

'I Can't Even Buy Apples If I Don't Use Mobile Pay?': When Mobile Payments Become Infrastructural in China

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Despite slow adoption in the US, mobile payments are the *de facto* solution for hundreds of millions of users in China for everything from paying bills to riding buses, from sending virtual "Red Packets" to buying money-market funds. In this paper, we use the theoretical lens of infrastructure to study users' interactions with ubiquitous mobile payment systems in China, focusing on Alipay and WeChat Pay, the two dominant apps on the market. Based on data from a survey (n=466) and follow-up interviews (n=12) with users in China, we describe the diverse usage patterns across physical, social, and digital ubiquity, and a series of challenges people face. Reflecting on the lessons we learned from the Chinese case – in particular, problems and pitfalls – we discuss some implications both for design and for policy. Our findings have important implications for other countries that have been moving towards greater adoption of mobile payments.

CCS Concepts: • **Human-centered computing** → **Human computer interaction (HCI)**.

Additional Key Words and Phrases: Alipay; WeChat Pay; Mobile Payments; Infrastructure; China

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1 INTRODUCTION

While mobile payment systems have seen only modest adoption in US, they have taken off dramatically in China. In 2018, more than 80% of Chinese consumers used mobile payments in their daily lives. In contrast, in the US as of 2019, the adoption rate of major mobile payment apps was less than 10% [43].

The two dominant Chinese mobile payment apps, WeChat Pay and Alipay, boast 600M and 520M users respectively, and together control over 90% of the Chinese market [17]. Mobile payments are on the verge of replacing all other payment methods in a number of Chinese cities [13]. For example, some Chinese street vendors and taxi drivers have started to refuse cash [35], and there are even panhandlers on the street that accept donations via mobile pay [17]. Figure 1 shows

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Fig. 1. Alipay and WeChat pay are the two dominant mobile payment apps in China, with 600M and 520M users respectively. Users commonly scan QR codes with their mobile phone to initiate a transaction, with the picture showing such QR codes on a newspaper booth, a subway ticketing system, and a bike sharing service in Beijing.

examples of how scanning Quick Response (QR) codes with one's smartphone camera initiates mobile payments at a variety of businesses and locations.

In this paper, we use the analytic lens of infrastructure to explore how users interact with mobile payment systems in China. We root our concept of infrastructure in Star and Bowker's seminal work [9, 48], understanding it as a stable sociotechnical substrate on which other tools and systems are built, and that always underpins, enables, or constrains social interactions. As previous scholars have pointed out, infrastructures (e.g., electric utilities, plumbing, IT services) often have a ubiquitous reach and scope. They are deeply embedded in existing technical structures and social environments and thus tend to become invisible and transparent [48]. According to this definition, mobile payment systems have become infrastructuralized in China with their ubiquitous reach, indispensable role in people's lives, embeddedness in existing sociotechnical structures, and invisibility in terms of people's level of awareness of the underlying technological system supporting their actions and interactions. At the same time mobile payment systems represent a unique type of infrastructure as compared with previously studied systems like scientific simulation or software. They are corporately owned and controlled, and involve connection of a variety of independent applications, supporting a diverse software ecosystem that serves many different purposes (rather than one common one as with other types of infrastructure). Given their unique properties, how might infrastructuralized mobile payment systems shape and impact users' experiences? In this paper, we set out to offer one possible answer to this question by studying users' experiences around mobile payment infrastructures in China.

The majority of previous literature on mobile money has looked at the motivations and barriers to adoption (e.g., [14, 18]) and the impact in the immediate aftermath of the introduction of payment systems (e.g., [19, 34]). Fewer studies have looked at what happens when mobile payments have already become "infrastructural". In this regard, China offers a vastly under-explored case. Although past work has considered regulatory and economic influences on the adoption of mobile payments

in China (e.g., [12, 16, 29, 52]), currently, the literature offers only a limited understanding of this ubiquitous system from the user's perspective. Previous literature here focuses on specific aspects of mobile payment apps, such as Red Packet gifting [54] and how design features of Alipay and WeChat Pay have allowed money to move beyond standard retail contexts to support other informal and nuanced social activities [24]. The sheer ubiquity and deep embeddedness of mobile payments in people's everyday lives in China, however, motivated us to dig deeper and examine mobile payment infrastructures across a broader set of contexts.

In this study, we conducted an online survey (n=466) and post-survey interviews (n=12) with users of Alipay and WeChat Pay in China and gathered stories from the perspective of end-users. We find that the most common uses of Alipay and WeChat Pay fall into three categories associated with the forms of ubiquity the system provides: physical, digital, and social. We also find that people face a set of technical, social, and interoperability challenges when mobile payments are infrastructuralized, revealing needs for reliable network connections, robust camera lenses, basic financial infrastructure, necessary digital literacy, as well as regulatory efforts.

Our contributions are two-fold:

- Using the theoretical lens of infrastructure to ground our findings, we offer a detailed description of users' experiences around infrastructuralized mobile payment systems in China. We unveil diverse usage patterns across physical, social, and digital ubiquity, and a series of challenges that users face;
- Based on the lessons we learned from China, in particular, challenges and pitfalls, we discuss a few implications. We (1) encourage designers to take into account the interdependence of mobile payments with existing technical, social and interoperability factors; and (2) urge policymakers to take proper measures to address the tensions underlying the infrastructuralization of corporate mobile payment platforms.

As one of the largest and most dynamic mobile payment markets in the world, China offers an important case for other countries that have been moving towards greater adoption of mobile payment systems. The lessons we learned from the Chinese case – in particular, problems and challenges – have important implications for designers and policymakers of future mobile payment systems.

2 BACKGROUND: ALIPAY AND WECHAT PAY IN CHINA

Below we review the history of Alipay and WeChat Pay, their onboarding process, functionality, and local and regulatory context that influence their use.

2.1 History

E-commerce giant Alibaba launched Alipay in 2004 as a web-based payment tool to facilitate transactions on its e-commerce website Taobao (a service similar to Amazon and eBay in the US). In 2008, Alipay was redesigned as a mobile payment app and was then officially licensed to offer "third-party payment" services in China in 2011. In 2013, Alipay started to offer money market accounts on its platform. It soon built that business into the world's largest money-market fund, with \$243 billion invested [21].

In 2013 social media giant Tencent launched its own competing payment service, WeChat Pay, as a component of WeChat. WeChat is a social messaging app Tencent launched in 2011 that combines the functions of instant messaging and social media. As of early 2018, WeChat had over 1 billion monthly active users [3].

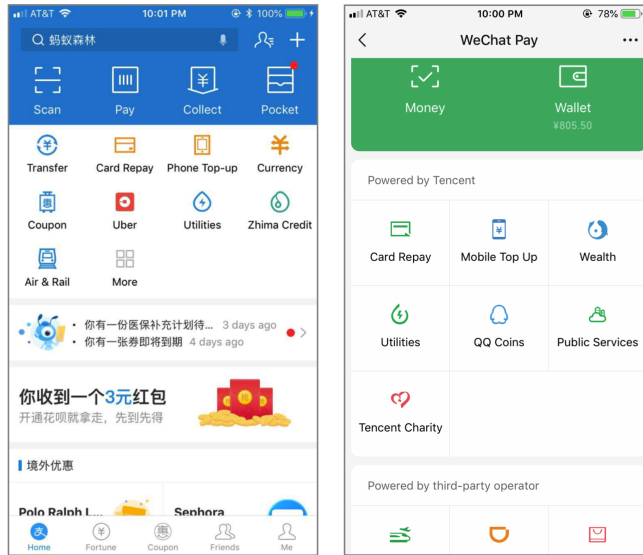


Fig. 2. English language versions of Alipay (left) and WeChat Pay (right). Both apps offer similar sets of services, ranging from online shopping to offline payments.

2.2 Accessing the Applications and Creating an Account

Users can download WeChat and Alipay for Android and iOS, set up an account using a cell phone number for verification purposes, and then bind with a banking account. Overseas users can register using international credit cards like Visa or Mastercard; however, due to government regulation, some of the functions only work if you use a Chinese bank card. Some people have noted that this requirement may cause problems for tourists and business travelers, as a few vendors and taxi drivers have started to accept mobile payment only [35].

