Eye-gaze-triggered Visual Cues to Restore Attention in Educational VR

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ABSTRACT

In educational virtual reality, it is important to deal with problems of student inattention to presented content. We are developing attention-restoring visual cues for display when gaze tracking detects that student focus shifts away from critical objects. These cues include novel aspects and variations of standard cues that performed well in prior work on visual guidance. For the longer term, we propose experiments to compare various cues and their parameters to assess effectiveness and tradeoffs, and to assess the impact of eye tracking. Eye tracking is used to both detect inattention and to control the appearance and location of cues.

Keywords: Educational VR, Attention, Eye Tracking, Visual Cues.

Index Terms: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism---Virtual Reality; K.3.0 [Computers and Education]: General

1 INTRODUCTION

A common problem for educational presentations is loss of student attention. In VR, there may be several distracting objects or scenery for students to look at besides the objects relevant to the current presentation. We are investigating visual cues to encourage students to return visual focus to the correct object when their visual focus shifts elsewhere. The cues are conceptually like some of those found in prior work on guiding attention to objects in AR, for example, for indicating the next target object in an AR training sequence [1] [5], although the prior work does not specifically focus on restoring attention after it has been lost. In addition to adapting some of the best-performing cues from the prior work, we introduce our own cue variations for future assessment.

Following a classification by Dillman et al., who classify visual cues in games, all our cues were designed for the purpose "look" and with varying "markedness" levels [3]. The "trigger" for a cue to appear is student inattention, based on eye gaze metrics.

The cues have been integrated into Kvasir-VR, an educational virtual reality field trip framework [2]. We illustrate cues in the context of an offshore training system involving a virtual oil rig (Fig. 1i). A pedagogical agent or live teacher gives descriptions of devices or objects during field trips, and cues appear or fade in when student inattention is detected based on eye-tracked gaze direction (when it deviates from the desired focus area by a substantial angle). Based on the level of student inattention, a different cue style may be used depending on its markedness. For example, if the student is looking very far away, we can use a tunnel vision effect because it is overlain on the screen rather than just a background effect.

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2 OVERVIEW AND SHARED PARAMETERS

The cues we implemented are named as follows: Arrow, Trail of Arrows, Attention Funnel, Navigation Sphere, Tunnel Vision, and Line Strip. Each cue is demonstrated through an associated video.

Our effects manager allows us to select which cue to use and whether to use an eye-tracked variation or only head gaze. Multiple parameters allow us to control the appearance or fading of cues. Some shared parameters are described below, with additional parameters mentioned later for specific cues.

Fade Angles parameters control how the cue fades in and out, based on the angle between the student's gaze vector and the vector from the student to the desired target area of visual focus. The fade angles specify the angles over which cues fade in and out.

A *size* parameter specifies how large to make a cue object.

A *placement* parameter influences where cues appear. There are three placement types: directly on the student's gaze vector (with cue distance from the head set equal to the distance between the head and the target, to match target depth), some percentage distance along a cubic Hermite curve with the head and target as endpoints and with tangents similar to those selected by Biocca et al. [1], or some percentage distance along an arc from the gaze point (above) to the target (the arc on a head-centered sphere with radius being the distance between the head and the target). Note that placing the cue at the zero-percent point along the arc is the same as the first placement type, directly on the gaze vector. Placing a cue some distance towards the target, rather than directly in front of the user, may help draw attention towards the desired direction.

Some cues have a *display* parameter. For certain cues, multiple objects (e.g., arrows) will appear. The parameter chooses between always showing all objects or adding more with increasing angle.

