HapticSphere:
Physical Support to Enable Precision Touch Interaction in Mobile Mixed-Reality

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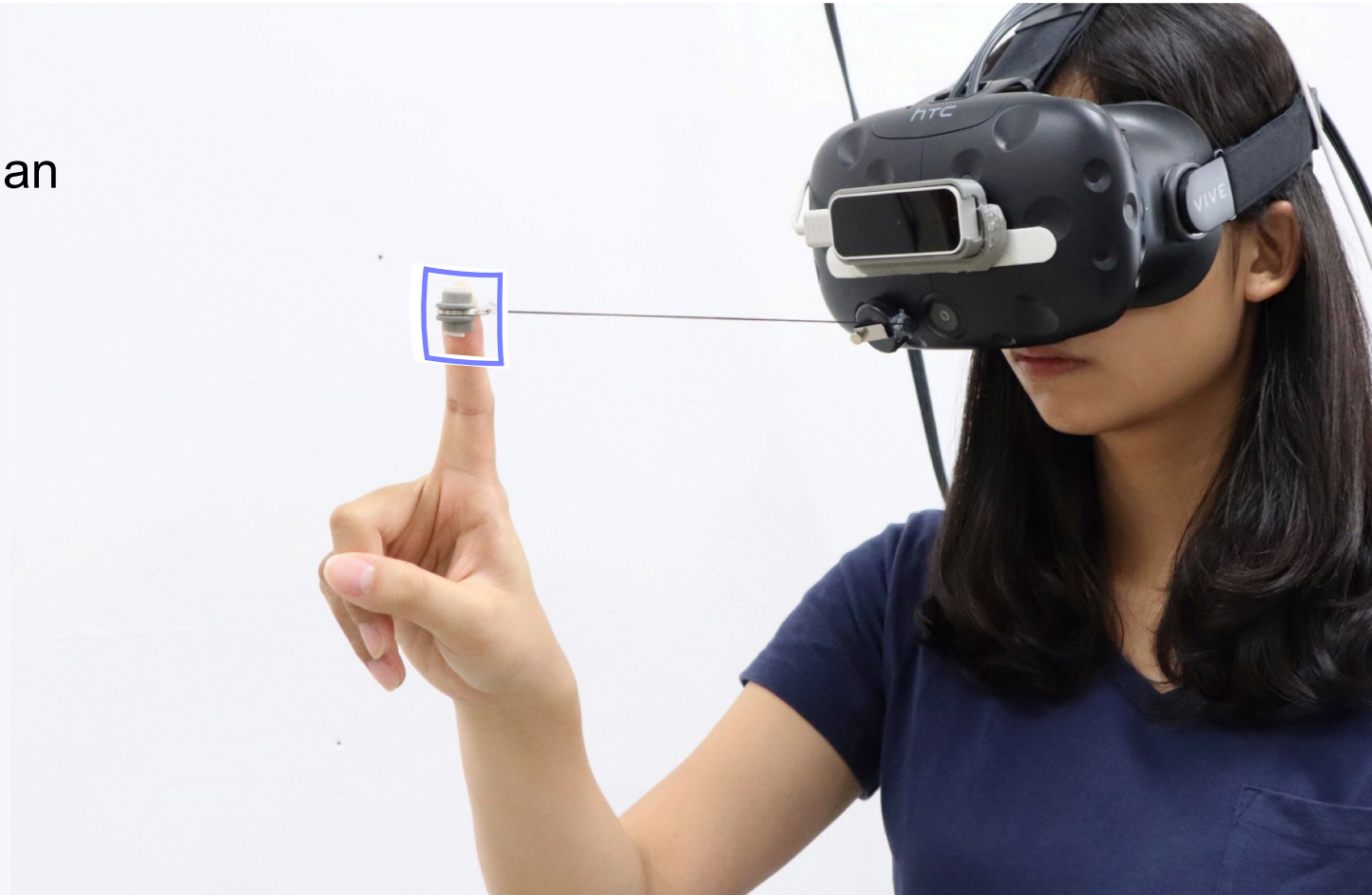
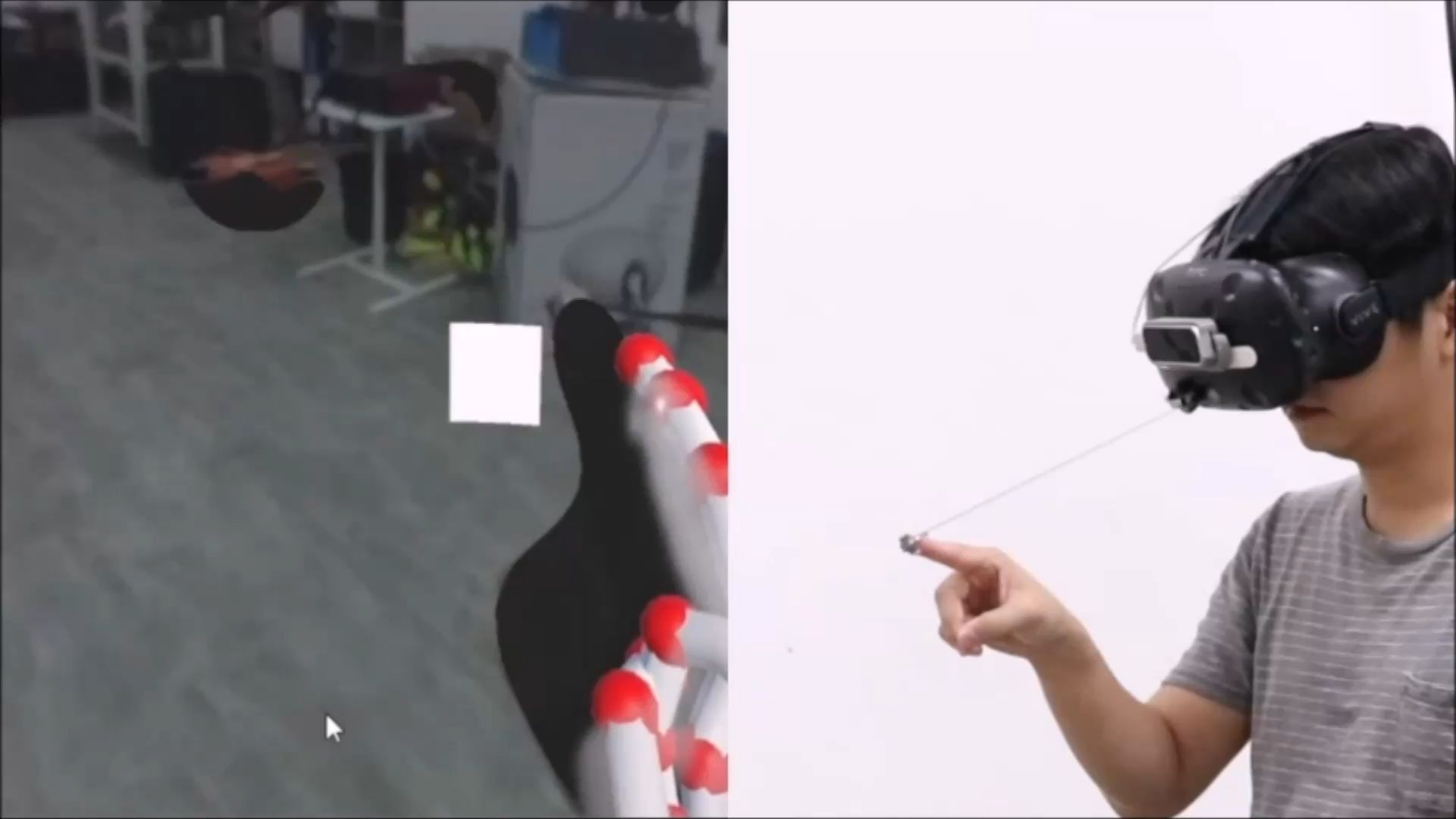




