# IEEE VR

IEEE COMPUTER SOCIETY

IEEE

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Make Virtual Reality diverse and accessible

# Eye Fixation Forecasting in Task-Oriented Virtual Reality

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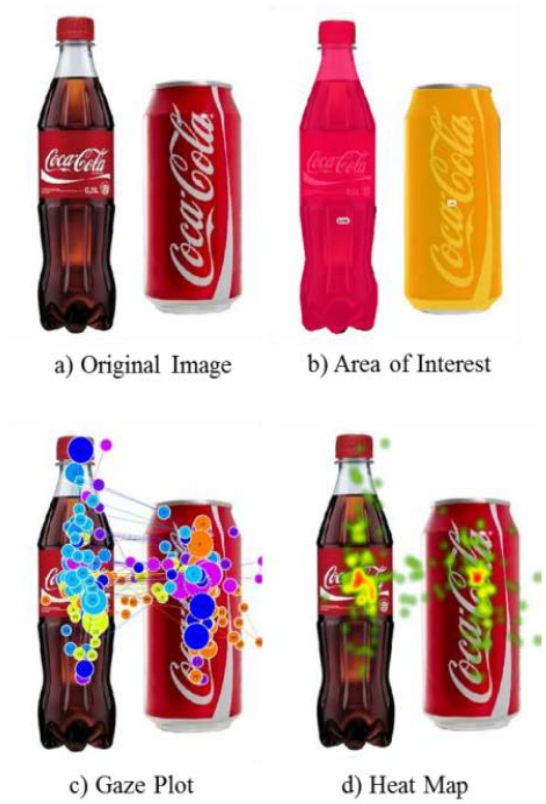
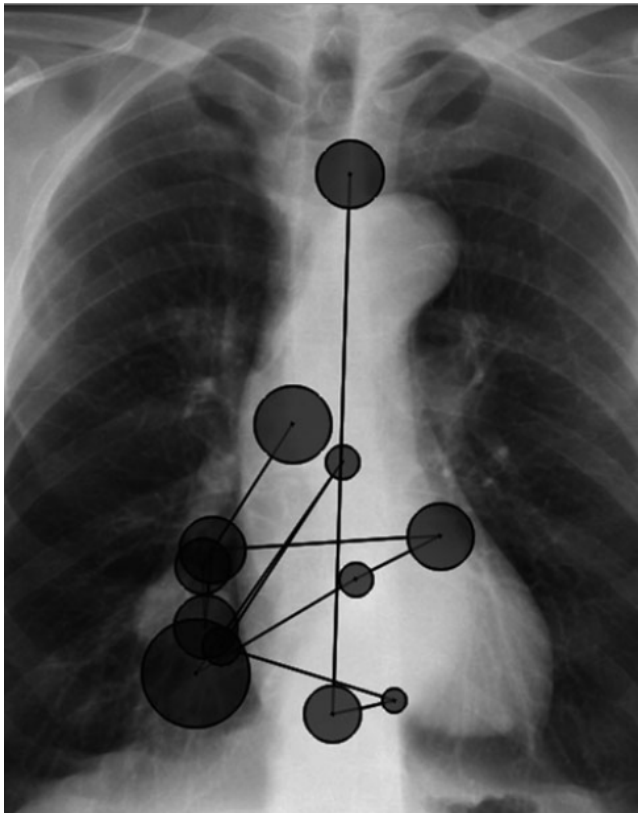
cranehzm.github.io/EyeFixation

## Human Visual Attention

# Background

## Application of Visual Attention



Marketing Strategy Analysis [Zamani et al. 2016]

Cognitive Research [Kiefer et al. 2017]

Medical Education [Kok et al. 2017]

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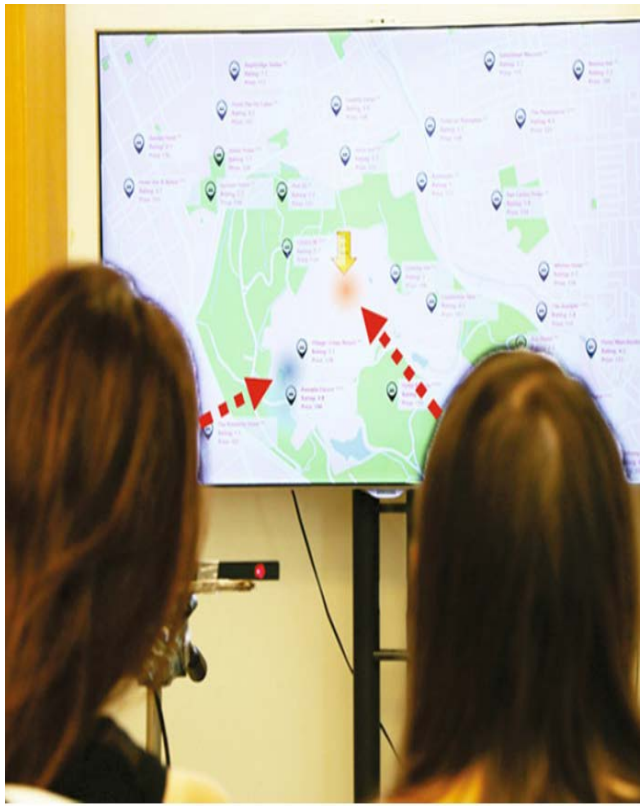
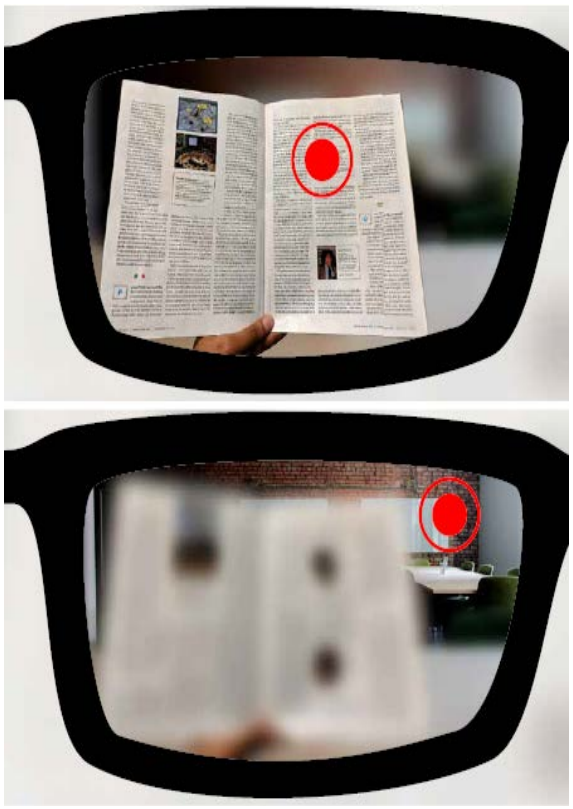
## Application of Visual Attention

