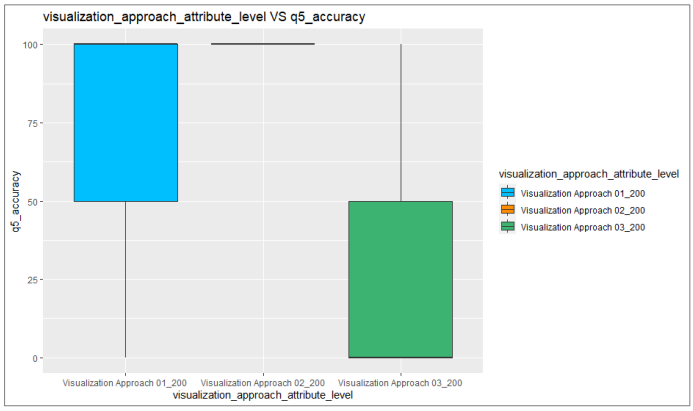
(c) 120 vertical attribute level



(d)150 vertical attribute level



(e) 180 vertical attribute level



(f)200 vertical attribute level

Figure 18: Boxplots indicating the effectiveness of q5 for three visualization approaches at different vertical attribute levels.

5.3 Enjoyment

Enjoyment serves as a subjective gauge, reflecting the pleasure and engagement users experience when interacting with a visualization approach. To quantify this, participants were asked to provide enjoyment scores using a 7-point Likert scale for each visualization approach, ranging from 1 to 7. The conversion process involved transforming these Likert scale ratings into a standardized range of 0 to 100. Specifically, a "Strongly Agree" response corresponded to a score of 100, while a "Strongly Disagree" response equated to a score of 0. Intermediate values were calculated proportionally, aligning with the Likert scale ratings. The tabulated results of these enjoyment scores are presented in Table 12.

Table 12: Bootstrapping results: Influence of the visualization approach on the enjoyment score at different vertical attribute levels.

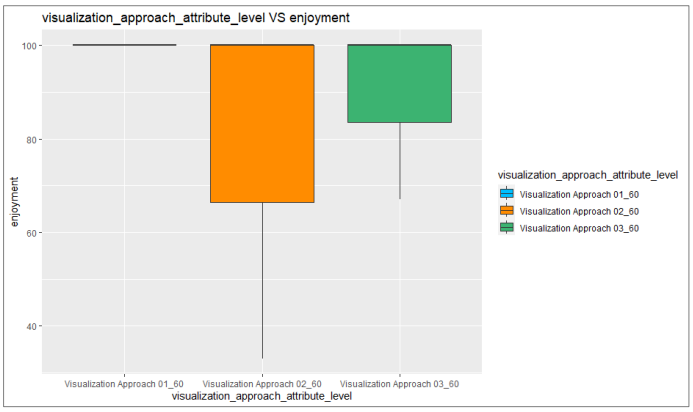
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	-22.333	-67.000	0.000	-0.009	18.326
		90	-11.000	-44.667	16.667	0.385	16.375
		120	16.667	-44.000	60.667	-0.408	25.744
		150	11.333	-22.000	44.667	0.069	17.061
		180	-44.333	-83.333	-5.667	0.149	19.503
		200	27.333	-44.667	71.667	-0.647	27.813
		Overall	-3.722	-26.833	17.444	0.380	11.090
Scrolling Baseline Approach	Zoomable circle packing Approach	60	-11.000	-33.000	0.000	0.086	9.041
		90	22.333	17.000	27.667	0.061	4.373
		120	44.333	11.333	72.000	-0.258	16.191
		150	27.667	5.333	55.667	-0.153	12.814
		180	11.333	-22.000	33.333	0.461	14.814
		200	49.667	-0.333	83.000	0.247	20.374
		Overall	24.056	9.111	39.883	-0.006	8.051
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	11.333	-22.000	44.667	-0.424	20.191
		90	33.333	0.000	55.667	0.406	15.551
		120	27.667	-5.667	71.667	0.182	21.483
		150	16.333	-11.333	38.667	-0.069	12.695
		180	55.667	11.000	78.000	0.249	17.964
		200	22.333	-22.000	72.333	-0.006	25.584
		Overall	27.778	11.269	46.278	-0.253	8.916

The key takeaways are:

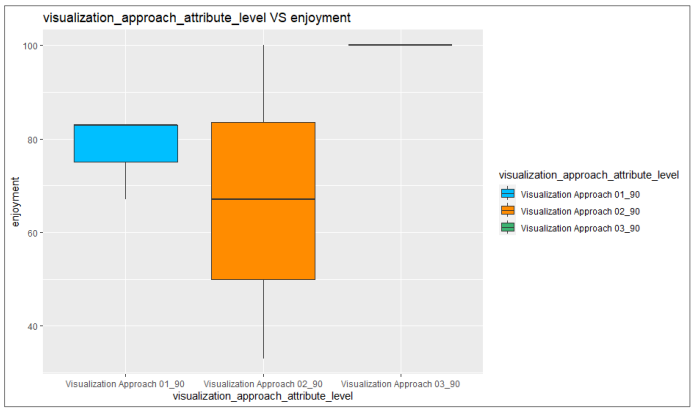
- Scrolling baseline approach vs Spiral-type leaflet markers approach: At the 180 vertical attribute level, the scrolling baseline approach had a statistically significant advantage over the spiral-type leaflet markers approach.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach exhibited significant higher enjoyment scores at the 90, 120, and 150 vertical attribute levels, as well as overall.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing approach demonstrated a significant advantage solely at the 90 and 180 vertical attribute levels, as well as overall.

