



Manuscript 📄



Videos 📺



PaperToPlace

Transforming Instruction Documents into Spatialized and Context-Aware Mixed Reality (MR) Experience



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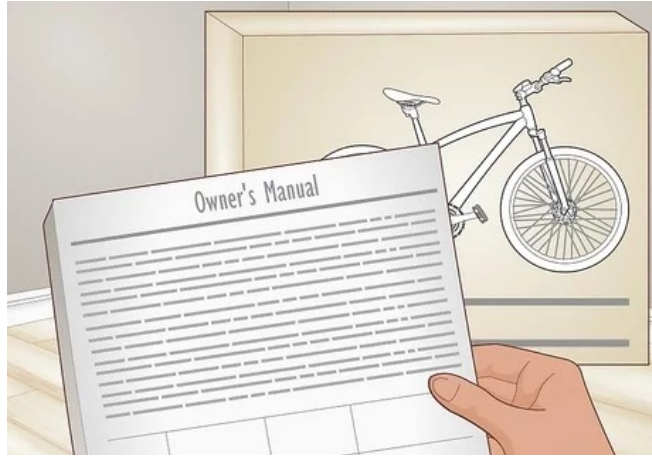
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Instruction Documents are Used in Many Tasks



Assemble Bike 🚲



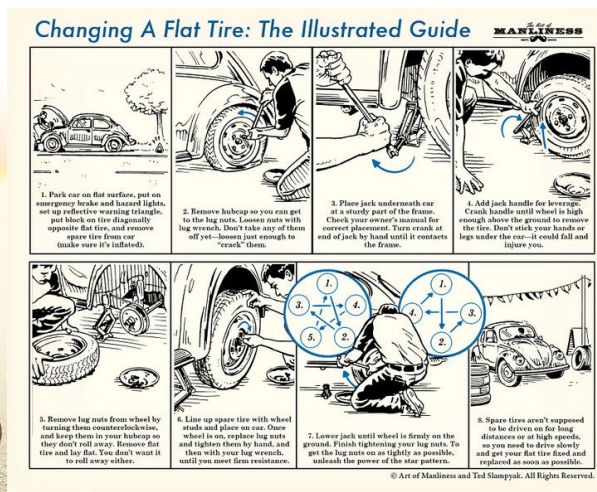
Cook New Dishes 🔍



Use Gym Equipment 💪



Change Tires 🛞



Assemble Furniture 🗄️





This is tedious! 😞



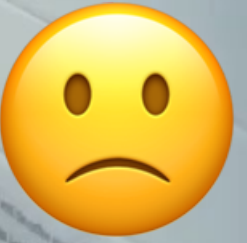
Instruction and information
are bounded by the papers!

Reading Instructions





Figuring Out Real-World Objects



Performing Tasks while Repeatedly Referring to the Instructions



Bring Instruction Documents into MR



Dynamic 365 Remote Assistant by HoloLens '19



CAPturAR, UIST '20



ProcessAR, DIS '21

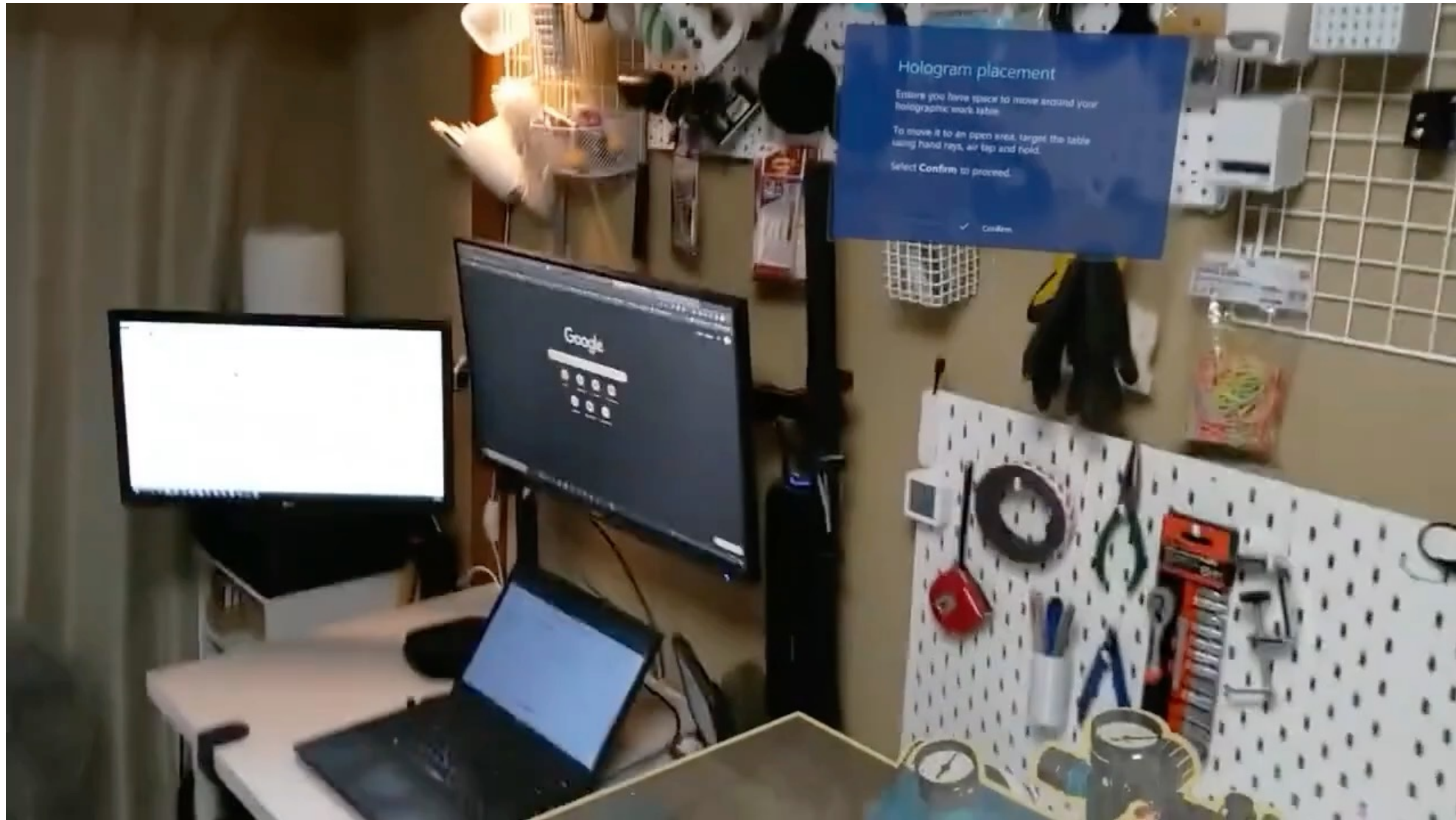
Problems

- Not capable of reusing existing paper instructions;

Problems

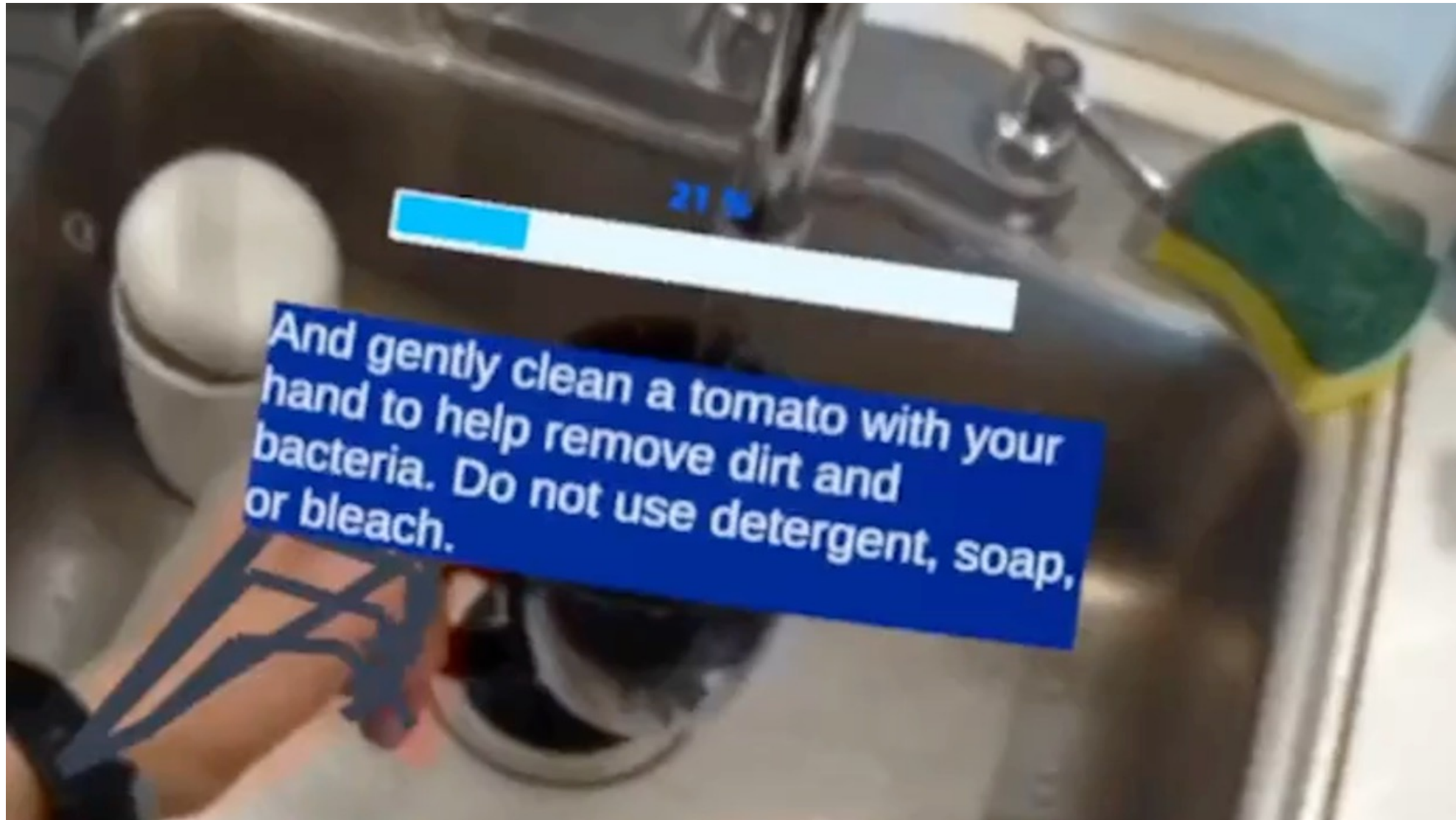
- Not capable of reusing existing paper instructions;
- Cannot dynamically adapt to the change the real-world environment;

Instructions might be too far to be read ...