Gaze-based Interaction
[Pfeiffer et al. 2008]



Collaborative System
[Zhang et al. 2017]



Gaze-contingent Eyeglasses
[Padmanaban et al. 2019]

# Background

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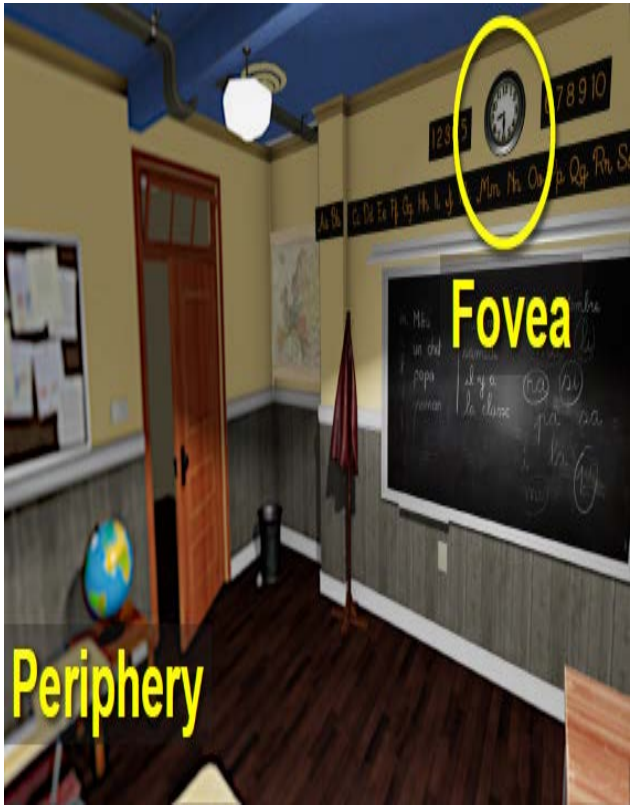
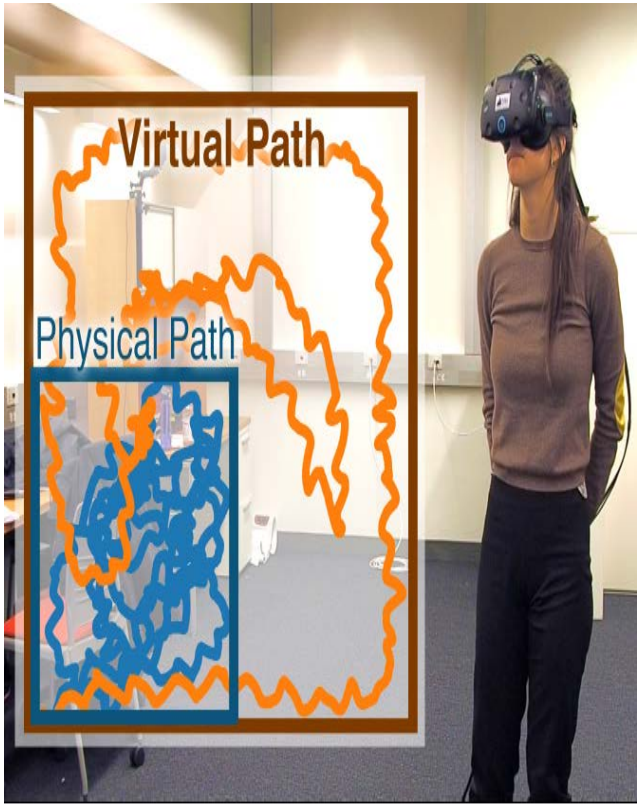
## Application of Visual Attention in VR




Gaze-contingent Rendering
[Patney et al. 2016]




Redirected Walking
[Sun et al. 2018]

Layout Optimization
[Alghofaili et al. 2019]

# Background

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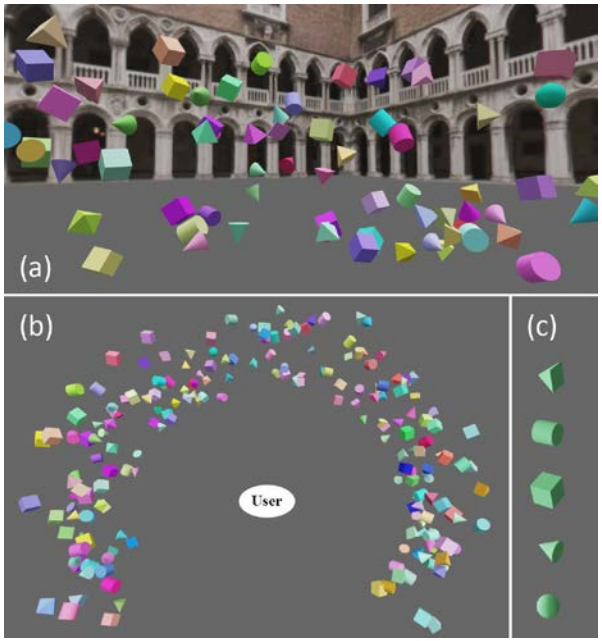
## Application of Visual Attention in VR

VR Content Design
[Sitzmann et al. 2018]




Gaze Guidance
[Grogorick et al. 2017]

LOD Management
[Lee et al. 2009]