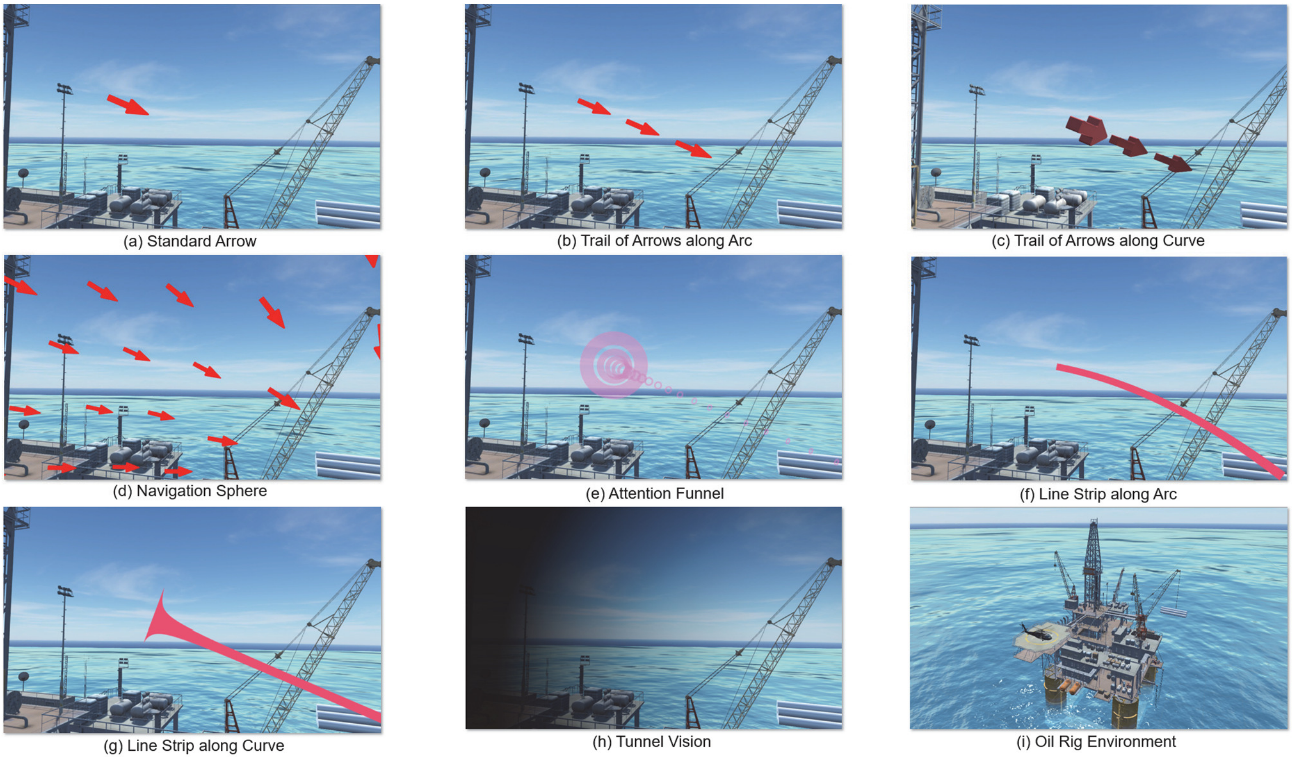
Because other objects in a VR scene may occlude visual cues that are placed some distance in front of the viewer, we render objects such as arrows in such a way that they appear "through" other objects. This is done with two-pass rendering: one pass renders the object normally and the other pass renders it semi-transparently without the depth test, allowing the second version to be seen through occluding objects This way, if the cue is occluded, it appears like the occluding object has some transparency.

3 ATTENTION-RESTORING CUES

The *standard arrow* (Fig. 1a) is a single 3D arrow. It is placed according to parameters above and is oriented to point towards the target (specifically, it is aligned to point along the arc or along a cubic curve, depending on the placement parameter).

The *trail of arrows* (Fig. 1b/1c) places multiple arrows along the arc or curve between the student's gaze and the target object. This is expected to provide a stronger cue than a single arrow, and one that can grow in markedness as the student's focus drifts farther.

The *navigation sphere* (Fig. 1d) is a novel cue that is a field of arrows on a head-centered sphere. Arrow placement does not depend on any gaze tracking, so arrows appear static rather than moving. The arrows appear at vertices of an (invisible) icosphere and are oriented to point along an arc towards the target, as for the standard arrow. A parameter varies the number of arrows,



(a) Standard Arrow (b) Trail of Arrows along Arc (c) Trail of Arrows along Curve (d) Navigation Sphere (e) Attention Funnel (f) Line Strip along Arc (g) Line Strip along Curve (h) Tunnel Vision (i) Oil Rig Environment

Figure 1: Attention-Restoring Cues

corresponding to different icospheres with different levels of detail. This, and arrow size, allows us to tune the strength of the cue.

The *attention funnel* (Fig. 1e) is based on the one created by Biocca et al., which was created by placing multiple rings along a cubic curve between the student and the target [1]. An attention funnel did not produce good results in the Renner study [5], and this seems to be due to the limited field of view that the student had in that AR simulation. Biocca showed that an attention funnel increased search consistency by 65% [1].

The *line strip* (Fig. 1f/1g) is a simple but novel cue that we believe is effective due to its clarity. A thick line strip (appearing like a curved banner) is displayed along the arc or cubic curve, showing a full path from the student's current gaze to the target.

Our *tunnel vision* (Fig. 1h) cue is a vignette-type cue that progressively darkens portions of the scene far from the target as the student attention drifts. We use a screen-space shader to orient a tunnel effect in front of the student (with an offset toward the target), which gets more prominent (darker, sharper) the farther the student looks away. The open portion of the tunnel never leaves the student's viewport completely, to prevent confusion about where to shift visual focus. The parameters for the tunnel vision effect include how dark the tunnel gets, how fast/smoothly it fades to that darkness, and the tunnel shape/size.

4 CONCLUSION AND FUTURE PLANS

We propose an experiment to compare the effect that each attention-restoring cue has on the student's experience and eye behavior. This study will also allow us to compare the value of using eye tracked vs. head gaze-based cues. We will also consider additional cues that are promising based on prior studies, such as the SWAVE [5].

The first phase of the study will tune the cues using parameters discussed earlier. This will make sure that the cue types are performing well individually. A second phase of the experiment will compare the tuned cues. We will instruct the student to find an object and present each cue in a random order. We will then have the student rank each cue based on preference. We will also measure the speed and accuracy that the student had in finding the object with each cue. This study will give us insight on how to improve attention-restoring cues and will allow us to assess the effectiveness of the cues when integrated with a pedagogical agent that presents content in a VR field trip [4]. Other study variations can assess the value of eye tracking and the use of cues when distracting content appears and shifts student visual focus.

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