On the Influence of Representation Type and Gender on Program Comprehension

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“Programming is far more complex than usual human mental activities studied by psychologists” (Weinberg and Schulman, 1974)
Mental Model
Program Comprehension

- Over 35 years of research
- Rich with diverse theories

Think-aloud  Observational studies  Questionnaires
Eye-tracking Technology

EyeLink II
(SR Research)

faceLAB 5
(Seeing Machines)

SMI Eye Tracking Glasses
(Sensomotoric Instruments)
Hawthorn Effect

<<Implementation>>

AbstractTool

# 'View : DrawingView

+ AbstractTool(itsView : View, 
  + drawing) : DrawingView
+ edition() : DrawingEd
+ view() : DrawingView
+ activate() : void
+ deactivate() : void
+ mouseDown(MouseEvent event, x : int, y : int) : void
+ mouseDrag(MouseEvent event, x : int, y : int) : void
+ mouseUp(MouseEvent event, x : int, y : int) : void
Representation’s type

Program's characteristics

Developer’s characteristics

Task variability

Program Comprehension
Representation Type (Graphical vs. Textual)

Apple

• Round
• Red or Yellow
• Edible fruit

Vs.
Developers’ Characteristics

- Expertise (novices vs. experts)

There is still a great divergence between developers’ abilities that cannot be detected only by their level of expertise. (Storey, 2005).
Thesis Statement

Representation type and gender:

• To impact the cognitive process
• To impact developers’ efficiency and effectiveness
• To be proxy for developers’ viewing strategies
  • To be inferred partly from the developers’ eye-movements
Systematic Literature Review (SLR)

Evidence-based Paradigm

Evidence-based Software Engineering (EBSE)

SLR about SLRs in SE

1992 2004 2010

UML Unit Testing Theory
A Systematic Literature Review on the Usage of Eye-tracking in Software Engineering
A Systematic Literature Review
Descriptive Statistics

<table>
<thead>
<tr>
<th>How many</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ 1990 - 2014</td>
</tr>
<tr>
<td>✓ 36 articles</td>
</tr>
<tr>
<td>✓ 9 journal</td>
</tr>
<tr>
<td>✓ 2 workshop</td>
</tr>
<tr>
<td>✓ 25 conference</td>
</tr>
</tbody>
</table>

Under revision, IST Journal, 2013
A Systematic Literature Review

Topics

- Code comprehension (12)
- Model comprehensions (10)
- Debugging (9)
- Collaborative interaction (3)
- Traceability (2)
A Systematic Literature Review
Metrics

• Effort:
  • Fixation, Saccades
  • Visited AOIs
• Visual gaze behaviour
• Scan-path
A Systematic Literature Review

Limitation

- Technology
- Data analysis
- Participant & material selection
- Experimental setting
A Systematic Literature Review

Conclusion

• To provide descriptive statistics
• To present an annotated bibliography
• To summarise all the metrics and tools
• To present limitations
• To provide a unified terminology for reporting
A Systematic Literature Review
Lesson Learned

KEEP CALM AND STUDY FACTORS

USE METRICS

MITIGATE LIMITATIONS
Picture Is Worth a Thousand Word

1. **Lamp doesn't work**
   - **Lamp plugged in?**
     - **No** → **Plug in lamp**
     - **Yes** → **Bulb burned out?**
       - **Yes** → **Replace bulb**
       - **No** → **Repair lamp**
The Impact of Representation Type

Only a few works compare textual vs. graphical representations for program comprehension

RQ1: Developers’ preferred representation

RQ2: Impact of representation type on time, accuracy, and effort

ICPC, 2013
The Impact of Representation Type

Task

Session 1

Session 2

Session 3
1. What is/are the resource(s) that helps in having health emergency monitored?
   a) biological sensors
   b) biological sensors and patient log book

- Patient log books
- Biological sensors
- Monitor health factors
- Monitor history of the patient
- Monitor the stairs
- Cameras
- Falls sensors

Patient log books and biological sensors are relevant.
1. What is/are the resource(s) that helps in having health emergency monitored?
   a) biological sensors
   b) biological sensors and patient log book

Goal: “patients’ falls monitored” that is OR operationalised by
   Task: “monitor the stairs” using
       Resource: “falls sensors” and “cameras”

Goal: “health emergencies monitored” that is operationalised by
   Task: “monitor history of the patient” via
       Resource: “patient log books”
   Task “monitor health factors”
       Resource: “biological sensors”
The Impact of Representation Type
Participants

Total: 28

<table>
<thead>
<tr>
<th>Academic Background</th>
<th>Gender</th>
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</thead>
<tbody>
<tr>
<td>PhD</td>
<td>Masters</td>
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<tr>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>
RQ1: Is Graphical More Effective?
RQ2: Impacts on Developers’ Efficiency