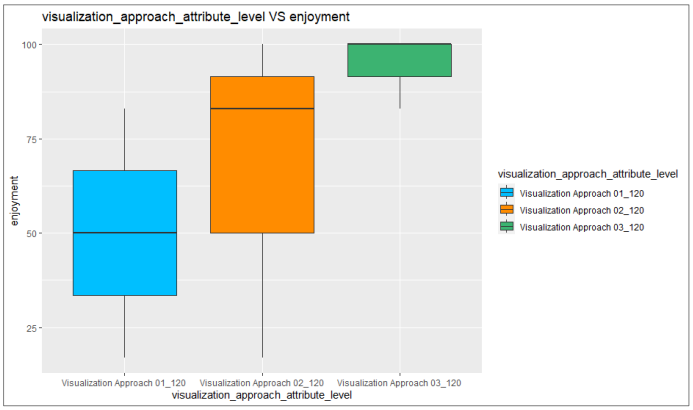
Figure 19 illustrates the graphical representation of enjoyment score for each visualization approaches at different vertical attribute levels.



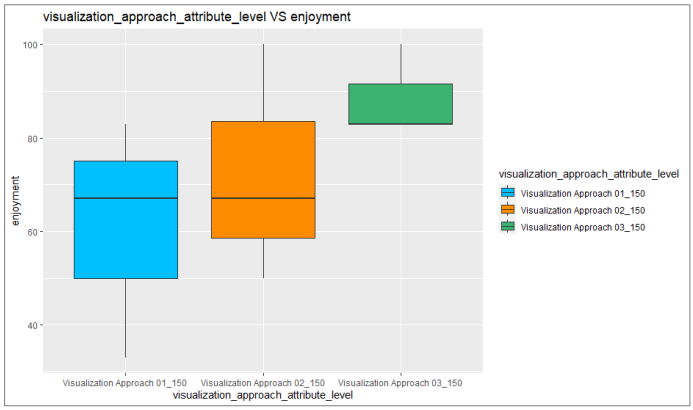
(a) 60 vertical attribute level



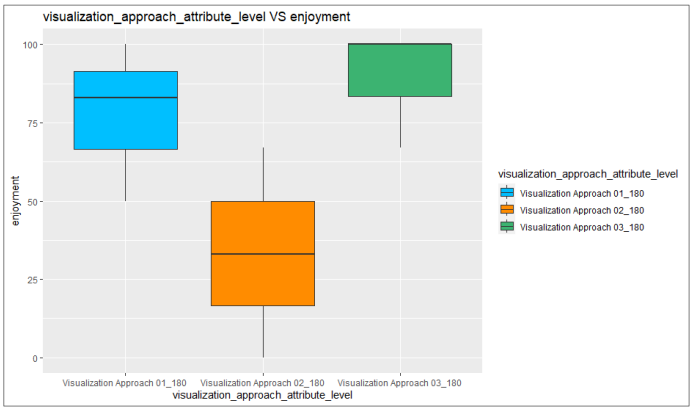
(b) 90 vertical attribute level



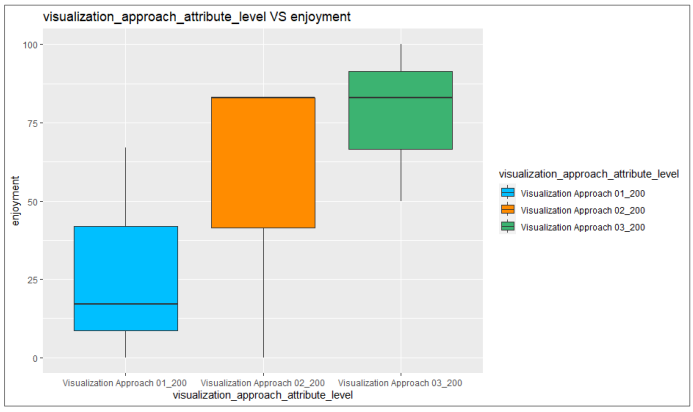
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 19: Boxplots indicating the enjoyment score of each visualization approaches at different vertical attribute levels.

5.4 Usefulness

Usefulness refers to the degree to which a product, service, or system fulfills a practical purpose or provides value to users in achieving their goals. The usefulness scores were obtained through a single feedback question employing a 7-point Likert scale for each visualization approach. Participants rated their experience on a scale ranging from 1 to 7, and the scoring method aligned with that used in the preceding subsection on Enjoyment (Sub section 5.3) . The results of the usefulness scores are presented in Table 13.

Table 13: Bootstrapping results: Influence of the visualization approach on the usefulness score at different vertical attribute levels.

