person perspective (e.g. boss fights in *Shadow of the Colossus* [L13]). AR designers cannot use this type of cue.

Importance of Discover Cues. Based on existing AR experiences (e.g. [17, 6, 14, 13, 9]), we expect *Discover* cues to be extremely important in the early days of AR: first, not everything in the physical world is interactable or tagged; second, users do not yet have well-developed mental models of the classes of AR applications that might exist (i.e. since certain applications may make some objects more or less likely to be interactive targets); and finally, the visual language of these kinds of interaction cues in AR are not yet well-developed. While the first two issues may end up being overcome over time, it is important for designers to consider how to evolve the visual language. Designers will need to prudently consider the interplay between expectations of the physical environment and the AR application to engender effective designs.

Trade-off: Markedness. The markedness dimension of the framework raises interesting questions about "naturalness" and "jarringness." Users in an AR context are not bound to the content provided by the AR headset. If *Subtle* cues are designed too subtly in an AR context, they could be missed (likely undesirable). Thus, while *Subtle* cues may seem desirable as a goal (as in games [20]), marked cues may be more desirable if the intention is for users to see them.

The application context also has a role to play here: if the AR experience is intended as a tool, easily visible (i.e. well-marked) cues are probably desirable. In contrast, an AR game designer may instead intend for the player to experience challenge, and opt for less marked cues. Similarly, the aesthetics of the environment should be considered: if the location is renowned for its beauty, cues should not interfere with the user's experience of the space.

Trade-off: Triggers and Causality. We have outlined a range of ways in which cues can be triggered, ranging from things that are conceptually "close" to the user (*User-triggered*) to things that are conceptually "far" *(Other/Agent-triggered*). *User-triggered* cues are easy for users to understand, whereas *Other/Agent-triggered* cues will be difficult for users to understand since the cause of the trigger may not be visible. To this end, designers should use primarily obvious triggers (e.g. *Persistent*, *User-triggered*, and *Context-triggered* but only where context is obvious, such as a physical position in space).

Visibility and "Fit" of Cues. We are also limited as AR designers by current sensing technologies: most do not yet capture a high-fidelity model of the scene. Consequently, most AR is unable to properly clip the rendered visual based on what ought to be visible, and simply render atop people and objects in the scene (cf. [1–3,17]). Clipping these visuals properly will aid in interpretability of cues; alternately, designers should consider decorating cues to indicate whether the actual physical object/location *should* be visible (e.g. given known buildings, hills, mountains, etc. in the space). Similarly, we cannot yet accurately use *Emphasized* cues on physical objects. For example, the Vienna Tour Guide (Figure 5) uses a yellow *Integrated* polygon around points of interest. An *Emphasized* cue that tightly highlights or outlines the tower would be more effective and aesthetically appropriate; however, current consumer grade technologies cannot track real world objects with sufficient granularity and fidelity for this. This explains why the bulk of interaction cues in the AR context are *Integrated* cues rather than *Emphasized* or *Subtle* cues.

Beyond the technical challenge of rendering photorealistic visuals for *Subtle* cues, a designer needs to consider: the physical context that the cue appears in (e.g. while the boulders of Figure 4-i may not work in an office context, they may be appropriate for certain outdoor contexts); the user's mental model of the environment coming into the situation (e.g. how much does the user already know about the environment, how willing are they to suspend disbelief), and the user's mental model of the artefacts being rendered (e.g. can the user understand cue in context).

While beyond the scope of the discussion here, the near-future ability to render effective *Subtle* cues raises interesting ethical questions: is it right to show someone something that is not present (e.g. doors in Figure 4-e,f), or to visually take away an object that is physically there (e.g. Figure 4-g)? This is particularly important if the alteration of the user's view could lead to accidents or injury.

Impact of Form Factor. With handheld AR, designers should assume users can see both the AR perspective and a real perspective on the world. Here, *Subtle* cues will seem jarring, as users will be able to easily see differences between perspectives. We recommend designers focus on making it clear whether a destination or target is likely to be visible, and from what orientation the target object should be visible. Ignoring these factors draws attention to the implementation of the cue rather than allowing a user to interpret the cue from the augmented view (i.e. that they are overlaid atop the viewport anyway). For example, in the Lowe's App [14] (Figure 1-right), the white placard always faces the user, meaning the cue cannot be used to identify which shelf the product is on. Instead, setting the orientation of the placard to match the target object would allow a user to employ the placard to its full potential.

CONCLUSIONS

Video game designers have developed and honed a visual language for interaction cues. Our interaction cue framework illuminates the roles of purpose, visual design and interaction design for these cues. Further, we find that it can describe interaction cues from AR experiences, and we show how designers can use this framework to generate new designs for interaction cues in AR. Designers of AR experiences as well as those building AR platforms (e.g. [7]) will be able to build from this work to develop a parallel visual language of interaction cues for AR.

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