Why not just do all hackathons online? A comparative study between online and in-person events

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Abstract

Hackathons and similar time-bounded events have become a popular form of collaboration in various domains. Current research on hackathons has mostly studied them as in-person events and pointed towards them being *radically co-located* as the main reason for their popularity and success. The global pandemic of 2020-2021 has led to a proliferation of online hackathons, while we do not yet know whether online and in-person formats are perceived differently by the participants.

To compare the two and explore their similarities and differences, we conducted a mixed-methods study following a *sequential explanatory design*. We first surveyed a total of 940 participants from seven in-person and eight online hackathons in recent years, then interviewed six participants and six volunteer mentors from a recent online hackathon.

To our surprise, we found that participant satisfaction towards online hackathons was not lower than in-person hackathons. We further found that the perceived quality of participation is significantly correlated with participant satisfaction, which corroborates previous studies. This effect is emphasized for *satisfaction with process* in the case of in-person events. In addition, we found a connection between participant satisfaction and networking being one of their motivations to participate in the event. Finally, we discussed the pros and cons of the online format suggested by the interview subjects. Our findings contribute to better understanding participants' perceptions of online hackathons and similar forms of online collaboration.

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Chapter 1

Introduction

Hackathons[1] and similar time-bounded events have become a popular form of collaboration in various domains [25, 82]. During such events, participants commonly form teams and work on a project that is of interest to them [66]. Hackathons have been organized in the context of corporations [45, 56, 74], (higher) education [30, 70], civic engagement [34, 49, 82], (online) communities [3, 18, 41], and others.

Most of the reported research so far has focused on studying events where teams meet in the same physical space covering aspects such as how teams self-organize [86], how to support newcomers [57], how to deal with diverse audiences [27], how to encourage participation [82], and how to organize events [39, 58, 65]. Research perceives this setting of *radical co-location* [60], i.e., that the *"entire project team in one room for the duration of the project"* [84] to contribute to the success of hackathons. Co-located teams are generally perceived to be more successful than their virtual counterparts [23, 61]. Co-location is considered to contribute to the development of social ties [77], foster casual encounters and unplanned conversations [47], and contribute to establishing trust [17, 61, 63]. Co-location also is perceived to foster productivity [85] which is often attributed to the availability of situated knowledge that can support coordination and problem-solving [84]. Moreover, co-location provides opportunities to recognize and adjust to potentially problematic differences in cognitive styles [75]. The global pandemic of 2020-2021, however, made it impossible for organizers to organize co-located or in-person events. Hackathons did not disappear, though. Instead, we saw that organizers started to organize hackathons as online events, which provided the opportunity for us to study this particular style of collaboration in an online context.

We aim to explore distant team collaboration in a specific setting by studying the perceptions of participants of online and in-person hackathons. We will particularly focus on the satisfaction of participants for three main reasons. First, hackathons are organized in a wide variety of contexts, with organizers and participants having different goals that are not always aligned [51]. We use satisfaction as our dependent measure, which allows us to accommodate a variety of goals. Second, satisfaction has been found to be an antecedent of continuation intentions and behavior in various contexts, such as the continued use of information systems [7], e-commerce [16], e-learning [1], and others. Continuing a project beyond the hackathon is an important goal in many

[1]We will use the term hackathon as a substitute for similar time-bounded events throughout the remainder of this article.

contexts. Third, hackathon teams often form specifically for an event [67]. Individual satisfaction can thus be perceived as an indicator of how individuals perceived their team collaboration during an event. These considerations lead to the first research question:

RQ1. How does satisfaction differ between participants of online and in-person hackathons?

The question of whether or not an individual is satisfied in a collaborative setting, however, strongly depends on that individual's perceptions about the quality of their participation in and influence on team decisions [87]. The *perceived quality of participation* has been found to be related to satisfaction in a work-related context [2] and in educational settings [46]. Our aim is thus also to study if the perceived quality of participation can affect satisfaction in online and in-person hackathons:

RQ2. How does the perceived quality of participation affect satisfaction?

Individuals can have different goals and motivations to participate in a hackathon, as discussed before. Prior research in organizational [7, 31, 43] and volunteer contexts [5, 24] provides evidence for a connection between motivation and satisfaction. This connection is generally considered to be bidirectional in that satisfaction may affect motivation [31], and motivation may, in turn, affect satisfaction [7, 24]. In the context of our study, we focus on the latter connection since our aim is to investigate differences related to satisfaction in online and in-person hackathons. Prior work on motivation affecting satisfaction commonly builds on the expectation confirmation theory, which postulates a direct influence of confirming an individual's expectations on satisfaction [59]. We thus expect that individuals who, e.g., reach their goals during a hackathon will be more satisfied. Moreover, prior work has established that the influence of motivation on satisfaction may depend on the nature of the motivation. Some motivations like career orientation were found to positively affect satisfaction in a volunteer context, while others, like extrinsic rewards, were not [5]. We thus aim to also study how different motivations to participate in a hackathon may affect satisfaction in online and in-person hackathons and consequently also ask the following third research question:

RQ3. How do different motivations to participate affect satisfaction?

To answer these three main research questions, we designed our study following a sequential explanatory strategy. We first conducted a survey of 15 hackathons, including seven in-person and eight online events. The events were organized in various domains, including corporate, entrepreneurial, collegiate, and community, and were organized with different goals, including addressing issues caused by the global pandemic, fostering innovation and learning, engaging community newcomers, and others. Utilizing established scales, we collected survey responses from 940 individuals. Our findings revealed no significant differences related to satisfaction between participants of online and in-person events. We did, however, find a significant influence of the perceived quality of participation on individual satisfaction in both online and in-person events. This influence is emphasized for process satisfaction in the case of in-person events. Finally, we found a connection between networking motivation and individual satisfaction.

We then conducted interviews with six volunteer mentors and six hackers from a recent online hackathon. Given our quantitative results from the survey responses, the interviews focused on trying to understand better how the subjects perceived the online format of communication and

collaboration and its effectiveness during the event. We found that the participants were generally satisfied with the virtual collaboration process in the end, despite clear initial issues such as establishing communication. In addition to the significance of networking motivation shown by the survey analysis, other motivations such as learning also seem to contribute to individual satisfaction. Finally, we discussed the pros and cons of online collaboration as perceived by the interview subjects.

The contribution of this paper is as follows. It extends our current understanding of the differences between online and in-person collaboration in a specific collaborative setting. It shows that individual satisfaction does not automatically have to be lower in an online compared to an in-person setting and by providing a better understanding of the relationship between perceived participation quality, different motivations, and individual satisfaction. It provides some insights into aspects of virtual collaboration and how we can improve them in hackathons and similar online settings.

Chapter 2

Background and related work

In this section, we will situate our study in the context of related work on hackathons (section 2.1) and virtual collaboration (section 2.2).

2.1 Hackathons

Hackathons started as collaborative coding events in the early 2000s, during which young developers often formed ad-hoc teams and engaged in intense collaboration over a short period of time to complete a project and compete for prizes [12]. Since their beginnings, they have proliferated into various domains and are now organized with the aim to create innovative technology [12, 78], tackle civic and environmental issues [38, 40, 83], spread knowledge [30, 53, 70] and expand communities [41, 57]. While hackathons often include the creation of technology and, in many cases, the development of software, there is also a large variety of events that focus on the creation of other artifacts such as content in Wikipedia [26] or policy [32].

The proliferation of hackathons has also led to an increased interest in studying them. In this context, one can generally distinguish between two types of studies on hackathons as outlined by Falk et al. [25]: research *with* and research *on* hackathons. Research *with* hackathons refers to studies that utilize hackathons as an integral part of their study design. Examples for such studies can be found in an educational context where hackathons have been used as extracurricular activities [22] or as an integral part of the curriculum [69]. Moreover, hackathons have also been used in a research context where researchers utilized them to support ideation [35] and technical development [9] during research projects and to study teamwork [4]. Research *on* hackathons focuses on studying the hackathon format itself. Examples for works in this context are studies on how learning takes place at an event [29], how different formats can support design processes [68], how teams self-organize [86], how diverse participants perceive hackathons [33], and how hackathon outcomes can be sustained [67]. The work presented in this paper is situated in the context of work *on* hackathons since our study focuses on the perception of participants of online and in-person events. We do, however, perceive our findings to be also relevant for researchers and practitioners that organize and study collaborative team events outside of the context of hackathons.

Most prior work on hackathons focuses on in-person events, as discussed in the introduction,

with researchers reporting that teams prefer co-location [13] and that co-location can increase productivity [65]. Recently there has been an increase in reports related to online hackathons, though. These studies, however, mainly focus on reporting insights based on events that were aimed at addressing the effects of the global pandemic [6, 10]. While much is known about differences between in-person and online collaboration in many work contexts (see the following section), differences between co-located and online hackathons have not been extensively studied yet, despite the rapid growth in the prevalence of this form of collaboration. Our work addresses this gap.

A common measure to assess teamwork is satisfaction since satisfaction has been found to be related to team performance [42]. Studies in the context of hackathons often utilize satisfaction as an indicator for collaboration success [27, 57]. When assessing satisfaction in the context of team collaboration, scholars commonly distinguish between *satisfaction with process* and *satisfaction with outcome* [11, 73]. The prior refers to the perception about the team procedures and tools used, while the latter refers to the perception of an individual that the work produced meets certain requirements. We will utilize the same distinction as the basis for our analysis in this paper.

