What can we learn from surveys on the importance of software development productivity factors?

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Abstract: A proper interpretation of survey results on the importance of software development productivity factors requires an understanding of what the responses reflect. To find out more about this, we conducted a survey with 79 experienced software professionals. The strongest connection found was between the high perceived importance of a productivity factor and how frequently the respondents had experienced that a low performance on that factor had caused productivity problems. We argue that it is challenging to interpret survey-based results on the importance of productivity factors. Instead of conducting more surveys on the importance of such factors, we recommend asking directly about previous experiences related to productivity factors and including contextual information that enables proper interpretation of the responses.

1. Introduction

There is no shortage of studies aiming at identifying characteristics of people, processes, and products that influence software productivity. The identified number of such characteristics, often termed productivity factors, is large. As an illustration, the review of productivity factors in (de Barros Sampaio, Barros, de Aquino, e Silva, & de Lemos Meira, 2010) examined thirty-nine productivity factors covered in the research literature and the review in (Wagner & Ruhe, 2018) reports from a set of studies identifying between and ten and around 250 productivity factors. By introducing a finer level of detail of the productivity factors and extending the scope of addressed contexts, one may argue that the number of productivity factors relevant in at least one context can get as large as desired. For example, the reliability of the power supply is usually not considered to be a productivity factor in software development, but there are contexts where this matters a lot.

Many of the reported studies not only report the existence of these factors but also try to rank them in terms of the importance or strength of influence on productivity. This strong interest in the importance of productivity factors is motivated by their obvious importance. The results may, for example, be used to focus the improvement effort on the factors that affect productivity most. Many of the studies on the relative importance of productivity factors are survey-based. Table 1 displays elements of three such studies, and exemplifies that such surveys vary in the factors included, how they ask about the importance, and whom they ask. While this variance in study designs is likely to affect the results, all studies share the interest in trying to identify the importance of different productivity factors.

Table 1: Three examples of surveys on software development productivity factors

Study	(Blackburn, Scudder, & Van Wassenhove, 1996)	(Paiva, Barbosa, Lima Jr, & Albuquerque, 2010)	(Machuca-Villegas, Hurtado, Puente, & Tamayo, 2021)
Year	1996	2010	2022

Number of productivity factors analyzed	11	32	13
Formulation of question	*To what extent were the following factors useful in reducing the overall software development time for the project?*[i]	*What is the influence of the factor on software development productivity?*[ii]	Questions of the type: *To improve productivity in software development teams …* [iii]
Scale points	Not at all helpful ... Very helpful	High positive influence … High negative influence	Strongly disagree … Strongly agree
Participants	98 respondents in management roles from Japan, US and Europe	77 software professionals from seven Brazilian companies	81 software professionals, mainly from Columbia
Three most important productivity factors	1) Better customer specifications 2) Better programmers of software engineers 3) Improvements in communications between team members	1) Commitment 2) Motivation 3) Consistent requirements	1) Communication 2) Collaboration 3) Commitment

i) The participants were requested to consider a recently completed project. The ranked importance of a factor is based on the median of the mean responses from Japan, the US, and Europe.
ii) Actual question is not included in the paper, and the one in the table may be inaccurate. The ranked importance of a factor is based on the proportion of responses with "High positive influence".
iii) There were 4-6 questions per productivity factor. The ranked importance is based on the score relative to the maximum possible score for a productivity factor.

The main motivation for initiating the study presented in this paper was the difficulty we had in interpreting results from such surveys on the importance of productivity factors, such as those in Table 1. This difficulty is not only caused by the variation in productivity factors included in the survey, who was asked, and the formulation of the questions. A major part of the problem is related to interpreting what the respondents meant by productivity, what they understood with the different productivity factors, and, in particular, what they meant by "more important" (or "more influential").

To illustrate this type of interpretation problem, assume that an empirical study reports that *psychological safety* is perceived as a more important software development team productivity factor than *developer skill*.[1] We can think of several possible evaluation processes used by the respondents, which may be combined, of this finding, including the following five:

1. The *variation* in psychological safety explains the variation in productivity among the teams very well, and better than the variation in developer skills. This includes a stronger connection between an increase in psychological safety and an increase in productivity, than the corresponding connection for developer skill. As there are

[1] This is, for example, what is reported in the frequently cited survey and interview-based study on google software development teams, see for example (rework.withgoogle.com/print/guides/5721312655835136/). Unfortunately, the above study is not published or peer-reviewed, and our requests for more information about the study have been conducted remain unanswered, but we suspect that this study has the same challenges as described earlier.

neither commonly accepted measures of the level of psychological safety or developer skill, nor of the level of productivity, the strength of such connection may be hard to evaluate for the respondents.

