ACM VRST'25 MONTREAL

AR-TMT: Investigating the Impact of Distraction Types on Attention and Behavior in AR-based Trail Making Test

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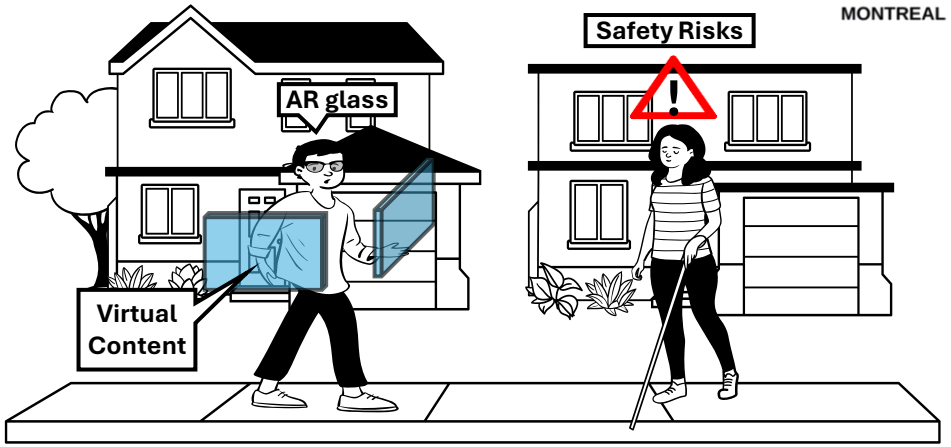
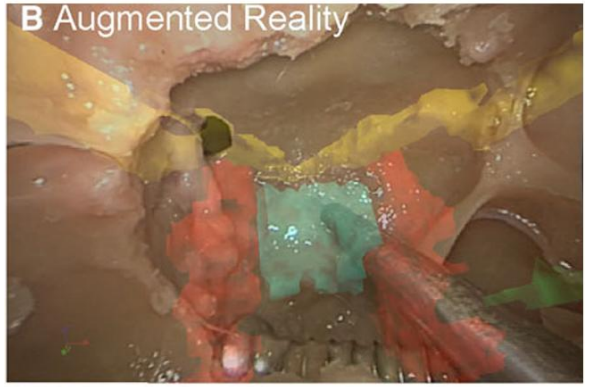
Motivation

- **Safety risks** of **distraction [1]** or **inattentional blindness [2]** from visually complex scenes in AR environment
- The importance of **understanding distraction** for attention-aware AR system
- Distraction effect could vary with **its features** and **context**.





Inattentional Blindness in AR [2]

[1] Kim, Hyungil, and Joseph L. Gabbard. "Assessing distraction potential of augmented reality head-up displays for vehicle drivers." Human factors 64.5 (2022): 852-865.
[2] Dixon, Benjamin J., et al. "Inattentional blindness increased with augmented reality surgical navigation." American journal of rhinology & allergy 28.5 (2014): 433-437.

Research Questions

- **RQ1:** How can distractions in AR be **categorized** by attentional mechanisms?
- **RQ2:** How do **different distraction types** affect users' **attention** and **behavior**?
- **RQ3:** How does users' **attention control** influence their **vulnerability to distraction** in AR environments?

Contributions

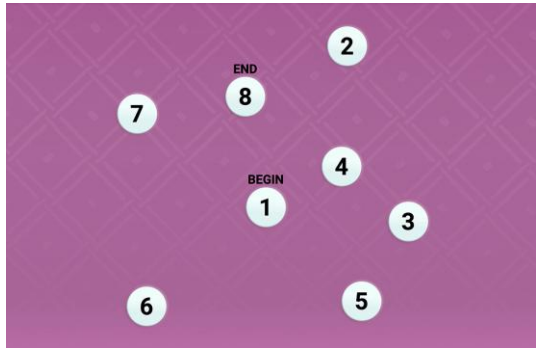
- Built the **AR-TMT application** using **Guided search model** and **Trail Making Test** to systematically categorize and analyze distraction mechanisms.

- Evaluated **each distraction type's impact** on performance, gaze, motor, and subjective measures.