Motivation

Touchscreens provide physical support…


…with haptic feedback and
finger stabilization on the go


Midair touch interaction, however,
lacks such physical support

HapticSphere

HapticSphere

integrates a finger tracking device with a passive string

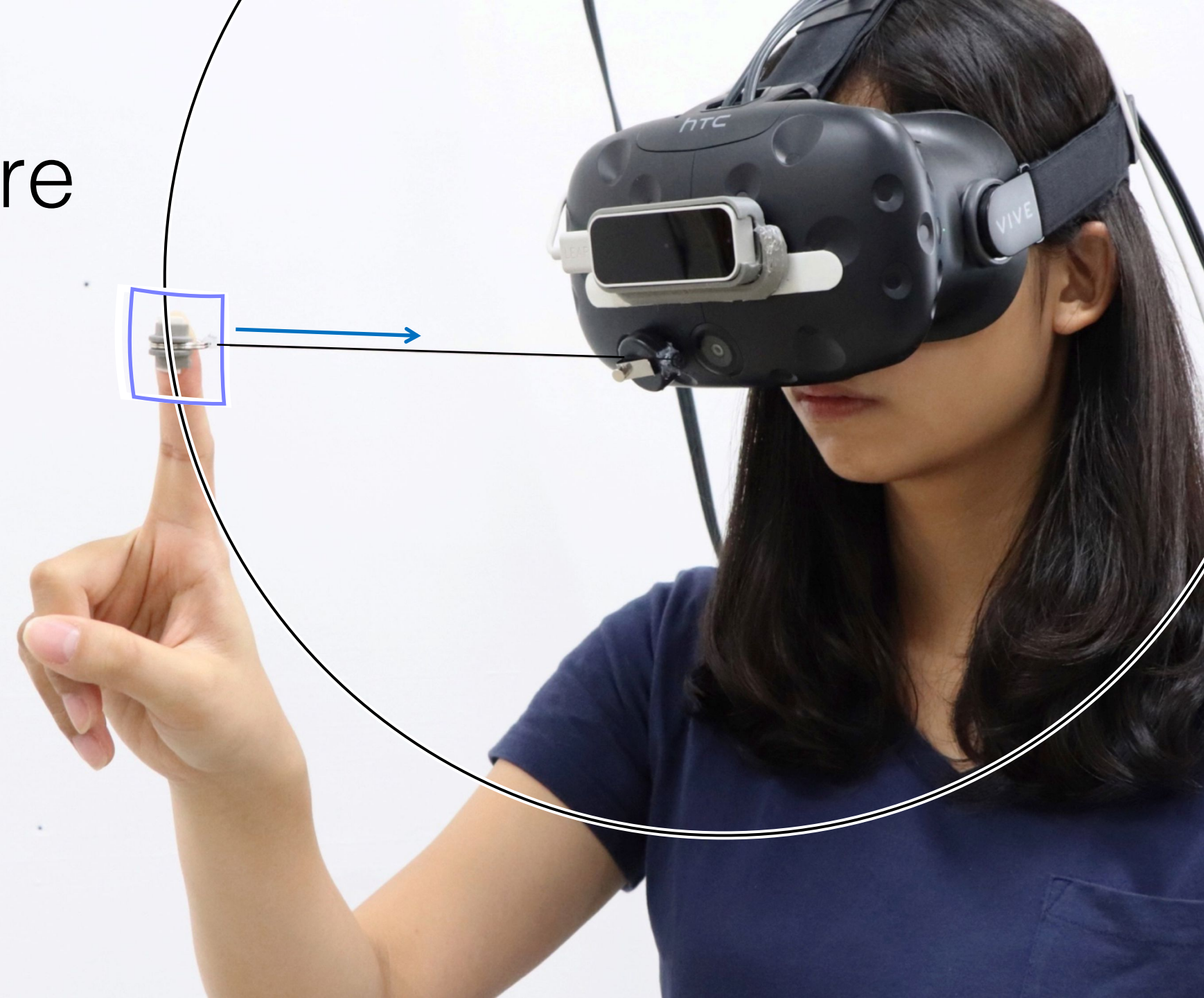
HapticSphere

integrates a finger tracking device with a passive string

suggesting a solid spherical interface surrounding the user

HapticSphere

the user perceives
physical support
when reaching the
maximum extension



Speed: 1.5X

An Example Scenario on Mobile Mixed-Reality

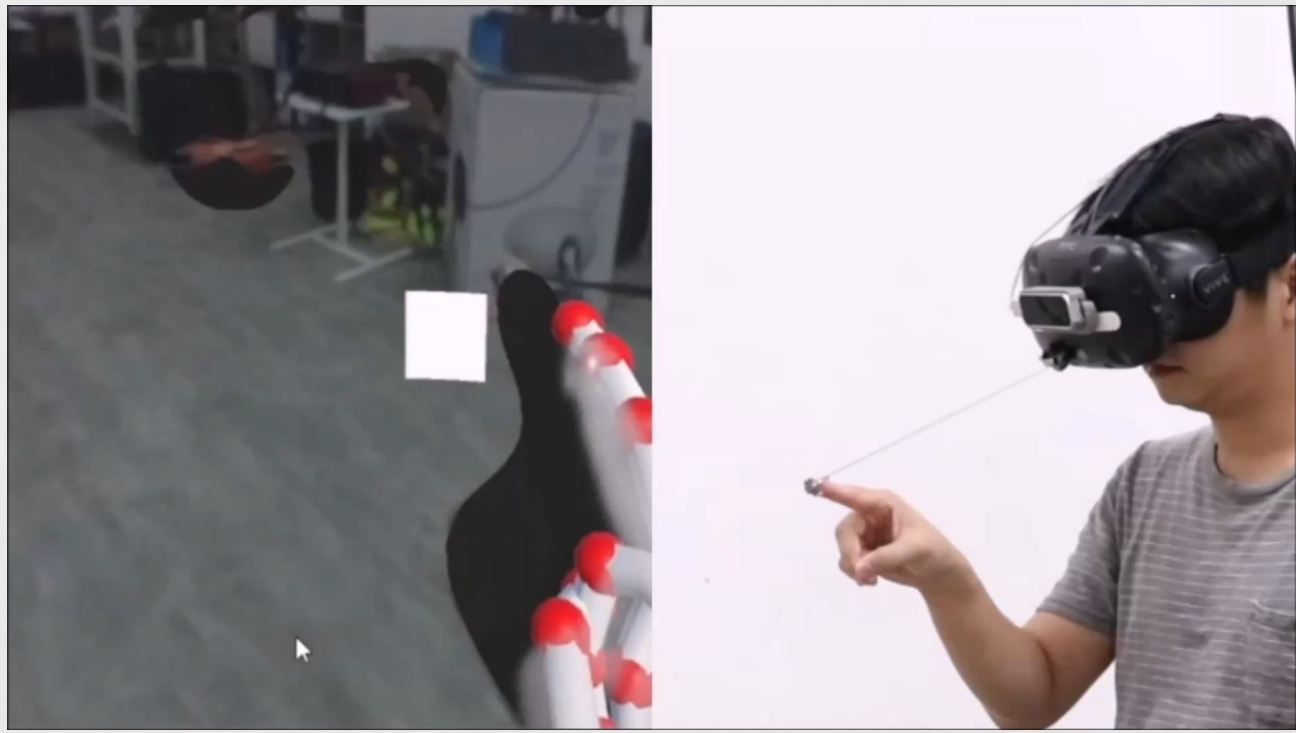
the main challenge is the walking touch interaction.

that the unconstrained hand motion while walking impacts touch precision.

HapticSphere focus on providing force feedback on the fingertip for precise touch interaction.

