

Investigating visual attention in physics using scan-path eye movement analysis

Adrian Madsen, Adam Larson, Lester Loschky & N. Sanjay Rebello, *Kansas State University*

OBJECTIVE

Understand how top-down and bottom-up processes influence incorrect problem solvers in physics.

PROBLEM: Consistent Wrong Answer Patterns in Physics

Two explanation types for consistent wrong answer patterns in physics: cognitive and perceptual.

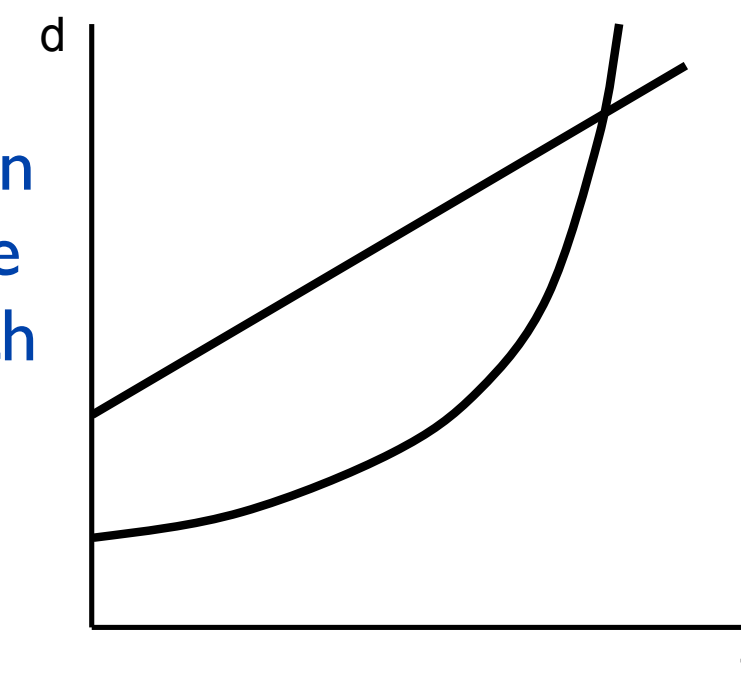
Cognitive

- Misconceptions based on naïve theories¹
- Misapplication of resources²
- Miscategorized ontology³

Perceptual

- Attention initially caught by perceptually salient, plausible & relevant elements.
- Student answers based on perceptually salient elements.⁴

The motion of two objects is represented in the graph. When are the two objects moving with the same speed?



Top-down Processes

Bottom-up Processes

METHOD

Participants: 10 PhD students in physics with teaching experience and 14 introductory psychology students who have taken a physics course

Eye Tracker: Eye Link 1000 desktop mounted eye tracker

Instructions and calibration of eye tracker

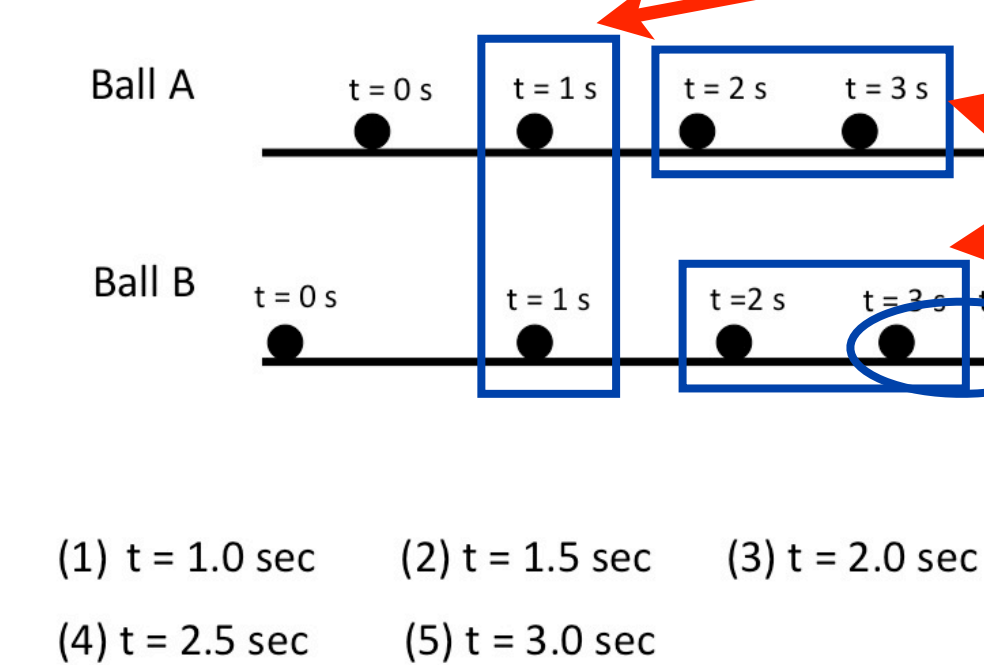
Answer 10 multiple-choice questions while eye movements recorded

