THE SKY IS NOT THE LIMIT:
Multitasking Across GitHub Projects

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Kelly Blincoe (@KellyBlincoe)
Qi Xuan
Casey Casalnuovo
Dana Damian
Prem Devanbu
Vladimir Filkov
Multitasking is common
**EXAMPLE:** GitHub developer (25 Nov 2013 – 18 May 2014)

<table>
<thead>
<tr>
<th>Mon</th>
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**#Projects**

- White: 0
- Light yellow: 1
- Yellow: 3
- Light green: 5
- Black: 8

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### Software developers multitask too

**EXAMPLE:** GitHub developer (25 Nov 2013 – 18 May 2014)

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#Projects
- 0
- 1
- 3
- 5
- 8

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#Projects: 0, 1, 3, 5, 8
Software developers multitask too

**EXAMPLE:** GitHub developer (25 Nov 2013 – 18 May 2014)
Example: GitHub developer (25 Nov 2013 – 18 May 2014)

Why?

- Request from other dev’s / management

Software developers multitask too
Software developers multitask too

**EXAMPLE:** GitHub developer (25 Nov 2013 – 18 May 2014)

**WHY?**

- Request from other dev’s / management
- Dependencies
Software developers multitask too

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#Projects

5

8

**WHY?**

- Request from other dev’s / management
- Being “stuck”
- Dependencies
- Downtime
**Software developers multitask too**

**EXAMPLE:** GitHub developer (25 Nov 2013 – 18 May 2014)

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#Projects

- Request from other dev’s / management
- Dependencies

**WHY?**

- Being “stuck”
- Personal interest
- Downtime
### Example:
GitHub developer (25 Nov 2013 – 18 May 2014)

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### Why?
- Request from other dev’s / management
- Dependencies
- Being “stuck”
- Personal interest
- Downtime
- Signaling

Software developers multitask too.
Theory: How does multitasking affect performance?

<table>
<thead>
<tr>
<th>PROS</th>
<th>CONS</th>
</tr>
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</table>

[Image of a busy character doing multiple tasks]
Theory: How does multitasking affect performance?

PROS

- Fill downtime
  Switch focus between projects to utilize time more efficiently
  (Adler and Benbunan-Fich, 2012)
Theory: How does multitasking affect performance?

**PROS**

- **Fill downtime**
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  (Adler and Benbunan-Fich, 2012)

- **Cross-fertilisation**
  Easier to work on other projects if knowledge is transferrable
  (Lindbeck and Snower, 2000)
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**CONS**

- **Cognitive switching cost**
  Depends on interruption duration, complexity, moment
  (Altmann and Trafton, 2002)
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- **“Project overload”**
  Mental congestion when too much multitasking
  (Zika-Viktorsson, Sundstrom, Engwall, 2006)
**Theory: How does multitasking affect performance?**

**PROS**

- **Fill downtime**
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**In theory:**

- Productivity vs. Amount of multitasking
Hardly any empirical evidence

Rule of thumb (Weinberg, 1992) - not based on data

- Working time available per project
- Loss to context switching
Hardly any empirical evidence

Rule of thumb (Weinberg, 1992) - not based on data

<table>
<thead>
<tr>
<th>Number of simultaneous projects</th>
<th>Working time available per project</th>
<th>Loss to context switching</th>
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<td>5</td>
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Hardly any empirical evidence

Rule of thumb (Weinberg, 1992) - not based on data

Recent work:
- Resuming interrupted tasks (Parnin and DeLine, 2010)
- Work fragmentation (Sanchez, Robbes, and Gonzalez, 2015)
Hardly any empirical evidence

... but lots of data to test theories on.
This work: Large-scale empirical study

**WHAT?**

Multitasking across projects

- Trends
- Reasons
- Effects
- Limits

**HOW?**

Sample:
- 1,200 programmers
- 5+ years of activity
- 50,000+ projects total

Data mining + User survey
(15% resp. rate)
This work: Large-scale empirical study

Software developers multitask too

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**WHY?**

- Request from other dev’s / management
- Dependencies
- Being “stuck”
- Downtime
- Personal interest
- Signaling

**HOW?**

- Data mining
- User survey (15% resp. rate)

**Sample:**

- 1,200 programmers
- 5+ years of activity
- 50,000+ projects total

**EXAMPLE:**

GitHub developer (25 Nov 2013 — 18 May 2014)

- Downtime
- Request from other dev’s / management
- Dependencies
- Signaling
- Personal interest
- Being “stuck”

**Trends & Reasons:** Details in paper

**REFERENCES**

- Working for free? Motivations of participating in open source projects
  A. Hars and S. Ou. HICSS 2001
- The open source software development phenomenon: An analysis based on social network theory
  G. Madey, V. Fresh, and R. Tynan. AMCIS 2002
- Activity traces and signals in software developer recruitment and hiring
  J Marlow, L Dabbish. CSCW 2013
Effects: perception vs. data

“When contributing to multiple projects in parallel, I:

- Feel more productive: 52%
- Contribute more code overall: 34%
- Review more pull requests: 31%
- Resolve more issues: 29%
- Introduce fewer bugs: 23%
- Increase project success: 15%

- Strongly disagree: 15%
- Disagree: 23%
- Neutral: 29%
- Agree: 31%
- Strongly agree: 34%

Percentage
Effects: perception vs. data

“When contributing to multiple projects in parallel, I:

15% Strongly disagree 23% Disagree 29% Neutral 31% Agree 34% Strongly agree 47% 40% 33% 29% 23% 5% 100 50 0 50 100

feel more productive

52%
Effects: perception vs. data

“When contributing to multiple projects in parallel, I:”

<table>
<thead>
<tr>
<th></th>
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<th>Disagree</th>
<th>Neutral</th>
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- resolve more issues
- contribute more code overall
- review more pull requests
- feel more productive
- contribute more code overall
- review more pull requests
- resolve more issues
- introduce fewer bugs
- increase project success
Effects: perception vs. data

“When contributing to multiple projects in parallel, I:”

- **Increase project success**: 15% Strongly disagree, 23% Disagree, 29% Neutral, 31% Agree, 34% Strongly agree.
- **Introduce fewer bugs**: 52% Strongly disagree, 29% Disagree, 23% Neutral, 5% Agree, 47% Strongly agree.
Effects: perception vs. data

**PERCEPTION**  "When contributing to multiple projects in parallel, I:"

<table>
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<th>Question</th>
<th>Percentage</th>
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<td>feel more productive</td>
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<tr>
<td>contribute more code overall</td>
<td>29%</td>
</tr>
<tr>
<td>review more pull requests</td>
<td>23%</td>
</tr>
<tr>
<td>introduce fewer bugs</td>
<td>5%</td>
</tr>
<tr>
<td>resolve more issues</td>
<td>40%</td>
</tr>
<tr>
<td>increase project success</td>
<td>47%</td>
</tr>
<tr>
<td>feel more productive</td>
<td>33%</td>
</tr>
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<td>5%</td>
</tr>
</tbody>
</table>

**EMPIRICAL DATA**  Multitasking vs. code production
Effects: perception vs. data

**PERCEPTION**  “When contributing to multiple projects in parallel, I:”

<table>
<thead>
<tr>
<th></th>
<th>Strongly disagree</th>
<th>Disagree</th>
<th>Neutral</th>
<th>Agree</th>
<th>Strongly agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>15%</td>
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<td>47%</td>
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**EMPIRICAL DATA**  Multitasking vs. code production

Daily multitasking correlates to amount of code produced.
Effects: perception vs. data

PERCEPTION

“When contributing to multiple projects in parallel, I:”

<table>
<thead>
<tr>
<th>Response</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongly disagree</td>
<td>15%</td>
</tr>
<tr>
<td>Disagree</td>
<td>23%</td>
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<tr>
<td>Neutral</td>
<td>29%</td>
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<tr>
<td>Agree</td>
<td>31%</td>
</tr>
<tr>
<td>Strongly agree</td>
<td>34%</td>
</tr>
</tbody>
</table>

- increase project success: 47%
- resolve more issues: 40%
- feel more productive: 33%
- contribute more code overall: 29%
- review more pull requests: 23%
- introduce fewer bugs: 5%

EMPIRICAL DATA

Multitasking vs. code production

Daily multitasking correlates to amount of code produced

Weekly and day-to-day scheduling of work matters
**Effects: perception vs. data**

**PERCEPTION**

“When contributing to multiple projects in parallel, I:”

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**EMPIRICAL DATA**

Multitasking vs. code production

- **Daily multitasking correlates to amount of code produced**
- **Weekly and day-to-day scheduling of work matters**
- **No scheduling is productive beyond 5 projects/week**
Modeling multitasking

- Period matters

<table>
<thead>
<tr>
<th>MON</th>
<th>TUE</th>
<th>WED</th>
<th>THU</th>
<th>FRI</th>
<th>SAT</th>
<th>SUN</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>D</td>
<td>A</td>
<td>D</td>
</tr>
</tbody>
</table>

‣ Period matters
Modeling multitasking

- Period matters
- Effort matters
  (A vs. B)
Modeling multitasking

- Period matters
- Effort matters
- Break matters
  (A vs. D)

‣ Period matters
‣ Effort matters
‣ Break matters
‣ …

(A vs. D)
Modeling multitasking

- Period matters
- Effort matters
- Break matters
- ...

Day-to-day

Daily

Weekly

WE MODELED:
- One-week panels
- Three dimensions
## Multitasking dimensions

### 1. Projects per Day

<table>
<thead>
<tr>
<th>Project</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tbody>
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</tbody>
</table>

**Working sequentially vs. Within-day multitasking**

<table>
<thead>
<tr>
<th>Project</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
<tbody>
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</tbody>
</table>

**Day**

- Project A: Day 3, 4, 5
- Project B: Day 2, 3, 4
- Project C: Day 1, 2, 3
- Project D: Day 1, 2, 3
Multitasking dimensions

1. PROJECTS PER DAY

Working **sequentially** vs. Within-day multitasking

**AvgProjectsPerDay = 1**

**AvgProjectsPerDay = 2.2**
Multitasking dimensions

2. WEEKLY FOCUS

Focusing on **one project** vs. Contributing **evenly to all**

**High focus**

**Low focus**
2. WEEKLY FOCUS

Multitasking dimensions

Focusing on one project vs. Contributing evenly to all

Shannon entropy:

\[ S_{\text{Focus}} = - \sum_{i=1}^{N} p_i \log_2 p_i \]

High focus

Low focus

Fraction commits in project i
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day

vs.

Switching focus

\[
\text{AvgProjectsPerDay} = 1 \\
S_{\text{Focus}} = 1
\]

\[
\text{AvgProjectsPerDay} = 1 \\
S_{\text{Focus}} = 1
\]
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

Focus shifting networks (Xuan et al, 2014)

AvgProjectsPerDay = 1
$S_{Focus} = 1$

AvgProjectsPerDay = 1
$S_{Focus} = 1$
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

<table>
<thead>
<tr>
<th>Day</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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</tbody>
</table>

Projects A, B, C, D:
- Project A: Day 1
- Project B: Days 4, 5
- Project C: Days 4, 6
- Project D: Days 1, 2, 3, 4, 5, 6, 7
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

![Day-to-day focus chart]

- Project A
- Project B
- Project C
- Project D

Day

1 2 3 4 5 6 7
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

<table>
<thead>
<tr>
<th>Project</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
<th>Day 5</th>
<th>Day 6</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
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</tbody>
</table>

A

B

C

D
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

Project

Day

1 2 3 4 5 6 7

A
B
C
D

A
B
C
D

1 2 3 4 5
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

Project

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

Day

1 2 3 4 5 6 7

A

B

C

D

A

B

C

D
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

<table>
<thead>
<tr>
<th>Project</th>
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<tbody>
<tr>
<td>A</td>
<td>1</td>
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</table>

A → B → C → D → A

A → C → B → A

D → C → B → D
Multitasking dimensions

3. DAY-TO-DAY FOCUS

**Repetitive day-to-day** vs. **Switching focus**

- **Repetitive day-to-day**
  - Project A
  - Project B
  - Project C
  - Project D

- **Switching focus**
  - Project A
  - Project B
  - Project C
  - Project D

![Diagram showing repetitive and switching focus patterns.](image-url)
Multitasking dimensions

3. DAY-TO-DAY FOCUS

Repetitive day-to-day vs. Switching focus

Day-to-day focus

<table>
<thead>
<tr>
<th>Day</th>
<th>Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
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<td>6</td>
<td>B</td>
</tr>
<tr>
<td>7</td>
<td>C</td>
</tr>
</tbody>
</table>

Switching focus

A → B → C → D → A

1/2 → 1/7 → 1 → 5/7 → 1/2
## Multitasking dimensions

### Repetitive day-to-day vs. Switching focus

<table>
<thead>
<tr>
<th>Project</th>
<th>Day 1</th>
<th>Day 2</th>
<th>Day 3</th>
<th>Day 4</th>
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<th>Day 6</th>
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<tbody>
<tr>
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<td>✅</td>
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### Markov entropy:

\[ S_{\text{Switch}} = - \sum_{i=1}^N \left[ p_i \sum_{j \in \pi_i} p(j|i) \log_2 p(j|i) \right] \]

How predictable is my focus tomorrow if today I work on project j?
Linear mixed-effects regression

Response:
LOC added / week

Controls:
- time
- total projects
- programming languages

Random effect: developer
- developer-to-developer variability in the response

Random slope: time | developer
- developers more productive initially may be less strongly affected by time passing

Longitudinal data
- 1,200 developers
- 5+ years each: multiple weeks of observation

Predictors:
- Projects
- Weekly focus
- Projects per day
- Day-to-day focus
Multitaskers do more; scheduling matters

Projects per day

Weekly focus

Day-to-day focus (repeatability)
Multitaskers do more; scheduling matters

Projects per day

vs.

More within-day multitasking

Weekly focus

Day-to-day focus (repeatability)
Multitaskers do more; scheduling matters

Projects per day

Higher LOC added

More within-day multitasking

Weekly focus

Higher focus

More repetitive day-to-day work

Day-to-day focus (repeatability)
Multitaskers do more; scheduling matters

Projects per day

- More within-day multitasking

Weekly focus

- Higher focus
- More repetitive day-to-day work

Day-to-day focus (repeatability)

- Interaction effects: No scheduling is productive over 5 projects/week
Multitaskers do more; scheduling matters

Theory: How does multitasking affect performance?

**Pros**
- **Fill downtime**
  Switch focus between projects to utilize time more efficiently
  (Adler and Benbunan-Fich, 2012)

- **Cross-fertilisation**
  Easier to work on other projects if knowledge is transferrable
  (Lindbeck and Snower, 2000)

**Cons**
- **Cognitive switching cost**
  Depends on interruption duration, complexity, moment
  (Altmann and Trafton, 2002)
  (Borst, Taatgen, van Rijn, 2015)

In theory:

```
Productivity

Amount of multitasking
```

“Project overload”
Mental congestion when too much multitasking
(Zika-Viktorsson, Sundstrom, Engwall, 2006)

**Interaction effects:**
No scheduling is productive over 5 projects/week
Implications - awareness

Average 2.7 projects/day (median 2; range 0-10)
Average 6 projects/week (median 5; range 0-30)

Multitasking correlates to amount of code produced
No scheduling is productive beyond 5 projects/week
Implications - awareness

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**Multitaskers do more: scheduling matters**

**Projects per day**
- **Higher LOC added**

**Weekly focus**
- **More within-day multitasking**

**Day-to-day focus (repeatability)**
- **Higher focus**
  More repetitive day-to-day work

**Interaction effects:**
- No scheduling is productive over 5 projects/week