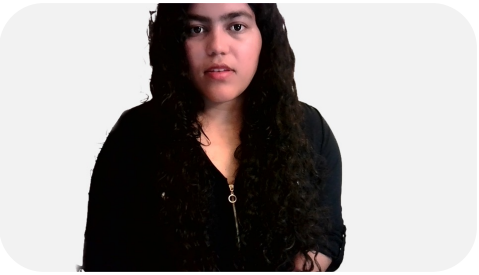
CHI 2021

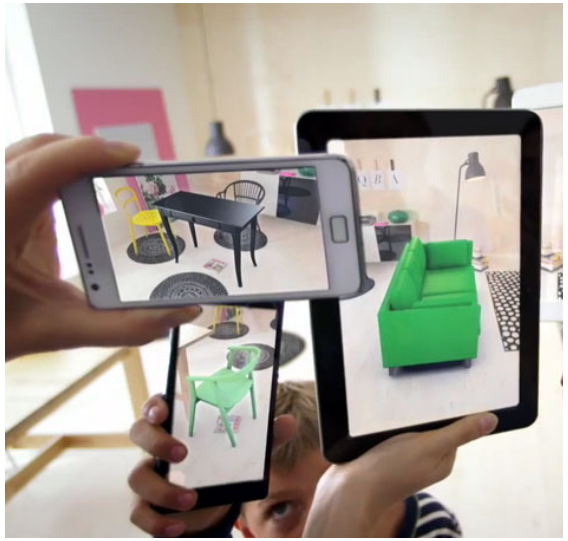
Do You Really Need to Know Where "That" Is?

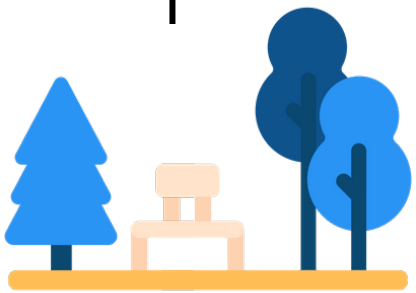
Enhancing Support for Referencing in Collaborative Mixed Reality Environments

Janet Johnson, Danilo Gasques, Tommy Sharkey, Evan Schmitz, and Nadir Weibel

janetjohnson@ucsd.edu



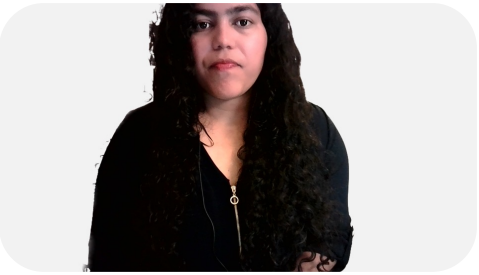




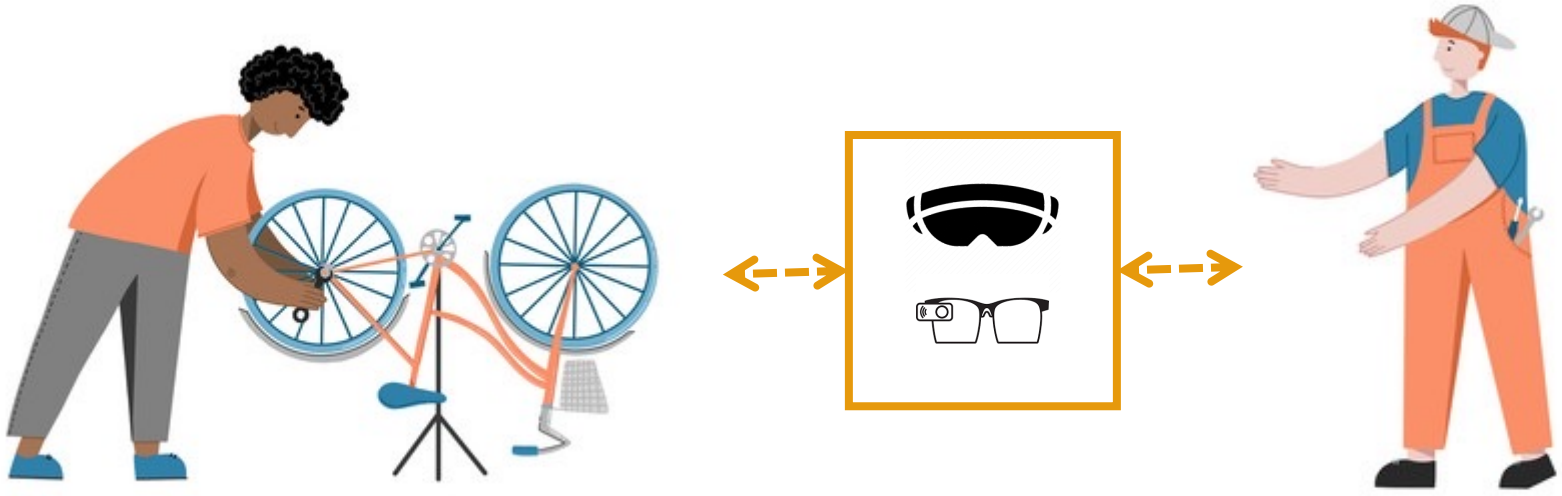
Real World

A taxonomy of mixed reality visual displays, Paul Milgram and Fumio Kishino, 1994.

