Impact of context switching and work interruptions on software development processes

Alexey Tregubov*, Barry Boehm, Jo Ann Lane, Natalia Rodchenko
University of Southern California

* presenting author
Motivation

- Cross-project multitasking overhead is often observed in

  - Matrix organizations - resources are shared between several projects for better resource utilization.

  - Multiple releases of a product – if a product is released more than one time, resources are shared between maintenance of previous releases and a new version (typical for small mid-size teams).

  - System of System (SoS) environments – in SoSs, if a constituent system is developed for several customers (e.g. different software distributions/releases for each customer), resources are shared between different work contexts.
Cross-project multitasking overhead is often not accounted when projects are estimated. This may cause underestimation in project planning.
Multitasking in work environment

- Work productivity
- Work quality

- Work interruptions

- Corporate culture
- Office Environment
- Personality
- Personal process

- Cross-project multitasking

- Work scheduling, technical processes

Management
Psychology
Work interruptions

DO YOU HAVE A MINUTE?

YES.

BUT I DON'T HAVE THE FIFTEEN MINUTES IT WILL TAKE ME TO GET BACK INTO THE CODING "ZONE" AFTER YOUR INTERRUPTION.

I ONLY NEED ONE MINUTE.

WHAT PLANET ARE YOU FROM?!!!
Cross-project multitasking in software development

- When developers work on several projects at the same time (over a week or even a day), they switch between them spending some time on context switching.

- Not all context switching is bad, but we only focused on excessive switching between different projects, which is interrupting work and causing productivity decline.

- Context switching between projects cost/time consists of
  - **physical time to switch** – switch between repositories, DBs, servers, etc. takes time
  - **cognitive context switching** – getting into ‘flow mode’ takes time
RQ1. What is the quantitative effect of cross-project multitasking overhead on development effort and quality?

- **H1.a** The number of cross-project interruptions is (not) linearly proportional to the number of projects.
- **H1.b** The G. Weinberg’s heuristic is (not) applicable for cross-project multitasking overhead estimation in software development teams.
- **H1.c** The number of cross-project interruptions is (not) linearly proportional to the number of reopened tasks (rework).

RQ2. How can COCOMO II model be improved to account for cross-project multitasking overhead?

- **H2.** Using the multitasking effort multiplier (MEM) in the locally calibrated COCOMO II model can improve prediction accuracies of the COCOMO II.
Gerald M. Weinberg’s heuristic

Weinberg's heuristic

% of effort spent on multitasking

Number of projects at the same time

<table>
<thead>
<tr>
<th>Number of projects</th>
<th>% of effort spent on multitasking</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>3</td>
<td>40</td>
</tr>
<tr>
<td>4</td>
<td>60</td>
</tr>
<tr>
<td>5</td>
<td>80</td>
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</tbody>
</table>
Research methodology

RQ1: impact of multitasking on effort and quality

- Compute quality metric
- Count cross-project interruptions for each data point
- Compute MEM for each data point

RQ2: COCOMO II calibration

- Test hypothesis
  - H2a,b
- COCOMO II calibration
- Evaluate model prediction accuracies
- Count cross-project interruptions for each data point

Source data: work logs of different project groups
Data collection

- Industry projects:
  - Two groups of projects, one year each
  - Work logs in JIRA – hours reported daily for each task in each project
  - Schedules were updated every 2-3 days
  - SLOC added and changed for each project

- 577 students projects
  - 10 teams/projects, 5-11 weeks development phase
  - Work logs in JIRA – hours reported weekly for each task in each project
  - Schedules were updated every 2 weeks
  - SLOC added and changed for each project
Cross-project work interruptions (CSCI577 class projects)

Average number of interruptions per week per developer

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>S</th>
<th>p</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.61110</td>
<td>2.418</td>
<td>0.0003</td>
<td>29</td>
</tr>
</tbody>
</table>

Average number of projects per week vs. Average number of interruptions
Cross-project work interruptions (industry)

Average number of interruptions per week per developer

- $R^2 = 0.4563$
- $S = 2.198$
- $p < 0.005$
- $n = 154$
Cross-project work interruptions (CSCI577 class projects)

Average number of interruptions per week per developer in log space

<table>
<thead>
<tr>
<th></th>
<th>R²</th>
<th>0.785</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>0.617</td>
<td></td>
</tr>
<tr>
<td>p</td>
<td>0.0001</td>
<td></td>
</tr>
<tr>
<td>n</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>
Cross-project work interruptions (industry)

Average number of interruptions per week per developer in log space

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>R²</td>
<td>0.48</td>
</tr>
<tr>
<td>S</td>
<td>379</td>
</tr>
<tr>
<td>p</td>
<td>&lt;0.005</td>
</tr>
<tr>
<td>n</td>
<td>142</td>
</tr>
</tbody>
</table>
Cross-project work interruptions (CSCI577 class projects)
Cross-project work interruptions (industry)
Multitasking effort multiplier (MEM)

\[
Effort = A \times [\text{Size}]^{B + \sum_{j=1}^{5} S_{F_j}} \times \prod_{j=1}^{17} E_{M_j} \omega \times MEM
\]

\[
MEM = f(I, R, E) = \frac{E}{E - IR} = \frac{1}{1 - R \frac{I}{E}} = \frac{1}{1 - R \frac{I/t}{E/t}}
\]
Cross-project multitasking effort multiplier (CSCI577 class projects)

Average MEM per week per developer

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<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>$R^2$</td>
<td>0.11</td>
</tr>
<tr>
<td>$S$</td>
<td>0.2</td>
</tr>
<tr>
<td>$p$</td>
<td>0.008</td>
</tr>
<tr>
<td>$n$</td>
<td>29</td>
</tr>
</tbody>
</table>