2.3 Application Functionality and Services Provided

Both Alipay and WeChat have designed their respective systems as an integrated ecosystem that connects various third-party services. Users can use each app to access a wide range of third-party services all in a central place, without ever leaving the app. Both apps divide their services into three sets of features: (1) conventional mobile payment services, (2) municipal and billing services, and (3) third-party services (see Figure 2 for screenshots of WeChat Pay and Alipay, and examples of services they offer). The first layer, conventional mobile payment services, contains core functionality including a digital wallet, money transfer between end users, and offline transactions via QR codes. In the second layer, both apps offer services essential to people's everyday lives, such as paying credit cards or cell phone bills, accessing utility bills (e.g., electricity, gas, water) and a variety of government services including travel visas and business licenses. In this layer, both apps also offer financial investment services such as the ability to manage money market accounts. The third layer of services are associated with third-party providers and other commercial entities. For example, both apps now offer access to services like ride-hailing, food delivery, and movie-ticket purchasing. Users can complete these tasks and pay within the app with just a few taps.

2.4 Local and Regulatory Context

Mobile payment systems are deeply embedded in specific local and regulatory context. A number of factors have contributed to the wide adoption and usage of mobile payments in China. First, China is a mobile first country; over 700M smartphone users offer fertile ground for mobile apps to grow [12]. Second, as with many developing countries, China lacks basic financial infrastructure – its first credit card was only released in the late 1980s [55]. In 2017, the People's Bank of China reported that the average number of credit cards owned per person in China is only 0.39, compared to 2.6 in the US [50]. The lack of basic financial infrastructure also leads to ingrained habit of cash payment (instead of credit cards). In 2006, cash in circulation accounted for over 13% of China's GDP, while in the US it only accounts for 6.4% and only 3.5% in UK [55]¹. Third, Alipay and WeChat Pay also offered massive financial rebates and promotions to encourage the use of mobile pay. Finally, Financial Technology (FinTech), which refers to technology enabled financial solutions [5], has received strong government support. In 2018 the Chinese government revised its banking and finance system regulations to allow mobile payment companies to provide many banking functions [52]. In this paper, we consider mobile payments and challenges from the end-user's perspective, all against the backdrop of these specific local and regulatory contexts.

3 RELATED WORK

3.1 Infrastructure Studies

Over the past two decades, a long and rich tradition in Computer-Supported Cooperative Work, Science and Technology Studies, and Information Systems has contributed to our understanding of sociotechnical aspects of information infrastructures. An infrastructure is a stable sociotechnical substrate on which other systems and tools are built, and that underpins, enables or constrains social interactions. Star and her colleagues [9, 48] in some of the earlier work on this topic, identified several properties of infrastructures, including embeddedness, transparency, reach or scope, learned as part of membership, links with conventions of practice, embodiment of standards, built on an installed base, becomes only visible upon breakdown, and fixed in modular increments. Extending this line of research, special attention has been granted to the studies of networked information technologies that support scientific collaboration and research activities, i.e., e-infrastructures, e-studies or cyber-infrastructures [23, 27, 39, 41].

As a research field, CSCW has a growing interest in infrastructures. Past work, which often built upon rich and in-depth ethnographic data, has paid special attention to the processual, relational, and labor dimensions of infrastructures by revealing the complex human labor, organizational practices, and existing infrastructures those systems are built on [15, 45]. Closer to this work, infrastructure studies related to mobile payments and alternative currencies have highlighted how new technological infrastructures intersect with existing domains [20], how unintended consequences might emerge with the introduction of new mobile money app [19], and how the seemingly standalone mobile payment infrastructure has actually been supported by many existing systems and human labor [15].

In this work, we mobilize this long and rich tradition to ask a different and complementary question, that is, how infrastructuralized mobile payment systems shape and impact users experiences, using China as a case. Following Star [48], we consider mobile payment systems as being infrastructuralized in China for its ubiquitous reach and indispensable role in people's lives, its embeddedness in existing sociotechnical structures, and its invisibility in terms of people's level of awareness of the underlying technological system supporting their actions and interactions.

¹Note that cash in circulation might not be equivalent to the use of cash for payments. However, comparable cross-country data on cash usage is not available and cash in circulation is often used as a proxy [7].

At the same time, Chinese mobile payment systems represent a unique type of infrastructures compared with previously studied systems such as scientific simulation or software. They are hybrid systems combining features of infrastructures and platforms [38], corporately owned and controlled, and involve connection of a variety of independent applications, supporting a diverse software ecosystem that serves many different purposes (rather than one common one as with other types of infrastructure). Although recent studies have started to explore the infrastructuralization of technology platforms in China (e.g., by studying the evolution of WeChat [37]), we focus our attention specifically on users' experiences around mobile payments. Our findings reveal diverse usage patterns, and a series of challenges that users face with mobile payment systems when they have become ubiquitous and pervasive, which have important implications for understanding how mobile payments should be designed and governed to better serve users' needs.

3.2 Mobile Money

With the growing penetration of mobile technologies into financial services, the topic of mobile money has received increasing attention. A rich body of research has examined how to successfully introduce and implement mobile payment services from a technical and policy perspective, often with an aim to achieve "financial inclusion," especially for developing countries [11, 14, 33].

In the HCI community, a different line of research focuses on interactions between people and mobile payment technologies. This body of work has been predominantly qualitative, collecting observational and interview data from a specific country or region, and often inspired by work in anthropology and sociology viewing money as an important site to study social interactions (e.g. [32, 57]). Examples here include a study of the introduction of M-Pesa in Kenya [31], mobile payments [25] and the push toward a cashless society in India [34], the use and social interaction around Bristol Pound in the UK [36], the combination of social and mobile payment through Venmo in the US [2, 10], as well as successes and challenges users in North America have experienced with mobile payments [18]. Across these studies, researchers find that mobile payment adoption and usage are social, culturally situated phenomena, where local values and cultural practices have a strong influence on whether and how such systems get used and integrated into daily practice.

Previous research on mobile money has primarily looked at the motivations and barriers to adoption (e.g., [14, 18]) and the impact in the immediate aftermath of the introduction of payment systems (e.g., [19, 34]). Fewer studies have looked at what happens when mobile payments have already become "infrastructural" and how such infrastructuralized systems impact users' experiences. In this regard, China offers a vastly under-explored case. In this paper, we utilize the analytic lens of infrastructure to explore how users in China interact with ubiquitous and embedded mobile payment systems. The lessons we learned from the Chinese case – in particular, challenges and pitfalls – have important implications for other countries that have been moving towards greater adoption of mobile payment systems.

3.3 Mobile Payments in China

With the growing influence of Alipay and WeChat Pay in the Chinese market, mobile payment apps have attracted increasing attention. The past literature, however, has explored the phenomenon primarily from a political, economic, and regulatory perspective (e.g., [12, 16, 29, 52]). Although they have contributed important insights and helped us understand different dimensions of China's mobile payment systems, we only have a very limited understanding of these mobile payments in China from the end-user's perspective.

In the past few years, a handful of HCI scholars have started to look at users experiences around mobile payments in China. For example, Wu and Ma [54] offered insights on how Red Packet gifting is used to manage group dynamics on WeChat, identifying bonding, altruism and reciprocity as

three most important values. Kow et al. [24] gathered interview data about uses of mobile payments from people in Beijing, Hong Kong, and California. They introduced the framework of “special digital monies” to explain how the flexible design features of Alipay and WeChat Pay can help users expand their payment practices beyond standard retail contexts. For example, they looked at how the customized representation of digital Red Packets in both apps has satisfied users’ cultural needs to send “ceremonial money” to their family members.

This previous work provides a useful understanding of some aspects of mobile payment use, but misses out on the broad set of other features available within infrastructuralized Chinese mobile payment systems. Alipay and WeChat Pay provide access to a large number of third-party applications in a centralized location. In addition, in China, these apps are becoming ubiquitous technologies – they can be used in many different contexts for almost every purpose. However, we currently do not have a good description of how these apps fit into people’s lives, how they use them, or the prevalence of different types of use.

In this paper, we take a new and complementary angle, enriching our understanding of users’ experiences of mobile payment systems in China in three ways. (1) Using the theoretical lens of infrastructure to ground our findings, we explore how users interact with ubiquitous and embedded mobile payment systems, complementing previous works that focused on specific and nuanced uses. (2) We complement previous qualitative exploration, taking a mixed-method approach to present a holistic overview of a much wider range of mobile payment practices in China. Our work identifies a series of uses not described in previous work and provides data on the relative prevalence of those uses. (3) We explore what challenges people in China face with mobile payments when they have become infrastructuralized, something not explored in the previous work.