Explain reasoning for answers while watching playback of eye movements

BACKGROUND: Areas of Interest Analysis of Eye Movements

Determined % fixation time for novice-like, thematically relevant and perceptually salient areas of interest (AOI) for full problem duration. Compared for correct and incorrect solvers.

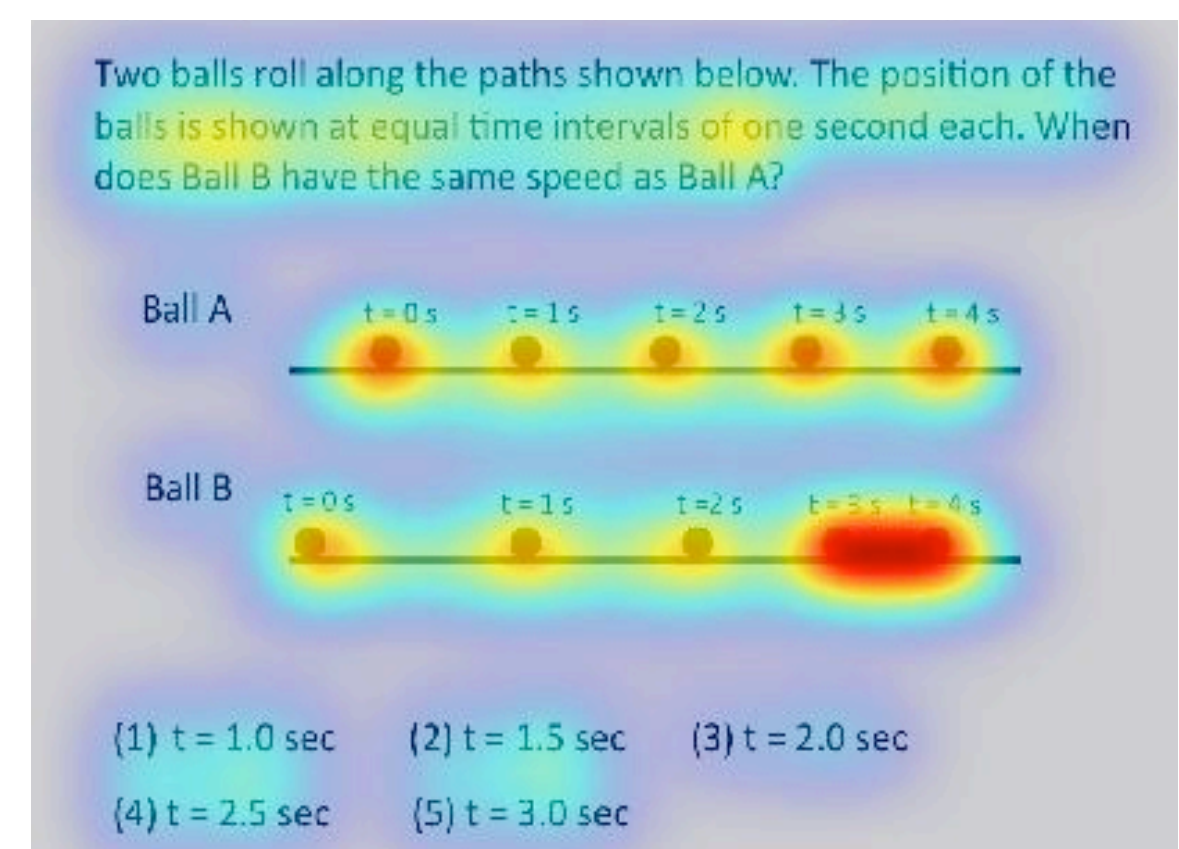
Two balls roll along the paths shown below. The position of the balls is shown at equal time intervals of one second each. When does Ball B have the same speed as Ball A?