HMD plus a
passive string

This physical support stabilizes user finger
improving touch precision in walking situatio



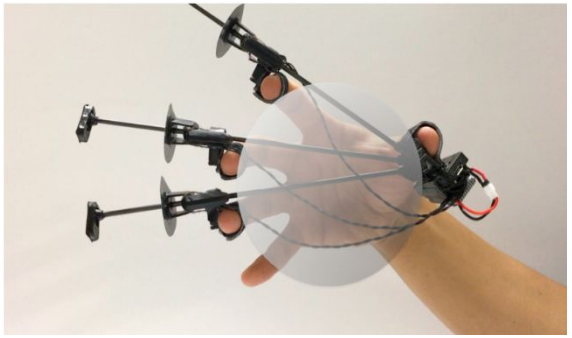
Related Work

- Wearable Force Feedback Interfaces
- String-Based Haptic Interactions

Wearable Force Feedback Interfaces

Hand-scale feedback

HapticLink
(CHI ‘18)

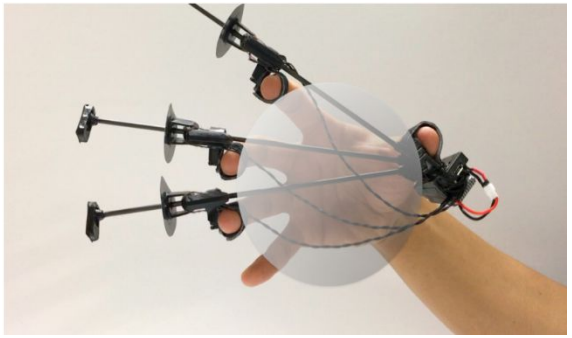


Wolverine
(UIST ’16)

Wearable Force Feedback Interfaces

Hand-scale feedback

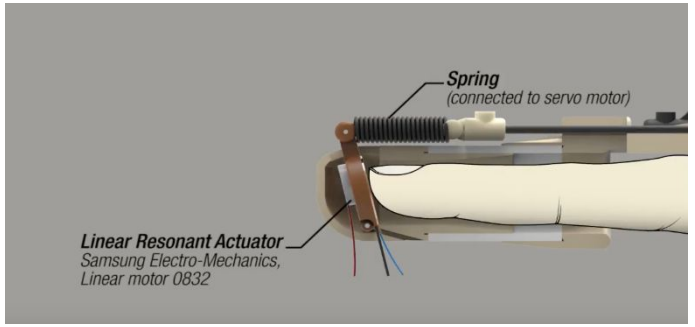
HapticLink
(CHI ‘18)



Wolverine
(UIST ’16)

Finger-scale feedback

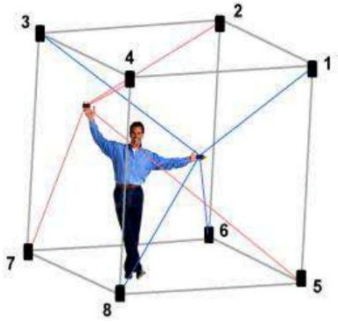
Gravity Grabber
(SIGGRAPH ETech ’07)



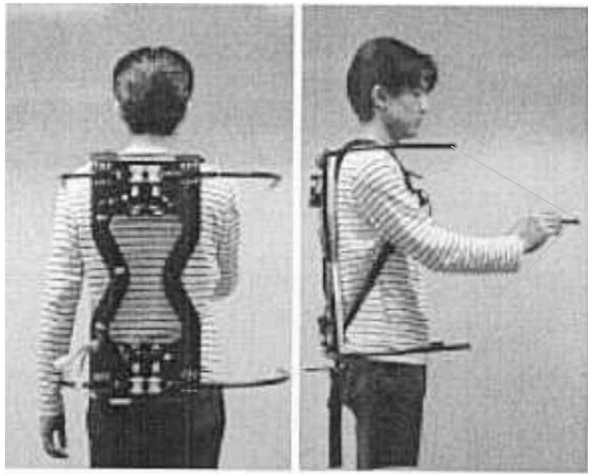
HapThimble
CHI ‘16

String-Based Haptic Interactions

Active feedback



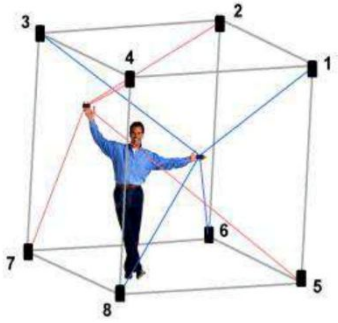
SPIDAR
(JVRC'09)



HapticGEAR
(IEEE VR '01)

String-Based Haptic Interactions

Active feedback



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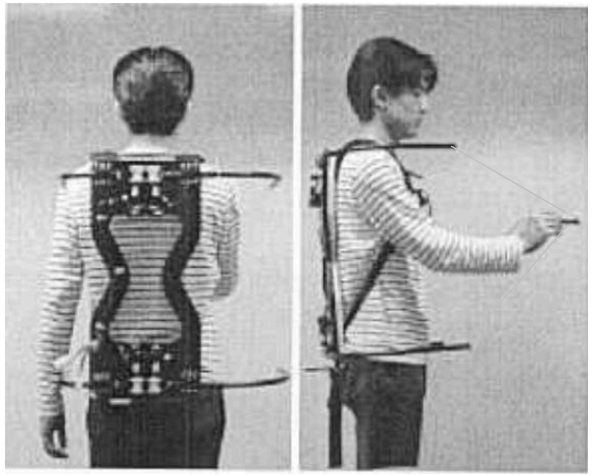
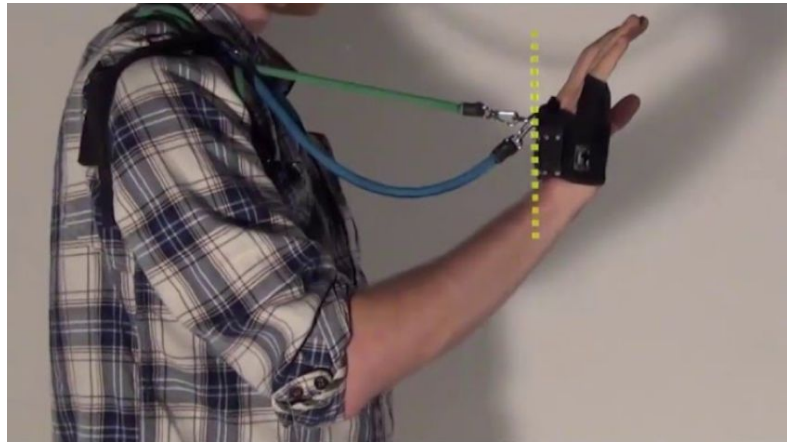


HapticGEAR
(IEEE VR '01)