Example from Dynamic 365 Remote Assistant by HoloLens '19

... or too close to occlude the real-world tasks



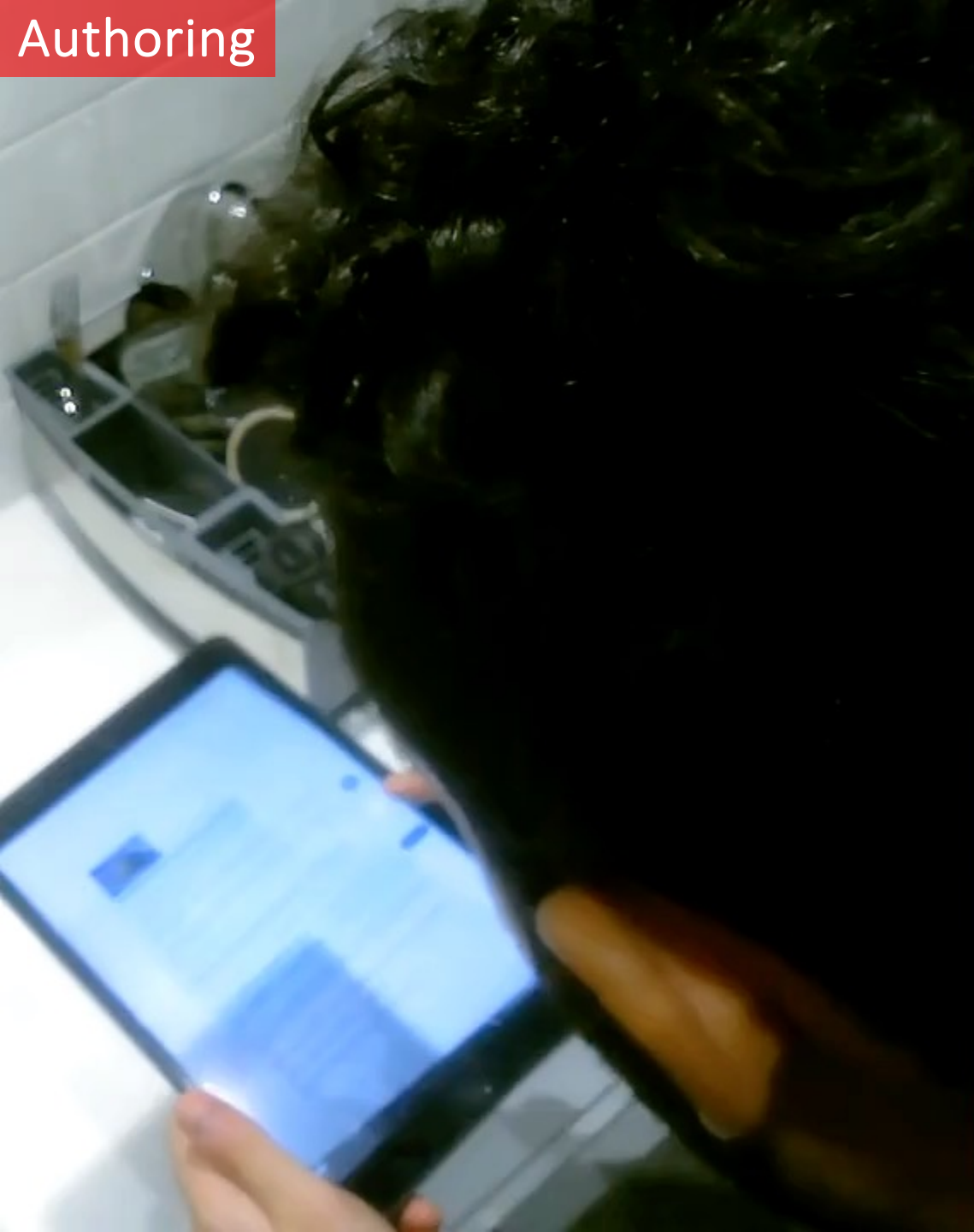
Example from PaperToPlace, UIST '23, Supported By Meta Quest Pro

Let's bring paper instructions to physical place!

PaperToPlace

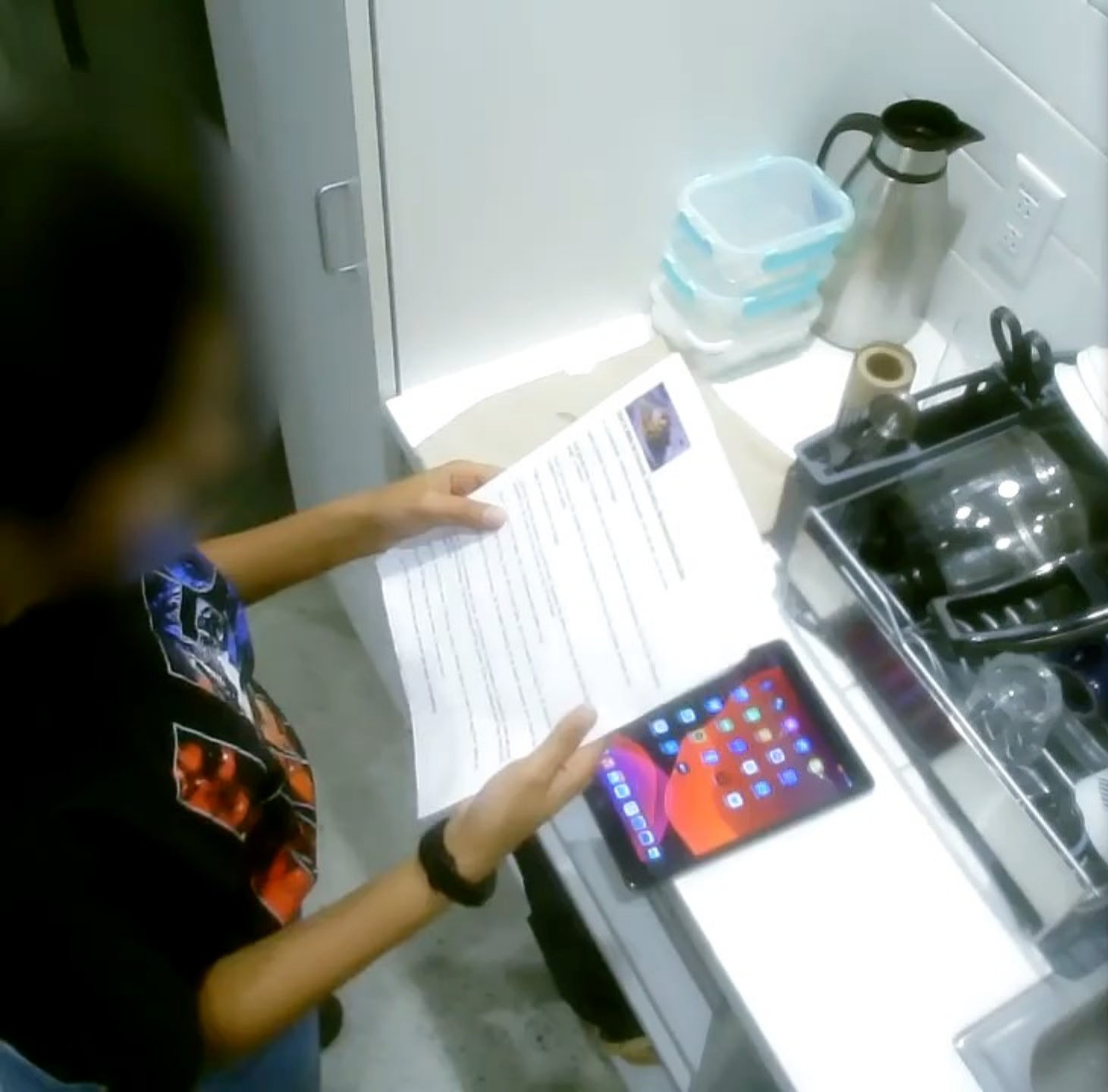
Transforming Instruction Documents into
Spatialized and Context-Aware MR Experience

Authoring

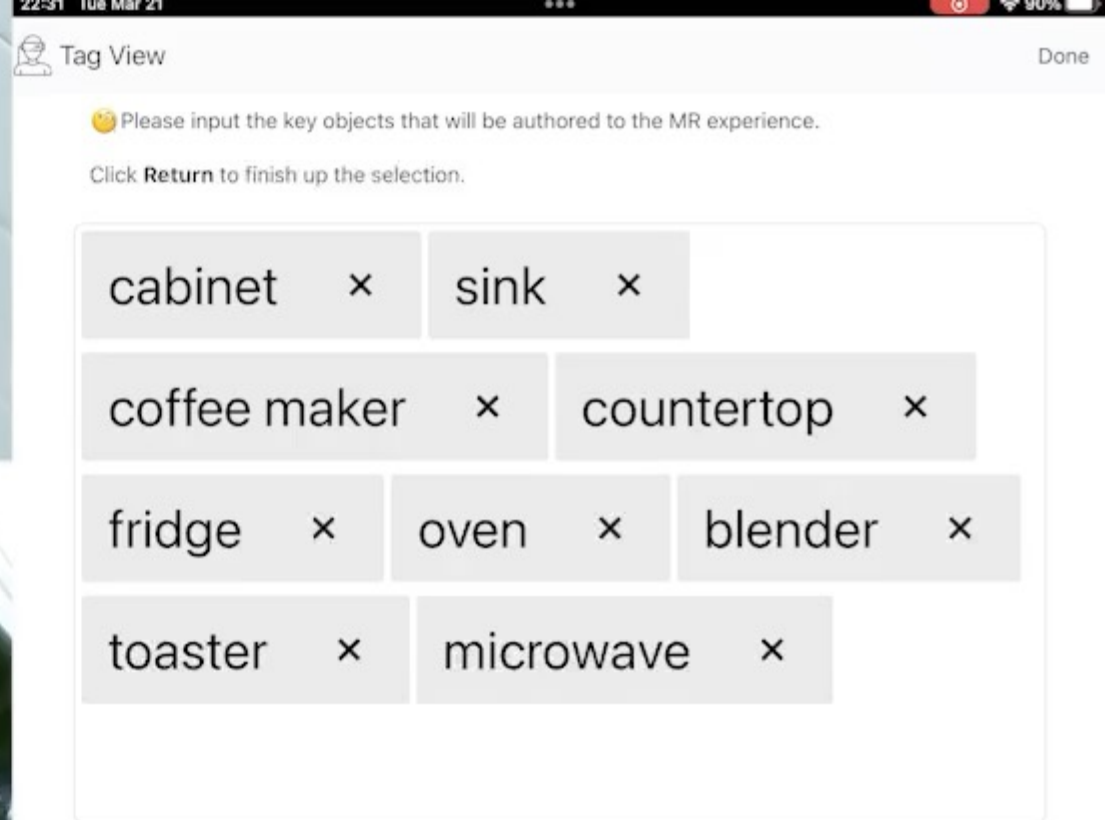


Consumption





Waiting app to
be launched ...





