Eye Tracking Technologies to Analyze and Visualize the Behavior of Secure Coders

Daniel Davis

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Research Advisor / Committee Chair – Dr. Feng Zhu

THE UNIVERSITY OF
ALABAMA IN HUNTSVILLE

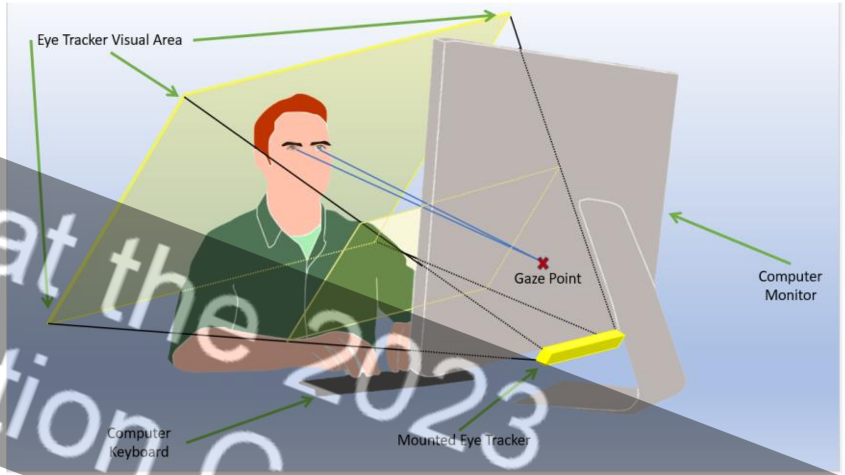
Introduction

- Secure coders techniques and procedures
- Costly coding security flaws in applications
- Common Weakness Enumeration (CWE) repository
- Build hands-on secure coding learning modules
- Eye tracking technologies to capture behaviors
- Literature survey of existing visualization analysis
- Static vs (linear and non-linear) dynamic stimuli
- Eye tracking design and analysis framework
- Decision matrix for designing experiment

- Limitations of current visualization methods used in eye tracking
- Scrolling stimuli
- Participant-editable stimuli
- Creating Areas of Interests (AOIs)
- How do coders find and mitigate security flaws
- How developers read/write code, utilize security tools, and read instructions
- Transitions among eye tracking stimuli and between software application