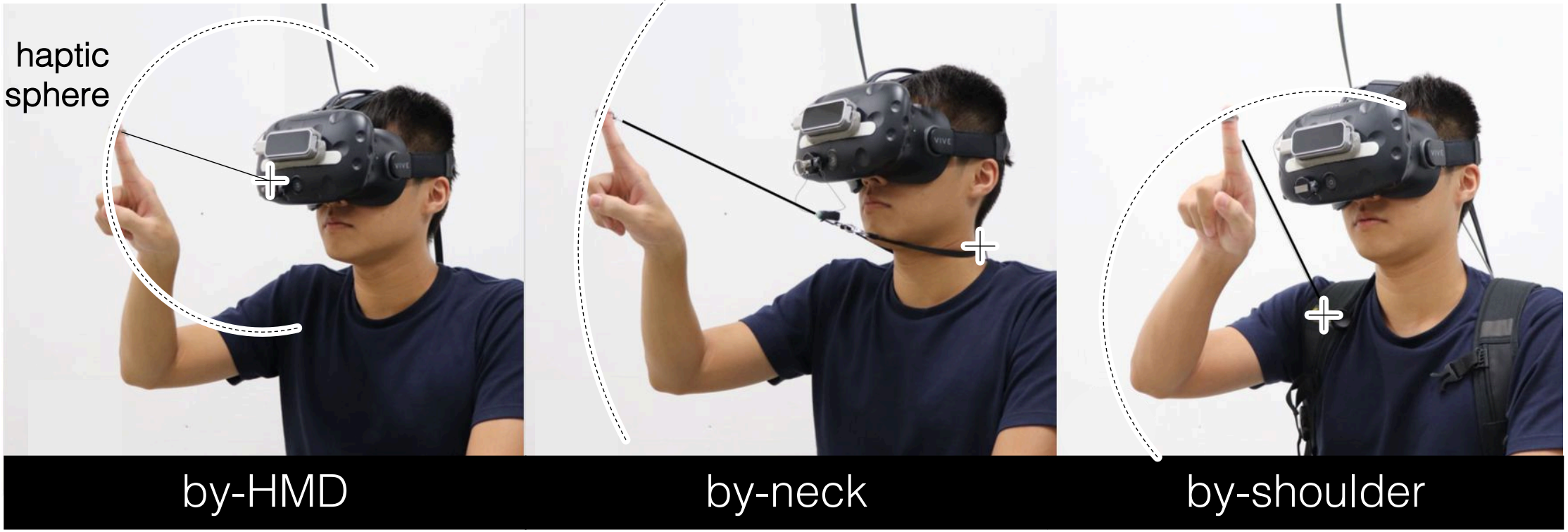
Passive feedback



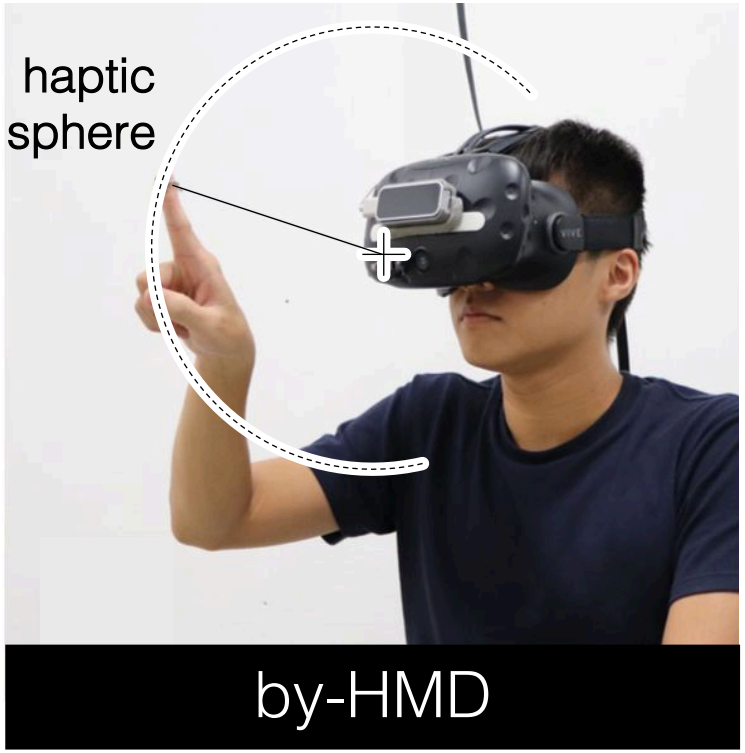
ElasticArm
(IEEE VR'15)

haptic sphere

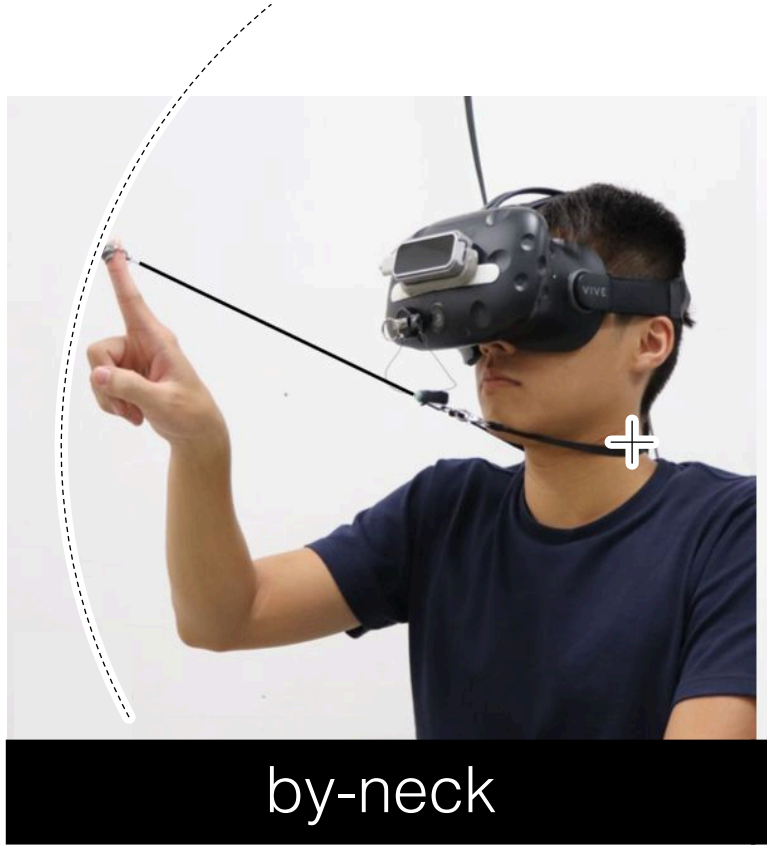
string attachments



string attachments



String constrained to head



String not constrained to head
(this asks to additionally model the head motion.)

To deal with a haptic sphere in different situations,
we propose head-coordinated touch interaction and
propose the estimation of a grand haptic sphere

Head-coordinated touch

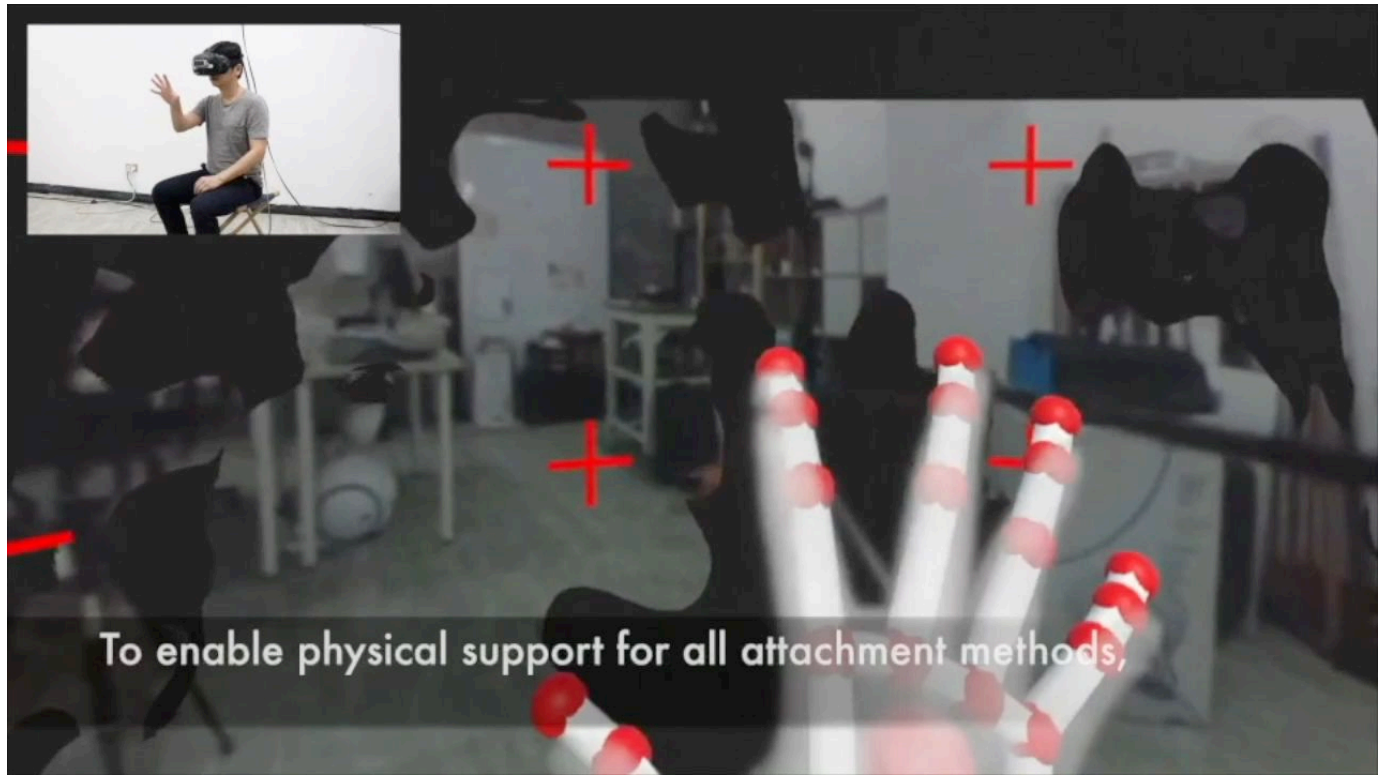
asks for always addressing a touch operation
with the user's heading. (e.g., always look at where a touch occurs)

This effectively removed
the degree-of-freedom
introduced by head
motion.