Virtual World

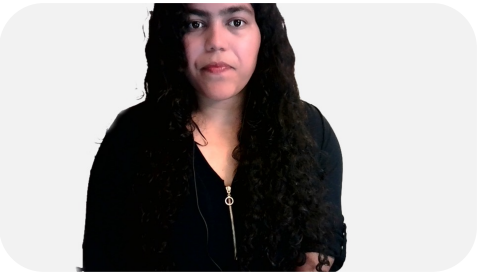


Physical Task



Local “worker” manipulates real world objects

Remote “helper” provides guidance

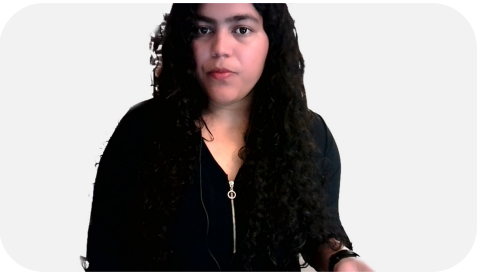


screwdriver | that's on your right

↓

Making the reference

WHAT



screwdriver | that's **on your right**

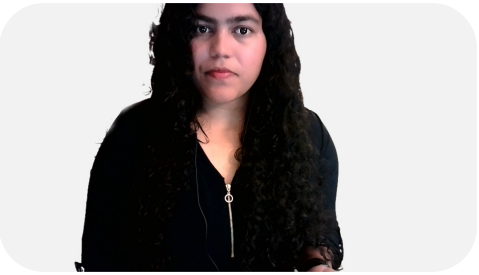
↓ ↓

Making the reference

Understanding the reference

WHAT

WHERE

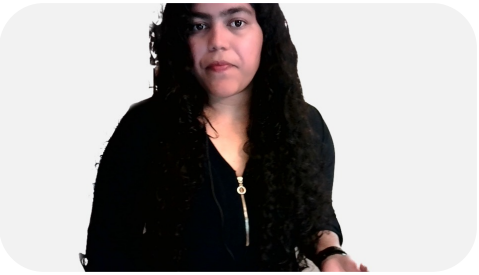


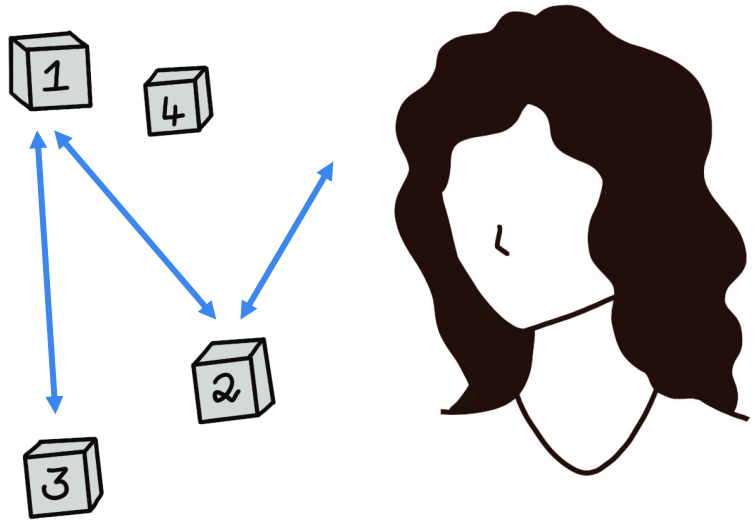
DEIXIS

that piece

Making the reference — **WHAT**

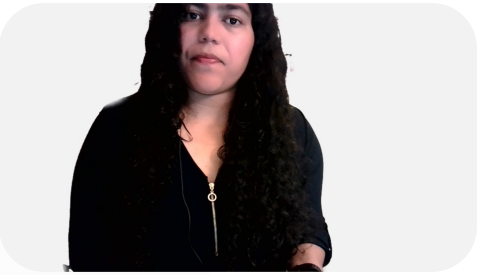
Understanding the reference — **WHERE**

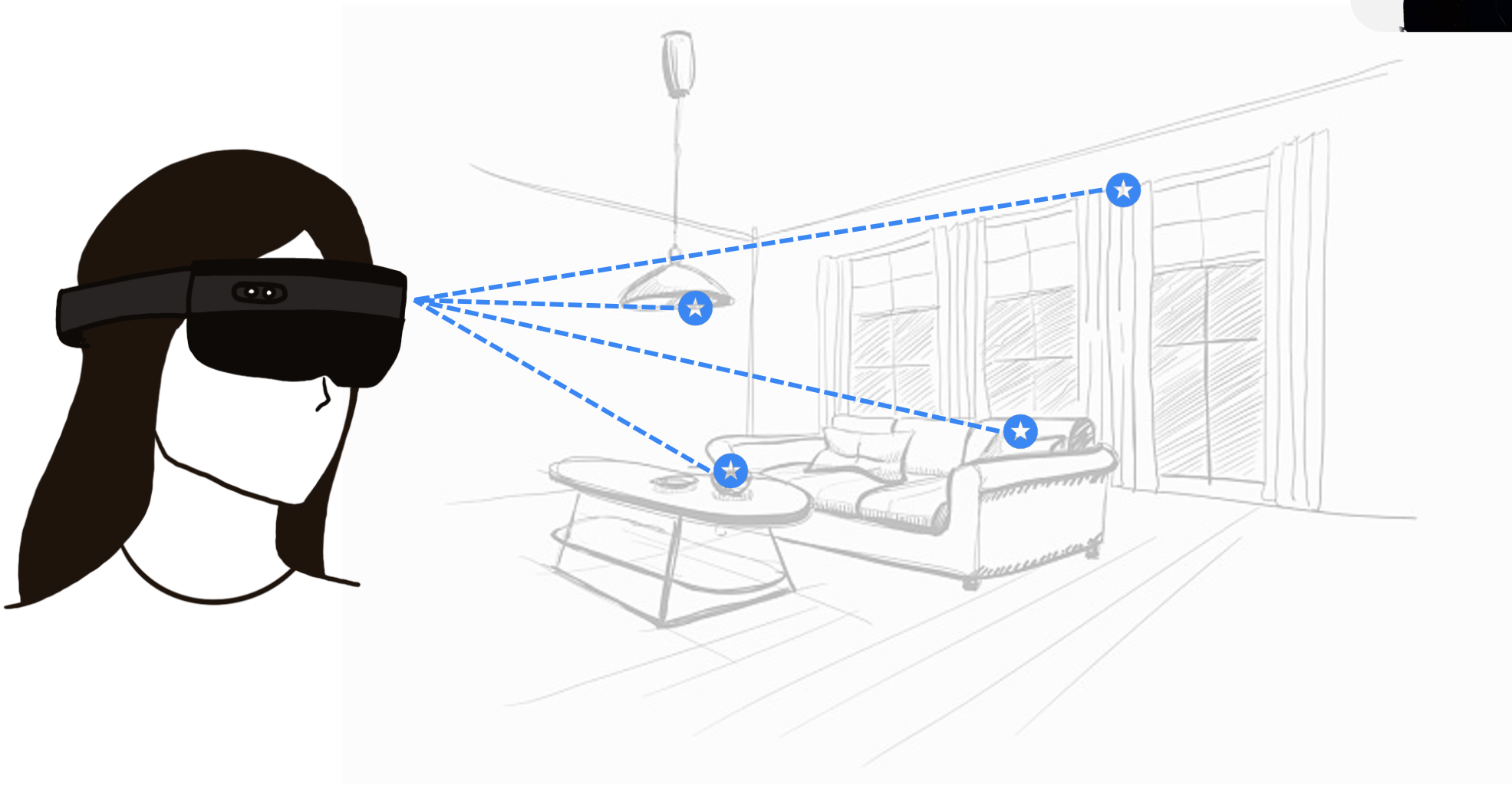


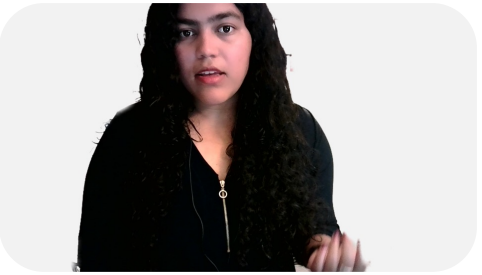


Spatial information or an awareness of spatial relationships in the task space is fundamental to the helper's ability to direct attention to an object.

Mixed Reality is inherently aware of the environment it is in.



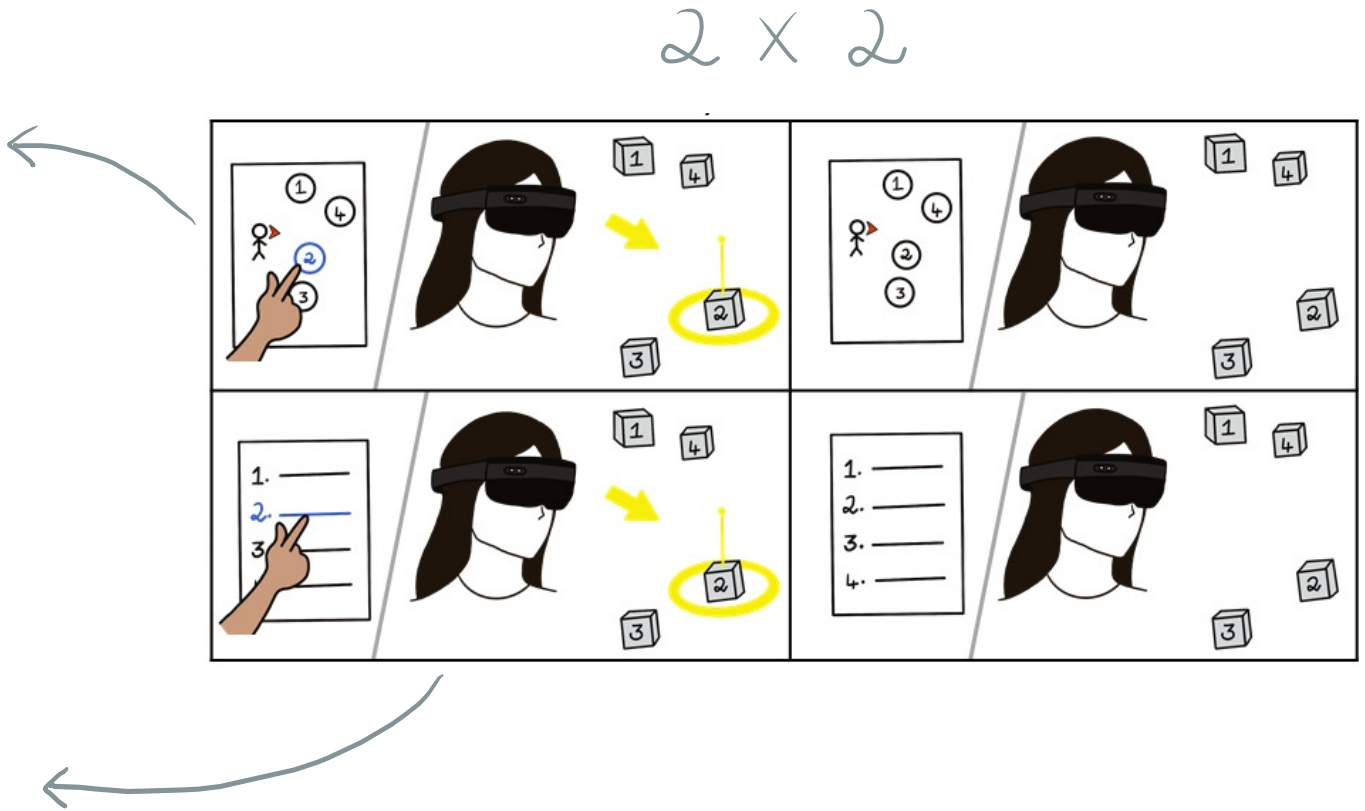




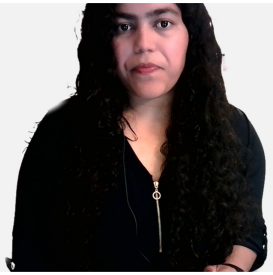
Opportunities Mixed Reality presents to make referencing easier:

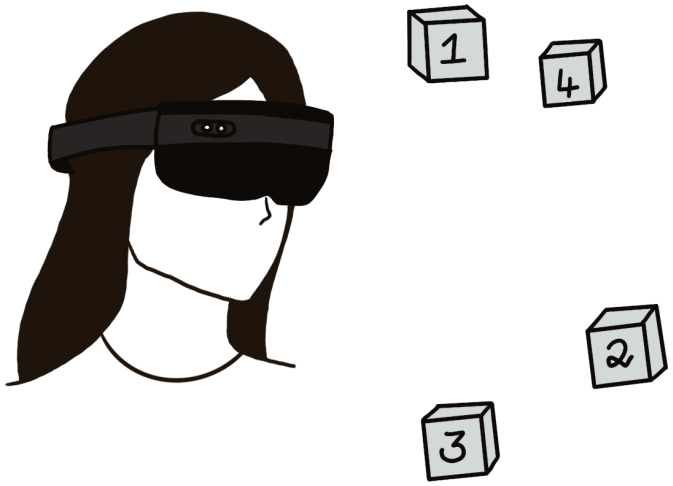
1. Explicitly Providing Helpers with Spatial Information