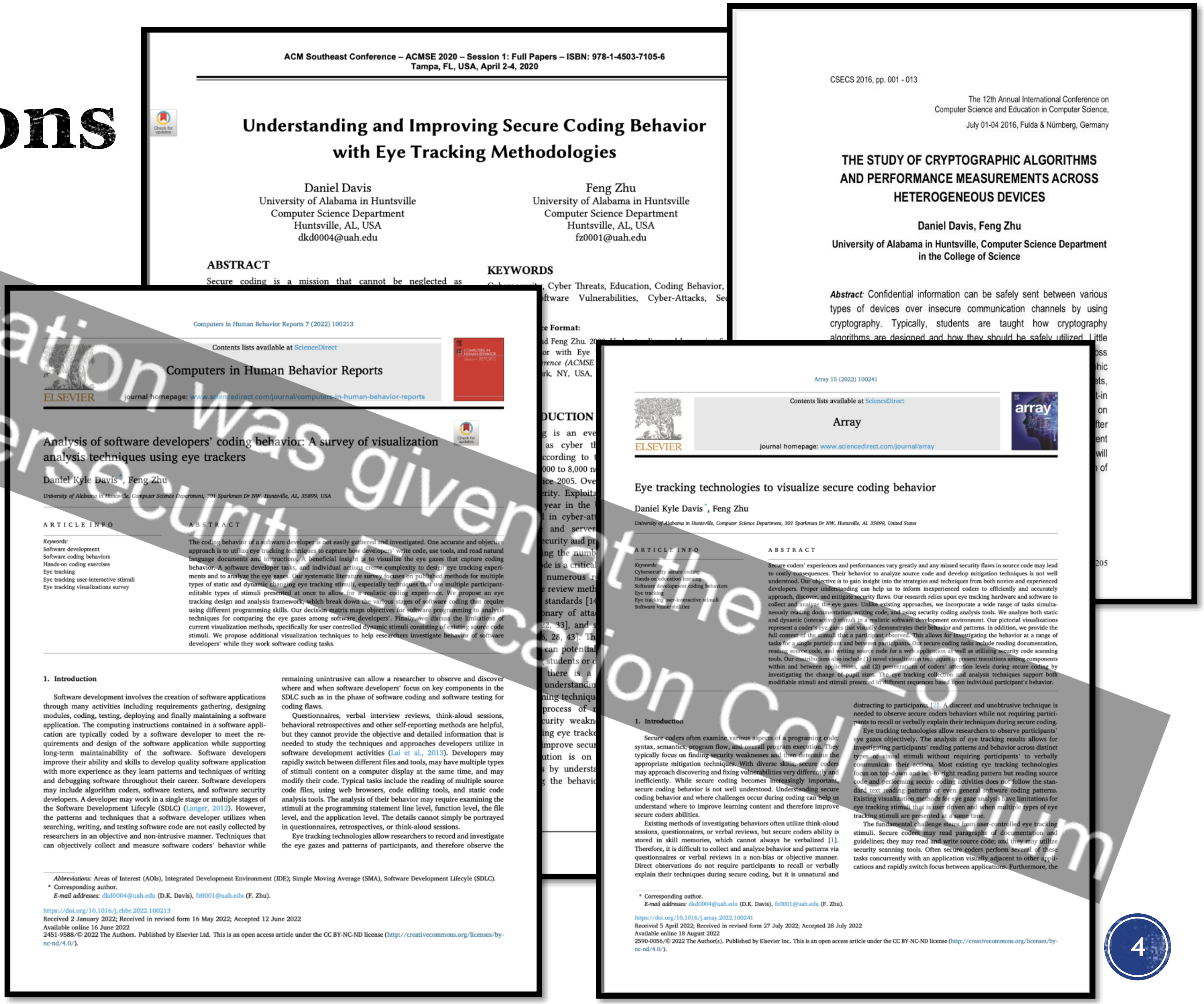
Research Contributions

- Classification of the goals, objectives, participant tasks, and visualization techniques in distinct stages of the SDLC for eye tracking
- Understanding of secure coders' behaviors with multiple types of visualizations of distinct aspects in secure coding and over a timeline
- At the low level, we process eye movements, the speed of movement, the duration of eye fixation, and changes in pupil sizes
- At the medium level, we examine participants' eye gaze at the application and source code files or function level
- At the high level, we present participants' secure coding patterns and strategies
- We propose swimlane diagrams, state transition diagrams, and pupil size fluctuation diagrams
- Developed our Eye Tracking Design and Analysis Framework for software development with a focus on secure coding
- A decision matrix for mapping objectives/tasks in the SDLC to specific aspects of eye tracking design, analysis, and comparison
- Guide on the type of software tasks and eye tracking stimuli to present to participants



Publications

- The Study of Cryptographic Algorithms and Performance Measurements Across Heterogeneous Devices
  - Computer Science and Education in Computer Science (CSECS)
  - July 2016
  - Pages 205 - 219
- Understanding and Improving Secure Coding Behavior with Eye Tracking Methodologies
  - Association for Computing Machinery Southeast (ACMSE)
  - April 2020
  - Pages 107 - 114
- Analysis of Software Developers' Coding Behavior: A Survey of Visualization Analysis Techniques Using Eye Trackers
  - Computers in Human Behavior Reports
  - August 2022
  - Pages 1 - 28
- Eye Tracking Technologies to Visualize Secure Coding Behavior
  - Array
  - September 2022
  - Pages 1 - 34



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Understanding and Improving Secure Coding Behavior with Eye Tracking Methodologies

Daniel Davis
University of Alabama in Huntsville
Computer Science Department
Huntsville, AL, USA
dkd0004@uah.edu

Feng Zhu
University of Alabama in Huntsville
Computer Science Department
Huntsville, AL, USA
fz0001@uah.edu

ABSTRACT

KEYWORDS

CSECS 2016, pp. 001 - 013

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THE STUDY OF CRYPTOGRAPHIC ALGORITHMS AND PERFORMANCE MEASUREMENTS ACROSS HETEROGENEOUS DEVICES

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University of Alabama in Huntsville, Computer Science Department in the College of Science

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Analysis of software developers' coding behavior: A survey of visualization analysis techniques using eye trackers

Daniel Kyle Davis*, Feng Zhu

University of Alabama in Huntsville, Computer Science Department, 301 Sparkman Dr NW, Huntsville, AL, 35899, USA