2. A *good* performance in psychological safety has a strong connection with high productivity, and this connection is stronger than with a very good performance in developer skills. There are similar interpretation problems as for the above interpretation, but it may perhaps be easier to think back on teams with high productivity and their main characteristics than trying to identify a general relationship.
3. A *poor* performance in psychological safety has a strong connection with low productivity and this connection is stronger than with a low performance in developer skills. This interpretation is analog to the previous, with similar challenges.
4. The *frequency of experienced productivity problems* caused by low performance in psychological safety is high, and higher than for developer skills.
5. There is a *belief* that psychological safety is important, and that it is more important than developer skills based on sources not related to own experience. This may, for example, include general knowledge about software development and teamwork, opinions of other software developers, and what is a common belief in their professional communities.

It will typically be hard to know which of the above types (or combinations of them), or other types of interpretations are reasonable to assume are in place when responding to questions on the importance of these two productivity factors. It is also possible that the two productivity factors will have different types of interpretations and that different respondents will base their answers on different interpretations. Assume, for example, that a respondent never has experienced anything other than teams with highly skilled developers and never experienced that low developer skill has led to productivity problems. The psychological safety in the teams has, on the other hand, varied a lot, and sometimes (when psychological safety has been low) team members have reported problems too late in the project, which has led to large problems. For this respondent, it may be natural to give psychological safety a high score, and developer skill a much lower score. When, later, experiencing a team with productivity problems due to the low skill of some of the developers, the perceived importance of developer skill may increase substantially and exceed that of psychological safety.

To further complicate this interpretation of the survey-based importance of productivity factors, there may be substantial challenges related to analyzing to what extent a factor, such as increased psychological safety, actually *causes* productivity in a particular team or project, or is just an indicator of a well-composed and skilled team. The interpretation of causal relationships in the teams and projects may consequently easily be affected by prior beliefs on importance, i.e., the type of influences often denoted as “you see it if you believe it” or “confirmation bias” (Chattopadhyay et al., 2022; Jørgensen, 2013; Jørgensen & Papatheocharous, 2015).

The study reported in this paper aims to address some of the above challenges and to guide future attempts to conduct such studies. We do not intend to cover all types of possible interpretations of what the high importance of a productivity factor may mean or all types of potential connections in this paper. The focus is on the following, potentially relevant, interpretations (which are similar to the four first exemplified with psychological safety and developments skill earlier), i.e., to what extent a higher

importance of a productivity factor, as experienced by the respondent, is connected with:

1. Larger variation in how well previous projects and teams have performed regarding that productivity factor. This analysis is motivated by that if a respondent has experienced a high degree of variation regarding a productivity factor, assuming that the productivity also varies with that factor, this will lead to a perception of a higher importance of that factor.
2. Better performance in previous projects and teams regarding that productivity factor. The analysis is motivated with that it may be easier to recall a connection between very good performance on a productivity factor and high productivity, than trying to connect the full range of variance as in 1.
3. Poorer performance in previous projects and teams regarding that productivity factor. The analysis is motivated similarly to 2, but with poor performance on a productivity factor and low productivity.
4. A higher frequency of observing low performance on a productivity factor has caused low productivity. This interpretation is similar to 3. but puts a stronger emphasis on that the respondent has actually (believed to have) observed a causal connection between the productivity factor and the productivity.

For productivity factors where none of the above four interpretations give a fit to the responses, a fifth natural interpretation is more likely, i.e., that there is a belief, based on other sources than own experience, that the factor is important. This may be especially relevant if this productivity factor has received a lot of attention in the software development communities as important for high productivity.

The productivity factors chosen for examination in this paper are mainly those related to team productivity factors and selected from previous studies on such factors, such as (Machuca-Villegas et al., 2021). There is no intention to have a complete list of such factors, as the main purpose of this paper is to examine how previous experience regarding a productivity factor is connected to the perceived importance of the productivity factors.

The remaining part of the paper is organized as follows. Section 2 describes the study design. Section 3 presents the results. Section 4 discusses the results and concludes.

2. Study Design

The design elements of our survey are described in Table 2 and information about the survey participants is given in Table 3.

