Understanding the Working Time of Developers in IT Companies in China and the United States

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// We identified three temporal patterns shown in commit activities among Chinese and American companies and found that Chinese businesses are more likely to follow long work hours than American ones. We also conducted a survey on the trends of, reasons for, and results of overtime work. Our study could provide references for developers to choose workplaces and for companies to make regulations. //

WORKING OVERTIME IS a common social problem in modern life. According to the American General Social Survey in 2018, more than 27% of employees experienced mandatory overtime work in the United States.[1] In March 2019, a project called *996ICU* was launched on GitHub[2] to debunk the infamous work schedule in some Chinese IT companies, called *996*. Employees who follow the 996 work schedule labor from 9:00 a.m. to 9:00 p.m. for six days per week. The exposure of the abnormal working hours on social media quickly caught the attention of the public and was reported by leading news media around the world.[3–5]

The heated discussions represent a pressing demand to better understand the work rhythm, which is tightly coupled with people's living conditions. Extended work hours are correlated with adverse health.[6] The expanded schedule could cause sleep disturbances,[7] predispose citizens to major depressive episodes,[8] and lead to increased mortality.[9] In the domain of software engineering, it is quite common for developers to switch among multiple activities[10] and software projects[11] over the course of a week.

It is important to analyze the different working time across companies. For developers, understanding the general schedule of a company could help them learn about its culture. For managers and executives in industry, knowing the general working time of their employees could help them set expectations and labor conditions to achieve greater work efficiency. However, previous studies[12,13] related to schedules in the software engineering domain were mainly project or individual based, so were limited for interpreting working time at the organizational level. Furthermore, working time is likely to be

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influenced by local cultures. There is a lack of investigations into the working hours of IT companies across different countries.

This article aims to fill in this gap by studying and comparing the working time of software developers in IT companies from two representative countries, i.e., China and the United States. Our goal is to explore both the similarities and differences between working time in modern IT companies through valid data interpretation to reflect on general IT work conditions and their extended impact, such as on labor productivity and societal pressure.

We crawled and used a real-world data set of code submissions from GitHub, a leading online developer community. We applied a machine learning model to cluster the temporal pattern of code submissions and conducted a comprehensive analysis to investigate the data. Furthermore, we carried out a qualitative survey-based study to better understand developers' working time. The major contributions of this article are as follows.

- We designed a data-driven approach with machine learning techniques and identified three temporal patterns shown in the commit activities among 86 IT companies on GitHub. We found that Chinese companies are more likely to follow long working hours than their American counterparts.
- We present an empirical analysis on the extent of overtime work in these companies. We found that in China, developers in large companies are more likely to work overtime than those in small companies. Also, if developers in Chinese businesses have to work during the Lunar New Year holiday, they are more likely to work during regular off hours than on other dates.
- We conducted a survey of 92 developers to understand the situation of, reasons for, and results of working overtime. We found that working overtime is prevalent among developers. People tend to work extra hours when there are deadlines or emergencies. Developers who work less frequently on weekends are more likely to believe additional working hours could increase their productivity.

Background and Related Work

Background

During the software development process, developers use Git, a widely used open source distributed version control system, to keep track of their progress. New code is submitted via Git by using "commit," which records the code submission information, including author, local time, and the code to be added or removed. The frequency of commits during a period of time reflects, to some extent, whether developers are actively working on software projects during that time. The temporal distribution of the commit activities could reflect the circadian and weekly work pattern.[12]

Online social networks record rich information about user activities that can be used to understand human behaviors.[14,15] Online developer communities are a special kind of social network that enable developers and organizations to conduct collaborative development and share code. The commit logs can be retrieved from the online developer communities if the projects are uploaded and made public by companies. GitHub is a leading online developer community that has a population of 31 million developers and hosts more than 96 million repositories.

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Figure 1 shows the temporal distributions of commit activities in three companies collected from GitHub in the form of a heat map. Company A is a leading Internet company in China with a history of more than 20 years. Company B is a start-up in China that was founded in 2014, maintaining a platform for discovering and sharing technologies. Company C is an American company that offers business and employment-oriented services and operates via websites and mobile apps. They represent three distinct patterns: 1) developers in company A who work overtime during weekdays, 2) those in company B who work overtime on both weekdays and weekends, and 3) those in company C who follow typical working hours.

Related Work

Researchers explored the factors that may influence employees' working time. Beckers et al.[16] proposed that the likelihood of working overtime is influenced by gender, age, job requirements, and salary. In addition, situations of working overtime in some domains were studied. It was reported that American scientists were likely to work at night, while most Chinese scientists worked on weekends.[17]

In the sector of software development, Claes et al.[12] investigated the time stamps of commit activities of software projects from Mozilla, Apache, and a local Finnish IT company to study developers' working hours. They found that two-thirds of the developers typically worked from 10:00 a.m. to 6:00 p.m. and did not work at night or on weekends very often. Eyolfson et al.[13] reported that commits made between 12:00 a.m. and 4:00 a.m. were most likely to have bugs.

Although some tangential evidence has been found regarding the working hours of individuals and certain projects in the software engineering domain, investigations into interpreting working time at the organizational level and comparing the working time of IT companies in different countries are lacking. In this article, we conduct a study to understand and compare the working time of software developers in IT companies from two representative countries, i.e., China and the United States.

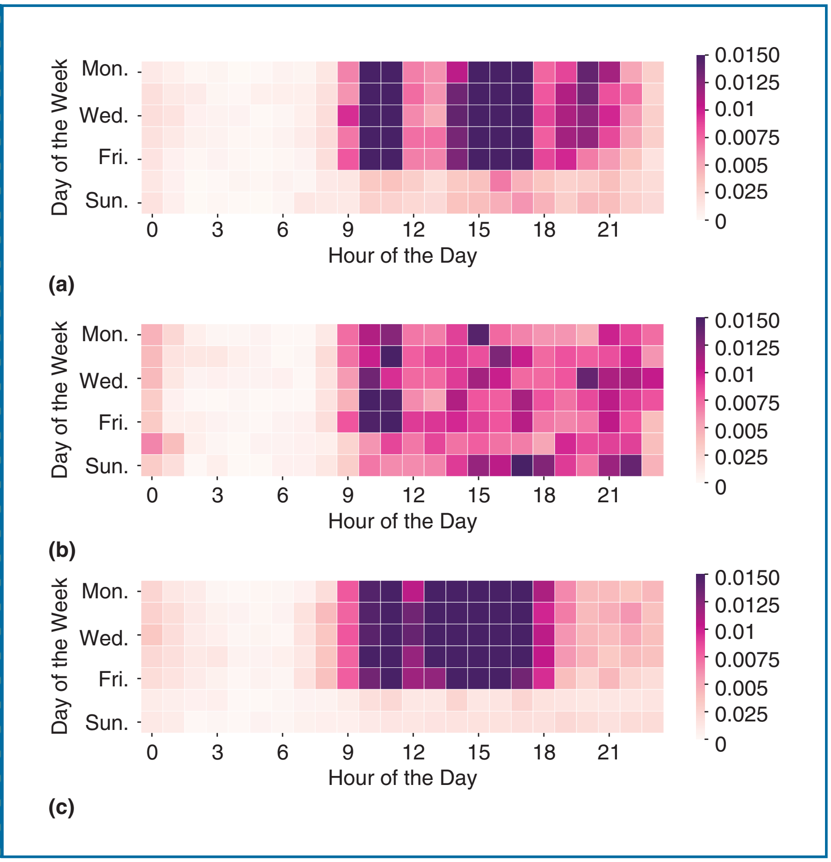

FIGURE 1. The temporal distributions of commit activities in three companies: (a) Company A, (b) Company B, and (c) Company C. The *x*-axis represents 24 h of the day and the *y*-axis represents seven days of the week. The color bars on the right show the mappings of commit frequency to the darkness of the color: the darker the color of a time slot, the higher the commit frequency during the period.

Research Questions

We aimed to study the working time of IT companies in China and the United States. Our study is guided by three motives, which yield five subsequent research questions. First, we defined a company's work rhythm as the pattern of its time allocation for code submissions during weekdays and weekends. We identified representative work rhythms among IT companies and examined general discrepancies between companies of the two countries in terms of work rhythms.

- *Research question 1*: What are the representative work rhythms among IT companies in China and the United States?
- *Research question 2*: How do the work rhythms of IT companies vary across countries?

Second, we sought a deeper understanding of overtime work in various groups of companies and during different time periods. We explored whether there is a relationship between the intensity of overtime work and company size. We set 10,000 employees as the boundary between large and small companies according to *Fortune*[18] and divided companies into two groups. We tested whether there is a difference in the ratios of overtime commits between large and small companies. In addition, we investigated whether developers are more likely to make commits in regular off hours around holidays than other dates. We targeted the Lunar New Year holiday for Chinese companies and the Christmas holiday (the week starting from Christmas day) for American companies.

- *Research question 3*: Is there a relationship between overtime work and company size?
- *Research question 4*: Is overtime work influenced by holidays?

Third, to compensate for the results of empirical analysis on the crawled data, we carried out a qualitative survey-based study. We asked developers about the situations of overtime work in their companies and the reasons for working overtime. In addition, to understand the results of overtime work, we asked developers about the frequency of working on weekends and their perspectives on productivity during extra working hours.

- *Research question 5*: What are the trends of, reasons for, and results of working overtime?

Empirical Analysis of the Work Rhythms of IT Companies

Data Collection

We used the GitHub application programming interface to obtain the commit logs from GitHub. We only collected publicly accessible information. We consulted GitHub about our study and received their approval for the data collection and analysis in our research. The data set was collected between 1 and 27 May 2019, covering the accounts of 101 IT companies and their source repositories on GitHub. They are a combination of large technology companies and start-ups in the United States and China. We filtered out those commit logs without time zone information and only selected companies with at least 30 contributors and 300 commits. Finally, we formed our data set with a total of 86 companies, among which there are 12,041,474 commits and 9,050 developers from 39 companies in China, as well as 232,497,720 commits and 53,594 developers from 47 companies in the United States. We released the full list of companies and the repositories in our data set.[19]

Notice that our data set only includes public open source projects on GitHub, which may only reveal the publicly visible work activities. Besides, we can only analyze the commit activities with the data set, which might not reveal the exact working hours since there are other work-related activities such as meetings and project planning. Still, the time distribution of commits could be an important indicator for the working hours.

Representative Work Rhythms of IT Companies

Research Question 1: What Are the Representative Work Rhythms of IT Companies in China and the United States?

To identify the work rhythms of companies, we calculated the commit frequencies in different time periods and used clustering algorithms to analyze the data. For each company, we computed the ratio of the commits in each hour of the day on weekdays to all commits on weekdays. We performed the same calculation for weekends. Following the calculations, we obtained the 24-dimensional vectors for weekdays and weekends, respectively, with each element representing the average commit frequency in one of the 24 h. We concatenated the two vectors as a 48-dimensional vector and then applied *k*-means, a classical clustering algorithm, to discover the representative work rhythms.

To select the number of clusters *k*, we iterated *k* from 2 to 8 using the *k*-means clustering algorithm. A higher silhouette coefficient score indicates better defined clusters. When $k=3$, the silhouette coefficient score is the highest. We also observed the sizes of the clusters and visualized patterns of each *k*. We found that when there are more than three clusters, the new ones have very few individuals and do not show distinct patterns. We chose $k=3$ based on the results.

Figure 2(a) and (b) shows the average commit frequency of the detected patterns during each hour of the day on weekdays and weekends. The characteristics of each pattern are summarized as follows.

- *Pattern 1*: These companies endure longer working hours on weekdays than others.
- *Pattern 2*: While the developers in these companies work from 9:00 a.m. to 6:00 p.m. on weekdays, following regular working hours, they make more code submissions on weekends than those in other businesses.
- *Pattern 3*: These companies follow typical working hours on weekdays, from 9:00 a.m. to 6:00 p.m., and developers rarely submit code changes on weekends.

Research Question 2: How Do the Work Rhythms of IT Companies Vary Across Countries?

The number of companies from China and the United States with each pattern is shown in Figure 2(c). Patterns 1 and 2 are more prevalent among Chinese companies, while American businesses mainly follow pattern 3. To statistically validate the observation, we applied the Fisher's exact test. For each pattern p_i, we assumed the null hypothesis H_0 is that Chinese and American companies are equally likely to follow p_i. Since we tested the three hypotheses simultaneously, we applied the Bonferroni correction to limit the family-wise error rate. The significance level was 0.0167, which is equal to 0.05 divided by the number of hypotheses. If the p value is under 0.0167, we could conclude that Chinese and American companies are significantly different in terms of pattern p_i. We also reported the odds ratio (OR). The distance from 1 of an OR indicates the magnitude of the effect size. An OR greater than 1 indicates that Chinese companies are more likely to follow p_i than American businesses while an OR lower than 1 indicates that American companies are more likely to follow p_i than Chinese businesses. The results indicate that businesses in the two countries are significantly different in these three patterns: pattern 1: p value = 2.706×10^{-8}, OR = 23.47; pattern 2: p value = 0.0166, OR = 5.06; pattern 3: p value 1.359×10^{-12}, OR = 0.02.

Insights Into Working Overtime in IT companies

To investigate the situations of overtime work, first we need to determine the companies' regular working hours. We follow Claes et al.'s method.[12] Companies are assumed to follow an 8-h work schedule on weekdays. For each company, we determined which 8-h slot had the greatest number of commits in a day. Given the time stamps of commit activities of a company, for each starting time t, we computed the number of commits made between t and $t + 8$ h. We selected the interval with the highest number of cumulative commits as the working hours of the considered company. Since companies may change their working hours over time, we restricted the time of commits from 2018 to 2019, to reflect the recent labor status of developers in these companies. Still, we removed businesses with fewer than 30 contributors or 300 commits. Finally, we obtained a data set with 25 companies in China and 39 companies in the United States.

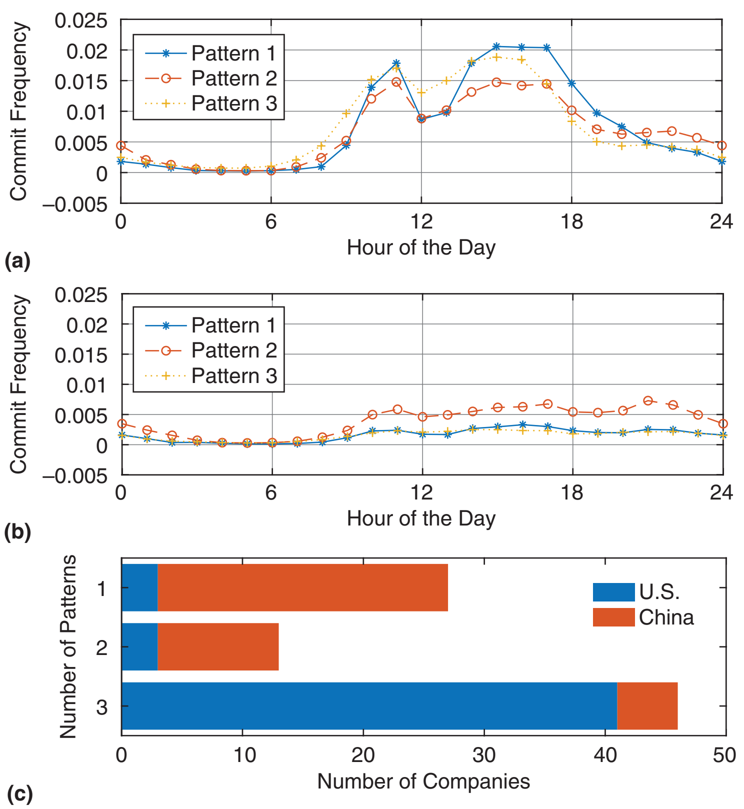

FIGURE 2. The clustering results on (a) weekdays and (b) weekends show the average commit frequency of each detected pattern during each hour of the day on weekdays and weekends. (c) The number of companies in each pattern is described.

Research Question 3: Is There a Relationship Between Overtime Work and Company Size?

We set 10,000 employees as the boundary between large and small companies. For each company, we calculated the ratio of commits outside working hours to commits in total. Figure 3(a) shows the aggregated results in violin plots. To statistically validate whether large businesses have significantly different amounts of overtime commits than small ones, we performed the Mann–Whitney U test. Results are measured by p values. The significance level is 0.05. We reported Cliff's delta (d) for effect size. d ranges from −1 to 1. If d is greater (less) than 0, it quantifies how often the numbers of overtime commits in large companies are higher (lower) than those in small ones. In China, large companies have more overtime commits than small companies do (p value = 0.028, d = 0.53). In the United States, we did not detect a significant difference in the number of overtime commits between large and small companies (p value > 0.05).

Since there are more employees in large companies, they may set more comprehensive regulations and standardized workflows than small companies, to better manage their employees. The regulations for holiday arrangements and benefits for the overtime work may increase employees' willingness to work overtime. However, due to the standardized workflows, the peripheral work of programming, such as waiting for approval or communicating with colleagues in different departments, may take up a lot of time during working hours, so developers might have to work on their projects after working hours.

Research Question 4: Is Overtime Influenced by Holidays?

We compared the commits in regular off hours in four time periods: one week before the holiday, during the holiday, one week after the holiday, and other dates. For each type of time period, we only considered companies that have at least one commit during that period. The results of Chinese and American companies are shown in Figure 3(b) and (c). We performed the Mann–Whitney U test to validate whether there was a significant difference in the commits in regular off hours before, during, and after the holiday and other dates in each country. We applied the Bonferroni correction and set the significance level as 0.0167. We also reported Cliff's delta (d), which measures how often the number of commits in regular off hours during a specific period of time are higher or lower than those of other dates. In Chinese companies, if developers have to work during the Lunar New Year holiday, they are more likely to toil during regular off hours than on other days (p value $= 0.0044$, $d = 0.53$). We did not detect a significant difference in the commits in regular off hours between the week before or after the holiday and other dates (p value > 0.0167). In American companies, we did not detect a significant difference in the four types of time periods (p values > 0.0167).

One possible reason is that during the daytime on the Lunar New Year holiday, people are likely to take part in various activities outside the home, such as visiting friends, so they might have to work after they come back.

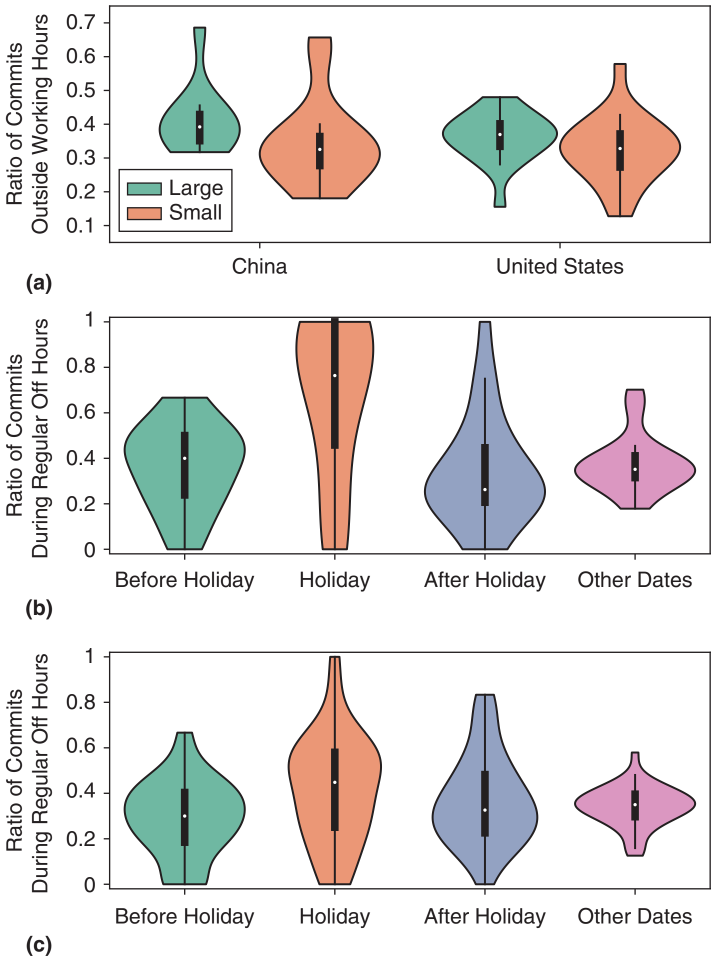

FIGURE 3. The degree to which work is performed outside the commonly expected working hours. The rotated kernel density plot on each side shows the data distributions. The black bars in the middle represent the quartile range, the extended line represents the 95% confidence interval, and the white point represents the median. (a) The ratio of commits outside working hours to total commits is given in large and small companies in China and the United States. The ratio of commits during regular off hours to total commits made (b) before, during, and after the Lunar New Year holiday and other dates in Chinese companies and (c) before, during, and after Christmas and other dates in American companies.

Survey Study on Overtime Work

We designed a survey study to tackle research question 5: "What are the trends of, reasons for, and results of working overtime?" We asked developers about how they and their colleagues are experiencing overtime work, what makes them work overtime, and how they think of the productivity during extra working hours. Our survey was reviewed and approved by the Research Department of Fudan University, Shanghai, China. Before releasing the survey, we first conducted a pilot test with seven developers from different companies to fill out the questionnaire, then interviewed them for comments on the survey. We modified the survey according to their feedback and then published it online. We first sent questionnaires to 10 developers from selected IT companies (including large technology companies and startups in China and the United States in our data set) and then asked them to pass along the survey link to other developers. Our online version had 1,516 views and we received 92 responses. Except for two participants who wanted to keep their company information confidential, 52 were from Chinese companies and 38 were from American companies.

Self-Reported Experience of Working Overtime

To understand developers' experiences of working overtime, we included five statements and asked participants how the statements fit with their situations in the form of five-point Likert scale questions. For each statement, participants could choose one of the following five options: strongly disagree, disagree, neutral, agree, and strongly agree. We plotted a bar chart for the Likert scales, as shown in Figure 4(a). We find that working overtime is prevalent among developers and that most do not enjoy it.

Reasons for Working Overtime

To understand the reasons for working overtime, we set a multiple-choice question and listed nine common reasons as options according to the pilot test. Participants could choose one or more options and their responses are shown in Figure 4(b). The most common reason for working overtime is approaching deadlines. The least three voted reasons indicate that providing incentives are not that effective to encourage developers to work overtime.

Extent of Overtime Work on Weekends and Its Relationship With Productivity

We set a multiple-choice question about the frequency of working overtime on weekends. We asked participants to choose one of the following options: never work on weekends, sometimes work on weekends, work on either Saturday or Sunday every weekend, work on both Saturday or Sunday every weekend, or other work schedules. We set another multiple-choice question about whether extra working hours increase productivity. Participants could choose one option among the following: extra working hours increase productivity, extra working hours do not increase productivity, stay neutral, or have no experience of working overtime.

We cross-checked the responses to the two questions and plotted a Sankey diagram, i.e., Figure 4(c), to display the responses. All four people (100%) who work on both Saturday and Sunday every week replied that extra working hours does not increase productivity. Among the 15 people who work on either Saturday or Sunday during the weekend, seven (46.67%) responded that extra working hours increases productivity, while six (40%) held the opposite view and two (13.33%) were neutral. Among the 13 people who sometimes work on weekends, eight (61.54%) believed that extra working hours increases productivity, while four (30.77%) held the opposite view and one (7.69%) was neutral. Among the 26 people who never work on weekends (but work overtime on weekdays), 18 (69.23%) believed extra working hours increases productivity, while eight (30.77%) did not.

Weekend recovery is helpful for improving work performance on weekdays.[20] Too much work on weekends may cause fatigue and decrease productivity.

In this article, we cross-checked the working time of developers at IT companies in China and the United States. We identified three representative work patterns in our data set and found significant differences between companies in the two countries. The findings indicate that Chinese companies are more likely to follow longer working hours, which clearly acknowledge the 996 phenomenon in the Chinese IT industry. Our results show that developers in large companies in China are more likely to work overtime than those in small companies. Also, if developers in Chinese companies have to work during the Lunar New Year holiday, they are more likely to toil during regular off hours than on other dates. According to the results of our survey, working overtime is prevalent among developers and the most common reason for it is approaching deadlines. Developers who work less frequently on weekends are more likely to believe extra working hours could increase their productivity.

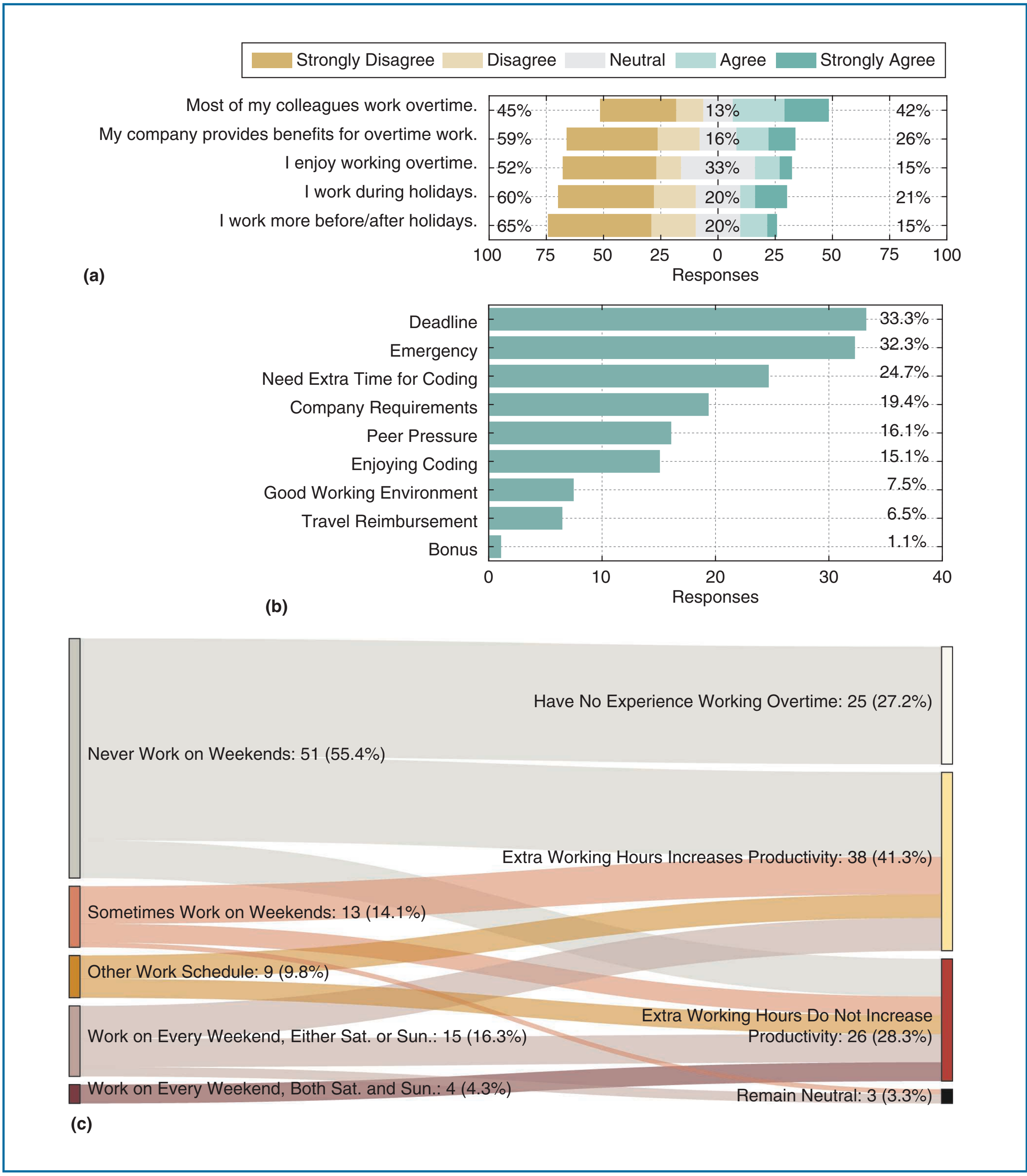

FIGURE 4. The results of the qualitative survey. (a) The developers' self-reported experience of working overtime. The numbers on the right are the percentages of respondents who agree or strongly agree with the statements. The numbers on the left are the percentages of respondents who disagree or strongly disagree with the statements. The numbers in the middle are the percentages of respondents who stay neutral. (b) The numbers on the right are the percentages of respondents who choose the reasons for working overtime. (c) The frequency of working overtime on weekends and perspective on whether extra working hours increases productivity. The number and percentage of respondents who agree with each statement are displayed next to the label.

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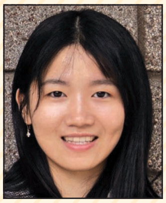

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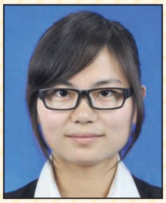

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We provide suggestions for both developers and managers. For developers, we suggest that they should be aware of the difference in work time culture among different companies when choosing workplaces. For managers and executives, we suggest that if their employees are experiencing overtime work, they should ensure that they have adequate rests on weekends.

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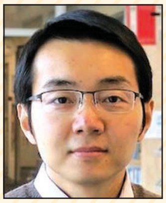

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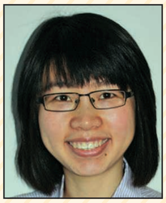

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