2.2 Virtual collaboration

Virtual collaboration is not a novel phenomenon. There is a considerable body of work that focuses on the challenges of virtual and online compared to in-person collaboration, in particular related to globally distributed software development teams [36, 37, 55]. In this context, researchers have identified distance – geographical, temporal and, perceived – as well as the nature of work to be completed and the group composition as important aspects that can affect virtual collaboration [52]. Our aim is to contribute to this body of work by comparing multiple instances of a specific collaboration setting that was conducted as online and in-person events.

Regarding distance, online hackathons are geographically but not temporarily distributed events. They are by design time-bounded events that commonly last between 24 hours and a few days during which teams engage in intense collaboration [66]. It can thus be expected that challenges caused by a temporal distance, such as additional coordination overhead due to different time zones [44, 71, 80], will only be of limited relevance in the context we study. Both geographical and perceived distance will, however, be of relevance to the context we study. Prior work provides an indication that both can lead to difficulties in establishing trust [62, 76] and the necessity for increased interaction and coordination due to a lack of opportunities for informal interaction [20, 36] and a lack of situated knowledge [84]. Works in the context of open source communities, however, have shown that geographically distant teams might still feel near [50], especially when collaborating individuals engage in intense communication [72]. The setting that we study can reasonably be perceived to be similar since teams need to engage in intense communication due to the short-term nature of a hackathon.

In addition to distance, the nature of work and the group composition have been found to affect virtual collaboration. Regarding the nature of teamwork, researchers commonly distinguish between tightly and loosely coupled [61]. Tightly coupled work is generally perceived to require more articulation [79] and thus hinder collaboration [62, 79]. There are, however, also findings

that report advantages of distant over in-person collaboration because it forces collaborators to engage more, thus inevitably learning more about each other [8]. In our study, we will not address this aspect, though. While teamwork during a hackathon can be tightly or loosely coupled in nature, we do not perceive this aspect to have a strong influence in the context we study because the nature of work will remain the same in online and in-person hackathons. Regarding group composition, it is important for individuals to perceive themselves as being able to participate and having an influence on team decisions in order to be satisfied [87]. Research on virtual teams has shown that individuals can feel isolated [14]. There are, however, also studies that did not report differences related to participation in an online or in-person setting [28]. Our aim is to study the influence of perceived quality of participation on satisfaction in a specific collaboration context.

Chapter 3

Empirical methods

To answer the main research questions stated in the introduction (chapter 1), we designed a study following the *sequential explanatory strategy* – quantitative analysis followed by qualitative exploration attempting to provide reasoning for the quantitative results [19]. This approach is suitable because our aim was to study differences related to the satisfaction of participants of online compared to in-person events (**RQ1**). Moreover, we aim to study how differences related to perceived quality of participation (**RQ2**) and different motivations (**RQ3**) may affect an individual's perceived satisfaction in online and in-person events. Quantitatively examining a large sample of hackathons and participants allows for more robust and significant findings regarding the relationship among these factors. On the other hand, participant satisfaction is an intrinsically subjective measurement. It is thus worth trying to further understand the rationale behind the individual perceptions through interviews. The survey instrument and interview guide, as well as data collecting, analysis, and storage procedures, have all been approved by the university institutional review board.

In the following chapters, we first introduce our survey study and quantitative analysis procedures (chapter 4) followed by its results (chapter 5), then describe the interview study method (chapter 6) and results (chapter 7), and finally discuss major findings throughout the study and their implications (chapter 8).

Chapter 4

Survey and quantitative analysis

In the following, we describe the survey study context (section 4.1), the survey design (section 4.2), and our analysis procedure (section 4.3).

Event	Responses	Theme
	Online Hackathons	
48 for the Future	9	Innovations for post-Covid life
Hack the Crisis Afghanistan	80	Innovations to address the pandemic
Hack the Crisis India	300	Innovations to address the pandemic
Hack the Crisis - The Global Hack	100	Innovations to address the pandemic
LUT DigiEduHack 2020	27	Innovations for the future of education
PEARC 2020	3	Collegiate hackathon in the HPC community
HPC in the City (Supercomputing 2020)	18	Collegiate hackathon in the HPC community
World of Code 2020	9	Community building around a novel FLOSS resource
	In-person Hackathons	
Brainhack & TrainTrack 2018	83	Community event to share best practices
Future City 2020	73	Innovations for the smart city
Microsoft Hackathon 2017	198	Corporate innovation
PEARC 2018	11	Collegiate hackathon in the HPC community
Supercomputing 2018	7	Collegiate hackathon in the HPC community
Cloud HPC (Supercomputing 2019)	8	Collegiate hackathon in the HPC community
World of Code 2019	14	Community building around a novel FLOSS resource

Table 4.1: Events surveyed and numbers of survey responses

4.1 Setting and procedure

For our study, we surveyed participants of 15 hackathons; eight of these were organized online, and seven as in-person events. The in-person events were selected from hackathons or hackathon organizers the authors were familiar with, while the online events were mostly ones the authors had access to during the 2020-2021 pandemic. We chose online and in-person hackathons with varying characteristics and themes because our aim is to assess differences related to satisfaction between online and in-person hackathons (**RQ1**) and the effect of perceived quality

of participation (**RQ2**) and individual motivation (**RQ3**) on satisfaction beyond the confines of specific events. To achieve this, the surveyed hackathons were of varying sizes and durations, concerning different domains and addressing different themes, such as innovation, education, and community building. The hackathons we studied consequently attracted participants from different backgrounds, including students, entrepreneurs, researchers, volunteers, and corporate employees (Table 4.1 provides an overview). At the same time, we ensured that the selected events still fulfill the main characteristics of a hackathon in that each was a time-bounded event during which teams collaborate on projects that are of interest to them [66].

We administered the surveys directly after each event. For in-person events, we administered them on-site directly after the final common activity. We utilized both online and printed forms. In the case of the online hackathons, we sent individual invitation emails to event participants directly after each hackathon. The emails contained a link to an online survey form for that event. We also sent a reminder one week after the initial invitation to entice more responses. Response collection was closed two weeks after each online event. Answers were anonymous.

4.2 Survey design

For the design of the survey, we mainly relied on existing Likert scales [48] that have been utilized in prior work on hackathons [27, 56, 58]. Table 1 in appendix 9 contains the complete survey instrument.

We first included two scales to assess individual satisfaction perceptions to address **RQ1**. The first scale covered satisfaction with a team's process. It was proposed by Filippova et al. [27] based on a scale developed by Reinig [73] and consists of four items that were assessed on a five-point scale. Similarly, for the second scale, which assessed satisfaction with a team's outcome, we also utilized a scale proposed by Filippova et al. [27] which was based on a scale by Reinig [73]. This scale consists of four items and is assessed on a five-point scale that is anchored between "strongly agree" and "strongly disagree".

In addition, we included a scale to assess an individual's perception of their quality of participation (**RQ2**). This scale was also based on a scale proposed by Filippova et al. [27], which they adapted for the hackathon context from a scale proposed by Paul et al. [64]. It consists of four items that are assessed on a five-point scale that is anchored between "strongly agree" to "strongly disagree".

Related to studying the motivation of participants to join a hackathon (**RQ3**), there was no readily available scale that we could utilize. We thus developed a scale based on common participation motivations, which include the aim to learn, network, collaborate, and potentially advance their careers. For this scale, we asked the participant "To what extent was your decision to participate in [hackathon X] motivated by [motivation Y]" and assessed each question on a five-point scale anchored between"not at all" and "completely" (Table 1 in appendix 9 contains the complete motivation scale). There might be other motivations for participants to attend hackathons, such as winning prizes, but since not all hackathons are competitive events and include prizes, we decided not to include those motivations.

Finally, our survey instrument also included common demographic questions, including the age of the participant, their gender, and their perception about their minority status. We utilized

this simple way of assessing perceived minority status since minority perception is individual can be based on many different aspects like race, gender, expertise, background, and others.

4.3 Analysis procedure

We obtained a total of 940 valid survey responses – 546 from online and 394 from in-person events – from the 15 hackathon events we surveyed. After receiving the survey responses, we first unified the different scales in that we replaced the stated agreement with numeric values from one to five, with five corresponding to being most agreeable with the scale item description and one to being least agreeable. We then combined responses to the set of common questions from all surveys into a single data set, adding two variables to each response – a categorical variable indicating which hackathon the response came from, and an "online" indicator variable of whether the hackathon was held online (=1) or in-person (=0).

We then assessed the internal consistency of the three existing scales using Cronbach's alpha [81]. The respective values were at 0.832 for *satisfaction with process*, 0.892 for *satisfaction with outcome*, and 0.855 for *perceived quality of participation* which makes all scales suitable for further statistical analysis. For the motivation scale, we conducted an exploratory factor analysis which we will discuss in section 4.3.2.