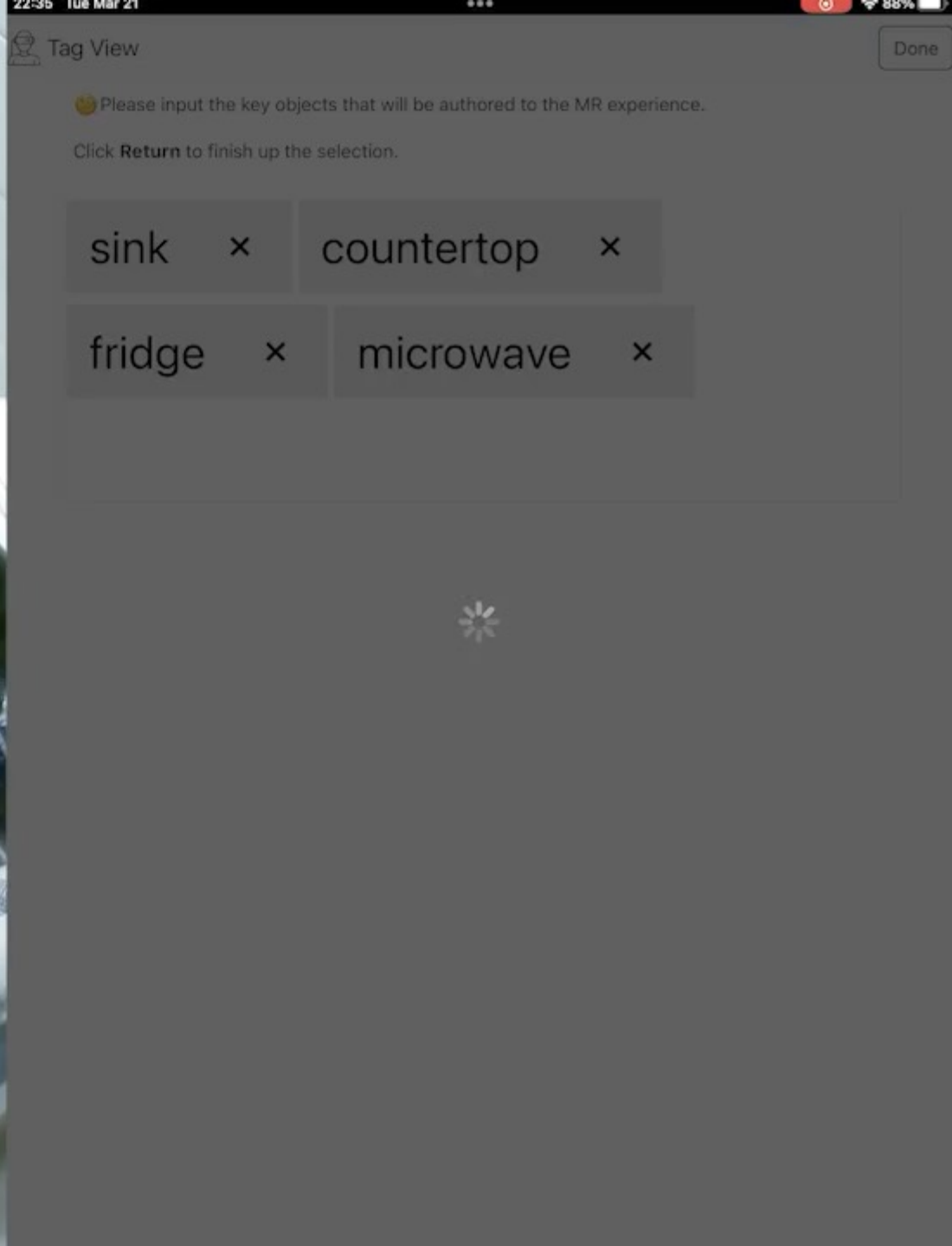
22:32 Tue Mar 21 90%

Steps Overview

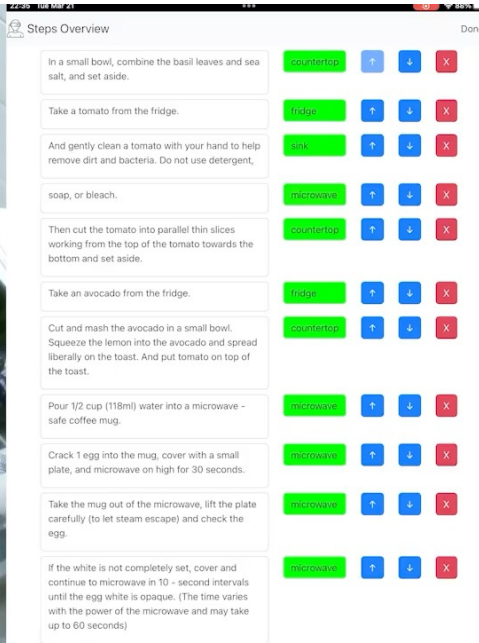
Done

- In a small bowl, combine the basil leaves and sea salt, and set aside. edit ↑ ↓ X
- Take a tomato from the fridge. edit ↑ ↓ X
- And gently clean a tomato with your hand to help remove dirt and bacteria. Do not use detergent, soap, or bleach. edit ↑ ↓ X
- Then cut the tomato into parallel thin slices working from the top of the tomato towards the bottom and set aside. edit ↑ ↓ X
- Take an avocado from the fridge. edit ↑ ↓ X
- Cut and mash the avocado in a small bowl. Squeeze the lemon into the avocado and spread liberally on the toast. And put tomato on top of the toast. edit ↑ ↓ X
- Pour 1/2 cup (118ml) water into a microwave - safe coffee mug. edit ↑ ↓ X
- Crack 1 egg into the mug, cover with a small plate, and microwave on high for 30 seconds. edit ↑ ↓ X
- Take the mug out of the microwave, lift the plate carefully (to let steam escape) and check the egg. edit ↑ ↓ X
- If the white is not completely set, cover and continue to microwave in 10 - second intervals until the egg white is opaque. (The time varies with the power of the microwave and may take up to 60 seconds) edit ↑ ↓ X
- Carefully pour off the water in the mug, using a edit ↑ ↓ X

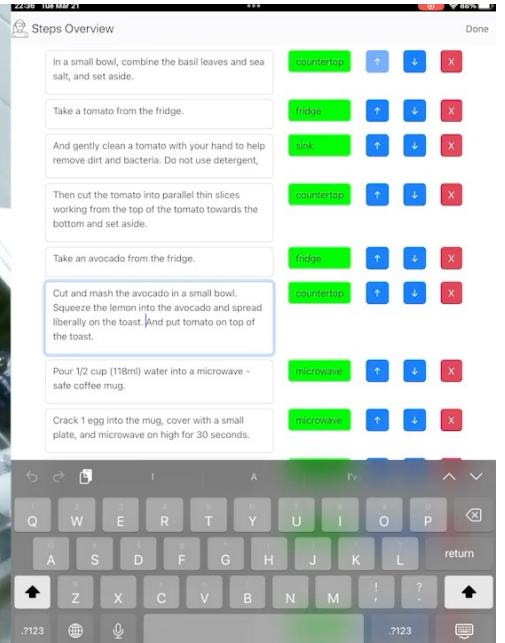
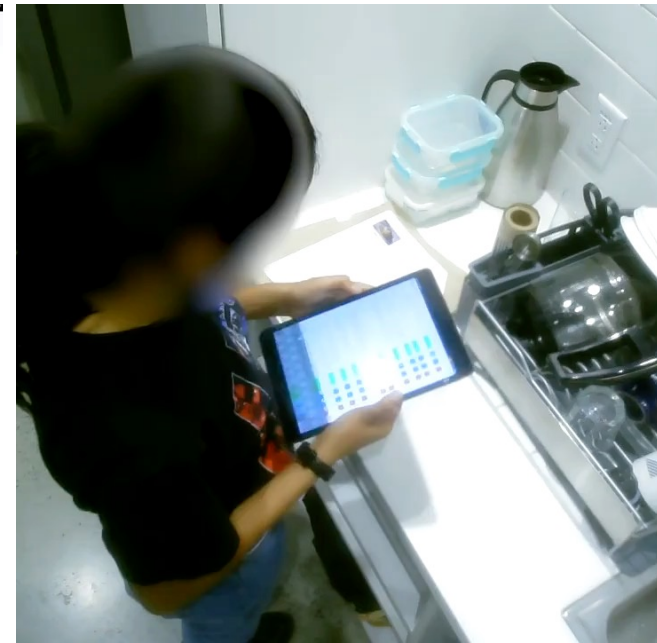
A Machine Learning Enhanced Approach