Novice-like areas from interviews (confirmed by previous research)

Thematically relevant areas defined by experts

Areas of high perceptual salience¹⁻²



Saliency map produced by Itti, Koch and Niebur algorithm.⁵

Results of AOI Analysis (full problem duration)

	% of Fixation Time
Thematically Relevant AOI	Correct > Incorrect (5 of 6 problems)
Novice-Like AOI	Incorrect > Correct (5 of 6 problems)
Perceptually Salient AOI	No differences found

Further Analysis of Perceptually Salient AOI

- Compared % fixation time for first 2 seconds of viewing diagram.
 - Effects of perceptual salience most pronounced < 2 sec.
- No statistically significant differences, but raw % of fixation time > for incorrect solvers on 5 of 6 problems.
- No effect or lacking statistical power?

Evidence for top-down processes primarily influencing attention of correct and incorrect solvers.

REFERENCES

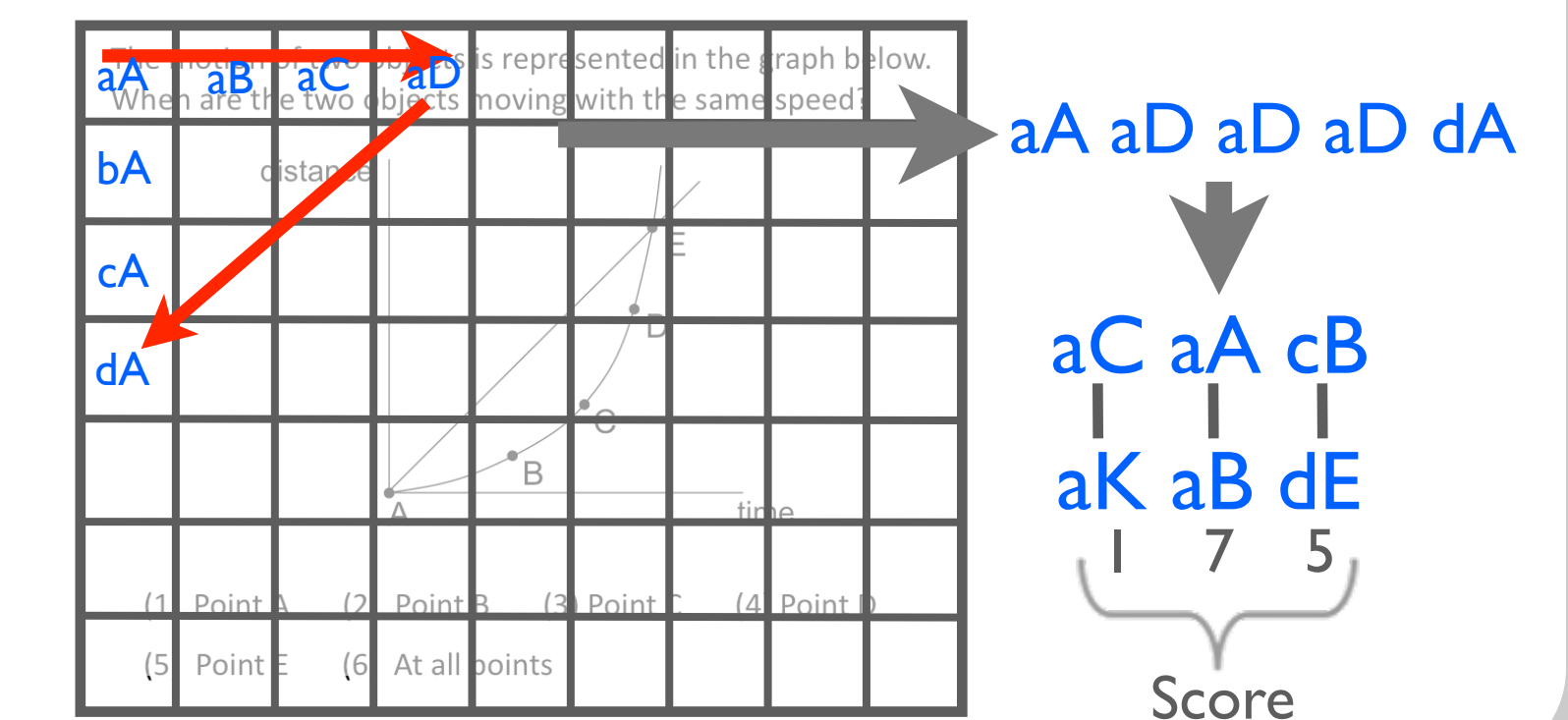
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ANALYSIS: ScanMatch