2. Automatically Guiding Workers to Referenced Objects

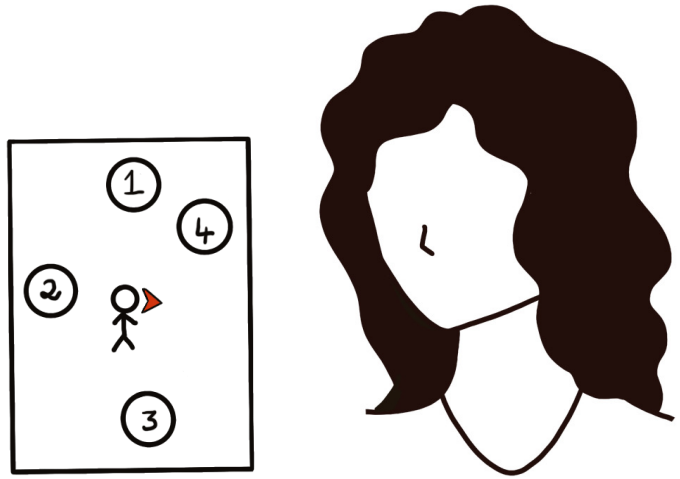


1 Explicitly Providing Helpers with Spatial Information



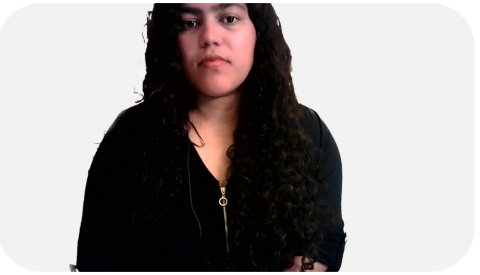


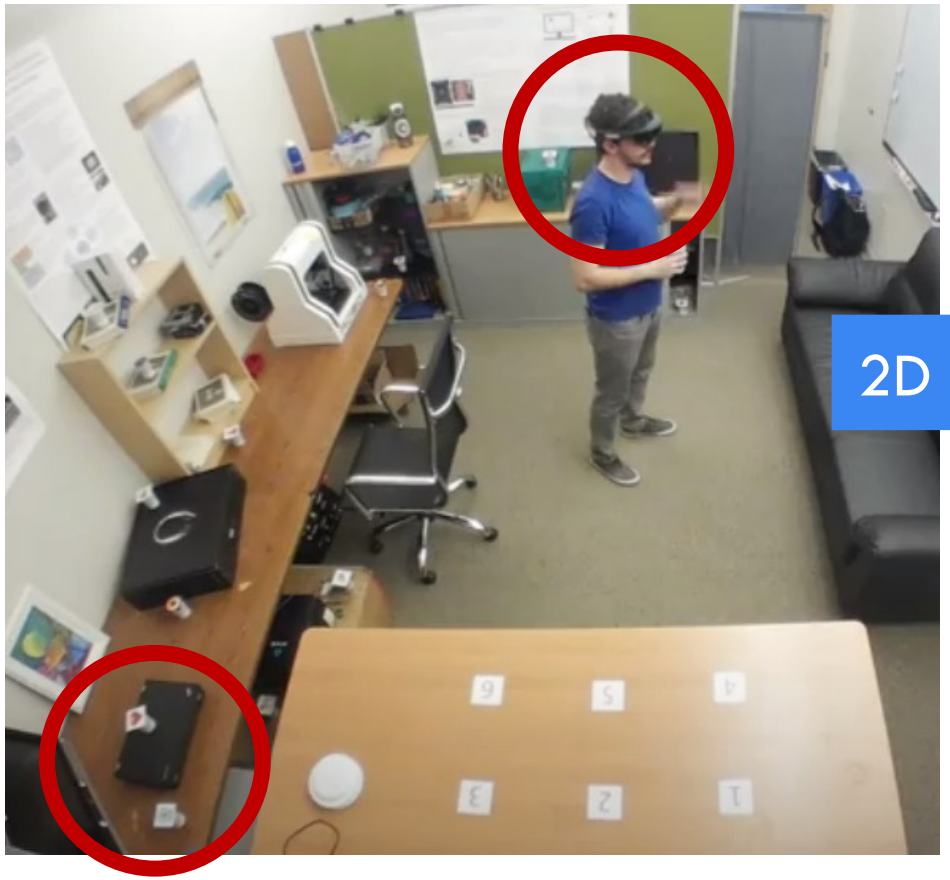
Local “worker”



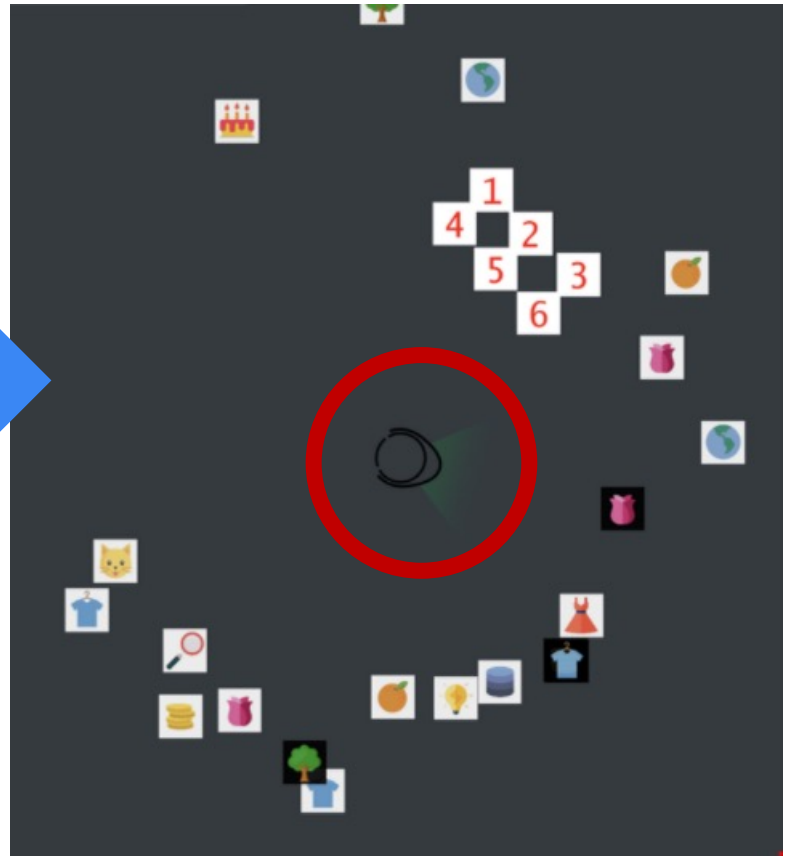
Remote “helper”

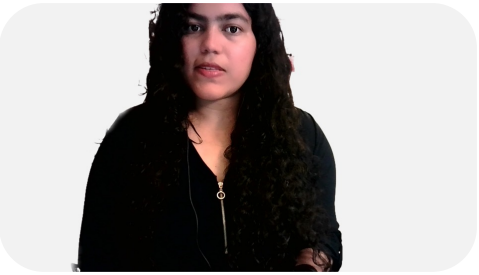
1 Explicitly Providing Helpers with Spatial Information