Post-Edit the Authored Instruction Step



Delete Redundant Instruction Step



Split a Long Instruction Step into Two Shorter Steps

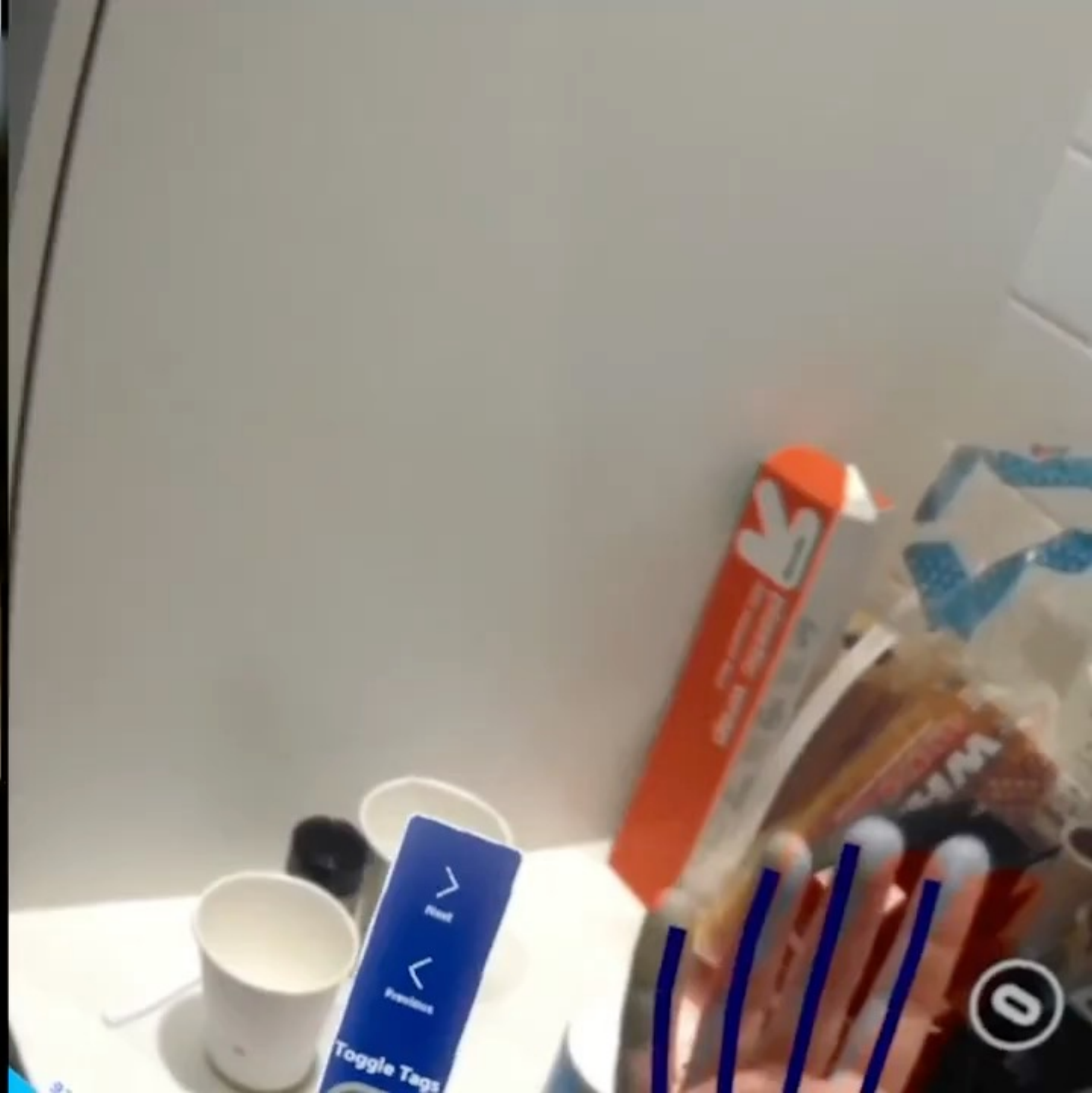


Steps Overview

Done

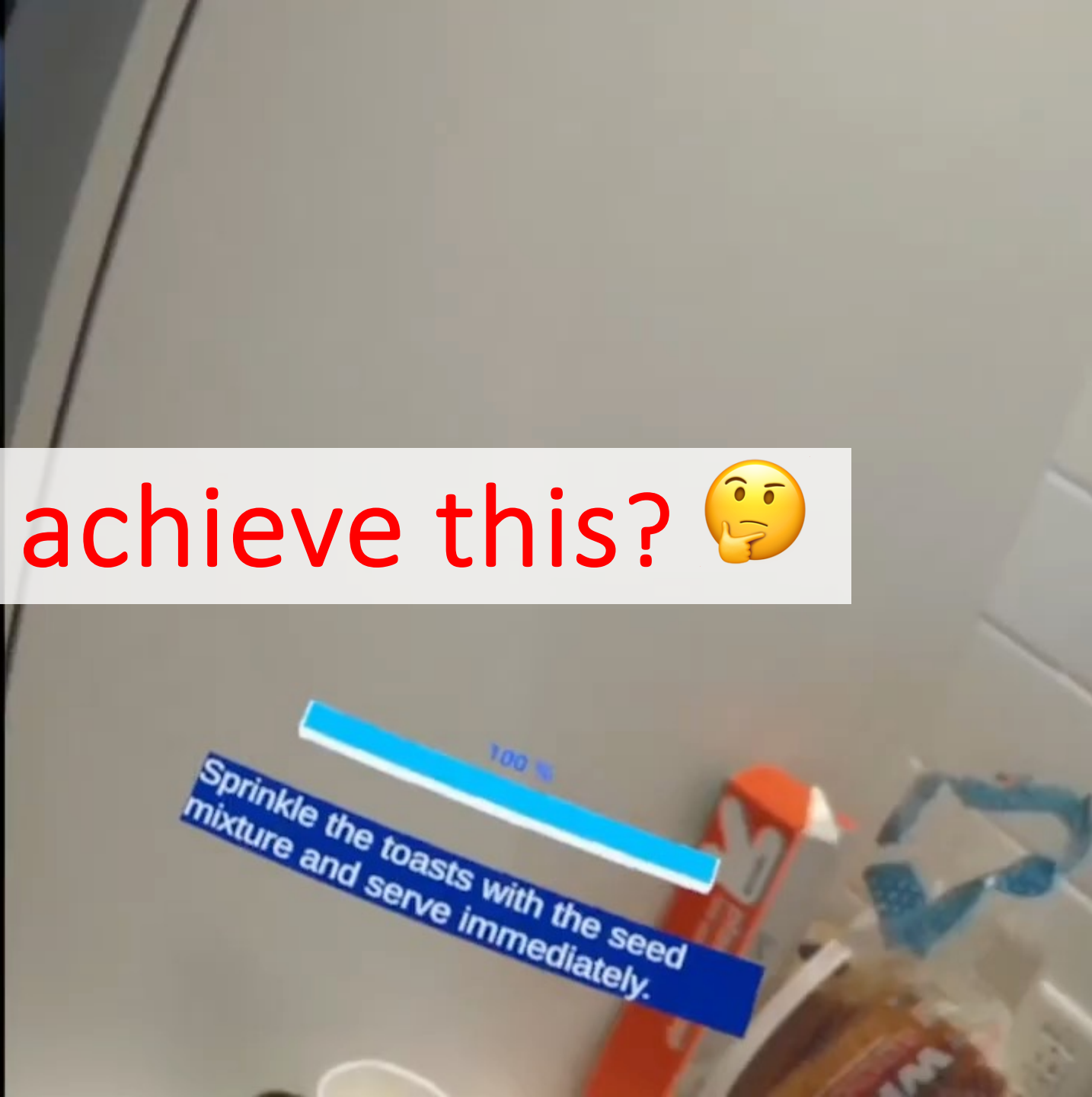
In a small bowl, combine the basil leaves and sea salt, and set aside.	countertop	↑	↓	X
Take a tomato from the fridge.	fridge	↑	↓	X
And gently clean a tomato with your hand to help remove dirt and bacteria. Do not use detergent,	sink	↑	↓	X
Then cut the tomato into parallel thin slices working from the top of the tomato towards the bottom and set aside.	countertop	↑	↓	X
Take an avocado from the fridge.	fridge	↑	↓	X
Cut and mash the avocado in a small bowl.	microwave	↑	↓	X
Squeeze the lemon into the avocado and spread liberally on the toast. And put tomato on top of the toast.	sink	↑	↓	X
Pour 1/2 cup (118ml) water into a microwave - safe coffee mug.	sink	↑	↓	X
Crack 1 egg into the mug, cover with a small plate, and microwave on high for 30 seconds. Take the mug out of the microwave, lift the plate carefully (to let steam escape) and check the egg.	countertop	↑	↓	X
Crack 1 egg into the mug, cover with a small plate, and microwave on high for 30 seconds. Take the mug out of the microwave, lift the plate carefully (to let steam escape) and check the egg.	countertop	↑	↓	X
If the white is not completely set, cover and continue to microwave in 10 - second intervals	countertop	↑	↓	X

Consumption Pipeline





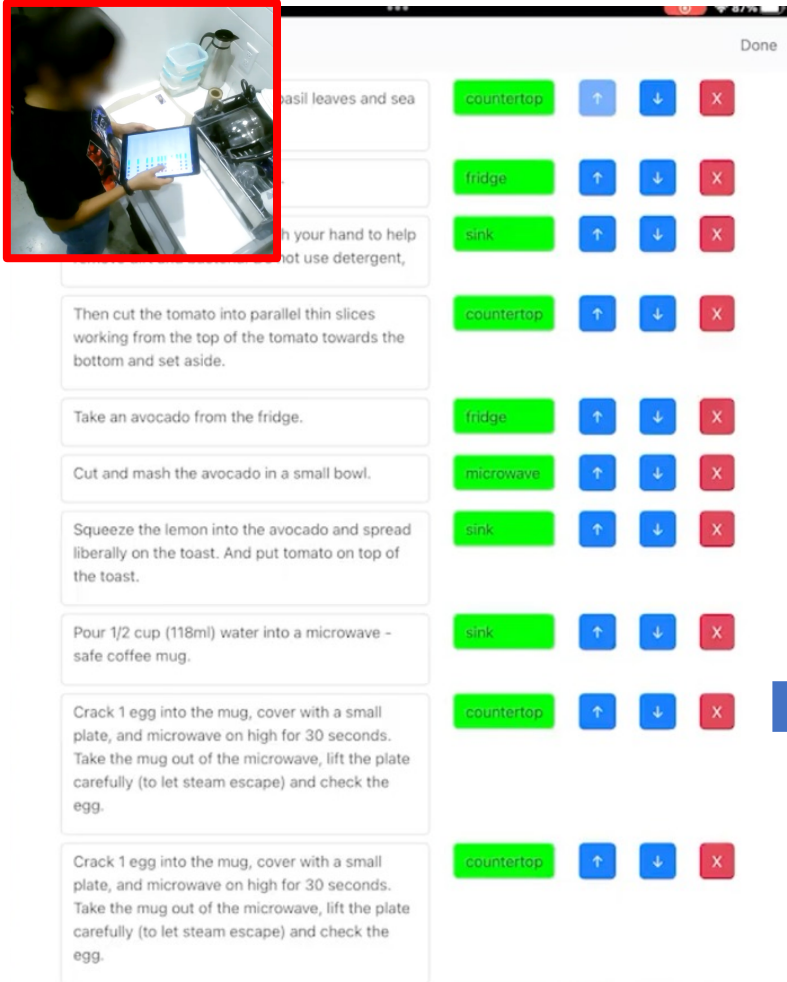
How do we achieve this? 🤔



100 %
Sprinkle the toasts with the seed mixture and serve immediately.

