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More on this paper (or others of our lab) at: <https://lab.plopes.org/#VR-side-effects>



VR Side-Effects: Memory & Proprioceptive Discrepancies After Leaving Virtual Reality

Antonin Cheymol, Pedro Lopes. In Proc. UIST'25 (paper)

Our brain's plasticity rapidly adapts our senses in VR, a phenomenon leveraged by techniques such as redirected walking, hand redirection, etc. However, while most of HCI is interested in how users adapt to VR, we turn our attention to how users need to adapt their senses when returning to the real-world. We found that, after leaving VR, (1) participants' hands remained redirected by up to 7cm, indicating residual proprioceptive distortion; and (2) participants incorrectly recalled the virtual location of objects rather than their actual real-world locations (e.g., remembering the location of a VR-extinguisher, even when trying to recall the real one). We discuss the lingering VR side-effects may pose safety or usability risks.



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antonin cheymol, pedro lopes



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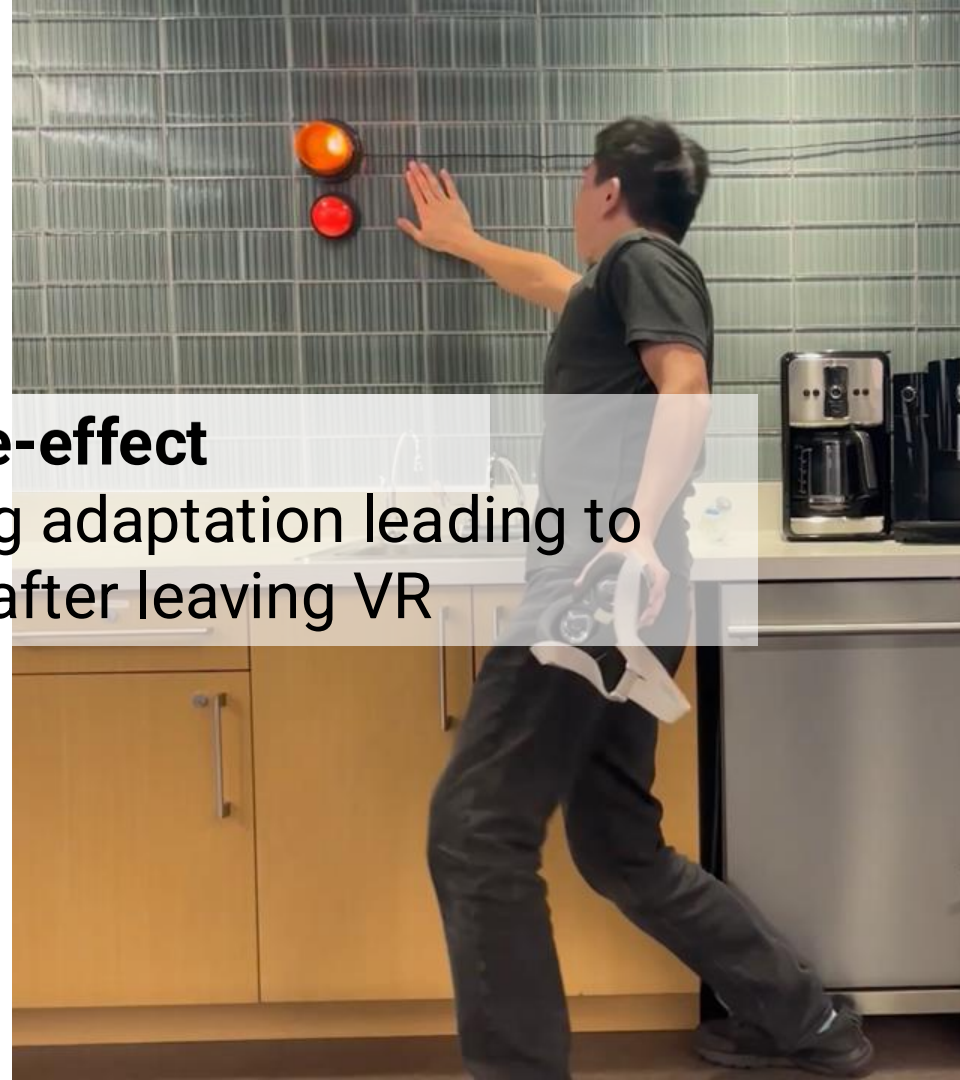


