Extended Thinking for Gesture Interaction in Extended Spaces

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Figure 1: Even in the vastness of open spaces (left), gesture interaction remains human scale (right). In this paper, we explore this tension with an analysis of end-user elicited gestures, which we characterize along both movement and cognitive dimensions from the unique perspective of extended thinking, a recent paradigm for reasoning on immersion in XR environments [25].

Abstract

Spatial interaction is typically designed around body-scale gestures, yet extended spaces provide a different perspective. In this work, we apply the Extended Thinking framework to analyze user-defined gestures for an extreme setting. Our findings, on the relationship between the scale of the environment and that of the human body, contribute insights for future spatial interaction design.

CCS Concepts

• **Human-centered computing** → **Empirical studies in HCI**; **Mixed / augmented reality**.

Keywords

Interaction in space, Mars, gestures, SpaceCHI, Extended thinking

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1 Introduction

Gesture interaction has traditionally been designed for and employed in environments reflecting the body scale, from the smallest settings as in microgesture input [4,12] to interactions with mobile devices [17], choreographed whole-body gestures at the intersection of art and robotics [19], and gestures performed with reference to the scale of a room [3,9] or an amphitheater [11]. All these environments, however, are controlled, readily integrating gesture sensing technology [1,20,27] and familiar feedback [29]; consequently, gestures reflect everyday intuitiveness [31], ergonomics [8], and meaning [21]. At the opposite end, vast environments, such as the extreme settings encountered in space missions [7], offer a different context for gesture interaction, where traditional assumptions about the scale of environment vs. human body no longer hold.

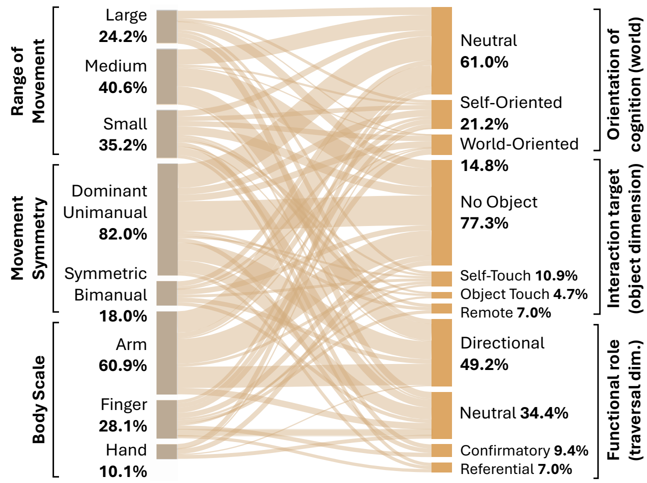

Figure 2: Gesture movement and cognitive attributes (N=128).

In this paper, we contribute an analysis of gestures performed in an extended space [24] by adopting the perspective of extended thinking [25], a recently proposed paradigm for immersion in XR environments. To this end, we conceptualize extended spaces as an extreme form of physical reality, with defining elements of extreme interactions [26]. The photograph in Figure 1, left emphasizes the *environment scale* of such a setting: vast, exposed, and remote; the photographs on the right focus on the *human scale*, exemplifying gestures performed by crew members. This tension of scales has implications for HCI in space [2] and space exploration [14,15].

2 Study

We analyze a set of 128 gestures collected from 8 analog astronauts (five male and three female, aged 21 to 30 years, M=24.8, SD=2.8), who spent two weeks at the Mars Desert Research Station (MDRS) [23], a research facility located in the Utah desert and surrounded by a Jurassic-Cretaceous geologic landscape [28] (Figure 1, left). Because the sample size was constrained by the housing capacity at the MDRS, we report a qualitative analysis of the elicited gestures according to their movement characteristics (range of movement, symmetry, body part) [13] and corresponding dimensions of extended thinking [25] (world, object, and traversal). Figure 1, right shows examples of gestures performed using the Tap Strap 2 device [22]. Gestures were collected following the end-user elicitation method [30] in response to 16 referents; details in [24].

To characterize gestures in terms of motor complexity, coordination, and body movement, we extracted the following attributes:

- **Range of movement,** defined by the proximity of the hands to the body during gesture production, with three categories, following Gheran et al. [6]: *small, medium,* and *large*.
- **Movement symmetry** characterizes how the hands are employed for the gesture. Following Piumsomboon et al. [16], we classified gestures as *dominant unimanual*, *nondominant unimanual*, *symmetric bimanual*, and *asymmetric bimanual*.
- **Body scale** of gesture production, defined according to the primary involved body part: *finger, hand,* and *arm*.

From the extended thinking framework [25], we adopted the following dimensions to describe cognitive roles of gestures:

- **Orientation of cognition**, corresponding to **the world dimension** in [25], describes reasoning about the nature of the world and one's presence within it. We distinguish three categories: *world-oriented* (gestures that intentionally reference the surrounding environment), *self-oriented* (gestures referencing the user's body), and *neutral* (gestures that imply no relationship with the external world or the self).
- **Interaction target,** corresponding to **the object dimension** in [25], describes reasoning about the nature of objects and the experiences they enable. We distinguish four categories: *remote reference* (gestures referring to a distant object), *object touch* (gestures involving direct interaction with an object), *self-touch* (direct interaction with the body), and *no object* (no explicit object interaction is depicted or implied).
- **Functional role,** according to **the traversal dimension** in [25], describes reasoning about navigation across different realities and object representations. We distinguish four categories: *directional* (gestures indicating navigation through space), *referential* (gestures indicating a destination, target, or representation) *confirmatory* (gestures that confirm the surrounding physical reality via movement and tactile sensations), and *neutral* (gestures with no traversal role).

We found a relatively balanced distribution of the elicited gestures in terms of movement range, with 40.6% *medium* gestures, but a majority of *dominant unimanual* (82.0%) and *arm* (60.9%) movements. According to their cognitive roles, 21.2% of the elicited gestures were *self-oriented*, 10.9% involved *self-touch*, and nearly half (49.2%) served a *directional* function; see Figure 2. At the same time, most gestures did not exhibit any particular orientation of cognition (61.0%), depicted object (77.3%), or functional role (34.3%). These findings align with the vastness and remoteness of the open space (Figure 1), and suggest a mismatch between the scale of the environment and that of the human body. The mappings between movement and cognitive characteristics are relatively uniform, without any discernible pattern emerging, which further suggests a lack of structure across the environment-body scales. For the consensus analysis of the elicited gestures, we refer to [24], while the complete set of gestures is provided in the supplemental material.

3 Conclusion

We explored end-user gestures through the lens of extended thinking [25], highlighting the tension between environment and body scales via movement and cognitive gesture attributes. Future work is recommended to further explore this tension in other spatial interaction contexts, including XR worlds with different opportunities for body movement [18,32] and environment [5,10] simulations.

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