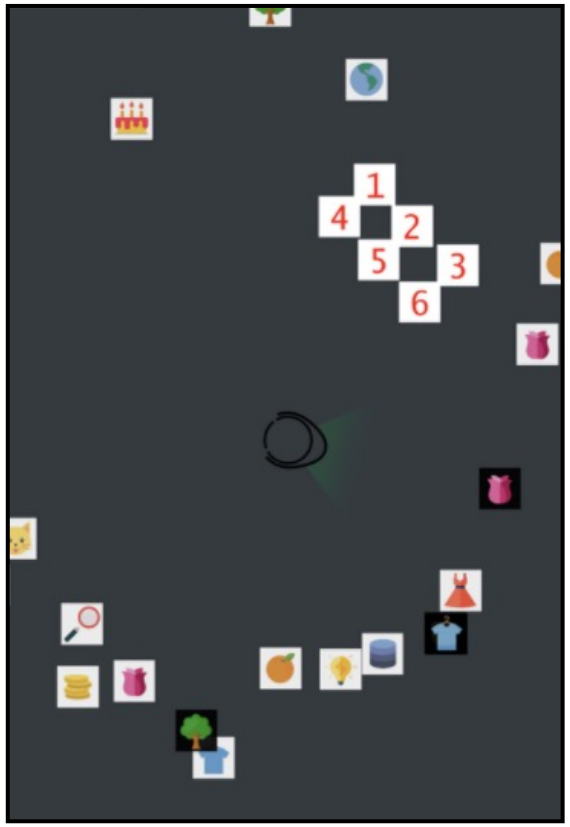




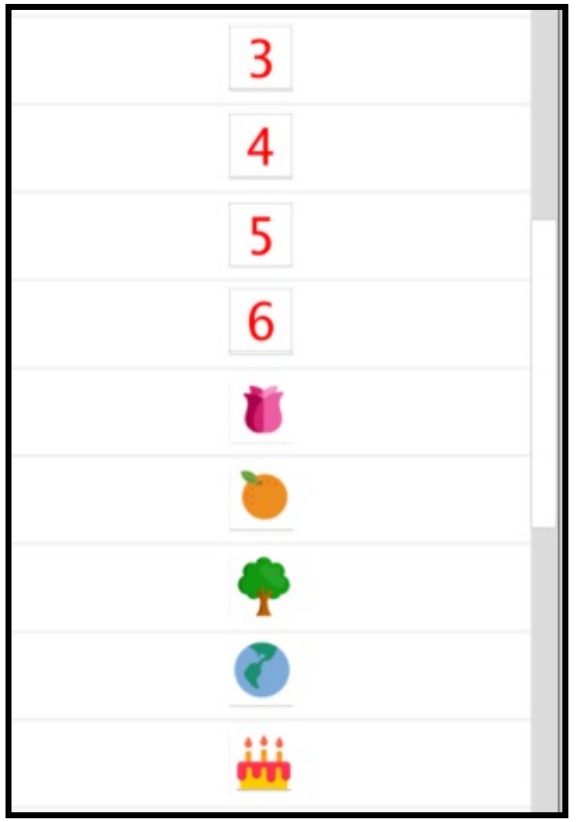
2D Map



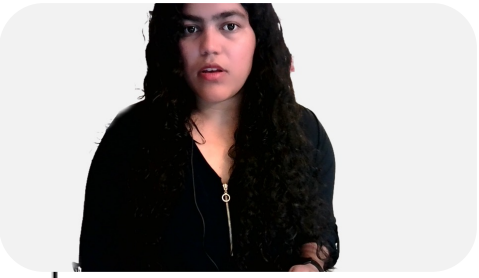


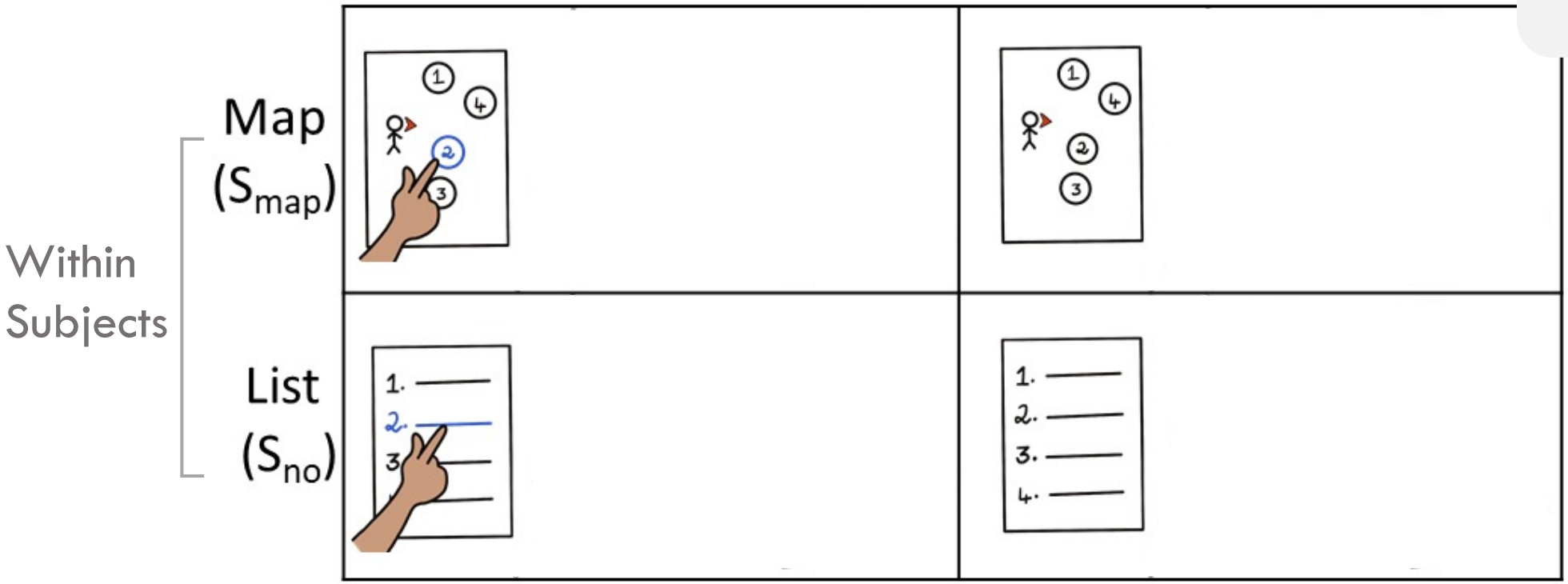


With Spatial Information



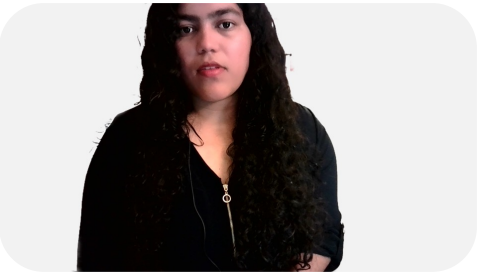
Without Spatial Information

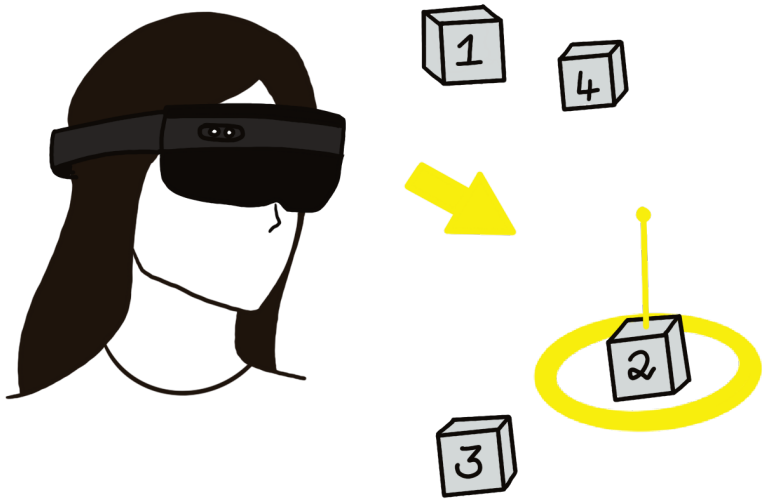




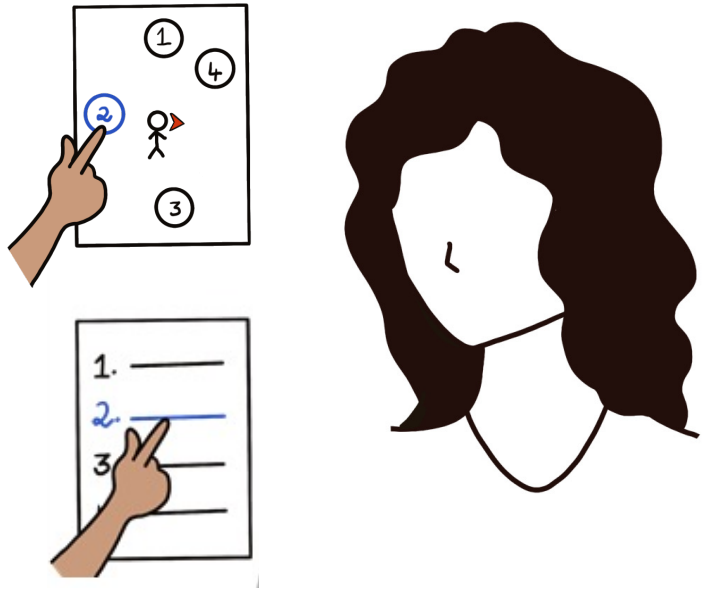
RQ1 Does explicitly representing relevant spatial information provide collaborators with enough information to support referencing?

2 Automatically Guiding Workers to Referenced Objects



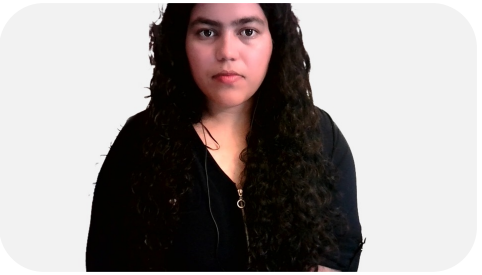


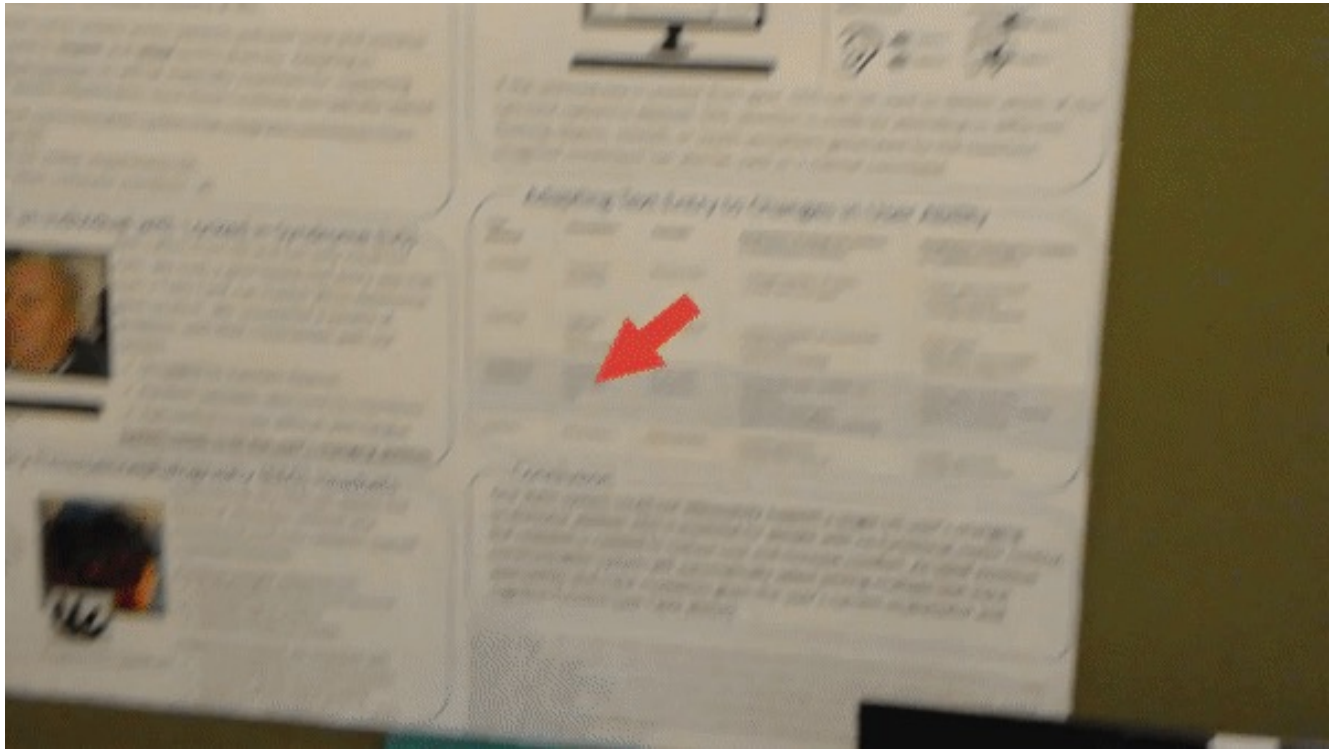
Local “worker”



