**Replication of Study "Neural mechanisms of attentional shifts due to irrelevant spatial and numerical cues" by Ranzini et al. (2009, Neuropsychologia)**

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## Introduction

The current replication project aimed to reproduce the attentional orienting effect induced by irrelevant numerical cues found in Ranzini et al. 2009 study (Ranzini, Dehaene, Piazza, & Hubbard, 2009). Previous research reported that irrelevant Arabic numerals could elicit automatic shifts of attention. The main idea of the original study is to test whether these automatic shifts of attention use the same mechanisms as volitional shifts of attention. In the original study, Ranzini et al. found a marginal significant interaction between the magnitude of cue and target location, i.e., faster detection time for left-sided targets cued by small numbers and right-sided targets cued by large numbers. This attentional cueing effect is the target finding for replication.

## Methods

The subjects participated in a speeded target detection task. Each trial started with a fixation point, followed by a central numeral cue. After a variable delay, a white circle appeared in the left or right visual field with equal probability. Participants responded as quickly as possible after target onset. The magnitude of the numeral cue did not predict which side the target would appear.

## Power Analysis

In the original study, 15 subjects were included in the data analysis and they completed trials in all conditions. A two-way (Cue Magnitude × Target Position) repeated measures ANOVA was conducted. The authors reported that the interactions approached significance, $F(1,14)=4.1$, $p = 0.06$. The information provided in the paper is insufficient to calculate the effect size and to determine the sample size based on power analysis (Potvin & Schutz, 2000). Therefore, sample size was decided based on the budget limit of the class.

## Planned Sample

Since the detailed statistics of the original results were not available, the sample size was determined by the budget limit for this course project ($40 - $50/student). The entire experiment lasted about 35 minutes. I planned to pay each subject 2 dollars for completing the task, and I

would recruit 18 - 22 subjects depending on the available fund, and the sample size would be larger than the original study (15 subjects). To replicate the demographics of the original study, the age of the participants was planned to be limited to 20 - 29. Only US citizens were qualified to participate in the experiment.

**Materials**

The fixation point (Courier New 18 pt, 4 mm) and the numerals (1, 2, 8 or 9; Courier New 18 pt, 2 cm × 1.3 cm) were white on a black background. The target was a white circle (diameter 1 cm) appeared at 9.2 cm eccentricity. The subjects responded to the onset of the target by pressing the "H" key on their keyboard.

**Procedure**

Participants were asked to sit one arm's length away from the screen. Each trial started with a fixation point lasting 500 ms, followed by a numeral cue presented for 300ms. After a variable delay (300, 400 or 500ms) a white circle appeared for 100 ms in the left or right visual field. Participants were instructed to make a speeded response to the target presentation by pressing "H". "They were allowed 2 s from target onset to respond, followed by a 2 s inter-stimulus interval (ISI)".

All participants completed 264 experimental trials, 24 of which were catch trials (i.e., no target appeared after the cue). There were 60 target trials and 6 catch trials for each digit 1, 2, 8 and 9, which were presented in random order. The experiment was divided into 12 blocks, each lasting approximately 3 min. Beside the experimental trials, "there were 10 training trials at the beginning of the experiment, and 4 dummy trials at the beginning of each block that were not analyzed. Subjects were explicitly told that the targets had a 50% probability of appearing on the left or right, independent of the cue and were not instructed to orient their attention in the direction indicated by the cue. In order to induce subjects to pay attention to the cue even though it was not relevant for the target detection task, subjects were required to answer questions concerning the cues they had seen in the previous block at the end of each block (e.g., "Did you see the number 1?")."

**Analysis Plan**

"Misses and reaction times faster than 100ms or longer than 1000ms were excluded from analyses, as well as all catch trials. Repeated measures ANOVAs were performed on reaction times with Cue Magnitude and Target Position as factors. "

In addition, the subjects' responses to the questions at the end of each block were also examined to test whether "the questions were effective at inducing subjects to pay attention to the cues, despite the fact that subjects were informed that the cues were not informative about the location of the upcoming target."

