Blending Software Engineering with Remote Working - Results from an MLR

Vincent Achukwu[1] (17393546), Alan Hian Wu [1](18332283), Jack O'Reilly[1] (18465312), Stephen Norton[1]

[1]Dublin City University, School of Computing, Dublin

{vincent.achukwu2, alan.wu2, jack.oreilly46, stephen.norton3}
@mail.dcu.ie

Abstract

In this paper our team gives a concise view on the topic of blending Software Engineering with Remote work utilising multivocal literature reviews (MLR). The topic of remote work, working from home, or teleworking has been studied in the past, but not to the extent it has been examined during the global pandemic. Our team has examined a large number of studies conducted during this period and have also compared them to previous studies in order to find the key benefits of remote work, key challenges, and what is the best practice going forward in regards to blending software engineering with remote work.
In our analysis, we found that the productivity of developers can vary significantly based on some key metrics such as programming language, project team size, project type, project age, and personal factors such as the home environment. We also looked at the mental and physical health of developers when working from home during the pandemic, we then compared them to studies before this period and found that working from home prior to the COVID-19 Pandemic has been less significantly stressful. We observed that Agile teams experienced less or no negative impacts when working remotely, but individual professions that rely more on communication (eg. programme managers) will find it more difficult to operate when working remotely. Our findings indicate that working remotely can offer great benefits to companies within the software industry compared to traditional on-site workplace environments, but our research has shown that this is not without its limitations.

1. Introduction

This research explores the topic of blending software engineering with remote working, primarily during the COVID-19 pandemic from early 2020 until 2022. The topic of remote working or teleworking is not by any means a new phenomenon, there has been much individual research done on remote work prior to the COVID-19 pandemic [33], but this area has experienced a great surge of interest in recent times. In order to keep our global economy functioning many industries needed to partially or completely move their workforce into the digital realm [25]. We aim to provide an in-depth analysis of how remote work influenced the workforce and how companies were able to complete the transition from traditional on-site work to working from home. The software industry is much better suited than other industries in this regard, with some companies within the industry already having the infrastructure and resources to enable their employees to work remotely, prior to COVID-19. This does not, however, mean the software industry is free from the struggles of moving a large workforce online [21]. Unlike previous research into this topic, our team is able to draw from many data sources of how remote work has influenced the world of software engineering and explore in great detail what worked well, as well as what did not.

Section 2 outlines the research methodology, while Section 3 presents the research we have carried out based on productivity, well-being, team management, and future recommendations for software engineers working remotely. Section 4 briefly discusses the limitations placed upon us while carrying out this research. Section 5 indicates the direction of future research regarding the topic of blending remote work with software engineering. Section 6 contains concluding remarks, including a summary of the findings and the answers to our research questions.

1.1 Research Questions

In order to allow for a structured approach and to best focus our efforts in this investigation, we decided to outline some key research questions:

RQ1: How has the shift to remote working impacted the productivity of developers?

Motivation: We want to investigate how working remotely has affected the productivity of software engineers over the COVID-19 Pandemic. We feel this is a very important factor that will likely determine whether or not software developers have the opportunity to continue working remotely after the COVID-19 restrictions have been lifted.

RQ2: How has the well-being of software engineers been affected by working remotely during the COVID-19 Pandemic?

Motivation: We aim to examine the impact of working remotely on the mental and physical health of software engineers during the pandemic, what is the difference between normal work from home and working from home in a pandemic, this research question addresses the many research papers and studies done for remote work during the period 2020 - 2022.

RQ3: How has software engineering team management evolved over the COVID-19 pandemic?

Motivation: We want to find out how software development teams cope with remote work, during the pandemic, what workflow worked and didn't, what method can still be used even after the pandemic.

RQ4: What recommendations should be made to companies whose software engineers may wish to remain working remotely after COVID-19 restrictions are lifted?

Motivation: Some software professionals have had a positive experience working remotely, where they have not only enjoyed the benefits mentioned in our report, but in many cases, they have also become more productive. Should they be forced to return to work in a traditional office environment, if working remotely has no negative impact on the company?

2. Research Methodology

2.1 Methodology

Each member of the team was first tasked with gathering relevant research papers regarding the topic of remote work and working as a software engineer during the COVID-19 Pandemic. Following the initial gathering of information, the team then decided on key research questions and began finding answers to these questions. There was much overlapping information that was relevant to each other's research which was shared during our organised regular meetings. Regularly exchanging our findings while working together allowed us to build up a strong base for our research. In these meetings, we discussed how we would structure our research paper so that our report would be both purposeful and comprehensive.

