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10-14-2012

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Recommended Citation

Ottley, Alvitta; Crouser, R. Jordan; Ziemkiewicz, Caroline; and Chang, Remco, "Priming Locus of Control to Affect Performance" (2012). Computer Science: Faculty Publications, Smith College, Northampton, MA.
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Priming Locus of Control to Affect Performance

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ABSTRACT

Recent research suggests that the personality trait Locus of Control (LOC) can be a reliable predictor of performance when learning a new visualization tool. While these results are compelling and have direct implications to visualization design, the relationship between a user's LOC measure and their performance is not well understood. We hypothesize that there is a dependent relationship between LOC and performance; specifically, a person's orientation on the LOC scale directly influences their performance when learning new visualizations. To test this hypothesis, we conduct an experiment with 300 subjects using Amazon's Mechanical Turk. We adapt techniques from personality psychology to manipulate a user's LOC so that users are either primed to be more internally or externally oriented on the LOC scale. Replicating previous studies investigating the effect of LOC on performance, we measure users' speed and accuracy as they use visualizations with varying visual metaphors. Our findings demonstrate that changing a user's LOC impacts their performance. We find that a change in users' LOC results in performance changes.

1 INTRODUCTION

Effective visualizations serve as an extension to a user's cognition and aids complex thinking. As a result, it is widely accepted that understanding a user's cognitive processes is integral to the effective design and evaluation of visualizations. Due to the inherent relationship between a user's cognitive processes and their personality, there has been a recent emergence of research into the impact of a user's personality on their performance when using visualizations [2, 4]. While several personality traits [2] have been shown to affect performance, the most compelling evidence is in support of the personality trait *Locus of Control (LOC)*.

LOC measures the extent to which someone believes that events are determined by their actions or by external forces. Persons who are categorized as having internal LOC (internals), believe that events are contingent on their actions and those who have external LOC (externals) believe that events are controlled by outside forces. In recent studies, this personality trait has been shown to correlate well with performance on visualizations with varying visual metaphors [2, 4].

While these studies observed a relationship between a user's LOC and their performance, it remains unclear whether changes in LOC affect performance on visualizations. Research suggests that an individual's LOC score varies and can even be intentionally manipulated [1]. We propose that a user's LOC when using a visualization may not always be stable and can be altered using a process similar to previous studies in personality psychology. We hypothesize that a change in LOC will result in a predictable change in their performance. Specifically, we posit that there is a *dependent relationship between LOC and performance*, i.e. users who are primed to be internal, external or average, will demonstrate performance measures similar to the respective groups of the previous studies.

To test our hypotheses, we replicated the experiment design of Ziemkiewicz et al. [4], keeping constant the views, dataset and tasks, while using existing priming techniques [1] to manipulate LOC. Three hundred online subjects with varying LOC scores were recruited via Amazon's Mechanical Turk service. Our findings show that priming users to be internal, external or average, elicits performance measures similar to the respective group from Ziemkiewicz et al. This provides evidence of a dependent relationship between LOC and performance.

2 RELATED WORK

Recent studies have found a correlation between LOC and performance on visualization interfaces. Green et al. reported this in their study [2] on the effect of personality dimensions on learning two dissimilar visualization tools. In their work, the source of the distinction between the two interfaces was ambiguous. There were a large number of design differences between the two visualization systems that may have interacted with LOC to produce performance differences. Ziemkiewicz et al. [4] extended this work by simplifying the visualizations studied in order to isolate the variable of layout design. They found a significant trend that suggests that Green et al.'s results were likely due to the visualizations' layout style, rather than to other factors.

While these studies demonstrate that there is a correlation between LOC and visual layout style in this type of hierarchical visualization, it is unclear from existing work what the nature of this relationship is. It is possible that there is a dependent relationship between the factors, such that a user's LOC directly affects a user's ability to work with these interfaces. In the current work, we examine this question through a targeted study that uses priming to manipulate the variable of LOC.

2.1 Priming Locus of Control

Fisher et al. [1] investigated how manipulating LOC through psychological intervention affects their disability. The study was performed on patients with chronic lower back pain who were randomly assigned to one of two groups; those who are either nudged to measure more internal or external on the LOC scale. LOC was manipulated by asking experience recall questions, where patients of the internally-primed group were asked to describe times when they felt in control (increase LOC) and patients in the externally-primed group were asked to give times when they did not feel in control (decrease LOC). They found that there was a significant difference in LOC scores before and after priming. They also assessed patients disability by using a lifting task and found that patients who were primed to be more internal on the LOC scale, on average spent more time performing the task and chose heavier weights than the externally-primed group. Patients who were externally-primed were more likely to give up or not try at all.

The results of Fisher et al. not only demonstrate that LOC can be altered through experience recall, but it also implies that this change in LOC can affect behavior and approach to solving a given problem. We propose that this result also extends to other tasks and we hypothesize that a change in users' LOC will affect a user's approach to problem solving and performance when using visualizations.

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IEEE Symposium on Visual Analytics Science and Technology 2012
October 14 - 19, Seattle, WA, USA
978-1-4673-4753-2/12/$31.00 ©2012 IEEE

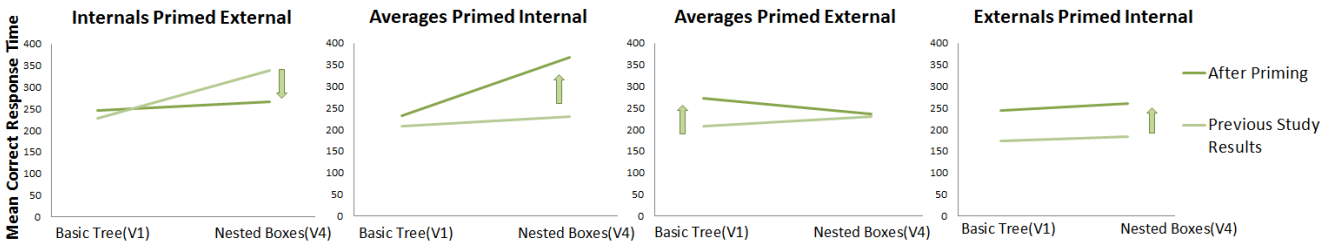

Figure 1: Mean correct response times in inferential task questions across the two views for each of the four priming groups. The average participants were successfully primed to behave as internal participants, while the internal and external participants were successfully primed to be more average.

3 Experiment

To test our hypotheses we replicated the study by Ziemkiewicz et al., holding constant the views, datasets, and questions to enable us to make accurate comparisons between the two results. Like Fisher et al., [1] we used an experience recall task to manipulate LOC. Since this was an online study, we provided text fields and required users to enter no less than three examples of 100 words each, to better ensure that the priming was effective.

We measured participants' LOC prior to and after the study to verify whether the recall task affected their LOC score. We used a 29-question Rotter LOC Scale [3] which is comprised of 23 forced-choice questions and 6 filler questions instead of the shorter LOC inventory used by Ziemkiewicz et al. The same questionnaire was used twice to maintain consistency between the measures, and we counterbalanced learning effects by altering the order in which the questions were presented and substituting the filler questions.

For this study, we used only the two most extreme views used by Ziemkiewicz et al., V1 and V4. Each participant then completed the tasks using each of the two views, of which the orders were randomized.

4 Results

We recruited 300 participants via Amazon's Mechanical Turk service and of the 300, we discarded the results of 71 participants for failure to complete the task as required. Data were also discarded if their interaction times were impractical (less than 10 seconds) and they also had no correct responses. The average LOC was 12 on a 23-point scale and there were 59 externals , 106 averages and 36 internals.

In our analysis, we split the participants into four priming groups based on their original LOC scores and the priming stimuli they received: internal-primed-external, external-primed-internal, average-primed-internal, and average-primed-external.

For all but one group (average-primed-internal), the priming prompts were successful at influencing the participants' LOC scores in the desired direction. We ran t-tests on pre-test and post-test LOC scores for each of the priming groups, and in each case the change was significant at a $p < .01$ level. The group averages-primed-internal was not significant with $p = .3$. Although we observed the statistically significant changes with the other groups, on average the mean difference was small in each case, with the mean magnitude of difference being $M = 1.69$ in the average group, $M = 1.45$ in the internal group, and $M = 1.37$ in the external group. Feedback from participants suggests this may be partly due to the fact that some users remembered their responses from earlier and tried to answer consistently.

Although the change in LOC score was not dramatic, we did find evidence that priming caused the expected behavior on visualization tasks. To test our main hypothesis, we performed a repeated measures ANOVA on Correct Response Time using a 2x4 mixed design of Visual Layout (within-subjects) by Priming Group (between-subjects). The ANOVA uncovered no significant main effect of Visual Layout, perhaps because the differences in performance across priming groups counteracted the overall differences in the effectiveness of each layout type. More relevant to our hypothesis is that this test revealed a significant interaction between Visual Layout and Priming Group, $F(3,57) = 2.85, p < .05$. This finding demonstrates that participants in the different priming groups showed significantly different patterns of performance between the two views. These results are summarized in Figure 1.

5 Discussion

The finding that priming LOC can cause a change in their performance on a visualization task has significant implications for visualization evaluation and research as a whole. For this particular visualization and task, a short priming exercise appears to be sufficient to erase individual differences or create them where they did not exist before. For example, by simply asking users to recall times when they didn't feel in control, the performance difference between the two views for internals change from about 2 minutes (110 seconds) to just 20 seconds. Such significant changes add nuance to previous findings on personality-based individual differences and suggests that subtle differences in a user's frame of mind may make a major difference in how they approach visualization use.

What this and previous studies ultimately highlight is that designing interfaces to help people think is a complicated endeavor. People think in different ways, and how they think is often situation-dependent. Visualization evaluation needs methods to analyze what frame of mind a visualization is best suited for. It is possible that personality factors such as LOC could be used to test this. Knowing, for example, that nested boxes are less suited to an internal frame tells us some information about nested boxes as a design.

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