

The Use of Eye-tracking during Engineering Problem Solving Tasks

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Outline

Introduction

- Why is eye gaze data important and useful?
- How has eye-tracking been applied widely?

Implementation

- Hardware and software
- Visual stimulus and human subjects

Example

- Study in students' visual attention in solving engineering problems
- Preliminary results

Saccades, Fixations and Scan Path

DANS, KÖN OCH JAGPROJEKT

På jakt efter ungdomars kroppsspråk och den "synkretiska dansen", en sammansmältning av olika kulturers dans, har jag i mitt fältarbete under hösten rört mig på olika arenor inom skolans värld. Nordiska, afrikanska, syd- och östeuropeiska ungdomar gör sina röster höra genom sång, musik, skrik, skratt och gestaltar känslor och uttryck med hjälp av kroppsspråk och dans.

Den individuella estetiken framträder i kläder, frisyrer och symboliska tecken som förstärker ungdomarnas "jagprojekt" där också den egna stilen i kroppsrörelserna spelar en betydande roll i identitetsprövningen. Upphållsrummet fungerar som offentlig arena där ungdomarna spelar upp sina performance-liknande kroppsspråk.



An example of fixations and saccades over text [1]. The eyes never move smoothly over static text.

An example of fixations and saccades over picture [2].

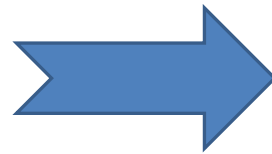
[1] http://upload.wikimedia.org/wikipedia/commons/e/ef/Reading_Fixations_Saccades.jpg

[2] <http://rupaper.com/post/17549>

The Eye-mind Hypothesis

In 1980, Just and Carpenter [3] formulated the eye-mind hypothesis: There is no appreciable lag between what is fixated and what is processed.

In other words, when a subject looks at a word or object, he or she also thinks about it, and for exactly as long as the recorded fixation.



[3] Just, Marcel Adam, and Patricia A. Carpenter. "Eye fixations and cognitive processes." *Cognitive Psychology* 8.4 (1976): 441-480.

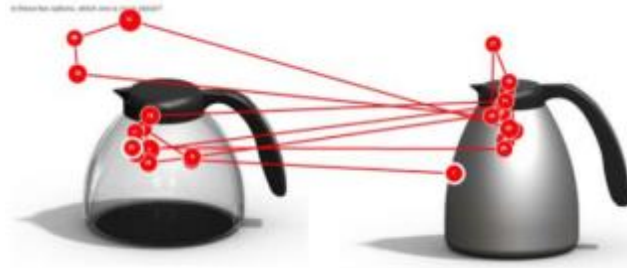
[4] http://sweetclipart.com/multisite/sweetclipart/files/symbol_eye_makeup_green.png

[5] http://marcs.uws.edu.au/files/images/iStock_000020432813XSmall.jpg

Various Applications of Eye-tracking in Research



Aviation
(Ottati et al., 1999)



Product Design
(Reid et al., 2012)



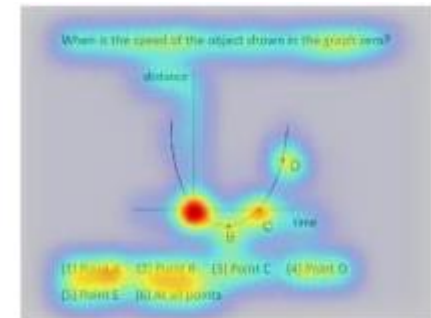
Visual Inspection
(Schuster et al., 2013)



Driving
(Chapman et al., 1998)



Advertising
(Rayner, 2001)



Problem-solving
(Madsen, 2013)

Eye-tracker Used to Corroborate Findings



An eye-tracker records and quantifies eye movements at 60-120 Hz

Uses near-infrared illumination to create reflection pattern on a user's eye; hidden sensors capture these patterns



Typical measures: fixation, *scan path*, *fixation time*

Experimental Design

Decision Category	Section order and question type		Stimuli Shown	Randomization
Opinions	I	Preference	Cars and coffee carafes	Predetermined pairs of stimuli randomized for each question type
	II	Stylishness		
Objective Evaluations	III	Width	Cars and coffee carafes	Each stimulus randomized for each question type
	IV	Length	Cars	
	V	Height	Coffee carafes	
Inferences	VI	Heat Retention	Coffee carafes	Questions randomized for predetermined pairs of stimuli
		Recyclability	Coffee carafes	
		Fuel Efficiency	Cars	

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		Recyclability	Coffee carafes	
		Fuel Efficiency	Cars	

Version 1 (Group 1)



FSV Silhouettes



Computer sketches

Version 2 (Group 2)



Simple Renderings



Realistic Renderings

A total of 4 different variations of each product was presented in 6 pairs of questions

