Measuring Neural Efficiency of Program Comprehension

Janet Siegmund, Norman Peitek, Chris Parnin, Sven Apel, Johannes Hofmeister, Christian Kästner, Andrew Begel, Anja Bethmann, André Brechmann

Motivation

How do programmers understand code? Traditional research methods are indirect and do not observe which cognitive processes developers use.

Functional magnetic resonance imaging (fMRI) allows us to observe brain activation during program comprehension.

Bottom-up comprehension
- Analyze code line by line
- Linear reading order
- Slow, tedious process

Top-down comprehension
- Guided understanding of code
- Based on prior experience
- Fast, efficient process

Bottom-up Comprehension   Top-down Comprehension

ICSE'14   FSE'17
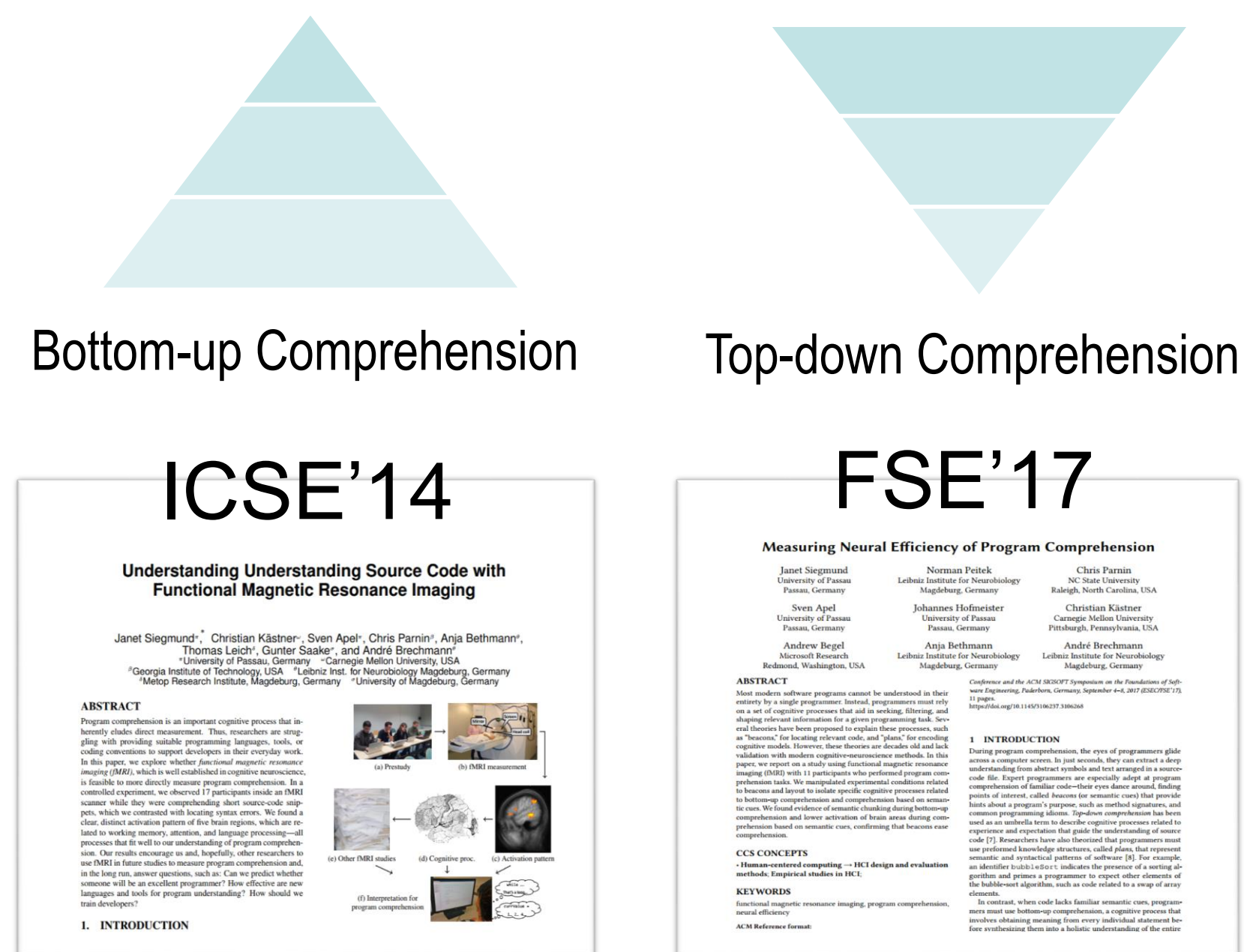
Research Questions

RQ1: Can we replicate the first fMRI study of program comprehension (Siegmund and others, ICSE'14)?

RQ2: What is the difference between bottom-up program comprehension and top-down comprehension in terms of activation and the brain areas involved?

RQ 3: How do layout and beacons in source code influence program comprehension?

Materials

Right: Code snippet without beacons and disrupted layout

Below: Code snippet with beacons and pretty-printed layout

```
01 public float arrayAverage(int[] array) {
02     int counter = 0;
03     int sum = 0;
04
05     while (counter < array.length) {
06         sum = sum + array[counter];
07         counter = counter + 1;
08     }
09
10     float average = sum / (float) counter;
11     return average;
12 }
```

```
01 public float ayyaoAwyyaky(int[] array) {
02     int
03     mgqakyy
04     = 0;
05     int sum = 0;
06
07     while   (mgqakyy
08             < array.length) {
09         sum =
10         sum + array[mgqakyy];
11         mgqakyy
12         = mgqakyy + 1;
13     }
14
15     float average
16         = sum /
17         (float) mgqakyy;
18     return
19         average;
20 }
```

Method

Task: After a training session participants determined the correctness of code snippets in the fMRI scanner.

Design: To evaluate the role of beacons and layout on top-down comprehension, we created four versions of the top-down snippets:

- Beacons and pretty-printed layout
- Beacons and disrupted layout
- No beacons and pretty-printed layout
- No beacons and disrupted layout

Additionally, two conditions without training are based on the first fMRI study (ICSE'14):

