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Effects of Visual Anchors in Sequential Presentations of Data Visualization

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ABSTRACT

The anchoring effect is a phenomenon that human cognition tends to be biased by initial information. The research concerning anchoring effects in visualization has received increasing attention in recent years, but it is still unclear how different presentations of visual anchors affect human cognition. Therefore, the aim of the current study is to investigate the effects of visual anchors in different sequential presentations on the performance of estimation. To investigate, two within-subject experiments were performed. In both experiments, the task was to estimate the value of target, which appeared after the visual anchors. User performance was assessed through behavioral metrics of estimation value and reaction time. The data of Experiment 1 reveals the existence of anchoring bias under a certain circumstance. Furthermore, the findings in Experiment 2 indicate vertical presentations of pie charts help reduce estimate deviation. These results suggest that vertical presentations of pie charts facilitate visual information processing and mitigate anchoring bias. Our findings of this study open the potential for discovering biased visual information processing and judgements, as well as bring some insights into the design of data visualization.

Keywords: Anchoring effect, Bias, Data visualization, Visual anchor

INTRODUCTION

At present, people need to process a great deal of complex information, and make more elaborate estimations or decisions than before. One particular concern when handling complex information is that the first piece of information tends to bias cognition and results in estimation deviation, which is known as the anchoring effect (Furnham & Boo, 2011; Tversky & Kahneman, 1974). Currently, some researchers on information visualization suggest that anchoring effects can not only be found in classical numerical anchors (Blankenship et al., 2008; Mussweiler & Strack, 2000), but in the form of visual anchors (Cho et al., 2017; Valdez et al., 2018; Wesslen et al., 2018). Recent studies in anchoring effects in visualization paid attention to investigating the existence of such effects in a variety of forms and tasks of data visualization (Cho et al., 2017; Valdez et al., 2018; Wesslen et al., 2018; Wesslen et al., 2019). However, these studies seem to focus only on examining whether participants' judgements would be biased in the same way as

classical research in psychology, and it is still unclear how and how far various sequential presentations of information affect participants' estimation. The present study is aimed to investigate the effects of different presentations of anchors on reduction of estimate deviation, thus providing some insights into mitigating this kind of cognitive bias.

This paper has two key goals. To examine the performance of bias reduction, it is necessary to verify the presence of bias. Thus, the first goal is to examine the existence of anchoring effects using the theory of anchor source, which tries to explain the mechanisms of anchoring by distinguishing two main anchoring processes (Epley & Gilovich, 2001). According to this theory, anchors can be divided into "experimenter-provided (EP)" and "self-generated (SG)" anchors. The EP anchor is provided directly by experimenters, whereas the SG one is generated by participants themselves (Epley & Gilovich, 2004; Mussweiler, 2003; Strack & Mussweiler, 1997). Considering that the existence of anchoring effects has been proved, the second goal is to check if the presentations of anchors modulate estimation deviation.

Based on previous findings (Ma et al., 2015; Qu et al., 2008), we hypothesized the following:

H1: Participants' estimation value would be affected by the prior anchors.
H2: The size of the anchoring effect would be lower under SG anchors than EP anchors.
H3: The estimate deviation value would be lower in experimental groups than in the control group.

GENERAL METHODOLOGY

Two experiments were performed to examine the effects of different presentations of anchors on the human performance of numerical estimation. In both experiments, participants were tasked to estimate the value of target stimuli. The same modified one-step paradigm (Wilson et al., 1996) was adopted in the two experiments.

Participants

Two groups of participants were recruited for two experiments (mean age: 23.52 years old, standard deviation (SD)=2.14). Each has a Bachelor's degree or above in design or engineering. They all have self-reported normal or corrected-to-normal vision. Each of participants was voluntary and was provided the written informed consent approved by Ethics Committee of Southeast University affiliated ZhongDa Hospital.

Procedure

Participants sat on a comfortable chair in front of a computer screen located at eye level at a distance of 75 cm in a quiet, normal light laboratory. Before taking the experiment, participants signed the informed consent form voluntarily. Following the practice blocks (10 trials) is the formal experiment. In

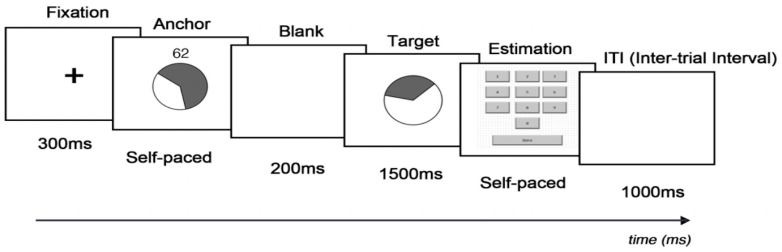

Figure 1: The procedure of one trial conducted in both experiments.

both experiments, the main session consisted of 4 blocks and each block consisted of 24 trials, resulting in 96 trials in total. The procedure of one trial is illustrated in Figure 1.