Table 2: Design elements of the survey

Study element	Description
Recruitment of the survey participants	We recruited software professionals offering team or project management services on the freelancer marketplace *Upwork.com*. Inclusion criteria to qualify for participating in the survey were experience from at least five teams or projects and good feedback from previous clients (at least 90% success rate). 178 invitations were sent to qualifying software professionals on Upwork.com. Of these, 79 were hired and paid (based on their ordinary hourly payment) for the participation in the survey.
The productivity factors	Team productivity factors presented to the survey participants are the following: • Software development competence and skill of the team members • Competence and skill in team management

examined	• Domain and business experience of the team members • Team autonomy (freedom to choose when and/or how to develop the software) • Psychological safety («The belief that one will not be punished or humiliated for speaking up with ideas questions, concerns, or mistakes, and that the team is safe for interpersonal risk-taking") • Trust between the team members (trust in that all are doing the right things and with the right intentions) • Job satisfaction and well-being of the team members • Use of efficient software development processes and tools (e.g., good use of agile software development practices) • Ability of team members to learn from and/or innovate based on feedback/experience. • Ability of team members to focus and prioritize • Job motivation and enthusiasm of the team members • Communication and collaboration within the team, with management and with clients • Composition of the team (good mix of roles, skills, and personalities within the team) • Interpersonal relationship and emotional intelligence Initially meant as a control question to examine to what extent the participants read the questions properly, we also added the productivity factor "Having a good lunch restaurant nearby". As we will describe later, this question turned out to serve another purpose, and did not work well as a control questions. The questionnaire is enclosed as Appendix A, which also include introductory text, the actual question formulations and more on the scales used.
The survey	The survey was distributed as an on-line link to a questionnaire developed using Qualtrics (www. Qualtrics.com). The median time spent on completing the survey was 14 minutes, and all spent more than five minutes. The survey had three separate parts (Parts A, B and C), where we: A. Asked the respondents to give an importance score, for high team productivity, for 14 productivity factors. B. Asked the respondents to assess their previous teams' performance for each of the productivity factors. C. Asked the respondents to assess how often each of the factors had caused productivity problems previously. When completing one part of the questionnaire and starting on a new, they were sent to a new questionnaire page, and could not see their previous responses. To avoid systematic sequence effects of the responses, we randomized the sequence of the productivity factors for each part of the questionnaire and for each participant.
The analysis	The analysis connecting the respondents prior experience and the perceived importance of a productivity factors is based on comparisons of mean values for ordinally scaled responses, such as the scale 1="very low importance" … 5="very high importance". While mean values of ordinal (Likert) scales may be debatable, we think that it is a reasonable choice in this context, see for example (Brown, 2011) for support of interval-scale analyses when using Likert scales. Where we have reasons to believe that there is a linear relationship between the scores on two scales, we include correlational analyses (Pearson correlation coefficient). When appropriate, we add analyses of statistical significance, where we claim statistical significance when $p<0.05$.
Excluded responses	As described earlier, we included a check question about the importance of having a good lunch restaurant nearby. The intention was to exclude those who gave a high importance score here. Several of the participants gave, however,

	this factor a score of "moderate" or higher. We asked many of them, after finalizing the questionnaire, about why they thought a good lunch restaurant was important. All had good answers, arguing that having a good lunch restaurant nearby was indeed important for productivity in their workplace. When examining their remaining responses, we found no indications of low quality, and we did not remove these responses. We found no reason to exclude any of the responses from the survey participants.
Validity and limitation of the study	The perhaps most critical part of survey-based studies of this type is to enable responses with sufficiently high quality, i.e., avoiding that the respondents are not reading and thinking sufficiently carefully before they give their answers. We believe the quality of the responses in this survey is good, perhaps as a consequence that answering the questionnaire was contracted, paid work for the respondents and because they were to receive an evaluation score from us as clients important for their future work. In addition, the strict criterion of only selecting experienced software professionals, with extensive management background and very good score from previous clients, may have added to the quality. We make no attempt to generalize the results regarding the importance of the productivity factors to other contexts (quite the opposite, as we argue that this is very challenging). What is more likely to be possible to generalize from our study are the results on the connections between previous experience and the perceived importance of a productivity factor. As will be seen in the analysis section, many of connections we claim to find are not very strong (although statistically significant) and the study design do not enable causal claims. While we find patters there are reasons to believe show causal connections, we cannot exclude that the connections are just correlational, and that there are other, perhaps more important, causal connections not identified by us.