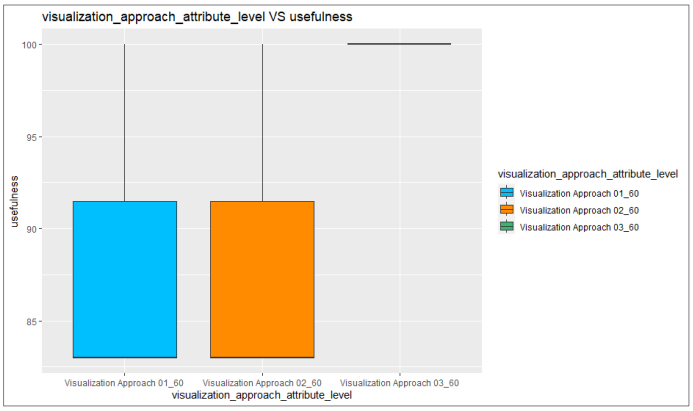
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	0.000	-17.000	5.667	-0.100	6.571
		90	-33.333	-55.667	-11.000	0.326	12.927
		120	-5.667	-50.000	16.667	-0.004	16.722
		150	-27.667	-50.000	0.333	-0.095	14.396
		180	-38.667	-83.000	-11.000	0.030	18.071
		200	22.000	-22.333	66.000	0.203	22.951
		Overall	-13.889	-32.389	6.389	0.034	9.917
Scrolling Baseline Approach	Zoomable circle packing Approach	60	11.333	0.000	11.333	0.022	4.628
		90	5.667	-17.000	11.333	0.097	6.595
		120	38.667	33.000	44.333	-0.022	4.621
		150	22.333	0.000	50.000	0.556	14.449
		180	33.667	-5.000	55.667	0.052	15.030
		200	55.667	28.000	83.333	-0.004	15.178
		Overall	27.889	14.944	43.556	-0.028	7.238
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	11.333	0.000	17.000	0.016	4.650
		90	39.000	5.667	55.667	0.017	12.893
		120	44.333	17.000	66.333	0.132	16.238
		150	50.000	38.667	61.333	0.212	6.662
		180	72.333	28.000	89.000	-0.140	16.343
		200	33.667	-5.000	72.333	-0.237	21.655
		Overall	41.778	26.162	57.556	0.070	8.090

The key takeaways are:

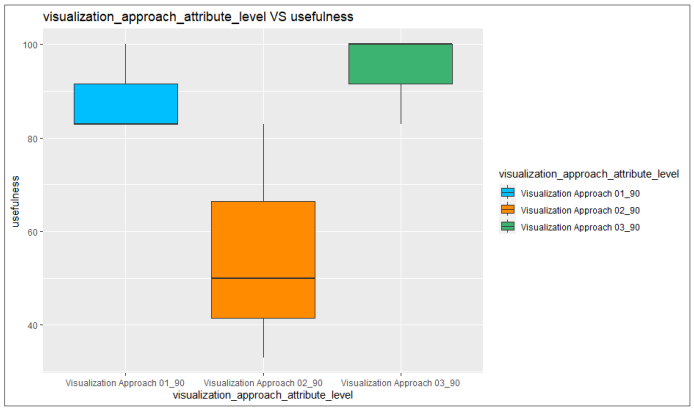
- Scrolling baseline approach vs Spiral-type leaflet markers approach: The scrolling baseline approach exhibited a statistically significant advantage over the spiral-type leaflet markers approach specifically at the 90 and 180 vertical attribute levels.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach showed significantly higher usefulness scores at the 60, 120, 150, and 200 vertical attribute levels, as well as overall. While it maintained a slight advantage at the remaining vertical attribute levels, these advantages did not reach statistical significance.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing approach displayed a significant advantage at all attribute levels as well as overall except for the 200 vertical attribute level and advantage was not statistically significant at the 200 vertical attribute level.

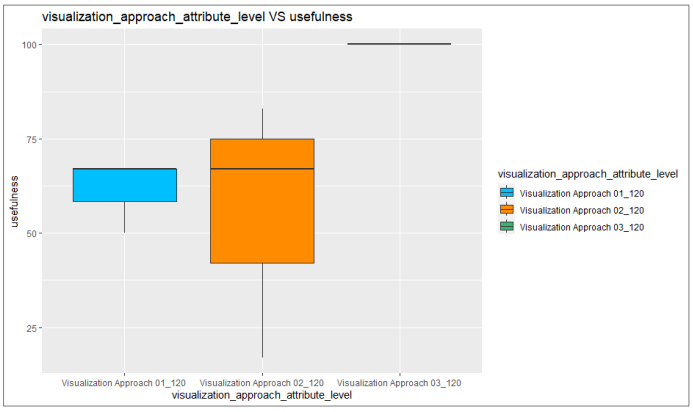
Figure 20 illustrates the graphical representation of usefulness score for each visualization approaches at different vertical attribute levels.



