

Contrast-based Subtle Cueing for Locating and Pointing Visual Target in Augmented Reality Scenes

Soon Hau Chua
NUS-HCI Lab
National University of Singapore
chuasoonhau@nus.edu.sg

Kevin McGee
Department of Communication and New Media
National University of Singapore
mckevin@nus.edu.sg

ABSTRACT

Explicit cues such as virtual labels are commonly used in augmented reality to direct visual attention. However, their presence can introduce visual clutter, which leads to decreased visual search performance, motivating research in subtler alternatives. While a recent work in subtle cueing has shown to be effective in detecting the presence of the target, its effectiveness in locating and pointing its actual location in the scene were not studied. The work in this paper is the first to study whether subtle cueing could improve the performance in locating and pointing a target in a specific region of a scene. The result of an empirical study indicates that subtle cueing improves the target locating performance without significant effect on the pointing movement time, representing an incremental contribution to the subtle cueing research.

Author Keywords

Subtle Visual Cueing, Visual Search, Augmented Reality

ACM Classification Keywords

H.5.1 [Multimedia Information Systems]: Artificial, augmented, and virtual realities; H.1.2 [User/Machine Systems]: Human factors

INTRODUCTION

One common way to direct human's visual attention in an augmented reality (AR) system is to use artificial visual cues that users are easily aware of, such as virtual annotations and labels. However, these explicit cues can increase visual clutter which correlates with decreased visual search performance [2].

A recent work showed subtle cueing, which applies a subliminal contrast differences surrounding the target as a cue, can improve visual search performance in target detection (presence/absence) tasks [1]. Compared to other work, subtle cueing is easier to implement and does not increase visual clutter at the subliminal contrast level [1].

RESEARCH QUESTIONS

We extended the work done previously on contrast-based subtle cueing [1] by investigating (i) **RQ1**: its performance in locating a target in a specific region of the scene, and (ii) **RQ2**: its effect on potentially increasing the movement time according to Fitts's law.

STUDY DESCRIPTION

Participants

Eight normal (20/20 vision) or corrected to normal (glasses) eyesight university students with experience in using keyboard and mouse, ranging from 18 to 25 years (mean age = 22), were recruited.

Materials

The experiment was conducted on a desktop computer with a 22-inch LCD monitor, full-sized keyboard, and mouse.

Study Design

Similar to the methodology in previous work [1], we conducted the study with a desktop computer showing outdoor scenes on the display in order to control the conditions that are difficult to control in an outdoor experimental setting.

In the experiment, participants were asked to first locate the target by indicating the region where it appeared, followed by clicking on the target embedded in the scenes. Three outdoor scenes images of size 1024 x 768 pixels were specifically chosen from the MIT SUN database [4] to simulate a typical AR scenario within a mid-range clutter ($5 < FC < 6$) level [3]. A black colored fly of 12 x 12 pixels was chosen as the target. The subtle cue, a square four times the area of the target, was sandwiched in between the target and background to function as an adjustable contrast layer.

Several details in the experimental design were taken into consideration due to the involvement of Fitts's law pointing tasks. First, the target locating and target clicking tasks in each trial were separated from each other (locating followed by clicking) to prevent searching time from factoring into the mouse movement time. Second, the cursor moving distance from the starting point to each eight possible target position was kept constant. Third, the width of the target was kept constant at 12x12 pixels. Finally, target clicking was designed to register only the clicks within the 12x12 pixels of the target as successful.

The independent variable was the contrast (alpha channel value) of the subtle cue, with two levels: 0 (cue-absent) and 0.2 (cue-present). 0 represents that the cue is transparent, and 0.2 represents the contrast level where it is considered subtle and significant in improving visual search

performance, discovered in prior work [1]. The dependent variables were reaction time (RT), error rate (ER), mouse movement time (MT), and pointing accuracy. RT was defined as the time lapsed from the beginning of each trial to the time where the target region was identified. ER was measured as the number of incorrect response in target locating over the total number of conditions. MT was measured as time to click the target after the target was identified. Pointing accuracy, measured in percentage, was determined by averaging the number of successful target clicking on the target itself to the number of clicking within the cue area. A within-subject design was used for this study. There were (3 images) x (8 target locations) x (2 contrast levels) = 48 different trials for each participant. All visual conditions were counterbalanced to prevent learning and ordering effects.