4.3.1 Extracting datasets.

We cleaned the data removing incomplete responses and extracted two datasets. The larger dataset contained all complete responses we received for both satisfaction scales and the scale for perceived quality of participation. The smaller subset contained complete responses for these three scales and also the motivation questions. The larger dataset, as a result, contained 483 complete responses, including 304 (62.94%) for online and 179 (37.06%) responses for in-person events. And for the subset, we had 438 complete responses, including 275 (62.79%) for online and 163 (37.21%) responses for in-person events. In addition, out of the 15 hackathons, the subset contained no observation from three relatively smaller events due to a lack of complete responses on the motivation questions.

4.3.2 Deriving dimensions of motivation.

We used *nScree* from the R package *nFactors* and found that only two dimensions were necessary to explain the responses to our five motivation questions based on Cattel's scree test [15]. We then used *factanal* to conduct an exploratory factor analysis of the five observed motivations. Table 4.2 presents the factor loadings of the two resulting factors for each motivation. Motivation "Advancing your career" was eliminated because it did not contribute to a simple factor structure (loadings between .3 and .5 on both factors). Thus, we derived the following two factors to be included as predictors in the subsequent analysis.

- Factor 1 (Motivation: Networking)
    - Meeting new people

    - Seeing what others are working on
    - Sharing your experience and expertise
- Factor 2 (Motivation: Learning)
    - Learning new tools or skills

	Factor 1	Factor 2
Learning new tools or skills	0.14	0.99
Meeting new people	0.60	0.29
Seeing what others are working on	0.68	0.14
Sharing your experience and expertise	0.66	0.07
Advancing your career	0.41	0.37

Table 4.2: Factor loadings for motivations to participate

4.3.3 Descriptive and preliminary analysis.

To answer the research questions stated in the introduction, we started by calculating descriptive statistics for all five variables in our dataset, i.e., *satisfaction with process*, *satisfaction with outcome*, *perceived quality of participation*, and the two motivation factors. We then conducted a correlation analysis to assess connections between the variables we measured. In this context, we were particularly interested in correlations between both satisfaction variables and whether or not a hackathon takes place online or in person (**RQ1**), between both satisfaction variables and *perceived quality of participation* (**RQ2**), and between both satisfaction variables and individual motivations (**RQ3**). Due to the anonymity of our survey responses, we cannot be entirely sure that an individual might not have participated in two of the events we surveyed. We can, however, reasonably assume that this would be unlikely due to the diversity of the events we surveyed. Nonetheless, we did not perform statistical tests to compare any single variable between online and in-person observations because observations from the same event are likely not independent.

4.3.4 Regression analysis.

Finally, to understand how *perceived quality of participation* (**RQ2**) and motivation (**RQ3**) affect *satisfaction with process* and *satisfaction with outcome*, respectively, controlling for other sources of variance, we performed four series of multiple regressions.

Treating *satisfaction with process* as the dependent variable, we constructed two types of multiple regression models, one for the larger dataset without motivation factors and one for the subset that includes motivation factors. For all models, we also included the "online" indicator variable to test a) whether the event being online or not by itself affects satisfaction (**RQ1**) and b) whether being online or not mediates the effects of other predictors. To assure conditional independence of the errors, for all models, we included the hackathon indicator to control for unobserved factors that potentially vary with each hackathon (and thus may introduce correlations among respondents participating in the same hackathon).

Similarly, we constructed two types of multiple regression models for treating *satisfaction with outcome* as the dependent variable.

Chapter 5

Survey results

In the following, we will first describe the results of the descriptive analysis and elaborate on perceived differences between online and in-person events (section 5.1, **RQ1**) before discussing the effect of satisfaction (**RQ2**) and motivation (**RQ3**) on individual satisfaction with their process (section 5.2) and outcome (section 5.3).

5.1 Descriptive analysis

Our survey demographics show that the participants were primarily between the ages of 18 and 24 (36%) and 25 and 34 (39%). Few survey participants were also between the ages of 35 and 44 (16%), 45 and 54 (6%), and 55 and 64 (3%). There were no survey participants that were 65 years or older. Related to the reported gender, our participants were mainly male (70%), with females only making up 30% of our survey population. Finally, 121 participants (12.9%) identified as a minority.

Related to the five variables we analyzed for this study, we found their mean values to be similar when comparing online and in-person events (Fig. 5.1). The standard deviations ranged from 0.64 (perceived quality of participation during online hackathons) to 1.14 (learning motivation in in-person hackathons). Moreover, we also found that the mean values for *satisfaction with process*, *satisfaction with outcome*, *perceived quality of participation*, and networking motivation were higher for online than for in-person events. Only the mean value for learning motivation was higher for in-person than for online events.

The correlation analysis (Table 2 in Appendix provides an overview) revealed that whether an event was organized online or in-person had a significant negative correlation ($r = -0.17, p < 0.0001$) with participants' satisfaction with the outcome they produced. This, however, was a weak correlation[1] which does not provide much indication towards a significant effect between outcome satisfaction and whether an event was organized as an online or in-person event. We will further examine this relationship in section 5.3.

Our analysis also revealed a significant moderate positive correlation between *perceived quality of participation* and *satisfaction with outcome* ($r = 0.51, p < 0.0001$) and between *perceived*

[1]We utilize the classification of Dancey and Reid [21] according to which correlations between 0.1-0.3 are classified as weak, 0.4-0.6 as moderate, and 0.7-0.9 as strong.

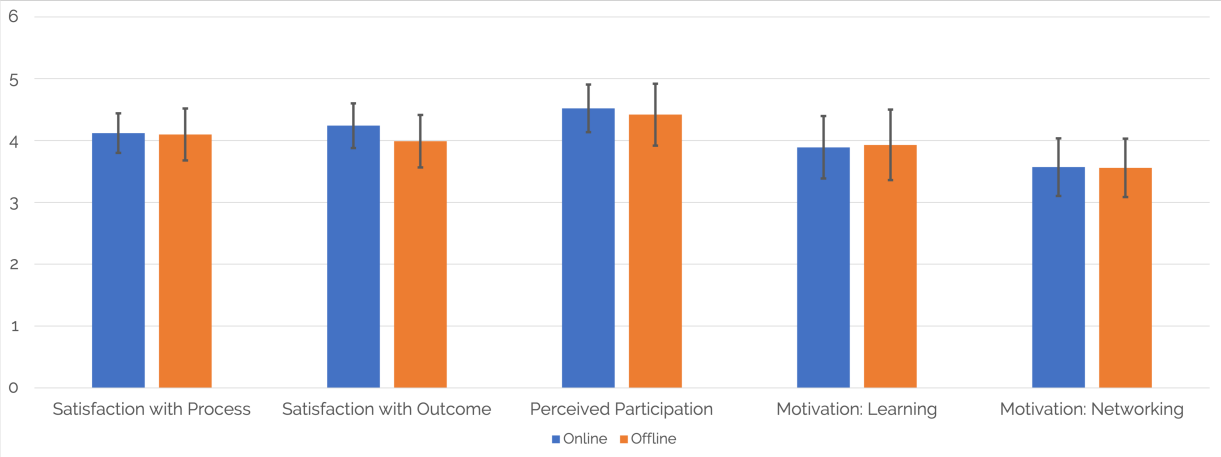

Figure 5.1: Mean and standard deviation of variables for online (blue/left) and in-person (orange/right) events.

quality of participation and *satisfaction with process* ($r = 0.56, p < 0.0001$). This finding contributes to answering **RQ2** in that it indicates that individuals who thought they could contribute to their team and participate in team decisions also showed high satisfaction values. We will further examine the relationship between these aspects in the following sections (sections 5.2 and 5.3).

We also found significant weak positive correlations between *satisfaction with outcome* and the two motivation factors – motivation to network ($r = 0.17, p < 0.001$) and motivation to learn ($r = 0.12, p < 0.01$) – we extracted and also between *satisfaction with process* and learning motivation ($r = 0.15, p < 0.001$) and motivation to network ($r = 0.20, p < 0.0001$). This finding contributes to answering **RQ3** because it indicates that satisfaction can be related to motivation in the context we studied. Moreover, it indicates that both motivations are similarly strongly related to both satisfaction measures. As with the previously discussed correlation, we will examine the relationship between these aspects in the following sections (sections 5.2 and 5.3).

Finally, the correlation analysis also pointed towards a significant moderate positive correlation between the two satisfaction measures we utilized ($r = 0.54, p < 0.0001$) and a significant weak positive correlation between the two motivation factors ($r = 0.30, p < 0.0001$). This points towards a similarity between the two motivation factors. Further analysis, however, reveals differences related to the effect of each motivation factor on perceived satisfaction (**RQ3**, section 5.2 and 5.3). Moreover, it indicates a close relationship between both satisfaction variables. One would thus expect similar results related to all three research questions (**RQ1** to **RQ3**), which will prove not to be the case when we further examined the influences of the different factors on satisfaction with process and with outcome (section 5.2 and 5.3).

5.2 Satisfaction with process

We constructed a series of multiple regression models on the larger dataset, with perceived quality of participation as the main predictor, before moving onto the subset and adding motivation

	Dependent variable:		
	Satisfaction with process		
	Model 1	Model 2	Model 3
Online indicator	0.286	0.111	1.393***
	(0.344)	(0.289)	(0.469)
Perceived quality of participation		0.575***	0.714***
		(0.041)	(0.057)
Online * Perceived quality of participation			−0.279***
			(0.081)
Constant	3.964***	1.407***	0.791***
	(0.199)	(0.247)	(0.302)
Observations	483	483	483
Adjusted R^2	0.072	0.347	0.362
Note:			*p <0.1; **p <0.05; ***p <0.01

Table 5.1: Models predicting satisfaction with process without motivation factors

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
Model 1	468	259.13				
Model 2	467	181.98	1	77.15	202.60	0.0000
Model 3	466	177.45	1	4.53	11.89	0.0006

Table 5.2: ANOVA of models 1, 2, and 3 predicting satisfaction with process

factors.

We first introduced only the indicator of whether a hackathon is online or in-person (Model 1), which does not by itself have a significant effect on satisfaction with the group process (**RQ1**, as was found in the descriptive analysis above, section 5.1). When combined with hackathon ID, which also is not statistically significant (not shown in the tables), this first model explained only 7% of variance. Then, we added individual's perceived quality of participation in their group effort (Model 2), followed by an interaction term between the online indicator and perceived quality of participation (Model 3). Table 5.1 presents these models (1, 2, and 3) in detail.

We found that perceived quality of participation has a strong and significant association with process satisfaction ($\beta = 0.58$, $p < 0.01$, Model 2), accounting for an additional 27.5% of variance (**RQ2**). While online or in-person does not directly associate with process satisfaction, we see a significant inverse interaction between the online indicator and perceived quality of participation ($\beta = -0.28$, $p < 0.01$, Model 3), which accounts for an additional 1.5% of variance. Based on ANOVA comparisons presented in Table 5.2, Model 3 explains the most variance in

	Dependent variable:				
	Satisfaction with process				
	Model 4	Model 5	Model 6	Model 7	Model 8
Online indicator	0.031	−0.111	1.245**	1.341***	1.581***
	(0.386)	(0.324)	(0.500)	(0.498)	(0.547)
Perceived quality of participation		0.568***	0.720***	0.700***	0.691***
		(0.042)	(0.060)	(0.060)	(0.060)
Motivation: Learning				0.011	0.022
				(0.031)	(0.039)
Motivation: Networking				0.082**	0.113***
				(0.033)	(0.042)
Online * Perceived quality of participation			−0.294***	−0.300***	−0.276***
			(0.083)	(0.083)	(0.085)
Online * Motivation: Learning					−0.021
					(0.063)
Online * Motivation: Networking					−0.074
					(0.068)
Constant	4.219***	1.661***	0.978***	0.699*	0.569
	(0.264)	(0.291)	(0.347)	(0.368)	(0.385)
Observations	438	438	438	438	438
Adjusted R^2	0.074	0.349	0.366	0.375	0.375
Note:					$^*p$ <0.1; $^{**}p$ <0.05; $^{***}p$ <0.01

Table 5.3: Models predicting satisfaction with process with motivation factors

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
Model 4	426	236.68				
Model 5	425	165.93	1	70.75	188.57	0.0000
Model 6	424	161.22	1	4.71	12.56	0.0004
Model 7	422	158.27	2	2.95	3.92	0.0205
Model 8	420	157.59	2	0.68	0.90	0.4066

Table 5.4: ANOVA of models 4 to 8 predicting satisfaction with process

the larger dataset.

The inverse association between the online indicator and perceived quality of participation implies that the effect of perceived quality of participation on satisfaction with process is stronger for in-person events. That is, for in-person events, the slope of perceived quality of participation is steeper as compared to online events.

Next, we investigated the effects of the two motivation factors on process satisfaction. Including complete responses to the motivation factors means we need to construct another series of models on the data subset. Table 5.3 presents these models (4 to 8) in detail.

Models 4, 5, and 6 replicate models 1, 2, and 3 from the larger dataset, respectively. We find that, on the smaller subset of data, the effects of perceived quality of participation ($\beta = 0.57$, $p < 0.01$, Model 5) and its interaction with the online indicator ($\beta = -0.29$, $p < 0.01$, Model 6) are similar to corresponding effects found on the larger dataset (Models 1, 2, and 3).

We then introduced the two motivation factors, "learning new tools" and "networking" (Model 7), followed by adding interaction terms between the motivation factors and the online indicator (Model 8). Motivation "learning new tools" does not have a significant effect on process satisfaction. In contrast, the "networking" motivation weakly associates with process satisfaction ($\beta = 0.08$, $p < 0.05$, Model 7) and only accounts for an additional 1% of variance (**RQ3**). The interaction between the online indicator and either motivation factor is not significant (Model 8). Overall, the models that include the motivation factors (Model 7 and 8), compared to that without including the motivation factors (Model 6), explain marginally more variance. Based on ANOVA comparisons shown in table 5.4, Model 7 explains most variance.

5.3 Satisfaction with outcome

Next, we constructed a set of multiple regression models to examine the effect of perceived quality of participation and the motivation factors on individual participant's satisfaction with the outcome of the event. Tables 5.5 and 5.7 present the models in detail. Models 1 to 3 are performed on the larger dataset, while Models 4 to 7 are performed on the smaller subset with the motivation factors.

Again, we first introduced only the indicator of online or in-person hackathons along with the hackathon IDs (Model 1). We found that the event being online or in-person does not have a significant effect on *satisfaction with outcome* (**RQ1**). Then, we included *perceived quality of participation*. Similar to the case with process satisfaction, perceived quality of participation has a significant positive association with outcome satisfaction ($\beta = 0.55$, $p < 0.01$, Model

	Dependent variable:		
	Satisfaction with outcome		
	Model 1	Model 2	Model 3
Online indicator	0.500	0.332	0.490
	(0.375)	(0.329)	(0.541)
Perceived quality of participation		0.552***	0.569***
		(0.047)	(0.066)
Online * Perceived quality of participation			−0.034
			(0.093)
Constant	3.929***	1.475***	1.399***
	(0.217)	(0.281)	(0.349)
Observations	483	483	483
Adjusted R^2	0.127	0.328	0.326
Note:	$^{*}p$ <0.1; $^{**}p$ <0.05; $^{***}p$ <0.01		

Table 5.5: Models predicting satisfaction with outcome without motivation factors

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
Model 1	468	307.19				
Model 2	467	236.14	1	71.05	140.25	0.0000
Model 3	466	236.07	1	0.07	0.14	0.7134

Table 5.6: ANOVA of models 1, 2, and 3 predicting satisfaction with outcome

2) (**RQ2**). However, unlike process satisfaction, there is no significant effect on outcome satisfaction from the interaction between perceived quality of participation and the online/in-person indicator (Model 3). This indicates that unlike in the case of satisfaction with process, the relationship between *perceived quality of participation* and *satisfaction with outcome* is not different between online and in-person events. The predictor of *perceived quality of participation* explains an additional 20% of variance on top of Model 1 that contains the online indicator and hackathon identifier.

We replicated Models 1 and 2 on the small subset to obtain Models 4 and 5. The effect of *perceived quality of participation* ($\beta = 0.54$, $p < 0.01$, Model 5) resembles the corresponding findings on the larger dataset (Model 2). We did not replicate Model 3 on the subset and also refrained from adding the interaction of online indicator and *perceived quality of participation* in subsequent models due to the absence of the effect shown by Model 3.

We then introduced the two motivation factors, "learning new tools" and "networking" (Model 7), followed by the interaction terms between the motivation factors and the online/in-person in-

	Dependent variable:			
	Satisfaction with outcome			
	Model 4	Model 5	Model 6	Model 7
Online indicator	−0.009	−0.144	−0.077	0.097
	(0.422)	(0.373)	(0.371)	(0.499)
Perceived quality of participation		0.539***	0.515***	0.515***
		(0.049)	(0.049)	(0.049)
Motivation: learning			−0.020	0.002
			(0.036)	(0.045)
Motivation: networking			0.102***	0.095*
			(0.039)	(0.049)
Online * Motivation: learning				−0.059
				(0.074)
Online * Motivation: networking				0.024
				(0.079)
Constant	4.438***	2.011***	1.817***	1.739***
	(0.289)	(0.336)	(0.363)	(0.401)
Observations	438	438	438	438
Adjusted R^2	0.140	0.331	0.339	0.337
Note:				$^{*}p$ <0.1; $^{**}p$ <0.05; $^{***}p$ <0.01

Table 5.7: Models predicting satisfaction with outcome with motivation factors

	Res.Df	RSS	Df	Sum of Sq	F	Pr(>F)
Model 4	426	283.71				
Model 5	425	220.04	1	63.67	124.06	0.0000
Model 6	423	216.38	2	3.65	3.56	0.0293
Model 7	421	216.06	2	0.33	0.32	0.7274

Table 5.8: ANOVA of models 4 to 7 predicting satisfaction with outcome

dicator (Model 8). Like with process satisfaction, only the motivation factor "networking" has a weak positive association with outcome satisfaction ($\beta = 0.10$, $p < 0.05$, Model 7) (**RQ3**). Given ANOVA comparisons presented in Table 5.8, Model 6 is the best, although adding the motivation factors only contributes an additional 0.8% of explained variance.