see video: <https://www.youtube.com/watch?v=uoJtpx78RmU>



VR side-effect

an unintended lingering adaptation leading to potential risks after leaving VR



motivation

Katori et al. UIST'25



adapting going **into** VR = **immersion**



adapting going **into** VR = **immersion**



adapting going **into** VR = **immersion**



adapting going **out** of VR = **instantaneous?**

Katori et al. UIST'25



adapting going **into** VR = **immersion**



adapting going **out** of VR = **instantaneous?**

related work

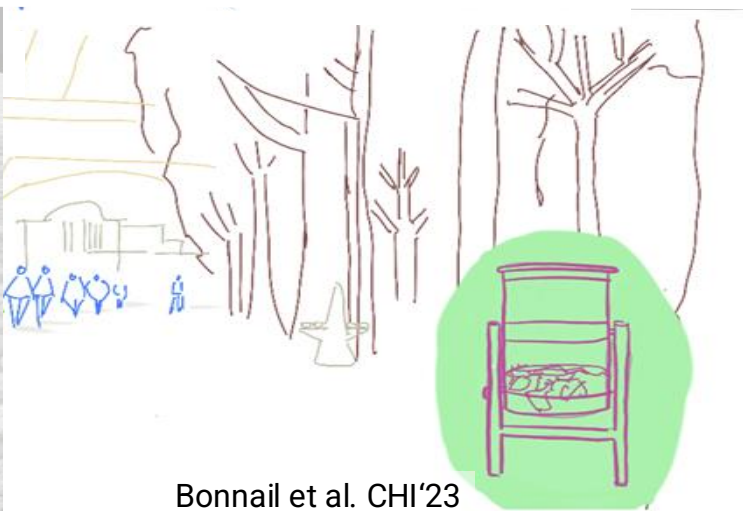
well-intended effects



well-intended effects



speculating on risks



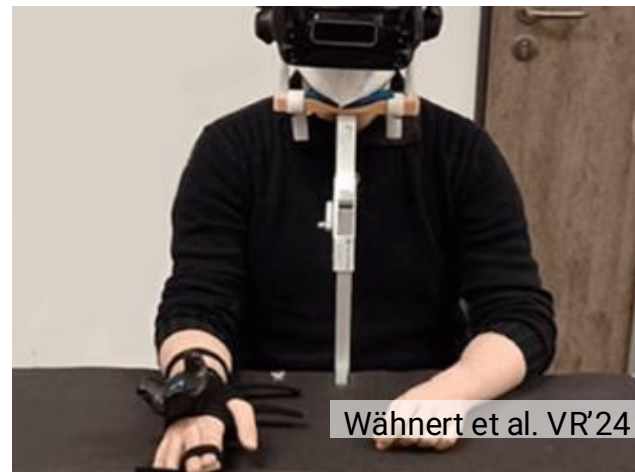
well-intended effects



speculating on risks



non-naturalistic interactions

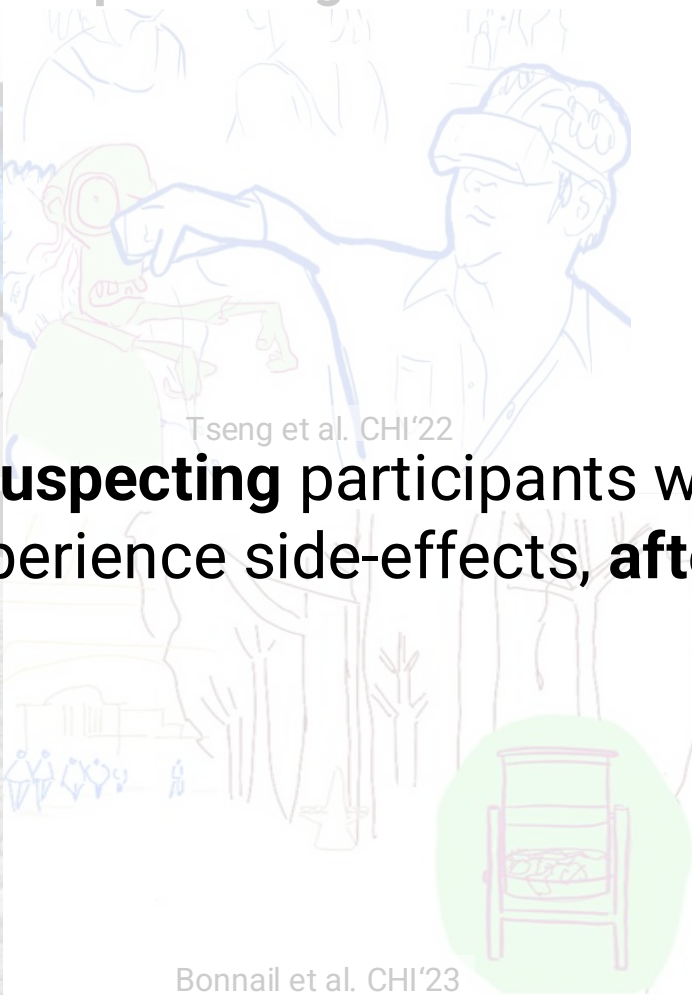


well-intended effects



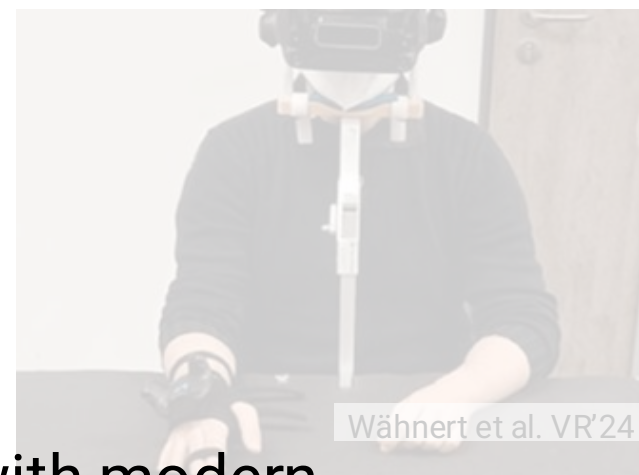
Li et al. Front. VR'21

speculating on risks



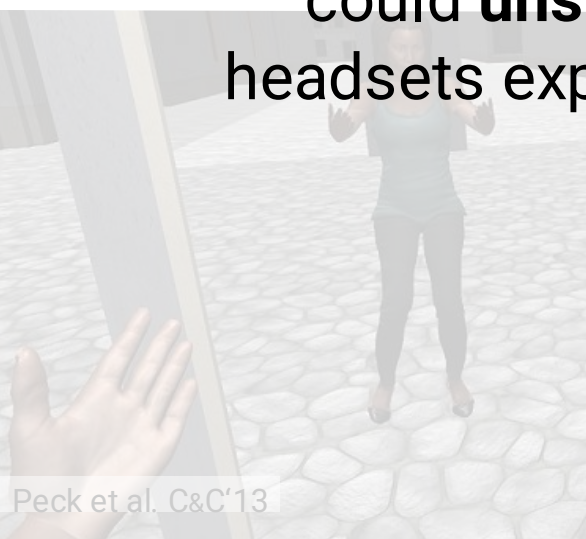
Tseng et al. CHI'22

non-naturalistic interactions



Wähnert et al. VR'24

could **unsuspecting** participants with modern headsets experience side-effects, **after** leaving VR?

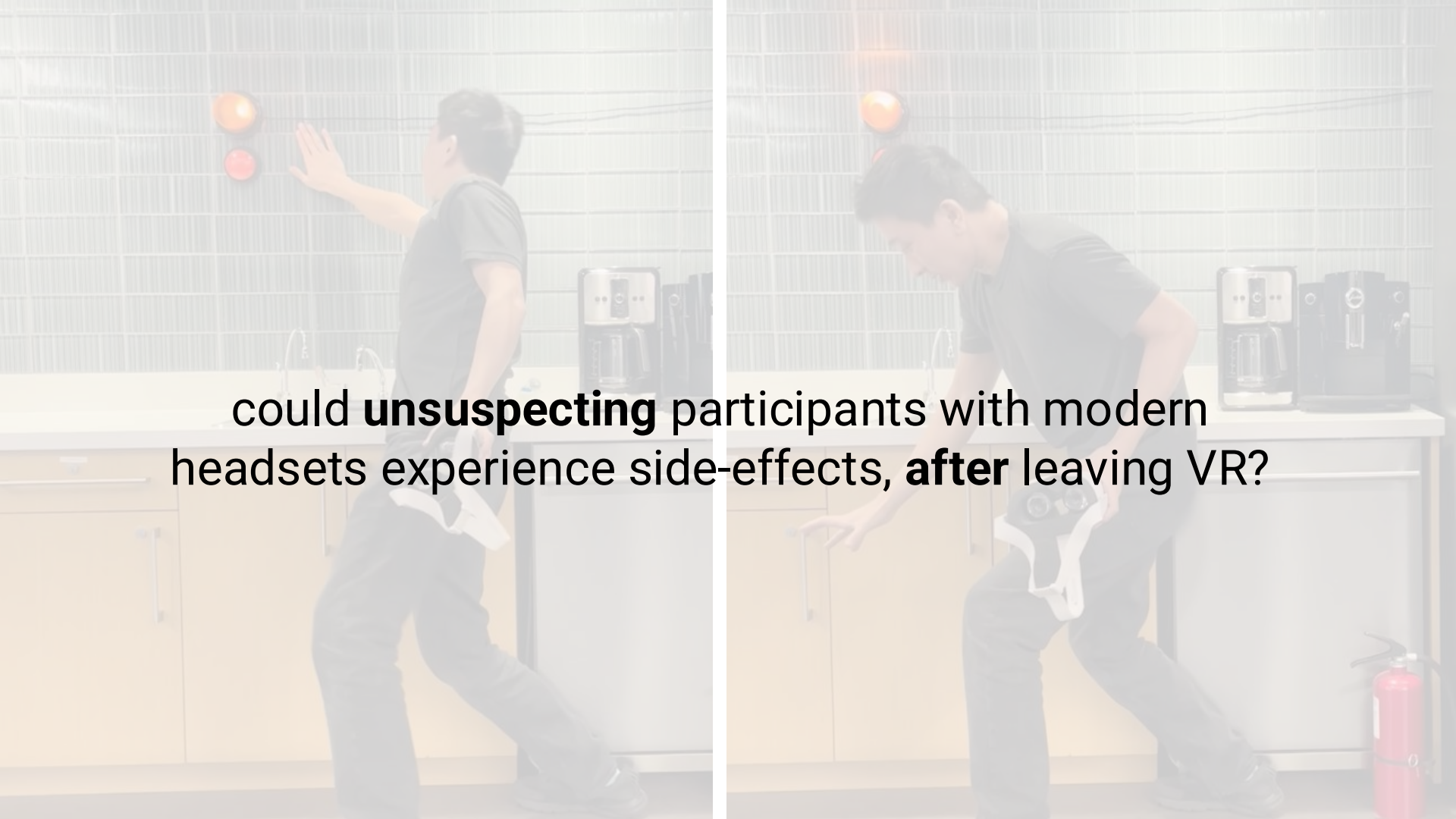


Peck et al. C&C'13

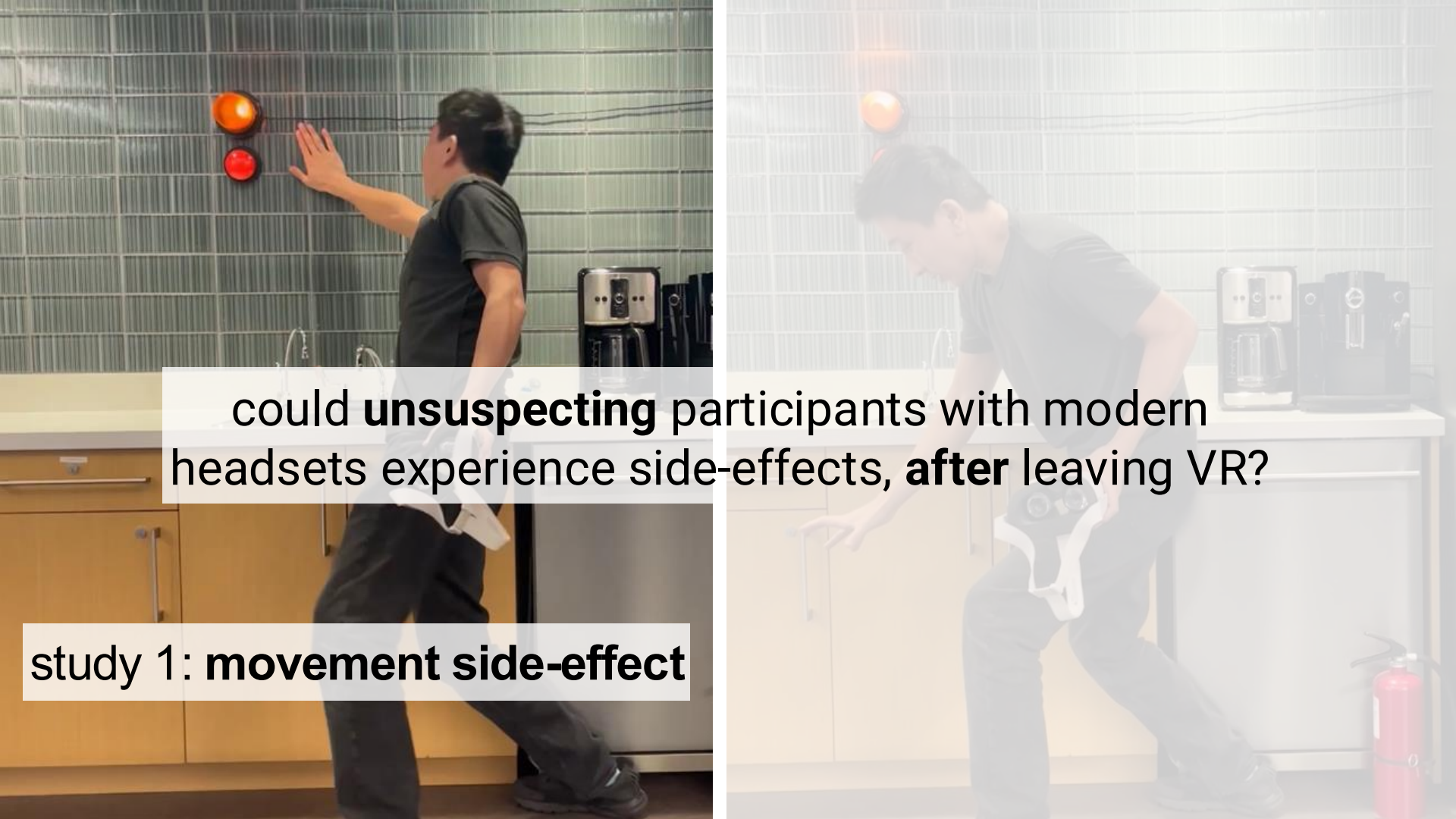
Bonnail et al. CHI'23



Rubo et al. CHBR'21



could **unsuspecting** participants with modern headsets experience side-effects, **after** leaving VR?