Grand Haptic Sphere

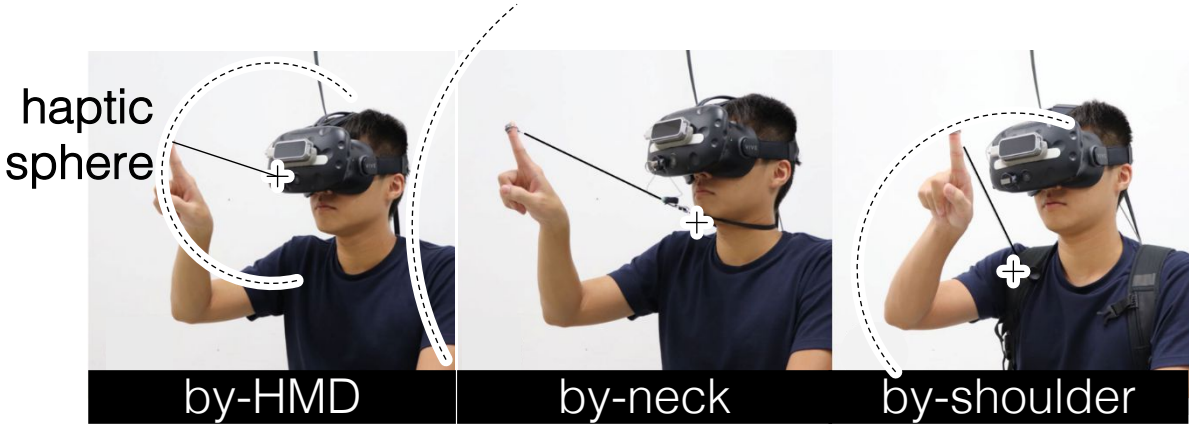
estimates the haptic sphere for touch interactions undergone the head-coordinated touch.

touch points are collected in the calibration process to estimate the sphere.



Summary

The acquisition of grand haptic sphere works for all attachment methods.
In latter interaction, the user needs to address a touch operation with head-coordinated touch.



Please refer to our paper for more detailed property of grand haptic sphere.

User Studies

Study 1: Visual-coherent Physical Support

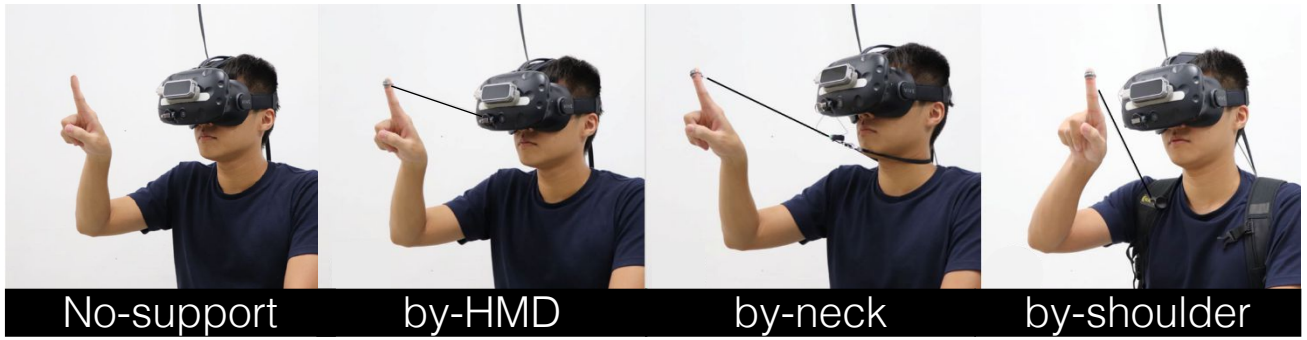
To know whether grand haptic sphere enables visual-coherent physical support during touch interaction.

Study 2: Toward Mobility

To understand the benefit of physical support in walking situation.

Study 1 : Visual-Coherent Physical Support

- Within-subject design
- Independent variable: Interface
  - No-Support
  - by-HMD
  - by-neck
  - by-shoulder



- Task:
  1. acquire a grand haptic sphere
  2. perform target acquisition with head-coordinated touch on targets laid on. the grand haptic sphere

1. Acquire a grand haptic sphere

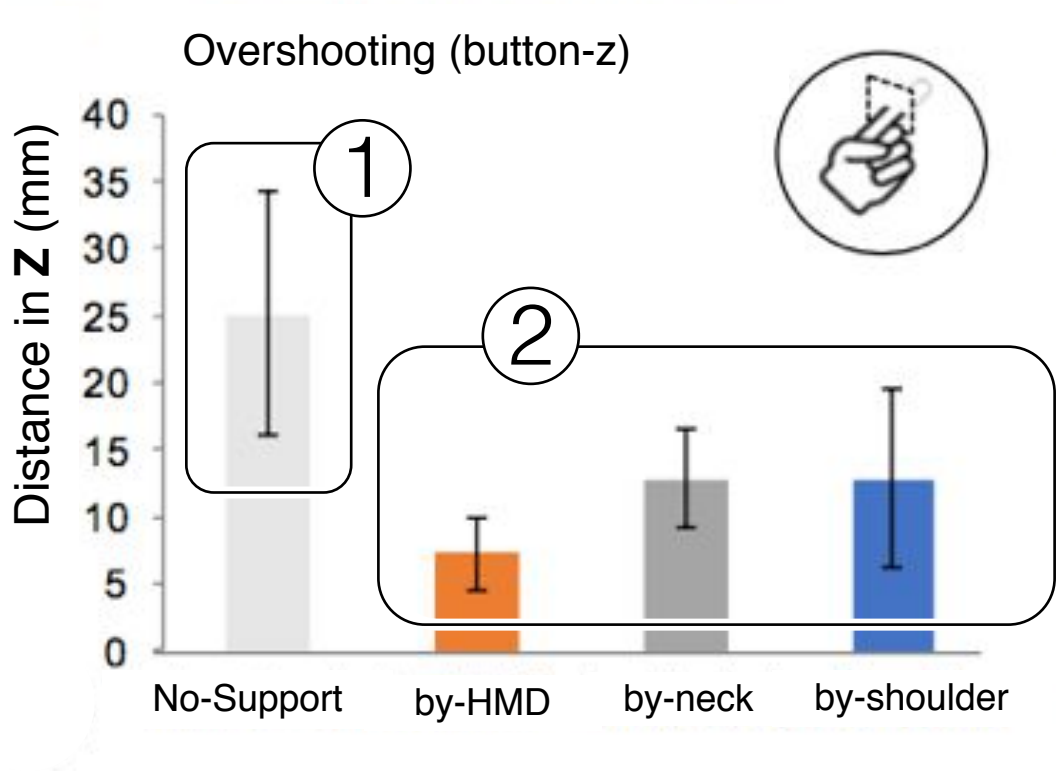
The Study Procedure. (SpeedUp 2X)

2. Perform target acquisition task

The Study Procedure. (SpeedUp 2X)