The multivocal literature reviews were used to perform the study for this paper. When looking at research papers, we executed search queries through the use of online search engines such as IEEE Xplore, Google Scholar, and Springer. The search strings evolved over time given that we sought to refine our search, in order to find better and more relevant studies for our research topic. This diversified different aspects of our topic (for instance, not only showing remote working, but also remote learning). Given our research is based on

how software engineering can be blended with remote working, we also considered papers and articles from the beginning of 2020 onwards relevant because the remote working environment we know today is drastically different to the remote working environment we had before the COVID-19 pandemic.

If we came across any relevant papers from these sources, we would include them in our reference list and if any of the cited papers within the documents seemed relevant (after thorough examination), we would include those in a list to be analysed further. Each member of the team thoroughly researched the documents in order to help us select which subtopics would be useful to research and analyse for our topic. We began with broad search strings which were slight variations from our search topic, including “working from home software engineering”, “software engineering covid”, “software professionals working remotely”. Upon further reading of the papers we came across, we refined our search strings by topic for each of our research questions.

Table 1: Review of Initial Search String Selection

Search String	**Results Chosen**	**Publisher**	**No. of Citations**	**Selection Criteria**
“Working from home software engineering”	A tale of two cities: Software developers working from home during covid 19 pandemic	ACM	45	Recent paper 2021, highest citations in search results
“Software engineering COVID-19”	To work from home or not work from home	SpringerLink	4	Recent paper 2021 Extremely relevant to our research area
“Software teams working remotely”	Predictors of well-being and productivity among software professionals during the covid-19 pandemic	SpringerLink	50	Recent paper 2021, highest citations in search results

Table 2: Refined Search Strings based on Research Questions

Research Area	Search Strings
Productivity	“Software engineer productivity”, “Remote work productivity”, “Impact of COVID-19 on productivity”, “Software developer remote work”, “Working remotely agile”, “Software teamwork COVID-19”
Well-being	“Mental and physical health of software engineers”, “Well-being software engineers”, “COVID-19 software developer health”, “Effects of remote work on well-being of software engineers”
Team Management	“Team management software”, “Team management COVID-19”, “Change in management remote work”, “Management of teams during COVID-19”, “Agile software remote work”, “Software Management”
Future Recommendations	“Software engineers remote work advantages and disadvantages”, “Impact of COVID-19 on software industry”, “Remote work benefits for companies”, “effects of remote work software companies”

2.2 Inclusion/Exclusion Criteria

Sources were included if they explored a similar topic as what we were looking for, as well as given that the relevant papers were in full-text format and written in the English language. We could rank the reliability of the papers we were looking for based on their citations and by comparing their titles to what we were looking for. Although this may not always be the most reliable method of searching for relevant papers, we carefully analysed those which we deemed relevant. For instance, the top results from Google Scholar which were from publishers of high ranking, as well as mainstream Software Engineering journals and conferences were included, such as Springer and IEEE Xplore.

3. Analysis

3.1 Productivity

The productivity of software engineers while working remotely is a topic that has had many conflicting reports over the COVID-19 Pandemic. In this section, we hope to explore this

issue, and answer **RQ1:** How has the shift to remote working impacted the productivity of developers? In a survey completed by OWL in 2018 [21] it was found that 52% of employees work from home at least once a week and 56% of companies allow remote work, this number has since skyrocketed in the survey conducted in 2020 [27] where 69% of the surveyed worked from home while working remotely can give developers great benefits it can also come with its own burdens it was found that employees will on average do 26 hours more work per month as there is no “hard stop” (specific routine at the end of a working a day to mark an end to work, eg. commute, peers leaving, etc), these are some of the top challenges for remote work in decreasing order found in the survey “Interruptions/being talked over”, “Background distractions from other participants”, “Staying focused”, “Video conferencing - audio quality”, “Video conferencing - video quality”, “Internet speed or connectivity”, “Meeting setup”. In the study “qualitative and quantitative insights about working from home” [4], it was found that the quality of family time has improved but it might lead to a lack of focus and poor work-life balance.