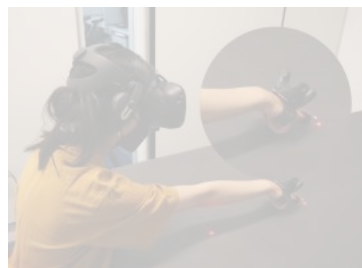
could **unsuspecting** participants with modern headsets experience side-effects, **after** leaving VR?

study 1: **movement side-effect**

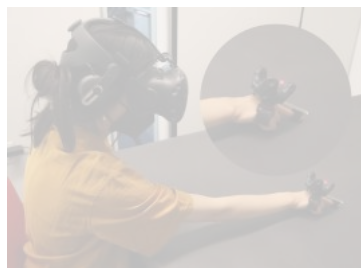
in VR: experiencing redirection



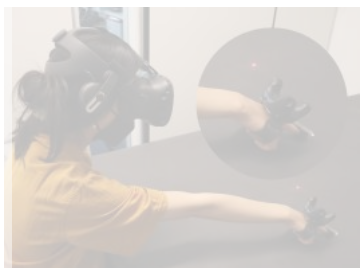
in VR: experiencing redirection



no gain



low gain



high gain

(unnoticeable)

in VR: experiencing redirection



outside VR: reaching



no gain



low gain



high gain

in VR: experiencing redirection



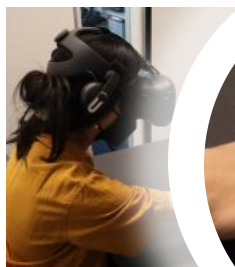
