GazeXplain: Learning to Predict Natural Language Explanations of Visual Scanpaths

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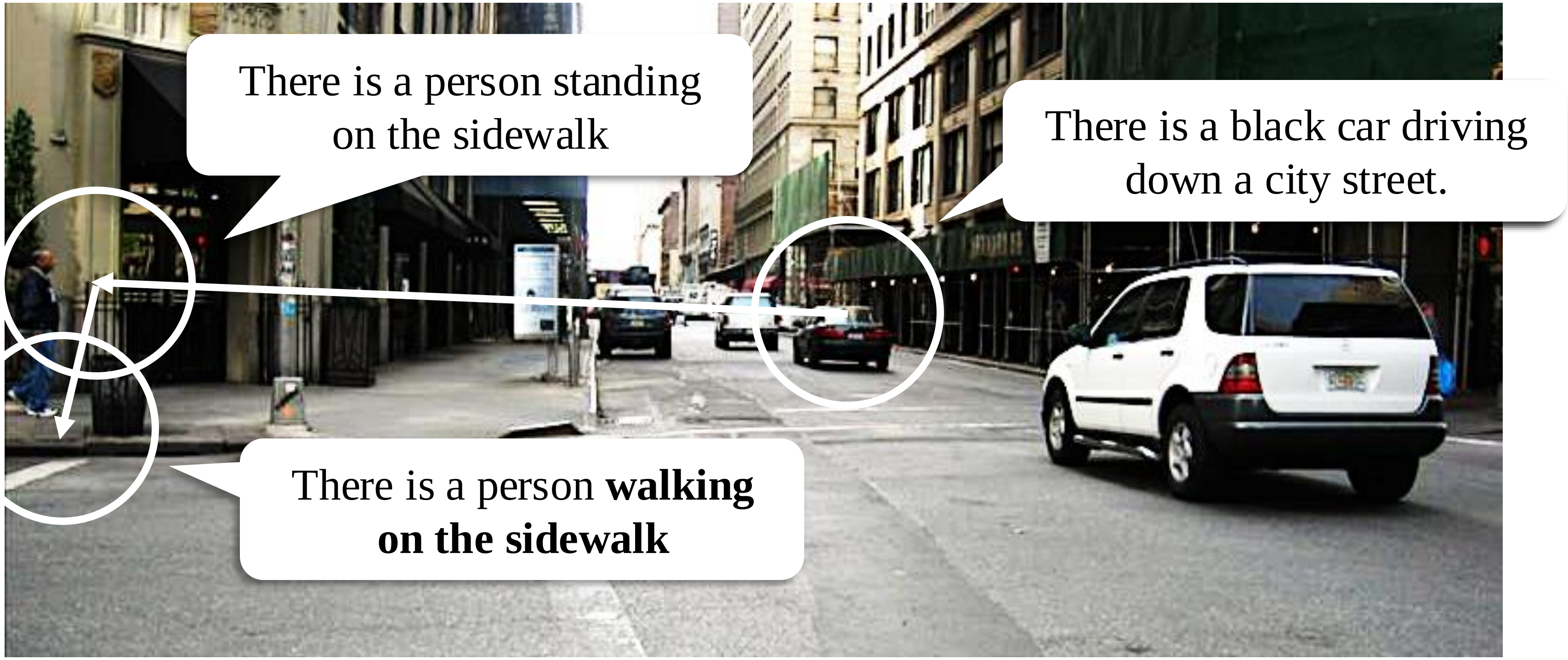
Motivation: Interpretable Visual Scanpaths

Q: Does the person on the sidewalk appear to be walking?

A: Yes



Scanpath prediction models are black boxes

Free-viewing

SaltiNet [M. Assens et al., ICCV Workshops, 2017]

PathGAN [M. Assens et al., ECCV Workshops, 2018]

IOR-ROI [W. Sun et al., TPAMI, 2019]

DeepGaze III [M. Kummerer et al., JoV, 2022]

Visual Search

IRL [Z. Yang et al., CVPR 2020]

ChenLSTM [X. Chen et al., CVPR 2021]

FFMs [Z. Yang et al., ECCV 2022]

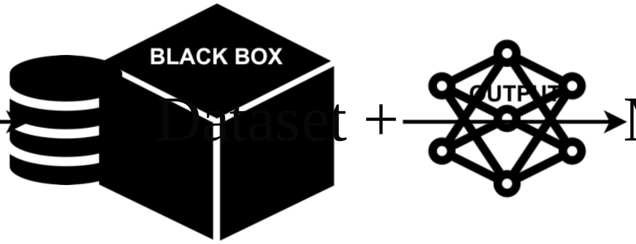
Gazeformer [S. Mondal et al., CVPR 2023]

VQA

ChenLSTM [X. Chen et al., CVPR 2021]

ISP [X. Chen et al., CVPR 2024]

Is the trash can to the
left of a chair?