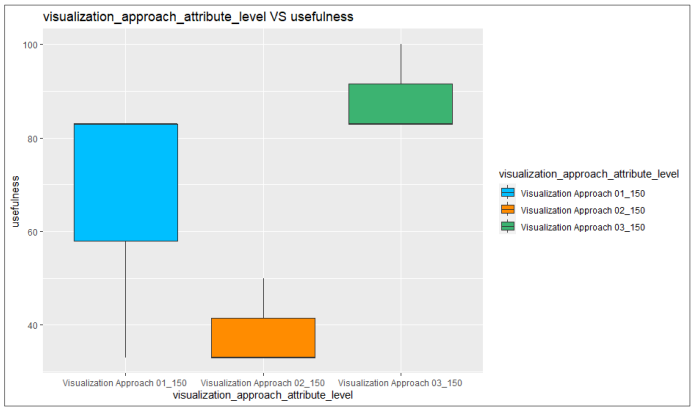
(a) 60 vertical attribute level



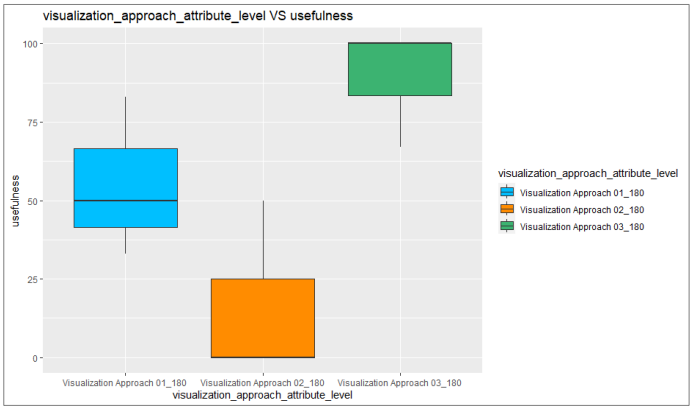
(b) 90 vertical attribute level



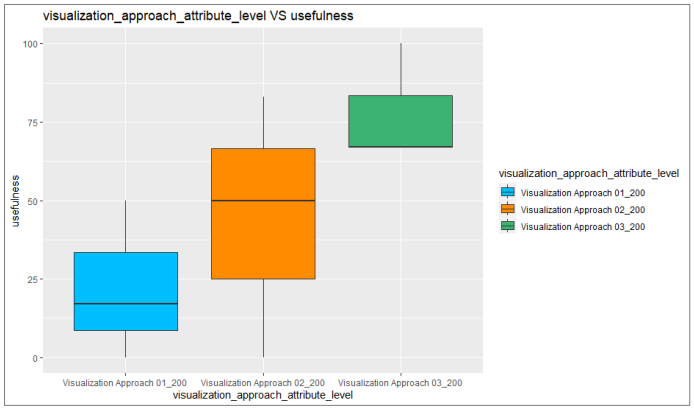
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 20: Boxplots indicating the usefulness score of each visualization approaches at different vertical attribute levels.

5.5 Satisfaction

The satisfaction scores were obtained through a single feedback question employing a 7-point Likert scale for each visualization approach. Participants rated their experience on a scale ranging from 1 to 7, and the scoring method aligned with that used in the preceding subsection on Enjoyment (Sub section 5.3). The results of the satisfaction scores are presented in Table 14.

Table 14: Bootstrapping results: Influence of the visualization approach on the satisfaction score at different vertical attribute levels.

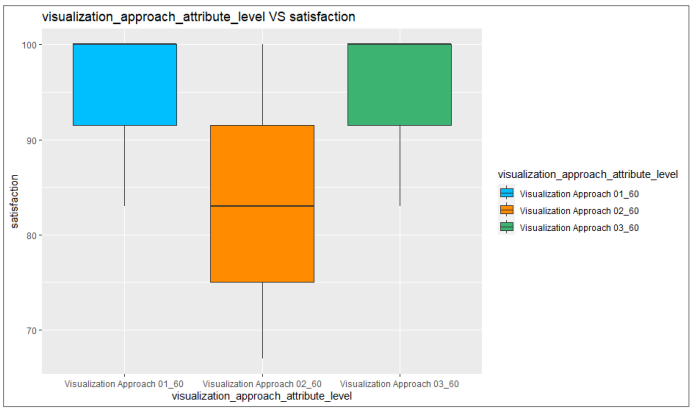
Visualization Approach A (9)	Visualization Approach B	Attribute Level	Mean Difference	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	-11.000	-27.667	5.667	0.032	9.086
		90	-22.333	-55.667	0.000	0.157	14.126
		120	-22.000	-60.667	17.000	0.183	20.296
		150	-5.000	-16.000	6.000	-0.114	8.918
		180	-61.000	-88.667	-33.333	-0.542	14.293
		200	33.333	-16.333	66.333	0.108	20.788
		Overall	-14.667	-33.056	5.722	0.076	9.819
Scrolling Baseline Approach	Zoomable circle packing Approach	60	0.000	-17.000	5.667	0.045	6.480
		90	5.333	-11.333	22.000	-0.098	9.153
		120	22.333	17.000	27.667	-0.066	4.301
		150	16.667	0.000	33.333	-0.045	10.154
		180	11.000	-11.333	22.333	0.116	8.993
		200	61.000	16.667	88.667	0.369	18.189
		Overall	19.389	6.500	36.889	-0.130	7.497
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	11.000	-11.333	22.333	-0.022	9.042
		90	27.667	5.333	55.667	-0.023	12.708
		120	44.333	0.000	72.000	-0.349	19.619
		150	21.667	16.000	27.333	0.032	4.611
		180	72.000	38.667	88.667	0.129	12.851
		200	27.667	-22.000	60.667	-0.036	19.610
		Overall	34.056	19.333	48.944	-0.107	7.565