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Eye tracking technologies to visualize secure coding behavior

Daniel Kyle Davis*, Feng Zhu

University of Alabama in Huntsville, Computer Science Department, 301 Sparkman Dr NW, Huntsville, AL, 35899, United States

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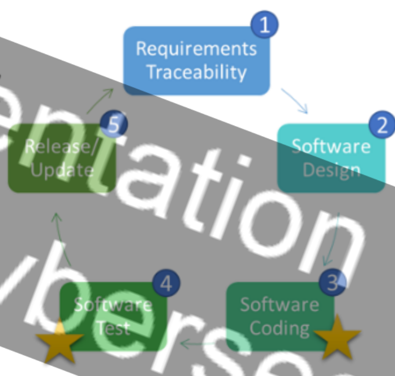
Study Design / Methods

Software Development Lifecycle



★ ➔ *Stages that we focused on in our framework*

High Level Objectives in each SDLC Stages

Software Requirements and Design Stage	Software Coding Stage
• Requirements Definition Documents • Graphical Modeling Languages (UML) • Reading Problem Statement • Design Reviews	• Answering Problem Statements • Reading Source Code • Writing Source Code • Utilizing IDEs • Code Reviews / Code Walkthroughs
Software Testing Stage	**Overlapping Stages of the SDLC**
• Reading Source Code • Testing Code Modifications • Running Code Scanning Tools • Reviewing Coding Analysis Tools • Utilizing IDEs • Code Reviews	• Reading Documentation / User Guides • Researching Online Guidance/ Solutions

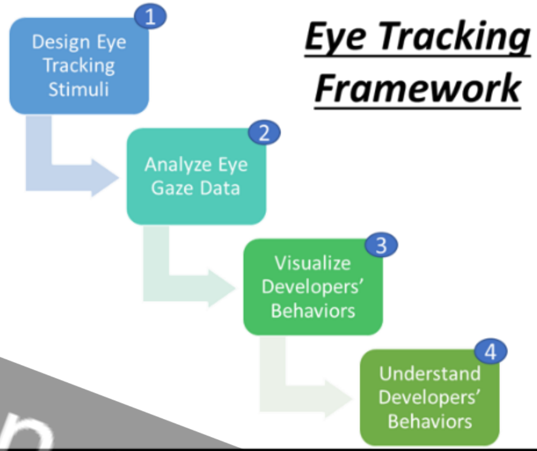
Software Coding

- Reading Source Code
- Writing Source Code
- Using IDEs/Tools

Software Testing

- Reading Source Code
- Using IDEs/Tools

Eye Tracking Framework


1
Design Eye Tracking Stimuli
2
Analyze Eye Gaze Data
3
Visualize Developers' Behaviors
4
Understand Developers' Behaviors

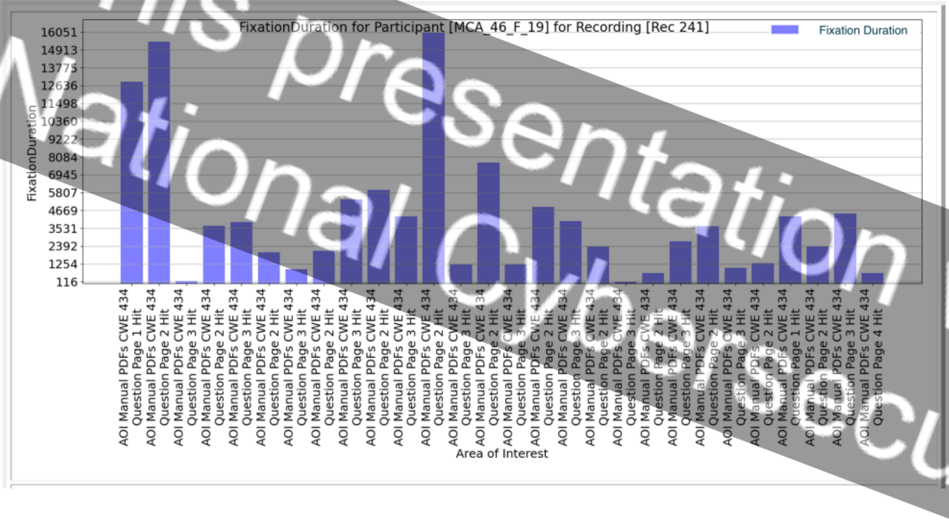
Design of Eye Tracking Stimuli

Types of Tasks	Types of Stimuli	Viewing Dimensions	Developer Interactive
• Natural Language Reading • Reading Source Code • Writing Source Code • Using IDEs/Tools	• Code Static Content • Linear Dynamic Content • Non-Linear Dynamic Content	• Single Stimuli • Side-by-Side Multiple Stimuli • Overlapping Multiple Stimuli	• Developer Non-Changeable • Developer Interactable