Table 3. Characteristics of the respondents

Countries	Argentina (1), Armenia (2), Belarus (1), Brazil (1), Bulgaria (3), Canada (1), Colombia (1), Egypt (4), Estonia (1), France (1), Georgia (1), India (9), Macedonia (2), Moldova (1), Netherlands (1), Pakistan (11), Philippines (5), Romania (3), Serbia (1), South Africa (1), Taiwan (1), Turkey (1), UK (2), Ukraine (20), US (2), and Venezuela (2).
Median years of experience as software professional	8 years
Median number of software development *projects* as a developer/programmer	6 projects
Median number of software development *teams* as a developer/programmer	8 teams
Median number of software development projects and teams in *management role* (project leader, team leader etc.)	10 projects and/or teams
Highest education level ("Other" includes both incomplete responses and other degrees).	Master's degree: 36 participants Bachelor's degree: 38 participants College: 5 participants
Experienced productivity in previous teams and projects (as perceived by themselves) in mean percentage per productivity category	Very high productivity: 22% High productivity: 29% Medium productivity: 31% Low productivity: 13% Very low productivity: 5%

As can be derived from the above descriptions of the participants, the majority of them were from typical outsourcing, lower-cost countries. In addition, they had extensive experience both as developers and managers, were well-educated, and perceived that most of their previous teams and projects had had high or very high productivity. All of them worked internationally, offering team or project management services. An examination of the participants' previous employers, as presented on their personal page at UpWork.com and in their cv-s, shows that nearly all of them currently worked in small or medium-large offshoring providers, or had worked in such software companies before offering services through UpWork.com.

3. Results

This section first reports results on the perceived importance and previous experience regarding the productivity factors (Section 3.1), and then reports on the connections between the importance and the previous experience regarding the productivity factors (Section 3.2)

3.1 Descriptive results

Tables 4-6 displays the distributions of responses for Part A (perceived importance of the productivity factors), Part B (previous perceived performance regarding the productivity factors) and Part C (previous perceived productivity problems caused by low performance on the productivity factors) of the survey.

Table 4: Perceived importance of productivity factors for achieving high software development productivity (three most important in bold)

Factor	Very low (1)	Low (2)	Mod. (3)	High (4)	Very high (5)	Mean	Rank
Development skill	0%	0%	16%	52%	32%	4.15	8
Management skill	0%	5%	27%	39%	29%	3.92	12
Domain knowledge	0%	8%	33%	46%	14%	3.66	13
Autonomy	0%	6%	43%	33%	18%	3.62	14
Psychological safety	0%	0%	13%	48%	39%	4.27	4
Trust	**0%**	**1%**	**4%**	**38%**	**57%**	**4.51**	**2**
Job satisfaction	0%	0%	15%	49%	35%	4.20	6
Processes and tools	0%	0%	19%	46%	35%	4.16	7
Innovate and learn	**0%**	**0%**	**8%**	**54%**	**38%**	**4.30**	**3**
Focus and prioritize	0%	1%	18%	47%	34%	4.14	9
Motivation and enthusiasm	0%	3%	9%	51%	38%	4.24	5
Commun. and collab.	**0%**	**0%**	**3%**	**33%**	**65%**	**4.62**	**1**
Composition of team	0%	5%	20%	38%	37%	4.06	10
Relations/emotional intel.	0%	4%	19%	49%	28%	4.01	11

The perhaps most striking result in Table 4, is that all productivity factors are, on average, quite similar in mean perceived importance and that all are perceived to be at least moderately important. The top three factors were good communication and collaboration, trust, and innovate and learn. All these factors are frequently found to be

perceived as important in other surveys (see for example the analyses of reviews of surveys of productivity factors in the (Oliveira, Conte, Cristo, & Valentim, 2018)), i.e., our results may not deviate much from those of other surveys including some of these productivity factors.

As argued earlier, the interpretation of the above results is not trivial. As an illustration, the factor with the lowest importance was found to be domain knowledge. In contexts where the domain knowledge is nearly absent and the other productivity factors are at a satisfactory level, this factor may sometimes, we argue, have the strongest influence on productivity and be the most important one to improve to increase productivity.

Perhaps even more illustrative for the problems of interpreting the results are the responses to the control question about the importance of having a *good nearby lunch restaurant*. Although the mean value was as low as 2.05 ("Low importance"), as many as 23 of the respondents gave this factor a "moderate" or higher importance (the majority of them located in Pakistan, India, or Egypt). When asking them for an explanation, they typically gave good rationales for the importance of a good nearby lunch restaurant, such as "Saves time to have it nearby" and "Good food is important for job satisfaction and productivity". We have no reason to doubt that these respondents perceived that this factor was important for productivity, sometimes even more important than a few of the other factors. The interpretation challenges are related to what this means. A good nearby lunch restaurant is hardly an important productivity factor in most contexts, as indicated by the responses from the majority of the respondents. One of the respondents even perceived a good lunch restaurant to be more important than development skills. This judgment sounds strange but it is possible to defend. That project manager may, for example, have experienced that project members have had low productivity due to leaving the office, for lunch, for a long time every day.