Connecting Paper Instructions with MR Experience

Experience Authoring



basil leaves and sea

counter top

fridge

sink

counter top

fridge

microwave

sink

sink

counter top

counter top

Then cut the tomato into parallel thin slices working from the top of the tomato towards the bottom and set aside.

Take an avocado from the fridge.

Cut and mash the avocado in a small bowl.

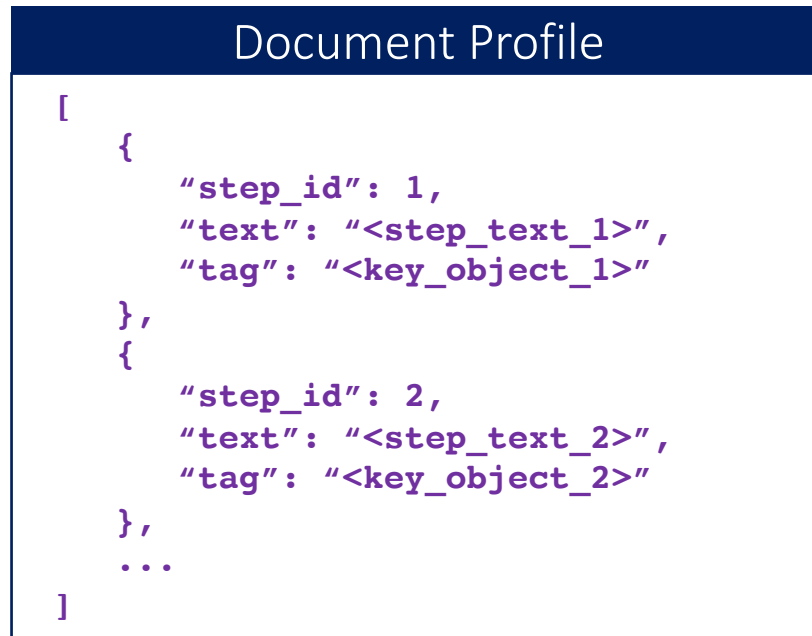
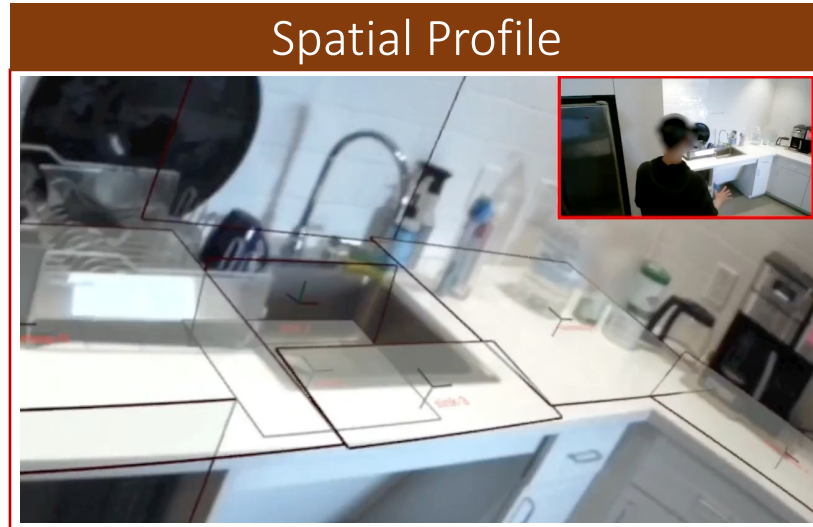
Squeeze the lemon into the avocado and spread liberally on the toast. And put tomato on top of the toast.

Pour 1/2 cup (118ml) water into a microwave - safe coffee mug.

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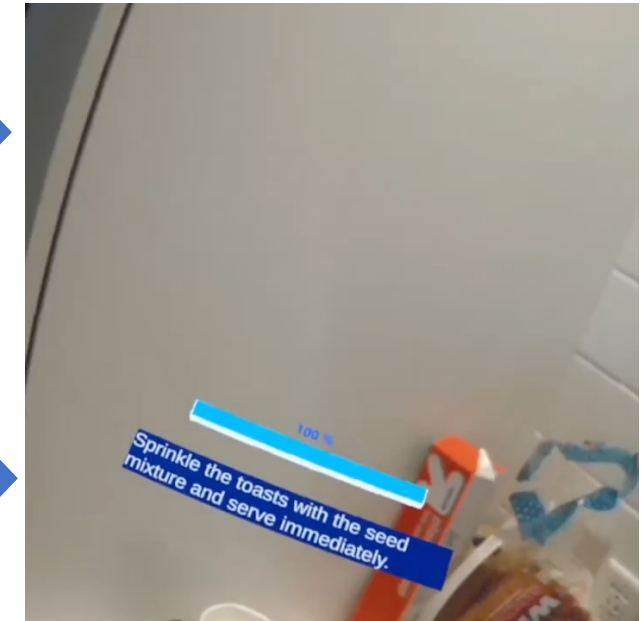
Done