Result of Study 1

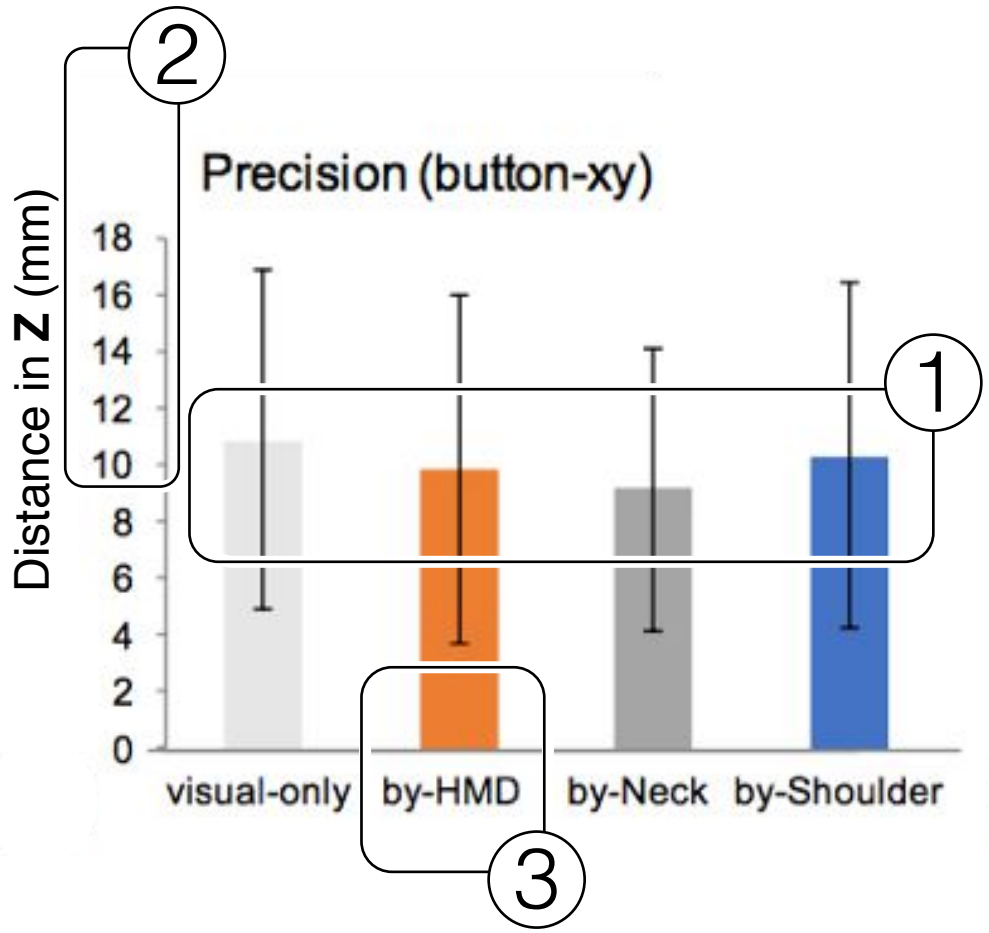
Overshooting



1. Without physical support, users encountered overshooting a target in depth.

2. Physical support appears in each selection to prevent the finger overshoot the interface.

Precision



1. Users performed target acquisition equally well in terms of precision.

2. Averaged precision is 10.4mm (SD: 5.87mm), suggesting an effective button size of 22mm by 22mm with 95% accuracy .

3. The by-HMD interface is adopted to the next study

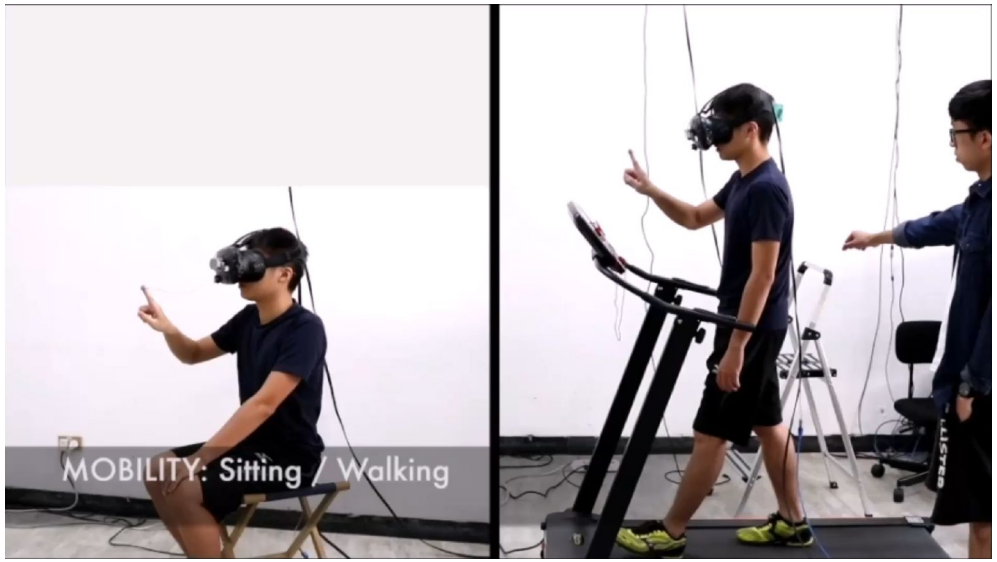
Study 2 : Toward Mobility

- Within-subject design
- Independent variables
  - Mobility: Sitting / Walking
  - Haptics: with Support & without Support
  - Buttons sizes: 25 / 30 / 35 / 40 mm
- Task:
  - perform target acquisition task