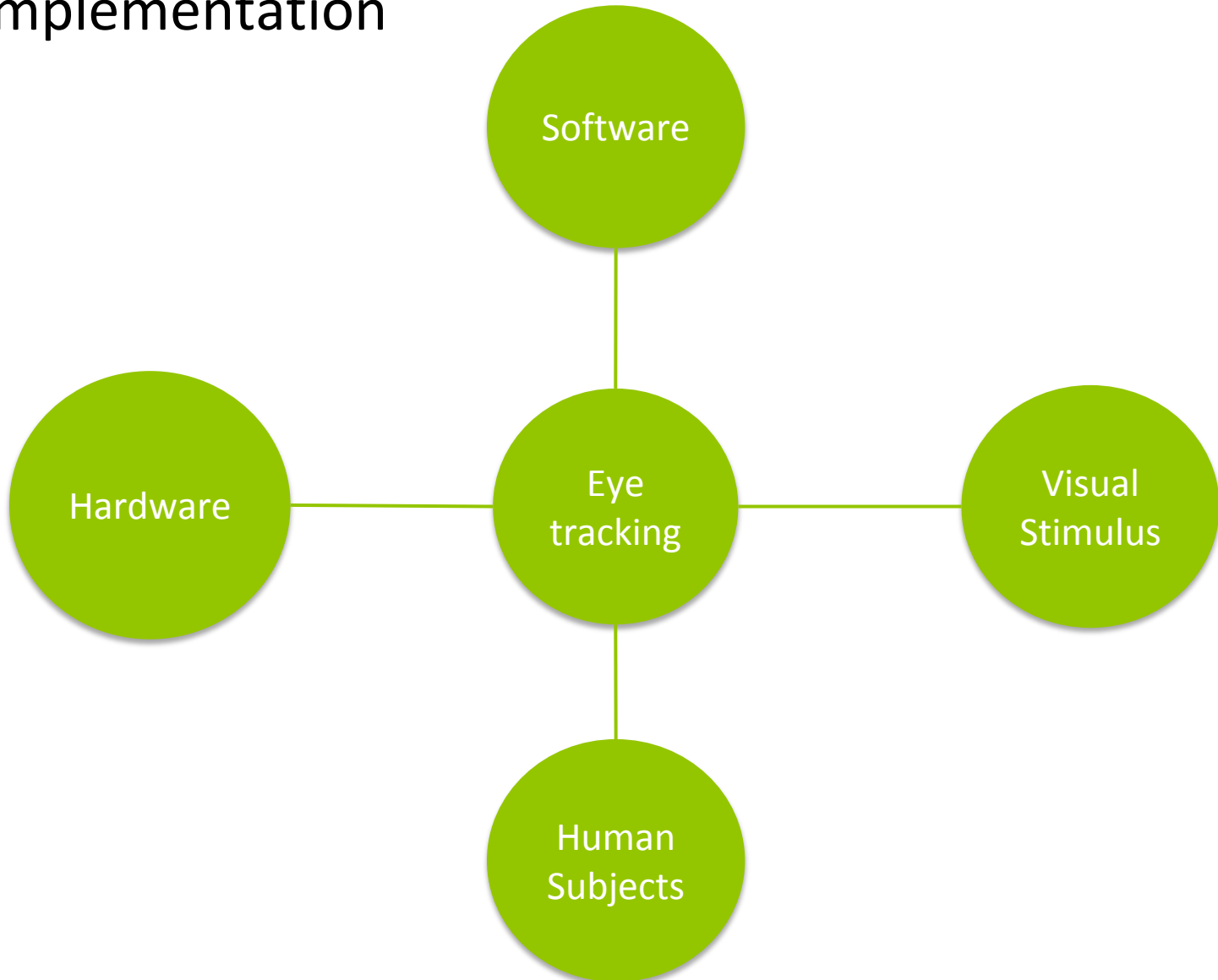
Examples of Questions that Motivate Eye-tracking Research

1. Which part of the visual stimulus do people mostly focus on?

2. What's the difference between different people's visual attention patterns?(e.g. novices vs. experts, high performers vs. low performers)

3. Can this visual attention pattern be utilized to improve the visual design or to train the novices?

Implementation



Hardware



Stationary eye tracker



Mobile eye tracker

Suppliers:



mirametrix®

tobii

EyeTech
Digital Systems

Software

Data Recording

- Tobii Studio™
- iMotions Attention Tool™
- EyeTech QuickAccess™

Statistical Analysis

- Microsoft Office Excel
- Minitab
- SAS
- R

Attention Tool

File Preferences Tools Help

Library

Studies (32)

- Dynamic_Test_1
- Problem_Solving_Test_7**
- Problem-Solving_Test_6
- Problem_Solving_Test_5
- Problem_Solving_Test_4
- Problem_Solving_Test_3
- Problem_Solving_Test_2
- Problem_Solving_Test_1
- Study 21-06-13 16h18m
- attention_1
- Study 10-05-13 11h13m
- Study 30-04-13
- Study 11-04-13 18h08m
- ScreenRecord11APR
- screen_record_8_APR

Respondent Details Respondent Statistics Gaze Calibration

22 001

Available sensor data : Eye tracker

Stimulus	Completion %	Time	Order
Welcome	99%	11.3s	#1
PSVT_Instruction1	94%	27.9s	#2
PSVT_Instruction2	98%	30.5s	#3
PSVT1	98%	33.3s	#4
PSVT2			
PSVT3			
PSVT4			
PSVT5			

Avg. Data Quality: 95%

0% — 100%
Show stimuli above 80% data quality

Not Connected

Respondents

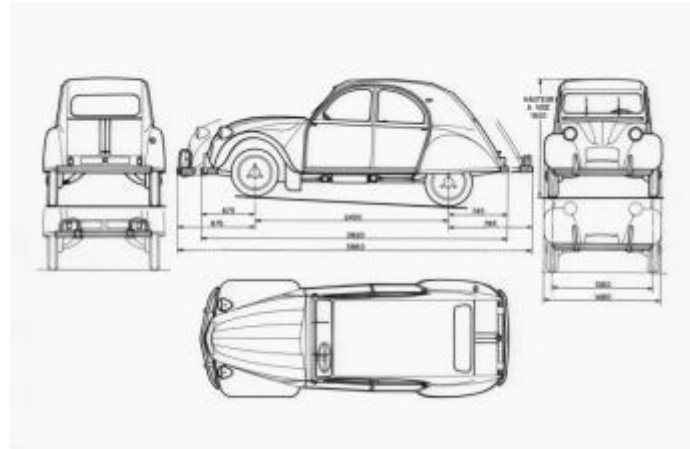
Name

- 22 014
- 22 013
- 22 011
- 22 010
- 22 009
- 22 008
- 22 007
- 22 005
- 22 004
- 22 003
- 22 001**

Females (4)