outside VR: reaching



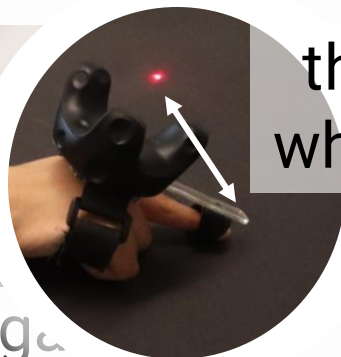
no gain



low gain

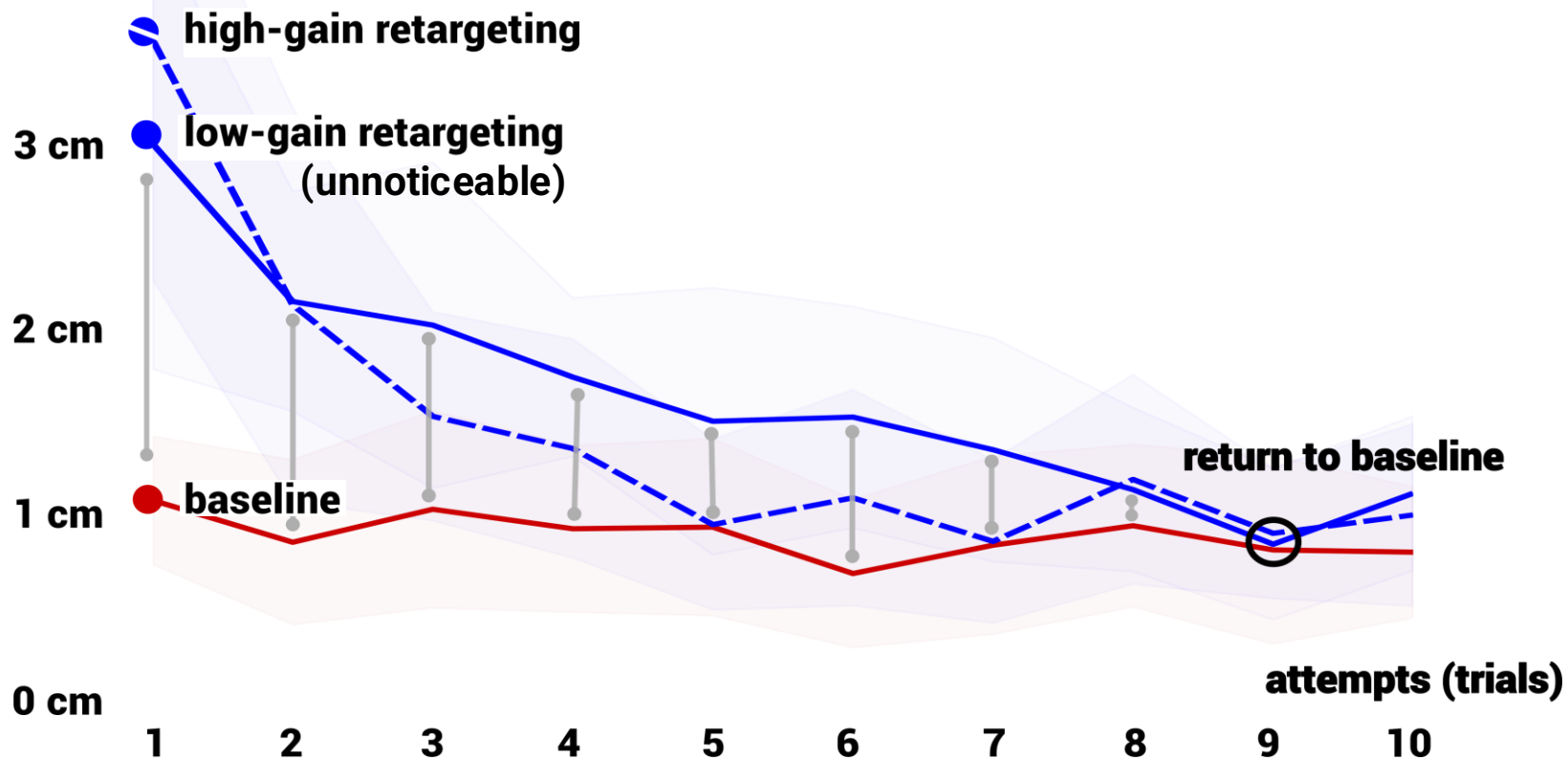


high gain

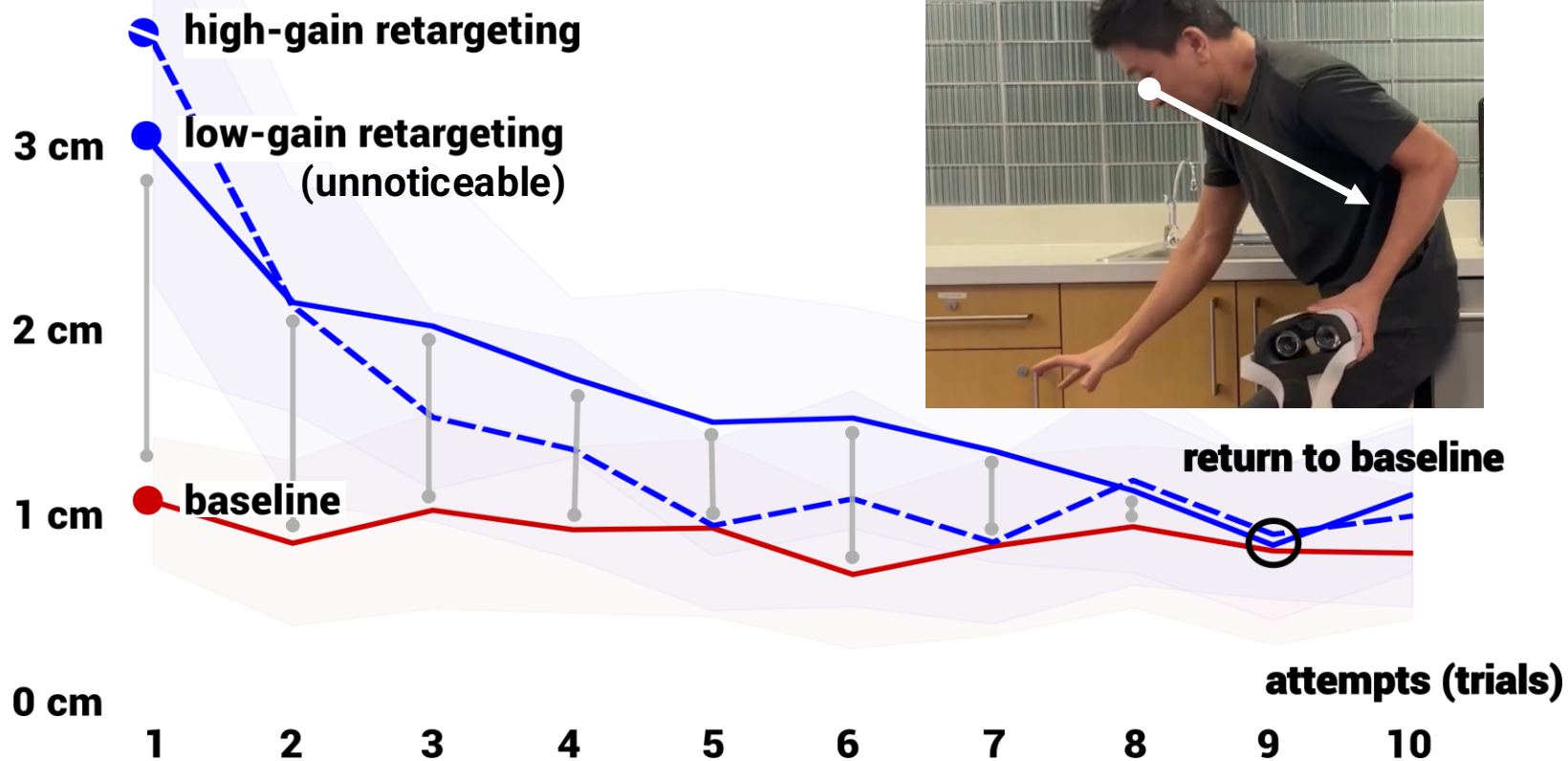


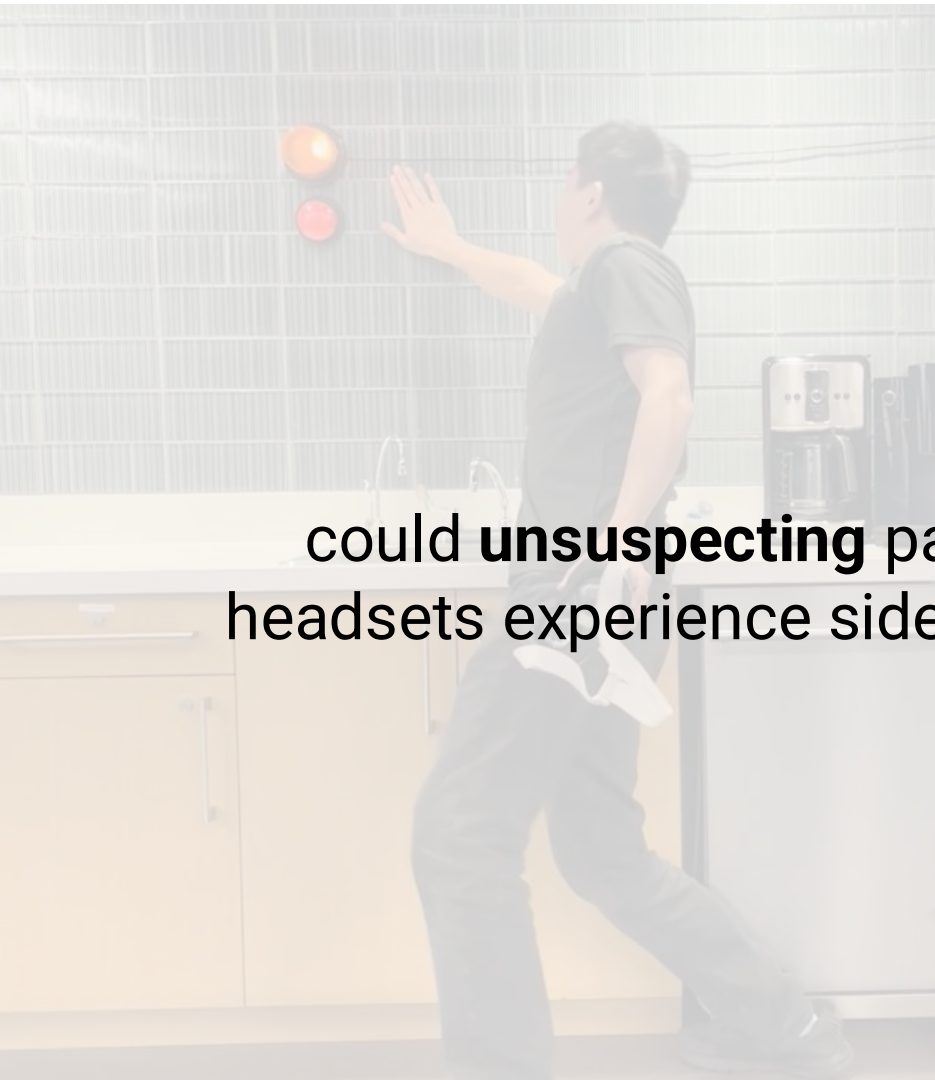
this difference is
what **we measure**

error from target



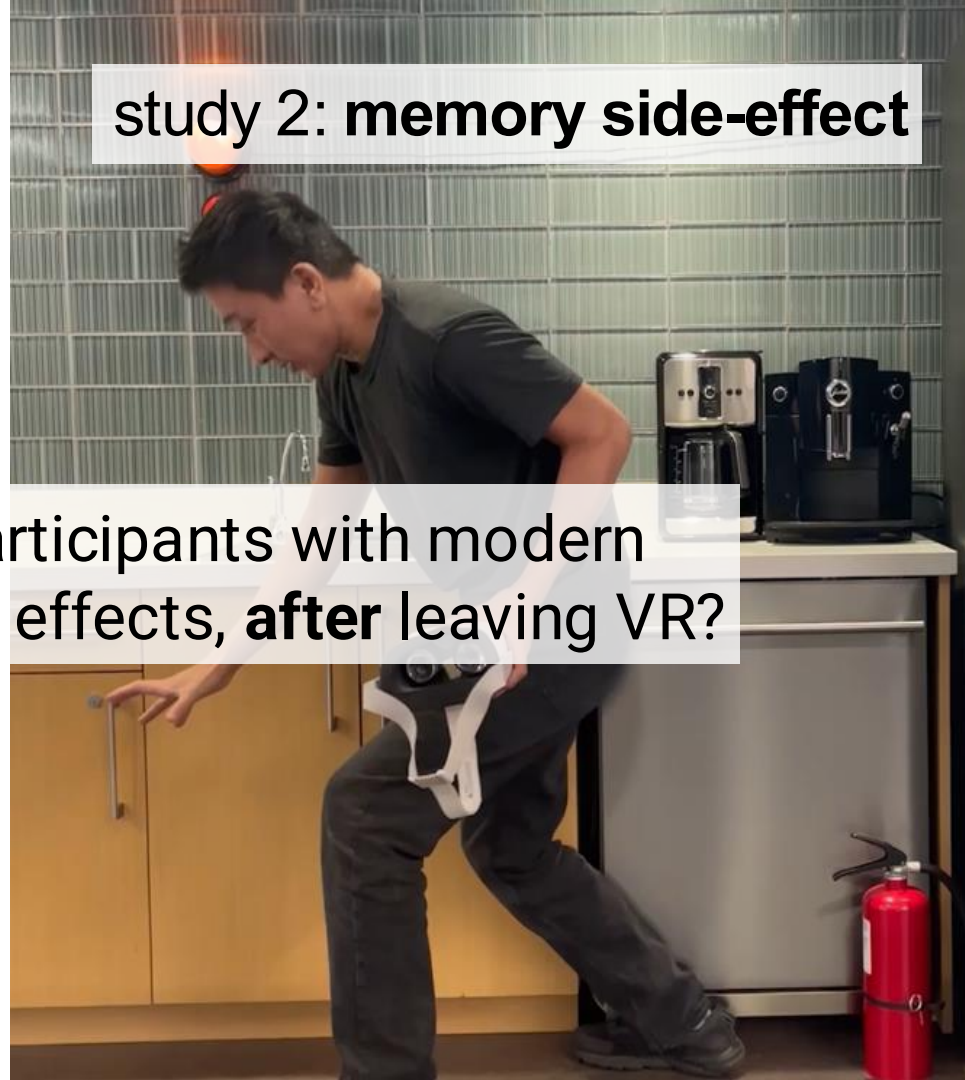
error from target

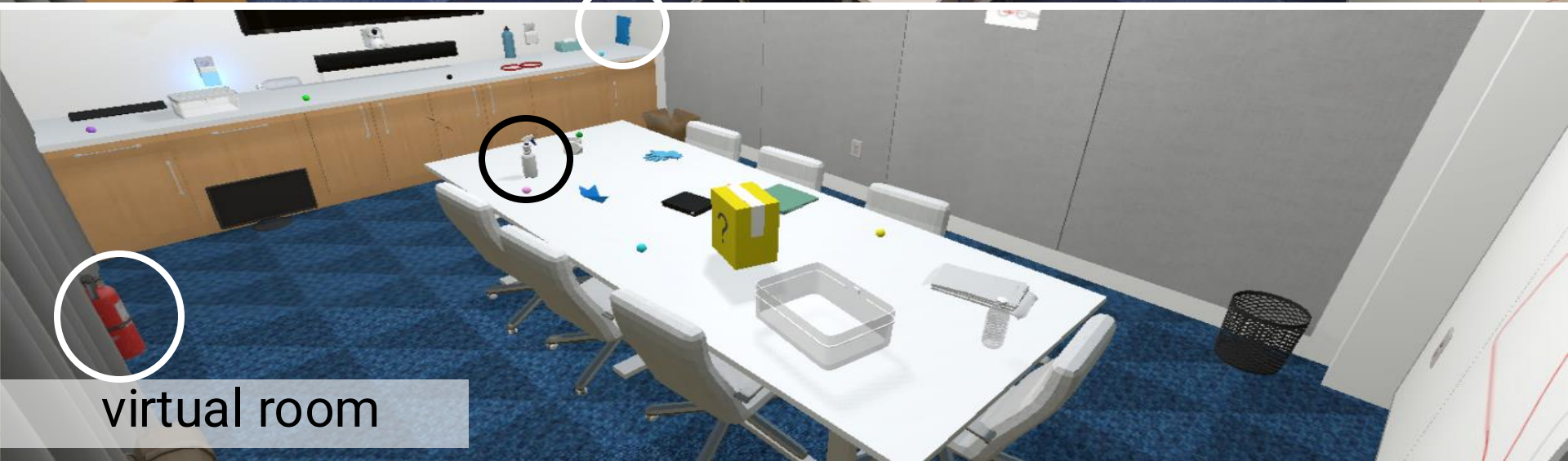




could **unsuspecting** participants with modern headsets experience side effects, **after** leaving VR?

study 2: **memory side-effect**





can you remember?