Analysis of Eye Gaze Data

Areas of Interest	Comparison Perspective	Quantitative vs Qualitative
• Single • Multiple • Overlaying	• Single Developer • Multiple Developers	• Descriptive Statistical • Statistical Graphic • Infographics

Results



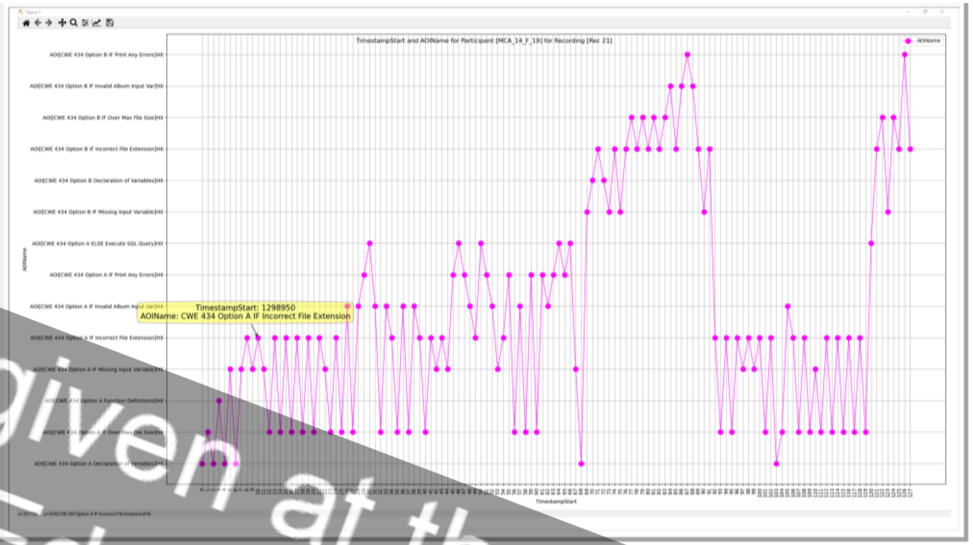
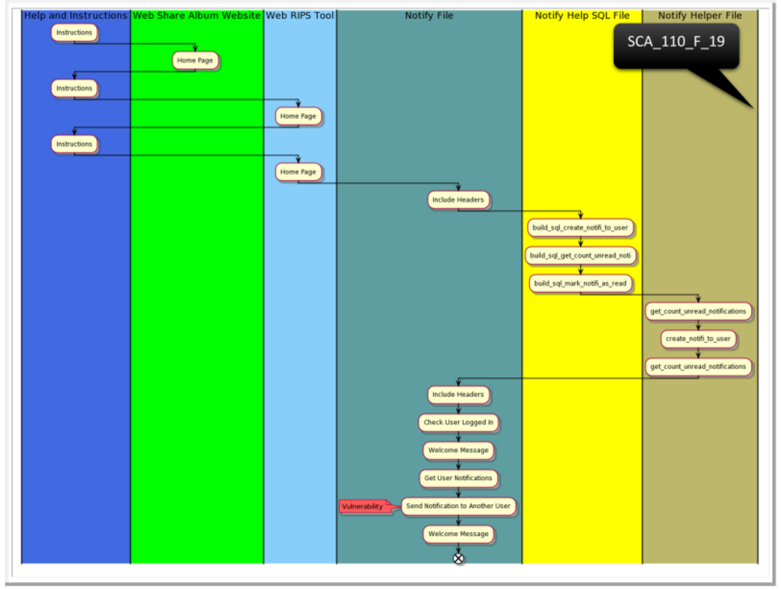
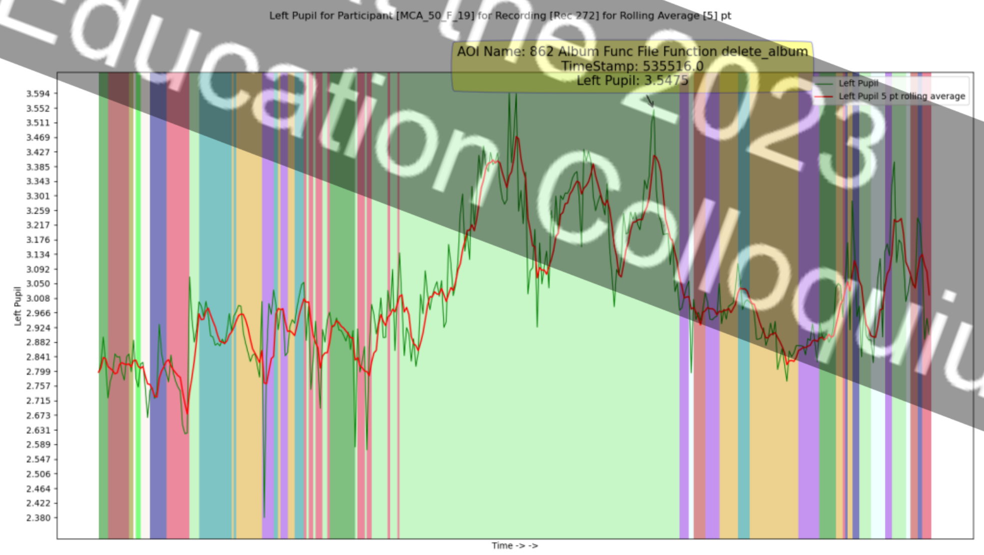