- 22 015
- 22 012

Choosing Visual Stimuli



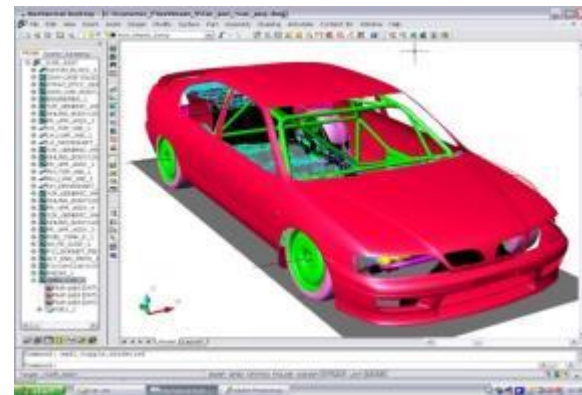
Figure



Webpage



Movie



Screen recording

Prescreening of Human subjects

Participants have to meet the inclusion criteria suggested by Pernice and Nielsen^[6] to satisfy the experimental conditions of eye tracking research:

- Have normal to corrected vision (contact lenses and glasses are okay except for bifocals, trifocals, layered lenses or regression lenses).
- Do not have glaucoma, cataracts, eye implants, or permanently dilated pupils.
- Can read a computer screen and the Web without difficulty.
- Do not need a screen reader, screen magnifier or other assistive technology to use the computer and the Web.

[6] Pernice, K., and Nielsen, J., 2009, "Eye tracking Methodology: How to Conduct and Evaluate Usability Studies Using Eye tracking," Nielsen Norman Group Technical Report.

A Study Using Eye Tracking in Our Lab

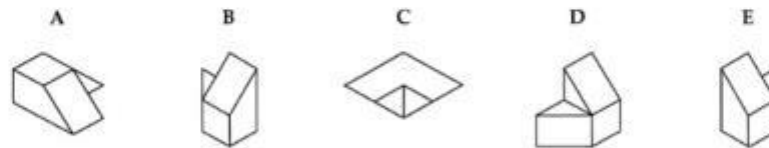
How do students
solve engineering
problems

Eye
gaze
Data

- Do students' spatial visualization skills correlate with their performance on solving solid mechanics problems ?
- Do different visual attention patterns exist in low and high performers in solving solid mechanics problems?