**Differences from Original Study**

In the original paper, all the participants were French. But in the current replication study, all the participants were US citizens. In addition, the original study used two types of cues (arrow and numerals) and the trials with different cues were interleaved with each other. In the current study, only numerical cues were used. Finally, the original study was conducted in the laboratory and the experimenters were able to control the viewing distance. By contrast, the current study was conducted on Amazon's Mechanical Turk, and the viewing distance may vary across subjects, resulting in different visual angles of the same stimuli for different participants.

The first difference is not anticipated to cause the results to deviate from the original results, since the differences between French and English language would not have specific impact on this task. The second difference may lead to a failure of replication (see Discussion below). The third difference may also lead to a failure to replicate the original results, since the attentional orienting effect occurs only when the cue and the target are close to each other. If the viewing distance is too small, the visual angle between the cue and the target may become very large, and no cueing effect would be observed.

## (Post Data Collection) Methods Addendum

### Actual Sample

Due to the budget limit for this course project, 17 subjects were recruited (male=8, female=9; mean age = 32.3, range=21-61). Each of them was paid $2.5 for participating in the experiment. A score was calculated to measure each participant's overall performance. They got 1 point for detecting a target within 2 seconds; -1 point for pressing the key before target appears or when no target appears, and 5 points for each correct answer they gave to the questions at the end of each block. Participants were told that this study would recruit 17 workers in total and the top 3 workers would get a bonus of $1. No subjects were excluded from final analyses.

### Differences from pre-data collection methods plan

Since the actual experiment lasted about 30 minutes, I raised the payment from $2 to $2.5. Therefore, I finally recruited only 17 participants. In addition, to avoid any confounding factors induced by asking subjects' age before the experiment, I did not limit the age of the participants to 20 – 29 as originally planned.

Finally, according to the stimuli sizes reported in the original paper, the viewing distance in their study should be approximately 1.2 m, which is too long for experiments conducted on Mechanical Turk. Also, the stimuli would be very small and hard to recognize. Therefore, I adopted the actual sizes of the stimuli (in centimeters) but changed the viewing distance from over 1m to one arm's length (median forward arm reach: male=63.8 cm; female=62.5 cm) (Yung, Cardoso-Leite, Dale, Bavelier, & Green, 2015). This resulted in larger visual angles of all the stimuli in my replication study as compared to the original study.

## Results

**Data preparation**

Data preparation strictly followed the analysis plan. “Misses and reaction times faster than 100ms or longer than 1000ms were excluded from analyses, as well as all catch trials. Repeated measures ANOVAs were performed on reaction times with Cue Magnitude and Target Position as factors. ”

**Confirmatory analysis**

Miss rate was around 2.77% and false alarm rate was around 9.31%. The repeated measures ANOVAs with Cue Magnitude and Target Position as factors showed that there were no main effects. The codes for the analyses in this replication report can be found here. The interaction between Cue Magnitude and Target Position did not reach significance, $F(1,16)=0.24$, $p = 0.63$ (Figure 1).

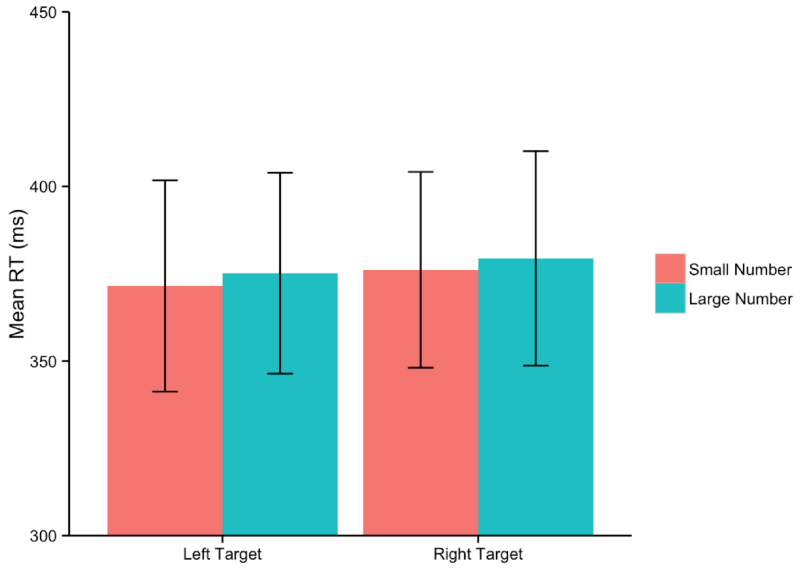


Figure 1. Mean reaction times are shown for number-cueing in function of the target position. Error bars indicate one SEM.

**Exploratory analyses**

To explore the possible strategies participants might use when viewing the numbers, I first divided the trials of each block into two categories: the trials before all of the four number cues have appeared (Type 1) and the trials after all of the four number cues have appeared (Type 2). I then included only the Type 1 trials in the analysis, since in those trials the subjects might be more motivated to pay attention to the cues. The results are shown in Figure 2.
Repeated-measures ANOVA indicates that the Cue Magnitude × Target Position interaction was not significant, $F(1,16)=0.70$, $p = 0.40$. Also, the results pattern is not consistent with the original

finding, i.e., detecting a left target is faster when a small number preceded the target, and the opposite was true for detecting a right target.

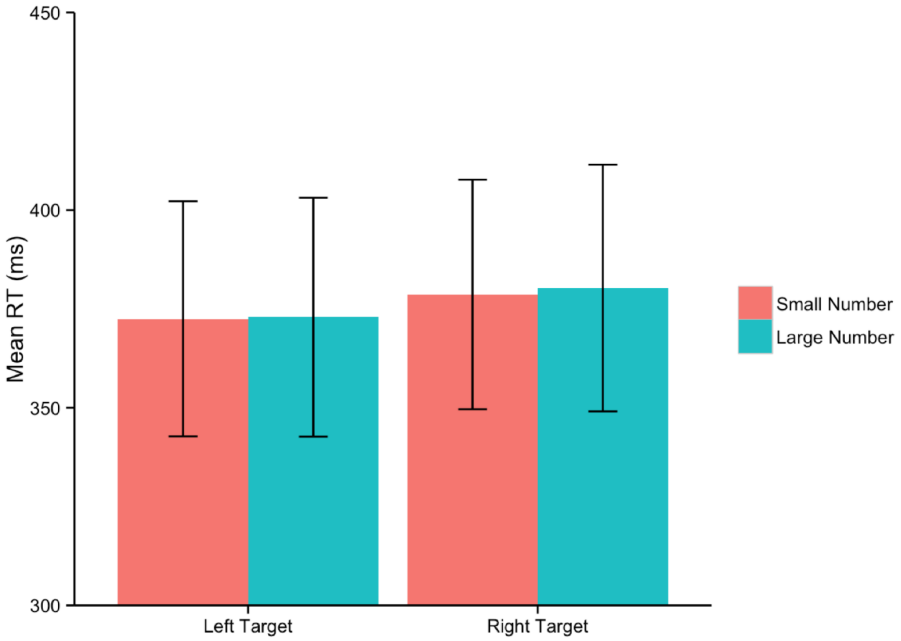


Figure 2. Mean reaction times are shown for number-cueing in function of the target position, including only Type 1 trials (see the above texts for more details). Error bars indicate one SEM.

I also examined the practice effect. It might be possible that the subject paid less attention as they became more familiar with the task. I plot the data of the first 6 blocks and the second 6 blocks separately (Figure 3). I found that neither of the results is entirely predicted by the original paper.