EXPERIMENT 1

The first experiment objective is to examine the existence of the anchoring effect, as well as investigate if the value and source of anchoring stimuli affect its existence.

Methods

(1) Experimental design

A 2 (anchor value: higher vs. lower) ×2 (anchor source: EP vs. SG) within-subject experimental design was adopted. Trials of EP and SG anchors were presented in separate blocks. Higher anchors or lower anchors were randomly presented in each block. The order of blocks was counterbalanced over all participants.

(2) Stimuli

Two anchoring pie charts was set for one target pie chart as higher anchor and lower anchor. In EP anchor condition, the anchors were provided directly through visual cues; while in SG anchor condition, the anchors were generated by participants themselves according to their experience of pie charts (see Figure 2A).

(3) Statistical analysis

The estimate values were averaged within each condition (EP-lower, EP-higher, SG-lower, SG-higher). For EP and SG anchor conditions, the estimate values under lower and higher anchor conditions were analyzed respectively using the related t-test. An alpha level of .05 was used. The metric of reaction time was analyzed in the same way as the estimate values.

Results and Discussions

It is shown that the estimate values are significantly higher for the higher anchor than for the lower one under EP anchors ($t(24) = 2.982$, $p = 0.006$). However, when it comes to SG anchors, there is no significant difference between higher and lower anchors ($t(24) = 0.476$, $p = 0.638$). In addition, no significant difference in reaction time is found under either EP anchor condition ($t(24) = -.161$, $p = 0.873$), or SG anchor condition ($t(24) = 1.005$, $p = 0.325$) (see Figure 3).

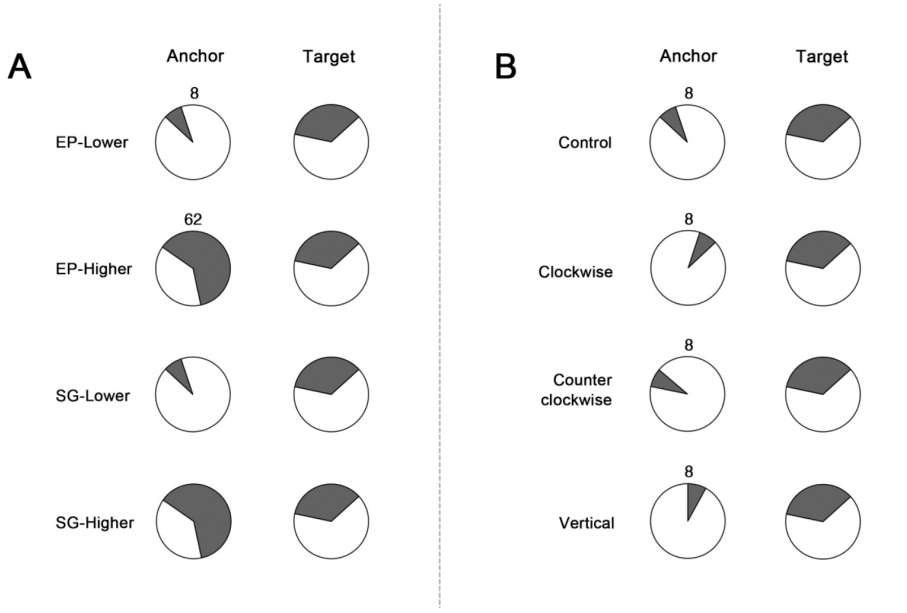

Figure 2: (A) Sample stimulus pairs used in Experiment 1. (B) Sample stimulus pairs used in Experiment 2.

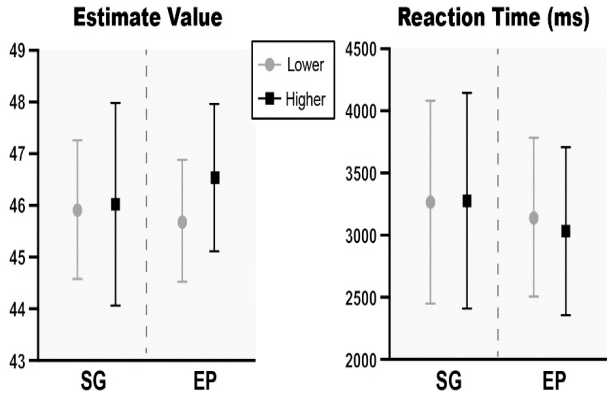

Figure 3: Changes in the metric of estimate value and reaction time under different conditions.

The results indicate a sizeable anchoring effect under the condition of EP anchors (**H1** is confirmed), but no anchoring bias under SG anchors. Thus, **H2** is partially supported. To further examine the comparative effectiveness of various presentations of data visualization in mitigating the anchoring bias, the second experiment was performed using EP anchors as stimuli.

