# Tactile motion coordinate transforms in the somatosensory system

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***Abstract*— Our ability to perceive motion information on the skin is key to manipulating dynamic objects in the environment. Previous studies show that the brain derives tactile motion representations by integrating local cues of the object that impinge on the skin (e.g., speed, intensity, direction), a mechanism known as the Full Vector Average model [1]. This model was derived from studies that placed the hand in the same posture. Yet, object perception and manipulation with the hand (i.e., haptics) is a highly dynamic and goal-directed function. Thus, it is key to study whether tactile motion perception is transformed by hand position, and whether these transformations depend on the reference frame in which the motion judgement is made. Here, we asked human participants to discriminate motion stimuli on the index finger in two reference frames (hand-centric vs. sternum-centric), with the hand placed in different positions. We found that human observers can systematically represent tactile motion under explicitly instructed reference frames. We further showed that tactile motion discriminations can be accurately decoded using a Bayesian generative model.**

## I. Introduction

Understanding how tactile motion representations are generated involves studying how the brain integrates cutaneous motion information with proprioceptive signals of the body, and how this integration mechanism is modulated by the reference frame upon which motion representations are derived. Although, previous studies [2] investigated how motion information on the finger is modulated by hand and head position, they failed to instruct participants which reference frame to make motion judgements in, thus leaving the question open of what biases are involved in human reports of tactile motion in a given reference frame. Our experimental design allows us to systematically explore the flexible representation of tactile motion across different postures under explicitly instructed task contexts. We developed a Bayesian generative model that accounts for how cutaneous motion direction and proprioceptive signals of the arm are integrated to generate motion representations in different reference frames.

## II. Task design

Observers perform a two-alternate forced choice tactile motion discrimination task under two task contexts: one in which they judge whether the stimulus is moving away or towards the thumb (Hand-centric), and another in which they judge whether it is moving leftwards or rightwards w.r.t. center of the body (Sternum-centric). Fourteen subjects (10 females) performed the experiment (10 Right-Handed, 2 Ambidextrous, 2 Left-Handed). The protocol was approved by the Research Subjects Review Board at the University of Rochester, and written informed consent was obtained from all participants.

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Each participant performs the task in three postures (Fig.1A) The palm and fingers are held in place using grips to restrict movement. Subjects are head-fixed and wear a VR headset that provides instructions on the task context, and blocks visual cues about stimulus motion and the proprioceptive state of the arm.

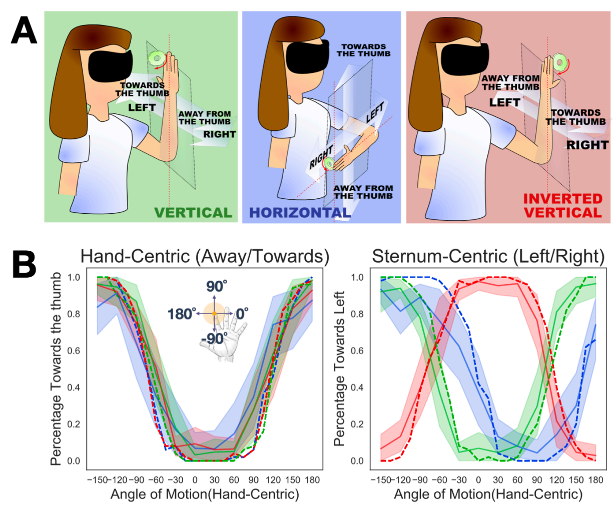


Fig. 1. **A**: Illustration of the three arm postures: Vertical (*green*), Horizontal (*blue*) and Inverted Vertical (*red*) and the two task contexts: Away or Towards the thumb (Hand-Centric), and Left or Right (Sternum-Centric). **B**:Psychometric curve (angle of motion in hand-centric reference frame) of population-level data, in hand-centric task (*left*), and sternum-centric task (*right*). Error-bars represent 95% confidence intervals. Dashed lines represent the fit of the computational model. Angle of motion direction w.r.t the hand (*inset*).

## III. Results

Subject behavior was modeled using a Bayesian generative model that can explain choices under the two reference frames (Fig. 1B). Overall, the population level-behavior was unbiased towards any one particular reference frame or posture, indicating that the subjects were able to perform near-complete reference frame transformations under explicit instruction. Moreover, introducing an additive bias parameter to the observed tactile motion in the computational model better explained the population-level results. We are currently working towards disentangling the source of the bias term in individual participant reports.

## References

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