real-room task

4 minutes



VR task

4 minutes

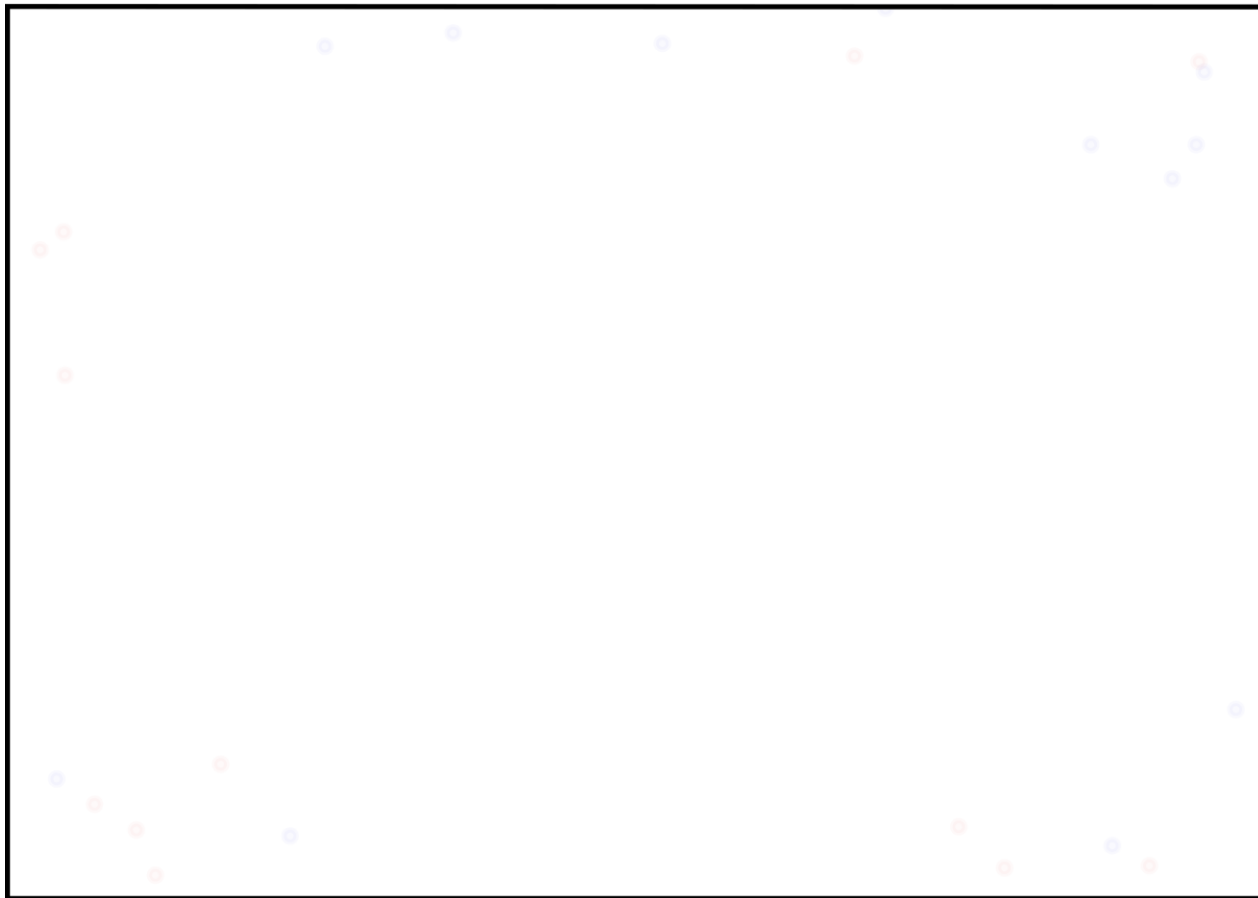


recall task

~5 minutes

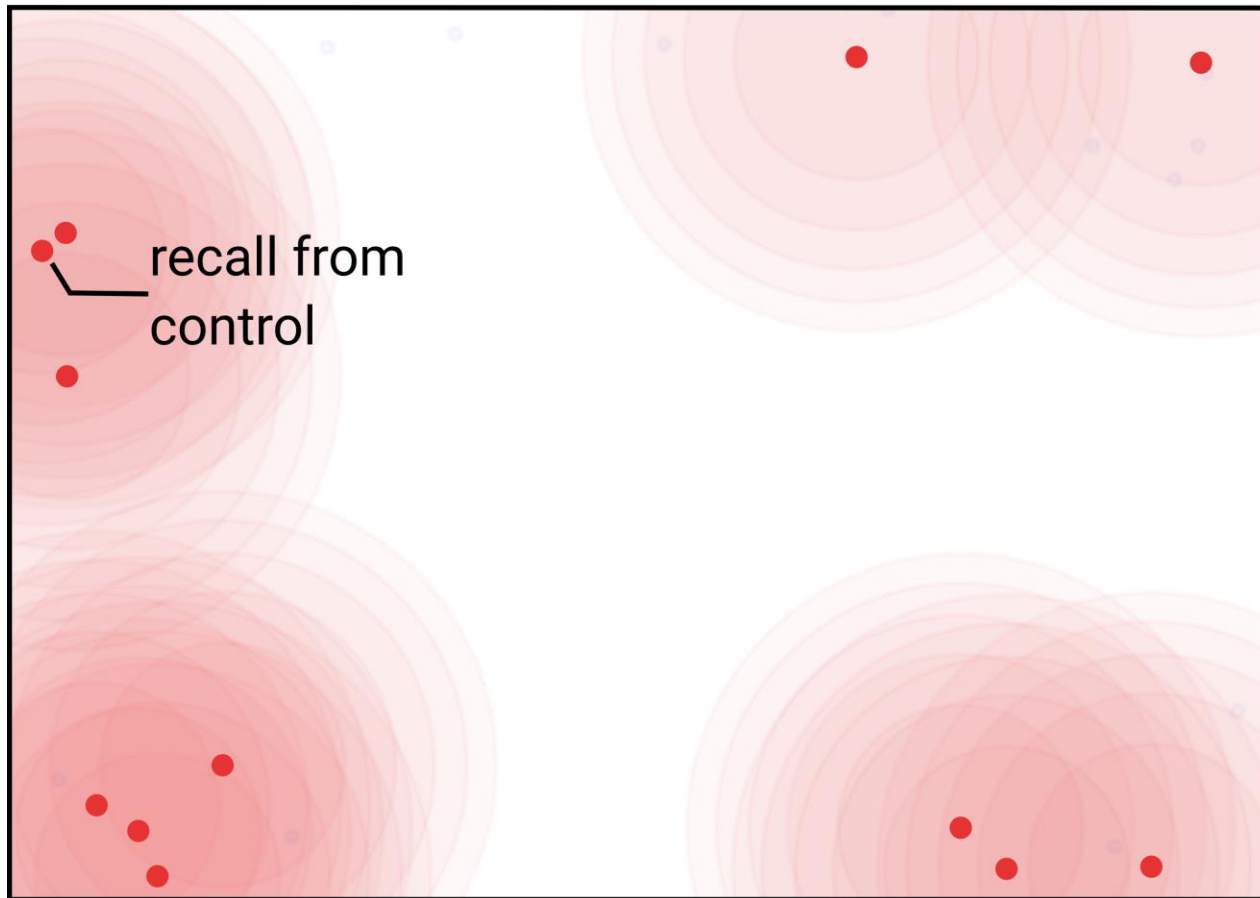


extinguisher



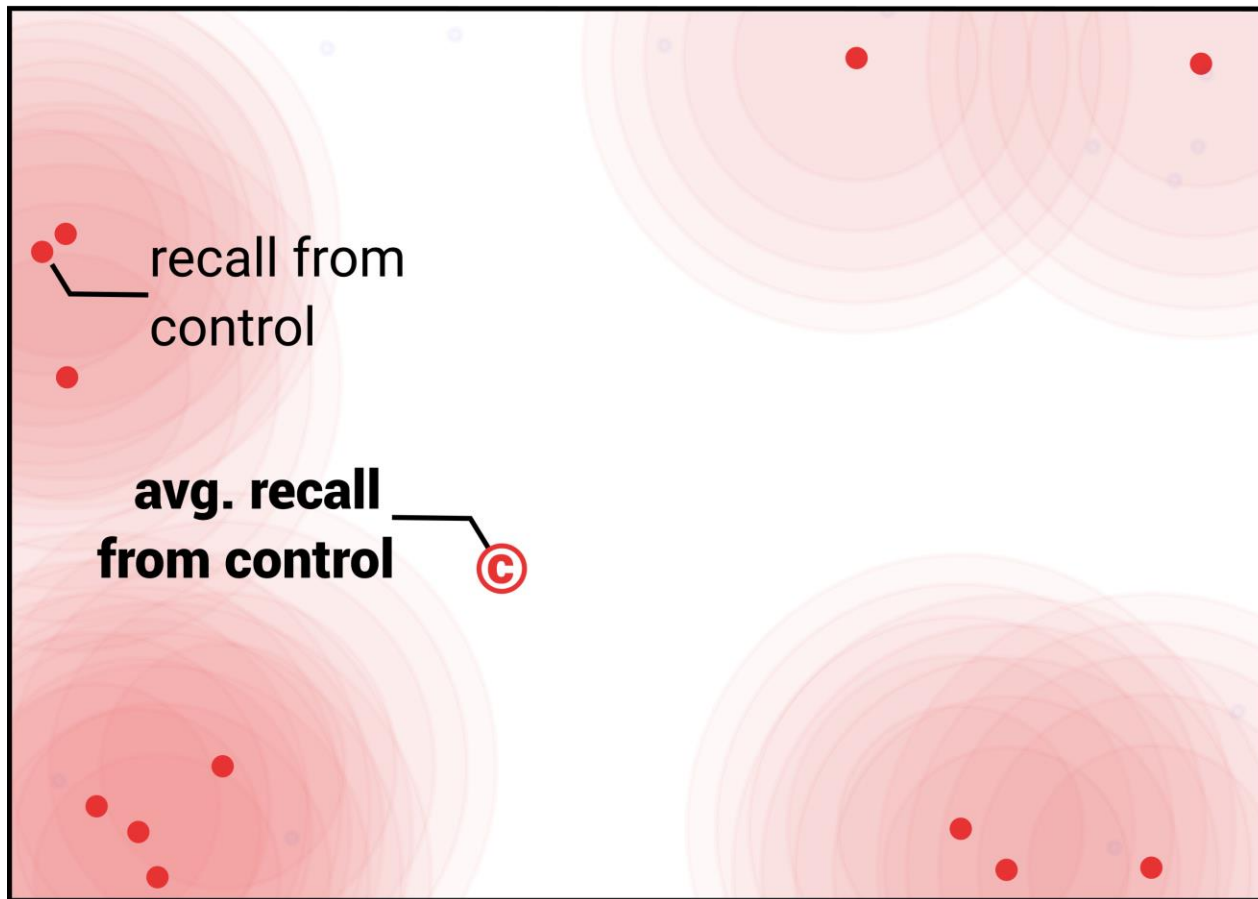


extinguisher



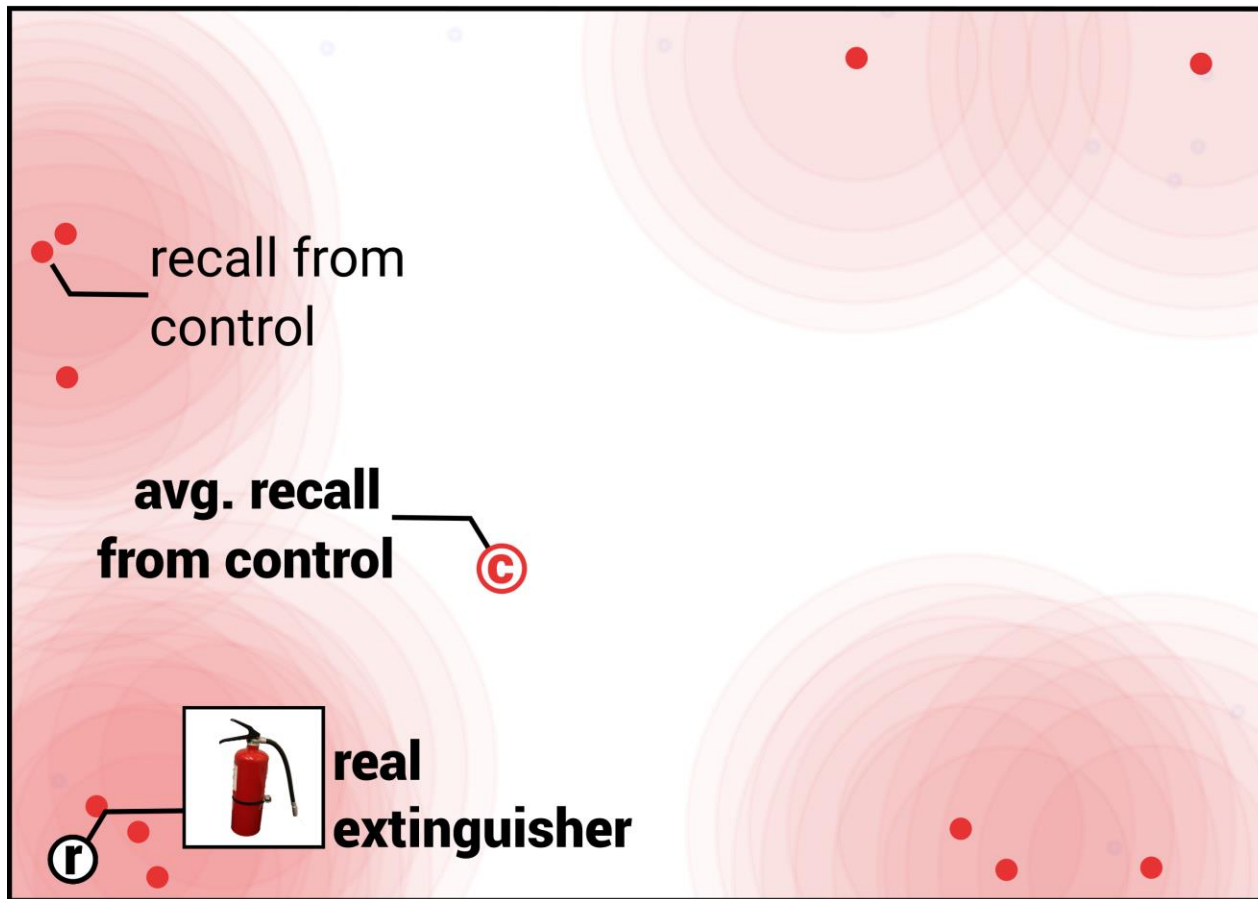


extinguisher



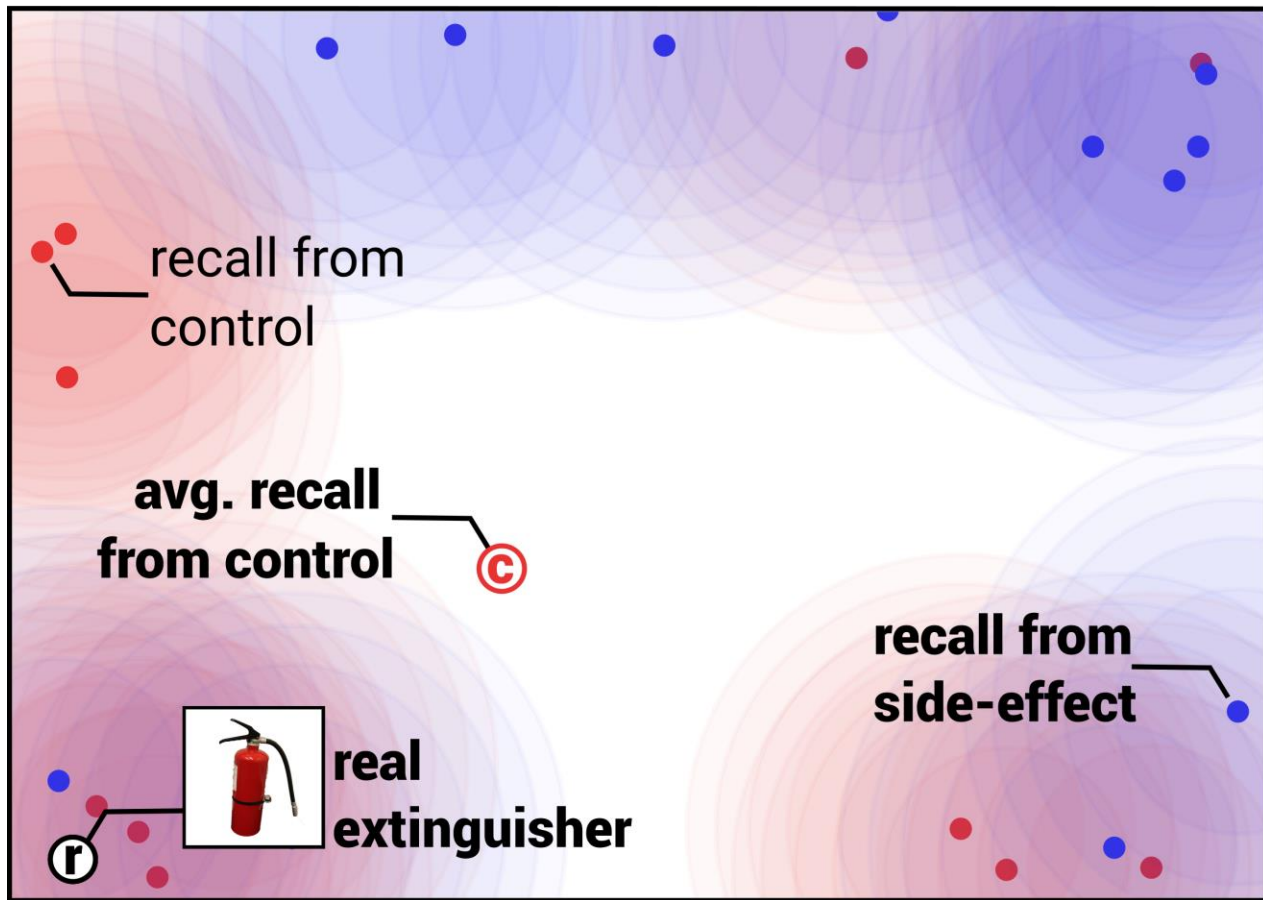


extinguisher



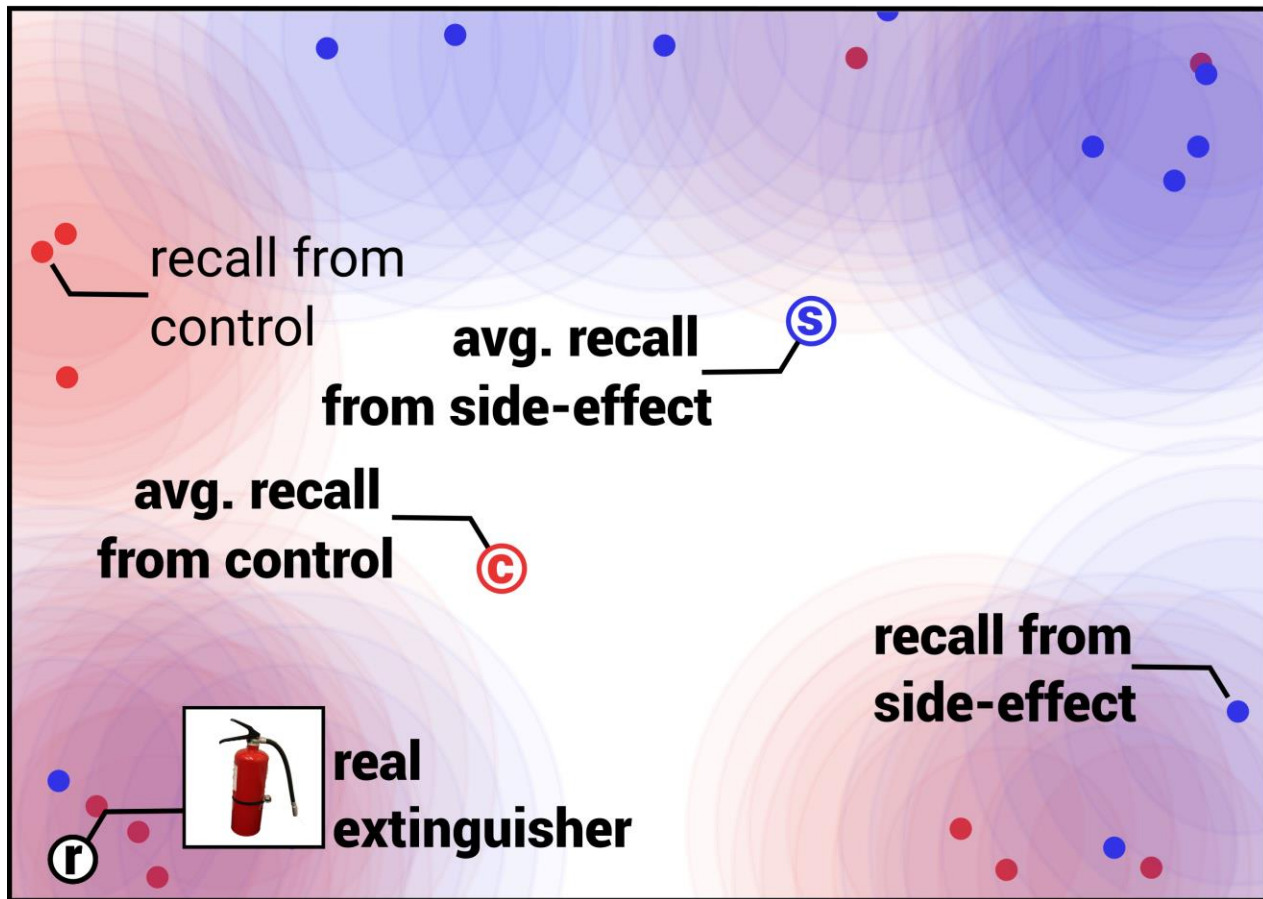


extinguisher



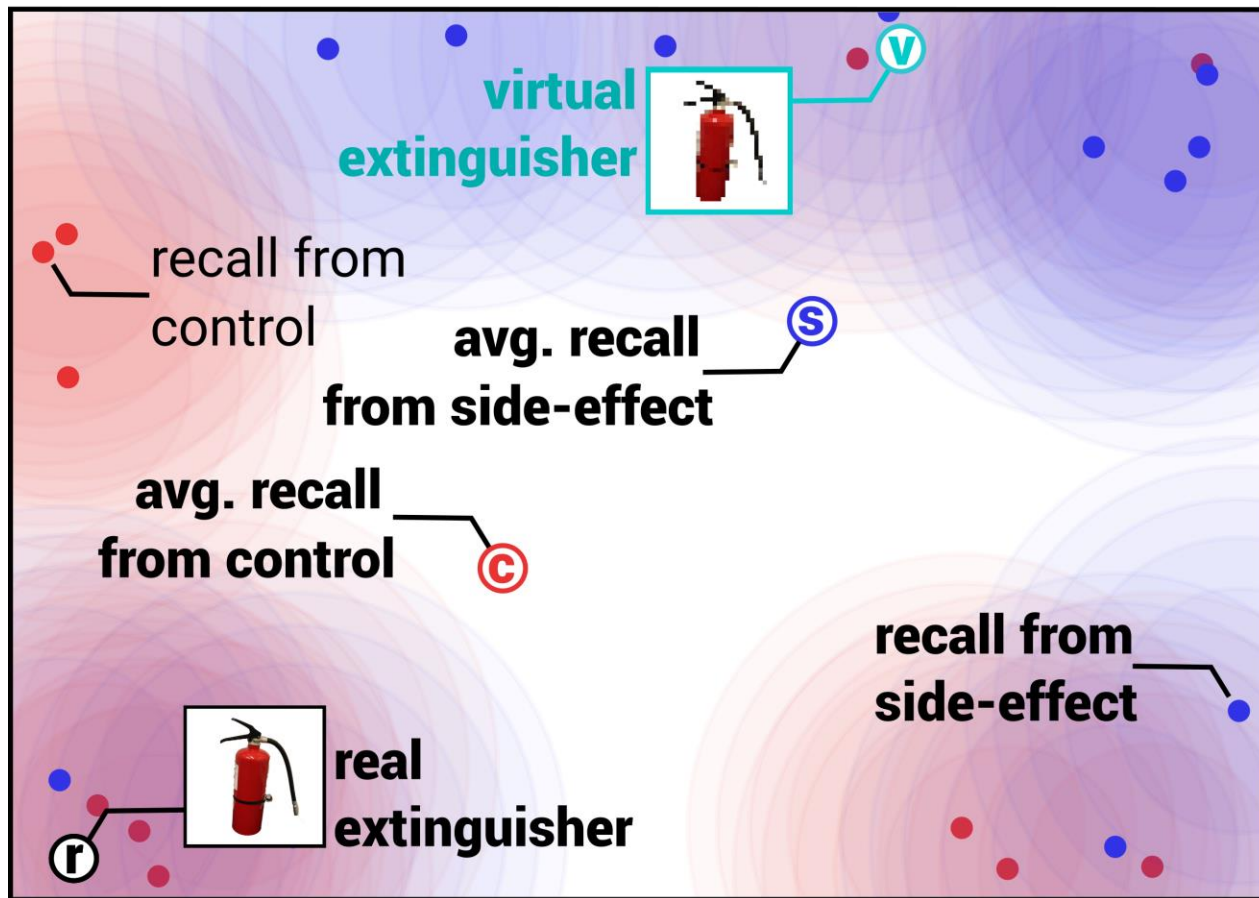


extinguisher



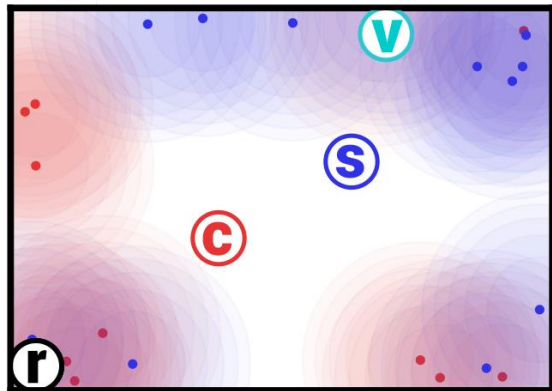


extinguisher

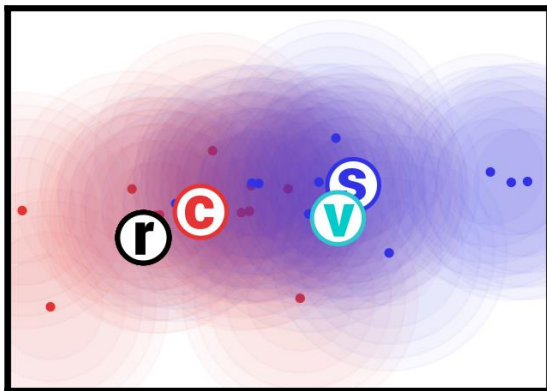