GazeXplain – Dataset

A rich collection of natural-language explanations annotated on **7,004** images and **86,407** fixations across diverse visual tasks. The explanations are concise, with lengths falling within **10.66 ± 3.54** words each.

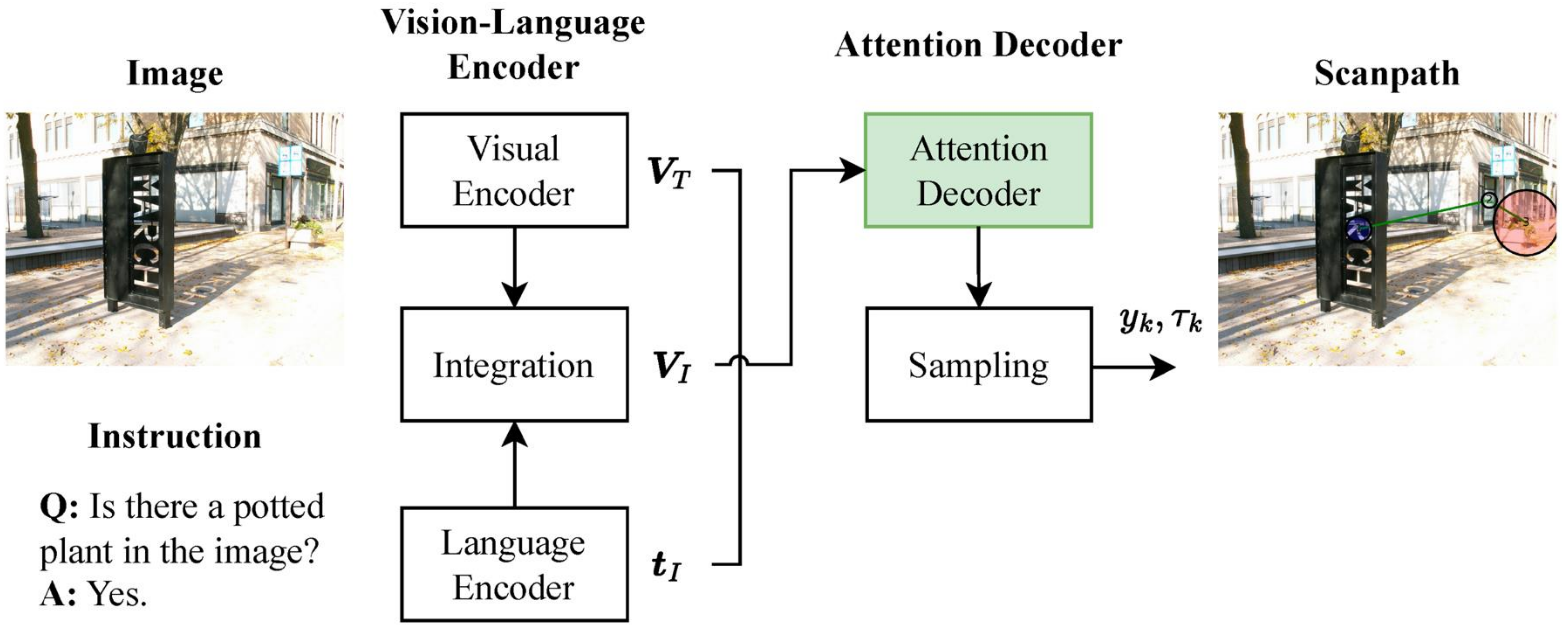
Scanpath

Explanation

1. There is a sign that reads "MARCH" in large white letters on a black background.
2. There is a small window on a building.
3. There is a potted plant on the sidewalk.