The key takeaways are:

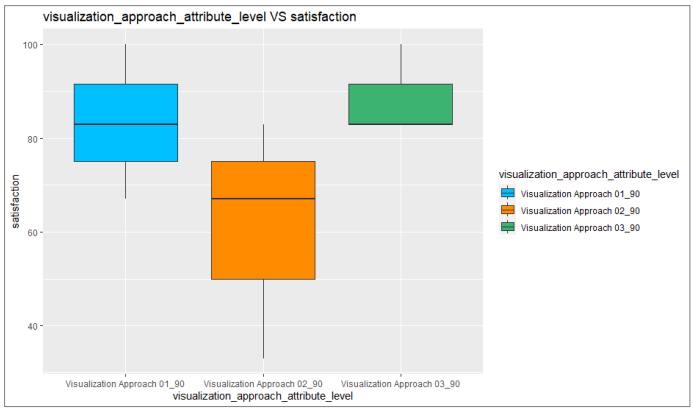
- Scrolling baseline approach vs Spiral-type leaflet markers approach: The scrolling baseline approach exhibited a statistically significant advantage over the spiral-type leaflet markers approach specifically only at the 180 vertical attribute level.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach showed significantly higher satisfaction scores at the 120, 150, and 200 vertical attribute levels, as well as overall. While it maintained a slight advantage at the remaining vertical attribute levels, these advantages did not reach statistical significance.
- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing approach displayed a significant advantage at all attribute

levels, as well as overall except for the 60 and 200 vertical attribute levels and advantage was not statistically significant at the 60 and 200 vertical attribute levels.

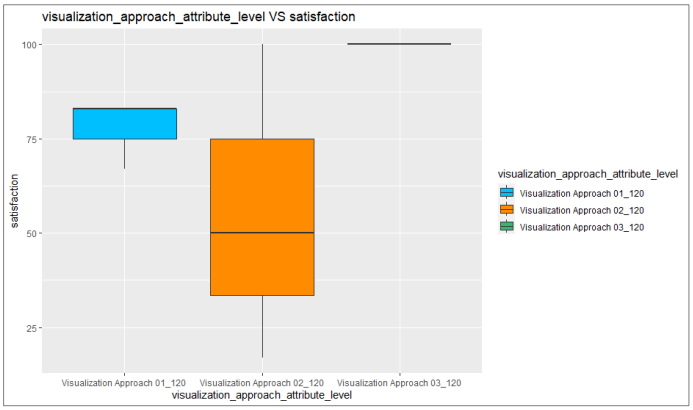
Figure 21 illustrates the graphical representation of satisfaction score for each visualization approaches at different vertical attribute levels.



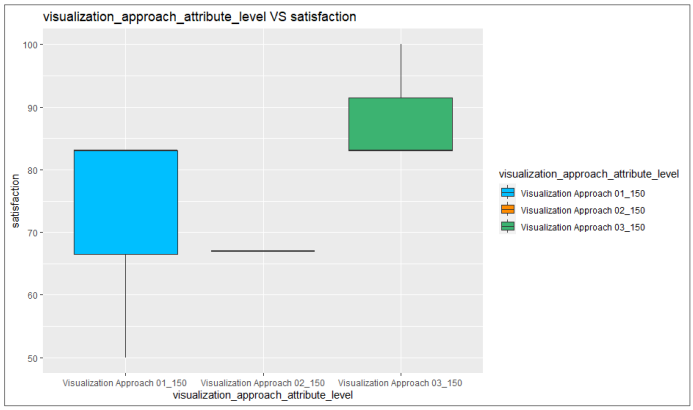
(b) 60 vertical attribute level



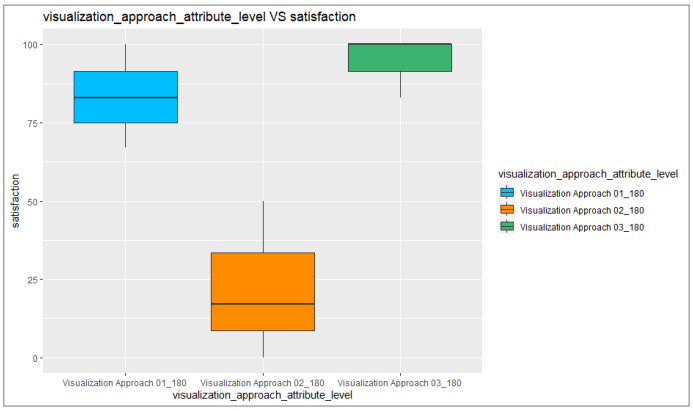
(b) 90 vertical attribute level



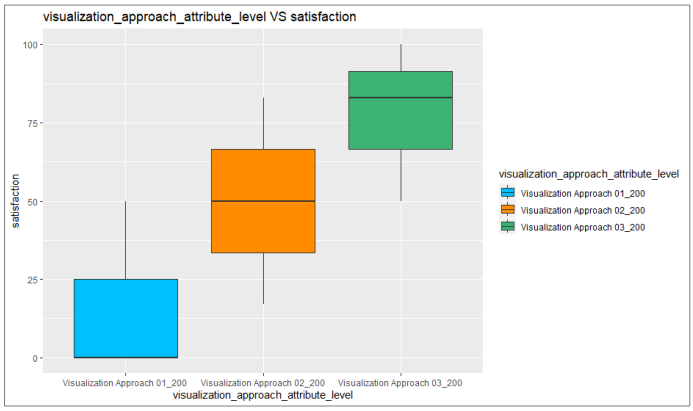
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 31: Boxplots indicating the satisfaction score of each visualization approaches at different vertical attribute levels.