EXPERIMENT 2

Based on the results of Experiment 1, showing no anchoring effects in SG anchors, the purpose of Experiment 2 is to evaluate how different presentations of EP anchors facilitate or hinder biased performance.

Methods

(1) Experimental design

A within-subject design was adopted. The independent variable was the presentations of experimenter-provided anchors (with four conditions: control, clockwise, counterclockwise, and vertical). The task and setting were similar to Experiment 1.

(2) Stimuli

Sample stimulus pairs in four conditions are shown in Figure 2B. In control condition, the angle of anchoring stimulus was randomly generated; in clockwise condition, anchor-target pairs aligned clockwise; in counterclockwise condition, anchor-target pairs aligned counterclockwise; in vertical condition, the angle of anchoring stimulus was set in vertical position.

(3) Statistical analysis

The estimate deviation values (difference between the correct value and the estimate value input by participants) were averaged within each condition and were analyzed using repeated-measure analysis of variance (ANOVAs). An alpha level of .05 was used. The Greenhouse–Geisser method was used to correct data that violated the spherical hypothesis, and the Bonferroni method was used to correct P-values in multiple comparisons. The metric of reaction time was analyzed in the same way as the estimate values.

Results and Discussions

The ANOVA results show that the main effect of presentation factor is significant on participants' estimate deviation values ($F(3,22) = 6.827$, $p = 0.01$, $\eta^2 = 0.221$). The multiple comparison analysis shows that the difference in estimate deviation value between the vertical and control condition reaches the statistically significant level ($p < 0.001$). In contrast, no significant difference is found when comparing the estimate deviation values between clockwise and control condition, as well as between counterclockwise and control condition. In addition, no significant difference in reaction time is found under four different conditions ($F(3,22) = 0.91$, $p = 0.945$, $\eta^2 = 0.004$) (see Figure 4).

In general, compared with the control condition, the estimate deviation is lower under the condition of vertical presentation. The results indicate that vertical presentations of pie charts help reduce estimation deviation. It is suggested that vertical presentations of pie charts facilitate visual information processing and mitigate anchoring bias. However, compared with the control condition, the estimate deviation under conditions of clockwise and counterclockwise shows no significant difference. Therefore, the evidence partially supports the third hypothesis (**H3**).

GENERAL DISCUSSION

The present study explored the influence of visual anchors in different sequential presentations on participants' performance in a numerical estimation task. The results of Experiment 1 revealed the existence of anchoring bias under EP anchors, but not under SG anchors. Thus, **H1** was supported, and **H2** was partially supported. In Experiment 2, the estimate deviation was

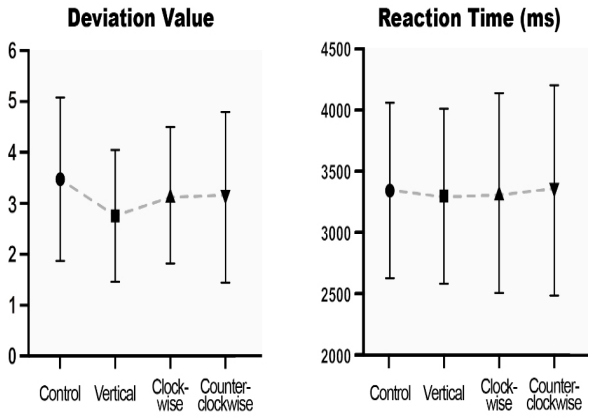

Figure 4: Changes in the metric of estimate deviation value and reaction time under different conditions.

lower under the condition of vertical presentations of pie charts than the control condition (**H3** was partially confirmed).

In Experiment 1, the lack of anchoring effects under SG anchors might be attributed to the experimental design. When the anchoring stimuli presented on the screen, the self-paced procedure made participants tend to skip SG anchors, because SG anchors included less useful information than EP anchors. Further work needs to be done to explore how to design an effective self-generated anchor in data visualization.

In Experiment 2, the results of implies that the vertical presentation of pie charts enabled to mitigate anchoring bias to some extent, although the estimate deviation has not been eliminated. This finding is in line with previous studies in psychology (Epley & Gilovich, 2005). In addition, although not statistically significant, the overall trends in the average estimate deviation values of three experimental groups are lower than the control group. The reason for statistically nonsignificant results might be the overmuch trials, which cause participants to memorize target stimuli.

CONCLUSION

To sum up, the existence of anchoring effects in data visualization is uncovered under two sources of anchors. Moreover, the effects of anchors of different presentations on decision-making is evaluated by comparing four types of visual anchors through various behavioral metrics. Our findings of this study open the potential for discovering biased visual information processing and judgements, as well as bring some insights into the design of data visualization, which might be applied to information visual analytic systems.

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