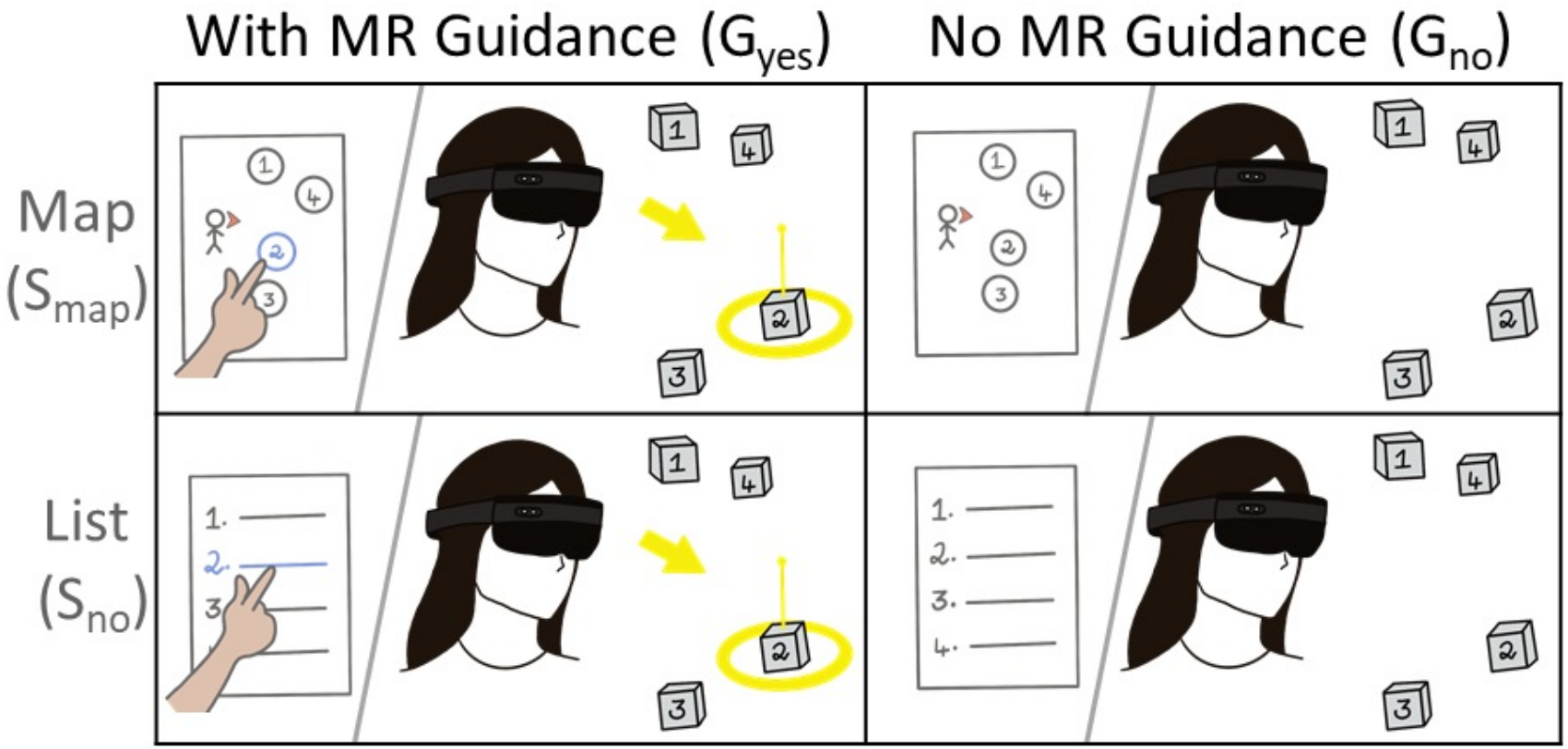
Remote “helper”

2 Automatically Guiding Workers to Referenced Objects



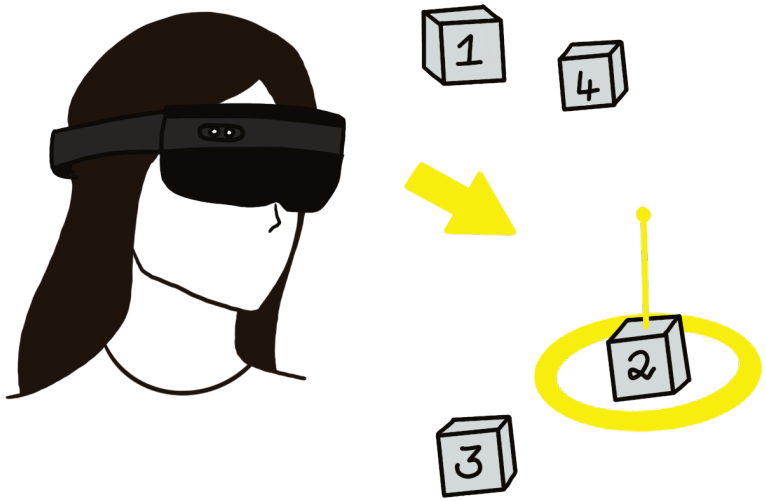


Between Subjects



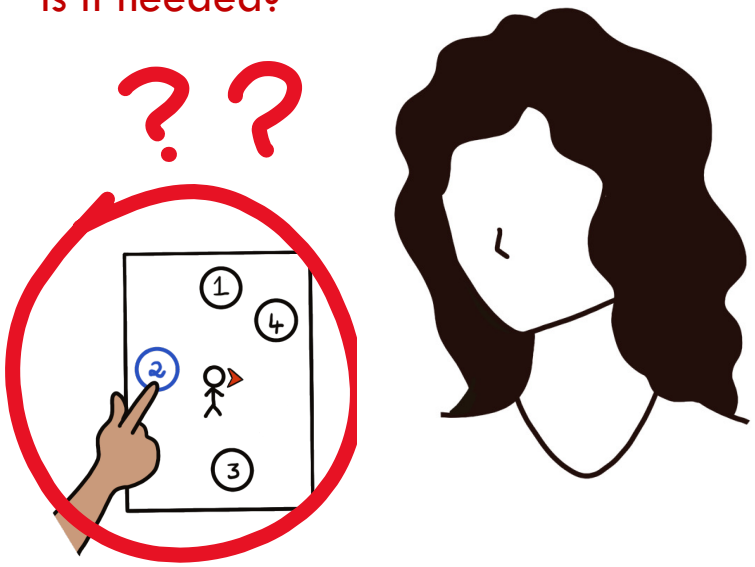
RQ2 Does automatic visual guidance to objects enhance task performance and reduce the overall effort required for remote guidance?

Do helpers still need spatial information in the presence of automatic MR guidance?

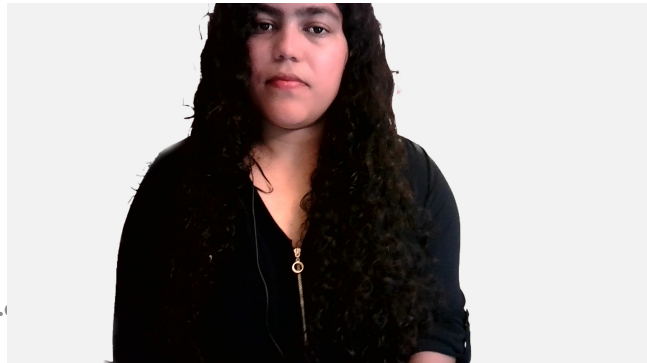


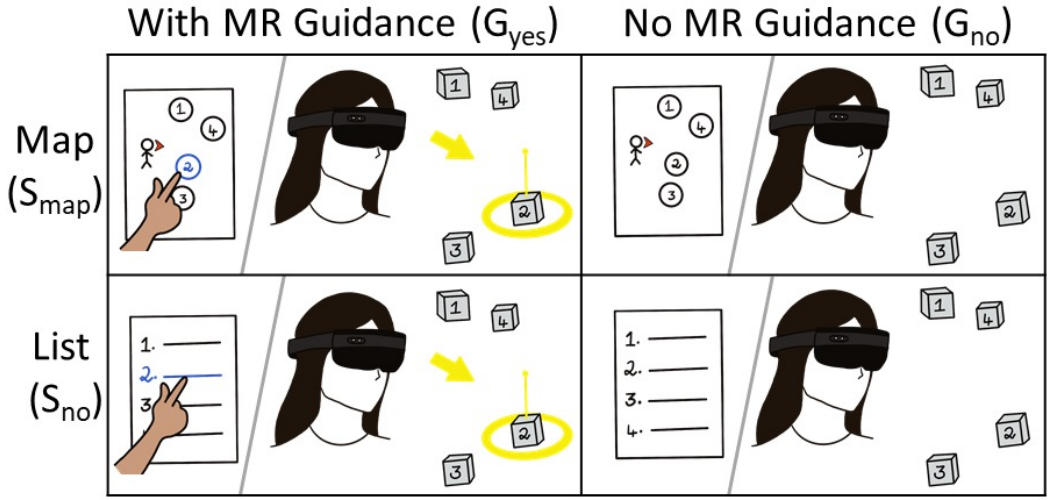
Local “worker”

Is it needed?



