# Common Angle Plots as perception-true visualizations of categorical associations

Heike Hofmann, *Member, IEEE,* and Marie Vendettuoli

**Abstract**—Visualizations are great tools of communications - they summarize findings and quickly convey main messages to our audience. As designers of charts we have to make sure that information is shown with a minimum of distortion. We have to also consider illusions and other perceptual limitations of our audience. In this paper we discuss the effect and strength of the line width illusion, a Müller-Lyer type illusion, on designs related to displaying associations between categorical variables. Parallel sets and hammock plots are both affected by line width illusions. We introduce the common-angle plot as an alternative method for displaying categorical data in a manner that minimizes the effect from perceptual illusions. Finally, we present results from user studies as evidence that common angle charts resolve problems with the line width illusion.

**Index Terms**—Linewidth illusion, Data Visualization, High-dimensional Displays, Parallel Sets, Hammock Plots, Müller-Lyer Illusion.

## 1 Introduction

A well-designed graph is a powerful tool that transends barriers of language to communicate complex concepts from author to audience. It becomes a problem if readers are unable to easily extract the main message, especially when distortion is encoded. The source of a distortion may be due to intrinsic deformities in the graph or simply the perceptual limitations of the audience. Examples include Tufte's *Lie-Factor* [1, p. 57–69] in which the proportion of the physical space occupied by the graphic is inconsistent with underlying data; calculated ratio (of proportions) less than one indicate underrepresentation. Another example is the Müller-Lyer family of illusions such as the sine wave, where viewers perceive extents at the curves to be of different height than in the straight regions even though all regions were of the same height [2].

Regardless of the cause of distortion, the graph author has a duty to create visualizations that allows readers to extract an accurate interpretation of the underlying data. The *Lie-Factor* provides a quantitative method to evaluate distortion due to graph deformities. In order to ascertain the impact of distortion due to perceptual limits, usability studies provide empirical evidence supporting underlying metaphorical models both known and unpredicted. This paper presents a method for developing new statistical visualization which incoporates usablity testing, a technique borrowed from the field of user centered design. It is our belief that the results of such testing allows a graph author to make design choices to reduce distortion due to perceptual limits. We describe how a routine user study during development of parallel coordinates for categorical data led to the unexpected and unpredicted discovery of the *line-width* illusion. We introduce the *common-angle plot* as an alternative method for displaying categorical data in a manner that minimizes the effect from perceptual illusions. The display preserves properties of parallel coordinates, such as the potential to visualize a large number of dimensions simultaneously, but also presents frequency information. Finally, we present results from user studies as evidence that common angle plots resolve the problem of the line width illusion.

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## 2 Related Work

This section describes a selection of related work as context for the contributions presented here.

### 2.1 Line width illusion

An example of the *line width illusion* is displayed in figure 1. This chart displays the balance of trade between England and the East Indies as shown by William Playfair in his Commercial and Political Atlas, 1786 [3], [4]. One purpose of this chart is to demonstrate the difference between imports and exports in a particular year and its pattern over that time frame. The difference in exports and imports is encoded as the vertical difference between the lines. When observers are asked to sketch out the difference between exports and imports [5], they very often miss the steep rise in the difference between the lines in the years between about 1755 and 1765. Figure 2 shows the actual difference between imports and exports.

This phenomenon is known and widely discussed in statistical graphics literature [5], [1], [6], [7]. It is due to our tendency to assess distance between curves as the minimal (orthogonal) distance rather than the vertical

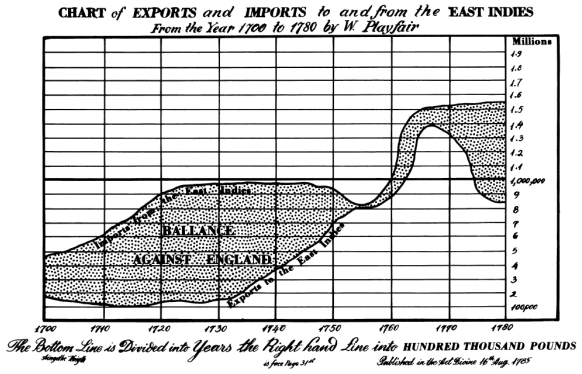


Fig. 1. Playfair's chart from the Commercial and Political Atlas (1786) showing the balance of trade between England and the East Indies. In which years was the difference between imports and exports the highest?

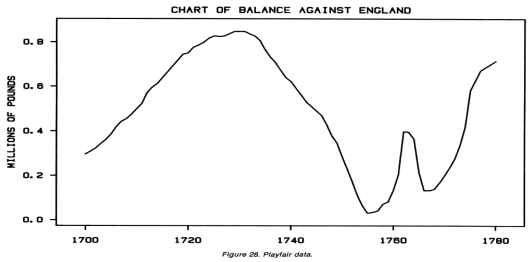


Fig. 2. Difference between exports and imports from England to and from the East Indies in the 18th century – the steep rise in the difference around 1760 comes as a surprise to many viewers of the raw data in figure 1.

distance – see sketch **??** for a visual representation of both.

In the perception literature, this phenomenon is known as part of a group of geometrical optical misperceptions of a context-sensitive nature classified as Müller-Lyer illusions [2]. Interestingly, there seems to be a general agreement that this illusion exists, but a quantification of it is curiously absent from the literature.

While we see the type of chart as shown in figure 1 proposed by Playfair quite commonly, particular in election years – where these kind of charts are used to enable comparisons of support for several candidates, the recommendation from the literature is to avoid charts in which the audience is asked to do visual subtractions, and show these differences directly.

However, the line width illusion is not restricted to this situation only. We next discuss how other charts, such as the parallel sets plots [8], are affected by it.

### 2.2 Hammock plots

### 2.3 Strength of the line width illusion

### 2.4 Parallel sets

## 3 Conclusion

The conclusion goes here.

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Appendix one text goes here.

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