# Background

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## Research Goals

- Analyze and reveal the characteristics of users' task-oriented visual attention in virtual reality
- Forecast (temporally predict future) eye fixations based on the characteristics of visual attention

# Related Work

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## Salient Object Detection

Top: Original Images; Bottom: Salient Objects

[1] https://mmcheng.net/msra10k/

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## Saliency Prediction

Top: Original Images; Bottom: Saliency Maps

[1] http://saliency.mit.edu/results_mit300.html

# Related Work

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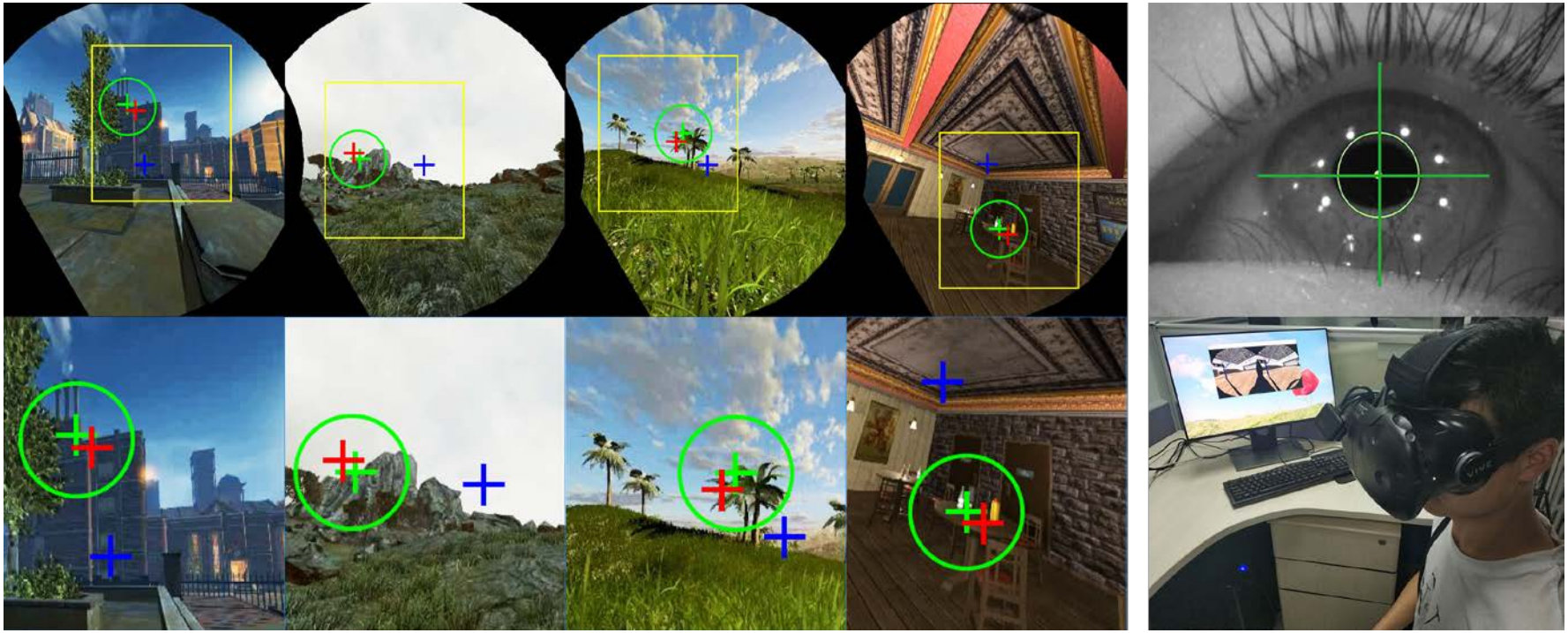
## Visual Attention Prediction in VR



Gaze Prediction in Static Free-Viewing Virtual Environments
[Hu et al. 2019]

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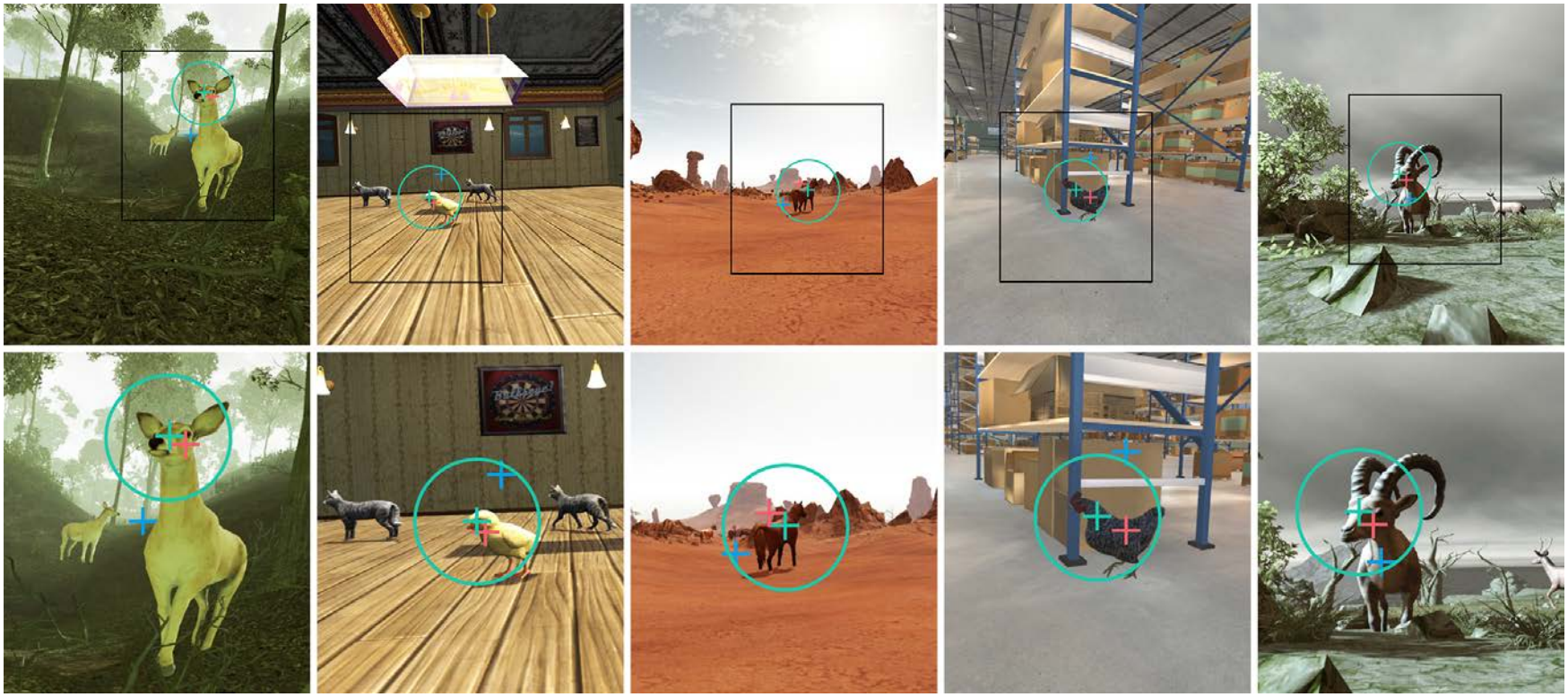
## Visual Attention Prediction in VR