Remote

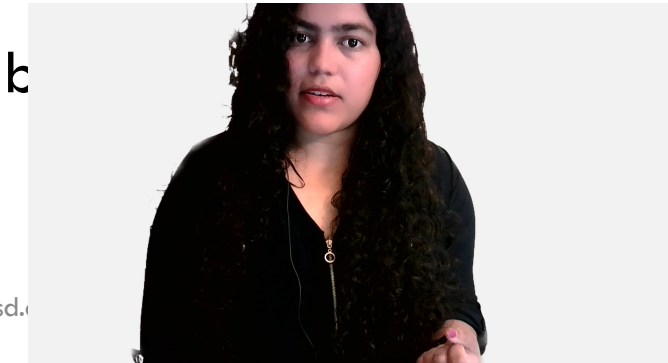




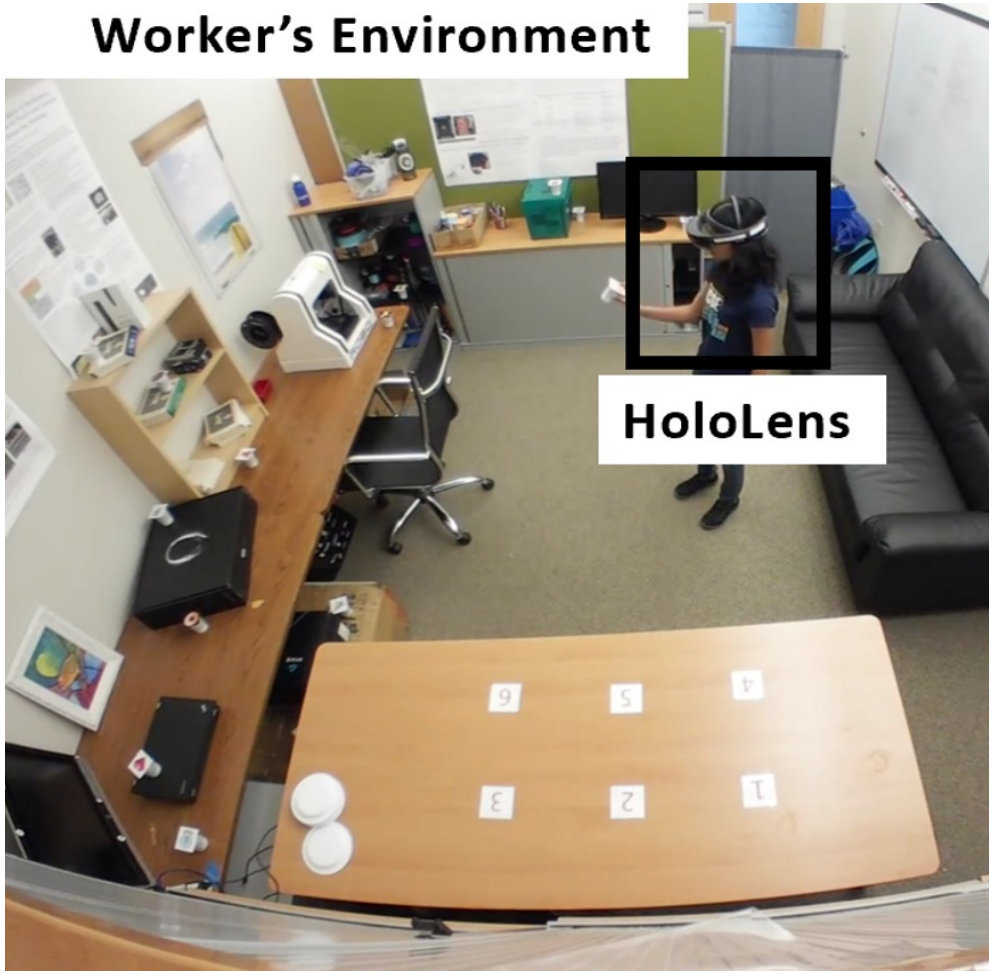
RQ1 Does explicitly representing relevant spatial information provide collaborators with enough information to support referencing?

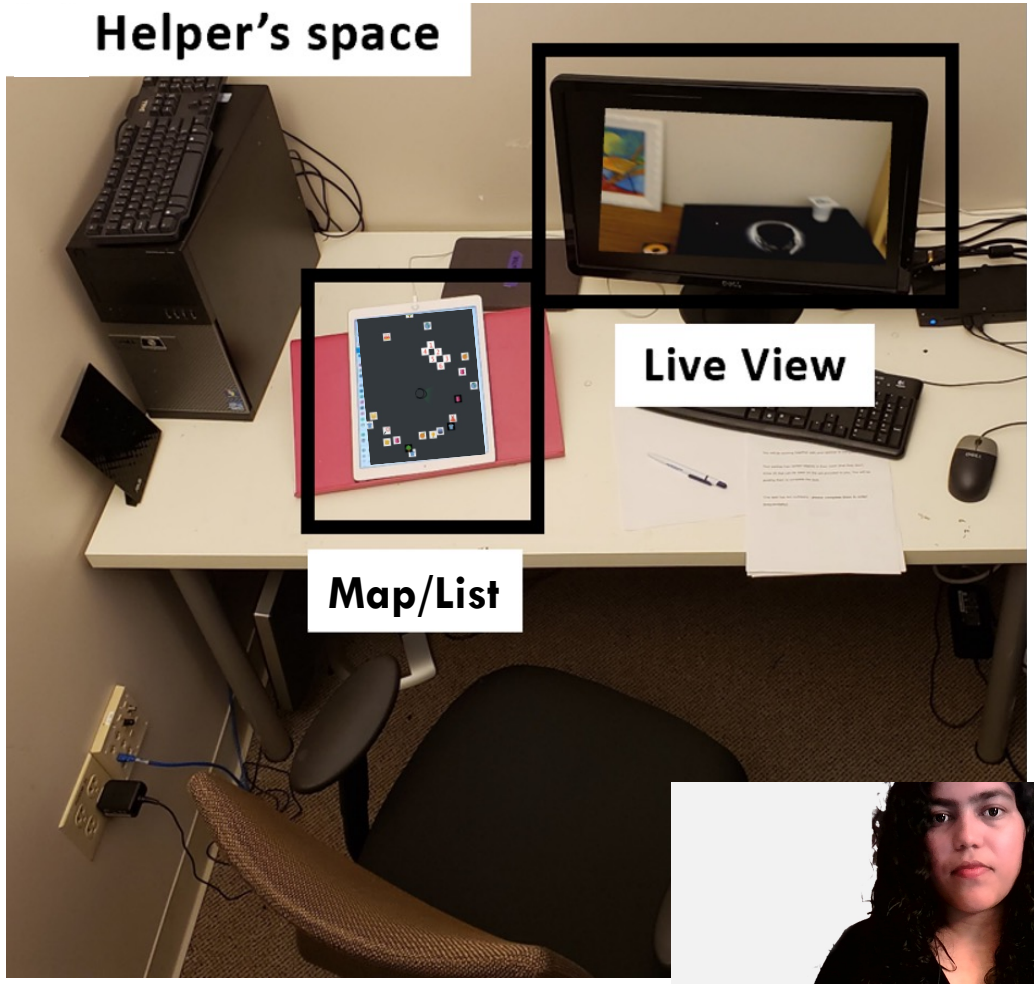
RQ2 Does automatic visual guidance to objects enhance task performance and reduce the overall effort required for remote guidance?

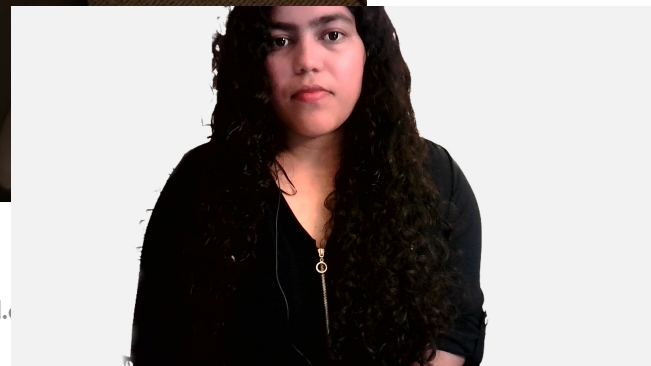
RQ3 How does the presence of MR guidance impact collab
for spatial information?



40 Participants (20 dyads) performed a simple task



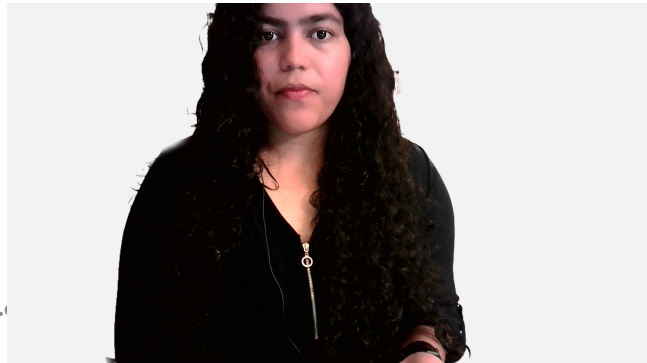




RQ1 Explicitly representing relevant **spatial information** provides collaborators with enough information to support referencing

Helpers **task load decreases** in the presence of explicit spatial information

Helpers use **more references** and provide richer guidance



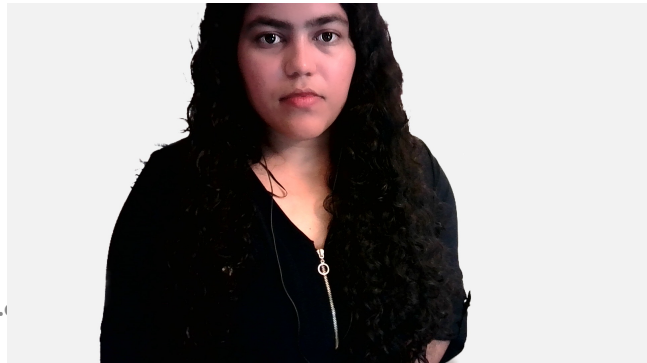
RQ1 Explicitly representing relevant **spatial information** provides collaborators with enough information to support referencing

Helpers **task load decreases** in the presence of explicit spatial information

Helpers use **more references** and provide richer guidance

It's to your right

Helpers need **less effort** to use spatial deixis



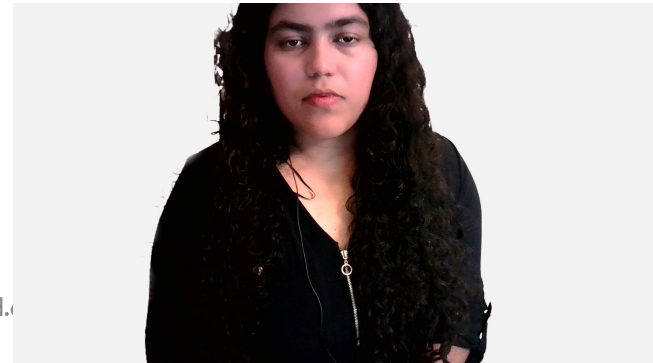
RQ2

MR Guidance enhances task performance and reduces the overall effort required for remote guidance.