- Bottom-up comprehension
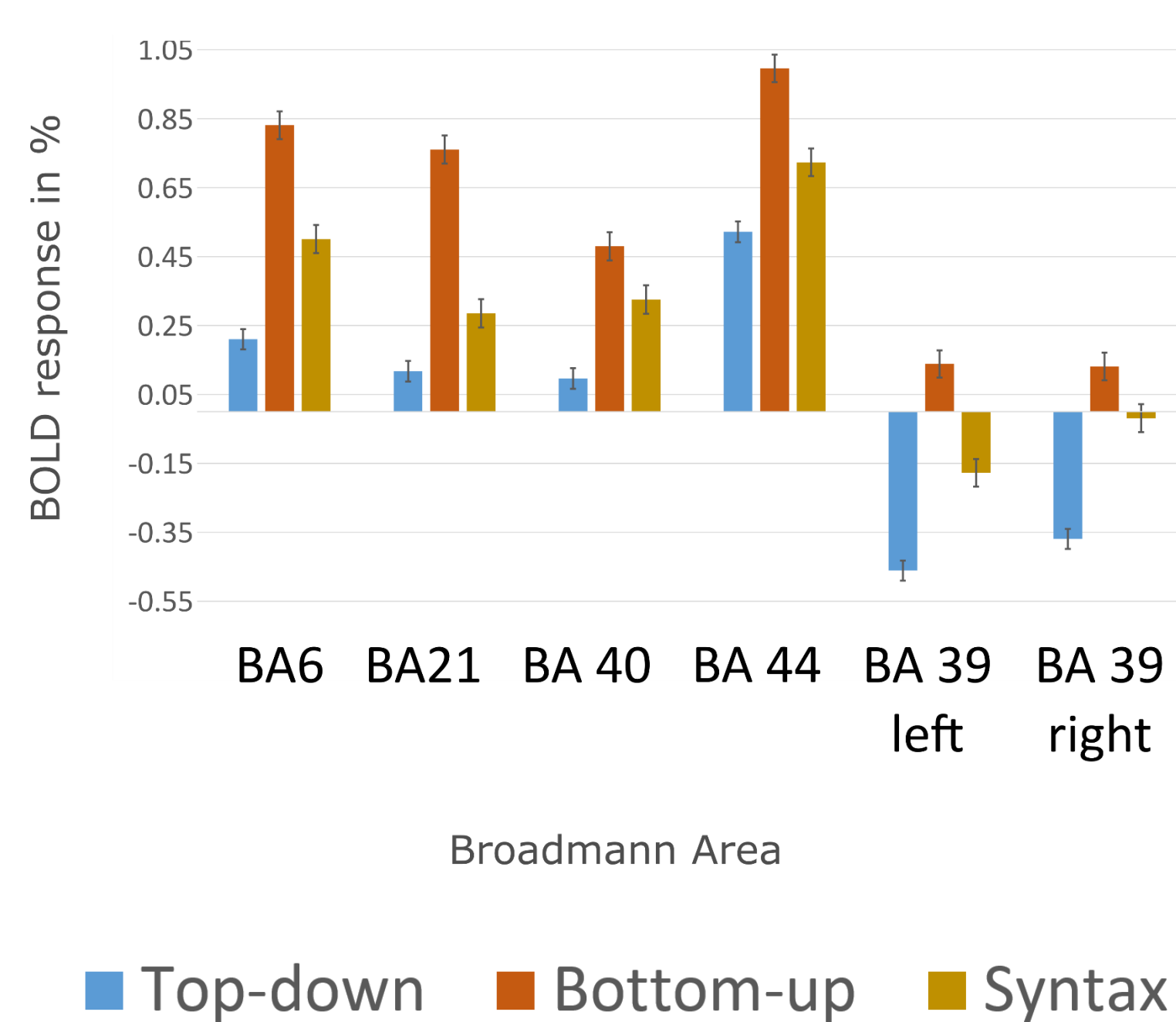- Finding syntax errors