Figure 1
TimestampStart and AOIName for Participant [MCA_14_F_19] for Recording [Rec 21]
AOIName
AOI[CWE 434 Option B IF Print Any Errors]Hit
AOI[CWE 434 Option B IF Invalid Album Input Var]Hit
AOI[CWE 434 Option B IF Over Max File Size]Hit
AOI[CWE 434 Option B IF Incorrect File Extension]Hit
AOI[CWE 434 Option B Declaration of Variables]Hit
AOI[CWE 434 Option B IF Missing Input Variable]Hit
AOI[CWE 434 Option A ELSE Execute SQL Query]Hit
AOI[CWE 434 Option A IF Print Any Errors]Hit
AOI[CWE 434 Option A IF Invalid Album Input Var]Hit
AOI[CWE 434 Option A IF Incorrect File Extension]Hit
AOI[CWE 434 Option A IF Missing Input Variable]Hit
AOI[CWE 434 Option A Function Definitions]Hit
AOI[CWE 434 Option A IF Over Max File Size]Hit
AOI[CWE 434 Option A Declaration of Variables]Hit
TimestampStart: 1298950
AOIName: CWE 434 Option A IF Incorrect File Extension
TimestampStart

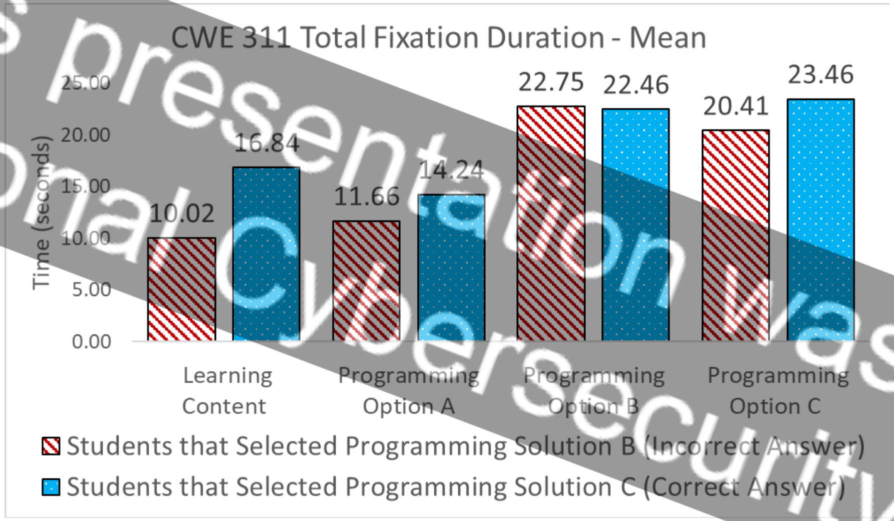

Help and Instructions | Web Share Album Website | Web RIPS Tool | Notify File | Notify Help SQL File | Notify Helper File