Gaze Prediction in Dynamic Free-Viewing Virtual Environments
[Hu et al. 2020]

# Related Work

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Our Work *vs.* Previous Work

- Prediction Goal

**Eye Fixations** *vs.* Salient Objects, Saliency Maps

- Scene

**Immersive Virtual Environments** *vs.* Images, Videos

**Task-Oriented Situations** *vs.* Free-Viewing Conditions

# Current Research

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- Propose a novel learning-based fixation prediction model (*FixationNet*)
- Analyze and reveal the characteristics of users' task-oriented visual attention in VR
- Build a task-oriented VR eye tracking dataset

# Data Collection

- Participants: 27 users (15 male, 12 female, ages 17-32)
- Stimuli: four immersive virtual environments
- Apparatus: HTC Vive, eye tracker
- Procedure: visual search task
- Data: VR content, task-related objects, eye fixations, head movements

Stimuli

# Data Collection

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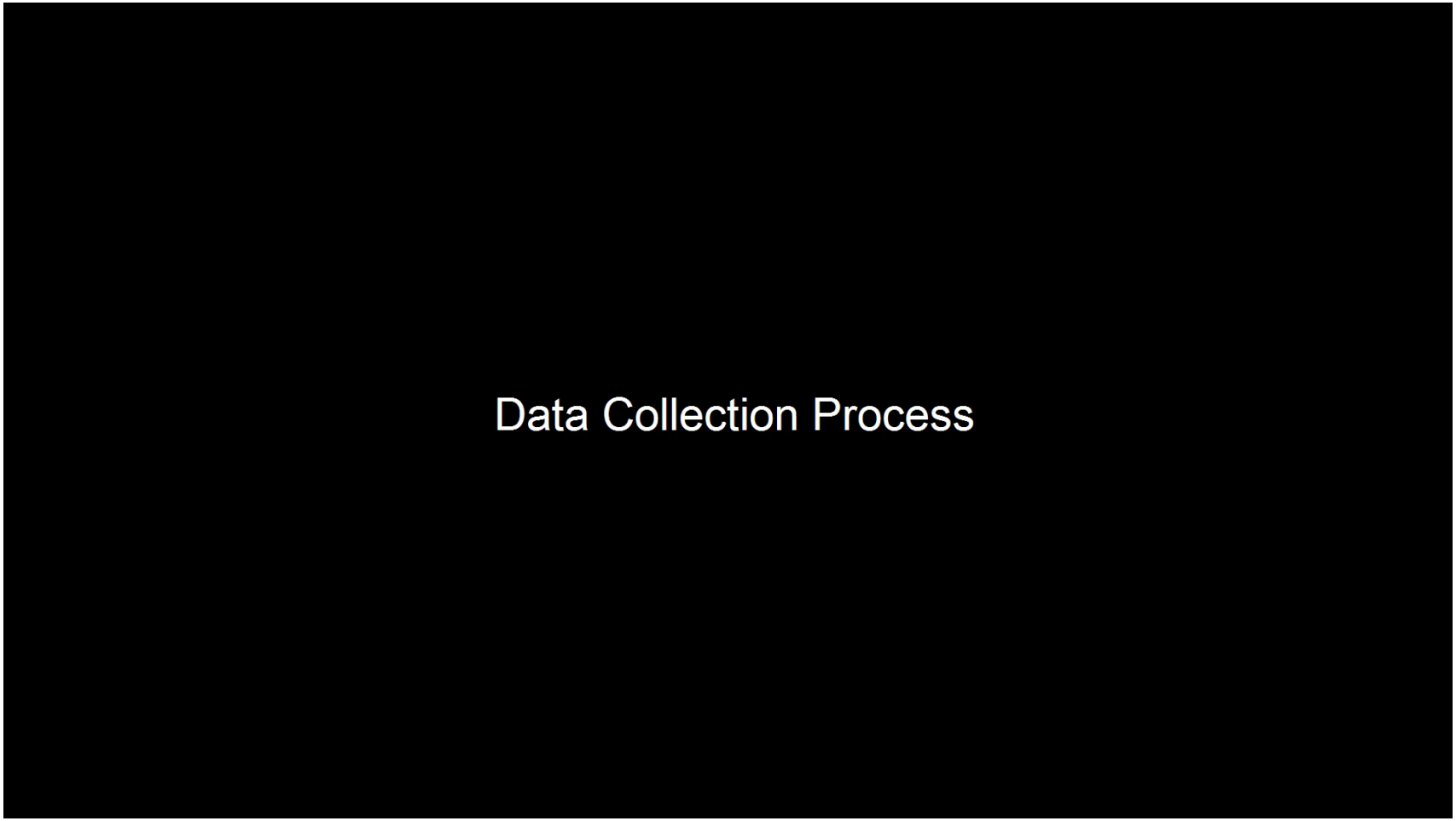
## Data Collection Process