Results

Fig. 2: Average BOLD response for all three tasks. BA 39 is activated/deactivated in both hemispheres, BAs 6, 21, 40, and 44 in the left hemisphere. The whiskers indicate the standard error of the mean of the activation in the different participants.
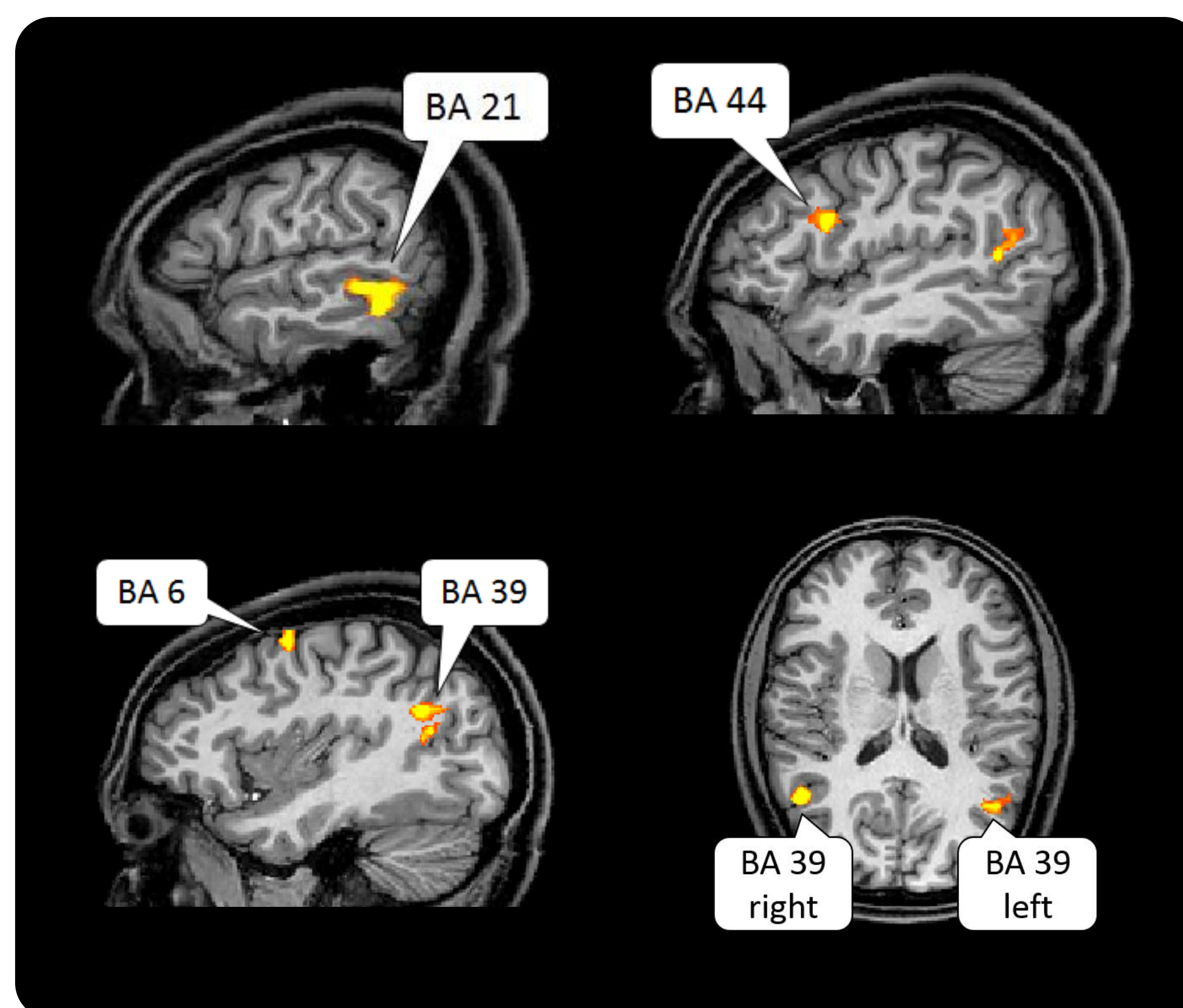
Fig. 1: Brodmann-area activation for top-down comprehension. All activation is in the left hemisphere. BA39 is deactivated, c.f. **Fig. 2**.
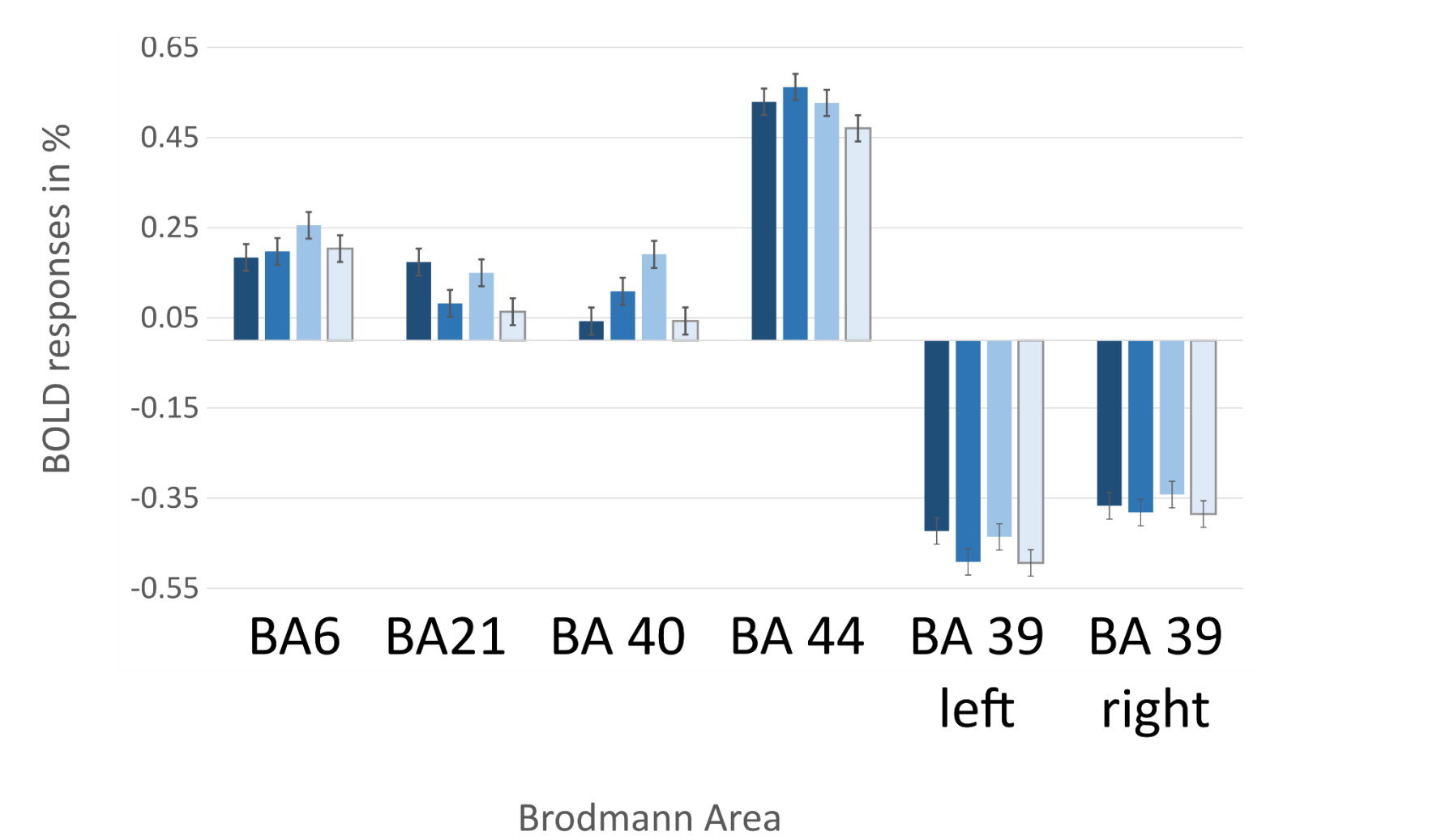
Fig. 3: Average BOLD response for top-down