5.6 Ease of use

Ease of use refers to the user-friendliness and simplicity of visualization approach . It reflects how easily individuals can interact with and navigate through a visualization approach without encountering unnecessary complications or difficulties. The scores for ease of use were obtained through a single feedback question employing a 7-point Likert scale for each visualization approach. Participants rated their experience on a scale ranging from 1 to 7, and the scoring method aligned with that used in the preceding subsection on Enjoyment (Sub section 5.3). The results of the scores for ease of use are presented in Table 15.

Table 15: Bootstrapping results: Influence of the visualization approach on the score for ease of use at different vertical attribute levels.

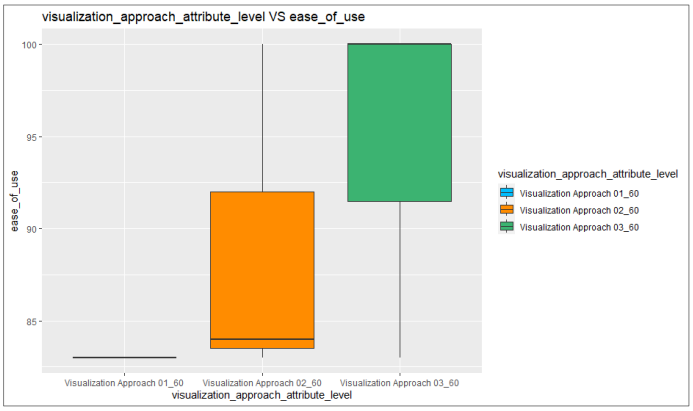
Visualization Approach A	Visualization Approach B	Attribute Level	Mean Difference	CI Low	CI High	Bias	SE
Scrolling Baseline Approach	Spiral-type Leaflet markers Approach	60	6.000	0.000	17.000	-0.017	4.598
		90	-61.333	-67.000	-55.667	0.101	4.548
		120	-22.000	-66.000	0.000	0.162	16.846
		150	-28.000	-55.667	-0.333	0.028	14.180
		180	-44.333	-77.667	5.333	0.396	21.550
		200	5.667	-49.667	61.000	-0.159	28.712
		Overall	-24.000	-40.611	-5.444	-0.028	9.046
Scrolling Baseline Approach	Zoomable circle packing Approach	60	11.333	0.000	11.333	0.118	4.611
		90	-5.333	-33.000	6.000	-0.210	10.261
		120	22.333	17.000	27.667	-0.002	4.409
		150	0.000	-39.000	22.333	-0.093	15.785
		180	0.000	-50.000	22.333	-0.540	19.071
		200	44.333	5.667	83.333	-0.187	20.356
		Overall	12.111	-0.778	26.056	-0.026	6.866
Spiral-type Leaflet markers Approach	Zoomable circle packing Approach	60	5.333	-11.667	16.000	-0.033	6.516
		90	56.000	34.000	56.000	0.099	8.911
		120	44.333	17.000	66.333	-0.436	16.491
		150	28.000	-17.951	50.333	0.075	17.966
		180	44.333	-27.667	88.667	0.104	27.705
		200	38.667	-17.000	71.667	0.113	21.591
		Overall	36.111	17.444	51.788	-0.005	8.760

The key takeaways are:

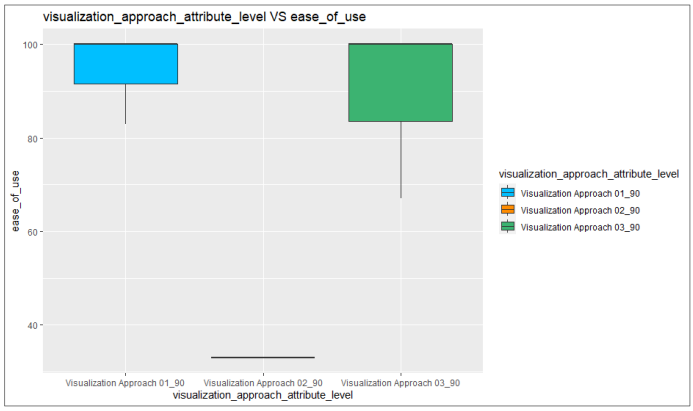
- Scrolling baseline approach vs Spiral-type leaflet markers approach: The scrolling baseline method demonstrated a statistically significant advantage compared to the spiral-type leaflet markers approach, particularly at the 90 and 150 vertical attribute levels, as well as overall. Conversely, the spiral-type Leaflet markers approach exhibited a significant advantage solely at the 60 vertical attribute limit.
- Scrolling baseline approach vs Zoomable circle packing approach: The zoomable circle packing approach showed significantly higher usefulness scores at the 60, 120 and 200 vertical attribute levels.