Visual Stimuli Used

PSVT Problem 1



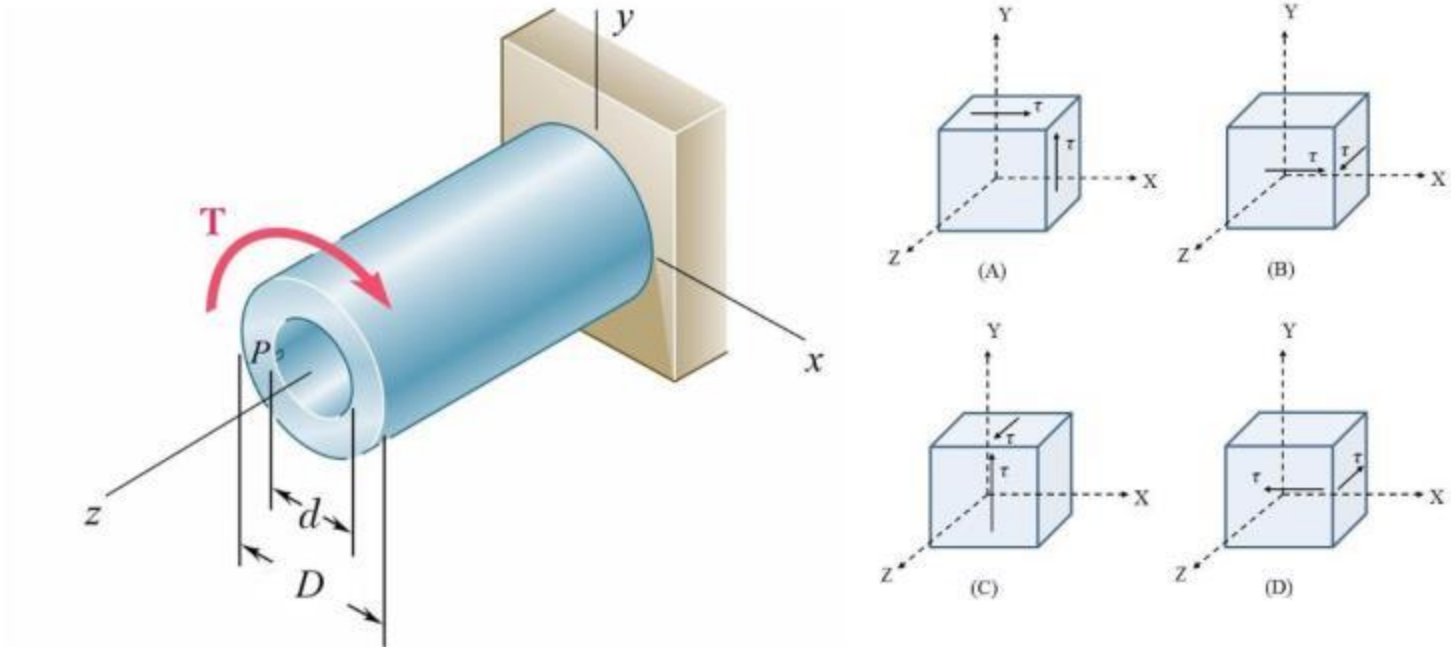
Your Answer

A B C D E



Visual Stimuli Used

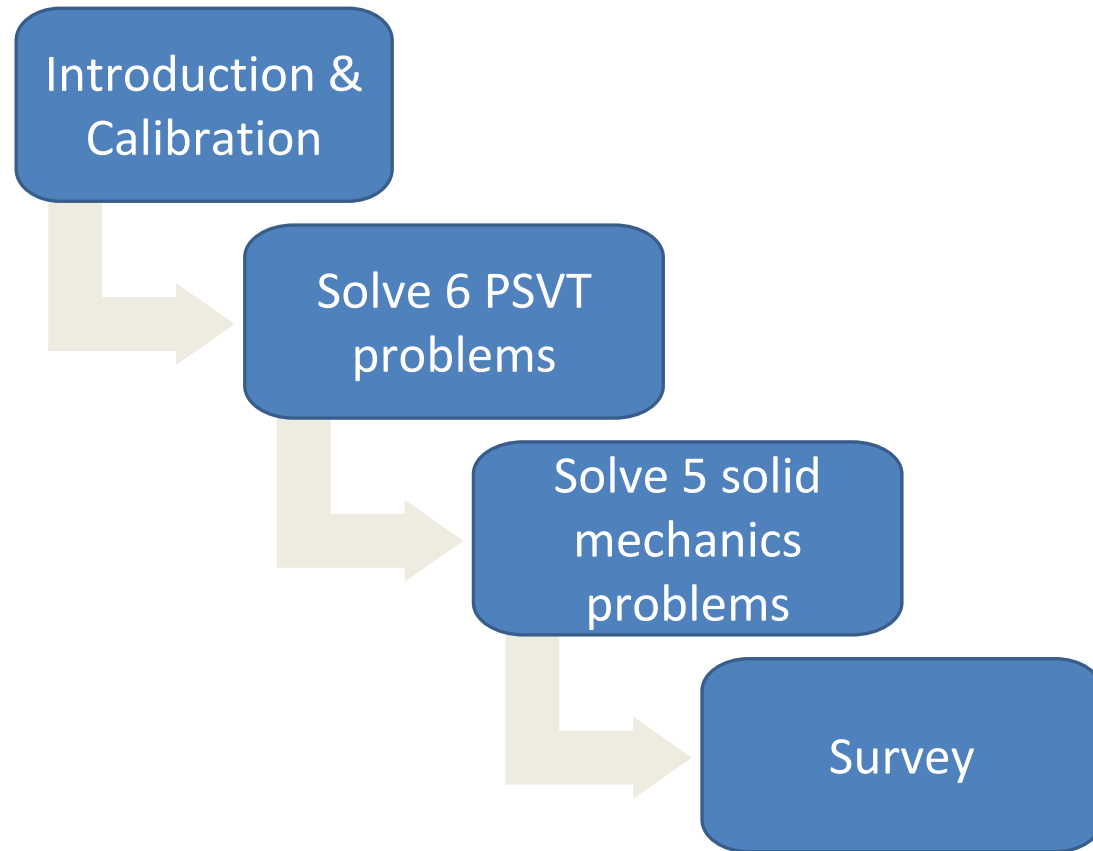
Problem 1: Try to select the most appropriate representation of the state of stress of the element at point P from the four choices. T is a torque.



Your Answer A B C D



Process and Experimental Procedure Used



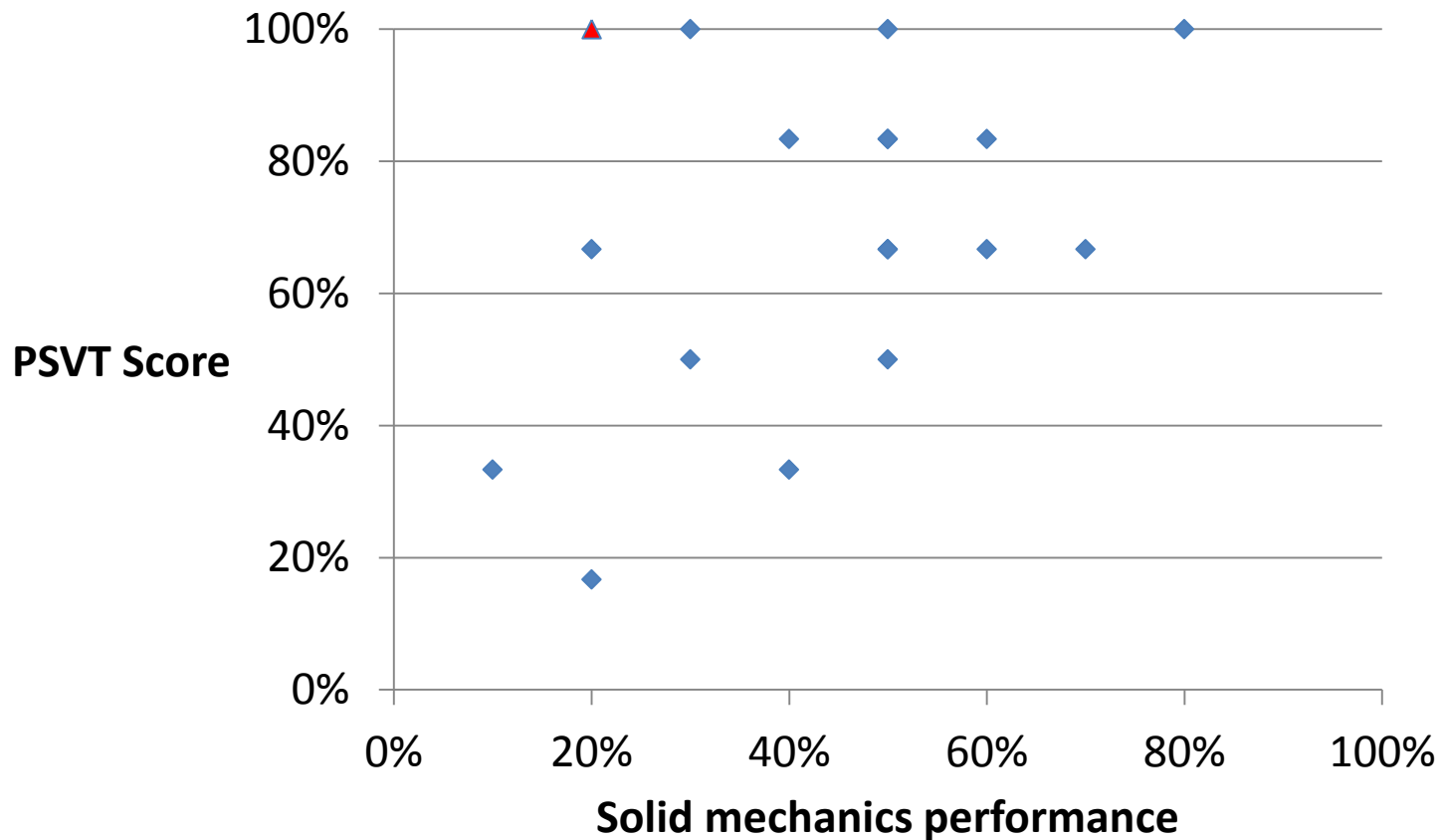
Experimental Apparatus Used and Participants

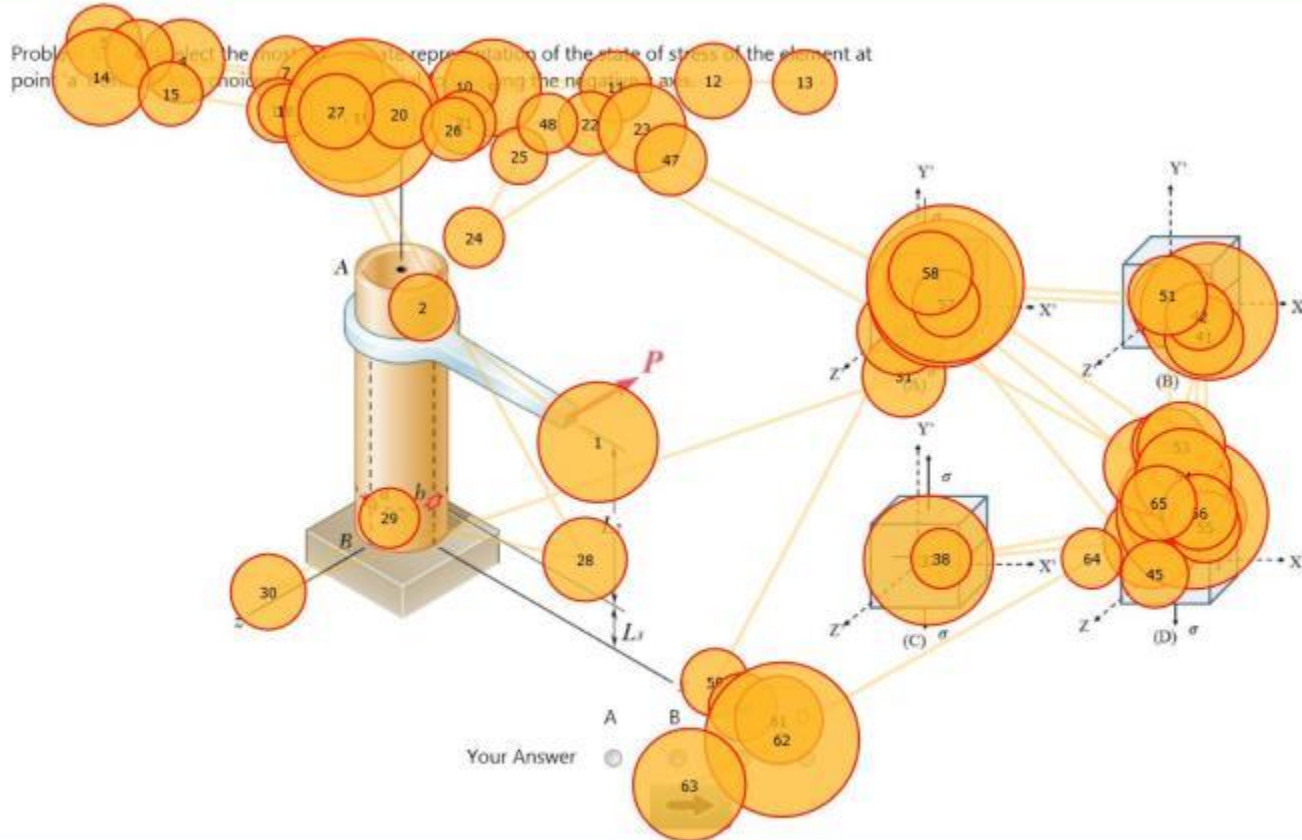
Apparatus	Model	Supplier	Features
Eye tracker	X-60	Tobii	Data rate: 60 Hz
Data recording	Attention Tool	iMotions	Easy, Fast & Reliable
Display	Compaq LA2306x	HP	Screen size: 23"
Computer	Thinkpad T530	Lenovo	Intel Core i5, 16GB Ram

	Participants	Gender		Grade	
		Male	Female	Junior	Senior
Number	18	14	4	11	7
Percentage	100%	77.8%	22.2%	61.1%	38.9%

Scatter plot of participants' PSVT score and solid mechanics problem performance

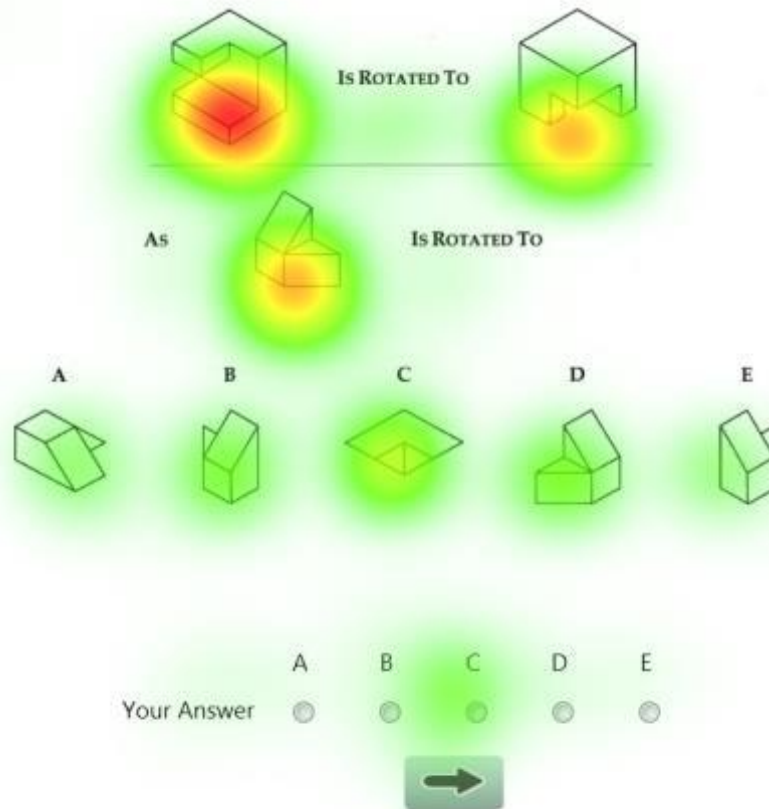
Pearson Correlation Coefficient = 0.541, $p = 0.025$