It has also been found that the productivity of developers will depend on the characteristics of the project [1] (eg. programming language, project age, project structure, etc). It was found that working remotely had both positive and negative impacts on developers productivity when working on C++ projects while only negative impacts were found on developers working on Java projects; there are both positive and negative impacts on APP projects when working from home but only negative impacts on SDK and Server projects, this might be due to the SDK and Server projects requires more communication between developers [20] compared to APP projects where developers can work on it locally. It was also found that newer projects were more negatively affected by remote work, due to the longer time it takes to train up new developers, while older projects will not be as impacted as older projects tend to be well documented and still have active developers working on maintenance. Larger projects (teams larger than 20 developers) will suffer more negatively than projects with smaller developers. It should be noted that these studies rely on self-reporting of developers and use productivity metrics such as commits, lines of code etc. Therefore, Goodhart’s law can be applied [23], as much of the previous research has shown that measuring productivity using these types of metrics can become detrimental in the long term [28].

As mentioned before, there have been many studies done on the topic of remote working prior to the pandemic [17, 33] and the majority of older studies have indicated a positive effect of remote work, but in more recent studies it was found that on average the productivity of developers does not show a significant difference when working from home compared to working on-site, but some developers will find this change to be highly beneficial and some detrimental [1, 7]. It should be noted that there is a distinct difference between working from home and being forced to work from home due to extenuating circumstances like a global pandemic, while under normal circumstances many remote

working workers will have a suitable environment to perform their daily tasks. In contrast, workers without a suitable setup for remote working can suffer much more [17]. In order to achieve a minimum loss in productivity from the transition from working in the office and working from home, there should be careful planning put in place in order to create an ergonomic and distraction-free area at the home office.

It should be noted that developers have lower perceived productivity when working from home [18], but it was also found that the self-reported productivity of developers tends to move up as developers get used to working from home [19], from the study [31] that investigated how developers perceive and think about their own productivity. It was found that a developer's sense of how productive they are can be distorted by how many interruptions and context switches they experience while working. Another study reported that the quality of the work environment will be another major contributing factor [29], while the effectiveness of the manager [30] can also play a major role in perceived productivity.

This shows that generally as developers start to get used to working at home the initial productivity decrease will slowly catch back up to a normal office productivity level, but it is important to remember that these changes are completely at an individual level, as people are affected differently.

3.2 Well-Being

In order to blend software engineering with remote work we need to consider the mental and physical health of the workforce while working remotely, this is an issue that has rightfully garnered much attention over the COVID-19 Pandemic. In this section, we examine the effects of remote working on the well-being of software professionals, and answer **RQ2:** How has the well-being of software engineers been affected by working remotely during the COVID-19 Pandemic?

An individual's well-being while working remotely is heavily influenced by their emotional stability, which can be defined as a person’s ability to control their emotions when stressed [18]. Studies have shown that working remotely during COVID-19 has largely had a negative impact on the well-being of software engineers, which is thought to be directly related to their productivity [6]. In a nightly diary study [22], it was found that there are many common challenges that developers experienced working from home, including feeling overworked, as well as struggling with their mental and physical health (physical issues such as increased repetitive strain pain, lack of movement, headaches, etc. and mental issues of isolation, depression and anxiety were also reported). Many also outlined problems with work-life balance and being “overloaded” with meetings while working remotely [22]. In the same

study it was mentioned that in order to address some of these challenges, a “no meeting” Friday was put in place, in order to aid the well-being of software engineers.The lack of commute has been credited as one of the great benefits of working from home, with the average person saving 30 minutes by not having to travel to work in Ireland (60 minutes in the Microsoft survey) [21].

A flexible schedule is another great benefit of working from home, and one that has proven to have a positive impact on the mental health of software engineers, as it has been reported to significantly lower stress levels [12]. There is, however, evidence that suggests flexibility is not an ideal solution as in many cases a flexible working schedule has resulted in an increase in daily working hours [13]. There is further evidence to support this claim [14] in which the researchers also pointed out that this way of working is not sustainable, and will prove to have a negative effect on the well-being of software engineers in the medium to long term. Another very interesting subject in relation to the mental health of software engineers that we found during our studies, is that developers have tended to take much shorter lunch breaks, due to the lack of, or in many cases, a complete absence of the social aspect that we are used to seeing before the COVID-19 Pandemic. This, coupled with many developers no longer having a set time to leave their workplace, has also led to the increase in hours worked while working remotely [15]. So what can software employers do to aid the well-being of their employees during these stressful times? We think that companies should do their best to support their workforce by assuring them that it is acceptable in some cases for there to be a drop in productivity levels [16], as the most important thing should be developing a sustainable work environment, where the mental health of software engineers is of great importance. It’s also worth noting that much research on working from home has been heavily criticised for relying on self-reports of perceived productivity [18], although perceived productivity does appear to correlate well with managers’ appraisals, so perhaps some of this criticism is unjustified in that regard [18].