Table 5: Frequency of experiencing good performance on productivity factors in previous projects/teams

Factor	Nearly all (1)	Most (2)	About half (3)	Some (4)	Few or none (5)	Mean	Rank
Development skill	11%	41%	29%	14%	5%	2.61	4
Management skill	5%	41%	28%	20%	6%	2.82	11
Domain knowledge	10%	25%	37%	24%	4%	2.86	12
Autonomy	6%	23%	39%	20%	11%	3.08	14
Psychological safety	**24%**	**27%**	**25%**	**18%**	**6%**	**2.56**	**2**
Trust	15%	34%	25%	18%	8%	2.68	8
Job satisfaction	16%	32%	29%	18%	5%	2.63	6
Processes and tools	14%	38%	24%	20%	4%	2.62	5
Innovate and learn	13%	39%	23%	20%	5%	2.66	7
Focus and prioritize	10%	34%	34%	19%	3%	2.70	10
Motivation and enthusiasm	11%	35%	30%	19%	4%	2.68	8
Commun. and collab.	**15%**	**41%**	**23%**	**14%**	**8%**	**2.58**	**3**
Composition of team	**16%**	**42%**	**27%**	**14%**	**1%**	**2.42**	**1**
Relations/emot. intel.	8%	25%	34%	28%	5%	2.97	13

As can be derived from Table 5, the three productivity factors that the respondents perceived as having the, on average, best performance score (lowest mean value) were those related to the composition of the team, psychological safety, and communication and collaboration. The three productivity factors with the, on average, worst (highest) performance were autonomy, relations and emotional intelligence, and domain knowledge.

Table 6: Frequency of experiencing that poor performance on a factor caused low productivity in previous teams and/or projects

Factor	Very often (1)	Often (2)	Several times (3)	A few times (4)	Never (5)	Mean	Rank
Development skill	18%	23%	29%	23%	8%	2.80	4
Management skill	14%	25%	24%	27%	10%	2.94	8
Domain knowledge	8%	25%	23%	38%	6%	3.10	12
Autonomy	8%	16%	39%	28%	9%	3.14	13
Psychological safety	8%	20%	30%	28%	14%	3.20	14
Trust	14%	24%	28%	25%	9%	2.91	7
Job satisfaction	**15%**	**30%**	**28%**	**19%**	**8%**	**2.79**	**3**
Processes and tools	13%	24%	28%	25%	10%	2.96	9
Innovate and learn	9%	24%	28%	29%	10%	3.08	11
Focus and prioritize	**13%**	**34%**	**22%**	**25%**	**6%**	**2.78**	**2**
Motivation and enthusiasm	18%	20%	28%	28%	6%	2.85	5
Commun. and collab.	**35%**	**32%**	**16%**	**16%**	**0%**	**2.14**	**1**
Composition of team	11%	33%	23%	25%	8%	2.85	5
Relations/emot. intel.	14%	19%	34%	23%	10%	2.96	9

Table 6 shows that the respondents have experienced poor performance on the productivity factors causing low productivity relatively often. The three productivity factors that most often caused low productivity, were poor communication and collaboration, poor ability to focus and prioritize, and low job satisfaction. As can be derived from the table, all productivity factors had more than 50% of the responses in the categories “several times”, “often”, or “very often”.

3.2 Connections

This section analyses the connection between the previous experience regarding productivity factors and the perceived importance of these productivity factors.

Table 7 summarizes the connections examined, how we analyze them, and the results of the analyses. The details of the analyses are displayed in Tables 8 and 9 and discussed below these tables.

Table 7. Summary of the analyses

Tested connection	Consequence for analysis	Results of analysis
1. A *larger variation* in how well previous projects and teams have performed regarding that	When experiencing that “about the half” of previous projects and teams had good performance on a productivity factor, this suggests the largest perceived variation on that	*No support* for the interpretation that the respondents give higher importance to factors where they previously have