Walking touch interaction on treadmill

Mobility

Sitting Walking

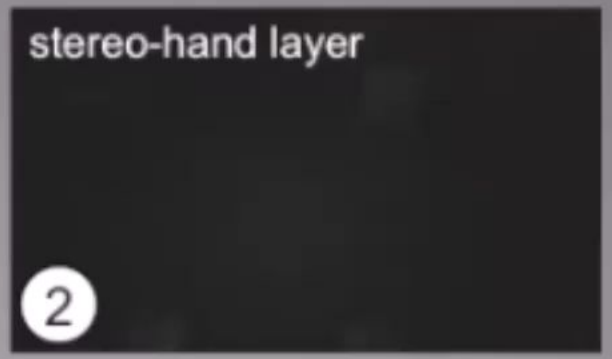


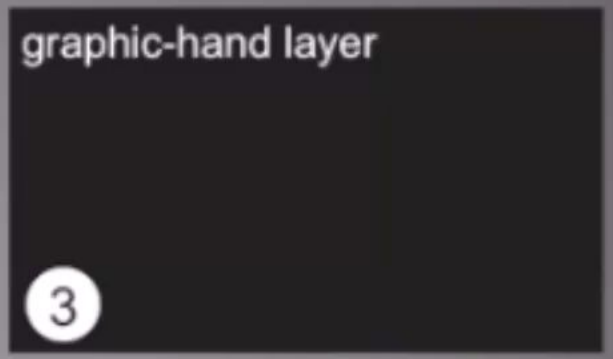
Haptics

without Support with Support

Button Size

25mm 30mm 35mm 40mm





1 + 2 + 3 = combined view

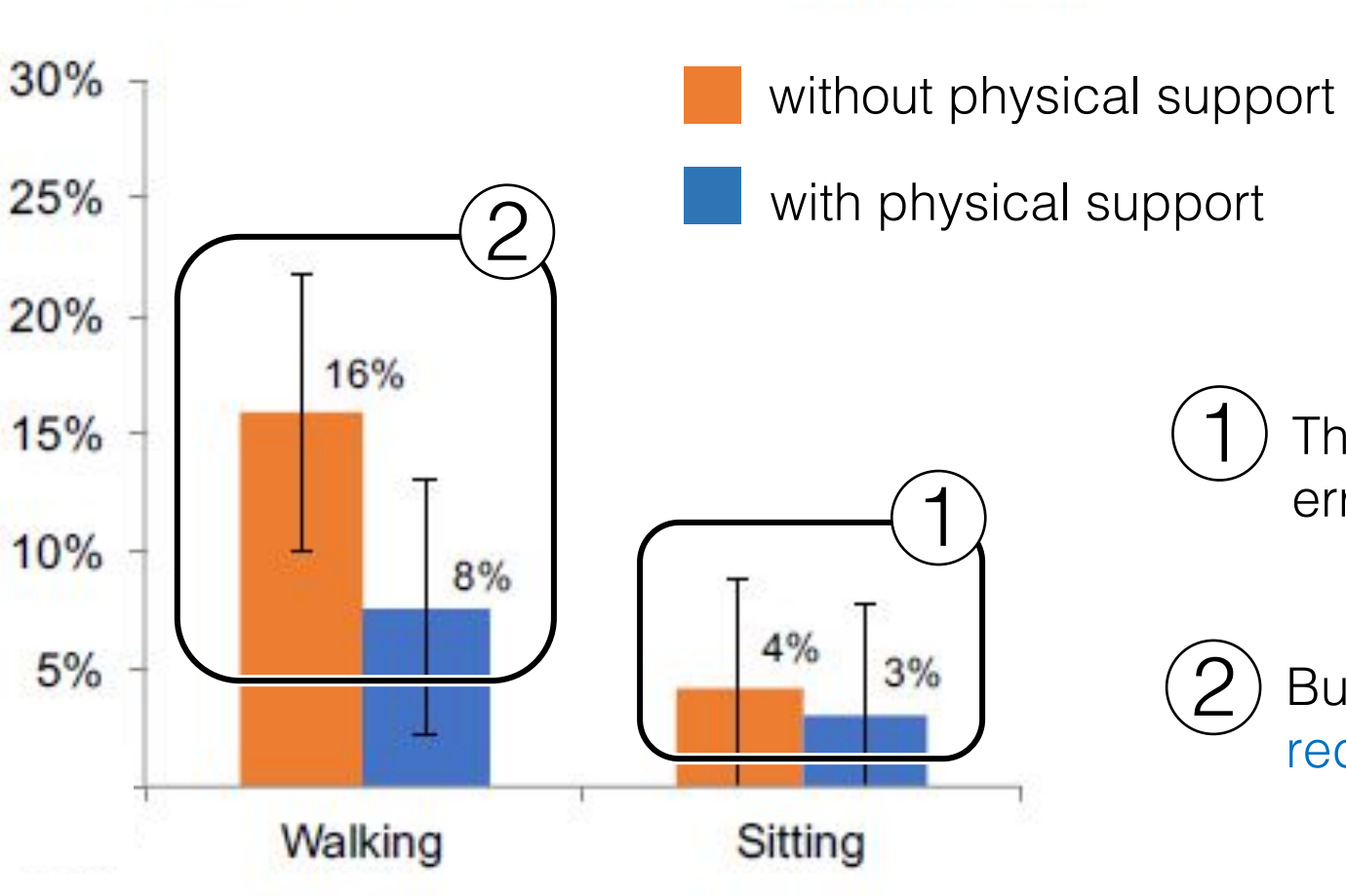
1 + 2 + 3 = combined view

We enable Mixed-Reality View by blending three layers together.