Chapter 6

Interview and qualitative analysis

The preliminary findings from the quantitative survey analysis indicate that, surprisingly, there is no significant difference regarding participant satisfaction between online and in-person hackathons. This contrasts conventional belief that co-location is important for successful collaboration. We, therefore, want to understand why participants might be equally satisfied with online hackathons and how they perceive the effect of being online on the collaborative process. To that end, we conducted semi-structured interviews with six volunteer mentors and six participants (hackers) from a recent online hackathon "HPC in the City: St. Louis" for Supercomputing 2021.

To explore the reasoning for individual satisfaction with the event and to learn about the subjects' perception of the online collaborative process, we devised an interview guide centered around these concerns, with questions such as the followings (see Appendix 3 for the full interview guide).

- What was your motivation to participate in the hackathon?
- Talk me through your first meeting. What did you talk about?
- What did you do to stay in touch with your team members?
- Were you satisfied with your project and the event?
- Would you participate in a similar event again?

We sent email invitations to participate in the interview study to all mentors and hackers after the event. We received responses from six mentors and six hackers and conducted and analyzed interviews with all 12 subjects. For the qualitative analysis, we focused on answering our initial questions – why participants might be satisfied with the event being online and how does the event being online affect the subjects' perception of the collaborative process. We used Otter.ai to transcribe the audio recordings of the interviews. Then, two of the authors independently listened to the recordings and read the transcripts, paying particular attention to aspects of how satisfied the subject was and what was the communication and collaboration process like, and along with another author, discussed the key findings. We describe the key findings in the next chapter.

Chapter 7

Interview findings

In general, we found that both mentors and hackers were satisfied with the event as well as their team collaboration during the hackathon. Only one mentor interviewed expressed a slight disappointment that their team could have put in more effort into the project. However, several subjects mentioned clear issues with communication or collaboration processes.

One common issue was that it took some time to form a stable team, as participants joined from all across the country, and many eventually worked with people whom they did not know before the hackathon. One subject (P2) described an especially precarious situation – "In the beginning, we thought we had three students, and then one student dropped out because he was traveling... So we ended up with two students. And in the meantime, one of those just became ill. And we found out that the other student had to take a day test..." Similarly, albeit less severe, cases were mentioned by several other subjects, where some team members either joined their project late in the event or dropped out after initial meetings.

In addition, several subjects mentioned that some or all members of their team had other priorities during the event. For example, one subject (P7) noted that "because a lot of people were doing stuff outside of the hackathon... there were five members on the team, [but] there were two or three who were consistently showing up to check-in and [the people there were] different every time", thus hindering the team communication somewhat.

On the other hand, advantages of the event being online that were pointed out include lower cost to participate, flexibility as to when to work on the project, and potentially easier communication with the technologies. One mentor (P8) indicated they would prefer to participate in future hackathons online to "allow for [their] students to participate... because if it is out of town, those things (transportation, hotel, etc.) could get costly." Considering that, as mentioned above, participants to the online hackathon might have other things to do at the same time, one subject (P12) pointed out that "[being] online gives [them] a lot more flexibility, [which] really worked in [their] favor this time, because [they] had classes and [other things] to attend to in the middle of [the hackathon]."

Access to technologies to facilitate virtual collaboration was a noticeable common theme among the interviews. In addition to Discord, which was established by the hackathon organizers and used as the primary form of communication throughout the event, several subjects also suggested they used Zoom meetings for easier discussion of project directions and progress. For example, one subject (P12) described the ease of the process – "I think it worked out pretty

well... We could just use Discord to know everyone's availability, and then just get on a [Zoom] call when that's possible." Nevertheless, one subject (P11) expressed some reservations about fully remote communication – "You can only go so far with all that, versus actually meeting someone in '3D'... Setting up a Google meet [is] not like a knock on your door kind of situation."

Finally, we found that participants can be satisfied with the event if their initial motivation to participate and expectations were met. For instance, one subject (P1) suggested that the subjective experience of fun and excitement is always an important element of hackathons and that "you never lose the fun of it and the excitement and the pressure" despite being the hackathon being online. Another subject (P12), who was a first-time hackathon participant, reflected on their experience with great satisfaction, "I always had this fear [that] if I'm going to use these different technologies trying to integrate everything, nothing is gonna work. But now that we did that... I'm more open now to trying out new technologies and integrating those with what I already know"; "We never imagined that there would be so much great teamwork with people you just met."

Chapter 8

Discussion

Our primary quantitative results provide evidence for a rather surprising answer to **RQ1**, which inquired about the differences in satisfaction between online and in-person hackathons. Our results showed no differences in satisfaction with the outcome; they, however, indicated higher satisfaction with the process for online hackathons when considering *perceived quality of participation* in online versus in-person contexts. This runs counter to decades of research that has identified many challenges for virtual teams and the only limited ability of technology to address those challenges [52].

There are at least three possible explanations. First, it may be the case that in the very brief format of the hackathon, face to face interaction among team members who are often completely unfamiliar with each other does not have time to develop into an advantage with the development of common ground [61, 62], trust [17, 63, 76], and other powerful factors that facilitate collaboration [77]. Virtual teams may have lower expectations and realize that they must function in the absence of these traditional facilitating factors, leading to a greater sense of satisfaction. The time-bounded nature of a hackathon might also have induced the necessity for frequent and direct communication, which has been found to mitigate the feeling of distance in prior work [72]. Our interview findings can corroborate this possibility as subjects indicated that a stable team formation could take a considerable period of time. While online team forming can be more difficult due to the lack of face-to-face interactions, it is conceivable that the team forming process can still take non-negligible time and effort in in-person hackathons, especially if the scope of the hackathon invites participants from different parts of the country.

Second, it is possible that for most hackathons that involved writing code, modern coding environments such as GITHUB have become very familiar to many participants, who are accustomed to collaborating in relative physical isolation. Indeed, our interview findings suggest that subjects enjoy the flexibility of working on their own time and that regular check-in meetings with other team members through virtual communication technologies are sufficient for project progression. Adding constant face-to-face interaction might be a bit disorienting and even disruptive from the participant's point of view. Production blocking in brainstorming [54] is a potentially relevant example of how in-person interaction can inhibit productivity because of process issues. We encourage future work that looks qualitatively at the interaction style of in-person and online events, as well as the use of collaboration technology to shed light on this issue.

Our interview findings provide a third potential explanation as to why participants do not see virtual collaboration in online hackathons as less satisfying than that in-person – recency bias. We note that the primary problem associated with the collaboration process in the online hackathon, as suggested by interview subjects, is the team forming process. While it can be frustrating when team formation takes an especially long time and much effort, it happens at the beginning of the event, and any frustration with the process can be masked by potentially smooth and successful collaboration later on in the event. As the surveys were all conducted after the event, participants might weigh the delightful collaboration later in the event more than the initial frustration when reflecting on their perception of the entire event. We thus suggest future research to address such recency bias by measuring participant perception multiple times during the event, including after the initial meetings.

Perceived quality of participation was a strong predictor of both process and outcome satisfaction (**RQ2**). This comes as no surprise as the quality of participation has long been shown to be associated positively with the performance of groups [2, 14, 46]. Interestingly, the online status of the hackathon appears to moderate the impact of quality of participation. The quality of participation has a stronger effect on *satisfaction with process* for in-person groups than for online groups. This could reflect the greater possibilities for improving the quality of participation for in-person groups, as compared to online groups, which may have a relatively limited range of possibilities. Future work should take a more detailed look at the factors that lead to the perceptions of quality of participation in both in-person and online settings.

Finally, there was a significant but weak association between networking motivation and satisfaction with both process and outcome (**RQ3**), thus confirming prior work in organizational [7, 31, 43] and volunteer contexts [5, 24] that found a connection between motivation and satisfaction. Our finding, however, provides more detail in that we found individuals who are motivated by the desire to connect to other people, for personal or professional reasons, to be more satisfied, since that is one result of a hackathon that is likely to be pretty consistently provided, regardless of how effective the hackathon was on other dimensions, such as technical accomplishments and satisfying processes. This finding also supports prior work in the context of volunteer groups that has established that some motivations have a positive effect on satisfaction while others do not [5].

8.1 Implications for practice

The primary implication for practice is to encourage online hackathons. Far from being a poor substitute for the in-person variety, on the global and subjective satisfaction measures, they seem to be just as effective. Virtual hackathons have many apparent advantages, including the potential for hackathons organized around common interests and the reduction in cost and environmental footprint for events to which people must travel. Moreover, they can at least partially be organized to be geographically independent since time-zone differences can still be expected to be difficult to navigate.

Our findings also point towards the more substantial influence of perceived participation quality on process satisfaction in an in-person compared to an online context. Organizers should thus find ways to foster the participation of all members within a team. This could be achieved

in multiple ways by, e.g., providing individual mentor support for each team, asking for specific deliverables that require all team members to participate equally, or ensuring that teams engage in collaborative ideation before directly starting to work on a project idea that not all team members might be on board with.

8.2 Implications for research

Many new research questions arise in the wake of these results. One set of questions concerns the actual outcomes as opposed to measures of satisfaction. Are the solutions as applicable, as likely to be built upon, as innovative, are the relationships among participants durable? These are important questions to probe the utility of online hackathons further.