productivity factor is connected with higher perceived importance.	factor. This should then be connected with higher mean importance of that factor.	experienced much variance in performance.
2. A *good performance* in previous projects and teams regarding a productivity factor is connected with higher perceived importance.	When experiencing that "nearly all" or "most" of previous projects and teams had good performance on a productivity factor, this suggests the best perceived performance on that factor. This should then be connected with higher mean importance of that factor.	*Support* for the interpretation that the respondents give higher importance to factors where they previously have experienced very good performance.
3. A *poor performance* in previous projects and teams regarding a productivity factor is connected with higher importance.	When experiencing that only "some" or "few" of previous projects and teams had good performance on a productivity factor, this suggests the worst perceived performance on that factor. This should then be connected with higher mean importance of that factor.	*Weak support* for the interpretation that the respondents give higher importance to factors where they previously have experienced bad performance.
4. A *higher frequency* of observing that a *low performance on a productivity factor has caused low productivity* is connected with higher importance.	The more frequently low performance on a productivity has been perceived to cause productivity problems, the higher the importance of that factor will be. This analysis is similar to the one in 3., but analyses a more direct connection between poor performance and productivity *problems*.	*Support* for the interpretation that the respondents give higher importance to factors they frequently have experienced have caused productivity problems. (This suggests an important difference between performing poorly on a factor and experiencing that a factor has caused productivity problems.)

Table 8: Mean importance of a factor, for categories of frequency of good performance in previous teams (highest value for each factor in bold)

Factor	Nearly all (1)	Most (2)	About half (3)	Some (4)	Few or none (5)
Development skill	4.00	4.06	4.26	4.18	**4.50**
Management skill	**4.50**	3.94	3.82	3.94	3.80
Domain knowledge	**4.50**	3.45	3.55	3.58	4.33
Autonomy	**4.00**	3.72	3.61	3.44	3.56
Psychological safety	4.37	4.33	4.05	4.29	**4.40**
Trust	**4.75**	4.37	4.65	4.43	4.33
Job satisfaction	4.23	**4.28**	4.22	4.00	4.25
Processes and tools	**4.73**	4.13	3.95	4.06	4.33
Innovate and learn	**4.80**	4.19	4.28	4.38	3.75
Focus and prioritize	**4.88**	4.15	3.89	4.20	4.00
Motivation and enthusiasm	**4.56**	4.21	4.21	4.20	4.00
Commun. and collab.	4.92	4.59	4.44	4.45	**5.00**
Composition of team	**4.46**	4.15	3.67	4.09	4.00
Relations/emot. intel.	**4.83**	3.90	4.11	3.77	4.00

Overall mean value	**4.54**	4.11	4.05	4.07	4.16

An examination of the above mean importance values suggests that the main pattern is that the highest importance is typically put on factors where the projects and teams have previously scored well, i.e., when nearly all or most previous teams and projects have had a good performance on the productivity factor. It may also be the case, but mainly for three of the factors, that higher importance is put on factors with very low previous performance. For none of the factors, it is the case that those with the most variance (as indicated by reporting that "about half of the teams and projects have had a good performance") are connected with the highest importance. This gives support to the connections that productivity factors are given high importance when previous experience has been very good, but no support to a connection between more variance in experience and higher perceived importance of a productivity factor. A connection between poor previous performance on a productivity factor and the high perceived importance of that factor cannot be excluded for some factors, e.g., development skill. Notice that we have not included a correlational analysis here, as opposed to Table 9, because the analyzed connection is not likely to be linear.

Table 9: Mean importance of a productivity factor, for categories of frequency of experience that poor performance has caused low productivity (highest values for each factor in bold, correlations with * indicates $p<0.05$ and with ** $p<0.01$)

Factor	Very often (1)	Often (2)	Several times (3)	A few times (4)	Never (5)	Corr. (r)
Development skill	**4.79**	4.22	3.91	4.06	3.67	-0.42**
Management skill	**4.36**	4.00	3.63	3.76	4.25	-0.11
Domain knowledge	**4.83**	3.90	3.39	3.53	3.00	-0.42**
Autonomy	**5.00**	3.54	3.55	3.36	3.71	-0.28**
Psychological safety	**4.83**	4.38	4.17	4.14	4.27	-0.19*
Trust	**4.82**	4.37	4.55	4.35	4.71	-0.08
Job satisfaction	**4.50**	4.17	4.14	4.13	4.17	-0.12
Processes and tools	**4.90**	4.16	4.05	4.05	3.88	-0.32**
Innovate and learn	4.14	**4.58**	4.36	4.09	4.25	-0.16
Focus and prioritize	4.70	4.11	3.88	3.95	**4.80**	-0.11
Motivation and enthusiasm	**4.57**	4.19	4.14	4.18	4.20	-0.15
Commun. and collab.	**4.79**	4.64	4.38	4.46	-	-0.26*
Composition of team	**4.67**	4.04	4.17	3.65	4.33	-0.19*
Relations/emot. intel.	**4.64**	3.93	4.00	3.89	3.63	-0.29**
Overall mean value	**4.68**	4.16	4.02	3.97	4.07	-0.22*

The results in Table 9 show a clear pattern. For nearly all productivity factors, the high importance of a factor is connected with the experience of that factor having caused low productivity "very often." The correlation column suggests that the connection between the frequency of previous experience of a factor and perceived importance of that factor is linear for many of the factors, i.e., the more frequently a respondent has experienced that a productivity factor has caused low productivity, the

higher the importance put on that factor. This is especially the case for the productivity factors development skill, domain knowledge, processes and tools, communication and collaboration, and relations and emotional intelligence. All productivity factors have a negative correlation between previous problems and perceived importance.