3.3 Team Management

Management practises within software engineering teams have changed significantly, as more teams are now operating in a remote environment than ever before. In this section, we highlight the changes in software team management and answer **RQ3:** How has software engineering team management evolved over the COVID-19 pandemic?

Software teams have certainly had their team management skills tested over the COVID-19 pandemic, with the majority of teams experiencing abrupt changes in the ways they communicate with each other [6], and work together as a team. COVID-19 restrictions meant that many companies around the world now had much, if not all, of their employees working remotely [32]. This created a need for communication tools, like video conferencing platforms such as Slack, Zoom and Microsoft Teams, which led to exponential growth in the

user bases of each of these applications [3]. Although these platforms have provided software teams with a way of collaborating with each other, many developers have reported that they felt less connected with the team, and studies have shown that the socialisation levels within teams have dropped significantly [32]. There has also been a notable decrease in group/pair programming sessions, which many teams regard as an essential part of team and project success [32]. Adapting to these changes has proved challenging for many software teams, with engineers feeling that they are having too many meetings, being overworked and as a result, damaging their physical and mental health. However, many software engineers have expressed their gratitude for increased family time, flexibility and team support. Team managers and scrum masters have come up with a few popular ways of boosting team productivity and morale over the COVID-19 pandemic, some of which include coffee mornings and game nights. These events play a key role in making the team feel connected, as studies have shown that there is a strong correlation between productivity levels and team morale [2].

Many traditional ways of informally observing and encouraging team members, as well as providing feedback were no longer available to software team managers while working remotely. Now they are relying on a much more structured approach, which usually takes the form of scheduled meetings that take place over a video conference. There is, however, a great deal of research claiming that teams operating within an agile environment have adapted well to working remotely [13]. Although agile teams had to shift to using online platforms, this did not prove to be too difficult as most of what is done in agile can still be achieved online with the use of tools like Kanban and Jira [10, 11]. In fact, many software teams have realised how agile methods are suited to support a remote working environment.

That said, there are also some downsides when it comes to using these online tools for maintaining the agile methodologies adopted by teams. Distractions have been reportedly common during Scrum meetings when working from home, as software engineers may have to reply to messages and emails during these meetings [13]. Moreover, working from home may also result in other problems such as a decrease in productivity and quality of software products. Given that many production-level projects require intensive collaboration and a coordination-based practice involving broad parties including clients and end-users for Agile, the standard and ongoing communication needed between these parties can be difficult to achieve. Poor communication among team members may also lead to misinterpretations that can be detrimental to the success of the project [20], and fatigue levels may rise due to long hours spent sitting during online meetings [15].

When examining the study [4], a simple subgroup analysis of change in productivity has found that there was no statistically significant difference between people managers (32% more productive) and individual contributors (35%). However, the difference between

software engineers (31%) and program managers (40%) was statistically significant. This can be due to the nature of their profession, where managers will experience more difficulty or downtime (no/long replies, online meetings) than software engineers due to their title inherently requiring more communication than software engineers.

3.4 Future Recommendations

In this section we want to answer the question **RQ4:** What recommendations should be made to companies whose software engineers may wish to remain working remotely after COVID-19 restrictions are lifted? In the 2020 OWL survey, it has shown that 1 in 2 people won't return to jobs that don't offer remote work [27], from that same survey, over 80% of employees expect to work from home at least three times per week. COVID-19 restrictions may have drastically changed how the majority of software engineers work for the foreseeable future. We have explored the benefits and limitations of working remotely at an individual level, but what does this mean for the organisations? With many companies operating within the software industry saving money on office space and overheads, as well gaining access to a much wider labour market to draw upon, why not permanently switch to working remotely for the future?

Well, there are some possible shortcomings and challenges of making the switch, such as the loss of control that many companies value dearly [33]. There are few accurate ways of monitoring the activity and performance of software engineers working remotely. With the action of informally observing team members no longer available in a remote working environment, organisations will have to decide what they truly value when making the decision to return to traditional work environments or not. As well as higher productivity being reported at an organisational level, there are also some benefits that companies should take into account when making their decision. By working remotely, or giving software engineers the opportunity to, companies gain an image of a flexible workplace, one that is very attractive to many software engineers, which will increase their chances of hiring the best talent possible [33]. We would recommend that companies should offer flexibility to software engineers, allowing them to work remotely for at least some part of the week. This way the company can take advantage of some of the benefits mentioned above, while still ensuring the opportunities for social interaction are available to those who wish to visit the office regularly. Companies will have to weigh the pros and cons of allowing software engineers to work remotely, and decide what they feel is best for themselves once COVID-19 restrictions are lifted.