Reduces task load for both helpers and workers

Increased task performance and communication efficiency.

Significantly **increased the use of deictic pronouns**



RQ2 **MR Guidance** enhances task performance and reduces the overall effort required for remote guidance.

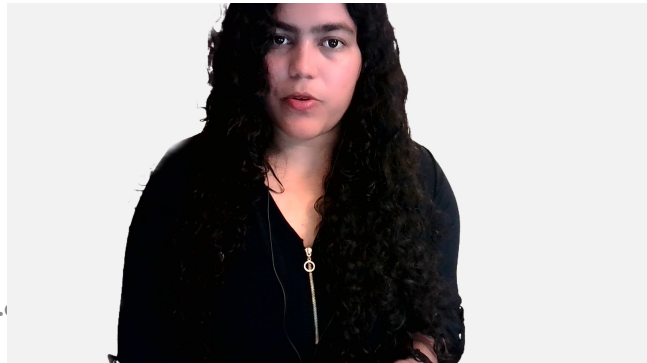
Reduces task load for both helpers and workers

Increased task performance and communication efficiency.

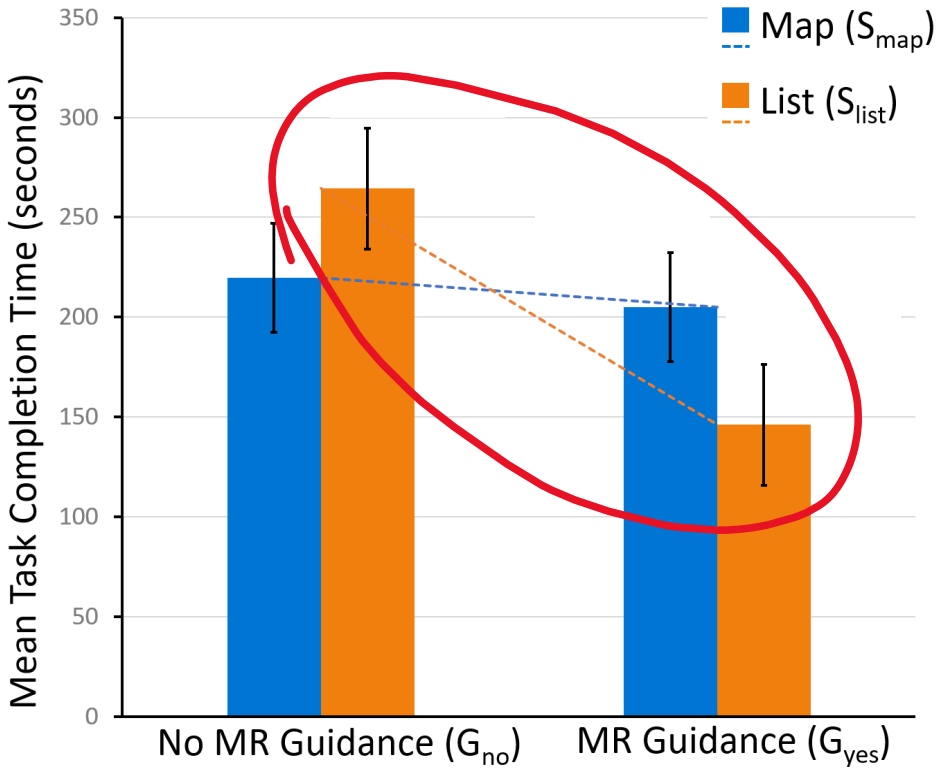
Significantly **increased the use of deictic pronouns**

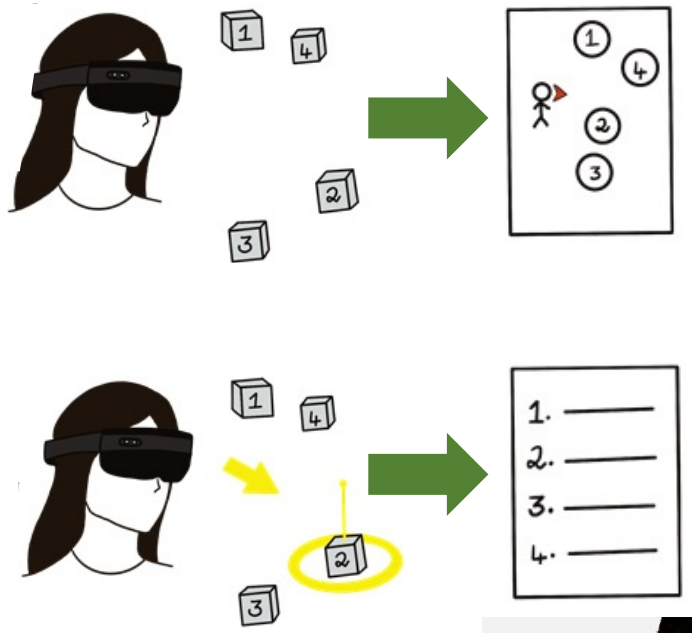
"the arrows were able to guide [the worker] perfectly, [and the helper] could focus on finding the next object" [H8].

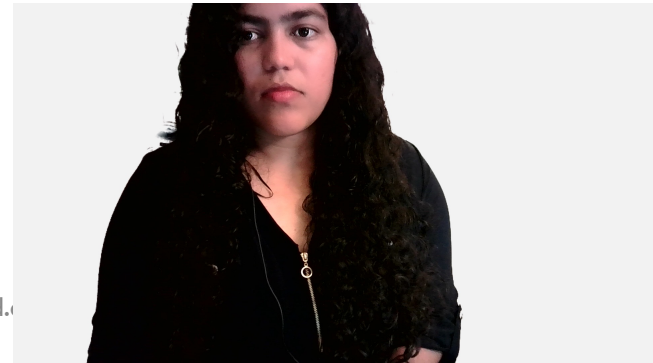
It allows for an alternate form of acknowledgement and task parallelization.



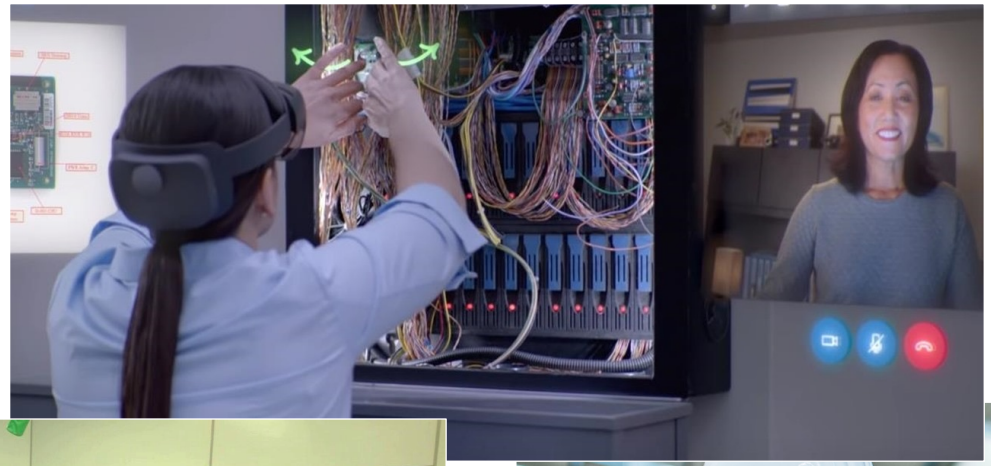
RQ3 MR guidance impacted the need for spatial information – it made it superfluous

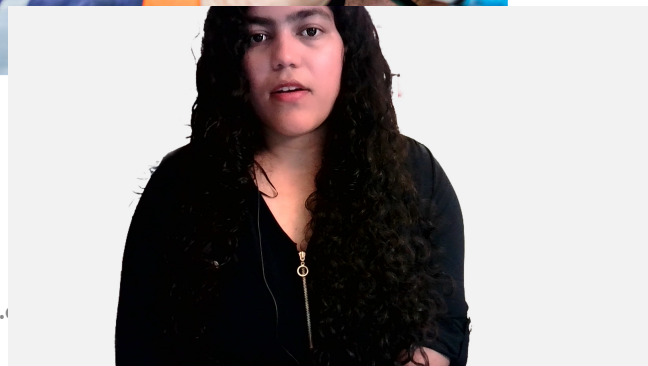




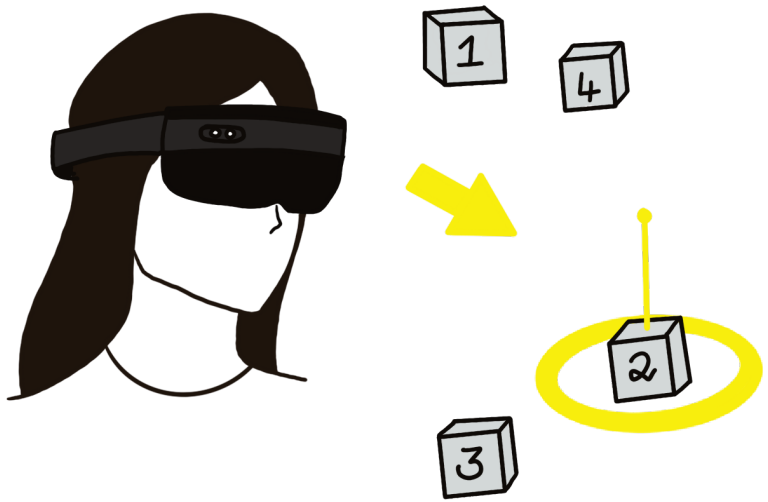


What does this mean?