4 METHODS

We conducted an online survey ($n=466$) and interviews ($n=12$) with users of Alipay and WeChat Pay in China to understand usage patterns, motivations and challenges.

There are a number of considerations behind our choice of study focus and methods. First, there are considerations with our study focus. While previous studies on infrastructures often utilized ethnography as a research method and gathered insights from multiple stakeholders embedded in a specific organization around a unique piece of infrastructure, we focused on how mobile payment infrastructures shape users’ experiences and therefore gathered data solely from users’ perspective. In limiting our focus on users’ experiences, we also – to a certain extent – performed what Larkin [26] calls the “categorical act”. While Larkin uses this term primarily referring to the act of selecting which part of the infrastructure to study, we extended the term here to describe our decision to focus on users’ experiences, instead of, for example, maintenance and repair. As Larkin points out, “since infrastructures involve multiple levels, any particular set of intellectual questions will have to select which of these levels to examine” [26, p. 330]. In this work, we focused on users’ experiences around mobile payment infrastructures given that there exists limited understanding in this area.

Second, there are also consideration with our methods. Since our aim was to study how a relatively large group of users interacts with infrastructuralized mobile payment systems, as well as the prevalence of those interactions, we opted to choose a mix of qualitative interviews and quantitative surveys. They helped us to reach a relatively larger and more diverse sample compared with more embedded and in-depth ethnographies.

4.1 Data Collection: Survey of Users of Alipay and WeChat Pay in China ($n=466$)

Following [6, 40], we first used an online survey-based methodology to collect stories about user experience with mobile payment apps in China. We developed this online questionnaire based on a pilot study we conducted in our metropolitan area in 2018 with Chinese students, visiting scholars,

Gender		Age		Education		App Use		Location	
Female	53.6%	18-29	40.3%	Middle school or less	1.7%	Only Alipay	1.5%	Mideast	15.5%
Male	46.4%	30-39	47.2%	High school	1.9%	Only WeChat Pay	1.3%	Northeast	6.0%
Other	0%	40-49	8.8%	2-year college	12.5%	Both	97.2%	East	38.6%
		50-59	3.1%	4-year college	74%			South Central	31.1%
		60+	1.2%	Graduate	9.9%			Southwest	6.7%
								Northwest	2.0%

Table 1. Summary of survey participants' demographic information and location (within a 6-sector grid of China).

and relatives living who had used either of the two apps in mainland China in the past six months. We first created our survey in English within our research team. The native Chinese authors then translated the survey into Chinese.

The survey consists of two sets of questions. The first set asked close-ended questions, e.g., yes/no, multiple choice, or 5 point Likert-style questions. We asked when and why people started to use Alipay and WeChat Pay, what factors motivated their daily usage, how they use these apps, and other similar questions. The second set asked open-ended questions to probe users' interactions with the two apps in greater detail. We asked our respondents to tell a story about their most interesting, surprising, and creative usage of mobile payment apps as well as challenges they face during the past month.

Following Lu et al. [30], who conducted their survey in China with live-streaming users, we conducted our survey using the same Chinese survey company SoJump.com. SoJump is one of the largest survey companies in China, and was in charge of distributing the survey on its platform. SoJump sources from a pool of over 2.6M potential respondents in different geographic locations in China and with diverse demographic backgrounds, which allows researchers to reach a more diverse population than many existing methods.

The survey was active in August 2018 for two weeks. It took on average 16 minutes to complete ($M=16.05$, $SD=17$). Each participant received a cash payment. In total, we received 639 completed responses. We removed 173 respondents who were not active users of Alipay or WeChat Pay or were not attending to the survey (i.e., failed the attention check question, completed too quickly, or provided gibberish answers). Our final dataset contained 466 completed survey responses.

Our sample was diverse in terms of demographics and geographic location (see Table 1 for key demographics). The 250 female and 216 male participants ranged in age from 18 to 69. The majority of them (97.2%) have used both apps. They lived across 26 different provinces in China, with educational backgrounds ranging from middle school to doctorate, and occupations including full-time students, managers, office workers, retirees, teachers, government officials, professionals, and so forth. At the time of our survey, two-thirds of our participants used Alipay for more than 3 years and less than half reported that they had used WeChat Pay for 3 years.

4.2 Data Collection: Post-Survey Interviews of Users of Alipay and WeChat Pay in China (n=12)

To better understand some findings from the survey, we conducted 12 interviews with survey participants who opted in to be contacted for a follow-up interview (See Table 2). In total, 86 out of the 466 respondents in our survey offered their contact information for follow-up interviews. To achieve diverse perspectives, we sampled our 12 interviewees from this pool of 86 based on age, gender, experiences of use, phone brand, location and the open-ended answers they offered in survey responses. We performed open coding after each interview, compared and discussed the interview data with the open-ended survey responses, until no new codes emerged, indicating

ID	Gender	Age	Years of Use	App Use	Phone Brand	Operating System	Location
P1	M	64	2	both	Huawei	Android	Mideast
P2	M	28	3	both	Huawei	Android	South Central
P3	F	38	5+	both	iPhone	iOS	East
P4	F	58	3	both	OPPO	Android	East
P5	M	43	5+	both	iPhone	iOS	Mideast
P6	F	35	4	both	iPhone	iOS	Mideast
P7	M	23	2	both	OnePlus	Android	South Central
P8	F	27	4	both	iPhone	iOS	Mideast
P9	F	26	5+	both	Huawei	Android	Mideast
P10	M	27	2	both	Sony	Android	Northeast
P11	F	19	2	both	iPhone	iOS	Mideast
P12	M	54	3	both	Xiaomi	Android	Northeast

Table 2. Summary of interview participants’ demographic information and location (within a 6-sector grid of China).

we reached data saturation. The interviews were conducted remotely using internet-based video conferencing from April to August 2019. Participants were compensated RMB50 for a 30-45 minute interview. In the interviews, participants were asked questions based on their survey responses, e.g., to recall the last time they used Alipay and/or WeChat pay in China, when they started to use them, how they started, why they kept using the apps, how they used the apps in their everyday lives, and what challenges they encountered in using the apps. We also asked them to tell us about any interesting or surprising uses of the apps they had engaged in or observed. All interviews were conducted by the native Chinese authors in Mandarin, recorded, and transcribed.

4.3 Data Analysis

We applied a grounded theory approach [49] to our open-ended questions in the survey and to our interview data. Our process started with open coding. Two native Chinese authors first read the dataset separately and held weekly discussions. They then coded the first 10% individually and met to reach agreement on the codes. One author then coded the remaining using the codes developed and discussed with the second one iteratively to resolve emergent issues (e.g., new codes or ambiguities). The codes, along with the relevant quotes, were then translated to English (and validated by another native author), for research group discussions. During group discussions, we further conducted axial coding and selective coding merging codes into themes. A number of key themes emerged from the process, such as ubiquity, embeddedness and invisibility, suggesting the infrastructure lens. Through iterative discussion and refining themes using deductive and inductive thing, we eventually reached the theoretical lens used in this paper.

5 FINDINGS

Below we discuss the findings from our survey and interviews in two areas: usage patterns and challenges. Survey participants are identified with a “S” and interview participants are identified with a “P”. Survey responses are also accompanied with percentages.

