

# Exploring Perceptual and Motor Gestalt in Touchless Interactions with Distant Displays

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## ABSTRACT

Markerless motion-sensing promises to position touchless interactions successfully in various domains (e.g., entertainment or surgery) because they are deemed *natural*. This naturalness, however, depends upon the mechanics of touchless interaction that remains largely unexplored. My dissertation first aims to deconstruct the interaction mechanics of touchless, especially its device-less property, from an embodied perspective. Grounded in this analysis, I then plan to investigate how visual perception affects touchless interaction with distant, 2D displays. Preliminary findings suggest that Gestalt principles in visual perception and motor action affect the touchless user experience. User interface elements demonstrating perceptual-grouping principles, such as *similarity of orientation* decreased users' efficiency, while *continuity* of UI elements forming a perceptual whole increased users' effectiveness. Moreover, following the *law of Prägnanz*, users often gestured to minimize their energy expenditure. This work can inform the design of touchless UX by uncovering relations between perceptual and motor gestalt in touchless interactions.

## Author Keywords

Gestalt psychology; Touchless interaction; Visual perception; Interaction design; Embodied interaction.

## ACM Classification Keywords

H.5.2 [User Interfaces]: Interaction Styles; Theory and methods.

## INTRODUCTION

Markerless sensing of whole-body movements has propelled the emergence of touchless interaction in a variety of domains, such as entertainment, surgery, interactive visualization, or collaboration. Because touchless interactions can essentially draw on existing gestures that we use in our everyday life, they are

characterized as Natural User Interfaces (NUI). NUI researchers are actively exploring different touchless gestures [8], user-interface elements [2], and interaction techniques [1] that can contribute toward the naturalness of touchless interaction. Equally relevant, but little explored are the interaction mechanics or sensory-motor details that can affect the touchless user experience.

To deconstruct its sensory-motor connections, we can view touchless interaction from an embodied interaction perspective [5]. Prior work used embodied perspective to discuss touchless interactions based on Merleau-Ponty's lived-body view of individual experiences and Wittgenstein's socially organized view of action [10]. But their interaction mechanics remain unexplored. For example, compared with other interaction modalities, such as touch-based or tangible computing—touchless interaction is *device-less*. Hence, there is no embodied conception of a tool—no transition of an input device from *present-at-hand* (an object of activity) to *ready-to-hand* (absorbed in the fabric of the activity) [5].

I argue that this device-less property of touchless interactions creates unique sensory-motor connections while interacting with distant, 2D displays, thus affecting the touchless user experience. This argument can be grounded in ecological psychology that views cognition as a construct involving the ability of an entity, action, and the environment [6]. For example, a chair affords sitting to a human, but not to an entity inappropriate for sitting (e.g., a fish). In touchless interactions, the absence of a device (and its constraints) and the use of our whole body (or body-parts) imply availability of all our physical abilities toward realizing affordances of any touchless system. So while interacting with a distant 2D display, we can use our hands or fingers to push, pull, roll, or make directional strokes in mid-air as interaction commands. However, I argue that the accessibility of all these physical abilities (that we use in a 3D world) to interact with a 2D display that lacks a 3D worldview violates how *seeing* and *acting* is related in our familiar 3D environment [6]. Thus, I further argue that the psychological principles affecting visual perception will have a significant effect on touchless motor action. Moreover, the sole presence of 2D visual feedback and proprioception in touchless interactions would amplify typical properties of motor control (e.g., motor planning, or motor learning).

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During the last two years of our work on touchless interactions with large displays, we observed that users' performance were often solely affected by certain visual properties of the UI. Moreover, users tend to make holistic oblique gestures instead of decoupled orthogonal hand movements. These findings—albeit ad hoc—can be explained using the Gestalt theory. Gestalt psychology—a popular proponent of *holism*—has played an illustrious role in providing theoretical foundations toward visual perception [11], and very recently motor action [7]. Inspired by preliminary findings, my aim is to conduct mixed-method studies to explore how gestalt principles in visual perception and motor action can drive the design of touchless interactions (i.e., to conduct quantitative studies to evaluate the effect of gestalt principles and qualitative studies to understand users' conscious experiences). This work on touchless, situated at the confluence of perceptual and motor gestalt, can also provide new insights to Gestalt researchers.