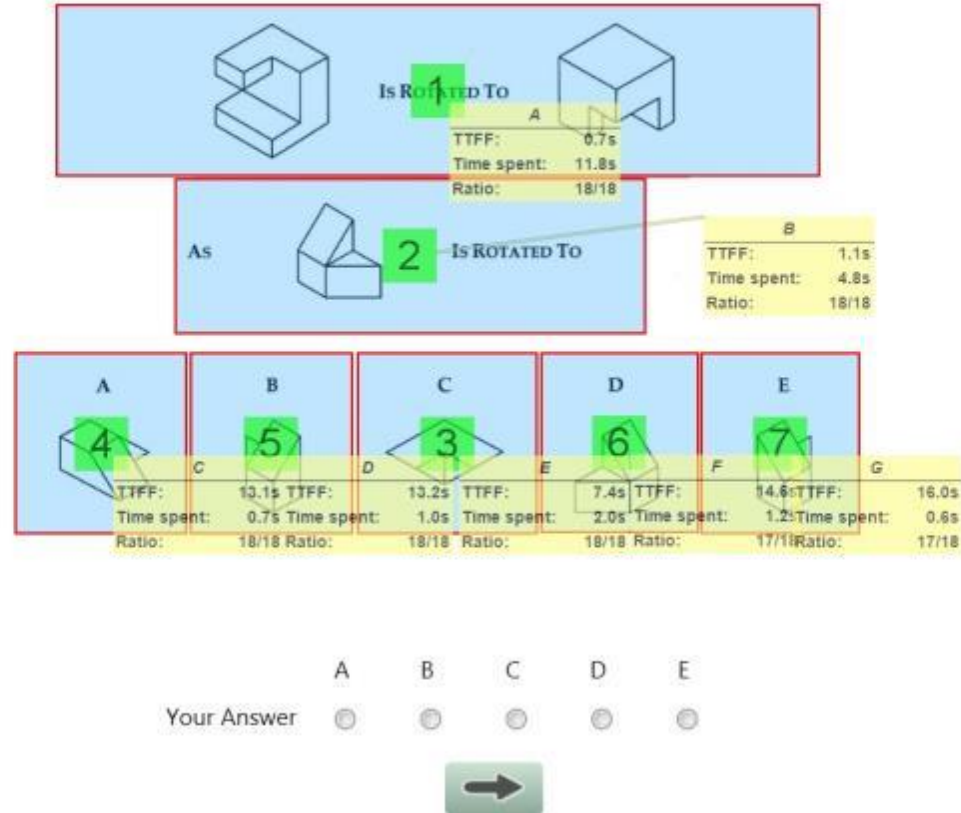
Gaze Replay of solid mechanics problem 5

PSVT Problem 1



Heat map of PSVT problem 1

PSVT Problem 1



The interface displays a sequence of 3D cube-like shapes. The first shape is a cube with a missing front face. The second shape is a cube with a missing top face. The text "Is ROTATED TO" is placed between them. Below this, a yellow box labeled 'A' contains the text: "TTF: 0.7s", "Time spent: 11.8s", and "Ratio: 18/18".

The third shape is a cube with a missing right face. The text "As" is to its left, and "Is ROTATED TO" is to its right. A yellow box labeled 'B' contains the text: "TTF: 1.1s", "Time spent: 4.8s", and "Ratio: 18/18".

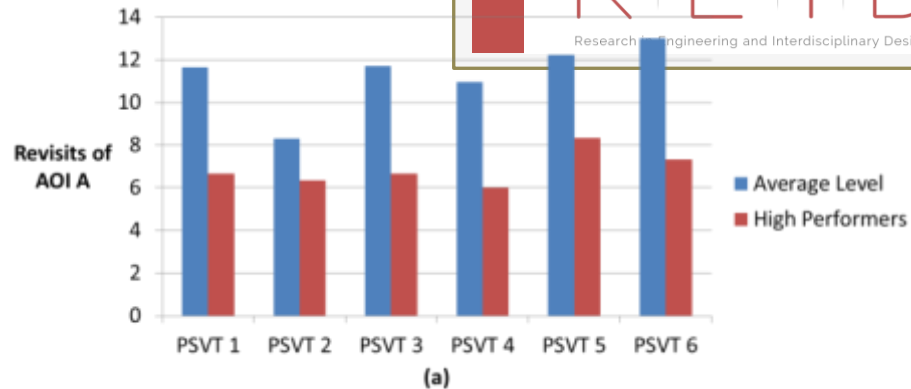
Below these are five options labeled A through E, each with a green number in a box: A (4), B (5), C (3), D (6), and E (7). Each option has associated performance data in a yellow box:

A	B	C	D	E
TTF: 10.1s	TTF: 13.2s	TTF: 7.4s	TTF: 14.6s	TTF: 16.0s
Time spent: 0.7s	Time spent: 1.0s	Time spent: 2.0s	Time spent: 1.2s	Time spent: 0.6s
Ratio: 18/18	Ratio: 18/18	Ratio: 18/18	Ratio: 17/18	Ratio: 17/18

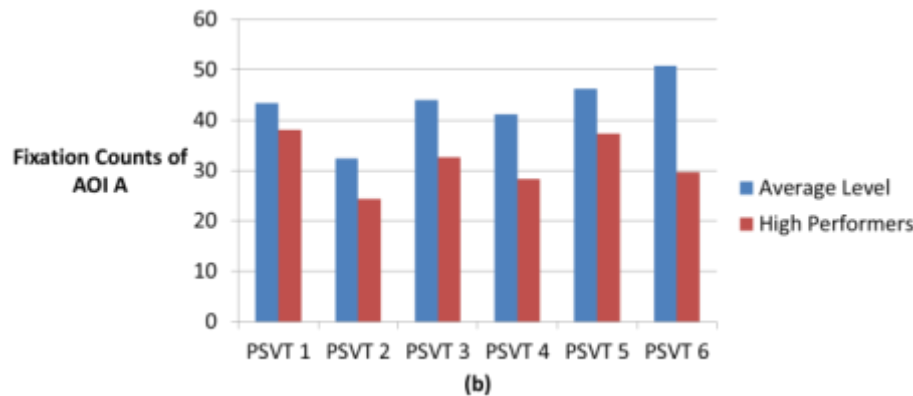
At the bottom, there is a "Your Answer" section with radio buttons for options A, B, C, D, and E. A green arrow button is positioned below the answer choices.

Stimulus: PSVT1 | Exposure time: 33.3s

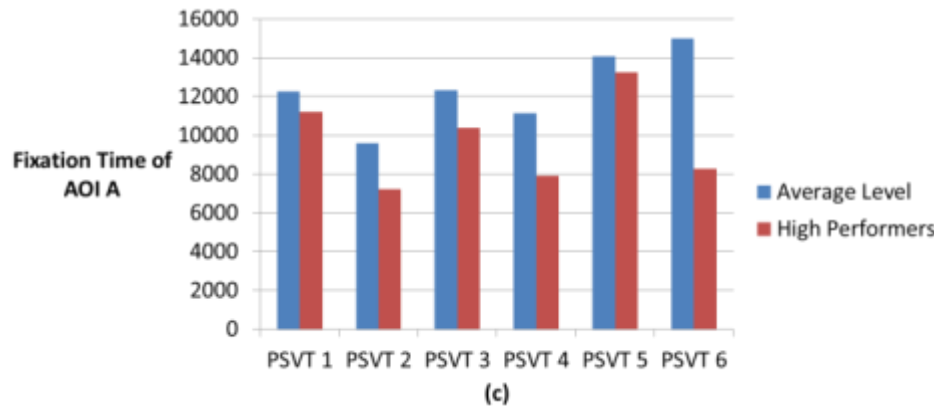
Areas of Interest (AOIs) of PSVT problem 1



$p=0.0001$



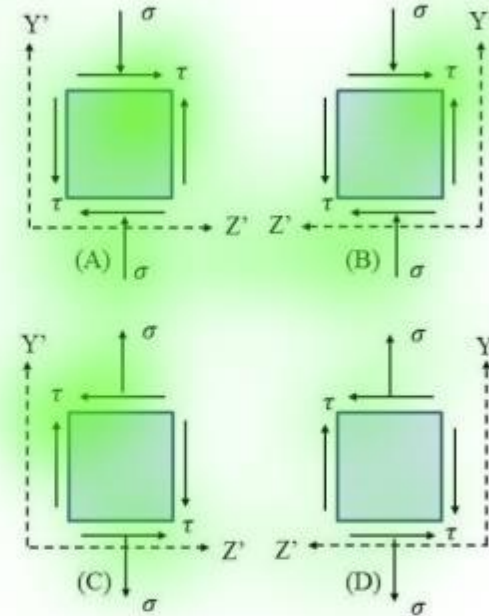
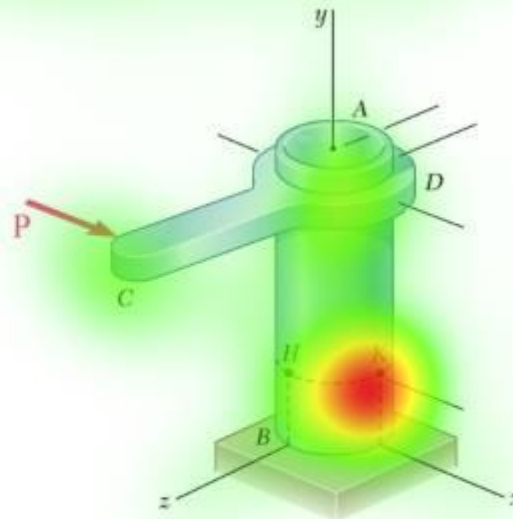
$p=0.004$



$p=0.028$

$\alpha = 0.05$

Problem 2: Try to select the most appropriate representation of the state of stress of the element at point K from the four choices. P is a horizontal force along the positive x axis.