5.1 Usage Patterns

In this section, we report on how our survey and interview participants used mobile payments in China. Our participants reported the ubiquitous reach of Alipay and WeChat Pay enabled them to develop an extremely wide range of activities, facilitated by the physical, digital and social ubiquity

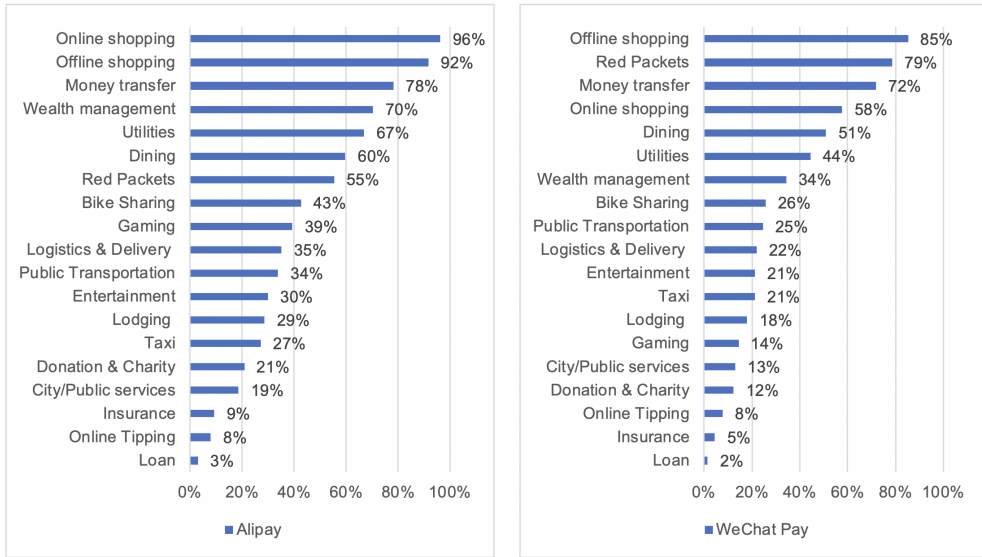


Fig. 3. Respondents' reported top usages of Alipay and WeChat Pay in the prior month, across physical (e.g., offline shopping, dining, transportation), digital (e.g., online shopping, wealth management), and social ubiquity (e.g., interacting with Red packets). Over 97% of our survey sample ($N=466$) used both apps (WeChat Pay $N=459$, Alipay $N=460$). It is worth noting that while Alipay and WeChat Pay differ in their top usage scenarios, in part due to the different business focus of their respective parent companies, their functions and uses have increasingly overlapped over time.

of the systems. Below we present the most popular uses of the two apps in our data across these three facets of ubiquity (see Table 3 for the ubiquity topology).

It is worth noting that while Alipay and WeChat Pay differ in their top uses, in part due to the different business focus of their respective parent companies, their functions and uses have increasingly overlapped over time, as shown in Figure 3.

Some differences remained between the two apps. For example, among our participants, online shopping (96%) was the most common use of Alipay, since e-commerce remains the core business of Alibaba. Users had been using Alibaba for online shopping for a long time and Alipay offered them a new access to Alibaba's different online shopping sites. In contrast, interacting through Red Packets (79%) was a top use of WeChat Pay, since social media is the main business of Tencent. Users had been building social networks on WeChat long before the launch of its payment app. As P2 reflected:

"In terms of shopping and financial related functions, I used Alipay more than WeChat Pay. Because from the very beginning Alibaba is for online shopping and transaction and WeChat is for communication so Alipay is more professional (for shopping and financial services), as least in my opinion."

5.1.1 Physical Ubiquity. The first dimension of ubiquity that emerged from our data was physical. Physical ubiquity refers to two intertwined aspects: (1) the incorporation of a large group of physical actors into the digital payments systems, such as brick and mortar stores, street vendors, restaurants, and different transportation tools; and (2) the embedding of the payment systems into the physical environment through artifacts that bridge the current transaction and the digital

Facet	Description	Sample Usage	Example Quotes
Physical ubiquity	Incorporation of a group of physical actors into the digital payment systems and the embedding of the systems into the physical environment through artifacts, such as the use of QR codes on menus or storefronts	Dining, transportation, offline shopping	"Now many restaurants don't even offer menus anymore. They have a QR board on the table – you're supposed to open up your mobile pay apps, scan the code, which leads you to the restaurant's home page. You order things using your phone and pay the bill after meal using the same app. Just that simple." (P8)
Digital ubiquity	Connecting a full range of potential online financial transactions, including utility payments, wealth management and public services	Wealth management, money transfer, utilities, public services	"I started to keep money in my Alipay account about one year ago, because the extra interest it paid you everyday. It's really easy and simple. You opened up the app in the morning, it immediately showed how much you earned yesterday – it's like the app is making money for you!" (P7)
Social ubiquity	Integration into a wide variety of social activities through support of pre-existing cultural practices and affordances for developing new social norms	Red Packets	"This year I sent 5.20 RMB to my wife on May 20 and she sent me 5.20 RMB back. The money actually was like nothing, you know, just 5 RMB, but the number meant a lot." (S84)

Table 3. Usage patterns across three facets of ubiquity – physical, digital, and social, with description, sample usage, and example quotes. Instead of using mobile payments solely for point of sale payment purposes, our participants now use mobile payment applications for a wide range of activities across physical, digital and social ubiquity.

financial space, such as the use of QR codes as a highly visible payment method. Below we report on these two aspects of physical in detail.

(1) Incorporating Physical Actors. The first aspect of physical ubiquity emerged from our data was the incorporation of a large number of physical actors into the digital payment systems. Our participants reported that they now use mobile pay across many physical locations in their daily lives, including brick and mortar stores, restaurants, and different transportation tools.

Offline shopping: From newspapers to fresh flowers. As might be expected, our participants reported that shopping was the most popular use of mobile payments. Surprisingly, we saw mobile payments used almost as much for offline shopping as online shopping, indicating that they have successfully integrated a large number of physical shops into their networks. For users of Alipay, in the past month, 92% used it for offline shopping, while this number for WeChat Pay was 85%. As Interviewee P3 reported:

"I used them to buy almost everything in my life. I don't really need my wallet anymore since they were so widely accepted – online shops like Taobao and Tmall, or physical stores like the newspaper booths downstairs. Once I even brought fresh flowers from farmers on the street using WeChat Pay."

Reading the menu, ordering, and paying, all within the mobile payment app. Dining was another popular use of mobile pay in China. Over half of our participants (60% of Alipay and 51% of WeChat Pay) reported using mobile payment apps in various dining scenarios in the past month

including: to pay bills after dinner, to order food directly from food delivery providers within the app, or just to grab some quick bites from street vendors.

Interviewee P6 described the ubiquitously integration of mobile pay in her daily dining routines:

“My day started with mobile pay! In the morning, I scanned QR code to grab some breakfast on my way to work. I opened them again during lunch time to order food deliveries. You know nowadays many restaurant owners only asked ‘Alipay or WeChat Pay’ when you asked for the bill? Because almost everyone is paying with mobile [for their food] now!”

Moreover, the often physical dining experience is also integrated within the payment systems. People now open the apps to view menu items and order food during in-restaurant dining. P8 described a type of novel usage of mobile pay in restaurant:

“Now many restaurants don’t even offer menus anymore. They have a QR board on the table – you’re supposed to open up your mobile pay apps, scan the code, which leads you to the restaurant’s home page. You order things using your phone and pay the bill after meal using the same app. Just that simple.”

Transportation: From ride hailing to subway riding. Our participants also reported transportation as a common usage for mobile payment apps in China. 34% of Alipay and 25% of WeChat Pay reported using mobile pay for public transportation fees like riding buses or subways. Users also reported frequently using mobile pay for taxi hailing (21% of WeChat Pay users and 27% for Alipay users) and bike sharing services (43% for Alipay and 26% for WeChat Pay).

Like other activities, a variety of transportation tools (e.g., bus, taxi, subway, bike) have also been increasingly incorporated into the digital payment systems. As P2 detailed:

“At first I went to their respective apps [if I want to call a taxi or ride a bike]. Now I found it is actually much simpler and easier to initiate the activities within the app. For example, if I want to call a taxi, I don’t go to Didi [a ride-hailing company] anymore. I just open up WeChat – actually it is always open on my phone – and click the Didi button.”

The connection between mobile pay and various transportation tools also reduces effort and switching costs, further incorporating Alipay and WeChat Pay into every aspect of users’ daily routines. P12 recalled:

“My commute route used to be very complicated. I need to ride the bus first, then switch to subway, then switch to bike sharing services. Now everything is connected on my Alipay. You don’t need to download, say, bike sharing app or carry your transportation card anymore. Just scan the QR code and that’s it.”

(2) The Visibility of QR codes. The second aspect of physical ubiquity was the widespread adoption of QR codes for users to initiate payments, which helped embed digital mobile payments into the physical environment. QR codes are two-dimensional, black and white bar codes readable by smartphone cameras. Our data suggests that QR codes are the dominant method for conducting mobile payment in China. Over 50% of our survey respondents indicated that they used QR codes to pay on a daily basis. Other payment methods, including in-app transfer, Near Field Communication (NFC), facial recognition, SMS payment, and sound wave – lag far behind in China (see Figure 4).