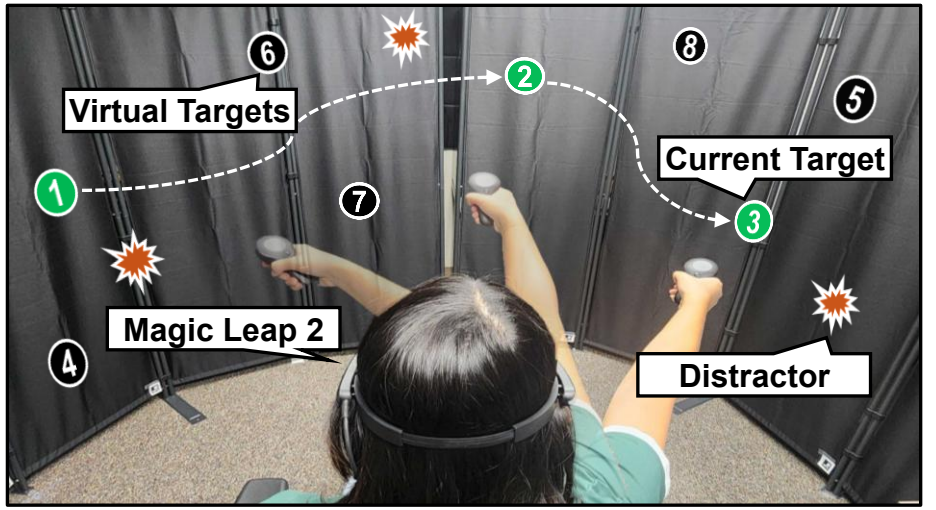
- Identified that **performance** correlates with **individual attention control** (R^2 = 0.20-0.35) under object-based distraction conditions.

Approach: Task

- AR adaptation of **Trail Making Test (TMT) [3]** as a cognitively demanding visual search task in AR
- Structured sequence with **multiple cognitive processes** (visuomotor speed, working memory, visual attention, etc.)
- **Well-suited to examine distraction mechanisms** for AR scenarios (e.g. industrial operation, surgical procedure)



Classic Trail Making Test [3]

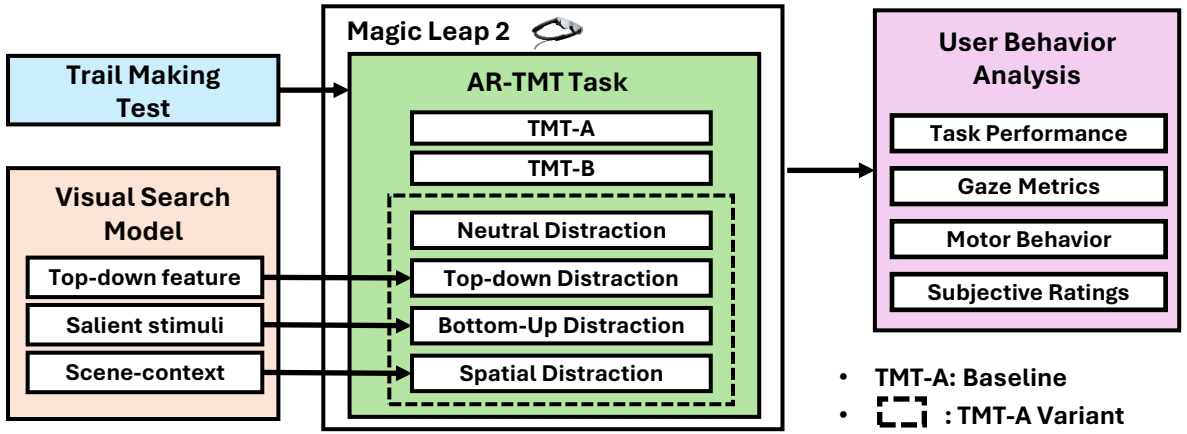


Experiment Setup

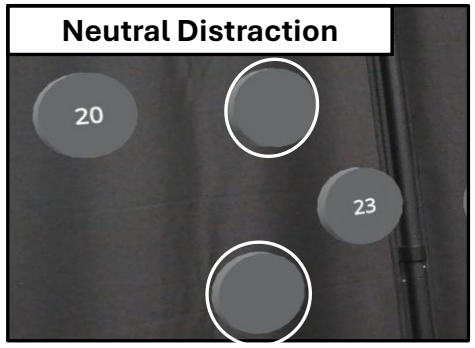
[3] Bowie, Christopher R., and Philip D. Harvey. “Administration and interpretation of the Trail Making Test .” Nature protocols 1.5 (2006): 2277-2281.