Given the higher *satisfaction with process* in online hackathons, it seems essential to explore the role of typical online technologies and practices in in-person hackathons. For example, participants may be encouraged to rely more on messaging platforms such as Slack for regular communication and requests for assistance from mentors rather than potentially disruptive oral requests? Why don't the affordances of face-to-face, including overhearing when other team members are having problems, or creating shared artifacts such as diagrams, lead to greater process satisfaction? How do online teams overcome these limitations?

Finally, it would also be interesting to conduct a longitudinal study of individuals who participate in multiple different hackathons and compare their satisfaction with online versus in-person events. Several of our interview subjects were first-time participants in hackathons or similar events. It is possible that satisfaction for these first-time participants was associated more with their initial expectations of the event rather than other aspects such as the collaboration process.

8.3 Limitations

The study concerns a limited set of hackathons. The relationships that we observe in this sample may differ from those in the entire population of all hackathons. We expect that the varying sizes and durations concerning different domains, and addressing different themes, such as innovation, education of the sample, may alleviate this potential external generalizability issue. The responses we obtained may reflect a somewhat special sample of participants (those willing to fill a survey) and may differ from the opinions of other participants and may thus be systematically biased. The survey questions are also mostly subjective and may have been understood differently by respondents from what we have intended. The fact that we build it as an improvement to previous well-designed surveys reduces the likelihood of such problems. However, we selected a small set of motivations to participate in the analysis. Different events may have additional theme-related or format-specific motivations such as "winning", which may contribute to satisfaction.

One of the more severe confounders for our comparison of online and in-person hackathons is the 2020-2021 COVID pandemic that resulted in numerous online hackathons. For example, the isolation of COVID-related lockdowns may have enhanced the feelings of camaraderie that participants felt while collaborating online, leading to greater feelings of satisfaction with the

process. Although we heard no specific mention of COVID-related situations or concerns in the interviews, several subjects did express they were satisfied with the event "given the circumstances". It is unclear whether they were referring to specific problems they encountered with their team or the COVID situation in general. As we move past the pandemic and learn lessons from how it influenced collaboration and work style, we should study online events held for convenience or other purposes rather than a necessity to see if the same results hold.

There might be other factors that affect satisfaction that were not in the focus of our study. For example, advancing job prospects was similarly weighted by both factors in our analysis and was, therefore, included in neither.

We conducted a thorough analysis of the assumptions underlying regression analysis and tried to take into account all predictors to ensure conditional independence, equality of variances, and normal distribution of the residuals. Specifically, responses from each hackathon are correlated, and we, therefore, included hackathon indicators as predictors to ensure the conditional independence of the residuals. Despite that, other variables we did not measure may also explain the relationships we observe or change them if added to the model. The hackathon indicator is nested within online/in-person indicators making the model overdetermined. We excluded the last hackathon indicator from the model to ensure that predictors are not collinear.

Chapter 9

Conclusion

Our study was inspired by the proliferation of online hackathons in recent years and especially during the 2020-2021 COVID pandemic. We designed a mixed-method study following a sequential explanatory strategy, surveying participants from 15 hackathons then conducting 12 interviews. Overall, this work suggests that given the factors we considered, online hackathons can be as effective and as satisfying as their in-person counterparts. As identified in this work, the problems associated with online collaboration, as well as the importance of the perceived quality of participation, should serve as a guide for facilitating effective virtual collaboration in hackathons and similar online events.

Bibliography

[1] Hosam Al-Samarraie, Bee Kim Teng, Ahmed Ibrahim Alzahrani, and Nasser Alalwan. E-learning continuance satisfaction in higher education: a unified perspective from instructors and students. *Studies in higher education*, 43(11):2003–2019, 2018. 1

[2] Zaid Alfayad, Lily Suriani Mohd Arif, et al. Employee voice and job satisfaction: An application of herzberg two-factor theory. *International Review of Management and Marketing*, 7(1):150–156, 2017. 1, 8

[3] Pantelis Angelidis, Leslie Berman, Maria de la Luz Casas-Perez, Leo Anthony Celi, George E Dafoulas, Alon Dagan, Braiam Escobar, Diego M Lopez, Julieta Noguez, Juan Sebastian Osorio-Valencia, et al. The hackathon model to spur innovation around global mhealth. *Journal of medical engineering & technology*, 40(7-8):392–399, 2016. 1

[4] David J Armstrong and Paul Cole. Managing distances and differences in geographically distributed work groups. 1995. 2.1

[5] Hyejin Bang and Stephen D Ross. Volunteer motivation and satisfaction. *Journal of venue and Event Management*, 1(1):61–77, 2009. 1, 8

[6] Alberto Bertello, Marcel LAM Bogers, and Paola De Bernardi. Open innovation in the face of the covid-19 grand challenge: insights from the pan-european hackathon 'euvsvirus'. *R&D Management*, 2021. 2.1

[7] Anol Bhattacherjee. Understanding information systems continuance: An expectation-confirmation model. *MIS quarterly*, pages 351–370, 2001. 1, 8

[8] Pernille Bjørn, Morten Esbensen, Rasmus Eskild Jensen, and Stina Matthiesen. Does distance still matter? revisiting the cscw fundamentals on distributed collaboration. *ACM Transactions on Computer-Human Interaction (TOCHI)*, 21(5):1–26, 2014. 2.2

[9] Stu Blair, Carl Albing, Alexander Grund, and Andreas Jocksch. Accelerating an mpi lattice boltzmann code using openacc. In *Proceedings of the second workshop on accelerator programming using directives*, pages 1–9, 2015. 2.1

[10] Bernadette Brereton. Euvsvirus hackathon project: A case study from a mentor's perspective. *All Ireland Journal of Higher Education*, 12(2), 2020. 2.1

[11] Robert O Briggs and Gert-Jan de Vreede. Measuring satisfaction in gss meetings. In *International Conference on Information Systems: Proceedings of the eighteenth international conference on Information systems*, volume 14, pages 483–484, 1997. 2.1

[12] Gerard Briscoe. Digital innovation: The hackathon phenomenon. *Creativeworks London*,

6:1–13, 2014. 2.1

[13] Gerard Briscoe, Tarek E Virani, and Mariza Dima. Hackathons: Why co-location? *Creativeworks London Working Papers*, 2015. 2.1

[14] Traci Carte and Laku Chidambaram. A capabilities-based theory of technology deployment in diverse teams: Leapfrogging the pitfalls of diversity and leveraging its potential with collaborative technology. *Journal of the Association for Information Systems*, 5(11): 4, 2004. 2.2, 8

[15] Raymond B Cattell. The scree test for the number of factors. *Multivariate behavioral research*, 1(2):245–276, 1966. 4.3.2

[16] Chien-Wen Chen and Serhan Demirci. Factors affecting mobile shoppers' continuation intention of coffee shop online store: A perspective on consumer tolerance. *" International Journal of Electronic Commerce Studies"*, 10(2):203–238, 2019. 1

[17] Ok-Kyu Choi and Erin Cho. The mechanism of trust affecting collaboration in virtual teams and the moderating roles of the culture of autonomy and task complexity. *Computers in Human Behavior*, 91:305–315, 2019. 1, 8

[18] R Cameron Craddock, Daniel S Margulies, Pierre Bellec, B Nolan Nichols, Sarael Alcauter, Fernando A Barrios, Yves Burnod, Christopher J Cannistraci, Julien Cohen-Adad, Benjamin De Leener, et al. Brainhack: a collaborative workshop for the open neuroscience community. *GigaScience*, 5(1):16, 2016. 1

[19] John W Creswell and J David Creswell. *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications, 2017. 3

[20] Daniela E Damian and Didar Zowghi. The impact of stakeholders' geographical distribution on managing requirements in a multi-site organization. In *Proceedings IEEE Joint International Conference on Requirements Engineering*, pages 319–328. IEEE, 2002. 2.2

[21] CP Dancey and J Reidy. Statistical without math for psychology, 2011. 1

[22] Steven Dow, Elizabeth Gerber, and Audris Wong. A pilot study of using crowds in the classroom. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, pages 227–236, 2013. 2.1

[23] Line Dubé and Daniel Robey. Surviving the paradoxes of virtual teamwork. *Information systems journal*, 19(1):3–30, 2009. 1

[24] Patrick C Dwyer, Joyce E Bono, Mark Snyder, Oded Nov, and Yair Berson. Sources of volunteer motivation: Transformational leadership and personal motives influence volunteer outcomes. *Nonprofit management and Leadership*, 24(2):181–205, 2013. 1, 8

[25] Jeanette Falk Olesen and Kim Halskov. 10 years of research with and on hackathons. In *Proceedings of the 2020 ACM Designing Interactive Systems Conference*, pages 1073–1088, 2020. 1, 2.1

[26] Rosta Farzan, Saiph Savage, and Claudia Flores Saviaga. Bring on board new enthusiasts! a case study of impact of wikipedia art+ feminism edit-a-thon events on newcomers. In *International Conference on Social Informatics*, pages 24–40. Springer, 2016. 2.1

[27] Anna Filippova, Erik Trainer, and James D Herbsleb. From diversity by numbers to diversity as process: supporting inclusiveness in software development teams with brainstorming. In *Proceedings of the 39th International Conference on Software Engineering*, pages 152–163. IEEE Press, 2017. 1, 2.1, 4.2, 9