Previous studies (e.g., [24]) have identified a few reasons behind the wide adoption of QR code as a payment method in China, including the fast transaction speed as well as the reduced amount of infrastructure required. Below we highlight a unique feature in our data that has emerged along with the infrastructuralization of mobile payment systems in China, namely, visibility. In particular, there are three dimensions of such visibility as reported by our participants in China: easy to see, easy to understand, and easy to act.

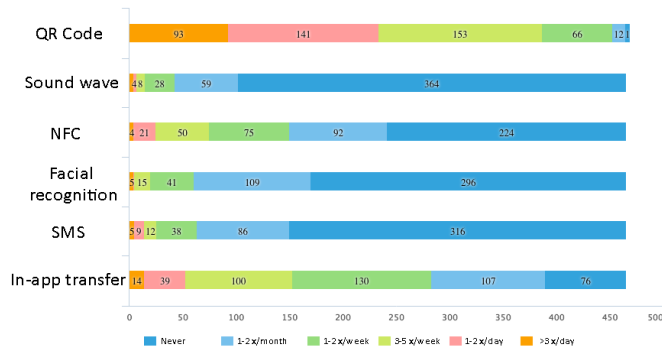


Fig. 4. Respondents’ reported use of mobile payment methods in the prior month (N=466). Over 50% indicated that they used QR codes to pay on a daily basis. Other payment methods in China, including in-app transfer, Near Field Communication (NFC), facial recognition, SMS payment, and sound wave – lagged way behind.

First, the high visibility of QR codes (as we saw in Figure 1) makes it easy for users to see and spot, signifying that mobile payment is accepted here. As interviewee P1 recalled,

“they [QR codes] are everywhere – breakfast vendors, supermarkets, grocery stores, restaurants, farmers on the street ... I don’t really have to ask the vendor, like ‘do you accept mobile payment here?’ When I saw the codes, I know immediately there’s something that I can buy [with my phone]!”

Second, seeing a QR codes in a specific context often makes it easy for users to understand the purpose. For example, P9 reported that in a wedding she attended in China, the guests knew immediately what to do when they saw a QR code:

“QR codes are so popular – now in China people are even using it to collect wedding Red Packets. The wedding company just put up a large QR code in front of registration desk, and we all know immediately it is used for sending our wedding Red Packets!”

Third, the widely promoted “scan” action and its tight association with QR codes also made it fast and easy for users to understand the transaction process as well as what to do next. For example, Interviewee P11 compared the use of QR code with other payment methods:

“It is very intuitive to me – you saw a QR code, you know you need to scan it, right? You can feel that you’re controlling the process. Other payment methods are more complicated. You saw a facial recognition screen – what you do then? It always made me nervous. And the whole NFC process is even more complicated. You need to find out a way to wake up the phone and get your digital wallet out first – I often failed at the very first step.”

5.1.2 Digital Ubiquity. The second dimension of ubiquity that emerged from our data is digital. Mobile payments were continually used in their core scenarios(i.e., online shopping), but also increasingly adopted and expanded to other digital domains like wealth management and public services. The applications connected the full range of potential online digital financial related activity.

Online Shopping: The one-stop shopping app. Online shopping remains one of the most popular forms of mobile payment usage across our survey participants. For Alipay users, over 96% used it for online shopping. For users of WeChat Pay, 58% used it for online shopping.

Interestingly, our participants reported that the apps now act as portal to online shopping merchant sites so they no longer visited the merchant's own site but simply shopped and paid all through the mobile payment app itself. Interviewee P11 noted:

"I used to shop on Taobao (a popular e-commerce site in China) a lot and that's what got me started to use Alipay. But nowadays I don't really go to Taobao. Instead, I opened up Alipay first – it has the Taobao button and lots of products recommended based on my interests. All things now started with and happened within Alipay."

Wealth management: The app that makes money for me. Another popular use of mobile payment apps was financial services, such as wealth management (34% for WeChat users, 70% for Alipay users), buying insurance (5% for WeChat and 9% for Alipay), and loan applications (2% for WeChat and 3% for Alipay), suggesting mobile payments have extended their digital footprints into a variety of financial services.

Our participants reported that they now kept money in the apps, using them as mini banks. As P7, a graduate student described:

"I started to keep money in my Alipay account about one year ago, because the extra interest it paid you everyday. It's really easy and simple. You opened up the app in the morning, it immediately showed how much you earned yesterday – it's like the app is making money for you!"

Users also reported buying money market funds and manage their wealth through mobile pay. Interviewee P5 said,

"I put a lot of money in Alipay. At first, it offered a service called 'Yu'e Bao,' basically a service that buys money market funds but the return was really high. Then the app analyzed your investment habits, compared them with other people in China and recommended other financial and insurance services. It's just very friendly than most banks in China."

Utilities and public services: The building blocks of everyday lives. A large proportion of our participants used mobile payments to interact with public service providers, utilities, and government services. 67% of Alipay users and 44% of WeChat Pay users in our survey reported they had used the apps to pay utility bills (e.g. electricity, gas, water, etc.) in the past month. By bringing a variety of public services into their digital platforms, mobile payment systems have further enlarged their digital sphere. P1, a retiree commented,

"(unlike young people,) we don't really do very fancy stuff using these apps. The most common function we used on mobile payments is to pay utilities. You have to do it every month – it's like the building blocks of your lives? Now we do it on WeChat Pay."

And 19% of Alipay and 13% of WeChat Pay users reported that they had accessed public and government services through mobile payment apps. Interviewee P2 reported:

"I recently renewed my visa application on WeChat Pay. Just followed the steps on the app and clicked all the buttons. It was supported by the National Immigration Administration so I feel it was very reliable."

5.1.3 Social Ubiquity. Mobile payment systems also had social ubiquity through support of pre-existing cultural practices and affordances for developing new social norms. Our participants also reported that interactions through mobile payment systems had become an important aspect of their social lives. One particularly interesting usage and example of this social ubiquity was the various uses of Red Packets which we focus on in the rest of this section.

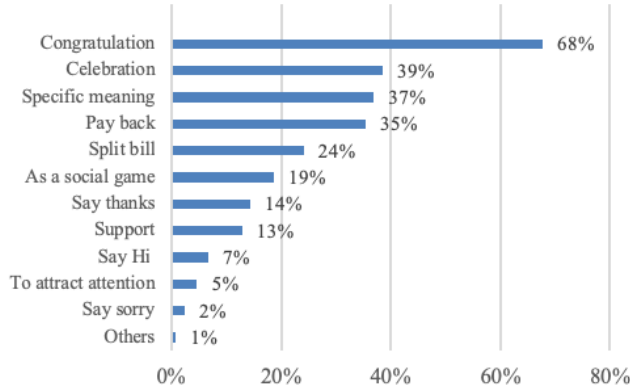


Fig. 5. Respondents' reported top usage of digital Red Packets in the prior month (N=466), including using Red Packets to congratulate, celebrate and support, sending out specific amount of money to convey specific meanings, using Red Packets to (re)organize social relations, as a social game, and to communicate a simple and quick message.

Red Packets: Money as a form of communication. Our participants reported that one of the most common uses of mobile payment apps in China was to interact with digital versions of Red Packets (55% of Alipay users and 79% of WeChat Pay users). Red Packets are small, red envelopes containing cash gifts, which is a deeply ingrained cultural practice in many Asian countries to say "best wishes" or "congratulations". Physical Red Packets are expected gifts in many occasions, including Spring Festival, weddings, and even kids' birthday parties, and they have translated well into digital form, with even more uses and practices growing from them.

Our results suggest users have developed and integrated various functions of Red Packets into their daily communication practices, as shown in Figure 5. Our participants reported some similar practices with Red Packets as found by [24, 54], including using money to celebrate, to organize group dynamics, and to play games. Below we highlight a few novel uses that have not been reported previously.

One interesting finding is users started to use Red Packets to convey a simple message, as mobile payment apps allow users to include texts along with the money. This practice suggests that the social meaning behind users' everyday activities are enriched by attaching it to money. For example, interviewee P5 told us that he sent out Red Packets in his WeChat social groups when he needed to distribute messages that are not immediately relevant to the purpose of the social group.

"One time I needed to get more clicks for my daughter's piece in an online piano competition. So I sent out the link to my college WeChat group along with a small Red Packet. On the cover of my Red Packet, I put 'sorry to bother' because I feel like the message is irrelevant to the group."