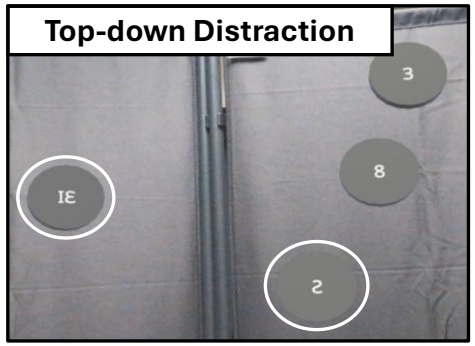
Approach: Attentional Framework

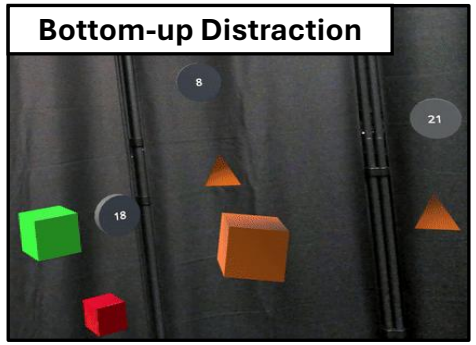
- **Guided Search model** [4] describes factors affecting attention
  - **Top-down feature (goal)**
  - **Salient stimuli**
  - **Scene-context**
  - History (priming)
  - Value

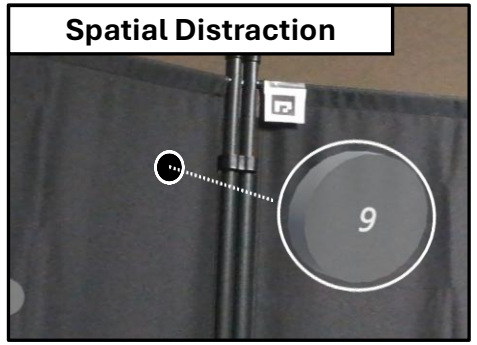


Experiment Framework





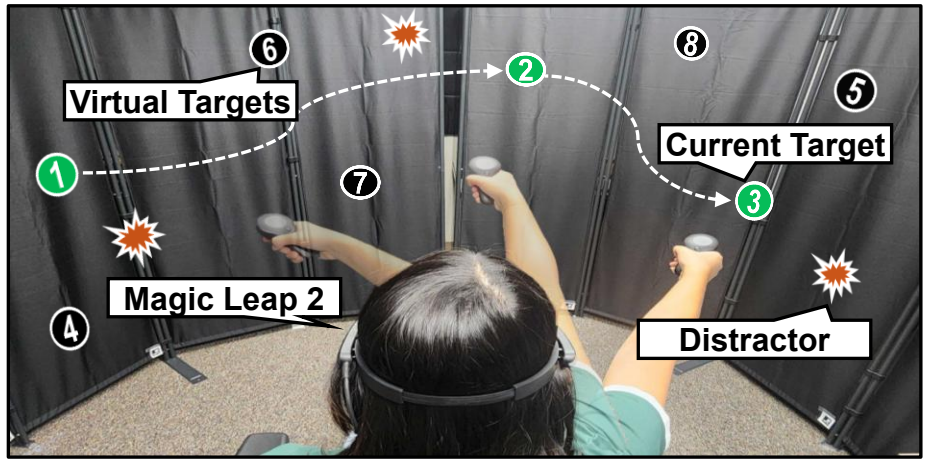




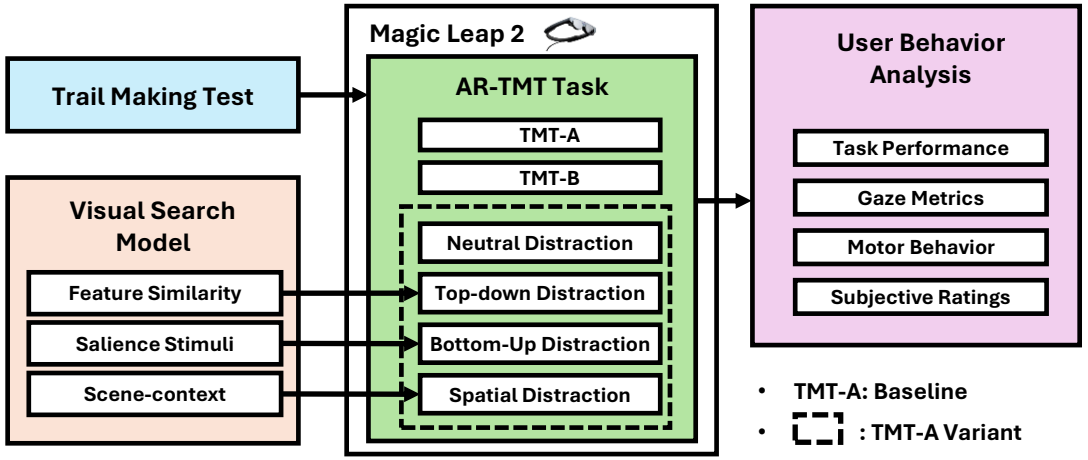
[4] Wolfe, Jeremy M., and Tod S. Horowitz. “Five factors that guide attention in visual search.” Nature human behaviour 1.3 (2017): 0058.