comprehension. BA 39 is deactivated in both hemispheres, BAs 6, 21, 40, and 44 are activated in the left hemisphere. The whiskers indicate the standard error of the mean of the activation in the different participants.
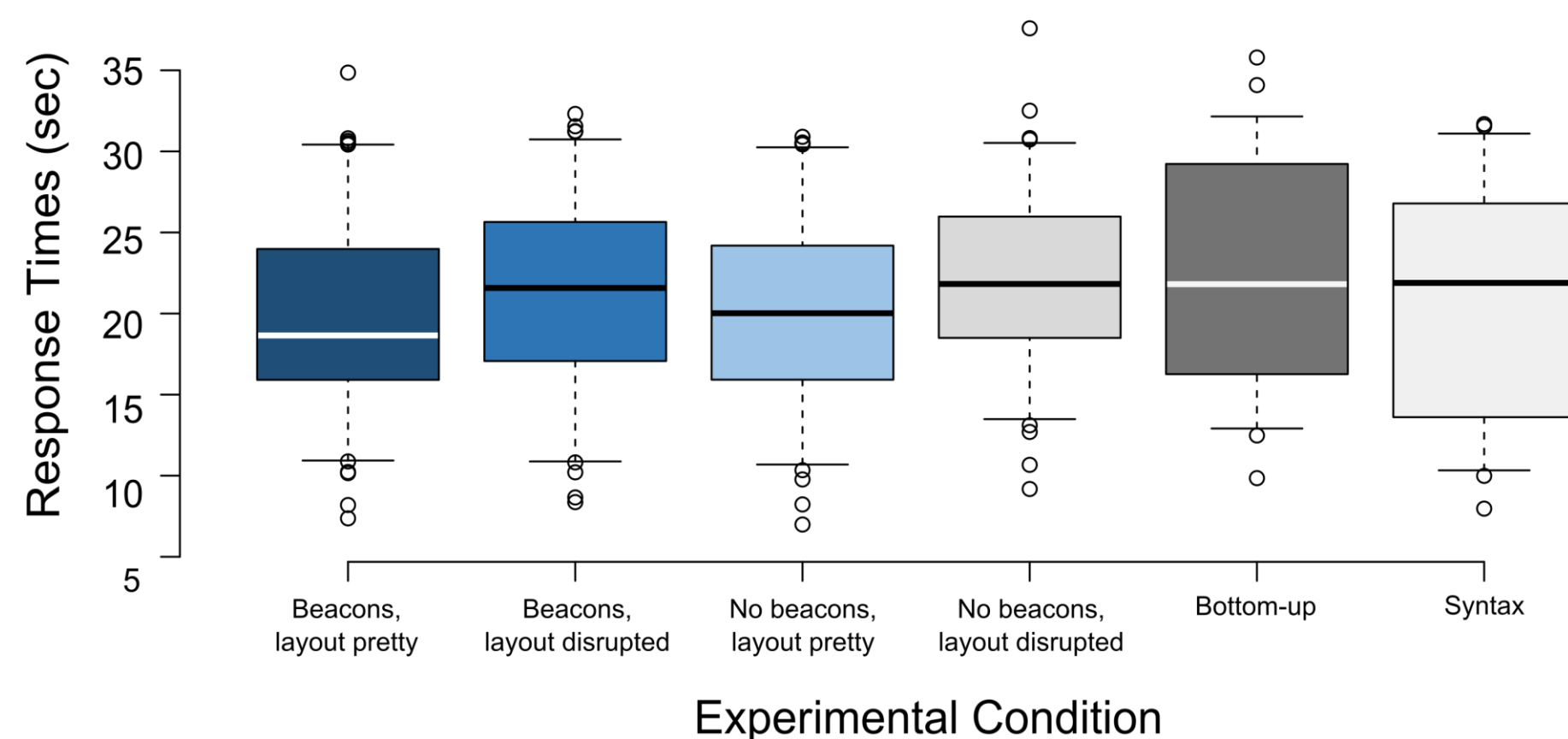
Conclusions:

RQ1: Activation in BAs 21, 40, and 44 within the brain's left hemisphere confirm the results of Siegmund et al. (ICSE'14)

RQ2: Top-down comprehension activates the same regions as bottom-up comprehension, except for BA 39, which is deactivated during top-down comprehension, but activated during bottom-up comprehension. For all areas, the activation is significantly lower for top-down comprehension than for bottom-up comprehension,

Fig. 4: Response times in seconds per condition.
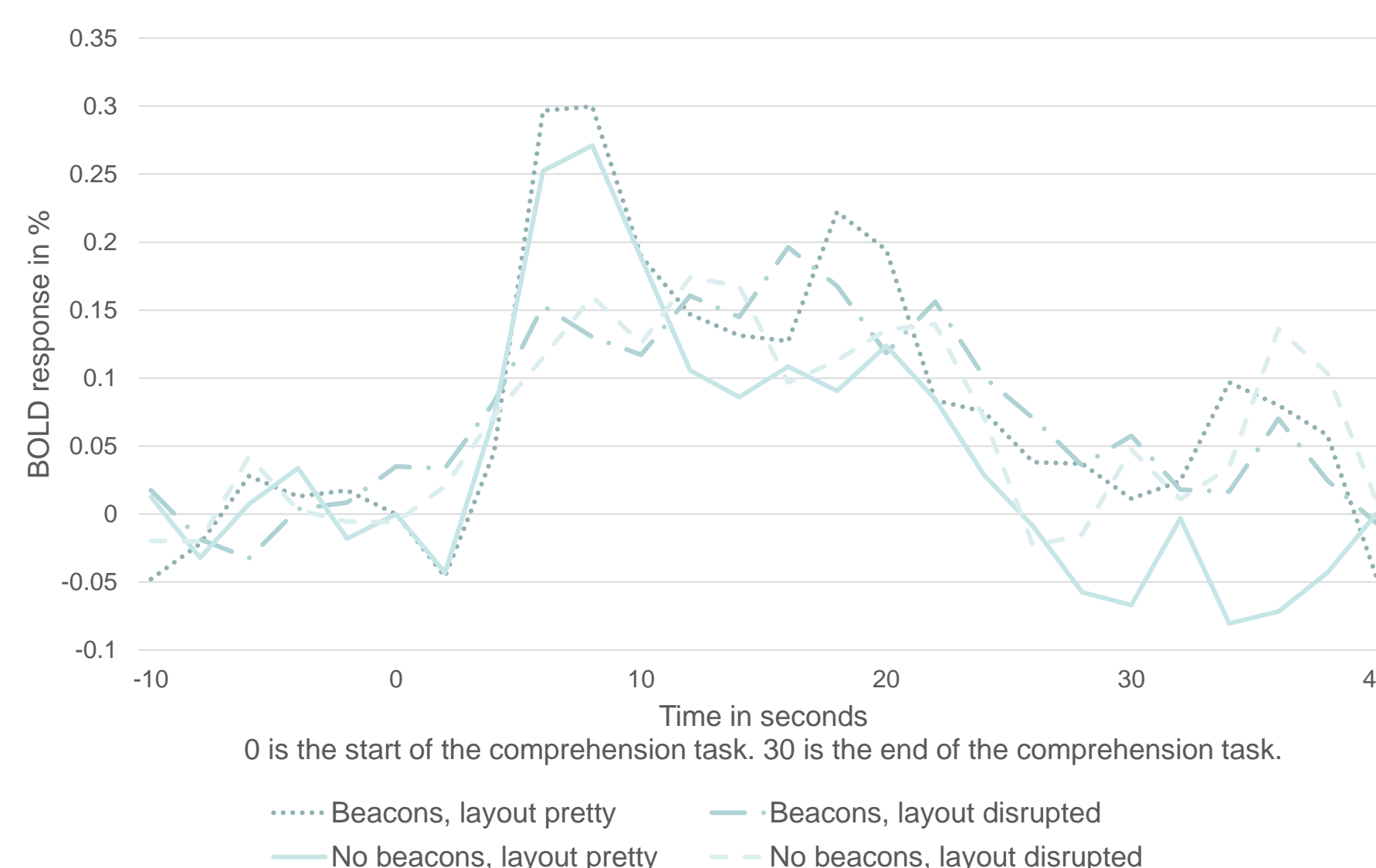
Fig. 5: BOLD response per condition for BA 21.

RQ3: We could not find any influence of beacons and layout on program comprehension.

Janet Siegmund, Christian Kästner, Sven Apel, Chris Parnin, Anja Bethmann, Thomas Leich, Gunter Saake, and André Brechmann. **Understanding Understanding Source Code with Functional Magnetic Resonance Imaging**. In *Proceedings of the ACM/IEEE International Conference on Software Engineering (ICSE)*, pages 378–389. ACM Press, May 2014

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