Dataset	Task	Images	Scanpaths	Length of Scanpath	Words per Fixation	Words per Scanpath
AiR-D	VQA	987	13,903	10.17 ± 2.23	10.79 ± 3.46	109.81 ± 31.27
OSIE	Free Viewing	700	10,500	9.36 ± 1.88	11.43 ± 3.99	107.07 ± 31.26
COCO-Search18 TP	Object Search	3,101	30,998	3.48 ± 1.82	9.84 ± 3.14	34.28 ± 20.55
COCO-Search18 TA	Object Search	3,101	31,006	5.86 ± 4.07	10.61 ± 3.45	62.21 ± 45.85

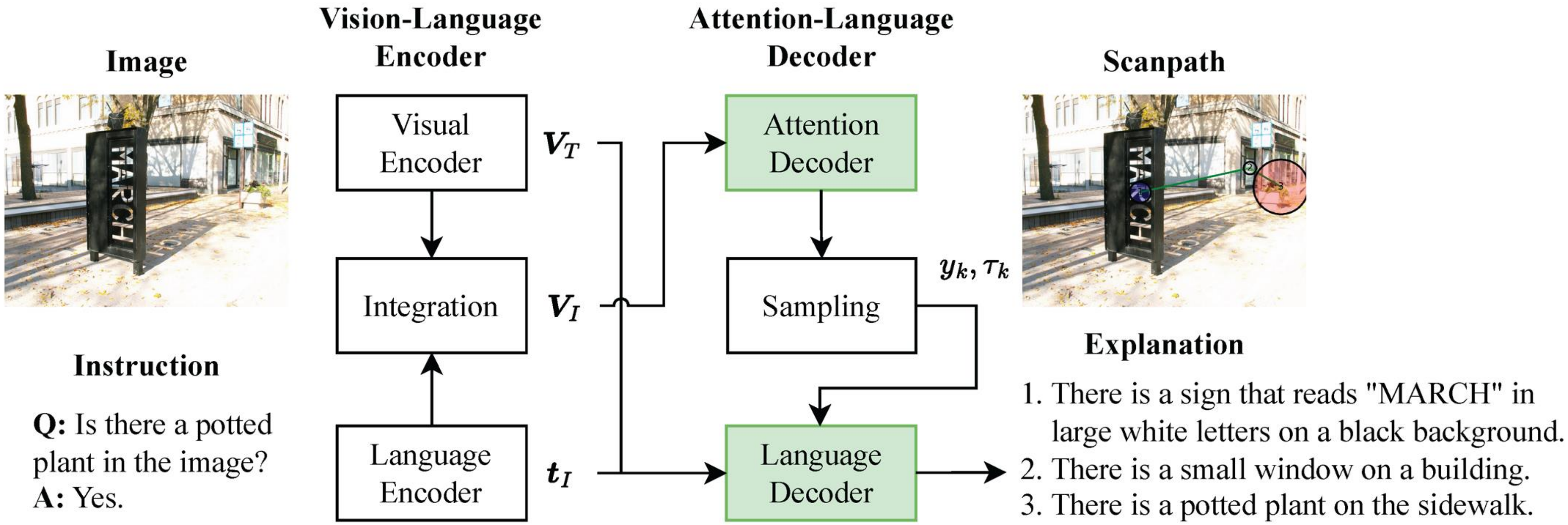
GazeXplain – Method



Baseline: Gazeformer [S. Mondal et al., CVPR 2023]