## BACKGROUND

### Touchless Interaction

Innovative applications of touchless systems are proliferating across domains, such as entertainment, surgery [10], patient-centric health settings [9], collocated collaboration, information visualization, or public spaces [10]. These systems' feasibility, adoption, or user experience is an active line of research. Another research direction deals with understanding naturalness of touchless interactions. To that aim, elicitation studies explore touchless gestures that users report natural as interaction commands. Fewer works have looked into understanding touchless interactions beyond the interface-centric view [10], or operationalizing the intuitiveness (or naturalness) of touchless interfaces [3]. With the current focus on investigating touchless UX from users' self-reports, we may be overlooking other implicit sensory-motor factors affecting touchless UX, such as visual aspects of the UI, or properties of motor action unnoticed by users.

### Embodied Interaction

Touchless interactions are distinctively characterized by the absence of a device—we engage with the system without a tool. Then from Heidegger's phenomenological view (later also developed in HCI), at no point in touchless interactions we have a *present-at-hand* device, such as a mouse or a pen, as the object of an activity [5]. Thus, in the context of interacting with computers, touchless interaction may be called as the ultimate form of Merleau-Ponty's lived-body experience—the body playing the crucial role in perception.

Specifically in visual perception, ecological psychology deals with the deep connection between *seeing* and *acting* [5, 6]. This connection becomes pertinent to touchless interactions and worthy of investigation, because in certain scenarios (e.g., interacting with distant, 2D displays), users

see a 2D UI but act with their whole body (or parts) that they are familiar engaging in a 3D environment with haptic feedback. This mismatch between visual perception and motor action in touchless interactions remains unexplored.

### Gestalt Psychology

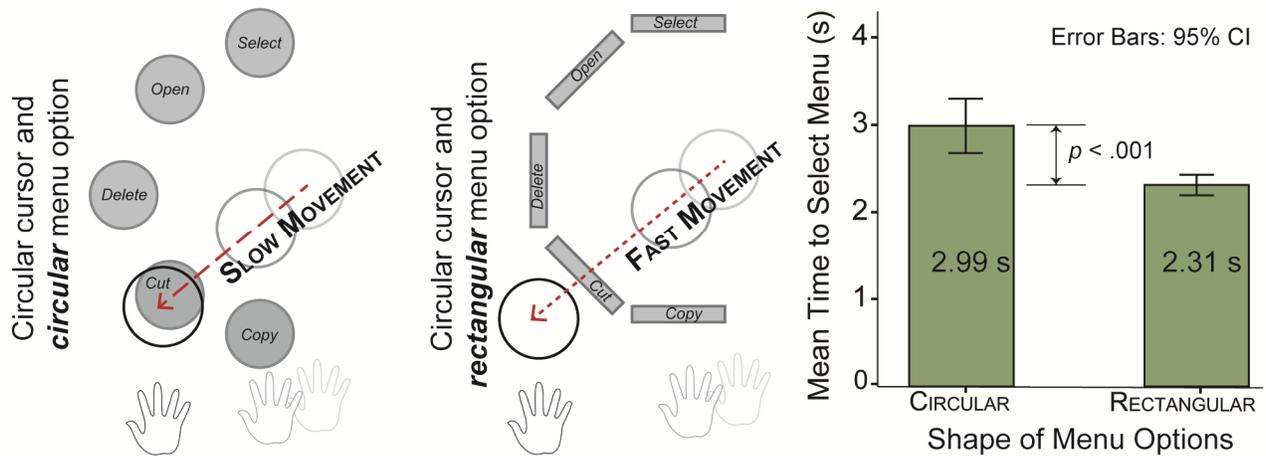
Gestalt psychologists argue that perceptual experiences and motor actions are inherently holistic, rather than a composite of unrelated structural units. A centennial review on Gestalt research showed how different methodological shortcomings of this research program have somewhat been addressed [11]. Specifically, the gestalt principles of perceptual grouping in vision, such as proximity, similarity, or continuity, have been quantified [11]. Another recent review analyzed reaction-time results from previous studies and argued that four fundamental Gestalt principles in perception also apply to the control of motor action—holism, constancy, mutual exclusivity, and grouping in apparent motion [7]. For example, certain motor actions, such as articulating a syllable during speech or making quick taps indicate the presence of motor gestalts (chunks). However, neither perceptual nor motor gestalt has been investigated in the context of touchless interactions.

Interacting with 2D touchless UIs using freehand gestures violates our familiar mental model of interacting with the 3D environment, and the effects of such a mismatch can be explained using Gestalt psychology. Specifically, I argue that gestalt principles in visual perception and motor action can provide a theoretical foundation to drive the next-generation touchless UX with distant displays.