In other cases, the money itself can become a message. Over 37% participants reported that they sent specific amounts of money to convey specific meanings. This is seen in traditional Red Packet gifting (e.g., sending someone 888 RMB means good fortune since the number 8 sounds similar to the phrase "getting rich" in Chinese). Mobile payment apps have facilitated this practice. For instance, because of similar sounds in Mandarin, the numbers 520 are slang for "I love you" and May 20 has also become Chinese Valentine's Day. Our participants reported that they sent Red Packets containing 5.20 RMB on May 20 as way to say "I love you". Oftentimes, there was no real

monetary transaction as the receiving end sent the same amount back. It was the number and the practice that mattered. S84 recalled:

“This year I sent 5.20 RMB to my wife on May 20 and she sent me 5.20 RMB back. The money actually was like nothing, you know, just 5 RMB, but the number meant a lot”.

5.1.4 Key Takeaways. In this subsection, we reported how people in China used mobile payment systems for an extremely diverse set of activities. Previous literature on infrastructures has suggested that one of the defining features of infrastructures is its reach and scope [48]. We saw here how the ubiquitous reach and scope of mobile payment infrastructures shape usage patterns, facilitated by the physical, digital, and social ubiquity of the systems.

Moreover, scholars of infrastructures have also highlighted the “integration of heterogeneity” in many information infrastructures, which not only allows connection of different technical components, but also allows different unrelated actors to build social practices on it [41, p. 234]. We saw here how such integration shapes users’ experiences of mobile payment infrastructures. On the one hand, the three facets of ubiquity achieved partially because Alipay and WeChat Pay allow various third-party services to be connected into their systems, acting as a basic infrastructure for a broad range of technical components. On the other hand, we also observed how both apps facilitate different unrelated actors to build social practices on them. For example, many novel and unexpected practices emerged with Red Packets, with participants describing how they sent a sorry message or used QR codes at weddings to send monetary gifts.

Finally, our findings have further suggested that when mobile payment infrastructures have become increasingly embedded in existing technical and social arrangements, i.e., “sunk into and inside of other structures, social arrangements, and technologies” [48, p. 381], users interact with the underlying systems through highly visible artifacts. On the one hand, they opened up the payment apps early in the morning and used it for things as mundane as daily breakfast. This indicates that mobile payment has been fully ingrained into their daily routines, which pushes the system to the level of social integration such that its presence became more invisible and powerful. On the other hand, when the infrastructure itself becomes embedded, people are motivated to interact with it through other visible artifacts and interfaces that signify the existence of such systems. QR codes emerged from our data as one such artifact. A particularly interesting example is the use of QR codes to order food in restaurants. Customers no longer use the dining menu to order food anymore, but rather scan the QR codes on the table instead. This suggests that mobile payment systems are starting to supersede pre-existing artifacts (i.e., menu) and practices (i.e., a waiter coming to take your order) in that space.

5.2 Challenges: When Mobile Payments Fail

In this subsection, we report on our findings around the failure points of China’s mobile payment systems. To identify these failures, we asked participants in both our survey and interviews to recall and describe the last time they couldn’t use mobile pay as desired and why, using open-ended questions. We applied the method of “infrastructural inversion” [8], which focuses on maintenance, upgrade, or breakdown of infrastructures, to explore the “breakdowns” [48] of China’s mobile payment systems.

For many people in China, a failure in mobile payments meant being cut off from a large part of the everyday economy. For example, as P1 recalled:

“At first I was hesitant to use mobile pay. Until one day I wanted to buy some apples in a local shop and the vendor only accepted mobile pay because he has no change. That’s a weird moment for me: I can’t even buy apples if I don’t use mobile pay?”

We identified three main categories of challenges through coding open-ended survey responses and follow-up interviews: (1) technical challenges, (2) social challenges, and (3) interoperability challenges.

5.2.1 Technical Challenges. Participants faced a set of technical challenges when using mobile pay. Limited and unstable network coverage emerged as a major pain point. S98 mentioned that a mobile payment practice once failed due to *"bad WiFi coverage in the B level of a local shopping mall"*. S406 mentioned he couldn't send out mobile Red Packets because *"it was in some remote mountain area and there was no mobile service."* While QR codes do not require any networking or power, users still needed a reliable network connection to use those codes, and poor wireless was a common explanation behind many failed payment attempts in our data.

Issues with mobile devices also emerged as another common technical challenge. For example, many users reported battery limits interfering with mobile payments. S54 mentioned she failed to use mobile pay because her phone was *"out of battery when I tried to buy some fruits on the street – so now I carry portable chargers and power banks with me"*. Damaged devices also caused problems. S547 mentioned when he tried to pay for a dinner bill, *"there were scratches on my mobile camera lens and I can't scan the QR codes – so I had to use cash"*.

To some extent, the first issue of unreliable wireless connectivity will likely be solved over time. However, the second issue of problems with one's own device is more problematic, as there is no general technical solution and also limited fallback cases for users.

5.2.2 Social Challenges. Our participants also reported a set of social challenges with respect to mobile payments. Since mobile payment apps still require users to link a smartphone with bank cards, financially or technologically marginalized populations may lag behind. For example, rural populations emerged as one such group in our data. S1 mentioned their transaction failed because *"it was a small shop in rural area and the owner did not even use smartphone"*. S602 mentioned she was on a trip to a small village and *"people there didn't really use anything other than cash"*.

Less technically knowledgeable populations (e.g., older users) were another critical group that had problems coping with the wide adoption of mobile payments. S120 reported he failed to use mobile pay because the vendor was *"at about the age of my grandpa and had no idea what is Alipay or WeChat Pay – or even what is smartphone"*.

P3 reported in once instance an elderly woman failed to pay the bus fare because she didn't use mobile pay. *"I think the driver was unreasonable – he said he only accepted Alipay or WeChat Pay. How can a woman like my grandma knows how to do this? So I went ahead and scanned my phone for her."*

P1 recalled the less tech-savvy vendor in his local market was actually losing business because he didn't know how to use mobile pay:

"When everyone in the market started to go mobile (for payments), his meat stand was among the few that didn't have a QR code and customers were starting to lose patience because it took longer to pay with cash ... sometimes even worse because nowadays many people no longer carry cash anymore."

In addition, there were also people who didn't want to move to mobile pay, or didn't want to use mobile pay in certain occasions. S472 mentioned *"the shop owner said he couldn't figure out how the technology works – the transaction speed is too fast and he felt he's out of control."* S339 reported he failed to send Red Packets to his friend because *"she didn't want to open up WeChat Pay account. She said it is too troublesome – you need to link your bank account, get it verified, lots of work."* P11 also mentioned in particular her mom refused to receive digital Red Packets. *"Once I wanted to send*

her a digital Red Packet for the Chinese New Year, she refused to accept, saying it is not formal. I guess people like my mom still prefers real red envelope with brand new cash."

Indeed, as the two apps have increasingly become the basic infrastructure of people's everyday lives in China, the social divides between "haves" and "have-nots" start to emerge around mobile payments. It therefore remains an important and open challenge how to design a system that can offer equal services to traditionally marginalized or less technically knowledgeable social groups. In addition, it is also important to note that there will always be non-users of certain technologies. The design and governance of mobile payment infrastructures, therefore, also need to consider how to accommodate those non-users' needs.

5.2.3 Interoperability Challenges. The third set of challenges that emerged from our data related to interoperability issues. Uneven service coverage was one such issue. Our survey participants reported that while mobile pay was widely adopted in major cities, smaller cities or rural towns were often not connected into the system yet. P12 recalled, *"I can scan QR code on buses in big cities now, like Shanghai or Beijing, but not in small cities. I think big cities started to accept mobile on their public transit systems first"*.

In addition, some reported that hospitals, gas stations, and government agencies in certain areas were not yet covered by mobile pay. S33 reported that he failed to use mobile pay in a hospital, *"people over there insisted to use cash, saying the hospital system has not been connected into mobile payment networks yet."*

Importantly, participants also reported that because of the fierce competition between Alipay and WeChat Pay, some merchants might reach an exclusive agreement with one company and deny transactions from the other. Such exclusive deals created barriers for users to conduct mobile payments when they only installed one app on their phones or didn't have a sufficient amount of money in the accepted app. Several participants reported that they failed to use mobile pay in the past month because the service provider only accepted one of the payment apps and refused the other. For example, S435 reported,

"last time I tried to pay in a supermarket – they told me that they had some type of deal with one of the apps, so the other one was not accepted. I didn't have enough money in the one that was accepted so I can't pay."