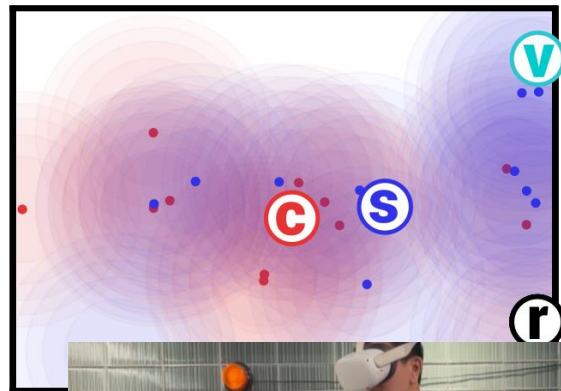
extinguisher



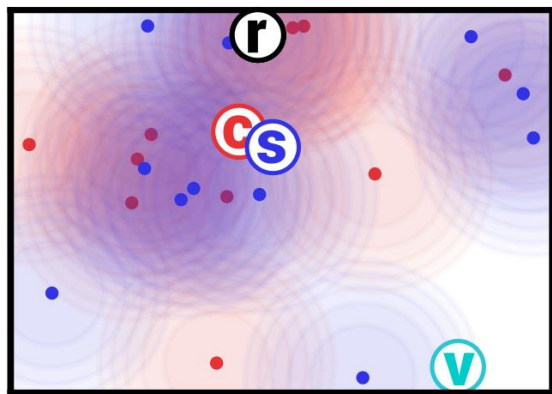
cup



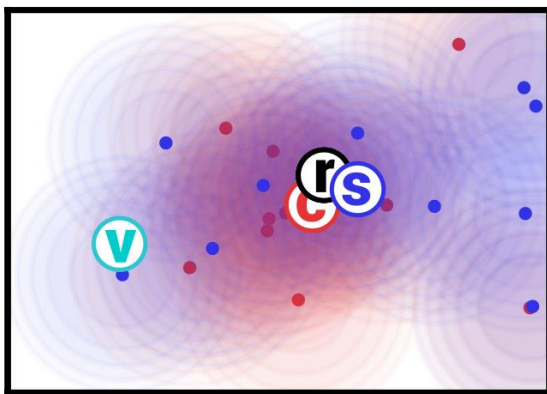
keyboard



paper box



paper stack



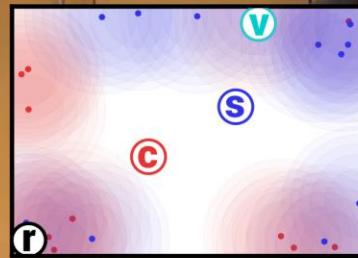
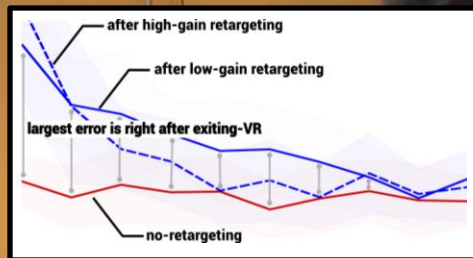
conclusion