# Analysis of Eye Fixation

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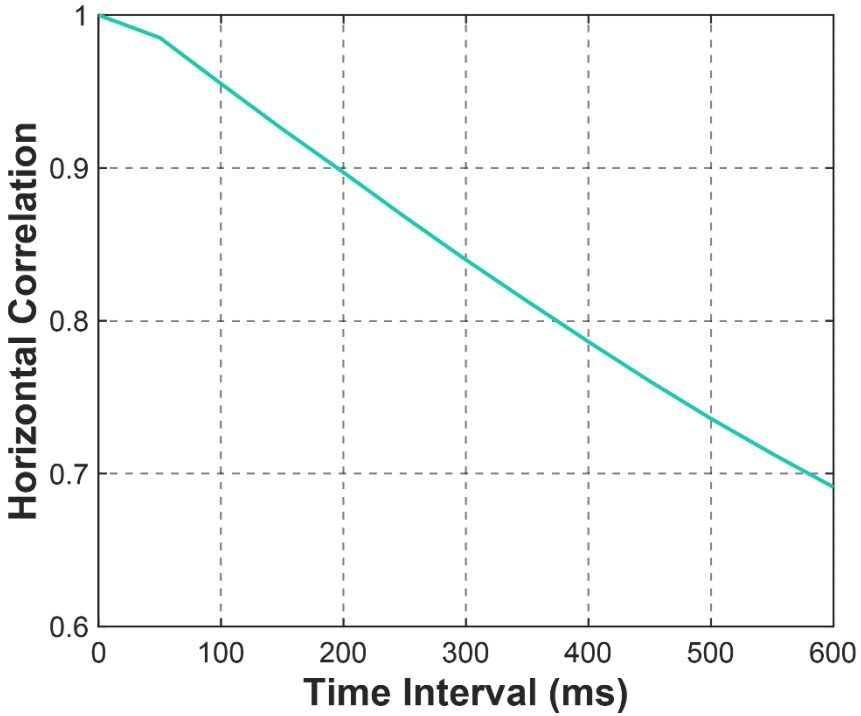
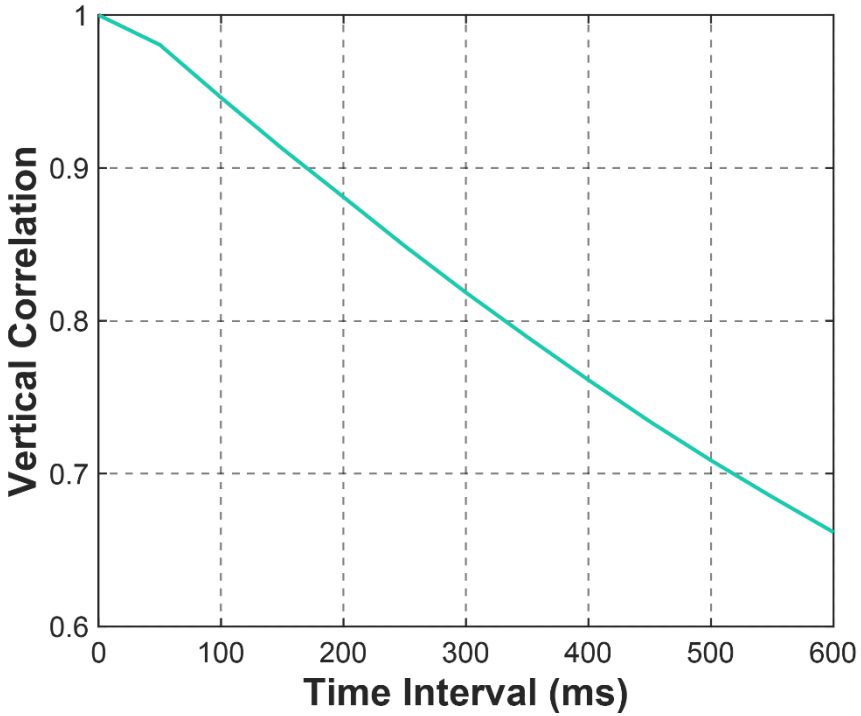
## Fixation-Gaze Correlation




Fixation-gaze correlations in the horizontal (left) and vertical (right) directions