<table>
<thead>
<tr>
<th>Type</th>
<th>Accuracy %</th>
<th>Wrong</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphical</td>
<td>97%</td>
<td>3%</td>
</tr>
<tr>
<td>Textual</td>
<td>98%</td>
<td>2%</td>
</tr>
<tr>
<td>Mixed</td>
<td>96%</td>
<td>4%</td>
</tr>
</tbody>
</table>
RQ2: Impacts on Developers’ Efficiency

<table>
<thead>
<tr>
<th>AFD(M)</th>
<th>AFD(Re)</th>
<th>AFD(Ir)</th>
<th>AFD(Q)</th>
</tr>
</thead>
</table>

M: Model  
Re: Relevant  
Ir: Irrelevant  
Q: Question
The Impact of Representation Type

Conclusion
The Impact of Representation Type

Conclusion

• Prefer graphical
• Work with graphical in mixed stimulus
• Find relevant parts faster
Start time of the first fixation on relevant AOIs
The Impact of Representation Type
Lesson Learned

Importance of Layout

Source code as structures text
Systematic Literature Review

Impact of Representation Type

Impact of Gender

Haunted Forest of Statistical Analysis

Mount of Thesis Writing

Conclusion

swamp of procrastination
Systematic Literature Review

swamp of procrastination

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swamp of procrastination
The Impact of Gender
Why Do We Care?

- Studying the need of one sub-population can benefit both sides
- Design tools better adapted to different developers
- Support different program understanding strategies
The Impact of Gender
Experiment 1: The Impact of Identifier Style

✓ Previous work, such as (Binkley et al., 2012) and (Sharif and Maletic, 2010c), reported contradictory findings.

RQ1: The impact of identifier style on effort, the task time, and accuracy

RQ2: The impact of gender on effort, the task time, accuracy, and viewing strategies
The Impact of Gender
Experiment 1: Task

Source code stimulus

```java
public class PrimeNumCalc {
    private final int UpperLimit = 100;
    public void calcPrimeNums() {
        int i = 0;
        int nCounter = 0;

        while (++i <= UpperLimit) {
            int innerLoop = (int) Math.ceil(Math.sqrt(i));
            boolean isPrimeNumber = false;

            while (innerLoop > 1) {
                if ((i != innerLoop) && (i % innerLoop == 0)) {
                    isPrimeNumber = false;
                    break;
                } else if (!isPrimeNumber) {
                    isPrimeNumber = true;
                }
                --innerLoop;
            }
            if (isPrimeNumber) {
                System.out.println(i);
                ++nCounter;
            }
        }
        System.out.println("Nr of prime numbers found: " + nCounter);
    }
}
```

What is the output of this program?

Question stimulus

Q1: what is the name of the class?

1. PrimeNumClac
2. NumCalculator
3. MyClass
4. PrClass
The Impact of Representation Type
Participants

Total: 24

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<td>10</td>
<td>9</td>
</tr>
<tr>
<td>BSc</td>
<td></td>
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<tr>
<td>3</td>
<td></td>
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</tbody>
</table>
The Impact of Gender

Experiment 1: Results

<table>
<thead>
<tr>
<th></th>
<th>Accuracy</th>
<th>Time (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>74%</td>
<td>5.94</td>
</tr>
<tr>
<td>Female</td>
<td>82%</td>
<td>7.18</td>
</tr>
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</table>
Q4) what is the name of the class?

1) 2D_frame
2) Painter
3) Java_2D_frame
4) My_class

1) 2D_Frame
2) Painter
3) Java_2D_Frame
4) My_Class
The Impact of Gender

Experiment 1: Conclusion

Men and women use different strategies to select the correct answer
The Impact of Gender
Lesson Learned

Different Attention Distribution
The Impact of Gender
Experiment 2: the Impact of SCEs

- Previous studies suggest that developers:
  - Avoid understanding the entire system
  - Focus on some parts

- Source code entities

<table>
<thead>
<tr>
<th>Class name</th>
<th>Method name</th>
<th>Comments</th>
<th>Variables</th>
</tr>
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</table>
The Impact of Gender
Experiment 2: the impact of SCEs