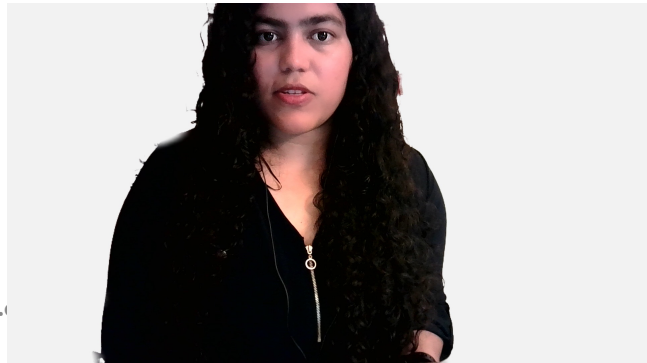




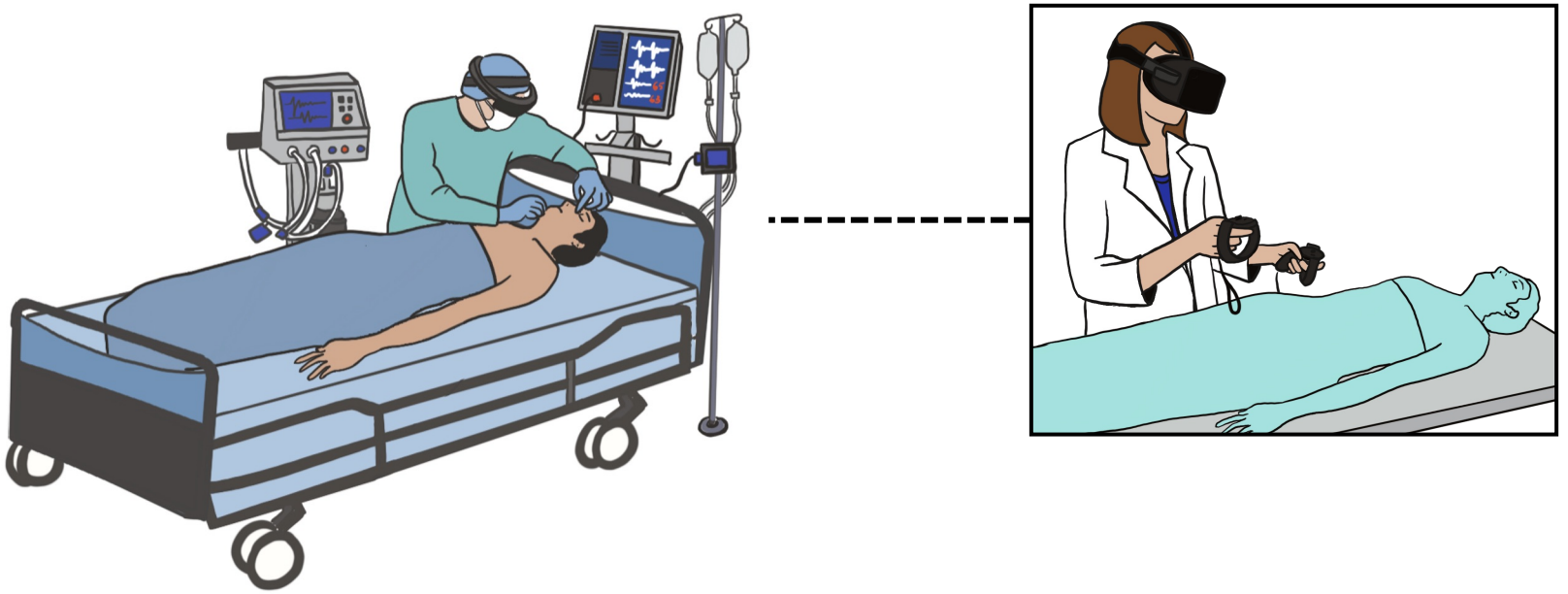
What does this mean?

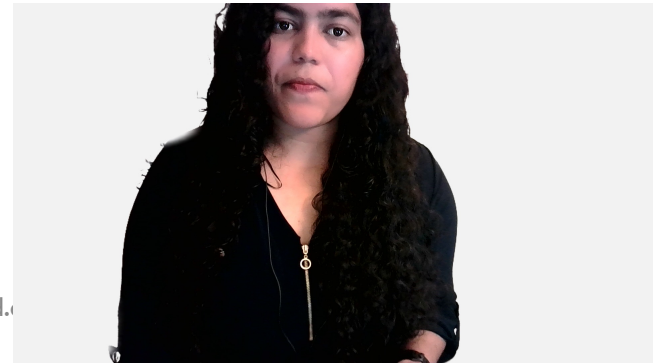


MR guidance is a way to partially ***offload*** **the referential process to the system**.

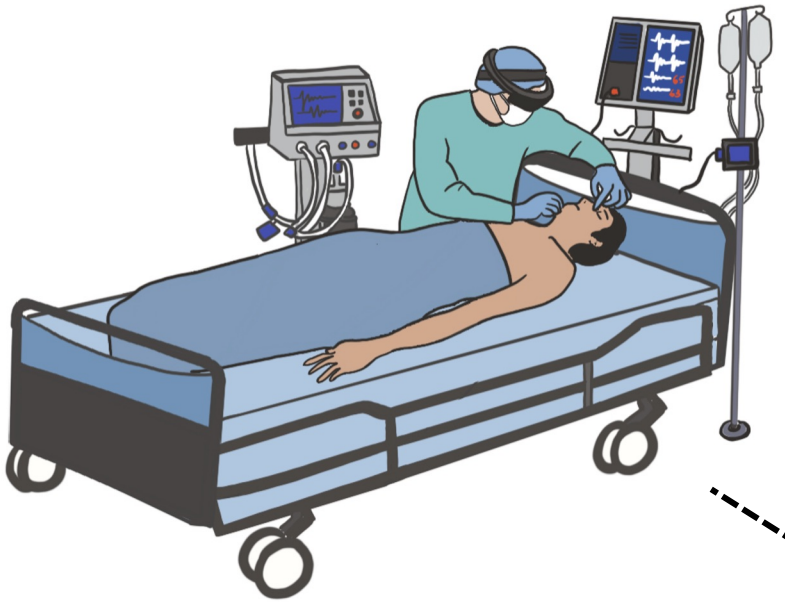


What does this mean?

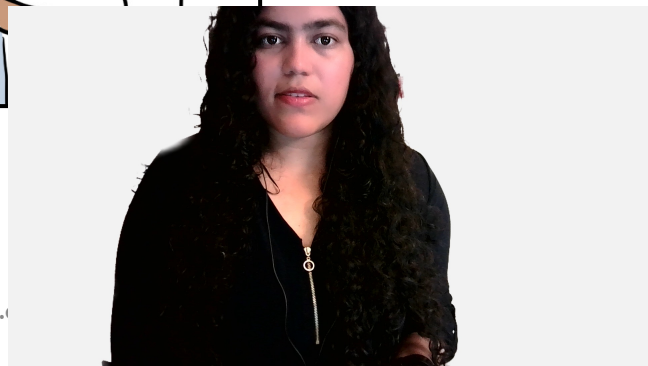




What does this mean?



Both MR guidance and alternate representations of spatial information ***make expertise more scalable and accessible***.



THANK YOU

Janet Johnson

janetjohnson@ucsd.edu

Do You Really Need to Know Where "That" Is? Enhancing Support for Referencing in Collaborative Mixed Reality Environments

Janet G Johnson
UC San Diego
La Jolla, CA, USA
janetjohnson@ucsd.edu

Danilo Gasques
UC San Diego
La Jolla, CA, USA
gasques@ucsd.edu

Tommy Sharkey
UC San Diego
La Jolla, CA, USA
tsharkey@ucsd.edu

Evan Schmitz
University of Washington
Seattle, WA, USA
ewschmit@uw.edu

Nadir Weibel
UC San Diego
La Jolla, CA, USA
weibel@ucsd.edu

ABSTRACT

Mixed Reality has been shown to enhance remote guidance and is especially well-suited for physical tasks. Conversations during these tasks are heavily anchored around task objects and their spatial relationships in the real world, making referencing - the ability to refer to an object in a way that is understood by others - a crucial process that warrants explicit support in collaborative Mixed Reality systems. This paper presents a 2x2 mixed factorial experiment that explores the effects of providing spatial information and system-generated guidance to task objects. It also investigates the effects of such guidance on the remote collaborator's need for spatial information. Our results show that guidance increases performance and communication efficiency while reducing the need for spatial information, especially in unfamiliar environments. Our results also demonstrate a reduced need for remote experts to be in immersive environments, making guidance more scalable, and expertise more accessible.

CCS CONCEPTS

• **Human-centered computing** → *Empirical studies in collaborative and social computing*; **Mixed / augmented reality**; *Collaborative interaction.*

KEYWORDS

1 INTRODUCTION

As expertise becomes increasingly distributed, and skilled personnel are not always available nearby, technology-mediated remote guidance is gaining traction as a significant area of interest in many domains like education, manufacturing, design, and healthcare. These domains typically involve physical tasks – like mechanical assembly, emergency repairs, or surgery – with collaborators manipulating real-world objects. When collaborators are in physically separated spaces, technology-mediated remote guidance substantially improves their ability to complete the task [38].

Given how inherently spatial physical tasks are, the immersive nature of Mixed Reality (MR) [41] – a technology that merges the real and virt
a collaborative r
where collaborat
space. This impr
ability to unders
general, MR allo
to-face collabora
collaborative int

The growth of
technology is ma
searchers in both
ing and understa