- ScanMatch: scan path analysis based on Needleman-Wunsch algorithm used for DNA sequencing.⁶
- Algorithm converts scan path to letter sequence and compares pairs of sequences, seeking optimal alignment by maximizing similarity score.
- Higher score indicates scan paths with strong similarity temporally and spatially.
- Calculated ScanMatch score comparing:
 - Correct solvers to one another (CC)
 - Incorrect solvers to one another (II)
 - Correct to incorrect solvers (CI)

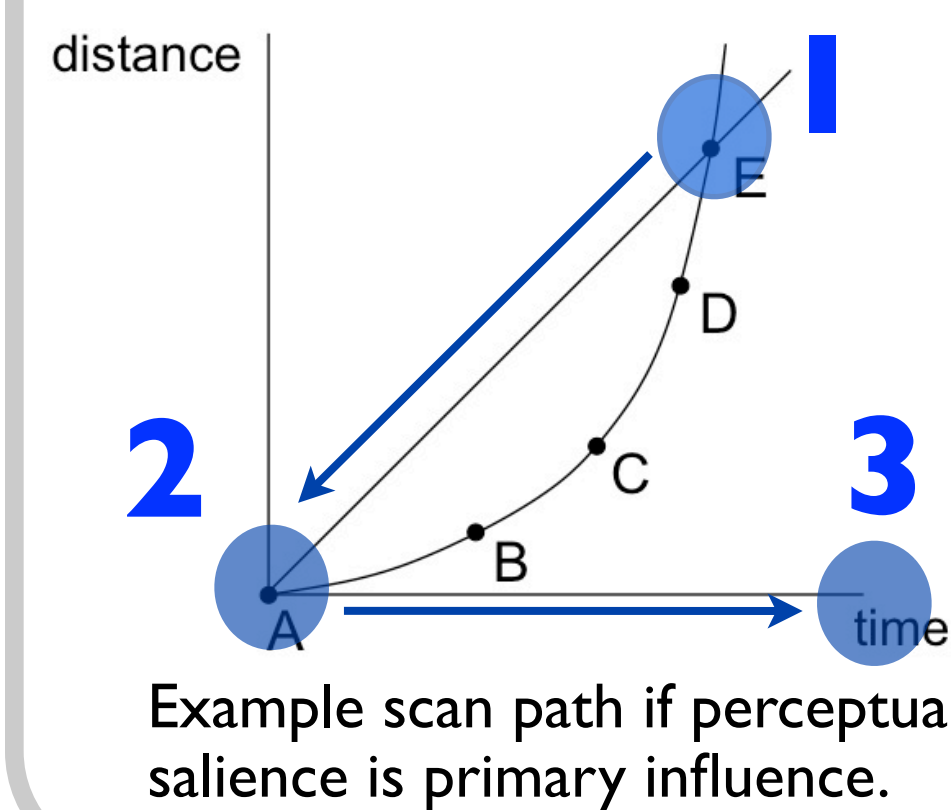
- Letter sequence binned temporally.
- Elements in each sequence compared & scored based on distance apart in grid.
- Gaps (& gap penalties) included to maximize score.
- Score normalized to maximum of one.