- Spiral-type leaflet markers approach vs Zoomable circle packing approach: The zoomable circle packing approach exhibited a significant advantage, demonstrating statistical significance, particularly at the 90 and 120 vertical attribute levels, as well as overall.

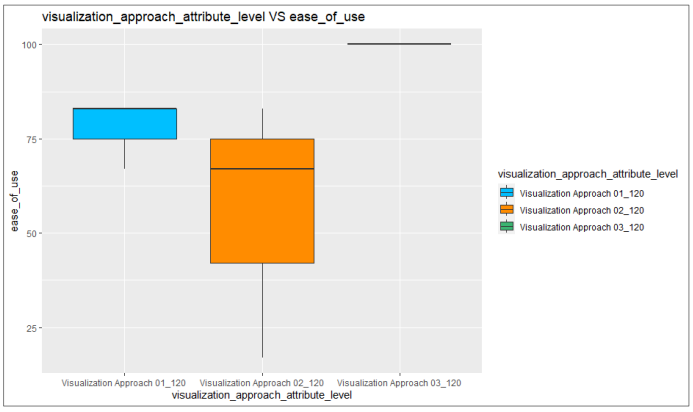
Figure 22 illustrates the graphical representation of ease of use score for each visualization approaches at different vertical attribute levels.



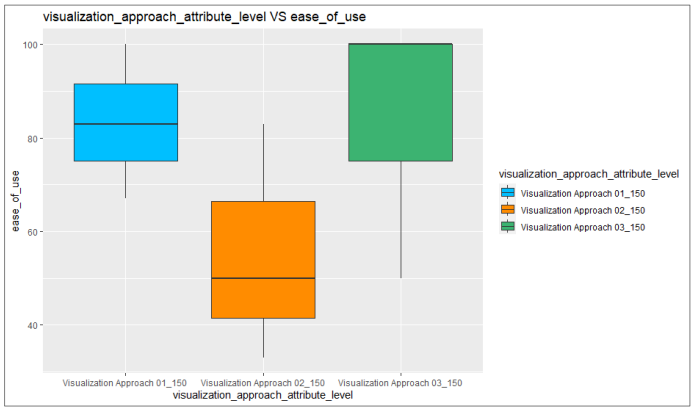
(a) 60 vertical attribute level



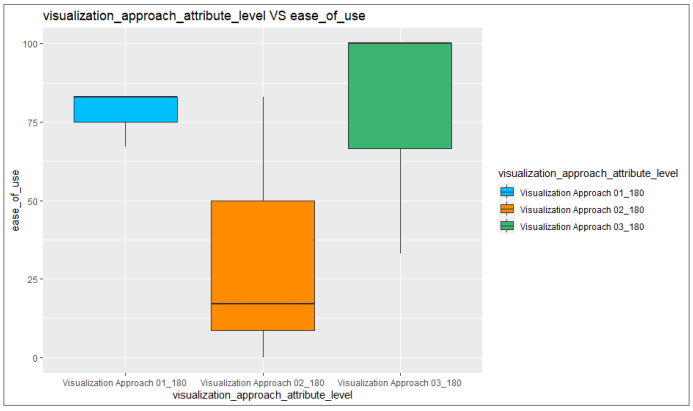
(b) 90 vertical attribute level



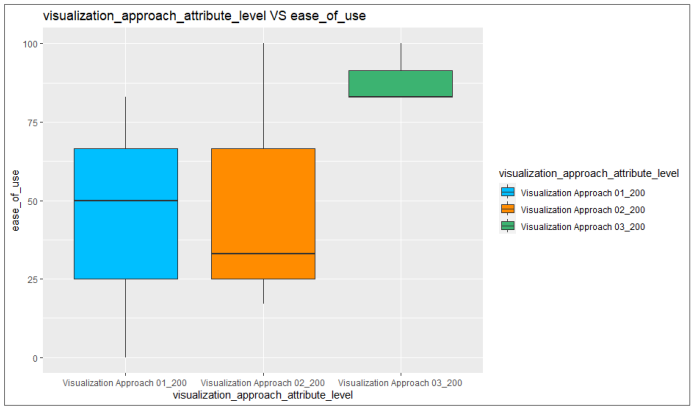
(c) 120 vertical attribute level



(d) 150 vertical attribute level



(e) 180 vertical attribute level



(f) 200 vertical attribute level

Figure 42: Boxplots indicating the ease of use score of each visualization approaches at different vertical attribute levels.

5.7 Participants' subjective preference

During the last stage of the user experiment, participants were asked to respond to the question, "Considering the three visualization approaches you've interacted with, could you please rank them in order of preference based on which one you found most effective in helping you answer the questions?" Participants were then instructed to provide their preferences by assigning Rank 1, Rank 2, and Rank 3 to the respective visualization approaches. Table 16 provides a breakdown of the vote counts for each rank assigned to the three visualization approaches. Additionally, Figure 23 offers a visual representation of these counts, showcasing the comparative preferences for each rank across the three visualization approaches.