As another example, P2 reflected,

"I was kind of angry when the cashier told me they only accept one of the apps. I think our payment system should allow different payment methods to be connected and used – we should have more payment methods, not fewer".

5.2.4 Key Takeaways. In this subsection, we discussed the failure modes or "breakdowns" [9] of mobile payment systems in China. It helps us make many invisible aspects underneath mobile payment systems visible and unveil a number of challenges and pitfalls users face with mobile payments in China. We noted that despite the ubiquitous reach of Alipay and WeChat Pay, users still face a series of technical, social, and interoperability challenges. Those challenges are important to identify, as they disclose the complex "installed base" [48] mobile payment systems have been built upon, revealing the needs for reliable network connections, robust camera lenses, basic financial infrastructure, necessary digital literacy, as well as regulatory efforts.

Moreover, studying the failure modes of mobile payment infrastructures also helps us better understand the limitations and boundaries of these ubiquitous systems, in particular with regard to marginalized communities. Rural populations emerged from our data as an important social group that sit at the boundaries of China's seemingly ubiquitous mobile payment infrastructures. Senior citizens who either lack necessary digital literacy or feel uncomfortable with digital payments are

another social group that are facing new challenges with mobile payments. In addition, we also observe that there are people who prefer not to use mobile pay. Those non-users are important to identify, in particular with mobile payments being infrastructuralized into the basis of people's everyday lives. Making the limitations and boundaries of mobile payments visible helps designers and policymakers better envision how to design future payment systems to accommodate the needs of those different social groups.

6 DISCUSSION

In this study, we offered a detailed description of users' experiences around infrastructuralized mobile payment systems in China. We presented diverse usage patterns across physical, social, and digital ubiquity, and a series of challenges they face. We next discuss our key findings, offer critical reflections, and unpack our implications for designers and policymakers.

6.1 How do infrastructuralized mobile payment systems shape users' experiences?

Despite slow adoption in the US, mobile payments have become "infrastructural" in China. In the popular media, China is often heralded as a model of the "cashless society," a possible preview of what's to come for the rest of the world [1]. In this paper, we probed deeper into this "cashless society" by looking at users' experiences around infrastructuralized mobile payment systems.

Thinking of mobile payments as infrastructures immediately brings to our attention their ubiquitous reach and scope [48]. As we noted in the Introduction, some street vendors and taxi drivers do not accept cash, and panhandlers have been documented using mobile pay. Our results also indicate how mobile payment systems in China are deeply intertwined with people's physical, digital, and social lives in multiple ways, as exemplified by their widespread use in transportation, restaurants, and personal wealth management, as well as the emergence of new kinds of social practices in sending money to others. In contrast, in the US, online and offline purchases typically end with payment via cash, credit cards, or existing mobile payment solutions like Apple Pay or Google Wallet [43]. For example, a user might go to Amazon's web site, add items to Amazon's shopping cart, and then pay at the end. In sharp contrast, in China, many similar services are initiated and ended entirely within Alipay and WeChat Pay, with these apps acting as a starting point to "open up" any number of activities. For example, we reported on how one could see a restaurant's menu, order food, and pay, all within the payment apps. We argue that this kind of centralization lets users see the entire range of services possible, making it easier to integrate new services into one's daily life. This centralization also facilitates positive network effects. That is, new services will want to be integrated with mobile payments because people already use them for so many activities, and users will want more services integrated because of the convenience of being able to access so many services in one place.

The infrastructure framework also helps us foreground the methods and interfaces that people used to access the underlying payment systems [48]. Just as people use plugs to access the electrical infrastructure and faucets to access the water infrastructure, QR codes are the dominant method for accessing mobile payments in China. We reported on how pervasive these QR codes are, for example in taxis, restaurants, street vendors, panhandlers, weddings, and more. These QR codes also act as highly visible artifacts that bridge the physical and the digital, signifying a mobile payment practice can be performed here. People can also see others taking a picture of a QR code and making a purchase, making these QR codes highly observable, one of the major factors identified in [42]. In contrast, American mobile payments providers, such as Apple Pay and Google Wallet, primarily use NFC [4]. While NFC may be more secure, it is also far more expensive to deploy compared to a QR code, and tend to be used primarily at Point of Sale (POS) terminals [50]. As we saw in our data, NFC also tends to be less visible than QR codes, making it less obvious that mobile payments can

be used, and harder for people to observe others gaining benefit from using them. The combination of these factors make NFC harder to deploy in some of the situations we reported on, and, thus, for new practices to emerge. For example, it would be hard to use NFC to send Red Packets as a wedding gift in the same manner as a QR code, because one would either need to get a POS terminal or leave their smartphone unattended somewhere, and neither of these would signify that one should use that device to send money to the happy couple.

Studying mobile payments as infrastructures has further brought to the conversation the underlying factors that support the functioning of mobile payments. The “breakdowns” [8] of Alipay and WeChat Pay in our data reveal how these systems are actually built upon many preexisting sociotechnical infrastructures. Users’ interactions around mobile payments in China, therefore, are both supported and constrained by factors like network coverage, smartphone battery life, and digital literacy. Following this line of inquiry, we saw other similar factors emerge. For example, as we discussed in the background, China lacks basic financial infrastructure and credit card systems, which leads to an ingrained habit of using cash. In this situation, mobile payments offered a number of significant advantages over cash, which likely contributed to their widespread adoption.

Finally, the infrastructure framework also offers us a chance to talk about the hybrid encounter between infrastructures and platforms in contemporary digital economy, in which corporate platforms have increasing acquired characteristics of public infrastructures [38]. As we saw, users reported that they can now access a wide range of public services via both apps. Indeed, many state-owned utility companies now allow users to pay utility bills using the two apps, including electricity, gas, water, Internet, and phone top-up. Moreover, under supportive government policies, both apps were able to build partnerships with different municipal offices, folding a growing number of government services into their systems, including applying for visas and business licenses as well as paying traffic fines.

6.2 Critical reflections on the infrastructuralization of mobile payments in China

The rise of mobile payments as a basic infrastructure is still relatively new. In this study, we have only seen the beginning of changes for end-users in China, and it is not yet fully clear what all of the societal implications will be yet. Below we offer some critical reflections on the changes we observed in our data.

6.2.1 Financial inclusion. Previous literature and policy discourse around mobile money often focus on how such technological innovation can reach populations that have not been covered by traditional banking services to create “financial inclusion,” especially in developing countries. By studying mobile money as infrastructure, recent studies offer important reflections and critiques towards this simplified technological discourse. For example, Ghosh and O’Neill [15] demonstrated that instead of a standalone platform, mobile money actually constantly interacts with many existing infrastructures already in place.

Our data from China echo this critical reflection. In this paper, through the study of the failure modes of Alipay and WeChat Pay, we show that these seemingly standalone systems have indeed been supported by many existing infrastructures, such as network connectivity, banking systems, and necessary digital literacy. Talking about “financial inclusion” without discussions of underlying infrastructures – and the structural factors that shape those underlying infrastructures – seems to be far from adequate. For example, in China, rural populations are one of the structurally disadvantaged social groups and often lack access to basic network and banking coverage. Indeed, despite great progress, the penetration rate of Internet connectivity and financial services remains low for rural populations in China. It is reported that in 2017, almost 200M rural Chinese remain

unbanked [44]. Only offering them mobile devices and mobile payment accounts, without taking into account the underlying structural issues, can hardly solve the problem.

Furthermore, our data also suggest that when mobile payments have been ubiquitously adopted and become the basic financial infrastructure – as many development discourse around “financial inclusion” had imagined, such infrastructuralization might inadvertently generate new challenges for people who cannot or prefer not to go mobile. Our participants reported many payment failures in this study. For example, elderly individuals had more difficulties using mobile payments and by making mobile pay into a basic infrastructure will cause many other problems for this group. While none of our participants reported on any issues related to accessibility, it is very likely that people with physical, visual, or cognitive disabilities would face new kinds of challenges. The recent spread of COVID might have further intensified the “mobile payments divide” we observed here as payment practices more and more shifted towards digital format. The implicit assumption around infrastructuralized mobile payments in China is everyone has a working smartphone, everyone has one of these mobile payment options, and everyone is digitally literate enough and capable enough to use it. However, those assumptions often need to be reconsidered when we think about the social groups that are at the boundaries of our technical systems. In this sense, our case also adds on to these ongoing critiques that single-mindedly pursuing technical solutions to “financial inclusion” is not only far from adequate, but sometimes will create new barriers and generate new forms of exclusion.

