Measuring Program Comprehension with Functional Magnetic Resonance Imaging (fMRI)

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http://fbsd.net/experiments/

**Measuring Program Comprehension**

Program comprehension is a complex, internal, cognitive process. Programmers understand source code either bottom-up by analyzing each statement, or top-down by recognizing familiar statements. The kind of process depends on the knowledge we have of a program’s domain. However, we cannot observe program comprehension directly, but have to use an indirect measurement approach.

However, no indirect measure captures the comprehension process completely. Instead, we want to directly observe the comprehension process. With our work, we measure program comprehension directly with functional magnetic resonance imaging.

Can we look inside a programmer’s brain?

**Functional Magnetic Resonance Imaging**

fMRI has been successfully applied to better understand cognitive processes, such as perception, attention, memory, or language understanding. Many of the relevant brain areas involved in these processes are to some degree recruited for program understanding, as well. We set out to unravel the differential contributions of the different brain areas in program comprehension with the aim of learning more about how different programmers with different skills and knowledge solve programming tasks.

Can we get a better understanding of program comprehension?

**How does fMRI Work?**

When a brain area gets activated, its oxygen need increases. Thus, the amount of oxygenated blood increases, and the amount of deoxygenated blood decreases. Both have different magnetic properties, which we can measure inside an fMRI scanner.

**Challenges of fMRI Studies**

The design of fMRI studies has to meet several requirements:

First, we need two kinds of tasks, one activating program comprehension and one control task that does not trigger program comprehension. By comparing resulting activation of both kinds of tasks, we get only the brain activation caused by understanding.

Second, all tasks must meet the following requirements. The difficulty must lead to response times between 30 and 120 seconds; the code size needs to fit on the small screen inside the fMRI scanner; overall, the time limit of one session should not exceed 60 minutes, to ensure attention of participants.

**Our fMRI Study**

**Experimental Design**

<table>
<thead>
<tr>
<th>Understanding task (60 seconds)</th>
<th>What is the output of the method?</th>
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<tbody>
<tr>
<td>Press button when output determined</td>
<td></td>
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<tr>
<th>Control task (30 seconds)</th>
<th>Locate 3 syntax errors in code.</th>
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<tbody>
<tr>
<td>Press button when all errors located</td>
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**Results**

1. Activation in typical language-processing areas
2. Activation in areas related to working memory, including problem solving and the phonological loop
3. All activated areas are in the left hemisphere, which is known to be related to analytical processes

In a nutshell, our results describe program comprehension as analytical problem-solving process that requires language comprehension and keeping values of variables in working memory

**Future Work**

Based on our results, we plan to address the following research questions in the near future:

- How does program comprehension differ from reading comprehension?
- What is the role of memory during understanding source code?
- How do software metrics and program comprehension relate?

**What the Future Might Bring**

In the long run, when we have an in-depth understanding of what happens inside a programmer’s head, we might be able to answer long-asked questions:

How should we teach programming?
What makes an excellent programmer?
How should we design tools and languages?