Table 16: The counts of votes for each rank

Visualization approach	Rank 1	Rank 2	Rank 3
Scrolling baseline approach	3	13	2
Spiral-type leaflet markers approach	0	2	16
Zoomable circle packing approach	15	3	0

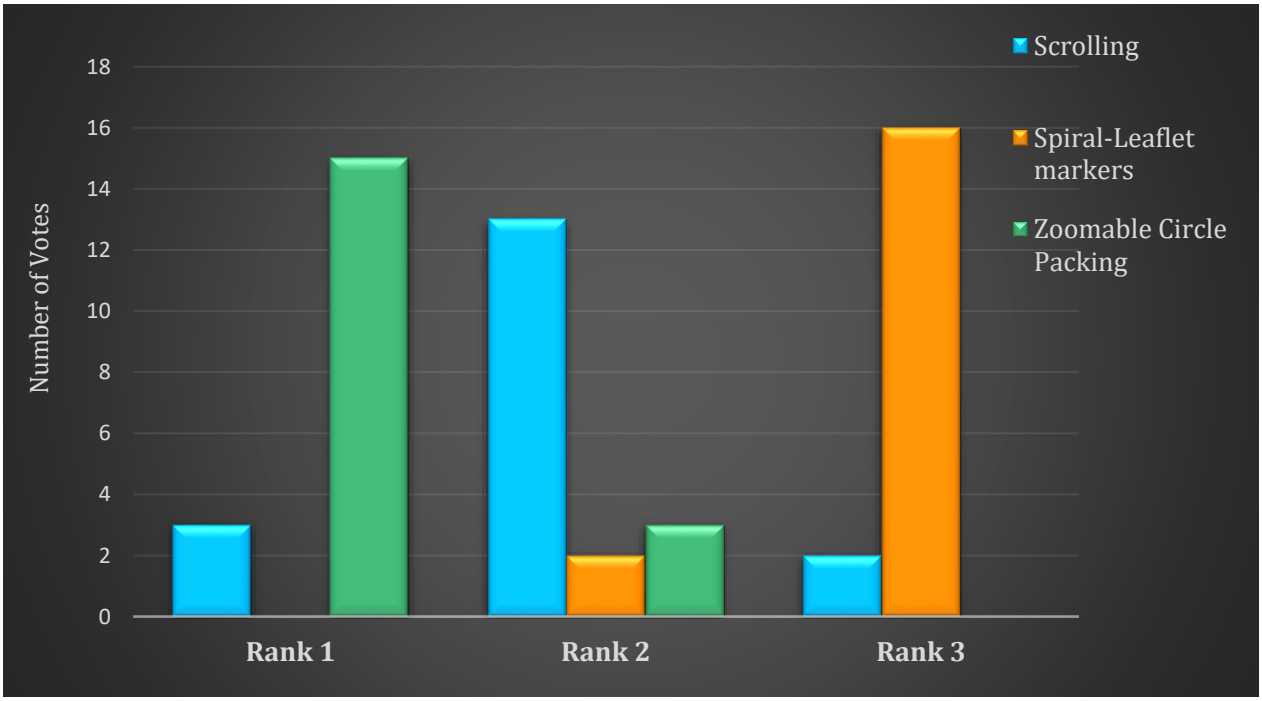


Figure 53: A bar graph illustrates the counts of votes for each rank for three visualization approaches.

The zoomable circle packing visualization approach emerged as the most favored among participants, garnering 15 out of 18 votes as Rank 1. In contrast, the Spiral-type leaflet markers approach received the least preference with 16 out of 18 votes as Rank 3, making it the least favored.

Subsequently, participants were prompted to respond to the question, "Could you please provide reasons for ranking them?" Based on the participants' responses, the key significant advantages of Zoomable circle packing approach and Scrolling baseline approach mentioned can be summarized as follows: *Zoomable circle packing approach* : Users have the capability to zoom in for a detailed inspection of specific attributes and seamlessly zoom out to transition to other attributes. The attributes are thoughtfully organized into clusters, grouping similar ones in close proximity. This systematic arrangement enhances navigation, making it easy for users to locate specific attributes efficiently. *Scrolling baseline approach*: Users can swiftly navigate through attributes by employing a rapid scrolling feature, allowing them to efficiently move through the content and explore different attributes without delays.

Disadvantages of Spiral-type leaflet markers approach and Scrolling baseline approach can be summarized as follows: *Spiral-type leaflet markers approach:* To locate a specific attribute, users need to click on multiple markers, as it can be challenging to distinguish the desired attribute among others within the same category. *Scrolling baseline approach*: The list view arrangement makes it difficult to easily identify attribute counts and discern attribute categories.

5.8 Impacts of participants background

The analysis of participants' backgrounds on dependent variables involved considering several background parameters, namely gender, computer literacy, familiarity with Leaflet.js marker patterns, and familiarity with D3.js zoomable circle packing visualization. The description of how these parameters can be influenced is outlined as follows.

- Gender: Male participants demonstrated a significant faster response only to the zoomable circle packing approach compared to the female participants.
  However, for all the visualization approaches, there were no significant differences observed between males and females for other dependent variables (effectiveness, enjoyment, satisfaction, ease of use).

- computer literacy: Across all visualization approaches, no significant differences were identified in terms of the various dependent variables, concerning computer literacy.
- Familiarity with Leaflet.js marker patterns and D3.js zoomable circle packing visualization: Familiarity with Leaflet.js marker patterns and D3.js zoomable circle packing visualization did not result in any significant advantages for any of the dependent variables across all visualization approaches.