RESULTS

Overall, the results show that subtle cueing does improve the visual search performance in locating the position of the target in outdoor scenes, but not the pointing movement time.

Locating Target: Reaction Time and Error Rate

In terms of RT, the results showed a statistically significant difference in mean RT (Figure 1a). Paired samples t -tests between cue-absent (control) and cue-present cases yielded t -value of $t[6] = 6.895$, $p < .001$. On average, RT in trials with subtle cueing is shorter than the trials without subtle cue by 1.52 seconds. In terms of error rate, the results showed a statistically significant difference in error rate (Figure 1b). Paired samples t -tests between cue-absent and cue-present cases yielded t -value of $t[6] = 7.202$, $p < .001$.

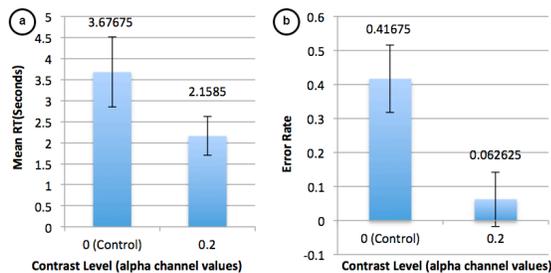


Figure 1. (a) Target spotting reaction time (RT) and (b) error rate (ER) for trials without subtle cueing (control) and with subtle cueing (0.2) Error bars depict standard deviation.

Pointing Target: Movement Time and Pointing Accuracy

The results of both sets of data show non-significant differences between the cue-absent (control) and cue-present trials. In terms of movement time, the results showed a non-significant difference. Paired samples t -tests between cue-absent and cue-present cases yielded t -value of $t[6] = 0.289$, $p > 0.05$. On average, MT in trials with subtle cueing is shorter by 0.01 seconds (Figure 2a). In terms of pointing accuracy, the results showed a non-significant difference in mean accuracy across cue-absent and cue-

present cases. Paired samples t -tests between cue-absent and cue-present cases yielded t -value of $t[6] = 0.975$, $p > 0.05$. On average, pointing accuracy in trials with subtle cueing is lower than trials without cueing by 4.29% (Figure 2b).

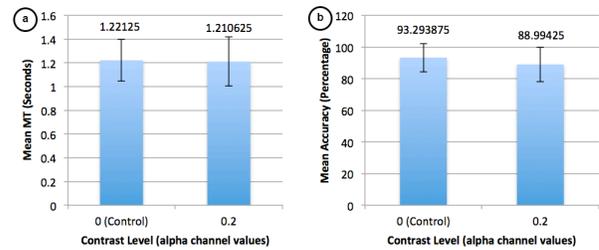


Figure 2. (a) Mean movement time (MT) and (b) pointing accuracy for trials without subtle cueing (control) and with subtle cueing (0.2) Error bars depict standard deviation.

DISCUSSION

The first half of our data (RT, ER) supports the finding from previous work that contrast-based subtle cueing improves visual search performance in AR outdoor scenes. At the same time, the results also indicate that this cueing technique is also effective in locating the position of the target, as it resolves one limitation in previous work where the indication of presence/absence does not accurately reflect the correctness in target spotting. On the other end, the second half of our data suggests that contrast-based subtle cueing has no significant impact on mouse movement time and pointing accuracy when the users are pointing a virtual object in outdoor scenes.

CONCLUSION AND FUTURE WORK

In conclusion, this study shows that while contrast-based subtle cueing improves visual search performance in locating the position of the target in outdoor scenes, it does not affect the pointing movement performance.

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