study 1: movement side-effect

study 2: memory side-effect

VR side-effect

an unintended lingering adaptation leading to potential risks after leaving VR



footage from user study

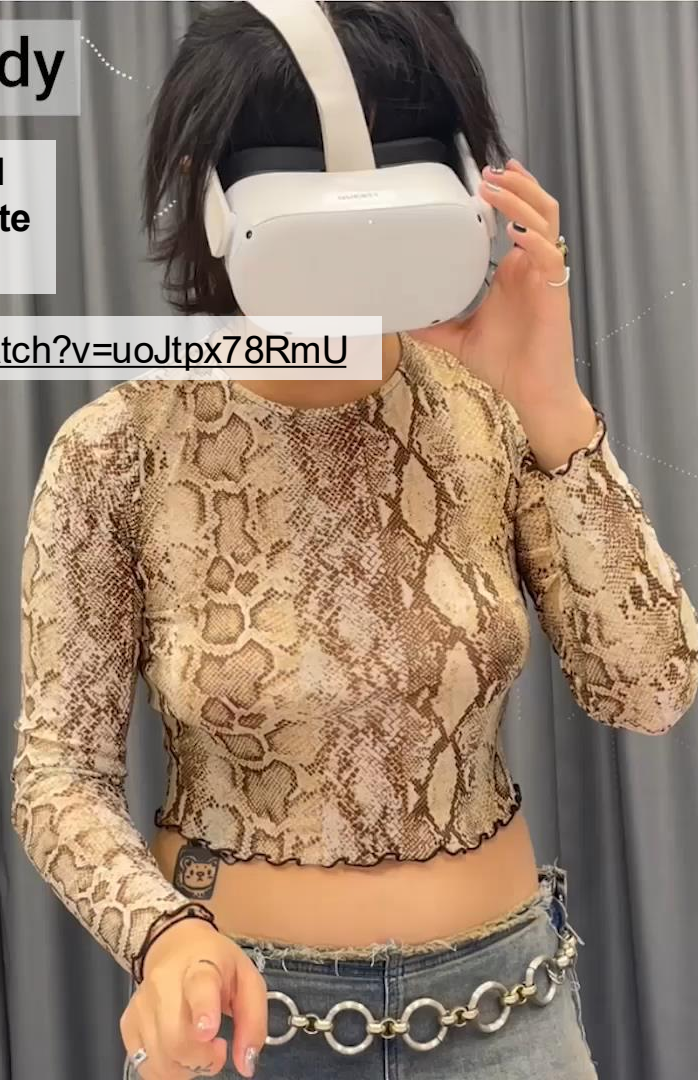
this is an additional study we conducted that you won't find in the paper, **we invite you to watch it on our video!**

see video: <https://www.youtube.com/watch?v=u0Jtpx78RmU>

real
extinguisher



virtual
extinguisher



call to action on VR side-effect

1. toward more empirical research
2. warn users ahead of time
3. label effect size
4. warn on exit
5. fading out the side-effect
6. avoid certain context/setups
7. Consider environmental risks

6 Design Suggestions and Call-To-Action for VR Side-effects

6 Design Suggestions

Side-effects

We propose a preliminary set of design suggestions for action for future VR creators & researchers.

A call-to-action for research on VR side-effects.

While research should follow to broaden our understanding of the side-effects that VR can induce side-effects in relatively unexplored areas. First, in this study, we

Design Suggestions

We propose a preliminary set of design suggestions for future VR creators & researchers.

1. A call-to-action for research on VR side-effects. While our work suggests that VR can induce side-effects in relatively unconstrained scenarios, more research should follow to broaden our understanding and better assess their risks. First, in this study, we only focused on a limited subset of the large variety of perceptual manipulations that can be presented to a VR user. Therefore, future work should investigate the potential of VR side-effects of other perceptual manipulations, such as walking curvature [53, 63], speed alteration [33], or alteration of one's virtual body structure [12], which would align with previous works reporting their influence on the occurrence of illusions within VR [19, 47]. Finally, additional research should continue exploring the different factors influencing movements and memory side-effects, for instance by addressing their aforementioned limitations.

Warn users ahead of time about the potential side-effects

Even though our study is quite simplistic, we suggest to warn users ahead of time about the potential side-effects. This could take the form of a warning message at the beginning of the VR experience, or a warning message during the experience if the user shows signs of discomfort. This could also be implemented as a warning message at the beginning of the VR experience, or a warning message during the experience if the user shows signs of discomfort. This could also be implemented as a warning message at the beginning of the VR experience, or a warning message during the experience if the user shows signs of discomfort.

2. **Warn users ahead of time about the potential side-effects.** While this might sound simplistic, we suggest to warn users ahead of time that they might experience side-effects. This could take the form of messages on the start-screen of the VR experience. For instance, a VR application using hand-retargeting could state: "This makes use of VR-effects that modify your movements such that you might experience some inaccuracy with your movements when using VR" or "This experience contains virtual objects that you might memorize the location of these items you might have around you. To understand the location of these items you might have around you, you might want to memorize the location of these items you might have around you."

Avoid certain objects/contexts/setup. While this design designer's goal, we recommend that they avoid certain objects, contexts, and setups if they are not critical for realizing the design. For example, avoid using VR headsets in public spaces, and avoid using VR headsets in public spaces.

6. Avoid certain design features. Objects or spaces are avoided if they are likely to cause confusion or discomfort to the user. For instance, unless necessary for reasons of experience, we recommend not altering attributes of the environment that relate to its safety (e.g., alarms, fire extinguishers, exit signage, escape routes, and so forth).

7. **Consider environmental risks.** Obviously, the side-effect depends on the environment it occurs in. As sets become more mobile, users wear them everywhere. Designers should consider in which scenarios these VRs will occur and take appropriate precautions regarding them. For instance, a VR experience at a theme park (a virtual roller coaster) is much less dangerous than a VR environment where users expect drastic experiences, such as a virtual driving simulator. A virtual driving simulator is much safer than one experienced at home, or while walking on a moving car [31, 49]. As such, designers can also include warnings/suggestions at the start of their VR experience to inform users about the risks of the VR experience in the usage context.

7 Conclusion

7 Conclusion

call to action on VR side-effect

1. toward more empirical research
2. warn users ahead of time
3. **label effect size**
4. warn on exit
5. fading out the side-effect
6. avoid certain context/setups
7. Consider environmental risks

6 Design Suggestions and Call-To-Action for VR Side-effects

6 Design Suggestions

Side-effects

We propose a preliminary set of design suggestions for action for future VR creators & researchers.

A call-to-action for research on VR side-effects.

While research should follow to broaden our understanding of the side-effects that VR can induce side-effects in relatively unexplored areas. First, in this study, we

our work suggests that VR can be used to assess the risks of different constrained scenarios, more research needs to be done to improve our understanding and better assess their risks. First, in the future, only focused on a limited subset of the large variety of perceptual manipulations that can be presented to a VR user. Therefore, other work should investigate the potential of VR side-effects of other perceptual manipulations, such as walking curvature [53, 63], speed alteration [33], or alteration of one's virtual body structure [12], which would align with previous works reporting their influence on the occurrence of illusions within VR [19, 47]. Finally, additional research should continue exploring the different factors influencing movements and memory side-effects, for instance by addressing the aforementioned limitations.

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While this might sound simplistic, we suggest to warn users ahead of time that they might experience side-effects. This could take the form of messages on the start-screen of the VR experience. For instance, a VR application using hand-retargeting could state: "this makes use of VR-effects that modify your movements such as you might experience some inaccuracy with your movements while using VR" or "this experience contains virtual objects which you might have around you. To memorize the location of these items you might have around you. To understand the well

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7. **Consider environmental risks.** Obviously, the side-effect depends on the environment it occurs in. As sets become more mobile, users wear them everywhere. Designers should consider in which scenarios these VRs will occur and take appropriate precautions regarding them. For instance, a VR experience at a theme park (a virtual roller coaster) is much less dangerous than a VR environment where users expect drastic experiences, such as a virtual driving simulator. A virtual driving simulator is much safer than one experienced at home, or while walking in a virtual city. As such, designers can also include safety instructions/suggestions at the start of their VR experience, depending on the usage context.

7 Conclusion

7 Conclusion

While a large amount of the HCI community has focused on understanding how users adapt to VR, in this paper, we focused on how they might need to adapt when returning to the real world. In that context, we report cases where even experienced VR users might experience a side-effect—an unwelcome change in behavior—leading to potential risks. Specifically, we found that VR use can lead to side-effects, with setting significantly lessening the magnitude of side-effects. Our results: movement side-effects (a side effect of using VR to move) and memory-side effects (a side effect of using VR to remember) can be reduced by setting. The user's real environment can be used to reduce the user's side-effects occurring when returning to the real world.

call to action on VR side-effect

1. toward more empirical research
2. warn users ahead of time
3. label effect size
4. warn on exit
5. **fading out the side-effect**
6. avoid certain context/setup
7. Consider environmental risks

VR Side-Effects: Memory & Proprioceptive Discrepancies After Leaving Virtual Reality

6 Design Suggestions and Call-To-Action for VR Side-effects

We propose a preliminary set of design suggestions and a call-to-action for future VR creators & researchers.

1. A call-to-action for research on VR side-effects. While our work suggests that VR can induce side-effects in relatively unconstrained scenarios, more research should follow to broaden our understanding and better assess their risks. First, in this study, we only focused on a limited subset of the large variety of perceptual manipulations that can be presented to a VR user. Therefore, future work should investigate the potential of VR side-effects of other perceptual manipulations, such as walking curvature [53, 63], speed alteration [33], or alteration of one's virtual body structure [12], which would align with previous works reporting their influence on the occurrence of illusions within VR [19, 47]. Finally, additional research should continue exploring the different factors influencing movements and memory side-effects, for instance by addressing their aforementioned limitations.

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work in the case where users abruptly leave VR (e.g., emergency VR headset crash, and so forth).

6. Avoid certain objects/context/setup. While this depends heavily on the designer's goal, we recommend that certain objects or spaces are avoided if they are not critical for the experience. For instance, unless necessary for realizing the experience, we recommend not altering attributes of objects that relate to its safety (e.g., alarms, fire extinguishers, exit signage, escape routes, and so forth).

7. Consider environmental risks. Obviously, the side-effect depends on the environment it occurs in. As VR sets become more mobile, users wear them everywhere. Designers should consider in which scenarios these VR side-effects will occur and take appropriate precautions regarding the environment where users expect drastic experience changes. For instance, a VR experience at a theme park (a moving car [31, 49]). As such, designers can also include warnings/suggestions at the start of their VR experience in the usage context.

7 Conclusion

While a large amount of the HCI community in how users adapt to VR, in this paper, we report how they might need to adapt when returning to that context, we report cases where even a short VR experience can lead to side-effects—an unwanted side-effect—leading to potential risks. Specifically, we report side-effects, with setting significantly less than expected results: movement side-effects (a side effect of hand retargeting) and memory-side effects (the user's real environment affects their VR experience).



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If you need a PPTX/editable version for your class, email us hci@uchicago.edu

More on this paper (or others of our lab) at: <https://lab.plopes.org/#VR-side-effects>



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