4. Discussion and conclusion

It should not be surprising that the current lack of clarity in how to interpret software development productivity, partly vaguely defined productivity factors, together with the lack of commonly agreed upon criteria on how to score the importance of productivity factors, lead to problematic interpretation of survey-based results on the importance of productivity factors. This was, amongst others, demonstrated by the responses on a factor we expected everyone taking the survey seriously would give a low importance score, i.e., the importance of a good lunch restaurant nearby. Several of the participants perceived this productivity factor to have a "moderate" or "high" importance and gave gave rational arguments for this. This is consistent with a strong context dependency on the importance of productivity factors, and the challenges of aggregating responses across a variety of contexts. Without understanding the work context of survey participants, it will be hard to interpret the results properly and make meaningful use of them. In addition, we have no access to the judgment processes behind the judgment or the criteria used for assessing one factor as more important than another, and it may be the case that the respondents themselves have no explicit criteria and just provide judgments based on what "feels right". We know from studies on unconscious judgmental processes (expert judgment) that people may use simple heuristics (Gigerenzer, 2008; Tversky & Kahneman, 1973), such as *availability* (if, for example, the first association with a productivity factor is an event where the team lost a deadline because of too long lunch breaks or article about the importance of psychological safety the strength of the message in this association may affect the importance given to the factor), *recency* (the last event experienced with strong influence on team productivity may be deemed more important), and *representativeness* (the most typical experience regarding a productivity factor is what is believed to represent its importance). The observation that software professionals are willing to answer poorly defined questions on the importance of productivity factors, including those in our study (where several respondents gave very positive feedback on the importance and the meaningfulness of the study), is perhaps not surprising, but not very confirming for the quality and interpretability of such studies.

If challenging to interpret what a high or higher importance of a productivity factor means, what can we then learn from the results of surveys on such factors? The results in this paper suggest that such results may tell us something about the previous experience of those responding. Respondents who have experienced that poor performance on a productivity factor has caused low productivity, are likely to give a high importance score on that factor. Another connection with perceived higher importance on a productivity factor, supported by our findings, is that prior performance on that factor has been good, i.e., that all or nearly all previous teams and projects have scored well on that factor. These two processes potentially guiding the decision on importance of a productivity factor are quite different, and it may be hard to know which will be the strongest and when they are used. There may also be other sources leading to the higher perceived importance of a productivity factor. It is easy to think of contexts where almost any reasonable factor may contribute to higher or lower

productivity, and qualify as a productivity factor. The number of such factors may consequently be as high as desired, given a sufficiently large variety of contexts.

Our recommendation based on the above reflections and our empirical results is that we should avoid conducting surveys on the importance or influence of productivity factors unless we come up with better ideas of how to pose the questions in more concrete, well-defined ways and include the context necessary to be able to give a proper interpretation of the results. A possible use of the results of such surveys may be to get some insight into the previous experience with the performance of these factors and how frequently they have caused productivity problems. If, however, that is the purpose of the survey, it would probably be a better idea to ask directly about their experience regarding the productivity factors and their connection to productivity problems.

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Appendix A: The survey questions

A) Factors connected with software development team productivity

Below is a list of factors potentially connected with the productivity of software development teams (productivity = developed software of value to the users/work-effort spent). Evaluate **how important you believe each of these factors are to achieve high software development team (inclusive project teams) productivity**.

	Very low/no importance to achieve high team productivity (1)	Low importance (2)	Moderate importance (3)	High importance (4)	Very high importance to achieve high team productivity (5)
High software development competence/skill of the team members	○	○	○	○	○
High competence/skill in team management	○	○	○	○	○
Good domain and business experience of the team members	○	○	○	○	○
High team autonomy (freedom to choose when and/or how to develop the software)	○	○	○	○	○
High psychological safety ("The belief that one will not be punished or humiliated for speaking up with ideas, questions, concerns, or mistakes, and that the team is safe for interpersonal risk-taking")	○	○	○	○	○
High trust between the team members (high trust in that all are doing the right things and with the right intentions)	○	○	○	○	○
High job satisfaction and well-being of the team members	○	○	○	○	○
Good use of efficient software development processes and tools (e.g. good use of agile software development practices)	○	○	○	○	○
Strong ability of team members to learn from and/or innovate based on feedback/experience	○	○	○	○	○
Strong ability of team members' to focus and prioritise	○	○	○	○	○
Strong job motivation and enthusiasm of team members	○	○	○	○	○
Good communication and collaboration within the team, with management, and with clients	○	○	○	○	○
Good composition of the team (good mix of roles, skills and personalities within the team)	○	○	○	○	○
Good interpersonal relationship and emotional intelligence	○	○	○	○	○
Good lunch restaurant nearby	○	○	○	○	○