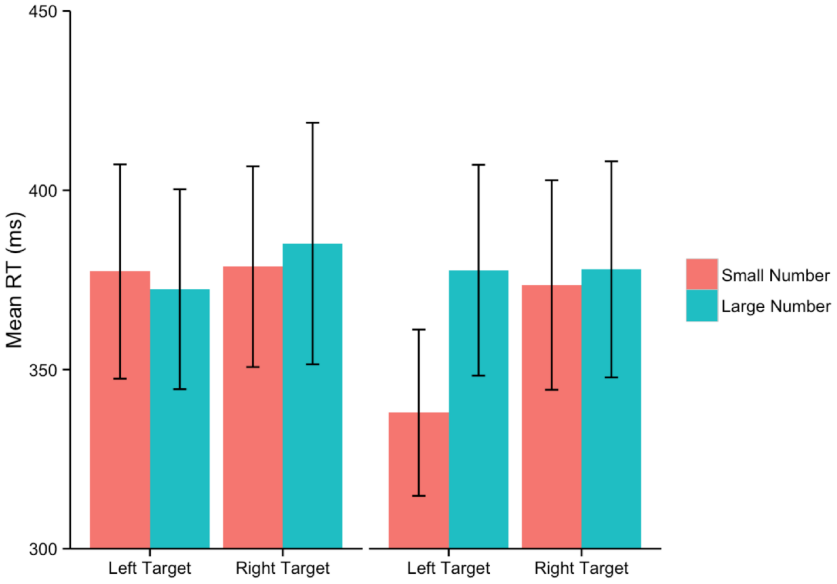

Figure 3. Mean reaction times are shown for number-cueing in function of the target position. Left: first half of the trials. Right: second half of the trials. Error bars indicate one SEM.

## Discussion

### Summary of Replication Attempt

The Cue Magnitude and Target Position interaction did not reach significance, which failed to replicate the original interaction effect. Several reasons may account for this failure of replication, which will be discussed below.

First of all, the original study also examined the attentional cueing effect induced by the arrow cues. Therefore, the arrow cueing trials were interleaved with the number cueing trials. Although they did not find a significant cueing effect induced by arrow cues, it is still possible that arrows served as salient directional cues and they encouraged the subjects to pay more attention to the central cues and shifted their attention accordingly. If this possibility is true, it would cast doubts on the authors' original claim that irrelevant numbers could shift people's attention, since a number cue itself could not orient attention -- cueing effect occurred only when numbers were presented with other more salient directional cues.

Second, the subjects might be less motivated to pay attention to the number cues. The only incentive for the participants to pay attention to the number cues was to answer the questions at the end of each block correctly. However, the questions only asked about whether one of the four possible number cues has appeared in the preceding block. In the experiment, each block has 22 trials. The probability that all four numbers has appeared in one block was very high and the answers to the questions were almost always "Yes". It is likely that after the subjects have seen all the four numbers in one block, they no longer pay attention to the numerical cues any more.

In the above exploratory analysis, I included only the trials before all of the four numbers have appeared in each block, but the results pattern is still inconsistent with the original results. Therefore, no strong evidence supports this explanation for the failure of replication. A related explanation is that the original study had additional questions to motivate the subjects to pay attention to the number cues, e.g., "Did you see more arrows or numbers?". These questions might encourage the participants to look at the numbers even when all the four numbers have appeared in one block.

Third, as mentioned previously, the visual angles of the stimuli in my replication study were different from the original study, since the visual angles in the original study were too small to make the stimuli easily recognizable. Attentional cueing effect occurs only in a limited spatial range. The targets on the left side of the screen and the right side of the screen should not be separated too far away from each other, since the distance may go beyond the scope of the attentional cueing effect. Since we did not use the original visual angles, it might be possible that

the eccentricity of the targets in my replication was too large that the numerical cues failed to facilitate the detection of the targets on the corresponding sides.

Fourth, the heterogeneity of the sample in my Mechanical Turk experiment may also account for the failure of replication. The age range of the original sample was 22-29, but in my replication it was 21-66. The standard error of the mean (SEM) in my experiment was much larger than those of the original study. The large individual differences may mask the real experimental effect.

Finally, since the first study demonstrating the attentional orienting effect induced by irrelevant numbers (Fischer, Castel, Dodd, & Pratt, 2003), several studies have used this paradigm to investigate the spatial representation of numbers. Most of them replicated the original findings (Fischer & Shaki, 2014), but some studies failed to replicate the original results, e.g., Zanolie and Pecher's 2014 study (Zanolie & Pecher, 2014). Also, in the original study, the interaction between cue magnitude and target position was very weak, which only reached marginal significance. It might be possible that under the current experimental settings, the cueing effect is indeed not robust and therefore hard to observe.

**Reference**


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