### PRELIMINARY FINDINGS: 'ON UNNOTICED SENSATIONS AND ERRORS OF JUDGEMENT'

We began studying touchless interactions as part of the Wall Display Experience Research (WADER) program, which aims to identify critical factors that are necessary to design next-generation interaction techniques to support collaboration around wall-size displays. While conducting controlled experiments to study visual feedback [4], interaction primitives [3] and command-selection techniques [2] for large-display touchless interactions, we observed certain performance trends that were unnoticed by users. Visual elements of the UI affected users' effectiveness (e.g., aiming a menu for command-selection) and efficiency (e.g., time taken to select a menu-option). Also, users always made similar errors while performing certain interaction primitives (e.g., pull-to-deselect). Interestingly, all our findings could be explained by gestalt principles of perceptual grouping: similarity by orientation, continuity, and the gestalt law of *Prägnanz*.

Across our experiments, users sat about 1.5 – 2.5 m away from a large display (4 x 1.5 m) and were tracked by Kinect sensors. In what follows, I briefly describe the findings that led to the conception of this dissertation proposal, some limitations of our experiments and the future research plan.



**Figure 1. Perceptual grouping by *Similarity of Orientation* principle affected the efficiency of touchless interaction: Expert users were faster when *crossing-to-select* a rectangular menu option than a circular menu option with a circular cursor.**

### Similarity of Orientation affects Interaction Efficiency

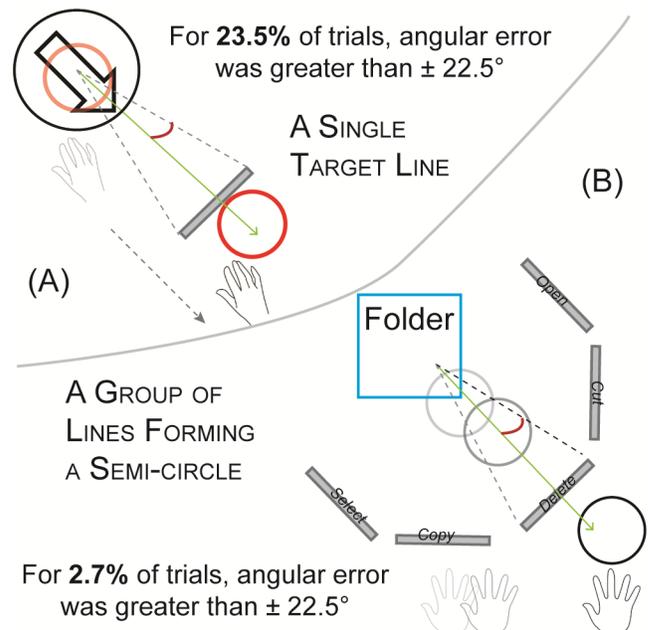
To relieve users from strictly complying with system-defined postures as interaction commands, we introduced a command-selection technique using mid-air strokes—Touchless Circular Menus (TCM) [2]. To trigger the contextual TCM, users would land on the target folder, and to select a command, users would simply cross the menu option (Figure 1). In our early iterations, the menu options (230px) were circular, isomorphic to the cursor (256px). During pilot testing with three expert users, we found them slowing down while crossing the menu-option. When the cursor was over the menu-option, users would tend to slow down as if they were placing the cursor over the menu-option, rather than crossing it (in spite of prior instructions and practice trials). The menu options were about 800 pixels away from the folder (13.7 cm in control space). When the menu options were modified to rectangles (at the same distance), users became significantly faster. This occurred in spite of users essentially traversing the same distance: For circular options, users had to move across half the menu-option, and for rectangles cross the entire menu-option. Shape of the menu options (circular,  $M=2.99s$ ,  $SD=2.0$ ; rectangular,  $M=2.31s$ ,  $SD=0.76$ ) significantly affected efficiency ( $\text{Log}_{10}$  reaction time) with a small effect size,  $n=161$ ,  $t(160)=4.19$ ,  $p<.001$ ,  $d=.33$ .

This finding can be explained using the gestalt principle of perceptual grouping by *similarity of orientation*: all else being equal, the most similar visual elements in orientation tend to be grouped together [11]. Our results suggested that users must have perceived the circular cursor and the circular menu-option as a group—at least momentarily—and thus slowed their motor action to discriminate between the object of action (the circular menu option) and the symbolic referent of their action (the circular cursor).