[28] Jerry Fjermestad. An analysis of communication mode in group support systems research. *Decision Support Systems*, 37(2):239–263, 2004. 2.2

[29] Allan Fowler. Informal stem learning in game jams, hackathons and game creation events. In *Proceedings of the International Conference on Game Jams, Hackathons, and Game Creation Events*, pages 38–41, 2016. 2.1

[30] Kiev Gama, Breno Alencar, Filipe Calegario, André Neves, and Pedro Alessio. A hackathon methodology for undergraduate course projects. In *2018 IEEE Frontiers in Education Conference (FIE)*, pages 1–9. IEEE, 2018. 1, 2.1

[31] Faheem Ghazanfar, Shuai Chuanmin, Muhammad Mahroof Khan, and Mohsin Bashir. A study of relationship between satisfaction with compensation and work motivation. *International Journal of Business and Social Science*, 2(1), 2011. 1, 8

[32] Marjolijn Haasnoot, Laurens Bouwer, and Jaap Kwadijk. A policy hackathon for analysing impacts and solutions up to 20 metres sea-level rise. In *EGU General Assembly Conference Abstracts*, page 17237, 2017. 2.1

[33] Caroline D Hardin. Gender differences in hackathons as a non-traditional educational experience. *ACM Transactions on Computing Education (TOCE)*, 21(2):1–30, 2021. 2.1

[34] Sarah Hartmann, Agnes Mainka, and Wolfgang G Stock. Innovation contests: How to engage citizens in solving urban problems? In *Enhancing Knowledge Discovery and Innovation in the Digital Era*, pages 254–273. IGI Global, 2018. 1

[35] Jasmine Hentschel, Samyukta Manjayya Sherugar, Rui Zhou, Vaishnav Kameswaran, Rajesh Chandwani, and Neha Kumar. Rice today, roti tomorrow: Diets and diabetes in urban indian households. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, pages 4069–4081, 2017. 2.1

[36] James D. Herbsleb and Audris Mockus. An empirical study of speed and communication in globally distributed software development. *IEEE Transactions on software engineering*, 29(6):481–494, 2003. 2.2

[37] James D Herbsleb and Deependra Moitra. Global software development. *IEEE software*, 18(2):16–20, 2001. 2.2

[38] Alexis Hope, Catherine D'Ignazio, Josephine Hoy, Rebecca Michelson, Jennifer Roberts, Kate Krontiris, and Ethan Zuckerman. Hackathons as participatory design: Iterating feminist utopias. In *Proceedings of the 2019 CHI Conference on Human Factors in Computing Systems*, page 61. ACM, 2019. 2.1

[39] Youyang Hou and Cliff Lampe. Sustainable hacking: characteristics of the design and adoption of civic hacking projects. In *Proceedings of the 8th International Conference on Communities and Technologies*, pages 125–134. ACM, 2017. 1

[40] Youyang Hou and Dakuo Wang. Hacking with npos: collaborative analytics and broker

roles in civic data hackathons. *Proceedings of the ACM on Human-Computer Interaction*, 1(CSCW):1–16, 2017. 2.1

[41] Daniela Huppenkothen, Anthony Arendt, David W Hogg, Karthik Ram, Jacob T VanderPlas, and Ariel Rokem. Hack weeks as a model for data science education and collaboration. *Proceedings of the National Academy of Sciences*, 115(36):8872–8877, 2018. 1, 2.1

[42] Timothy A Judge, Carl J Thoresen, Joyce E Bono, and Gregory K Patton. The job satisfaction–job performance relationship: A qualitative and quantitative review. *Psychological bulletin*, 127(3):376, 2001. 2.1

[43] Tan Shen Kian, Wan Fauziah Wan Yusoff, and Sivan Rajah. Job satisfaction and motivation: What are the difference among these two. *European Journal of Business and Social Sciences*, 3(2):94–102, 2014. 1, 8

[44] Benjamin Koehne, Patrick C Shih, and Judith S Olson. Remote and alone: coping with being the remote member on the team. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work*, pages 1257–1266, 2012. 2.2

[45] Marko Komssi, Danielle Pichlis, Mikko Raatikainen, Klas Kindström, and Janne Järvinen. What are hackathons for? *IEEE Software*, 32(5):60–67, 2015. 1

[46] Jan GM Kooloos, Tim Klaassen, Mayke Vereijken, Sascha Van Kuppeveld, Sanneke Bolhuis, and Marc Vorstenbosch. Collaborative group work: Effects of group size and assignment structure on learning gain, student satisfaction and perceived participation. *Medical Teacher*, 33(12):983–988, 2011. 1, 8

[47] Robert E Kraut, Susan R Fussell, Susan E Brennan, and Jane Siegel. Understanding effects of proximity on collaboration: Implications for technologies to support remote collaborative work. *Distributed work*, pages 137–162, 2002. 1

[48] Rensis Likert. A technique for the measurement of attitudes. *Archives of psychology*, 1932. 4.2

[49] Thomas James Lodato and Carl DiSalvo. Issue-oriented hackathons as material participation. *New Media & Society*, 18(4):539–557, 2016. 1

[50] Jennifer Marlow and Laura Dabbish. Designing interventions to reduce psychological distance in globally distributed teams. In *Proceedings of the ACM 2012 conference on Computer Supported Cooperative Work Companion*, pages 163–166, 2012. 2.2

[51] Maria Angelica Medina Angarita and Alexander Nolte. Does it matter why we hack?–exploring the impact of goal alignment in hackathons. In *Proceedings of 17th European Conference on Computer-Supported Cooperative Work*. European Society for Socially Embedded Technologies (EUSSET), 2019. 1

[52] Sarah Morrison-Smith and Jaime Ruiz. Challenges and barriers in virtual teams: a literature review. *SN Applied Sciences*, 2:1–33, 2020. 2.2, 8

[53] Arnab Nandi and Meris Mandernach. Hackathons as an informal learning platform. In *Proceedings of the 47th ACM Technical Symposium on Computing Science Education*, pages 346–351. ACM, 2016. 2.1

[54] Bernard A Nijstad, Wolfgang Stroebe, and Hein FM Lodewijkx. Production blocking and idea generation: Does blocking interfere with cognitive processes? *Journal of experimental social psychology*, 39(6):531–548, 2003. 8

[55] John Noll, Sarah Beecham, and Ita Richardson. Global software development and collaboration: barriers and solutions. *ACM inroads*, 1(3):66–78, 2011. 2.2

[56] Alexander Nolte, Ei Pa Pa Pe-Than, Anna Filippova, Christian Bird, Steve Scallen, and James D Herbsleb. You hacked and now what? -exploring outcomes of a corporate hackathon. *Proceedings of the ACM on Human-Computer Interaction*, 2(CSCW):1–23, 2018. 1, 4.2

[57] Alexander Nolte, Linda Bailey Hayden, and James D Herbsleb. How to support newcomers in scientific hackathons-an action research study on expert mentoring. *Proceedings of the ACM on Human-Computer Interaction*, 4(CSCW1):1–23, 2020. 1, 2.1

[58] Alexander Nolte, Ei Pa Pa Pe-Than, Abasi-amefon Obot Affia, Chalalai Chaihirunkarn, Anna Filippova, Arun Kalyanasundaram, Maria Angelica Medina Angarita, Erik Trainer, and James D Herbsleb. How to organize a hackathon–a planning kit. *arXiv preprint arXiv:2008.08025*, 2020. 1, 4.2

[59] Richard L Oliver. A cognitive model of the antecedents and consequences of satisfaction decisions. *Journal of marketing research*, 17(4):460–469, 1980. 1

[60] Gary Olson and Judith Olson. Mitigating the effects of distance on collaborative intellectual work. *Economics of Innovation and New Technology*, 12(1):27–42, 2003. 1

[61] Gary M Olson and Judith S Olson. Distance matters. *Human–computer interaction*, 15 (2-3):139–178, 2000. 1, 2.2, 8

[62] Judith S Olson and Gary M Olson. Bridging distance: Empirical studies of distributed teams. *Human-computer interaction in management information systems*, 2:27–30, 2006. 2.2, 8

[63] Wanda J Orlikowski. Knowing in practice: Enacting a collective capability in distributed organizing. *Organization science*, 13(3):249–273, 2002. 1, 8

[64] Souren Paul, Priya Seetharaman, Imad Samarah, and Peter P Mykytyn. Impact of heterogeneity and collaborative conflict management style on the performance of synchronous global virtual teams. *Information & Management*, 41(3):303–321, 2004. 4.2

[65] Ei Pa Pa Pe-Than and James D Herbsleb. Understanding hackathons for science: Collaboration, affordances, and outcomes. In *International Conference on Information*, pages 27–37. Springer, 2019. 1, 2.1

[66] Ei Pa Pa Pe-Than, Alexander Nolte, Anna Filippova, Christian Bird, Steve Scallen, and James D Herbsleb. Designing corporate hackathons with a purpose: The future of software development. *IEEE Software*, 36(1):15–22, 2019. 1, 2.2, 4.1