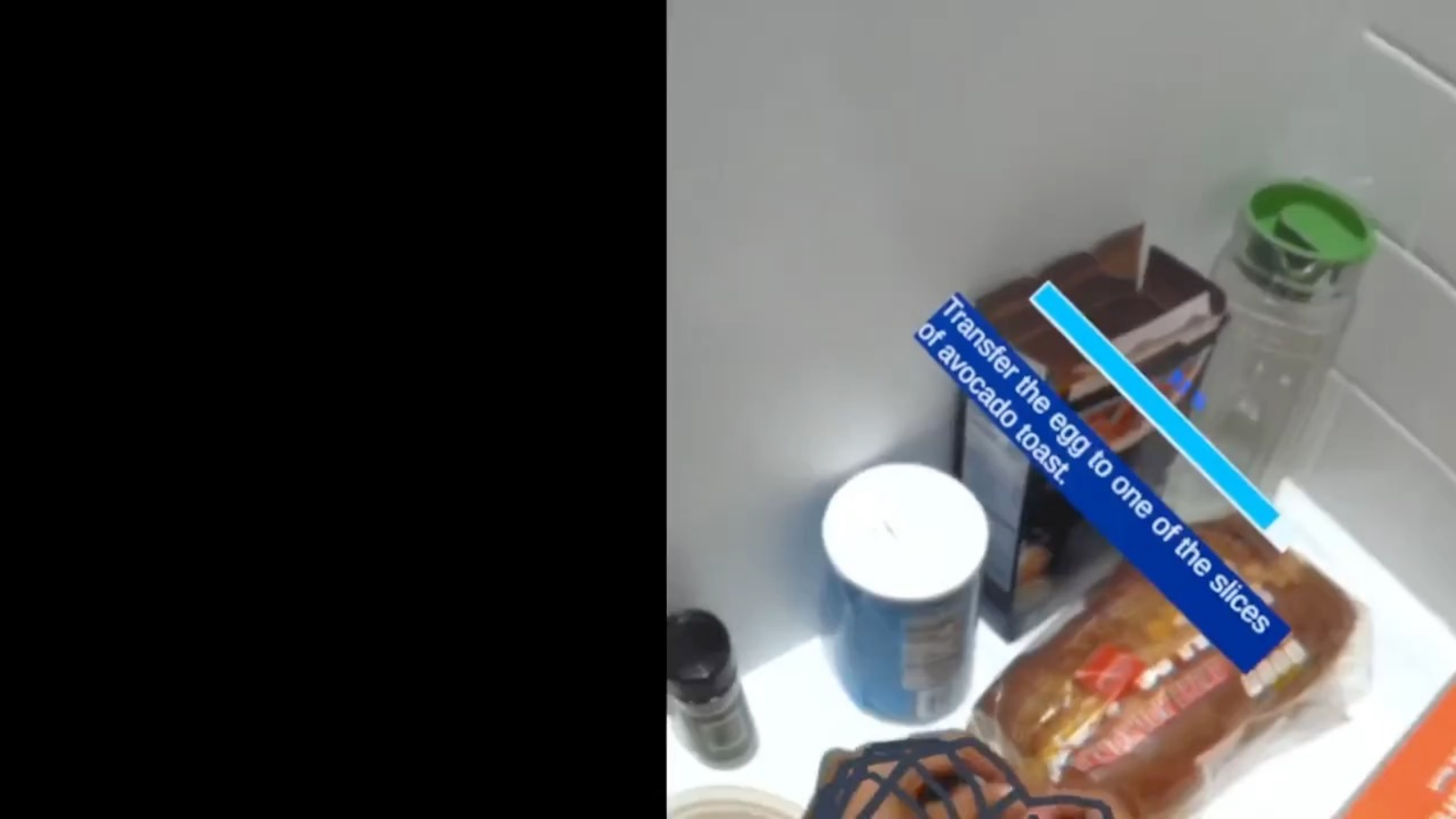


Document Profile

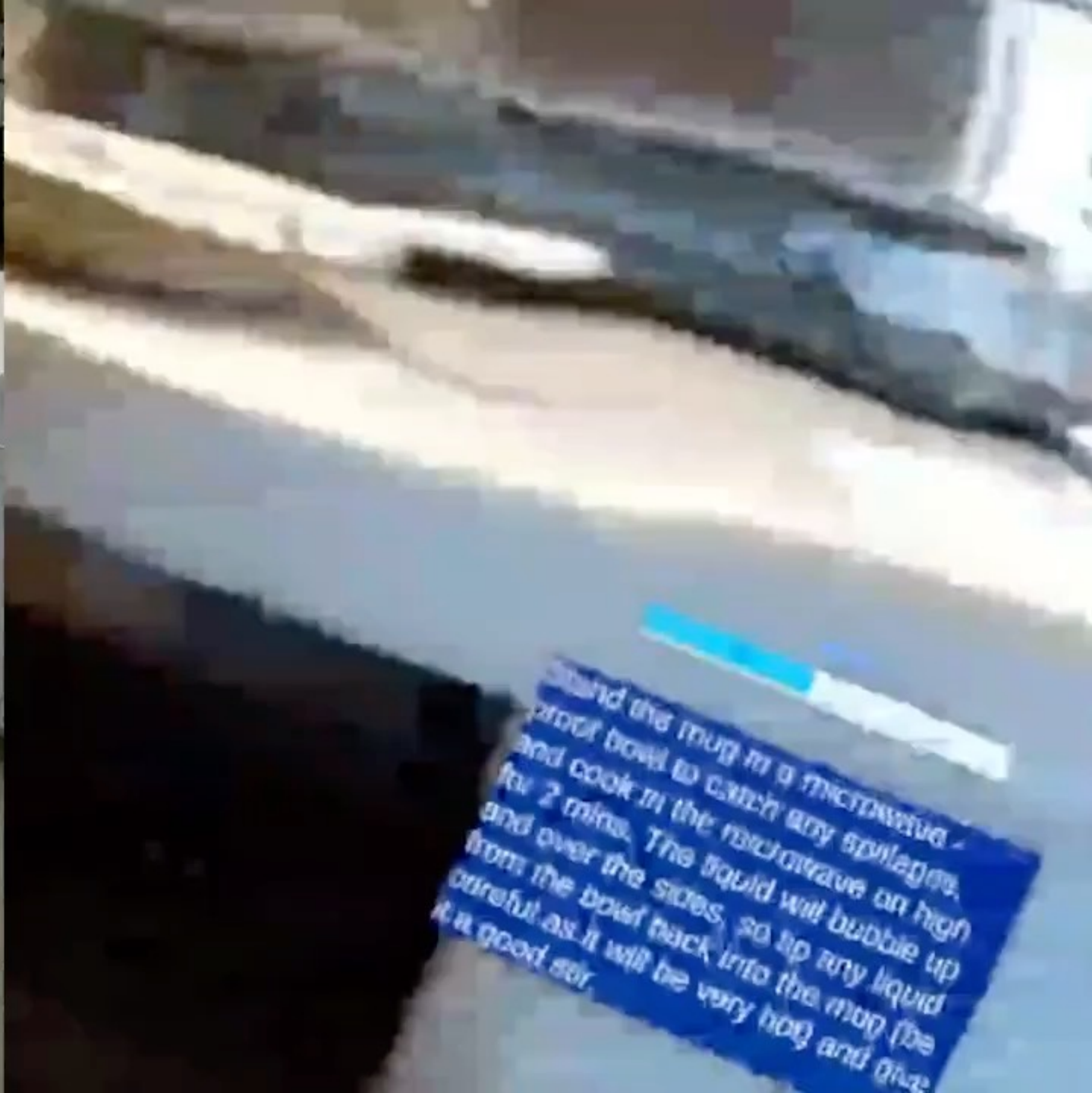
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  },  
  {  
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  ...  
]
```

Experience Consuming

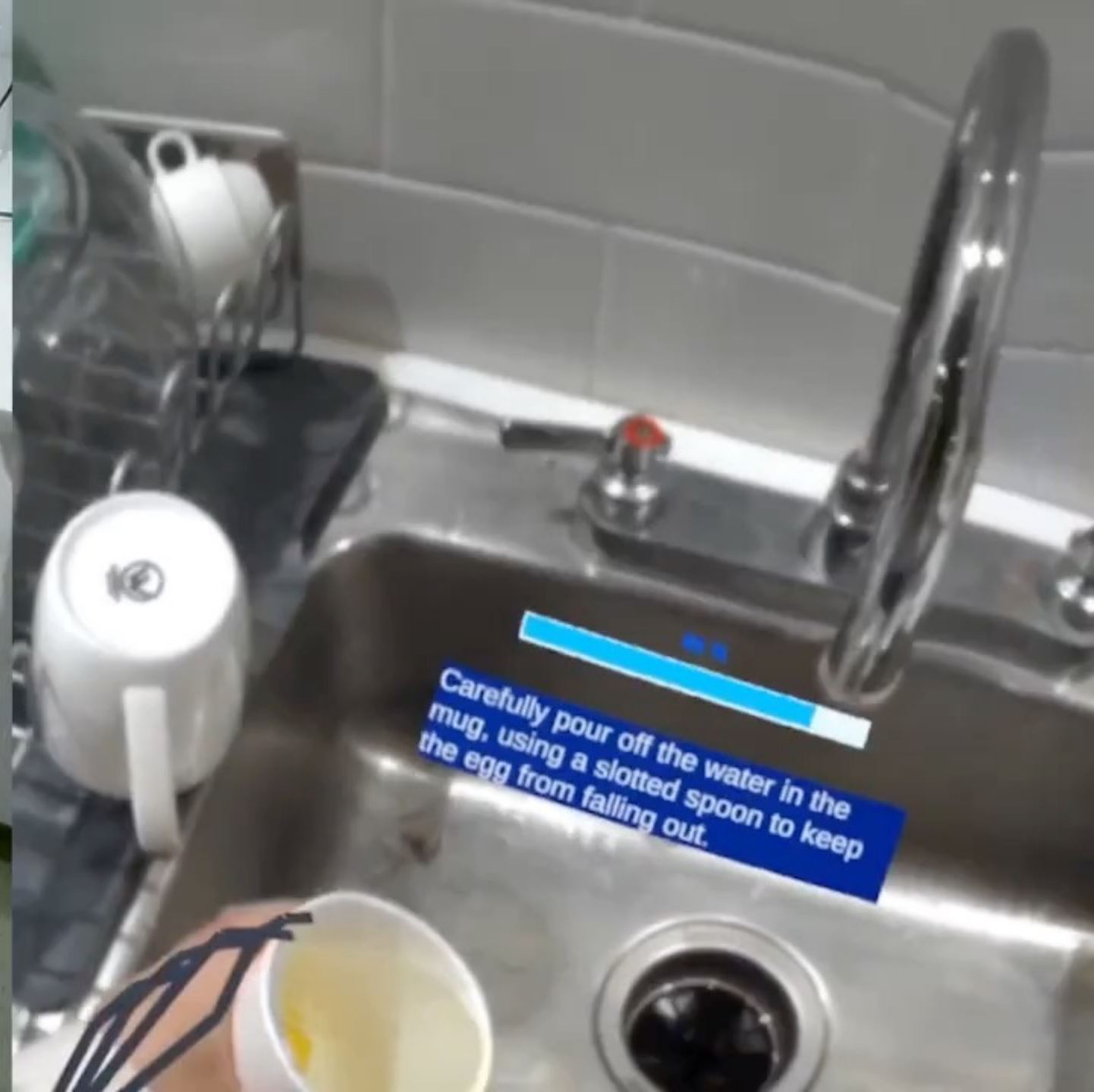




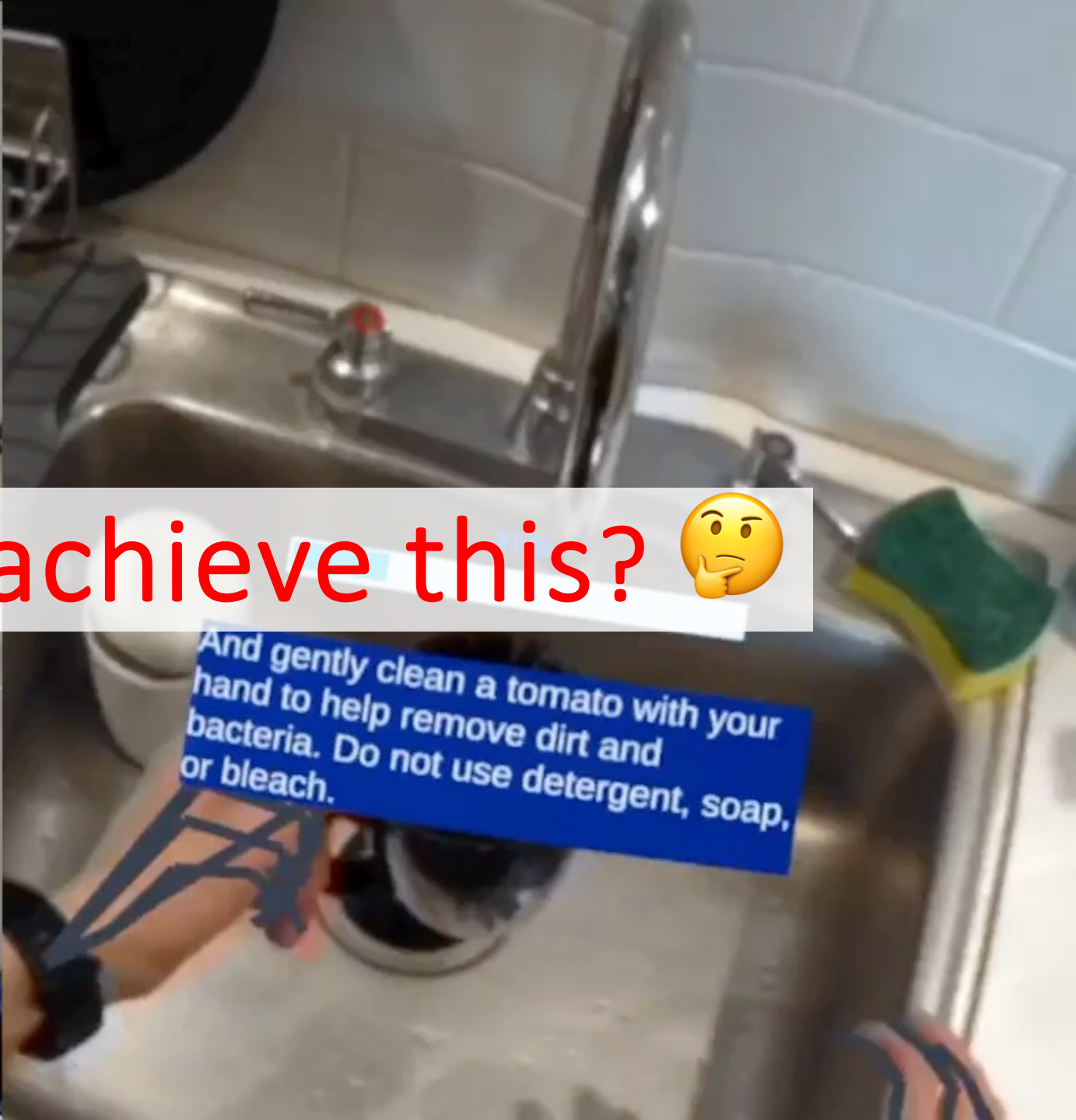
Transfer the egg to one of the slices
of avocado toast.



Stand the mug in a microwave-
proof bowl to catch any spillage,
and cook in the microwave on high
for 2 mins. The liquid will bubble up
and over the sides, so tip any liquid
from the bowl back into the mug (be
careful as it will be very hot) and give
it a good stir.

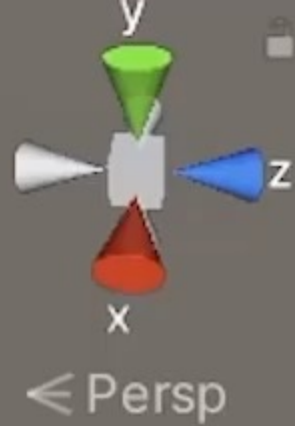
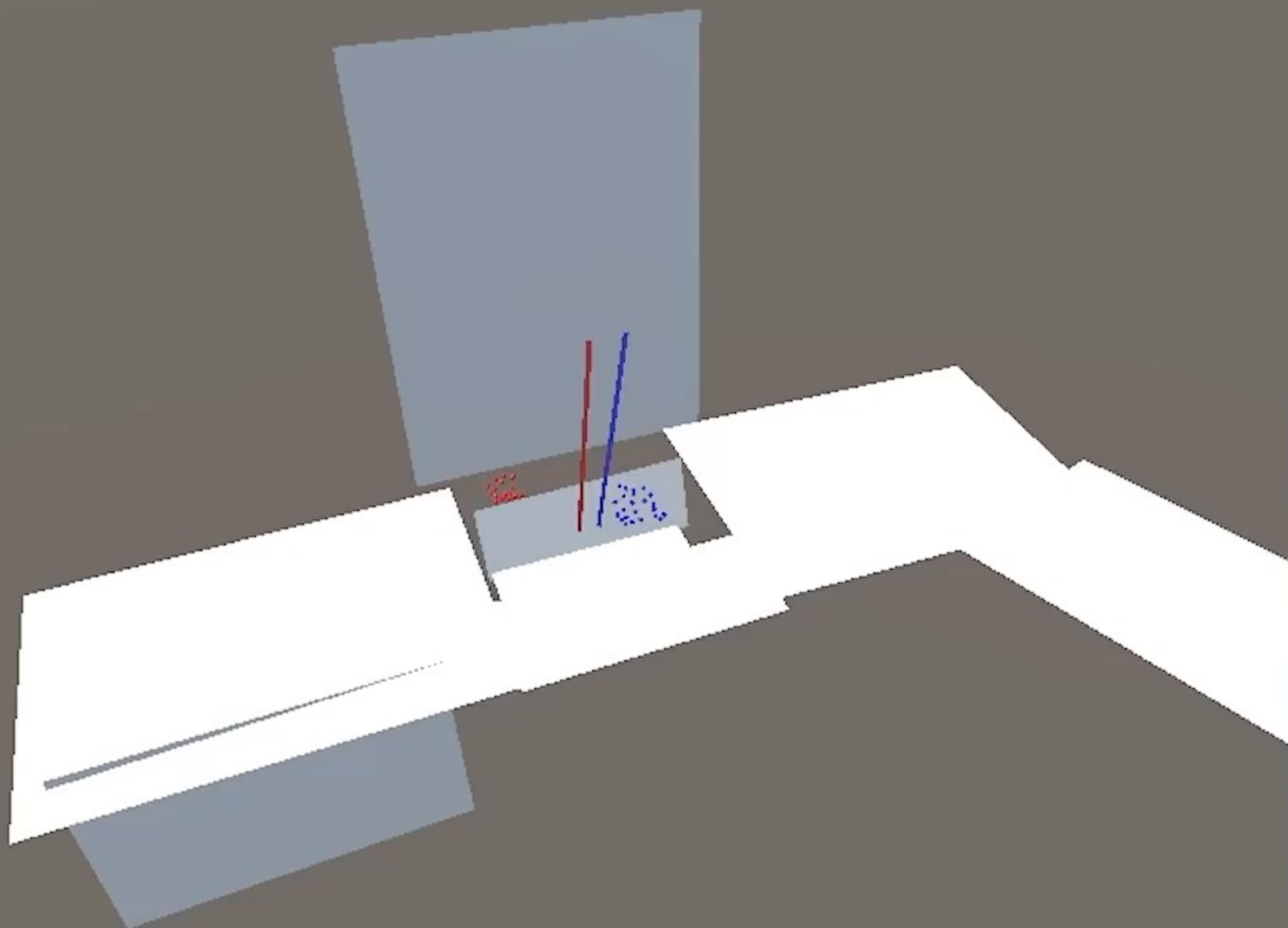






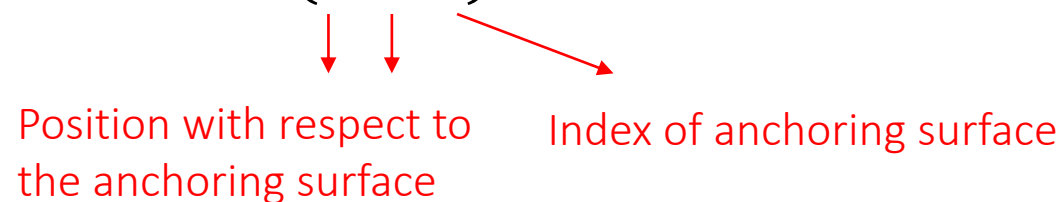
How do we achieve this? 🤔

And gently clean a tomato with your hand to help remove dirt and bacteria. Do not use detergent, soap, or bleach.



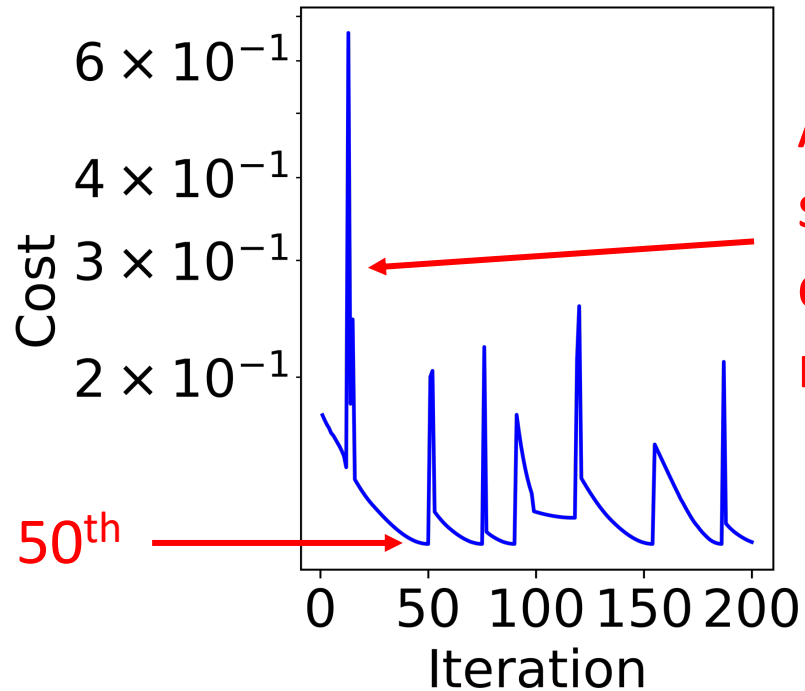
Finding Optimal Placements of Virtual Step with a Simulated Annealing Algorithm