B) Your experience of frequency of teams with good performance on each of the productivity factors

Below are the same productivity factors you evaluated earlier. This time, think back on the teams (including project teams) you have experience from and assess how well they scored on each of the productivity factors.

For each of the productivity factors evaluate whether you think "nearly all", "most", "about half", "some (but less than half)" or "few or none" of the teams you have experience from were "good" (or better than good) on each of the productivity factors.

You should consider a team to have been "good" regarding a productivity factor if the team's performance on this factor did not cause any productivity problems, but instead was a factor contributing to at least medium high productivity.

	Nearly all teams were good on this productivity factor (1)	Most teams were good (2)	About half of the teams were good (3)	Some of the teams were good (4)	Few or none of the teams were good on this productivity factor(5)
Software development competence/skill of the team members	○	○	○	○	○
Competence/skill in team management	○	○	○	○	○
Domain and business experience of the team members	○	○	○	○	○
Team autonomy (freedom to choose when and/or how to develop the software)	○	○	○	○	○
Psychological safety ("The belief that one will not be punished or humiliated for speaking up with ideas, questions, concerns, or mistakes, and that the team is safe for interpersonal risk taking")	○	○	○	○	○
Trust between the team members (trust in that all are doing the right things and with the right intentions)	○	○	○	○	○
Job satisfaction and well-being of the team members	○	○	○	○	○
Use of efficient software development processes and tools (e.g. good use of agile software development practices)	○	○	○	○	○
Team member's ability to learn from and/or innovate based on feedback/experience	○	○	○	○	○
Team members' ability to focus and prioritize	○	○	○	○	○
Team members' job motivation and enthusiasm	○	○	○	○	○
Communication and collaboration within the team, with management, and with clients	○	○	○	○	○
Composition of the team (the mix of roles, skills and personalities within the team)	○	○	○	○	○
Interpersonal relationship and emotional intelligence	○	○	○	○	○

C) Your experience on how often low performance on a productivity factor has been an important cause of low productivity of the team and/or the project

Similarly to the previous question, we ask you to use your experience from teams you have been part of or observed and evaluate them for each of the factors.

This time we would like you to assess **how often you have experienced that poor performance on a factor has STRONGLY REDUCED the productivity of the team/project (has been an important cause of LOW PRODUCTIVITY)**.

	Very often experienced that this factor has caused low productivity (1)	Often (2)	Several times (3)	A few times (4)	Never experienced that this factor has caused low productivity (5)
Low software development competence/skill of the team members strongly reduced the team productivity	○	○	○	○	○
Low competence/skill in team management strongly reduced the team productivity	○	○	○	○	○
Poor domain and business experience of the team members strongly reduced the team productivity	○	○	○	○	○
Low team autonomy (freedom to choose when and/or how to develop the software) strongly reduced the team productivity	○	○	○	○	○
Poor psychological safety ("The belief that one will not be punished or humiliated for speaking up with ideas, questions, concerns, or mistakes, and that the team is safe for interpersonal risk taking") strongly reduced the team productivity	○	○	○	○	○
Low trust between the team members (trust in that all are doing the right things and with the right intentions) strongly reduced the team productivity	○	○	○	○	○
Low job satisfaction and well-being of the team members strongly reduced the team productivity	○	○	○	○	○
Poor use of software development processes and/or tools (e.g. good use of agile software development practices)	○	○	○	○	○
Team member's poor ability to learn from and/or innovate based on feedback/experience strongly reduced the team productivity	○	○	○	○	○
Team members' poor ability to focus and prioritise strongly reduced the team productivity	○	○	○	○	○
Team members' low job motivation and enthusiasm strongly reduced the team productivity	○	○	○	○	○
Poor communication and collaboration within the team, with management, and with clients strongly reduced the team productivity	○	○	○	○	○
Poor composition of the team (poor mix of roles, skills and personalities within the team) strongly reduced the team productivity	○	○	○	○	○
Poor Interpersonal relationship and emotional intelligence strongly reduced the team productivity	○	○	○	○	○