6.2.2 The infrastructuralization of corporate platforms. Previous literature in media and communications [38] has discussed the hybrid encounters of platformization and infrastructuralization in the contemporary digital economy. They foreground, in particular, how profit-oriented digital platforms have increasingly assumed properties that are typically associated with traditional infrastructures (e.g., scale, ubiquity, and criticality of use), as well as how this process has generated tensions and contradictions. For example, Google’s web search has become so essential in users’ daily lives that could be seen as an infrastructure. However, its profit-driven nature and near-monopoly position remain a substantial concern in terms of how it controls the visibility of information resources.

In this paper, we saw similar tensions emerge from the infrastructuralization of mobile payments in China. In particular, the integration of physical, digital, and social ubiquity all through mobile payment apps has granted those profit-oriented platforms enormous power. For example, after launching the wealth management function, Alipay has quickly risen to become the world’s largest money market fund and a serious challenger to China’s traditional banks [56]. Such concentrated power in turn raises serious concerns over the privatization of access to essential services and corporate monopoly.

First, there are concerns over privatizing access to essential services. Our participants reported that mobile payments have become so indispensable that they can now – and sometimes have to – access a wide range of public services and fulfill essential daily needs via Alipay or WeChat Pay. This process is concurrent with the growing public-private partnership in China, in which profit-oriented platforms actively seek collaboration with state entities in development and offering access to essential public services. For many in China, a failure in mobile pay means being cut off from a large part of the everyday economy. This directly raises the danger of marginalized population being excluded from basic financial infrastructures. As previous scholars have argued, privatizing essential services might come at a high social cost. Because for-profit service providers – driven by market-based incentives – are more likely to discriminate than public service providers, for minorities are often perceived as harder-to-serve and therefore more costly [22].

Second, there are also concerns over corporate monopoly, especially given the dominant position of Alipay and WeChat Pay on the Chinese market. For example, their position as gatekeepers

can cause problems for other service providers, posing a potential barrier to entry. In particular, the ability of those apps to act as basic infrastructures to surface various third-party services has granted them a special role of controlling the entry point of the Chinese web. Our participants often accessed other digital services (e.g., taxi hailing) through Alipay or WeChat Pay. These payment apps, therefore, have the power to select which services to make visible (or not) to their vast number of users. The market dominance of only two payment apps can also generate troubles for users. Indeed, we saw that users were actually left with very few choices and were forced to use one of the payment apps when it signed an exclusive deal with the merchants.

6.2.3 The trade-offs between ubiquity and privacy. Finally, issues of digital surveillance also become visible. In particular, the integration of physical, digital, and social activities in one technical system generates serious concerns over systematic surveillance. Indeed, the ubiquity of mobile payment systems in China appears to be a double-edged sword. On the one hand, it makes things highly convenient and easy to access. On the other hand, it also means all of the data about users' activities are centralized. For example, WeChat already has access to all of the messages and social networks on its platform. The infrastructuralization of its payment arm has further extended such access to users' finances, purchases, and activities initiated through the app. Our study participants in China showed limited awareness of issues related with surveillance and privacy. However, as users' privacy attitudes differ greatly in different social and cultural contexts [53], this might raise serious concerns in other countries.

6.3 Implications

Here, we detail what we can learn from the Chinese case, in particular, problems and pitfalls, and unpack our implications for the designers and policymakers of future mobile payment systems.

6.3.1 For designers: Consider the interdependence of mobile payments with existing technical, social, and interoperability factors. Previous literature on mobile money infrastructures has pointed out the complex existing infrastructures that support the function of mobile money [15]. Our findings contribute to this line of research by identifying a series of additional factors that underpin China's mobile payment systems, including technical (e.g., reliable network connections, robust camera lenses), social (e.g., necessary digital literacy,) and interoperability (e.g., regulatory efforts). Instead of viewing mobile money as a standalone technical platform, therefore, we encourage designers of future mobile payments to consider the interdependence of their systems with those – often invisible – underlying factors.

On the one hand, this suggests that designers should think about and map out the necessary supporting infrastructures for their mobile money apps – network coverage? hardware support? social requirements? Or regulations? Such an exercise will help them better understand the limitations and boundaries of their technical systems, in particular, who will be included and who will be excluded, not because of the lack of access to the technical platform *per se*, but because of the lack of access to other underlying factors. On the other hand, this also suggests opportunities for designers to proactively identify the possible “intermediaries” [15] between their payment apps and the users their apps might not be able to effectively serve. For example, can we leverage adult children as the “intermediaries” to support senior parents' effective use of mobile payments?

6.3.2 For policymakers: Consider the tensions underlying the infrastructuralization of corporate platforms. Previous literature has discussed the tensions and contradictions underlying the infrastructuralization of corporate platforms [38], which raises serious concerns over profit-oriented corporate platforms monopolizing essential services of broad public value. Our findings echo this critical observation. In particular, given mobile payments' physical, digital, and social ubiquity, the

infrastructuralization of mobile payments in China not only means they are replacing previous dominant modes of payment, but also means that they are restructuring the basis of people's everyday life, raising concerns over corporate monopoly, digital surveillance, as well as privatizing access to essential services. Recently, scholars and policymakers in the US and Europe have developed strong policy proposals to regulate digital infrastructures in the public interest [47, 51]. As Plantin et al. argue [38, p. 259], traditional infrastructures (e.g., electric utilities and postal services) are often operating as "widely accessible services of broad public value," and thus "acquire the character of public goods, with governments or highly regulated monopoly firms taking responsibility for development, operations, and/or maintenance".

We therefore recommend policymakers who have been relentlessly pushing toward ubiquitous mobile payments to consider appropriate measures to address those concerns. For example, keeping cash as a mandatory alternative to mobile payments might be a necessary act to accommodate the needs of people who cannot or prefer not to go mobile. We also need to consider how to incentivize or regulate mobile payment platforms to integrate social goals – not only profit seeking – into their decision making process, such as making the system widely and equally accessible, especially to structurally marginalized populations. There are also issues of basic access as well, for example ensuring that the cost of a basic smartphone and basic network access are low enough for people, as well as fostering digital literacy. Policymakers should also consider what are appropriate uses of personal data by mobile payment providers, given the sensitivity of the data and potential pervasiveness of mobile payments. Lastly, to address potential issues of monopoly, policymakers should also consider open standards for mobile payments. Having an open standard for initiating mobile payments could make it so that multiple providers could compete and making it easier for users to switch providers if they want.

7 LIMITATIONS AND FUTURE WORK

It is important to highlight some specific limitations of our methods and data.

First, due to our focus on how the infrastructuralization of mobile payments shapes users' experience, our results were gathered solely from the end-user's perspective. This means we do not have insights from vendors, developers, managers, administrators, and representatives from the parent companies that infrastructure studies often include. There are opportunities for future work (1) looking at mobile pay in China from different stakeholder's perspectives; and (2) using different research methods, especially more grounded and embedded ethnographic observations.

Second, although SoJump is a widely-used research tool for conducting surveys in China [28, 46] and helped us reach a more diverse population than previous interview-based studies, our sample was still limited by SoJump's respondent pool. In particular, it was skewed towards younger users in urban and coastal areas. We note that the findings we reported here should therefore be viewed as an exploration of our sample's experiences but may not necessarily generalize to Chinese mobile payments users as a whole. Though limited, evidence from our sample reveals important insights regarding the boundaries and limitations of mobile payment systems in China, suggesting the need for more research with senior citizens and citizens in rural and inland areas, which we believe are important directions for future research.

Third, mobile payment systems are deeply embedded in specific local social, cultural, and regulatory contexts. Our findings may not be applicable to other countries with different regulatory requirements. This also suggests opportunities for comparative future research.

8 CONCLUSION

In this paper, we used the theoretical lens of infrastructure and drew empirical data from a survey and interviews to explore the diverse usage patterns of Alipay and WeChat Pay, the two dominant

mobile payment apps on the market, as well as challenges people face when mobile payments have become “infrastructural”. Reflecting on the lessons we learned from the Chinese case, we discuss a few implications of how to design and regulate future mobile payment systems to better serve users’ needs.

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