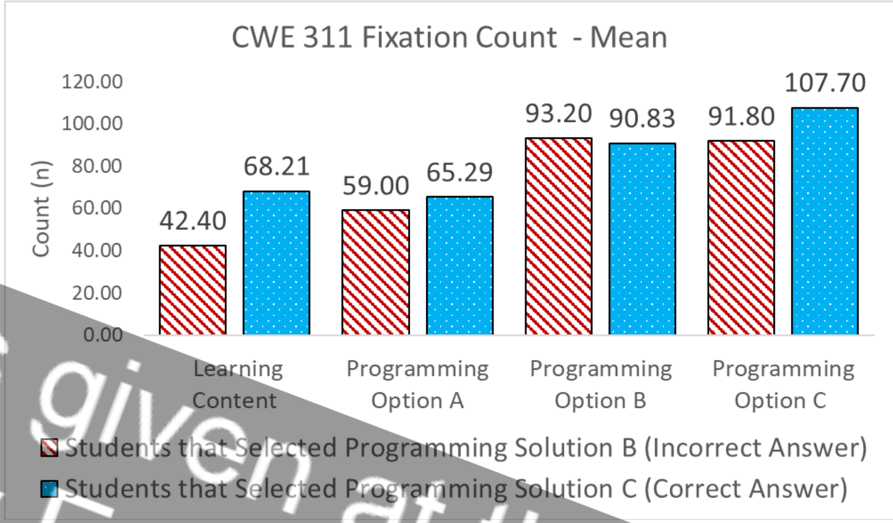
SCA_110_F_19

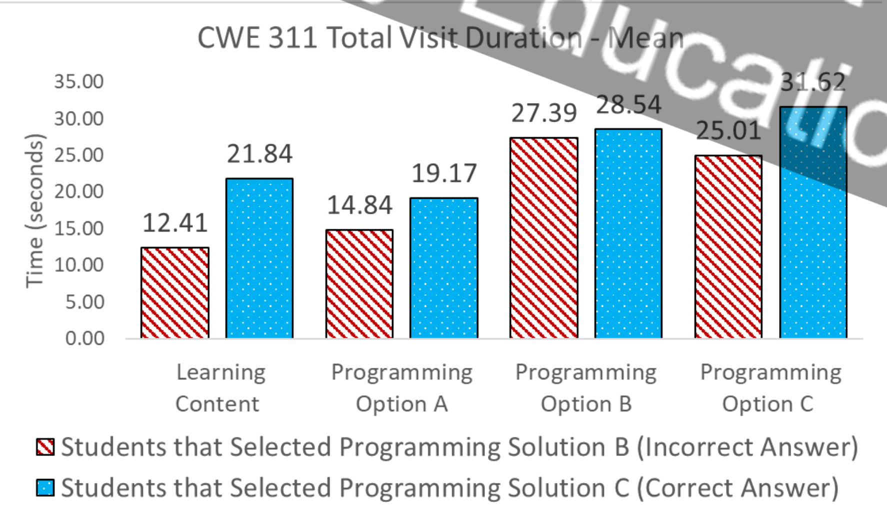
- Instructions
- Home Page
- Instructions
- Home Page
- Instructions
- Home Page
- Include Headers
- build_sql_create_notifi_to_user
- build_sql_get_count_unread_noti
- build_sql_mark_notifi_as_read
- get_count_unread_notifications
- create_notifi_to_user
- get_count_unread_notifications
- Include Headers
- Check User Logged In
- Welcome Message
- Get User Notifications
- Send Notification to Another User — Vulnerability
- Welcome Message



Secure Coder Responses CWE-311


CWE 311 Total Fixation Duration - Mean


CWE 311 Fixation Count - Mean


CWE 311 Total Visit Duration - Mean

Ongoing Work

- Our focus has been on analyzing the data at both the low-level and high-level
- One area we are investigating is to compare the behaviors of those that answered correctly with those that did not answer correctly
  - Methods being explored
    - Manually Analysis
    - Automated Analysis (low-level or high-level) (machine learning)
  - CWE Problems being explored
    - True/False if Software Flaw – CWE-443 or CWE-73
    - Programming Problem – CWE-862 or CWE-22
- Analyze reading patterns between novice and expert secure coders
  - Majority of our data is with novice secure coders

QUESTIONS / COMMENTS