- Each Possible Placements $\mathbf{a} = (r, c, s)$



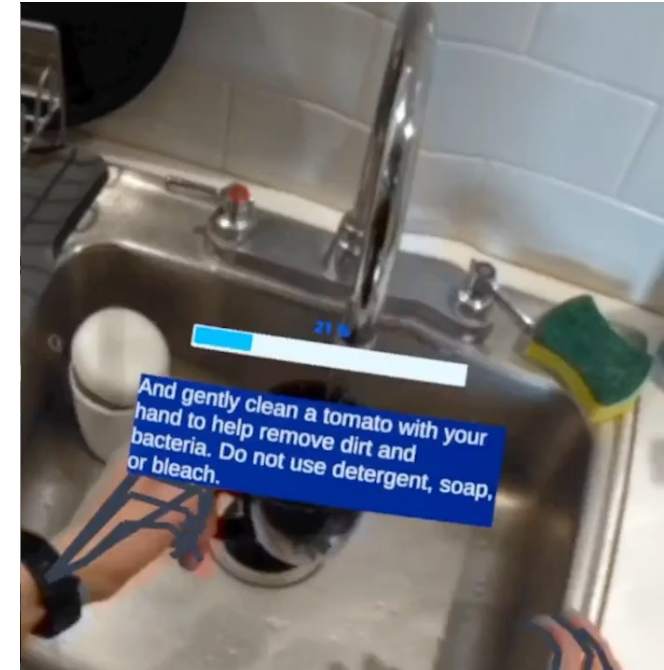
- Cost: $C_{total}(\mathbf{a}) = \lambda_V C_V(\mathbf{a}) + \lambda_R C_R(\mathbf{a}) + \lambda_{HA} C_{HA}(\mathbf{a}) + \lambda_P C_P(\mathbf{a})$
 - $C_V(\mathbf{a})$: How much areas of the anchoring surfaces are occluded?
 - $C_R(\mathbf{a})$: How far the step placement is away from user's attention?
 - $C_{HA}(\mathbf{a})$: Whether the instruction step is in front of the hands?
 - $C_P(\mathbf{a})$: How far the instruction step is away from the preferred location?
- Our goal is to find $\hat{\mathbf{a}}$, such that $\hat{\mathbf{a}} = \mathit{argmin} C_{total}(\mathbf{a})$

Finding $\hat{a} = \mathit{argmin} C_{total}(a)$

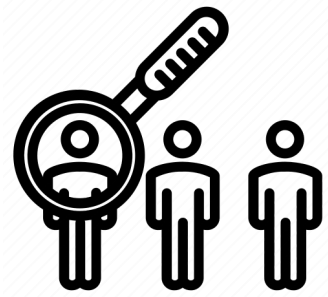


Searched
solution at 50th
Iteration

A sudden “jump” in the
search space to prevent
converging at local
minimal



User Studies ($N_{total} = 24$)



Authoring Pipeline

- Within-Subject Design ($N = 12$);
- RQs:
 - RQ1: How the proposed authoring pipeline is useful?