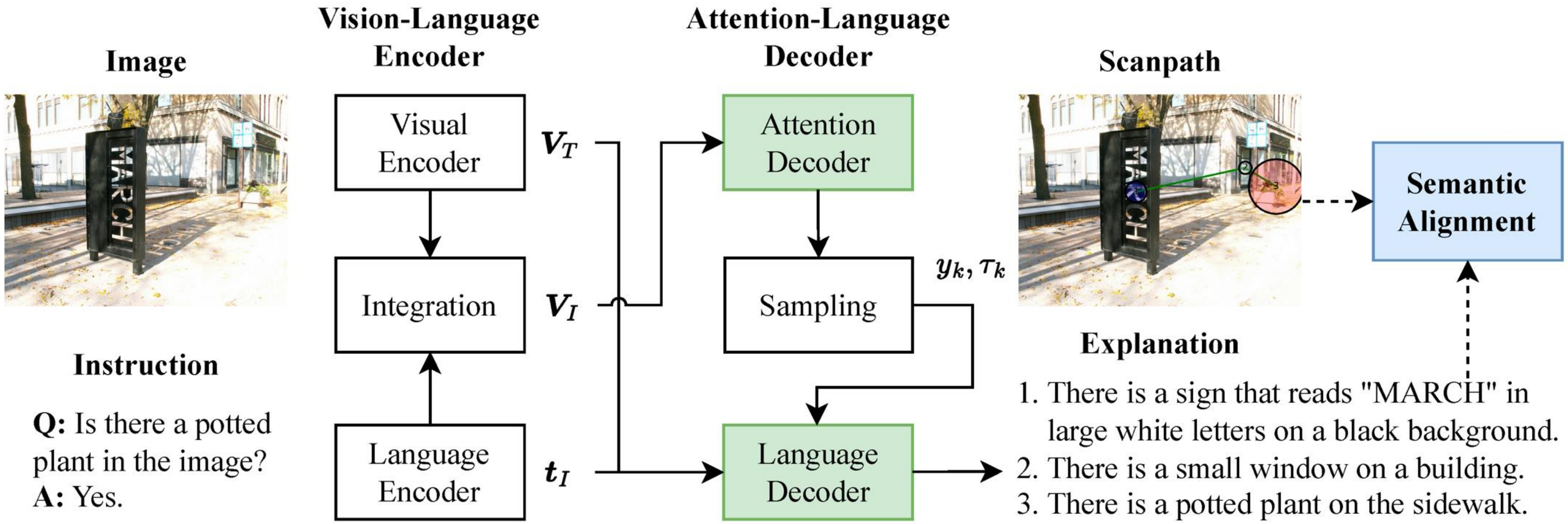
- Visual Encoder: ResNet-50 (Frozen) and Transformer
- Language Encoder: RoBERTa
- Attention Decoder: Transformer with Grid Classification

GazeXplain – Method



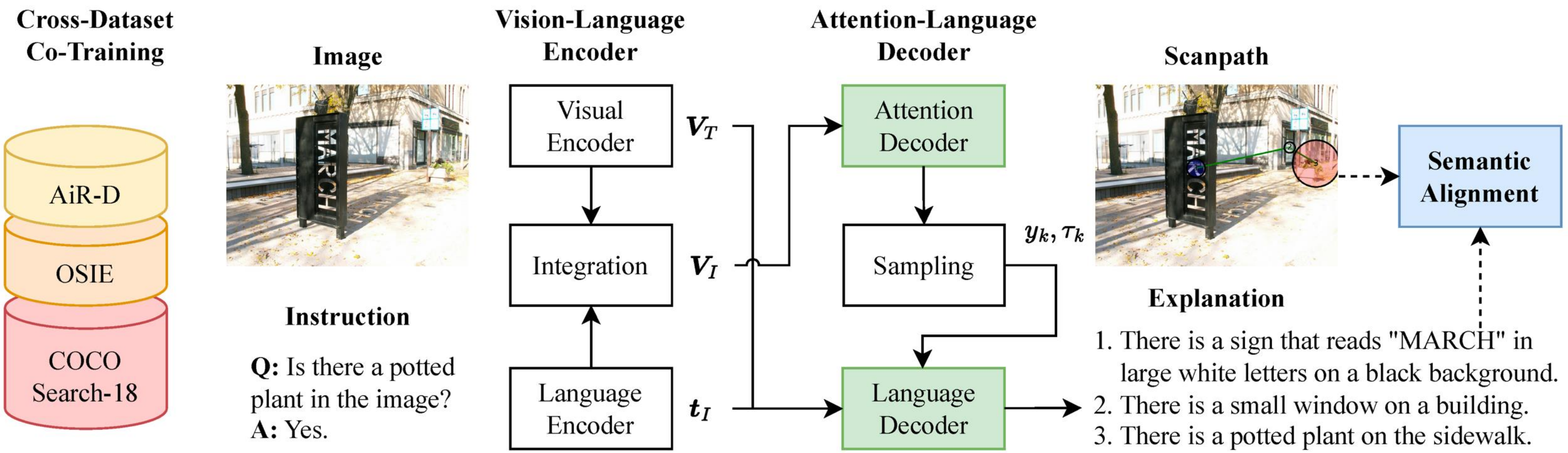
1. **Attention-Language Decoder (EXP):** Explanation generation with a language decoder (BLIP) to provide comprehensive semantic explanations for fixated regions.