Speed: 2.5x

Result of Study 2

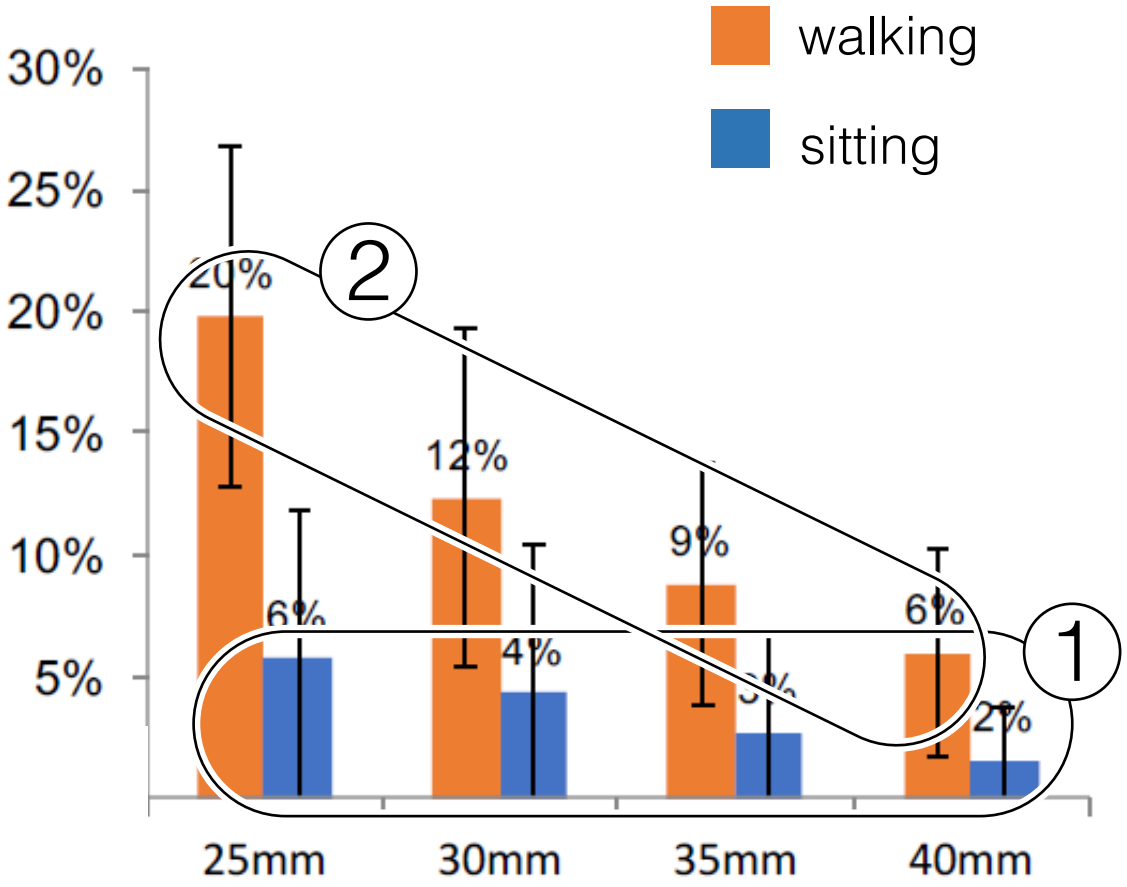
Error Rate



1 The physical support does not benefit error rates in the sitting conditions.

2 But the physical support significantly reduced errors in the walking conditions.

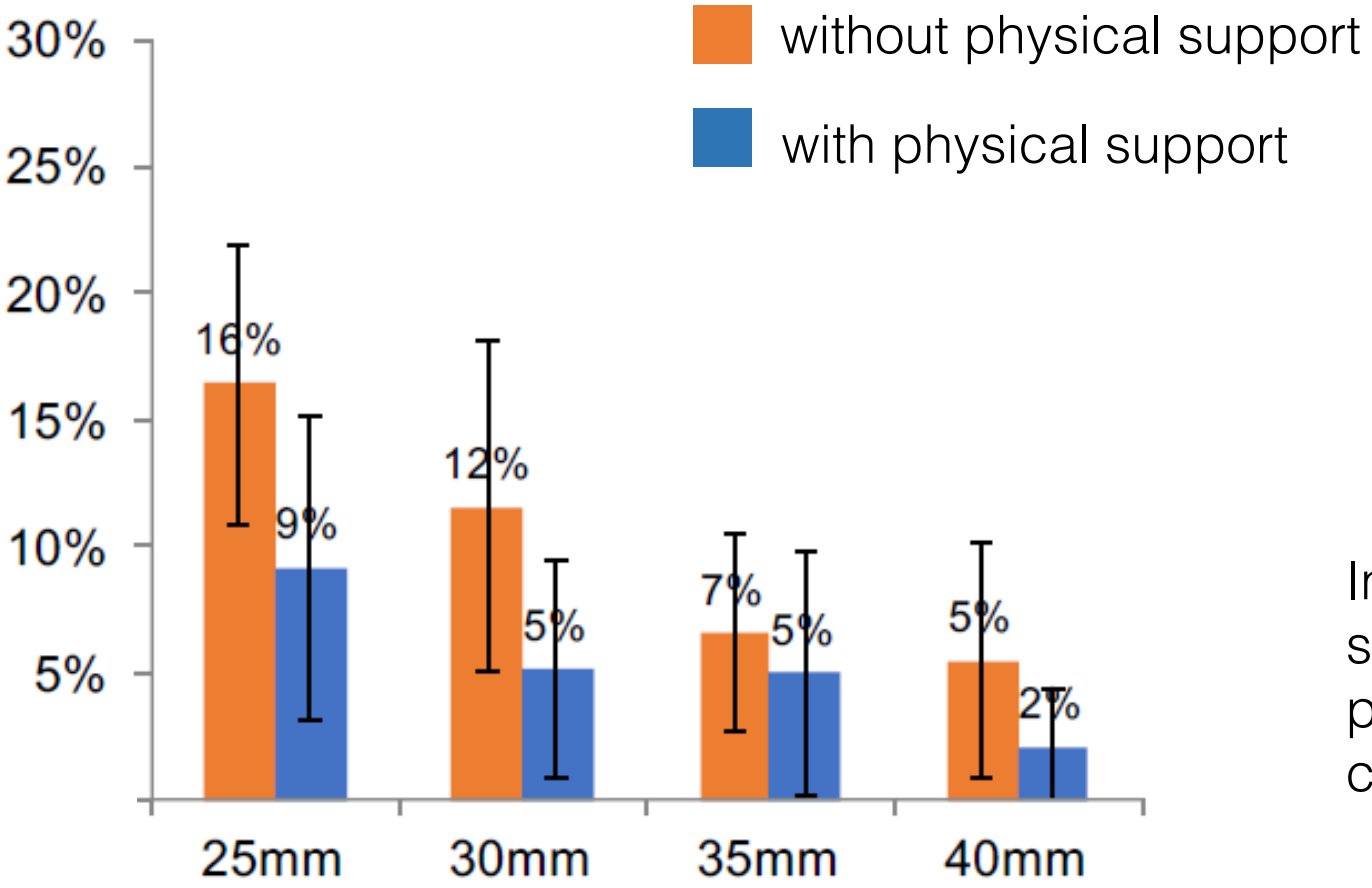
Error Rate



1. Button sizes do not matter with error rate in sitting conditions.

2. But in walking conditions, the error rates increase rapidly with decreasing button sizes

Error Rate (button size vs. walking)



In walking conditions, physical support significantly improved touch precision in all button sizes conditions over no-supports.

Summary

Goal: HapticSphere aims to providing force feedback on the fingertip for precise touch interaction.

Result: Physical support stabilized midair touch and effectively improved the touch accuracy particularly in the walking condition.

Limitation

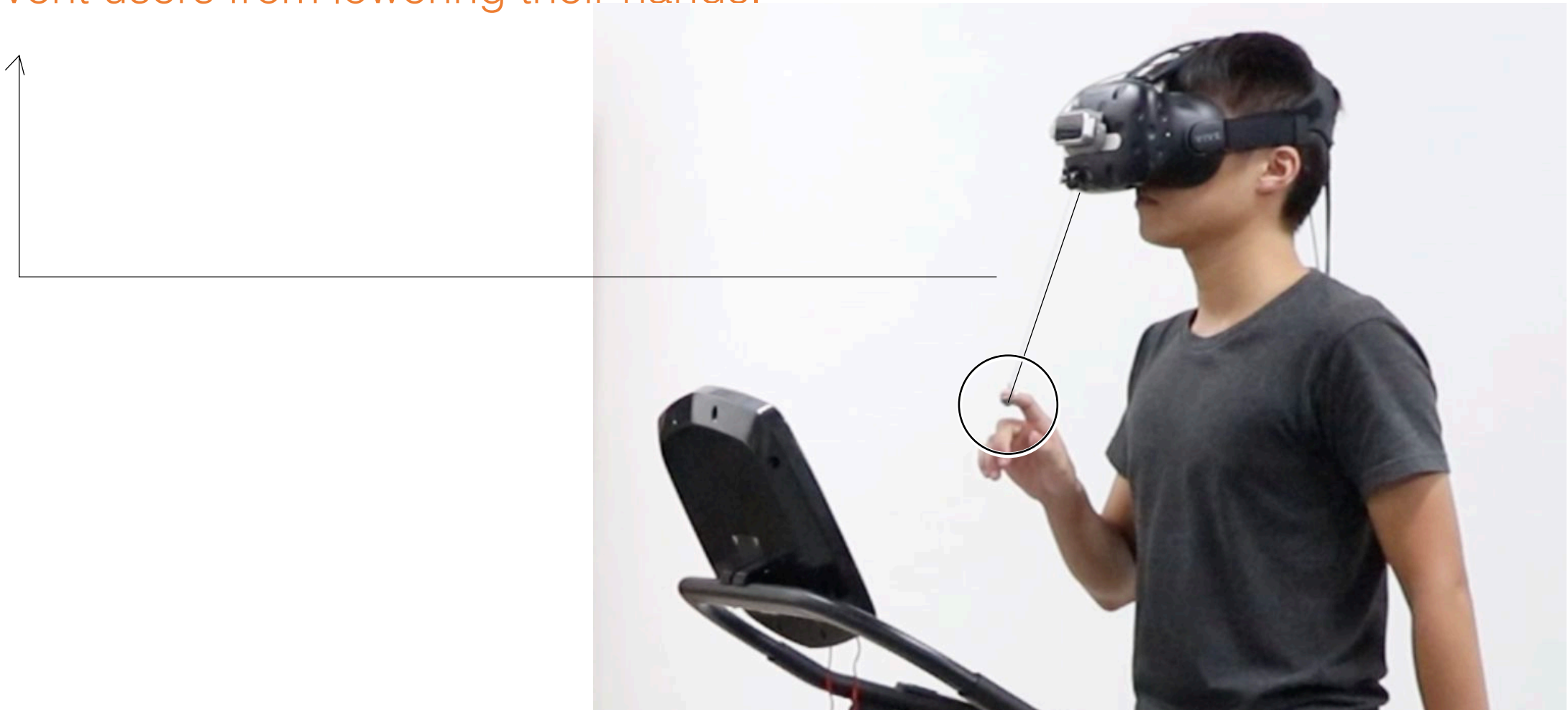
Leap Motion implementation

- the effective button size from study1 might be affected by tracking performance
- the limited field of view constrained the user's interaction space

A better finger tracker can improve the result as well as the interaction space

Ergonomic Concern

this string attached on the finger
prevent users from lowering their hands.



Ergonomic Concern

New design directly using the retractable body as the graspable interface allows to fast engage and disengage interaction.

Haptic Property of Physical Support

the perceived haptic sphere depends on the material properties of the string (flexible vs rigid string).

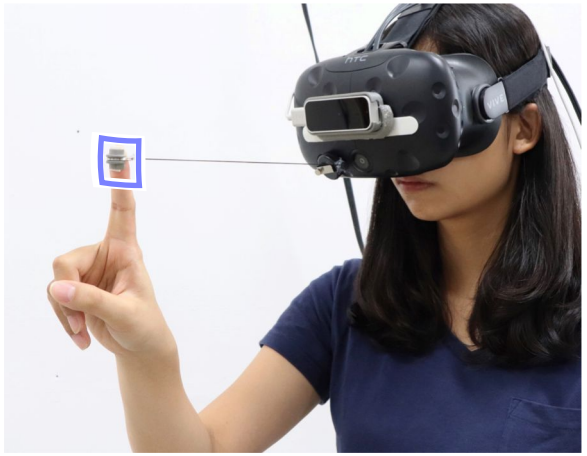
by using haptic retargeting techniques, the visual channel can compensate for inaccuracies in the haptic rendering.

L.-P. Cheng et al. Sparse Haptic Proxy (CHI'17)

Conclusion

- We proposed HapticSphere, a wearable spherical surface that allows physical support for in-air touch interaction.

- This physical support significantly improves in-air touch interaction in dynamic situations (e.g., walking).



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Physical Support to Enable Precision Touch Interaction in Mobile Mixed-Reality

Thank you for
your attention