Experiment

- A **mixed-design user study** with **34 participants**
- Independent variables: **six stages** (counterbalanced) and **attention control**
- Measures: completion time, fixation, saccade, gaze entropy, controller movement, subjective ratings (mental demand, subjective distractedness, spatial discomfort)
- Control condition (baseline) : no distraction stage (TMT-A)



Experiment Setup



Experiment Framework

Key findings: Distraction Types

*: p<.05, **p<.01, ***: p<.001

- **Top-down Distraction (TD)**
  - ↑ (2×***) completion time, ↑ (97%***) mental demand rating
  - ↑ (12.4%***) fixation rate, ↓ (-12.1%***) mean fixation duration

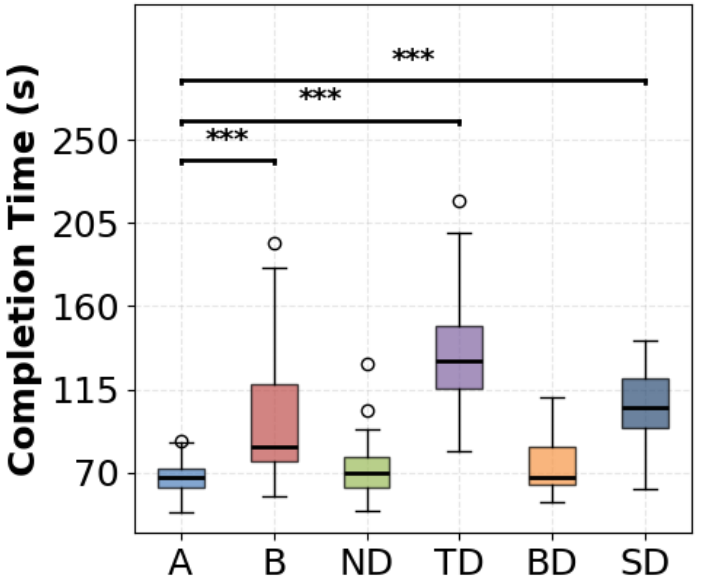
  ▶**Constant attention capture to distractors by target-distractor ambiguity**

- **Bottom-up Distraction (BD)**
  - Total completion time *ns*, ↑ (2.4×***) initial reaction time
  - ↓ (-5.3%**) spatial gaze entropy (**signal suppression hypothesis [5]**)

  ▶ **Involuntary transient attention capture**

- **Spatial Distraction (SD)**
  - ↑ (6.6%**) spatial and ↑ (4.0%**) temporal gaze entropy