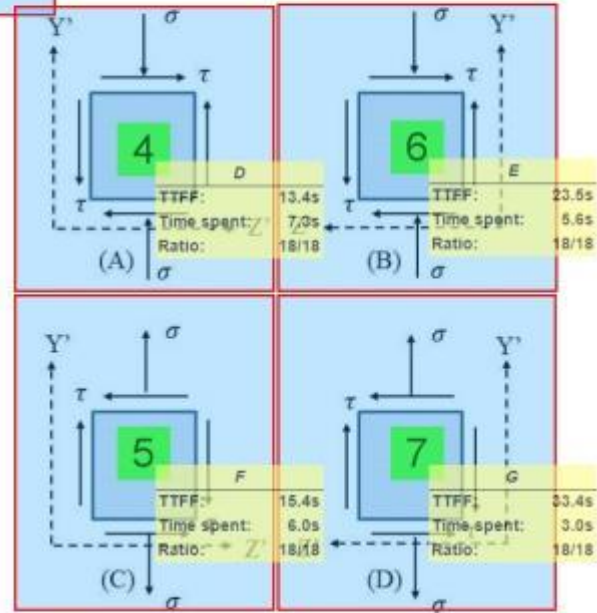
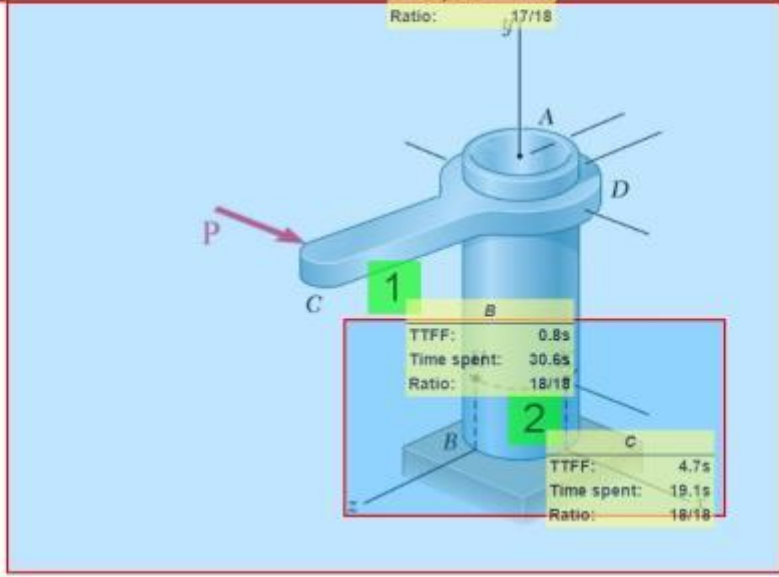


Your Answer A B C D



Heat map of solid mechanics problem 2

Problem 2: Try to select the most appropriate representation of the state of stress of the element at point K from the four choices. P is a horizontal force along the positive x axis.



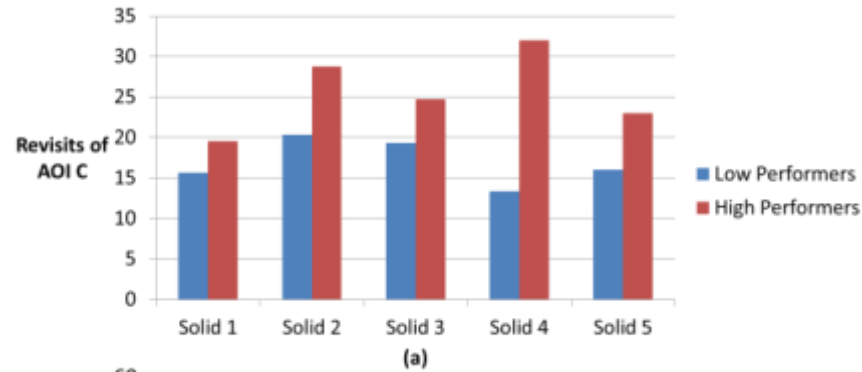
A B C D

Your Answer

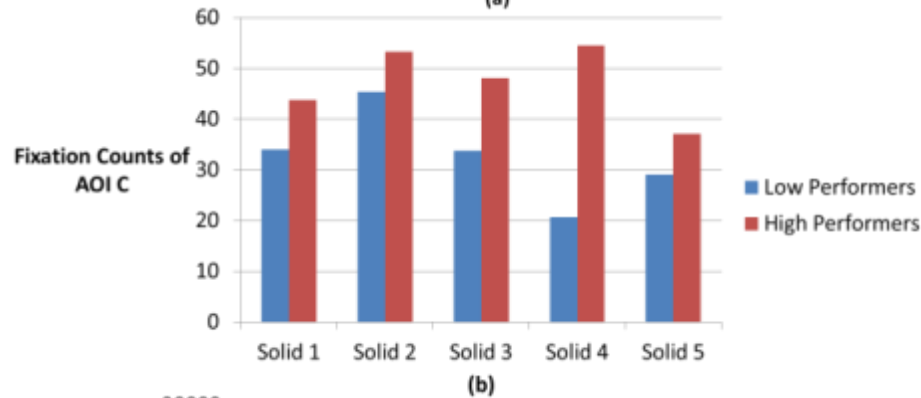
➔

Stimulus: P2 | Exposure time: 80s

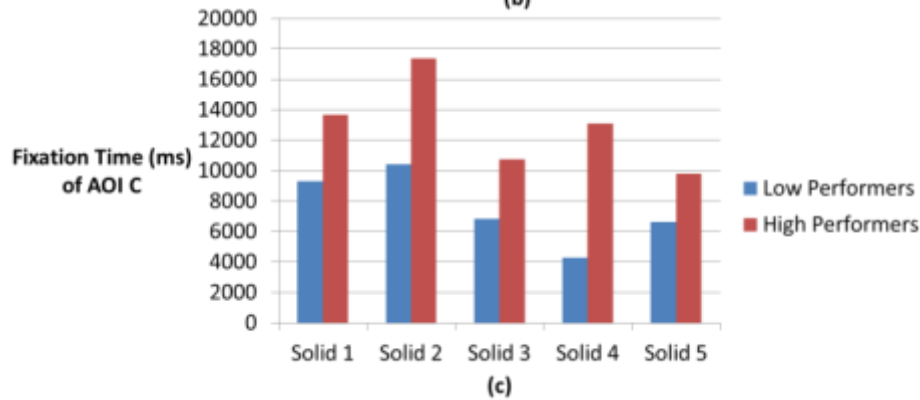
Areas of Interest (AOIs) of solid mechanics problem 2



$p=0.007$



$p=0.012$



$p=0.008$

$\alpha = 0.05$

Summary of the Preliminary Results

1. Participants' PSVT performances and solid mechanics problem performances are correlated positively.
2. High performers spent less time and fixated less frequently on the critical area of the visual stimulus of PSVT problems.
3. High performers focused on the critical areas of the problem diagram more frequently and longer than low performers did when solving solid mechanics problems.

THANK YOU!