Exploration of Stevens's Power Law

Justin Myerson and Michael Corace

1 Introduction

Numerous experiments have been conducted to explore the different relationships of stimuli in regards to Steven's Power Law. With new technologies and visualization techniques, many aspects of modern visualizations have not been thoroughly explored. Our goal is to help define how human perception is affected by these stimuli. Static comparative brightness affects every visualization designer, as users of electronic displays can alter the brightness at will. Understanding how their users will perceive different levels of brightness could help inform visualization designers how they can better represent data along this channel.

Another common stimuli that has not been thoroughly explored is velocity. Animation is a popular tool amongst designers, but it has been determined to not be an effective way of communicating information. Animation is, however, excellent at attracting attention. We plan to abstract a single piece of animation, in this case the velocity, and test how accurately its magnitude is perceived.

A series of experiments will be used to determine how well the magnitude of change in these channels is perceived by our volunteers. We plan to conduct experiments involving line length and area to prove that our method of data collection is accurate in reference to the established Steven's Exponents of these channels.

2 One-sentence Description

Exploring four different common visualization elements to recalculate the exponents associated with brightness, velocity, area, and line length in Stevens's Power Law.

3 Project Type

This project is an experiment based on results from outside participants.

4 Audience

Stevens's Power Law is widely cited and recognized as a go-to source for understanding the differences in how people perceive magnitudes of change for a variety of stimuli. This is especially important in the field of data visualization, where creating views that can be accurately analyzed by users is one of the biggest drivers behind choosing certain designs over others. If we conclude that the exponents traditionally associated with our chosen stimuli are significantly different, this could signal that perhaps our understanding of human perception of visualization elements, and the consequences of those differences in perception on visualization design choices, is not precise.

5 Approach

Our approach for each trial of the experiment is as follows:

1. We will show the user one element, A, and give them the value of the stimuli (for example, a square of area 10, a line of length 12, etc.).
2. We will show the user a second element of the same type, B, with a different value.
3. We will ask the user to report their estimation of the magnitude of element B.
4. The calculation of the exponent, E, will then be:

   $E = log_{(Diff)}(B_{Reported} / A)$, where
   $Diff = (B_{Actual} / A)$

   For example, if A = 5, B_{Actual} = 10, and $B_{Reported}$ = 10, the exponent calculated would be $\log_2 2 = 1$, because the participant estimated the value exactly.

   If A = 5, B_{Actual} = 10, and $B_{Reported}$ = 12, the exponent calculated would be $\log_2 2.4 = 1.26$, because the user overestimated the difference in magnitude.
5. For each stimulus, we will then calculate the average of the reported exponents.

6 Best-case Impact Statement

To succeed in this project, we aim to accomplish two things:

1. We intend to calculate new exponents for the velocity and static brightness stimuli, which are not included in the original Stevens's Power Law results.
2. We intend to either confirm or refine the values of the exponents for the area and line length stimuli based on the numbers presented in the original Stevens's Power Law.

7 Major Milestones

- Developing methods to test the stimuli we decided on.
- Building a tool to administer these tests and collect data.
- Administering the tests with multiple participants.
- Reviewing the data and drawing conclusions.

8 Obstacles

8.1 Major Obstacles

- We may inadvertently cause bias in the results by incorporating a secondary stimulus that affects the participants in an unknown way.

8.2 Minor Obstacles

- Implementing a velocity-based animation in D3 may be more complex than originally believed
- Finding enough willing participants for the data to be statistically significant.

9 Resources Needed

- Code to generate the necessary visualizations.
- A literature review of this space.
- Willing participants to conduct the experiment and get results.
- A process for analyzing the data collected.

10 Related Publications

Chevalier, Fanny, Pierre Dragicevic, and Steven Franconeri. "The not-so-staggering effect of staggered animated transitions on visual tracking." IEEE transactions on visualization and computer graphics 20.12 (2014): 2241-2250.

Heer, Jeffrey, and Michael Bostock. "Crowdsourcing graphical perception: using mechanical turk to assess visualization design." Proceedings of the SIGCHI conference on human factors in computing systems. ACM, 2010.

Rensink, Ronald A. "Seeing, sensing, and scrutinizing." Vision research 40.10-12 (2000): 1469-1487.

Stevens, S. S. “The Direct Estimation of Sensory Magnitudes: Loudness.” The American Journal of Psychology, vol. 69, no. 1, 1956, pp. 1–25. JSTOR.

11 References

Bernasconi, Michele, and Raffaello Seri. "What are we estimating when we fit Stevens’ power law?." Journal of Mathematical Psychology 75 (2016): 137-149.

Bolton, Matthew L. "Modeling human perception Could Stevens' Power Law be an emergent feature?." 2008 IEEE International Conference on Systems, Man and Cybernetics. IEEE, 2008.

G. Robertson, et al. "Effectiveness of Animation in Trend Visualization." IEEE Transactions on Visualization and Computer Graphics 14.6 (2008): 1325-32. Web.

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Stevens, S. S. "Concerning the psychophysical power law." Quarterly Journal of Experimental Psychology 16.4 (1964): 383-385.

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