  ▶ **Reduced search efficiency by randomized gaze pattern**

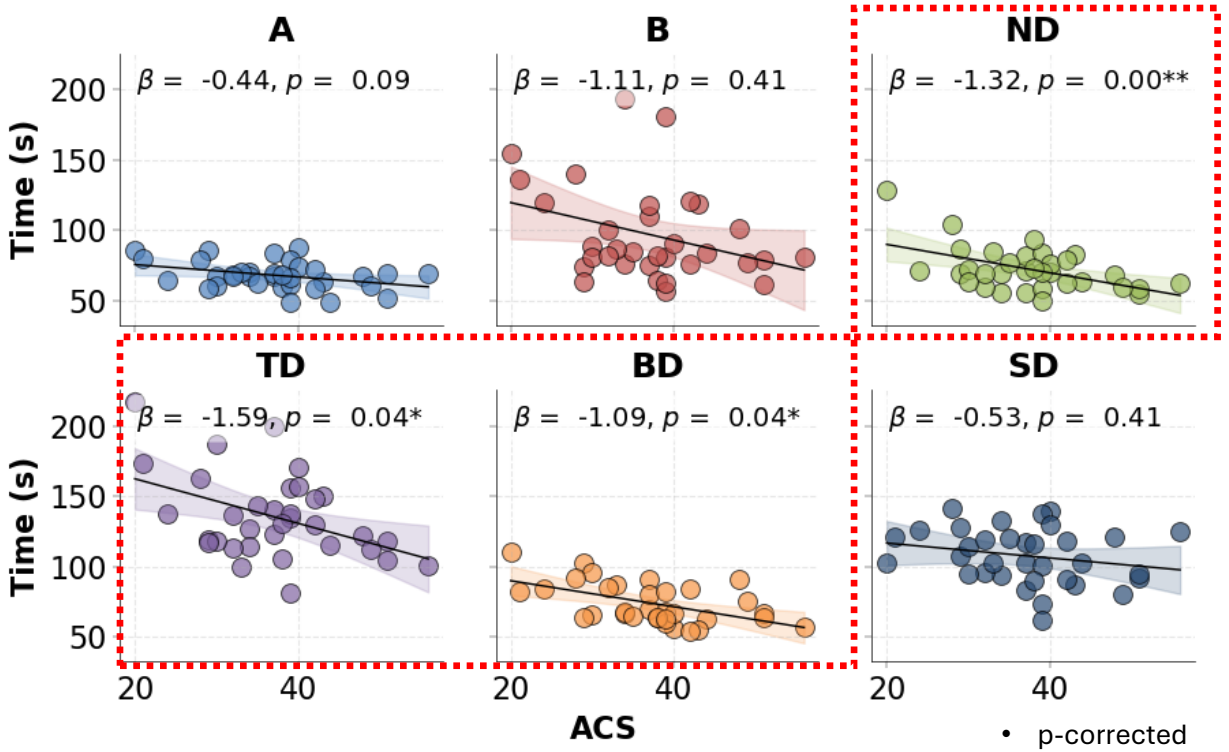


Completion time across stages

[5] Stilwell, Brad T., et al. "The role of salience in the suppression of distracting stimuli." *Psychonomic Bulletin & Review* 30.6 (2023): 2262-2271.

Key findings: Attention Control

- Measured **Attention Control Score (ACS)** of users with Flanker Squared test [6]
- **Correlation** between **performance** and **ACS** (R^2 = 0.20-0.35) in Neutral, Top-down, and Bottom-up distraction
- Distractors with **task-set representations [7]**
  - **Increase attentional capture** and require executive control
  - Attention control as a predictor of performance

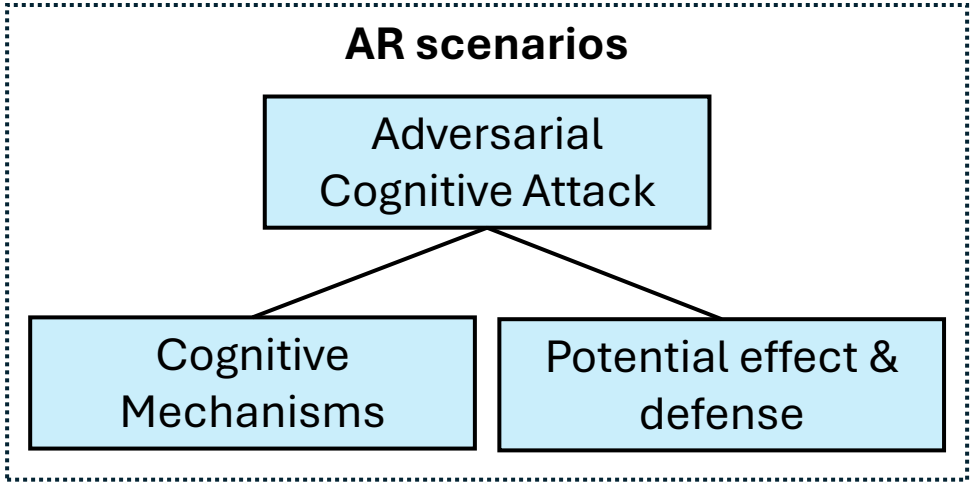


Performance vs ACS across stages

[6] Burgoyne, Alexander P., et al. "Nature and measurement of attention control." *Journal of Experimental Psychology: General* 152.8 (2023): 2369.
[7] Oberauer, Klaus. "The meaning of attention control." *Psychological Review* (2024).

Conclusion & Implication

- Distraction affects users' **attention** and **behavior differently** based on different attentional factors.
- **Attention control of individuals** is associated with their **distraction vulnerability in AR**.
- Findings have potential to extend to ecologically relevant AR scenarios for **cognitive security** or **attention-aware AR interface design.**



Thank you for your attention!

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Paper PDF

Code Repo

Demo Video

Acknowledgements

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