GazeXplain – Method



2. **Semantic Alignment (ALN):** Compute and optimize the cosine similarity to ensure the consistency between predicted fixations, explanations and visual features.

GazeXplain – Method



3. **Cross-Dataset Co-Training (CT):** Enable models to learn from multiple datasets simultaneously with scaling the image and scanpath into same resolution and structure the task-specific instructions into the standard VQA format.

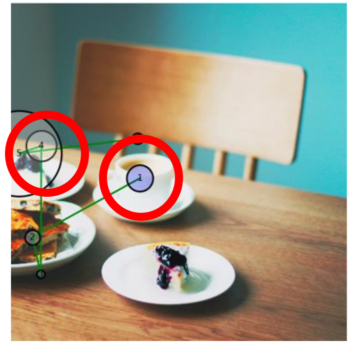
Scanpath Prediction Results

Method	Scanpath				Saliency			
	SM ↑	**MM ↑**	**SED ↓**	**SS ↑**	**CC ↑**	**NSS ↑**	**AUC ↑**	**sAUC ↑**
Human	0.403	0.803	8.110	0.336	0.830	2.328	0.879	0.797
SaltiNet	0.106	0.750	10.749	0.117	-0.014	-0.021	0.506	0.502
PathGAN	0.151	0.733	9.407	0.079	0.134	0.280	0.558	0.503
IOR-ROI	0.209	0.795	8.883	0.176	0.342	0.743	0.708	0.571
ChemLSTM	0.350	0.808	7.881	0.283	0.629	1.727	0.806	0.702
Gazeformer	0.357	0.811	7.962	0.287	0.550	1.512	0.760	0.670
GazeXplain	**0.386**	**0.817**	**7.489**	**0.308**	**0.662**	**1.851**	**0.808**	**0.719**

Qualitative Examples

Question: What fruits are on the dessert on the left side of the photo? **Answer:** Blackberries

Ground Truth



Gazeformer

GazeXplain

1: There is a cup of coffee on a saucer.

5: There is a small piece of cake with a blueberry on top.

2: There is a white cup with a spoon and a spoon.

6: There is a plate of food with a fork and knife.

1: There is a cup of coffee on a tray.

6: There is a plate with a piece of cake on it.

Ablation Study

Method			Scanpath				Saliency				CIDEr-R
1. EXP	2. ALN	3. CT	SM ↑	MM ↑	SED ↓	SS ↑	CC ↑	NSS ↑	AUC ↑	sAUC ↑	
			0.337	0.805	8.197	0.274	0.582	1.582	0.794	0.693	61.9
✓			0.339	0.805	8.216	0.280	0.614	1.674	0.806	0.706	91.9
✓	✓		0.346	0.806	8.250	0.284	0.631	1.733	0.807	0.713	115.1
		✓	0.356	0.812	7.834	0.292	0.582	1.597	0.781	0.688	66.7
✓		✓	0.378	**0.819**	7.693	0.299	0.647	1.797	0.806	0.713	97.3
✓	✓	✓	**0.386**	0.817	**7.489**	**0.308**	**0.662**	**1.851**	**0.808**	**0.719**	**123.1**

1. **Attention-Language Decoder (EXP):** These results suggest that by providing explanations for individual fixations, the model gains deeper insights into the underlying visual semantics, thereby refining its predictive capabilities.

Ablation Study

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2. **Semantic Alignment (ALN):** This indicates the importance of semantic coherence in guiding attention prediction models.

Ablation Study

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3. **Cross-Dataset Co-Training (CT):** This demonstrates the effectiveness of integrating diverse data sources for robust scanpath prediction and explanation.

Summary of Contributions

1. **Joint Prediction & Explanation of Scanpaths**
   A novel task that jointly predicts and explains scanpaths, offering a natural interface for understanding the underlying rationales for visual behaviors and reasoning processes to perform tasks.

2. **Ground-Truth Explanations**
   Provides detailed fixation-level explanations across three public eye-tracking datasets, offering detailed insights into the cognitive processes driving gaze behavior.

3. **General Model Architecture**
   Features an attention-based language decoder that predicts both scanpaths and their explanations, bridging the gap between visual patterns and their semantic interpretations.

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https://github.com/chenxy99/GazeXplain

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