Of Leaders and Directors: A visual model to describe and analyse persistent visual cues directing to single out-of view targets

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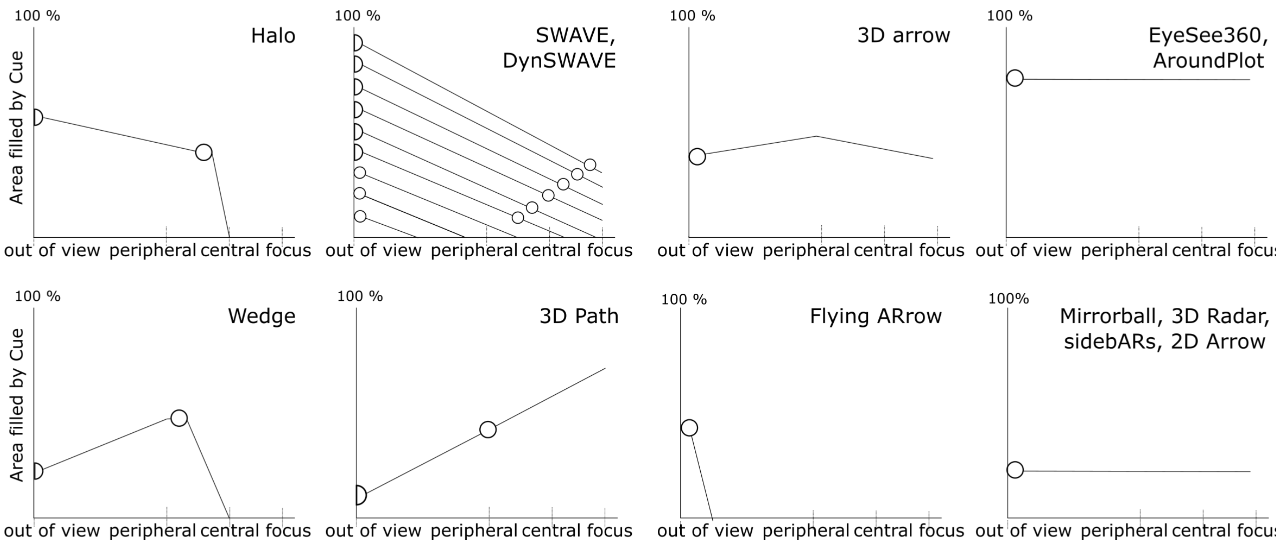

Figure 1: The models depict *in-view* the area of a cue's bounding box (y-axis) by target position (x-axis) while users move their head at a constant speed. Full circles (◯) denote cue completion, half-circles (◗) incomplete cues, i.e. clipped by screen borders.

ABSTRACT

Researchers have come up with many visual cues that can guide Virtual (VR) and Augmented Reality (AR) users to out of view objects. The paper provides a classification of cues and tasks and visual model to describe and analyse cues to support their design.

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1 INTRODUCTION

In assembly tasks, finding an object (e.g. a screw) when outside the user's field of view (FoV) or in an environment with visual distractors can pose a challenge. Visual cues rendered in augmented reality (AR) or virtual reality (VR) solve this by guiding user's attention to one, or more, target(s). The cues avoid cognitive load from unguided visual searches and reduce the time to locate targets. We distinguish between cues that either *lead* or *direct* attention to targets , see Figure 2, and between persistent and non-persistent cues i.e. whether the cue stays in view as the user attempts to locate the target. Visual guidance tasks have fallen into two types - 2D locating (2 DoF) and 3D manipulation (3D) tasks. However, previous research did not facilitate comparisons of cue behaviour between studies. The paper contributes a synthesis and comparison of cues in terms of their conceptual design through a visual model.

2 BACKGROUND

We refer to targets depending on their location relative to the field of view (FoV) as 1) *out of view* (outside roughly 180° [15]), 2) *in peripheral view* (between out of view and central view), and 3) *in* *central view* (within about 15° [15]). This relationship can be seen in Figure 2. When not distinguishing between targets location in term of central and peripheral view we will use the general term *in field of view*. Cues can differ in many ways but for this examination we classified cues based on whether they are 1) two or three dimensional, referring to whether the cue depicts a 2D representation or one (or more) 3D model(s), 2) attached in the users or world view, 3) leading or directing to targets, or 4) changing size between view stages (from out of view to central view). Previous work has used similar categorization for cue visibility and target connection [8]. However, it has focused on user collaboration scenarios in spatial augmented reality and has no indication of cue dimensions nor size modification. We also distinguish between persistent and non-persistent cues. Non-persistent cues disappear from the user's view as the user attempts to locate the out-of-view target, where persistent cues remain in the user's view. An example of a non-persistent cue is gesture-based cues i.e. pointing to an out-of-view object [10, 14].

