Correlation perception in scatterplots is invariant to dot size

Jessica Ip, Nicholas Chin, and Ronald Rensink | University of British Columbia

Background

Perception of correlation *r* in scatterplots can be reliably modeled using logarithmic and linear functions from Fechner's and Weber's laws [1,2].

Fechner's Law

$$g(r) = \frac{\ln(1 - b_{est} r)}{\ln(1 - b_{est})}$$

Weber's Law

$$JND(r) = k(1/b_{disc} - r_A)$$

systematically related by: bias parameter, *b* (b_{est} and b_{disc})

b_{est}: measure of offset in correlation estimation

b_{disc}: measure of offset in correlation discrimination
k: measure of variability (instance of Weber's fraction)
r_A: $r + 0.5 * JND$ (avg. of base and variant correlations)

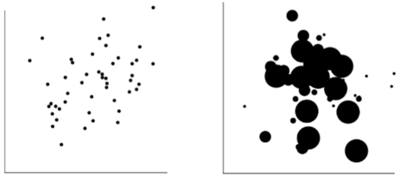
Crucially, by the **Fechner assumption: $b_{disc} = b_{est}$.** Scatterplot designs of different distributions (e.g., gaussian, uniform) and quantity of dots yielded similar performance in correlation perception [1,2].

Aim: What is the effect of dot size on the perception of correlation *r* in scatterplots?

Stimuli

Scatterplots of 48 solid black dots against a white background, with axes 6.5 cm x 6.5 cm and dot cloud 6 cm x 6 cm.

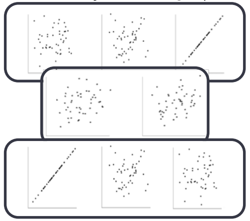
Five dot diameter conditions: 1 mm, 3 mm, 5 mm, 8 mm, and a mix of the previous four.



1 mm Mix

Methods

Within subjects-design (*N* = 18; 15F, 3M; Age_{Ave} = 22.1). Computer tasks with keyboard presses.



1. Initial magnitude estimation (bisection) task: Adjust the middle scatterplot until the correlation *r* is halfway of the two reference plots.

2. Discrimination task: Select the scatterplot with the higher correlation, continue until 75% accurate. Base correlations: 0.3, 0.6, 0.9.

3. Final magnitude estimation (bisection) task: Final estimation results are the average of the initial and final bisection tasks.

Results

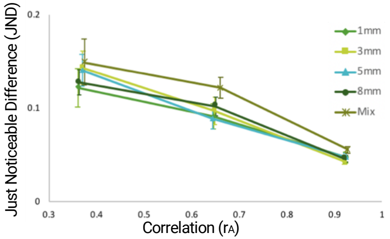


Figure 1. JND as a function of correlation (r_A). Error bars represent 95% CI.

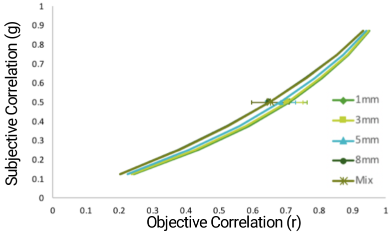


Figure 2. Subjective correlation (g) as a function of objective correlation (r). Error bars represent 95% CI.

- **Strong linear fits across conditions:** r^2_{1mm} = 0.984, r^2_{3mm} = 0.998, r^2_{5mm} = 0.995, r^2_{8mm} = 0.947, r^2_{mix} = 0.937
- **k's do not vary across conditions:** $F(4, 68) = 1.68$, $p = 0.17$. Average k = 0.16.
- **b_{disc} vs. b_{est} not significantly different across conditions:** $F(4, 170) = 2.30$, $p = 0.06$. No significant interaction effects ($p = 0.34$). Average b_{disc} = 0.80. Average b_{est} = 0.78.

Fechner assumption is satisfied ($b_{disc} = b_{est}$).

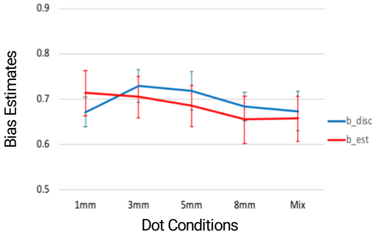


Figure 3. Bias estimates across dot conditions. Error bars represent 95% CI.

Conclusions

There is no significant effect of dot size on correlation perception.

1. More generally, the perception of correlation in scatterplots is not inferred from the pixels in the image. Instead, it appears to be based on more abstract representations of correlation, such as the distribution of the centroids of the dots [1,2].

2. Irrelevant size variations in dots noticeably affect estimates of average value in scatterplots [3]. In contrast, the indifference to dot size variation found here supports the possibility that correlation estimation relies on a different ensemble process than that for average value. It may also be related to the finding that dots can be selected based on color for perception of average value but not for correlation [4].

Future Directions

Is correlation perception in scatterplots also invariant to color, luminance, or shape of visual stimuli?

Insights from the perceptual processing of visual features in scatterplots could inform future approaches to visualization designs.

References

[1] Rensink, R.A., & Baldridge, G. (2010). The perception of correlation in scatterplots. *Computer Graphics Forum, 29*(3), 1203–1210.
[2] Rensink, R.A. (2017). The nature of correlation perception in scatterplots. *Psychonomic Bulletin & Review, 24*(3), 776-797.
[3] Kim, Y., & Heer, J. (2018). Assessing effects of task and data distribution on the effectiveness of visual encodings. *Computer Graphics Forum, 37*(3), 157-167.
[4] Elliott, M.A., & Rensink, R.A. (2019). Attentional color selection depends on task structure. *Vision Sciences Society*, St. Petersburg, FL, USA, May 2019.