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# Human field of regard, field of view, and attention bias

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ABSTRACT

*Background and objective:* Human field of regard (FOR) is an important concept that should be considered along with field of view (FOV) for people with/without handicaps, but previous studies have neglected this aspect of human perception. In the current study, we suggest and test a new virtual reality (VR) software with which to evaluate individual's detection abilities in the human FOR.
*Methods:* We conducted measurements of human FOV, FOR, and FOR with visual cue (FOR-cue), and we evaluated healthy adults' responses in a first experiment. Participants were asked to detect targets on a head-mounted display (HMD) as quickly as possible in three conditions: (a) FOV: the head rotation doesn't change the view of the screen in the HMD; (b) FOR: the head rotation changes the view of the screen in the HMD; and (c) FOR-cue: same with the FOR condition but an endogenous visual cue indicating the direction of stimulus. To address the need to increase the number of trials in the FOR condition, we also conducted a second experiment with new samples and four times of trial numbers.
*Results:* The participants' detection time results indicated that the FOV condition was faster than the FOR-cue and FOR conditions, and the FOR-cue was faster than the FOR condition. Interestingly, we found a unique characteristic in the FOR conditions that did not exist in the FOV condition: The target responses were faster for the left side than the right side. The results of the second experiment were consistent with the first, and head motion trajectory analysis showed that participants had more movement toward the left side than the right side in the early parts of each trial.
*Conclusions:* In this study, we suggested a new virtual reality (VR) evaluation technique and measured the human searching pattern in the FOR condition. We found a unique left-side attention bias in the FOR condition, and discussed implication of these results and potential attention bias factors. We believe this work is an important foundation for interactive 3D UI design, and we hope it will help people who have FOR handicaps.


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## 1. Introduction

A field of view (FOV) is the size of the visual field in degrees of visual angle that can be viewed instantaneously [1]. Previous studies suggested that the FOV affects individuals' responses to visual media, including immersion, presence, enjoyment, and physical side effects (e.g., simulator sickness) [2]. Additionally, a human field of regard (FOR) is important in the real world, as humans constantly move their heads and bodies when viewing. It should not be confused with the FOV which is the angular cone perceived at a particular time instant. The FOR is the total area that can be captured by movable sensing systems [1,3–5] and the FOR is much larger than the FOV. The FOR is important in virtual worlds, as well as in the real world. For example, when using the Cave Automatic Virtual Environment (CAVE) system [6], the user needs to look at the ceiling and floor screens, and sometimes at a back screen [7]. When using a head-mounted display (HMD) in a virtual world, the user needs to look around. Thus, the human FOR is important to consider along with the FOV in visual displays including wide HMDs, large displays, and multiple screens.

To contribute to the advancement of research on the human FOR, in this study, we designed and tested new software for employing virtual reality (VR) technologies. VR platforms offer immersive experiences to users in 3D worlds using computer-generated environments [8]. They can control precise simulations with exact timing and evaluation of human performance [9]. The current study used an HMD system as a display for visual stimuli. The HMD is a video display device that is fixed on a participant's head using adjustable headbands, with applications from gaming to medicine [10–12]. When users move their heads, the computer-generated images are translated or rotated as if they were in the simulated space. By turning on the head-tracking feature, an HMD system can be used to provide an FOR condition. An FOV condition also can be provided by simply turning off the head-tracking feature without putting any additional constraints on participants' head movements. Thus, an HMD system can easily be used to measure human's FOV and FOR. Moreover, an HMD system can provide depth perception by employing a stereoscopic view with a relatively high sense of presence [7]. Recently, new HMDs (e.g., Oculus Rift) with built-in head-tracking sensors have been released with reasonable prices, so we can apply these systems with a cost advantage.

Because few studies have measured the FOR of participants, we included an FOV condition along with the FOR condition. The FOR with cue (FOR-cue) condition was included for potential applications of FOR training for people with hemi-spatial neglect (this symptom is described in a later section). We expect there to be common and different aspects among these three conditions. Our initial hypotheses are as follows:

(1) The detection time of the FOV will be faster than those of the FOR and the FOR-cue, and the detection time of the FOR-cue will be faster than that of the FOR.
(2) The same detection pattern exists among the FOV, FOR, and FOR-cue conditions, in the horizontal, vertical, and radial directions.

## 2. Related works

### 2.1. Related studies in healthy people

Several studies have been conducted on the human FOV. Regarding detection time, our main target-dependent measure, previous studies suggested that there are no outstanding patterns in healthy people [13–15]. They showed the same tendencies for the left vs. the right sides, and for the upward vs. the downward sides [16,17]. Additionally, participants detected near targets more quickly than far targets due to the size effect of depth perception [18]. However, eye-tracking studies on web searching patterns found unique results. Nielsen investigated reading patterns for a web page with 232 participants, and found that users scan starting from the upper-left part of the web page [19]. Buscher et al. showed similar results using an eye-tracking method. They conducted a web page recognition task with 20 users, and the results showed that the most important area of web pages was the upper-left [20].

Previous studies have suggested the importance of FOR. Sowndararajan et al. compared a laptop display to a large, two-wall projection display, and found that participants showed significantly better memory performance with a larger display [21]. In a subsequent study, participants had better recall memory performances (higher response speeds and lower error rates) with higher FOV and FOR [22]. Laha et al. suggested that the FOR is an important factor for the feeling of immersion. Comparing a low FOR (a single-walled CAVE) to a high FOR (a four-walled CAVE) with volume rendering data, they found that the higher FOR achieved better quantitative and qualitative performances than the lower FOR [23].

Although previous studies emphasized the importance of higher FOR, to our knowledge, none has directly measured humans' abilities and patterns. To contribute to the research on the human FOR and find the principal factors to train people with deficits in FOR, we need to understand the performance and the specific characteristics of the searching patterns of healthy adults.

### 2.2. Related studies in patients

Healthy people seem to automatically coordinate their FOV and FOR. However, some people have deficits in one or both types of visual perception. People with hemispatial neglect, which frequently occurs after right hemisphere lesions, often fail to detect, attend, or respond to stimuli and events occurring in the contralesional space (opposite side of lesion, generally the left side) even though they do not have any problems in their vision [24].

Large-scale studies have shown that hemispatial neglect patients have deficits in the contralesional areas of their FOVs. The Behavioral Inattention Test (BIT) is one of a standardized assessment for patients with unilateral visual neglect [25–27]. For example, a line bisection task (a subtask in the BIT) requires indicating the midpoints of horizontal lines. Patients with hemispatial neglect placed their bisection marks too far to their ipsilesional side (same side of lesion, generally the right side), creating an overly large line segment in their contralesional hemispace [28–30]. The star cancellation task showed a similar