How Does Visual Attention Differ Between Experts and Novices on Physics Problems?

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OBJECTIVE

Investigate how the allocation of visual attention differs with varying levels of physics experience on physics problems where the critical information needed to answer the problem is contained in a diagram.

METHOD

Participants: 9 PhD students in physics with teaching experience and 13 introductory psychology students who have taken a physics course.

Physics Problems: Participants answered 10 multiple-choice conceptual physics questions where the information needed to answer the question was contained in a diagram.

1. Instructions and calibration of eye tracker
2. Answer 10 multiple-choice conceptual questions while eye movements recorded
3. Explain reasoning for answers to questions while watching playback of eye movements

BACKGROUND: Expert Novice Differences In Visual Attention

- Experts' visual attention is primarily driven by knowledge and they spend more time than novices looking at relevant information in figures. [1-3]
- Novices' visual attention is driven by noticeable features of environment and they spend more time looking at perceptually salient areas of figures and pictures. [4]
  - Expert chess players [3] and artists [2] spend more time looking at relevant areas of medium.
  - Novices were found to spend more time looking at salient features of a weather map. [4]

Research Question: How does expertise affect the fixation duration in perceptually salient versus thematically relevant areas in a figure?

ANALYSIS & RESULTS 1

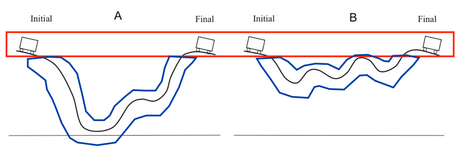
Perceptually salient and *thematically relevant* areas of interest (AOI's) defined by three independent raters. One-way ANOVA used to compare percentage of time spent in each type of AOI.

**Significance determined at alpha=.05 level. Green boxes indicate significant differences.

Problem 1

Thematically Relevant	Perceptually Salient
Correct: 26.6%(± 16.1)	Correct: 10.5% (± 8.2)
Incorrect: 21.4% (± 12.2)	Incorrect: 31.5% (± 18.3)*

If frictional effects can be ignored, how does the final speed of roller coaster cart A compare to the final speed of roller coaster cart B, if the mass of the carts is the same and they both start at rest?

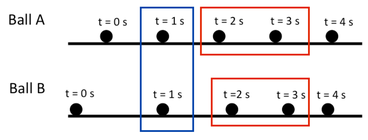


(1) The cart A is moving faster at the final position
(2) The cart B is moving faster at the final position
(3) Carts A and B have the same speed at the final position
(4) There is not enough information to decide

Problem 4

Thematically Relevant	Perceptually Salient
Correct: 46.6% (± 10.7)	Correct: 19.2% (± 8.2)
Incorrect: 25.8% (± 11.5)*	Incorrect: 29.0% (± 6.9*

Two balls roll along the paths shown above. 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.

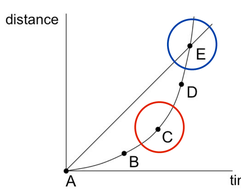


(1) t = 1.0 sec (2) t = 1.5 sec (3) t = 2.0 sec
(4) t = 2.5 sec (5) t = 3.0 sec

Problem 7

Thematically Relevant	Perceptually Salient
Correct: 29.9% (± 14.2)	Correct: 12.8% (± 9.0)
Incorrect: 18.0% (± 10.8)*	Incorrect: 25.3% (±15.8)*

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

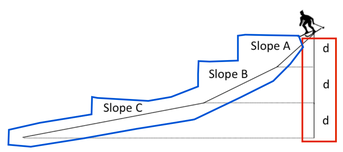


(1) Point A (2) Point B (3) Point C (4) Point D
(5) Point E (6) At all points

Problem 10

Thematically Relevant	Perceptually Salient
Correct: 26.0% (± 3.9)	Correct: 46.4% (± 17.1)
Incorrect: 14.3% (±11.0)*	Incorrect: 52.9% (± 19.3)

Rank the changes in potential energy during the skier's descent down each slope from greatest to least.

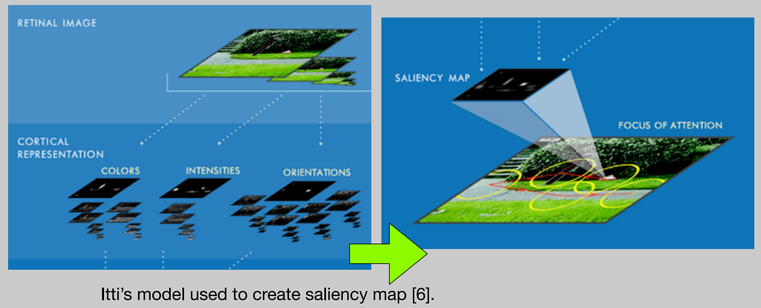


(1) $\Delta PE_A > \Delta PE_B > \Delta PE_C$ (4) $\Delta PE_A = \Delta PE_B > \Delta PE_C$
(2) $\Delta PE_C > \Delta PE_B > \Delta PE_A$ (5) $\Delta PE_B > \Delta PE_C = \Delta PE_A$
(3) $\Delta PE_A = \Delta PE_B = \Delta PE_C$

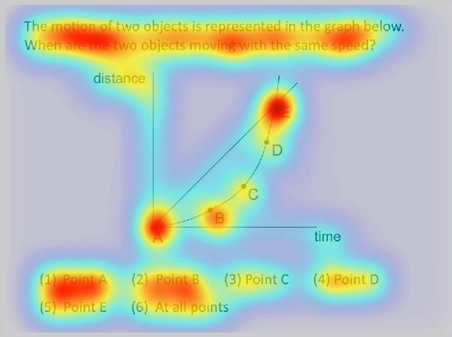
BACKGROUND: Saliency Maps

- Influences on Attention
  - *Bottom-up:* fast, automatic mechanism that biases observer toward attending to stimuli based on obviousness. Perceptual.
  - *Top-down*: slower mechanism which controls attention willfully and is task-dependent. Cognitive.
- Saliency Map: 2D map that encodes saliency of objects in visual environment. [6]
  - Orientation, intensity and color
  - Attention first goes to most salient location, then is inhibited and is automatically shifted to next most salient location.

Research Question: How does level of experience in physics influence deployment of top-down and bottom-up processes when viewing conceptual physics problems?

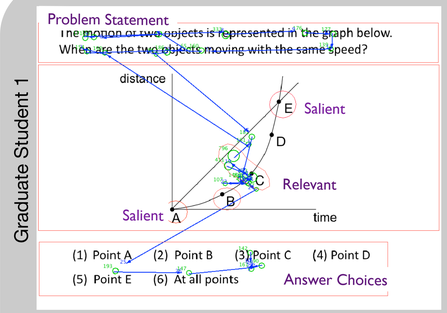


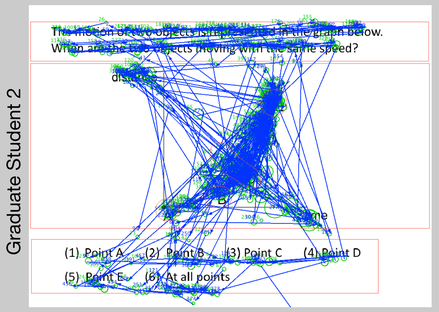
Itti's model used to create saliency map [6].

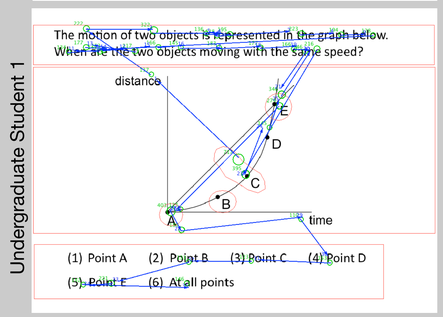


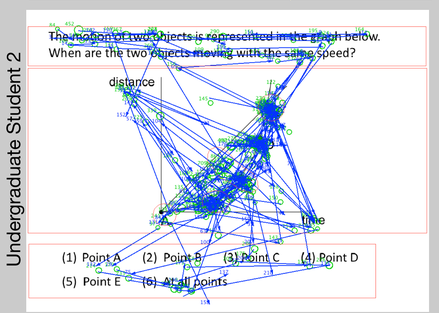
Saliency map of problem used in study. [5]

ANALYSIS & RESULTS 2





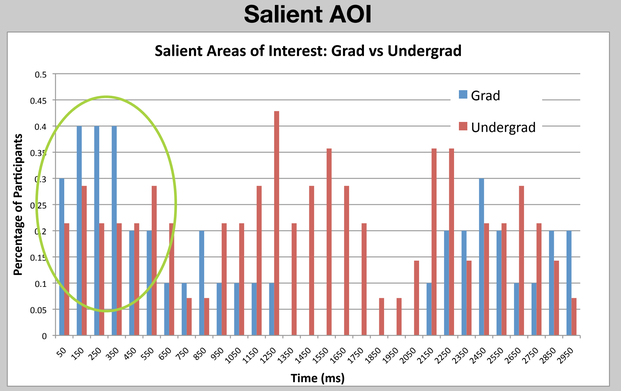




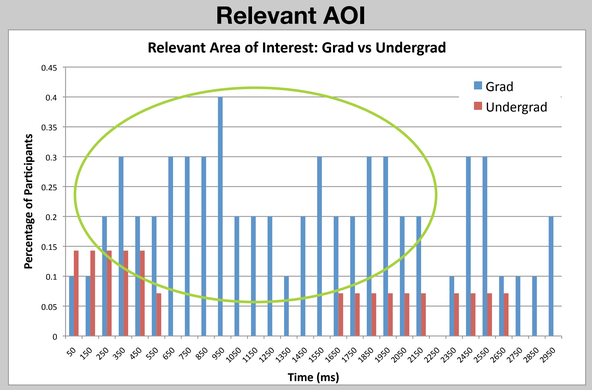
Analysis

- Areas of Interest (AOI's):
  - *Salient*: Itti's saliency map code.
  - *Relevant*: ratings by physics professor and graduate students.
  - *Problem Statement*
  - *Answer Choices*
- Determined fixation duration in each AOI over time.
- Binned fixations into 100 ms bins.
- Compared binned fixations for each AOI for graduate versus undergraduate students.

Salient AOI



Relevant AOI



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5. J. Harel, A Saliency Implementation in MATLAB: http://www.klab.caltech.edu/~harel/share/gbvs.php
6. Itti, L., & Koch, C. (2000). A saliency-based search mechanism for overt and covert shifts of visual attention. *Vision Research, 40* (10-12), 1489-1506.