HYPOTHESES

Hypothesis 1: If bottom-up processes based on perceptual salience of primarily influence attention of incorrect solvers:

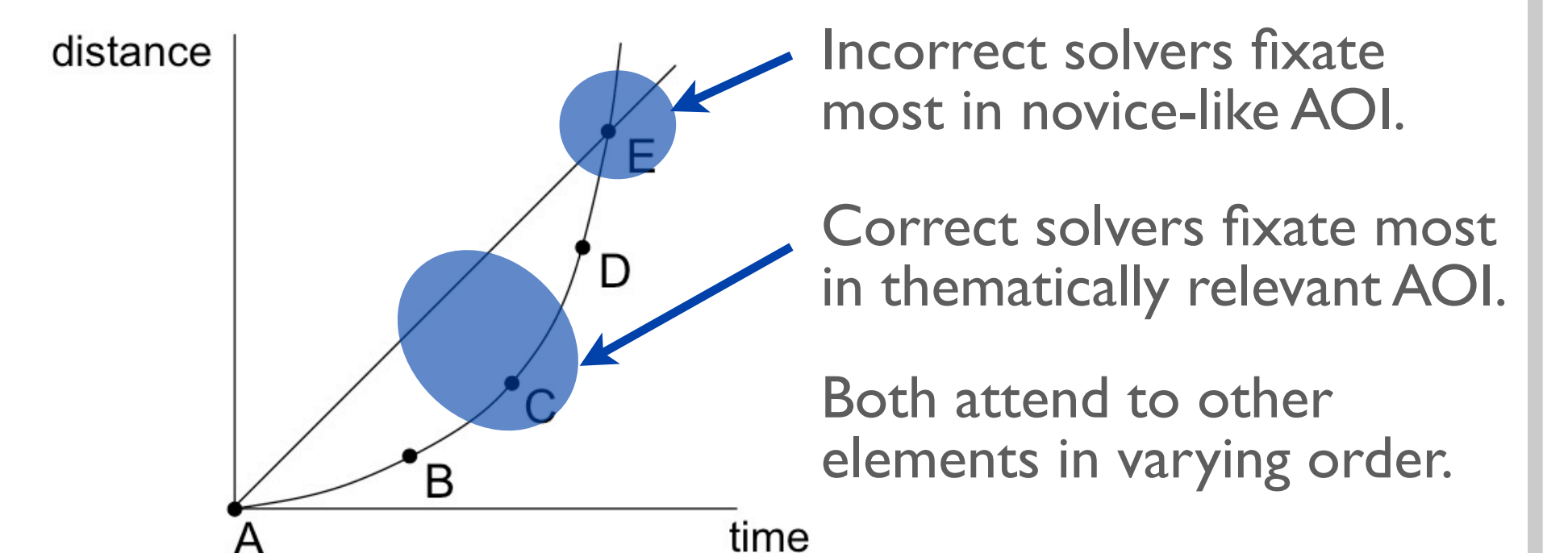
$$II > CC > CI$$



- Saliency models predict order & location of fixations = higher ScanMatch scores
- Correct solvers attend to similar regions of diagram in varying order = lower ScanMatch scores

Hypothesis 2: If top-down processes utilizing naïve theories primarily influence attention of incorrect solvers:

$$II = CC, II \& CC > CI$$



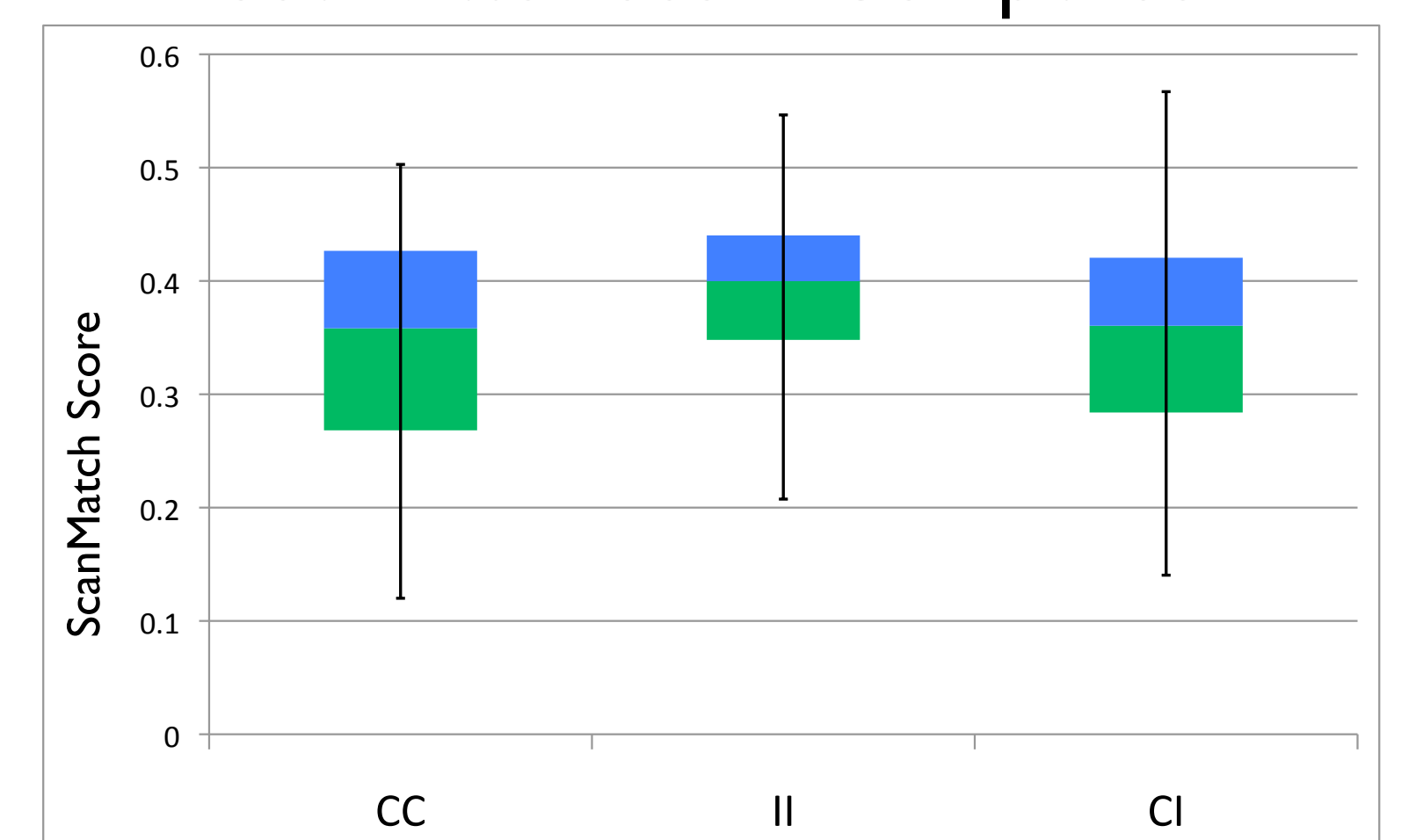
RESULTS

Completed one-way ANOVA comparing ScanMatch scores of CC, II & CI comparisons for each problem. If significant result obtained, used post-hoc contrasts to determine statistically significant comparisons.

Summary of Significant Differences

Problem	Comparison
1	II > CI (p<.001)
2	II > CI (p<.001)
3	II > CC (p=.005)
4	no significant differences
7	
10	II > CI (p=.05)

ScanMatch Score Comparison



Box and whiskers plot with median, max, min and 1st and 3rd quartile of the ScanMatch scores for each comparison.

CONCLUSION

- Found evidence for top-down naïve theories primarily influencing attention of incorrect solvers.
 - No differences between CC and II comparisons on 5 of 6 problems.
 - Consistent with previous finding, incorrect solvers greater % fixation time in novice-like AOI
- Did not find CC & II > CI as expected. Differences in way participants read elements of problem may lead to noise in the data.