4. Limitations of Research

Given that we are undergraduate students conducting this research paper under a time constraint, our research could have been more thorough and efficient with more research experience and better methods of data collection to cross-reference and refine them within the timeframe. This meant that we were to begin our research early in the semester in order to record our research methodology-related data sooner rather than later. Given that our topic is based on how software engineering can be and has been blended with remote working, this resulted in coming across a vast amount of related articles and papers published online. We had to refine our findings and change our search queries to find things more closely related to our research field. Searching a query such as “Software Engineering Remote Working” on Google Scholar resulted in over 3 million results which would have been too many to include for a human-led research project. As a result, we narrowed our research focus to four themes, Productivity, Well-Being, Team Management, and Future Recommendations. All four of these generally covered the main aspects of what our research was based on, satisfying both the general and software engineering context of remote work.

During the construction of this report, we mainly relied on studies that have been researched before in the past, and even studies before COVID-19. Although this allowed us to further our research by comparing how software engineering can be blended with remote work both before and after the pandemic (since March 2020), we did not put into place our own experiments and studies of getting up-to-date results about blending software engineering with remote working. For instance, nowadays people are used to remote working since COVID-19, whereas when the pandemic started, people felt restricted and trapped by having to isolate themselves while working [26]. Therefore, a lot of our research was based on secondary research and it is possible that circumstances may have somewhat changed ever since those studies were conducted.

5. Directions for Future Research

The COVID-19 pandemic has had a major influence on the performance of software engineers and will change how developers will work even years beyond the pandemic. Despite the prevailing opinions of the transition to the online world, the COVID-19 pandemic has led to some benefits of working remotely and has allowed software engineers to make their own decisions about what way of working best suits their needs. If in the future, another paper such as this is being conducted, we suggest collecting their own data or finding more recent studies given that much has changed since 2020. We also suggest researching roles other than “software engineers” as there have been many other related fields affected by the pandemic that have been faced with their own unique challenges. The COVID-19 pandemic has pushed the software industry to search for alternative methods to

the traditional approach of software engineering within offices and meeting rooms, where clients and developers could meet face-to-face. Software applications such as Zoom and Microsoft Teams were incorporated to allow for better communication amongst developers to help achieve an office-like experience, perhaps a more in-depth analysis on the differences brought about by the subtle changes that software engineers face in their everyday life, and the impact of these changes, would be a positive direction for future research related to this topic. The pandemic has led to plans and discussions on the need to modernise the working world with new technologies as well as to develop new organisational concepts for various types of software engineering practises, I would imagine in some years time that there would be much more to talk about regarding the world of remote software engineering, as the way we work today could be entirely different to how we work in the future.

6. Conclusions

RQ1: How has the shift to remote working impacted the productivity of developers?

From our research, we found that the shift to remote work does not affect the productivity of software engineers as a whole, as there can be many unique experiences, but at an individual level, developers can experience either great benefits or challenges while working remotely. The success or failure of moving software teams into remote working environments will most likely be decided by assessing the wants and needs of the individuals within the team. Factors such as experience level, team culture and quality of working environment should all be considered when making the decision to work remotely or not.

RQ2: How has the well-being of software engineers been affected by working remotely during the COVID-19 Pandemic?

We concluded from our investigation that the experiences of software engineers in regards to their physical and mental health have also been varied. Factors such as emotional stability, experience level, and personality have all been attributed to whether software engineers have benefitted or been negatively affected from working remotely.

RQ3: How has software engineering team management evolved over the COVID-19 pandemic?

It can be concluded that based on the research we have carried out, agile methodologies can have both a positive and negative impact when working from home during COVID-19. These techniques may need to be adapted to increase productivity levels and maintain

collaboration amongst the team [16]. It may be beneficial to offer more flexibility to software engineers, such as organising standups at a time that suits most/all team members

RQ4: What recommendations should be made to companies whose software engineers may wish to remain working remotely after COVID-19 restrictions are lifted?

From our research, we believe that companies will have to carefully consider the advantages and disadvantages mentioned in this section before committing to completely switching to working remotely or returning to work in traditional working environments full-time. We believe that a hybrid approach would be a safe option for many companies, as they may enjoy the organisational benefits listed above while also offering a flexible working schedule to their employees, which is certainly desirable to the majority of software engineers.

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