Eye fixations are highly correlated with historical gaze positions

# Analysis of Eye Fixation

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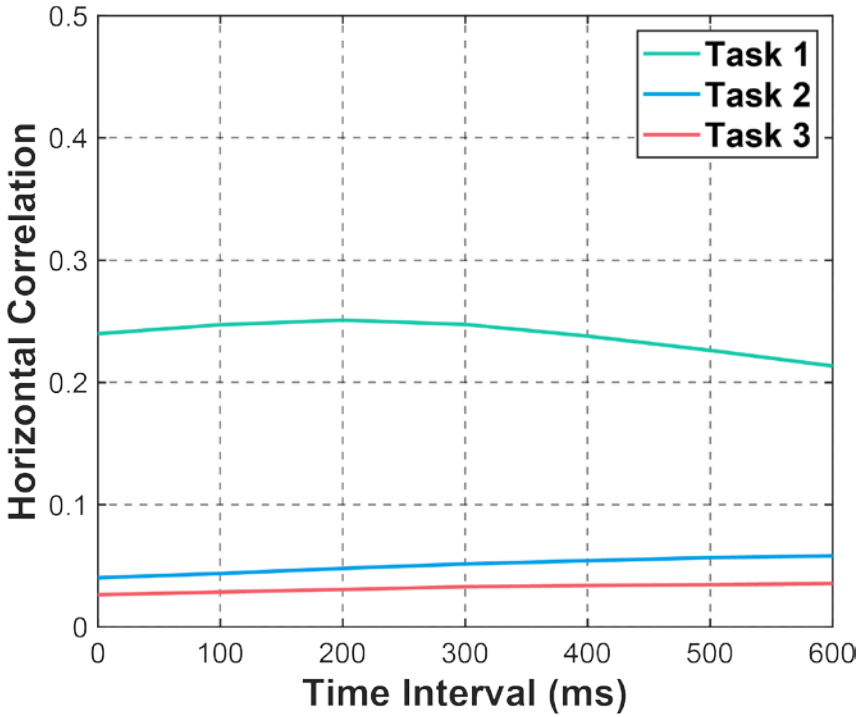
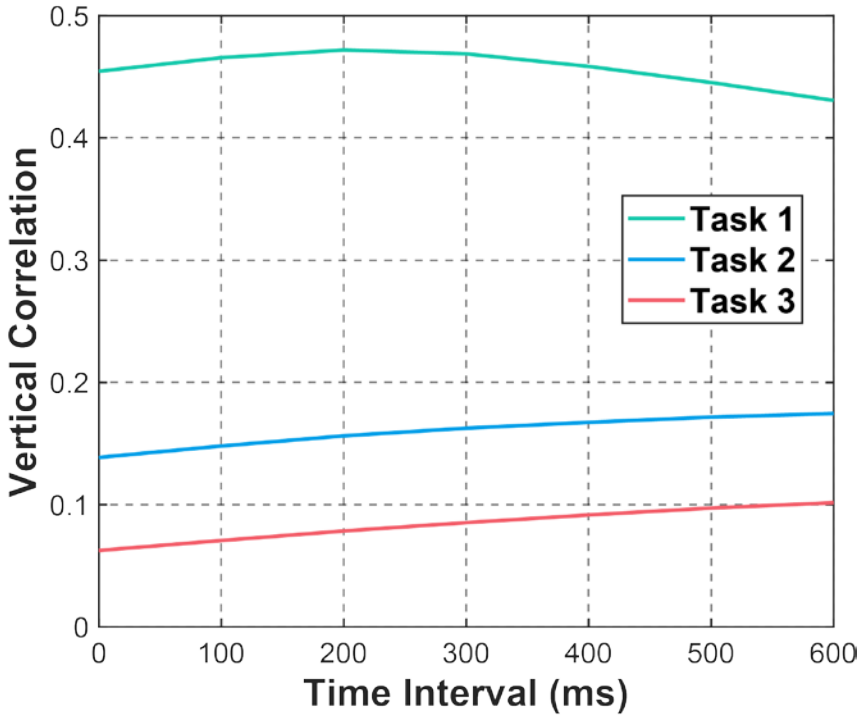
## Fixation-Task Correlation




Fixation-task correlations in the horizontal (left) and vertical (right) directions

Fixations are correlated with task-related objects

# Analysis of Eye Fixation

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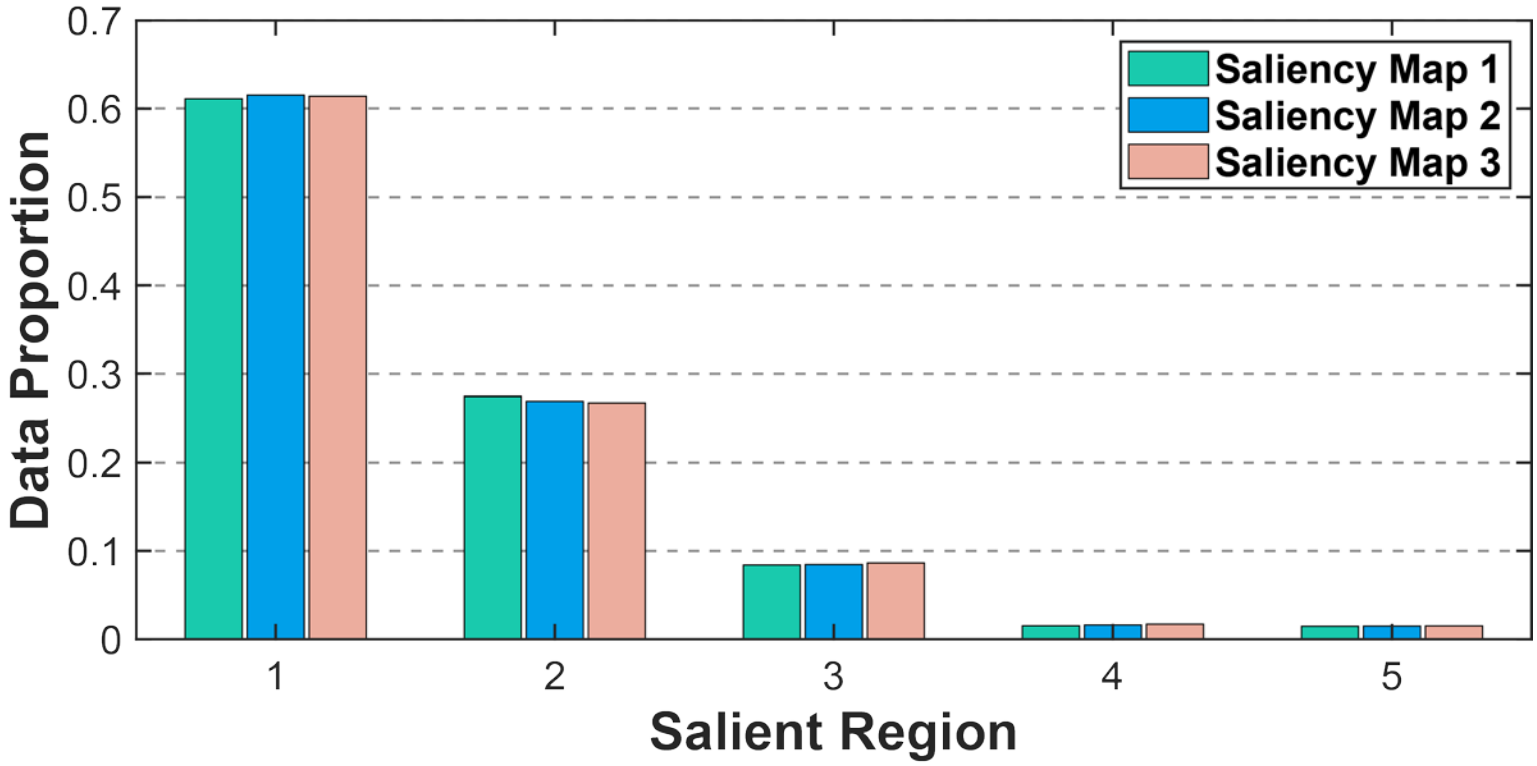
## Fixation-Saliency Correlation




The distribution of users' fixation positions on the salient regions

The fixation positions are mostly located in the regions with high saliency values

# Analysis of Eye Fixation

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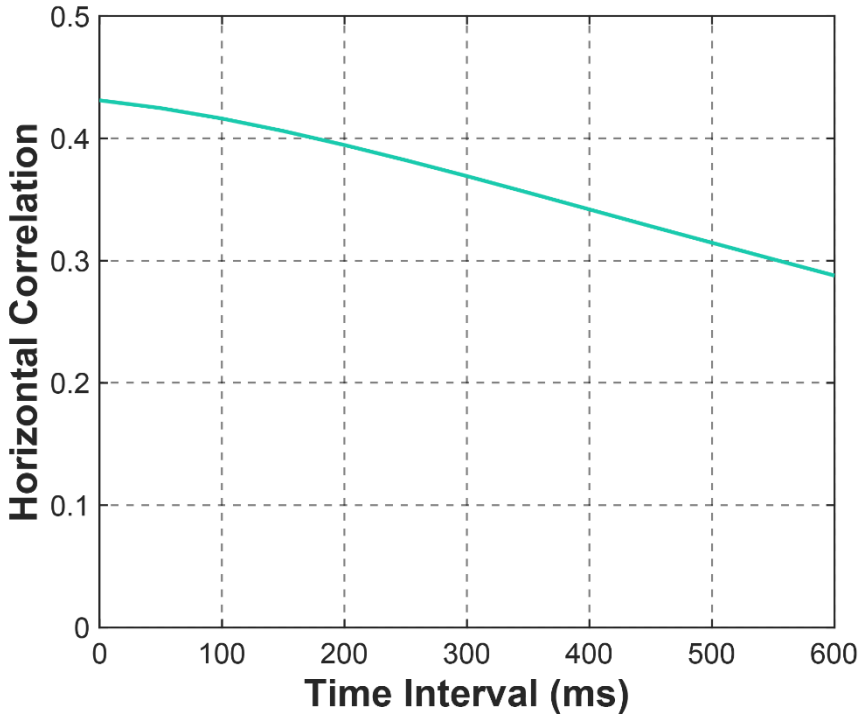
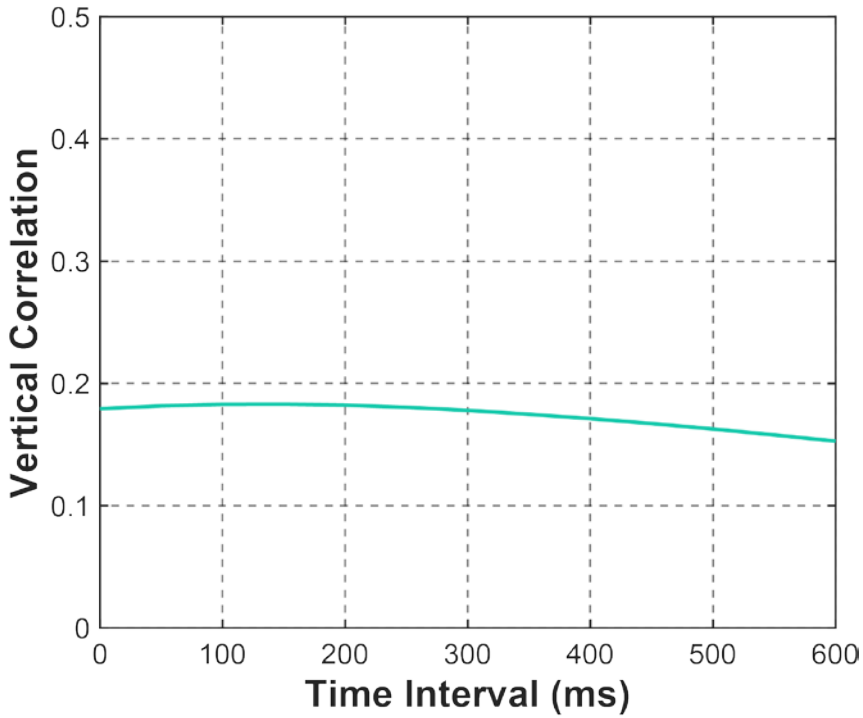
## Fixation-Head Correlation

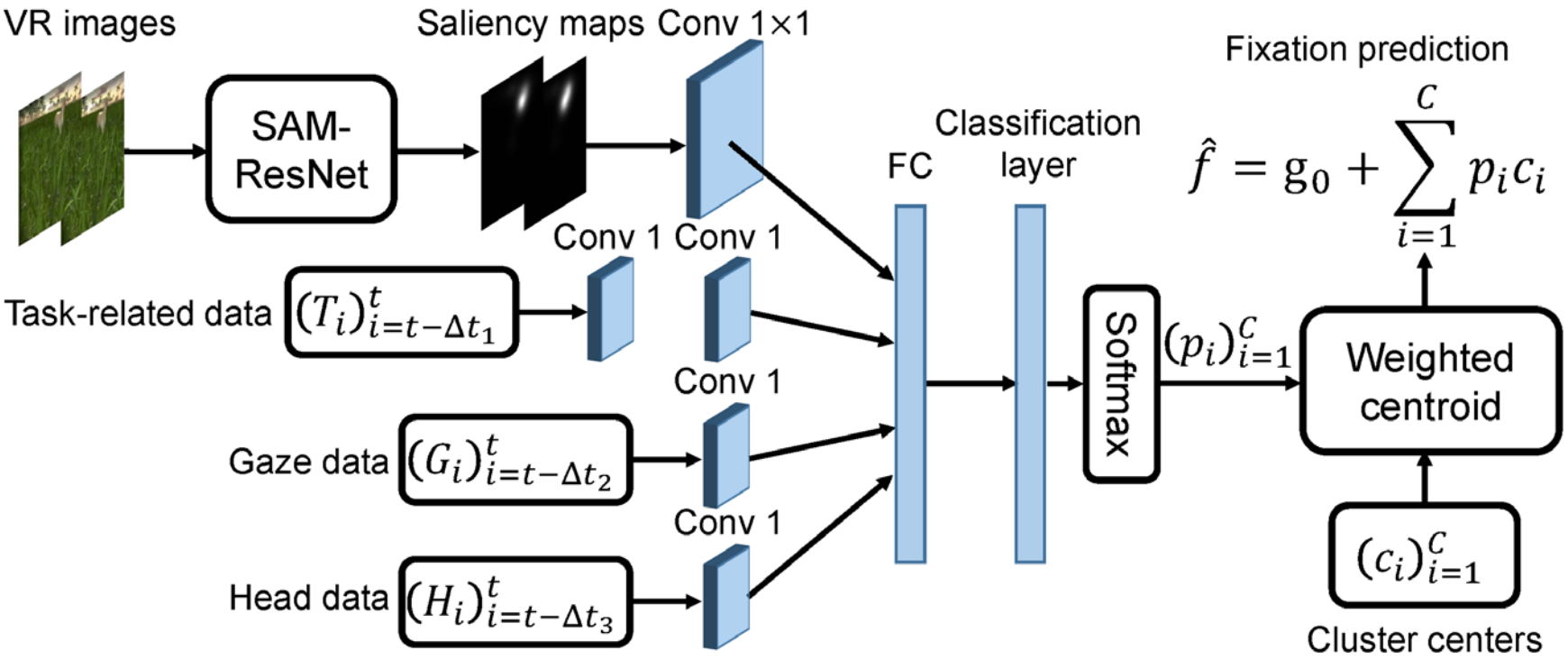



Fixation-head correlations in the horizontal (left) and vertical (right) directions

Fixations have correlations with head velocities

## FixationNet Model




Architecture of FixationNet model

# Results

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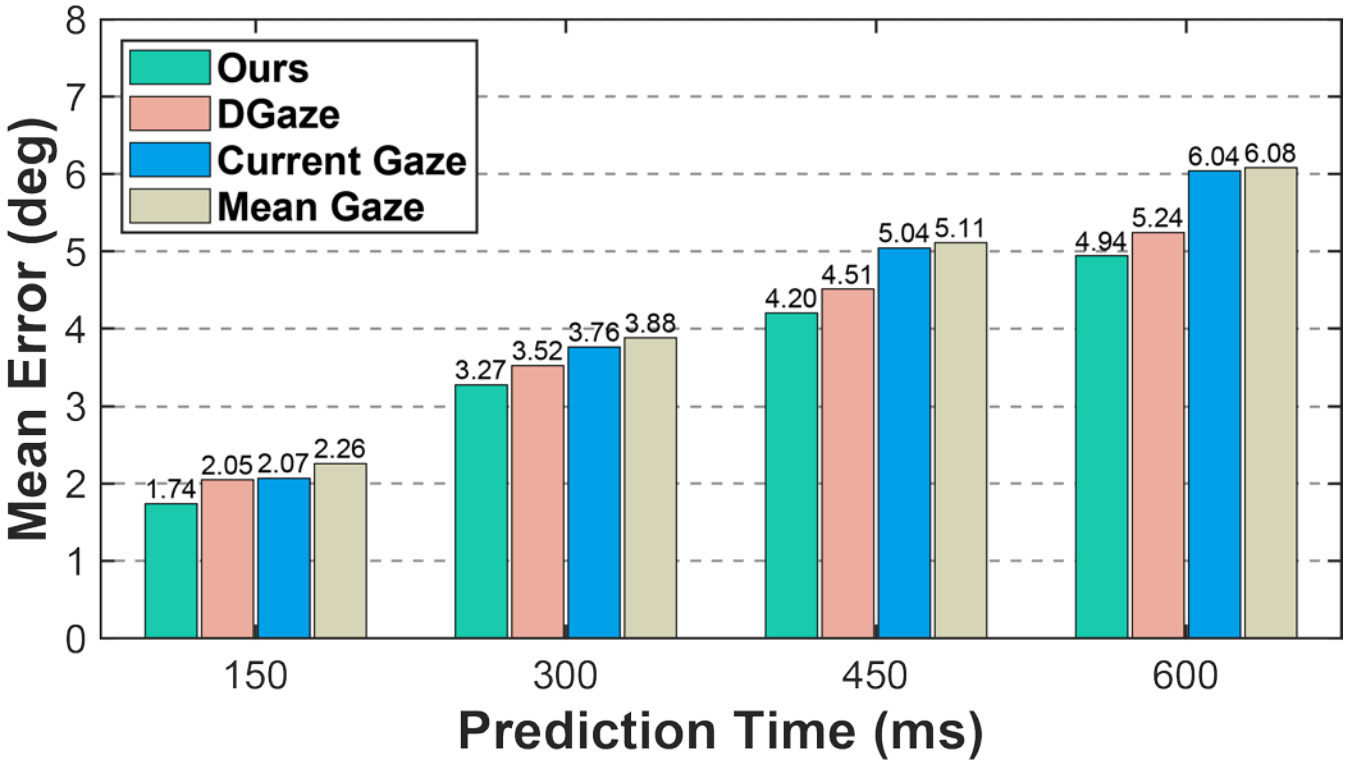
## Prediction Performance




Prediction performances at different time intervals

FixationNet outperforms other methods at different prediction times

# Discussion

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## Future Work

- Other Factors: Sound, users' mental states, users' gestures, users' behavioral habits, etc.
- Other Tasks: Text editing task, assembly task, collaborative task, etc.
- Application of the Model: Intelligent user interfaces and relevant areas.
- Other Systems: Augmented reality system, mixed reality system, mobile virtual system, etc.

Thank you