RQ3: What are the important source code entities (SCEs)
RQ4: Impact of gender on developers’ viewing strategies
The Impact of Gender
Experiment 2: Task

```java
// This class is responsible to communicate with database
// with the help of JDBC driver

public class DataDB {
    public void getMyTableData() {
        String myPath = "jdbc:microsoft:sqlserver://localhost:1433;DatabaseName=MyDatabase";
        String myAdrs = "com.microsoft.jdbc.sqlserver.SQLServerDriver";
        Connection myC = null;
        Statement newS = null;
        ResultSet newSet = null;

        myC = DriverManager.getConnection(myAdrs, "userid", "password");
        newS = dBConnection.createStatement();
        dQuery = "select * from myTable";
        newSet = newS.executeQuery(newWord);

        while (newSet.next()) {
            System.out.print(newSet.getString(1) + ",
                + dBResultSet.getString(2));
            System.out.print(";
                + newSet.getString(3) + "n");
        }
    }
}
```

This class uses JDBC driver to connect to a database and get data from myTable.
The Impact of Representation Type
Participants

Total: 24

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<tr>
<td>20</td>
<td>17</td>
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<tr>
<td>4</td>
<td>7</td>
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<tr>
<td>0</td>
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The Impact of Gender

Experiment 2: Viewing Strategies

```java
// This class is responsible to communicate with database
// with the help of JDBC driver

public class DataDB {

    Connection myC = null;
    Statement newS = null;
    ResultSet newSet = null;

    String myAddr = "com.microsoft.jdbc.sqlserver.SQLServerDriver";
    String myPath = "jdbc:microsoft;sqlserver://localhost:1433;DatabaseName=MyDatabase";

    public void getMyTableData() {

        String newWord = "";

        myC = DriverManager.getConnection(newURL, "userid", "password");
        newS = newConnection.createStatement();
        dQuery = "select * from myTable";
        newSet = newS.executeQuery(newWord);

        while (newSet.next()) {
            System.out.print(newSet.getString(1) + "," );
            + dResultSet.getString(2));
            System.out.println("" + newSet.getString(3) + "\n");
        }
    }
}
```

This class uses JDBC driver to connect to a database and get data from myTable
The Impact of Gender
Experiment 2: Viewing Strategies

Path: 1,2,1,2,3,4

Total time: 1780

Path: 1,2,3,2,3,1,2,4,3,1,3,4,3

Total time: 1315
Average length of scan-paths

- Q1: Men and Women are close in length.
- Q2: Men show a significant increase, while Women remain relatively stable.
- Q3: Men continue to rise, Women remain steady.
- Q4: Men peak, Women show a slight increase.
- Q5: Men decrease, Women also show a decline.
- Q6: Men show a moderate decrease, Women continue to decline.

Legend: Men (blue), Women (orange)
The Impact of Gender
Further Analysis

Method name is the most preferred type of SCEs.

```java
// This class accesses all files of a directory and
// finds files with specific type.
public class FileUtil {

    //create a FileFilter and override its accept-method
    FileFilter fileFilter = new FileFilter() {
        public boolean accept(File file) {
            if (file.getName().endsWith(".csv")) {
                return true;
            }
            return false;
        }
    };

    public void listFilesMethod(String dir) {
        File directory = new File(dir);
    }
}
```
The Impact of Gender
Further Analysis

• No difference between MiB and CiB
• Participants start looking at the Bigger SCE
• Method name, method name, method name ...
The Impact of Gender
Lesson Learned

• Do not rush into adaptation
The Impact of Gender

Conclusion

Our findings raise two significant new open questions:

1. Are there differences between viewing strategies of male and female developers while performing program comprehension tasks and whether these strategies impact their efficiency and effectiveness or not?

2. To which extent do current programming environments support these strategies?
Systematic Literature Review

Impact of Representation Type

Conclusion

Swamp of Procrastination

Mount of Thesis Writing

Impact of Gender

Haunted Forest of Statistical Analysis

We are here

Ph.D.
Systematic Literature Review

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Conclusion

Mount of Thesis Writing

Ph.D.
Apple

- Round
- Red or Yellow
- Edible fruit
Short term

• Analyze the impact of layout on developers’ performance
• Scan-path and AOI analysis
• Image processing approaches to analyze heatmaps

Long term

• Study developers’ viewing strategies and reading behaviour
• Analyze the applicability of our gender differences findings
Conclusion

Systematic Literature Review

Impact of Representation Type

Impact of Gender

Haunted Forest of Statistical Analysis

swamp of procrastination

Mount of Thesis Writing

Ph.D.

We are here
Awards

1. Le Fonds de recherche du Québec, Nature et technologies (FRQNT)

Journal Papers

2. An empirical study on the importance of source code entities for requirements traceability. EMSE, 2014

Conference Papers

2. Professional Status or Expertise for UML Class Diagram Comprehension: An Empirical Study Systematic. ICPC 2012
Apple

Vs.

- Round
- Red or Yellow
- Edible fruit