[67] Ei Pa Pa Pe-Than, Alexander Nolte, Anna Filippova, Chris Bird, Steve Scallen, and James D. Herbsleb. Corporate hackathons, how and why? a multiple case study of motivation, projects proposal and selection, goal setting, coordination, and outcomes. *Human-Computer Interaction*, 2020. 1, 2.1

[68] Hanna-Liisa Pender and David Lamas. How to tame a transdisciplinary interaction design process. In *Proceedings of the 10th Nordic Conference on Human-Computer Interaction*, pages 742–746, 2018. 2.1

[69] Birgit Penzenstadler, Stefanie Betz, Colin C Venters, Ruzanna Chitchyan, Jari Porras, Norbert Seyff, Leticia Duboc, and Christoph Becker. Everything is interrelated: teaching software engineering for sustainability. In *2018 IEEE/ACM 40th International Conference on Software Engineering: Software Engineering Education and Training (ICSE-SEET)*, pages 153–162. IEEE, 2018. 2.1

[70] Jari Porras, Antti Knutas, Jouni Ikonen, Ari Happonen, Jayden Khakurel, and Antti Herala. Code camps and hackathons in education-literature review and lessons learned. In *Proceedings of the 52nd Hawaii International Conference on System Sciences*, 2019. 1, 2.1

[71] Narayan Ramasubbu, Marcelo Cataldo, Rajesh Krishna Balan, and James D Herbsleb. Configuring global software teams: a multi-company analysis of project productivity, quality, and profits. In *2011 33rd International Conference on Software Engineering (ICSE)*, pages 261–270. IEEE, 2011. 2.2

[72] E Raymond. Homesteading the noosphere, the cathedral, and the bazaar: Musings on linux and open source by an accidental revolutionary. *Sebastopol Calf.: O'Reilly & Associates*, 1999. 2.2, 8

[73] Bruce A Reinig. Toward an understanding of satisfaction with the process and outcomes of teamwork. *Journal of Management Information Systems*, 19(4):65–83, 2003. 2.1, 4.2

[74] Bard Rosell, Shiven Kumar, and John Shepherd. Unleashing innovation through internal hackathons. In *Innovations in Technology Conference (InnoTek), 2014 IEEE*, pages 1–8. IEEE, 2014. 1

[75] Raghvinder S Sangwan, Kathryn W Jablokow, and Joanna F DeFranco. Asynchronous collaboration: Bridging the cognitive distance in global software development projects. *IEEE Transactions on Professional Communication*, 63(4):361–371, 2020. 1

[76] Saonee Sarker, Manju Ahuja, Suprateek Sarker, and Sarah Kirkeby. The role of communication and trust in global virtual teams: A social network perspective. *Journal of Management Information Systems*, 28(1):273–310, 2011. 2.2, 8

[77] Patricia M Sias and Daniel J Cahill. From coworkers to friends: The development of peer friendships in the workplace. *Western Journal of Communication (includes Communication Reports)*, 62(3):273–299, 1998. 1, 8

[78] Arlin Stoltzfus, Michael Rosenberg, Hilmar Lapp, Aidan Budd, Karen Cranston, Enrico Pontelli, Shann Oliver, and Rutger A Vos. Community and code: Nine lessons from nine nescent hackathons. *F1000Research*, 6, 2017. 2.1

[79] Anselm Strauss. The articulation of project work: An organizational process. *Sociological Quarterly*, 29(2):163–178, 1988. 2.2

[80] John C Tang, Chen Zhao, Xiang Cao, and Kori Inkpen. Your time zone or mine? a study of globally time zone-shifted collaboration. In *Proceedings of the ACM 2011 conference on Computer supported cooperative work*, pages 235–244, 2011. 2.2

[81] Mohsen Tavakol and Reg Dennick. Making sense of cronbach's alpha. *International journal of medical education*, 2:53, 2011. 4.3

[82] Nick Taylor and Loraine Clarke. Everybody's hacking: Participation and the mainstreaming of hackathons. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, page 172. ACM, 2018. 1

[83] Nick Taylor, Loraine Clarke, Martin Skelly, and Sara Nevay. Strategies for engaging communities in creating physical civic technologies. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems*, page 507. ACM, 2018. 2.1

[84] Stephanie Teasley, Lisa Covi, Mayuram S Krishnan, and Judith S Olson. How does radical collocation help a team succeed? In *Proceedings of the 2000 ACM conference on Computer supported cooperative work*, pages 339–346, 2000. 1, 2.2

[85] Erik H Trainer, Chalalai Chaihirunkarn, Arun Kalyanasundaram, and James D Herbsleb. Community code engagements: summer of code & hackathons for community building in scientific software. In *Proceedings of the 18th International Conference on Supporting Group Work*, pages 111–121, 2014. 1

[86] Erik H Trainer, Arun Kalyanasundaram, Chalalai Chaihirunkarn, and James D Herbsleb. How to hackathon: Socio-technical tradeoffs in brief, intensive collocation. In *Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing*, pages 1118–1130. ACM, 2016. 1, 2.1

[87] Linn Van Dyne and Jeffrey A LePine. Helping and voice extra-role behaviors: Evidence of construct and predictive validity. *Academy of Management journal*, 41(1):108–119, 1998. 1, 2.2

Appendix

Perceived satisfaction with process (based on [27])
Would you describe your team process as more... (1) Inefficient to (5) Efficient (1) Uncoordinated to (5) Coordinated (1) Unfair to (5) Fair (1) Confusing to (5) Easy to understand
Perceived satisfaction with outcome (based on [27]), anchored between strongly disagree and strongly agree
I am satisfied with the work completed in this team. I am satisfied with the quality of my team's output. My ideal outcome coming into my team was achieved. My expectations towards my team were met.
Perceived quality of participation (based on [27]), anchored between strongly disagree and strongly agree
Everyone had a chance to express his/her opinion. The team members responded to the comments made by others. The team members participated very actively during our collaboration. Overall, the participation of each member in the team was effective.
Motivations to participate, anchored between not at all and completely
Learning new tools or skills Meeting new people Seeing what others are working on Sharing your experience and expertise Advancing your career
Demographics
How old are you currently? (18 to 24, 25 to 34, 35 to 44, 45 to 54, 55 to 64, 65 to 74, 75 or older, Prefer not to say) Are you...? (Female, Male, Non-binary, Prefer not to say) Do you consider yourself a minority? (For example in terms of race, gender, expertise or in another way) (Yes, No, Prefer not to say)

Table 1: Scales utilized for the surveys

PQP = *Perceived quality of participation*
Sat PR = *Satisfaction with process*
Sat OC = *Satisfaction with outcome*
Mot Lrn = *Motivation: Learning*
Mot Nwk = *Motivation: Networking*
O/IP = *Online/In-person indicator*

	PQP	Sat PR	Sat OC	Mot Lrn	Mot Nwk
PQP	-				
Sat PR	0.56****	-			
Sat OC	0.51****	0.54****	-		
Mot Lrn	0.14**	0.15***	0.12**	-	
Mot Nwk	0.16***	0.20****	0.17***	0.30****	-
O/IP	-0.08	-0.03	-0.17****	-0.03	-0.02

Note: $^{*}p$ <0.05; $^{**}p$ <0.01; $^{***}p$ <0.001; $^{****}p$ <0.0001

Table 2: Correlation of analysis variables

Before the hackathon: What was your motivation to participate in the HPC in the City: St. Louis hackathon?
What did you think about the event being online? Probe: Potential problems to attend an online event, preference for online vs. in-person. (mentor) What was the goal of the project you suggested? How did you come up with the idea?
At the beginning of the hackathon: How did you find your team? How well did you know your team members?
(hacker) Please describe your project (incl. name). (hacker) Why did you choose to work on this particular project? What did you like about it? Probe: Technologies used, project theme, mentor, other team members, or other reasons. **Talk me through your first meeting.** What did you talk about? Probe: Did you distribute tasks? Did you set up your development environment? Did you share contact information? Did you set up milestones/internal meetings/checkpoints?
During the hackathon: Let's talk about how the hackathon went. What did you do after the first meeting?
(hacker) How did you know what to do? How did you know what the others were doing? Probe: What was your responsibility? What were the responsibilities of the other team members? Were the responsibilities clear to everyone? (hacker) Was everyone on the same page? If not, why not? Which issues did you face? (mentor) What kind of assistance did the students need? (mentor) What was the most difficult thing about mentoring this particular team? What did you do to stay in touch with your team members? Probe: Technologies, regular vs. on-demand meetings, among the entire team vs. sub-team What was particularly good/bad? What would you do differently next time?
In hindsight: Tell us something that worked out really well and something that you would do differently.
Were you satisfied with your project and the event? Would you participate in a similar event again? What advice would you like to give others that want to participate in a similar event?
Prior experience:
How many in-person hackathons did you participate in before the HPC in the City: St. Louis hackathon? How does the experience during the HPC in the City: St. Louis hackathon compare to those experiences? What were the advantages of the online setting? What were the issues? What did you like? What do you wish would be different? Please think about an online event where you worked together with a group of people that was particularly positive for you. Please describe that event for me. How does your experience during the HPC in the City: St. Louis hackathon compare to that event? What did you like? What do you wish would be different?

Table 3: Interview guide