Attached in View (AiV) and Attached in World (AiW) specifies a cue's position in view and whether or not this is static. An AiV cue has a specific static position in the user's view, staying in the same position during head movements. While the cue might rotate about itself, it does not change position in the FoV. AiW cues are usually connected to targets. They might leave the user's view or otherwise move as the user changes position compared to the target. These distinctions do not influence where in the user's view the cues are placed but how their position changes based on user movement. Not all cues change during the different stages of view or the transitions between them. Some cues that have been previously partially incomplete become complete as the target comes in view, depending on the cue's connection to the target and some cues might grow or shrink in size. Figure 1 depicts these relationships for all surveyed cues by type. As SWave/DynSwave can be broken down into multiple consecutive Halo cues, it has been modeled as such. Despite their differences, the cues rely on endogenous attention [3]. Users have to divide their attention between interpreting the cues and searching for targets.

We define a *leading* cue as being 'attached' to a target, meaning that some part of the cue is always spatially connected to the target. These include Halo [1], Wedge [7], SWAVE/DynSWAVE [12] and 3D Path [11]. Flying ARrow [6] is both a leading and directing cue. Leading cues rely on amodal completion [6] to guide the user: the user must interpret and mentally complete the out-of-view portion to understand the direction of the cue. A directing cue we define as

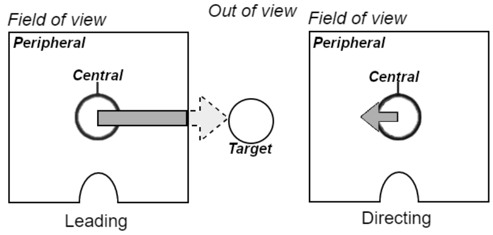

Figure 2: Leading (left) and directing (right) arrow cues to an out of view target (middle).

giving the user a general direction to the target instead of providing a direct path to follow. These include 3D arrow [2], EyeSee360 [5], AroundPlot [9], Mirrorball [2], sidebARs [13], and 2D arrows[4]. All the directing cues, apart from Flying ARrow, are fixed in the user's view occupying a specific area and many do not change as the target moves (c.f. Figure 1). Figure 2 illustrates a simple leading (left) and directing (right) cue in the form of arrows pointing towards a target.

3 VISUAL MODEL

We developed a visual model that articulates how cues visually differ while in use to describe, analyze, and compare cues. It plots the area filled by the cue on the y-axis dependent on where the target resides in relation to the users view (from *out of view*, to *in peripheral view*, to *in focus view*) on the x-axis. Non-persistent cues reach 0 on the y-axis (i.e. flying arrow, halo, wedge). The origin of x-axis denotes the target being behind the user (180°), while the far right denotes the target being in central view. The model simplifies the explanation of visual differences of cues, can help as an analytical tool in how the user might experience the cue, and supports the design of new cues. For example, the model illustrates that the directing cues tend to be a lot more static in their view while the leading cues take up a varying amounts of the users visual space depending on if the target is close or far away from the focus view. The model assumes a user will move their head at a constant speed and the same speed for each cue. A faster or slower head movement would change the model for dynamic cues such as Flying ARrow or SWave.

Most of the presented leading cues take up more space than the directing cues when the target is far away, but less space when near the target. Our models communicate this in the higher y-values for the leading cues (see Figure 1). Especially when considering multi-target tasks, leading cues are prone to overlap or clutter the screen earlier than directing cues. For examples, the leading Halo and Wedge use more of the display area than directing Mirrorball and AroundPlot, which needs far less display space to signify additional targets.This can help why (leading) cues cannot be used as efficiently in smaller as in larger displays.

Our visual model in Figure 1 focused on single targets at a time and does not articulate how cues scale with multiple targets. Some cues especially the leading ones will require linearly more space for additional targets while the footprint of targets in many - but not all - directing cues is smaller. However, such multi-target illustrations would rely heavily on assumptions about the placement of additional targets. The aim of our model as to visually explain the cue behaviour, which still allows for extrapolation to multiple targets.

4 CONCLUSION

The design of visual cues rely on two different paradigms leading and directing and we can compare them through a visual model. This model relates the space occupied by cues to the position of the desired targets in relation to the user view. Designers can leverage the model to better understand cue behaviour over time, compare between design alternatives, and systematically explore the relationship between cues and targets.

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