### Continuity affects Interaction Effectiveness

For another experiment that explored user performance of mid-air directional strokes [3], users performed the following task. As they reached a landing circle on the

display, a direction and a target line appeared (Figure 2A). To complete a trial, users stroked in that given direction across the target line. Although this experiment used the same gesture primitive as TCM (a mid-air directional stroke), we found a significant difference in users' effectiveness. Across the same individuals who participated in both of these experiments (mid-air strokes and TCM), we found that angular error for 23.5% of the trials was more than  $\pm 22.5^\circ$  in the first experiment, compared with only 2.7% of such erroneous trials in the second. The distance between the target line (or a menu option) and the landing circle (or a folder) was about 800 pixels. This finding can be explained by the structure of the TCM that was absent during the mid-air stroke experiment—a semi-circular



**Figure 2. Perceptual grouping by *Continuity* affected the effectiveness of touchless interactions: Experimental results from two studies suggested that users were less precise when aiming an isolated rectangular target (A) compared with a rectangle as part of a semi-circular arrangement (B).**

arrangement (Figure 2B). This exemplifies the gestalt principle of perceptual grouping by *continuity*: all else being equal, elements tend to be grouped together when they are aligned with each other [11]. Users were more precise with the TCM than the single line segment as they were aiming for a wider structure in TCM—a semicircle.

### Prägnanz affects Intuitiveness of Gesture Primitives

In another study, we explored *push-to-select* and *pull-to-deselect* gestures [4]. In a drag-and-drop task on a large display, we observed users often trying to select targets by following the shortest, oblique path, instead of a set of orthogonal paths. Similarly, when pulling to deselect, instead of a decoupled set of orthogonal movements (parallel to the display for translation and perpendicular for action), users intuitively made oblique motions toward the center of their torso (Figure 3). Such tendencies exemplify motor planning routines that seek to minimize our metabolic energy costs [3]. Overall, the holistic nature of this oblique motion can be explained by the concept of physical Gestalten or motor gestalt [7], which is derived from a more general *Law of Prägnanz*: all physical systems, when left alone, tend to achieve a state of maximum equilibrium with minimum energy expenditure [11].

### Limitations

Our findings are posteriori arguments and are limited by our tracking sensors. Other limitations include not explicitly controlling for the index of difficulty in the crossing-based trials, and a small sample size. I plan to address these limitations in my future work.

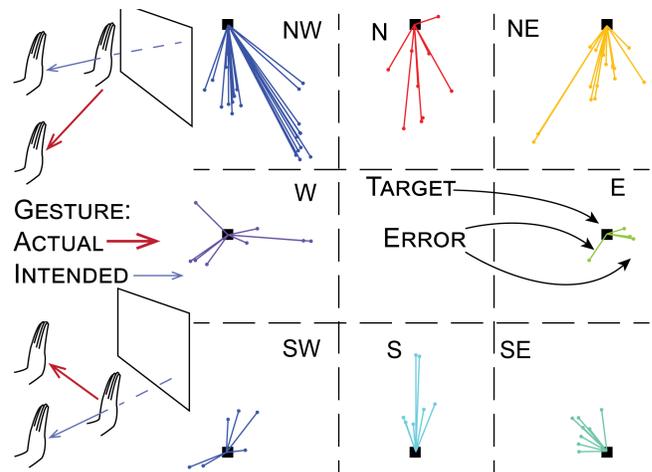
### CONCLUSION AND FUTURE WORK

This dissertation proposal aims to deconstruct the interaction mechanics of touchless from an embodied perspective. Specifically, I argue that the device-less property of touchless violates our familiar mental model of *seeing* and *acting* when interacting with 2D displays using freehand gestures. And the effects of such a mismatch can be explained by gestalt principles of visual perception and motor action.

As future work, I am designing controlled experiments to test how the gestalt principles of visual perception (e.g., closure, or symmetry) and motor action (e.g., holism, or grouping of apparent motion) affect touchless UX. Findings from these experiments will create the knowledge necessary to design the next-generation of touchless UIs and gesture primitives. I also plan to use these guidelines to design a touchless system for interacting with “beyond-the-desktop” visualizations on large displays (e.g., large-scale scatterplots, heat maps or graphical networks).

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**Figure 3. A holistic motor gestalt exemplifying the *Law of Prägnanz* affected gesture intuitiveness: When intending to make mid-air movements perpendicular to a vertical display, such as a pull gesture, users repeatedly made oblique motions toward the center of their torso—to optimally reach static equilibrium, thus minimizing their body’s energy expenditure.**

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