Embodied Exploration of Virtual Scenes

The impact of object reactivity and task guidance on exploration strategies and curiosity

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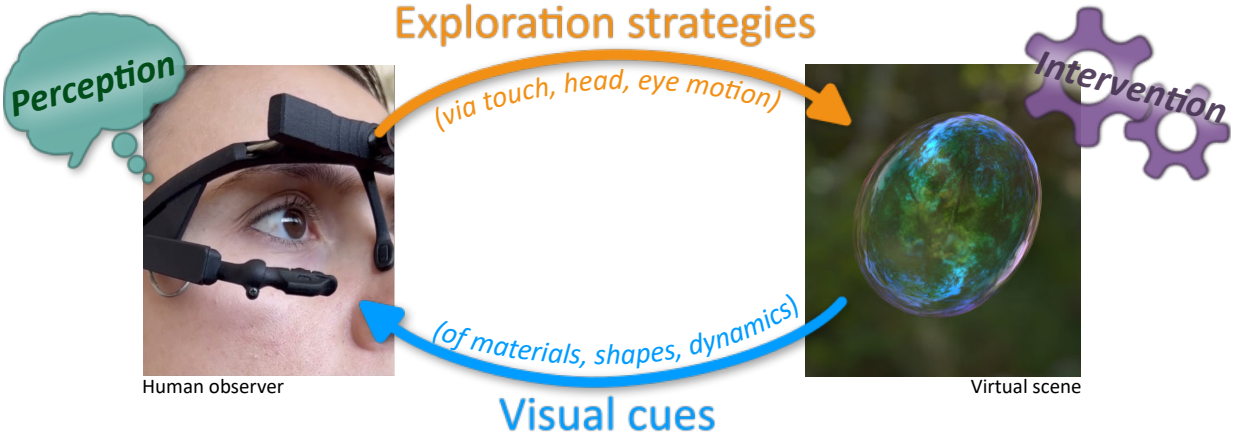

Figure 1: Our aim is to study how humans explore virtual scenes through embodied means (via touch, eye and head motion) when asked to judge object materials, shapes or dynamics. We hypothesize that different exploration strategies will bring about different visual cues. By modifying the virtual scene in real-time through specific *interventions*, we plan to unveil mechanisms involved in active *perception*.

1 Context

The 3-year PhD offer is part of the EXPLORA project (see explora-network.github.io), a 4 years EU-funded Doctoral Network (recruitment from February to October 2026). It will take place in France, at Inria Bordeaux. Eligible candidates must have lived in France no more than 12 months in the 36 months preceding recruitment.

The main focus of EXPLORA is the active exploration of objects, materials, scenes, and how this impacts visual, haptic and auditory perception. Our team will be concerned more specifically with the *visual perception* of virtual scenes, when one interacts with them through bodily motions on or in front of screens (touch, head or eye motion), which we call *embodied exploration*. Different persons are expected to employ different exploration strategies depending on the task they are given (e.g., see [Lin et al., 2025]). For instance, when asked to evaluate the appearance of a glossy object, the way reflections move might be explored in different ways: directly manipulating the object; observing it from different viewpoints; moving a flashlight around; etc. Our goal is to understand how these exploration strategies affect visual perception, with a particular focus on curiosity.

2 Objectives

The work carried out during the thesis will be centered on object appearance. We are thus mostly interested in visual cues to object *material* (glossiness, iridescence, etc), *shape* (curvatures, parts, etc) and *dynamics* (softness, ductility, etc). The same cues are likely to affect different aspects: for instance, reflections intensity and blurriness depend on material properties, they are distorted by surface shape, and they may move differently depending on object dynamics.

The main objective of the thesis is to give a dynamical account of object appearance: how visual cues are generated as a result of exploration under a given task, and how they influence further exploration, resulting in specific sensori-motor loops (see Figure 1). We first intend to characterize how different persons approach a same task with different exploration strategies, and how intrinsic *curiosity* may play out depending on the task. An original aspect of our approach is that we also plan to make *interventions* on the observed scene to modify the availability of visual cues to

sensorimotor loops. This requires to work with virtual scenes using real-time computer graphics techniques to grant low-latency visual feedback.

The envisioned interventions may exaggerate/mask visual cues (e.g., by increasing/decreasing highlight distortions [Vergne et al., 2009]); but they may also facilitate/ hamper exploration abilities (e.g., by increasing/decreasing inertia in object deformation [Rohmer et al., 2021]). Predictions may then be made on how interventions will affect sensori-motor loops, providing testable/falsifiable hypotheses to (in)validate via psychophysics experiments. Interventions will be used first and foremost to affect the immediate perception of an object, with real-time feedback. If time permits, we will also investigate whether interventions distilled throughout a trial may progressively modify object shape, material or dynamics without triggering awareness (akin to gradual change blindness experiments); and whether new exploration strategies may be learnt through repeated overt interventions across trials.

3 Methods

The project will first require to develop 2D and 3D real-time graphics applications, which may be interacted with through touch, eye or head tracking. The candidate will be able to work from two existing prototypes: a 2D touch-based application running on Android tablets; and a 3D renderer controlled by eye- and head-tracking implemented in Unity for desktop computers. Other devices (e.g, VR headsets) or middleware (e.g., Godot) might be considered. We will use these applications to run *live* psycho-physics experiments, with the goal to identify visual cues involved in the perception of materials, shapes or dynamics *during exploration*. We envision three main study designs to investigate how different exploration strategies and interventions may affect available visual cues:

- **Active tasks** in which the subject will be asked to perform judgments on object appearance. Tasks will be constrained to different extents, from specific guidelines to free exploration. We will study correlations between the apparition of visual cues appearing through exploration, and the task performance of subjects.
- **Passive tasks** will rely on similar experiments, except in this case subjects will be shown recordings of previous active task sessions. Visual cues available to subjects will thus be the same, yet we expect that passively looking at a video should affect performance compared to the active condition. The analysis will be complemented with eye-tracking data, which may reveal differences in anticipation between active and passive conditions.
- **Real time interventions** will be incorporated in active tasks, with the goal of masking or exaggerating visual cues in response to the subject's exploration. They will be used to test hypotheses on how actively-foraged visual cues affect object perception. Interventions themselves should not be attention-grabbing in order to avoid breaking the immersion: they will thus be constrained to changes that are less noticeable [Martin et al., 2023], or happen during lapses of attention such as eye blinks or saccades [Nakano et al., 2013].

4 Required skills

A Masters degree in computer science/engineering or similar, with a solid knowledge in 3D/GPU programming. Experience in XR/VR devices or experimental design would be a clear advantage.

References

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