 - How the ML could support (RQ2) a faster and (RQ3) an easier authoring experience?

Consumption Pipeline

- Within-Subject Design ($N = 12$);
- RQ: How could the consumption pipeline help users complete the task faster and easier?

Tasks



(T1) Scrambled Eggs

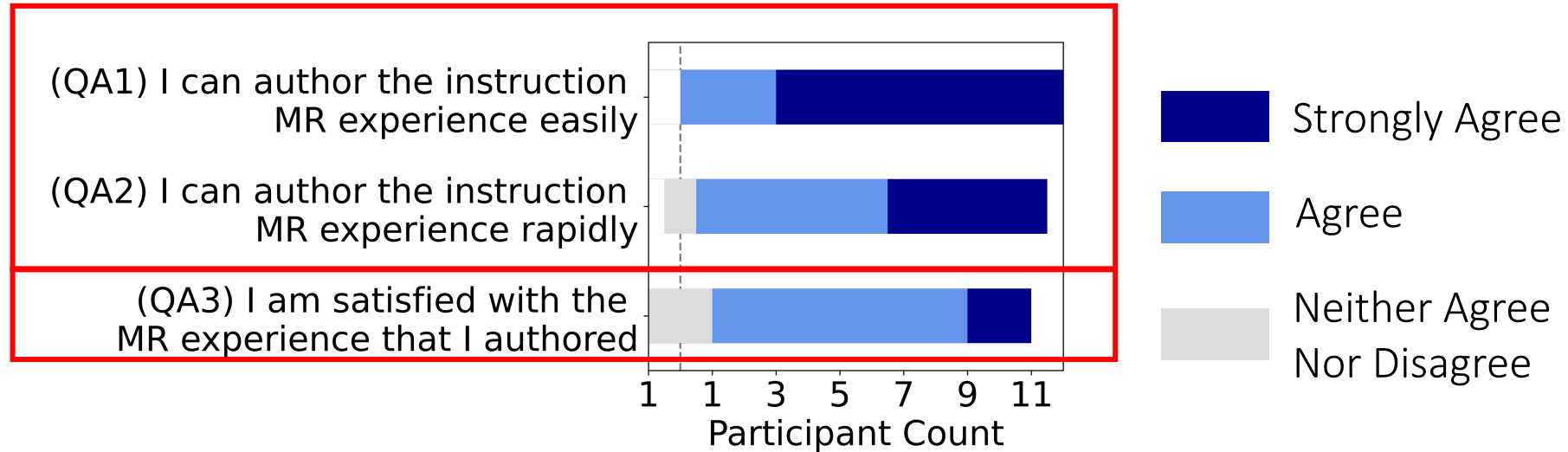


(T2) 🥑 Toast with
Microwave Poached Eggs



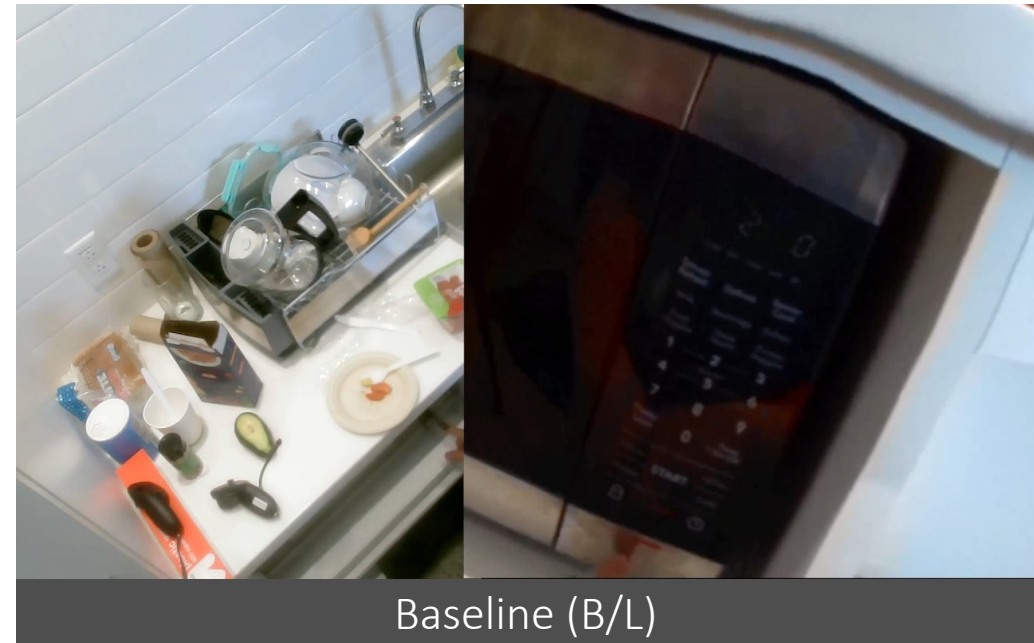
(T3) Mac'n Cheese

Evaluations Results – Authoring Pipeline (N = 12)

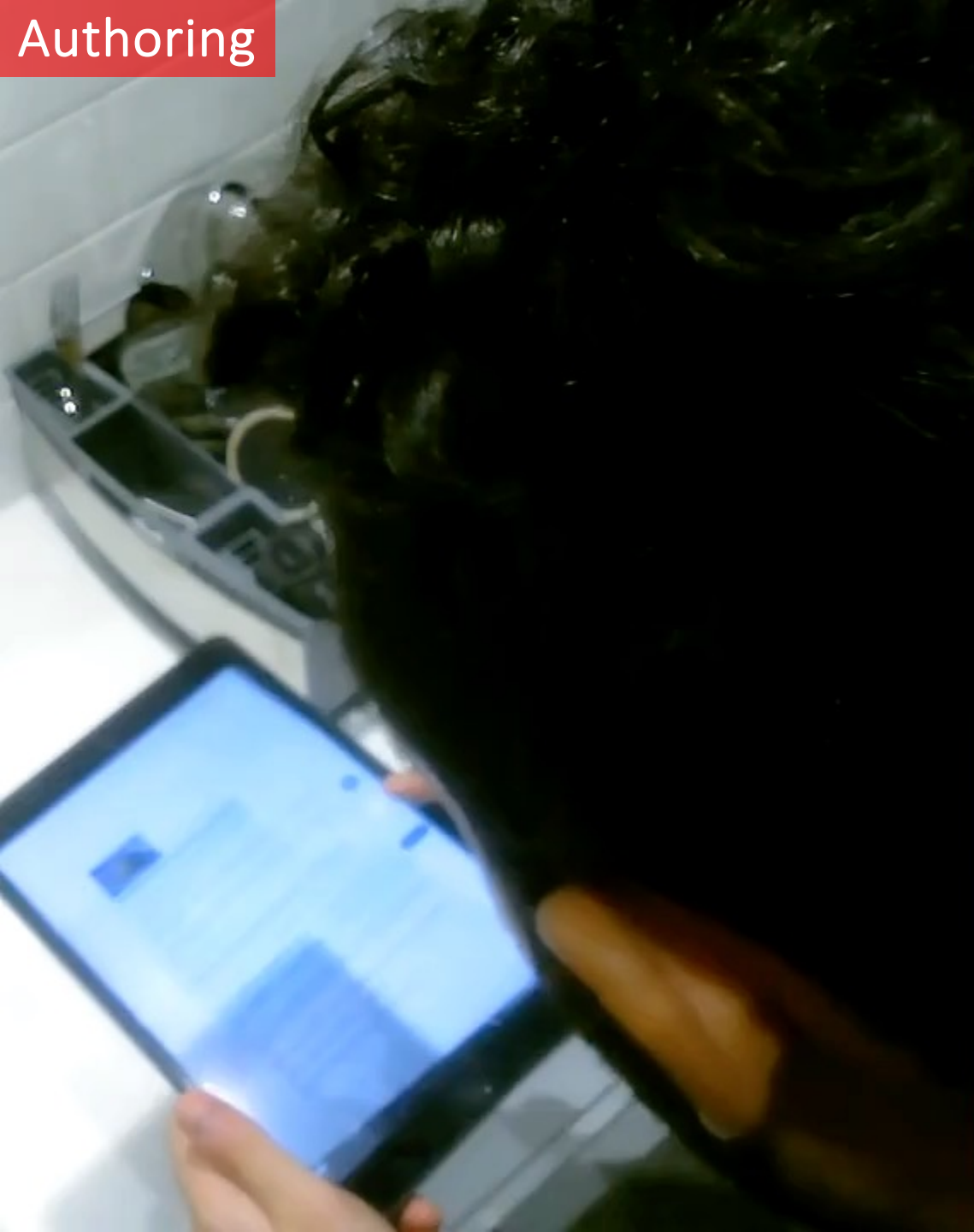


Evaluations Results – Consumption Pipeline (N = 12)

- Placements of instruction steps based on contexts could reduce the effort of context-switching.
- Segmented instruction help participants find the relevant information easier.



Authoring



Consumption



Please Refer to Our
Paper for More Details!



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Videos 📺



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I am currently seeking intern and full-time research position opportunity! Please email me!



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