Average number of projects per week

MEM

0.00  0.50  1.00  1.50  2.00  2.50

0.00  1.00  2.00  3.00  4.00  5.00  6.00
Cross-project multitasking effort multiplier (industry)

Average MEM per week per developer

- \( R^2 = 0.45 \)
- \( S = 0.01 \)
- \( p < 0.005 \)
- \( n = 154 \)
Comparison with Weinberg’s heuristic (CSCI577 class projects)

Comparison of effort evaluation and estimations

- Average effort on spent on interruptions
- Weinberg heuristic

% of full time equivalent (FTE)

Number of projects per week

1 2 3
Comparison with Weinberg’s heuristic (industry)
Impact on quality (CSCI577 class projects)

Grade deduction

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<thead>
<tr>
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<tbody>
<tr>
<td>$R^2$</td>
<td>0.44</td>
</tr>
<tr>
<td>$S$</td>
<td>2.25</td>
</tr>
<tr>
<td>$p$</td>
<td>0.051</td>
</tr>
<tr>
<td>$n$</td>
<td>9</td>
</tr>
</tbody>
</table>

Average number of interruptions per week per developer
Impact on quality (industry)

Average number of reopened JIRA tickets

<table>
<thead>
<tr>
<th>R²</th>
<th>0.71</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td>1.01</td>
</tr>
<tr>
<td>p</td>
<td>0.004</td>
</tr>
<tr>
<td>n</td>
<td>9</td>
</tr>
</tbody>
</table>

Average number of interruptions per week per developer

Average number of reopened tasks
Results: RQ1

- **H1.a.** The number of cross-project interruptions is (not) linearly proportional to number of projects.
  - Tested **negative**
  - For a given group of industry projects and CSCI577 projects the number of cross-project interruptions is not linearly proportional to number of projects. The linear correlation is relatively weak ($R^2$ is between 0.46 and 0.61 in all tests).

- **H1.b.** The G. Weinberg’s heuristic is (not) applicable for cross-project multitasking overhead estimation in software development teams.
  - Tested **negative**
  - For a given group of industry projects and CSCI577 projects cross-project multitasking overhead cannot be evaluated with the G. Weinberg’s heuristic because it overestimates effort for this type of work interruptions.

- **H1.c.** The number of cross-project interruptions is (not) linearly proportional to the number of reopened tasks.
  - Tested **positive**
  - For a given group of industry projects cross-project interruptions are linearly correlated with the number of reopened JIRA tickets.

- **H2.** The multitasking effort multiplier (MEM) can be automatically evaluated based on work log observations.
  - Tested **positive**
  - Work log analysis algorithm was implemented as part of the DES simulation framework and used to compute results presented above.
RQ2: Calibrated COCOMO II prediction accuracies

<table>
<thead>
<tr>
<th>COCOMO II</th>
<th>Local calibration of COCOMO II with MEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>PRED(.20)</td>
<td>32%</td>
</tr>
<tr>
<td></td>
<td>56%</td>
</tr>
<tr>
<td></td>
<td>63%</td>
</tr>
<tr>
<td>PRED(.25)</td>
<td>37%</td>
</tr>
<tr>
<td></td>
<td>58%</td>
</tr>
<tr>
<td></td>
<td>75%</td>
</tr>
<tr>
<td>PRED(.30)</td>
<td>38%</td>
</tr>
<tr>
<td></td>
<td>61%</td>
</tr>
<tr>
<td></td>
<td>81%</td>
</tr>
</tbody>
</table>
Results: RQ1

Causal Graphical Model – results summary

- **Number of projects** (Individual level)
- **Amount of work Interruptions** (Individual and team level)
- **Multitasking Overhead** (Metric: MEM) (Individual and team level)
- **Quality** (metric: reopened tasks or grade deduction) (Team level)

- **Effort** (Individual level)
- **Reimmersion time** (Individual level)

- Observation & Evaluation
- Implied causality or functional relationship
- Hypothetical association or causality

H1.a – tested by hypothesis

Metric or measurement
Challenges and threats to validity

- Reimmersion time does not necessarily capture the time needed to restore work context.
  - Used the average minimum estimation of the reimmersion time. In the worst case, the values found in this study serve as an lower bound for multitasking overhead.

- Self-tracking of the reimmersion time and hours devoted to projects may not be accurate

- Students may inaccurately report effort in Jira
  - To address this threat, students effort reports in Jira were graded every week. Additionally, weekly reminders were sent out about the reports.

- Academic environment, where graduate students of CSCI577 class worked, is different from developers in industry.
  - To limit the impact of deadlines in other classes, students in the selected sample were enrolled in the same classes (e.g. students who took 3 classes were all enrolled in software engineering class, algorithms class and AI class).
Future work

- The approach for counting work interruptions and evaluating their impact on effort can be applied to other types of multitasking. To do so, we need to develop methods for measuring the number of work interruptions caused by certain types of multitasking.

- The further accuracy evaluation of models with MEM (any COCOMO family model with MEM) should be done on a bigger sample of projects.

- The work log analysis tools, we used in the research, can be integrated with project tracking systems such as Atlassian JIRA to provide real-time information about work interruptions and their impact on productivity (e.g., calculate MEM).

- Further research should be done on how to schedule and organize work to reduce negative effects of work interruption on productivity.
Q&A, discussion
References


References


17. http://www.businessdictionary.com/definition/matrix-organization.html


Images courtesy: