Get Distracted or Missed the Stop? Investigating Public Transit Passengers' Travel-Based Multitasking Behaviors, Motives, and Challenges

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ABSTRACT

Mobile users commonly multitask during travel, but doing so on public transit can be challenging due to the dynamic nature of the environment as well as long-standing lack of infrastructural support. Nevertheless, HCI scholars and practitioners have devoted relatively little attention to developing technology for enhancing travel multitasking. To facilitate such development, we sought to understand travel multitaskers' practices and challenges while on public transit, and to that end, conducted a multi-methods study that involved shadowing and interviewing 30 of them. We identified four travel-multitasking patterns, characterized by distinct motives that affected these travelers' multitasking practices, receptivity to environmental stimuli, and task persistence. The two main challenges they encountered during travel multitasking resulted from mutual interference from their tasks and from the dynamic nature of transit environments. Based on these findings, design recommendations for public-transit agencies and mobile services are also provided.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in ubiquitous and mobile computing**.

KEYWORDS

Travel-Based Multitasking; HCI; Public Transit

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CHI '23, April 23–28, 2023, Hamburg, Germany

ACM ISBN 978-1-4503-9421-5/23/04…$15.00
https://doi.org/10.1145/3544548.3581391

ACM Reference Format:
Hsin-Ju, Lee, Fang-Hsin, Hsu, Wei-Ko, Li, Jie, Tsai, Ying-Yu, Chen, and Yung-Ju, Chang. 2023. Get Distracted or Missed the Stop? Investigating Public Transit Passengers' Travel-Based Multitasking Behaviors, Motives, and Challenges. In *Proceedings of the 2023 CHI Conference on Human Factors in Computing Systems (CHI '23), April 23–28, 2023, Hamburg, Germany*. ACM, New York, NY, USA, 14 pages. https://doi.org/10.1145/3544548.3581391

1 INTRODUCTION

Amid technological advancements and a growing emphasis on efficiency, people today are able to multitask almost anywhere and at any time. Multitasking on public transit is a key example of this [25, 30, 32]. Travel-based multitasking behavior is defined as when "individuals endeavor to do multiple things concurrently while en route to destinations" [8, 26, 41]. Previous studies have shown that, in addition to accomplishing their primary task, i.e., reaching the destination [29], travel is utilized by many travel multitaskers for various work-related and leisure purposes [28, 30, 41, 42, 66]. While some travelers use a range of technologies to engage in productive tasks that transform their "dead time" into meaningful time [24, 66] , others use tech for enjoyable activities such as listening to music, playing digital games, and viewing media on mobile devices [23, 30].

However, travel multitaskers' fragmented attention is likely to negatively impact their travel task: e.g., by missing their stop [15], losing belongings due to packing them up in a rush, or even hurting themselves due to disembarking too hurriedly. In addition, it may cause problems to their tasks-at-hand, i.e., the work the multitaskers are doing and paying attention to, since having to frequently divert one's attention to the travel task can impede these other tasks' progress and reduce their quality [57]. Moreover, active smartphone users who feel that public-transit environments are interruptive may develop negative perceptions of the environments [28].

While public transit has become a space in which people use a wide variety of information technologies, infrastructure and services that support this ubiquitous behavior have lagged far behind. To improve travel multitasking experiences via technological support for this behavior, more research attention and efforts from the

HCI community is needed. In particular, detailed understanding of travel multitaskers' practices on public transit and the challenges they encounter in this dynamic environment is largely absent from the literature, yet crucial to informing the kinds of infrastructural and technological support researchers, practitioners, and public servants need to develop. The present paper therefore explores a range of travel multitasking behavior patterns, identifies their underlying causes, and delineates the challenges travel multitaskers encounter on public transit, guided by the following two research questions:

- RQ1: What are travel multitaskers' behavioral patterns on public transit and the causes underlying them?
- RQ2: What challenges to travel multitasking do travel multitaskers frequently encounter?

To answer these questions, we conducted a qualitative study consisting of shadowing and semi-structured interviews with 30 travel-multitaskers in 6 cities in Taiwan. The former approach was adopted to observe travel multitaskers' in situ multitasking practices and reactions to environmental stimuli during their public-transit journeys, while the latter was intended to shed light on why they made certain decisions and how they perceived and felt about such decisions and travel experiences.

This paper makes the following three important contributions to the HCI and travel-multitasking literature.

(1) It identifies four main patterns of travel-multitasking behavior, each of which is characterized by a distinct motivation that is manifested in their task choices, their expectations of those tasks' progress and quality, and their receptivity to travel-task-related signals on public transit.
(2) It identifies three main types of challenges to travel multitaskers' travel tasks and tasks-at-hand that can result from mutual interference between these two classes of tasks.
(3) It identifies an additional three main types of concerns arising from the public transit's ever-changing environmental and interpersonal surrounding.

Based on our results, we also offer four high-level design recommendations to future transportation and technology providers, which we hope will improve travel multitaskers' experiences on public transit.

2 RELATED WORK

2.1 Attention and Multitasking

Attention determines what is perceived and what is not [14]. It is linked closely to "the voluntary and effortful control of action" [51], which means that it is associated with states of consciousness. Petersen and Posner, however, proposed that there is an attention system composed of an alerting network, an orienting network, and an executive-function network [47]. The first increases humans' sensitivity to external stimuli; the second manages the process of selecting the desired information from among various stimuli; and the third excludes irrelevant information and manages goal-oriented behaviors [6]. Clearly, *multitasking* – defined by Delbridge as engaging in "multiple task goals in the same general time period" with "frequent switches between individual tasks" [20] – has a close relationship with attention, insofar as people who multitask have multiple targets to process. Benbunan-Fich et al. [5] defined multitasking based on the principles of task independence and concurrency. Task independence refers to ongoing tasks being self-contained, while concurrency refers to multiple tasks being carried out with some temporal overlap. Depending on the amount of overlap, multiple tasks can be executed sequentially, starting one task after the completion of the previous one, where only one task is attended to at a time [5, 9]; in contrast, when multiple tasks are executed at the same time, they are performed in parallel. Salvucci et al. [53, 54] later proposed a "multitasking continuum" that characterizes multitasking practices based on the frequency of task switching. At one end of the continuum are multitasking practices that require nearly simultaneous processing, while at the other end are those with longer spans between switches. This continuum therefore accommodates both concurrent and sequential multitasking. In examining the interrelationship of the multiple tasks involved in multitasking, it can be useful to divide tasks into primary and secondary tasks: for example, according to the order in which they are mentioned, their perceived importance, the length of time people engaged in them, and/or the degree of their respective attentional-resource demands [29]. Given that people often have difficulty distinguishing between their own primary and secondary tasks unless given specific guidance, Kenyon [29] also recommended that "activities that a person will do anyway" can be regarded as primary tasks, while other overlaid or interleaved activities should be seen as secondary [29].

In order to achieve good multitasking performance, previous studies have pointed out that the competition among multiple tasks on cognitive resources [53] and the problem of residual attention during task switching [36] should be avoided. However, despite a common notion that multitasking refers to switching between tasks in the same time [20] , it has been argued that there is no universal agreement on the definition of multitasking. For this, Circella et al. [16] classified the relationship between the primary and the secondary tasks into three categories: *tasks switching*, which refers to alternation of tasks, but with only one task being performed at once; *tasks interleaving*, which refers to one task consumes the majority of the resources, while another remains in the background, and *tasks overlaying*, which refers to both tasks are performed at the same. The topic "travel-based multitasking" usually be categorized in the third category, where activities are overlaid on travels [7].

Apart from the perspective in neurophysiology, the notion of attention, which is seen as a limited ability and resource [59] from the field of economy is also core to multitasking. That is, according to Simon [56], people's attention and actions are competed by various received stimuli and inputs, and that people are only aware of the stimuli that appeal to them [27]. Nowadays, the pervasiveness of the Internet, the plethora of information and media, as well as the increasing availability of ubiquitous and mobile technology have allowed people to multitask nearly anywhere and anytime [1, 16, 21, 22, 46, 55, 58]. For example, multitasking during work has drawn considerable research attention including HCI and CSCW, as there is a general concern that multitasking in this context may harm the worker's productivity and performance. Investigating the impact of multitasking in workspace, Mark et al. found that interruptions, such as unavoidable task switching, reduce productivity at work [43]. Likewise, Leroy et al. showed that workplace

multitasking was linked to more emotional exhaustion [37]. Czerwinski et al. [17], who used a diary study to investigate multitasking behavior at work, suggested that the phenomenon of information workers sometimes altering their tasks-at-hand was a result of constant shift of the context at work, which inescapably caused interruptions to their tasks-at-hand. On the other hand, beyond workspace, researchers have also investigated multitasking behaviors during remote meeting. For example, Cao et al. studied workers' multitasking behaviors in this context and found that it is important to consider when and how much people are distracted when scheduling remote meetings [11].

In this study, we focused on public transit passengers' multitasking behaviors, commonly noted as *travel-based multitasking* in the literature, for the purpose of highlighting its distinct characteristics of multitasking in a rapidly changing and unstable physical and social environment compared to workspace or home. We provide a brief literature review in this line of research in the next section.

2.2 Travel-Based Multitasking

Information technology and digital services have gradually changed the way and places where people perform their activities [16]. Smartphones, laptops, tablets and other internet-enabled portable devices offer new possibilities for work and entertainment during travel, as well as increasing the multitasking ability of passengers [25, 30, 32, 42]. Travel-based multitasking behavior has been referred to as *"individuals' endeavor to do multiple things concurrently while enroute to destinations"* [16, 34, 60]. Different transportation modes and environments will lead to different travel-based multitasking practices and activities prevalence. For example, while car users must actively participate in driving and navigation [25, 32, 42, 44], public transit offers its passengers an opportunity to undertake productivity tasks along the travel [25, 32]. In addition, research has also shown that train travel results in more productive tasks than bus travel does[25, 61, 67]; specifically, train riders are found to be more inclined to read, use a computer, sleep, write, or work, whereas bus riders are more likely to enjoy the scenery [25, 61]. Lyons and Urry [42] pointed out that the limits of public transit, such as the level of crowdedness, seat availability, and facility characteristics are the core causes behind different levels and kinds of multitasking behaviors on public transit.

In addition to the influence of the physical environments, researchers have also found other concerns that had impacted passengers' practices of multitasking on public transit. For example, Axtell et al. [3] suggested that limited internet access and privacy concerns during train travel made it difficult for train passengers to make phone calls. Also due to privacy concerns, Tillema et al. [62] indicated that people preferred to have confidential conversations via quiet communication channels such as SMS, email on the train over phone calls.

Safety concern has also been found influential in public transit environment. Newton [45] showed that the ease of passenger distraction can be a predictor variable for theft at transit stations, suggesting that people may encounter property safety concerns when attention is frequently switched. Keseru et al. [31] conducted a field study to investigate the impact of public public's environment characteristics to the type of activities carried out by passengers during travels; they suggested that safety concerns influence the use of digital services, and thus it should be taken into account in public transit multitasking. Since the 2020 COVID-19 outbreak, De Vos [19] showed that passengers' concern with the risk of infection has affected their public transit behavior, such as choose to keep a social distance from other passengers [19]. Lastly, social acceptance also plays a role. As Campbell [10] suggested, passengers deemed making calls to be less acceptable on crowded Japanese trains and buses, and thus preferred to use their mobile phones quietly.

However, despite the number of studies investigating travel-based multitasking behavior in the transportation domain, most of these studies, if not all, focused on the passengers' choices of activities, and how different external factors and their concerns influenced their choices. Thus far, there is limited understanding of what makes passengers want to multitask in such a rapidly changing, unstable, and sometimes even risky and dangerous, environment, and how the reasons and causes behind their decisions to multitask on public transit in turn shape their multitasking behavior pattern on public transit and affect challenges they would encounter during multitasking, respectively. The current paper provide these insights.

3 METHODOLOGY

3.1 Recruitment

Participant recruitment for this study was divided into two broad stages, based on our aims for and approaches to data collection and analysis. The first stage, which involved shadowing, debriefing interviews, and semi-structured interviews, helped us to capture the broadest possible range of multitasking behaviors and challenges on public transit. As a result, the selection process focused on reaching participants with diverse characteristics and experiences with multitasking on public transit.

The second stage of data collection and analysis commenced after we had established a set of theoretical categories and codes based on the data generated by the 22 individuals who made up the first stage's final participant pool. In it, our focus has been on testing the saturation of our theoretical categories: a process referred to as theoretical sampling [12]. In this case, this process included looking for additional examples of multitasking scenarios that had appeared infrequently in our data up to that point. Because we found that our understanding of variations in both multitasking practices and challenges was mainly derived from semi-structured interviews, participants recruited in the second stage have only participated in semi-structured interviews, i.e., are not being shadowed.

For each wave of recruitment, we distributed recruiting ads via four main channels: Facebook groups with themes related to public transit, Facebook pages intended for recruiting research participants in our country, the researchers' personal networks, and word of mouth. Each ad contained a link to a screening questionnaire whose questions covered the respondents' demographic information; their travel behavior in the past six months (i.e., types of public transit they frequently took, and their journey purposes, frequencies, and timings); their frequent choices of tasks on public transit (adopted from [32]); and their tendency to multitask, as measured via the Polychronic-Monochronic Tendency Scale (PMTS) [38]. We then primarily selected participants who were diverse in terms

of their public-transit use and demographic characteristics, but who mostly had a high polychronic propensity, as individuals with such a propensity were more likely than others to have numerous and complex multitasking experiences. However, we also recruited some participants with a monochronic propensity to enrich our data.

In the first stage of the recruitment, we initially recruited 22 participants, 9 males and 13 females, ranging in age from 21 to 50 (M=26.3). In the second, we recruited 8 participants, 6 males, and 2 females, ranging in age from 21 to 40 (M=29.9). The participants' details are shown in Table 1.The public transit mode seen in the profiles were selected by participants based on the three modes of public transit they were most familiar with.

3.2 Shadowing Study

The main objective of the shadowing activity in phase 1 of our study was to observe people's multitasking behaviors, including their attention-switching, task choices, technology choices, and responses to the dynamic environments within public-transit vehicles. These observations allowed us to investigate their in situ behaviors that would have been difficult to obtain through retrospection, such as autonomous responses to environmental stimuli [33] (e.g., attention-switching triggered by vehicle-generated alerts), and behaviors linked to procedure memory [2] (e.g., habitual phone use). Our sites of observation consisted of one public-transit journey per participant, chosen by them. Among the 22 participants who were shadowed, 16 chose their routine commutes, and the remainder, occasional travel such as business trips or going to meet someone for social purposes.

Each shadowing session began as the shadowed participant waited to enter a public-transit vehicle, and ended when they exited it. Throughout this process, they were shadowed and observed by one member of the research team, who positioned themselves unobtrusively at least 5 but not more than 10 feet away to minimize the participant's awareness of their presence. Each observer observed and recorded field notes of the participant' multitasking behaviors and their context, including activities, devices used, attention-switching, progression of the journey, incidents within the participant's immediate surroundings, and other aspects of the vehicle environment such as its crowdedness and the nature, frequency and clarity of stop/station-arrival alerts. Immediately after the observation (i.e., when the participant successfully arrived at their intended destination), the observer walked with the participant to a quiet place and gave them a debriefing interview. Since all these debriefings took place in the middle of the participants' wider journeys, they were limited to a duration of 30 minutes to minimize interference with the participant's schedule for the rest of the day; and all participants were informed in advance about this time commitment. Specifically, the observer's questioning focused on quick clarifications of the participant's *in situ* perceptions, feelings, experiences, and rationales behind their multitasking decisions that might have been difficult to recall in a subsequent semi-structured interview, the questions for which were based on the data gathered during the observation and debriefing interview. Basic descriptions of the participants' shadowing sessions can be found in Table 1, above.

3.3 Stage 2: Semi-Structured Interview

Regardless of their participation in shadowing/debriefing, we invited each participants to a semi-structured interview lasting between 90 minutes and two hours, aimed at capturing their multitasking experiences on public transit over the preceding six months. Those who had participated in the shadowing study were also asked about specific behaviors and incidents the research team had recorded in field notes during their journeys. More specifically, the semi-structured interview questioning asked participants to walk through their multitasking experiences when taking public transit, including their procedures; their choices of tasks and technology; the rationales behind those choices; their feelings/attitudes toward incidents; their multitasking processes and outcomes; and the challenges and barriers they had encountered along different stages of their journeys, including waiting, riding, and disembarking.

3.4 Study Procedure

The study was conducted between late October 2021 and mid-June 2022. The research team contacted people who had completed the screening questionnaire and selected them based on the aforementioned selection criteria. The research team then walked the selected individuals through the study's objectives and procedures. They were informed that the study included being shadowed on one public-transit journey of their choice, and that this would be immediately followed by a 30 minute debriefing interview. After they provided their informed consent to participate, the research team agreed times and locations to meet each of them, such that the researchers could observe their entire journeys, from waiting for the vehicle to arriving at the destination. Before their respective meetings with the observer, each participants was sent an email reminder about the debriefing interview so that they could plan their schedules accordingly.

The participants were given the option of either in-person or online semi-structured interviews; ultimately, they all chose to participate online. All these interviews were therefore conducted via Google Meet, and all gave their consent to being recorded. They were compensated for their time based on the length of their participation in the field observation and semi-structured interviews, with compensation ranging between NT$400 and NT$480 (US$13-16) based on whether or not to participate in the shadowing study. Participants who participated in the shadowing study could receive an additional $80.

3.5 Qualitative Analysis

Our shadowing data covered a total of 18.2 hours on five types of public transit in six cities. Data collected during shadowing and the transcriptions of both types of interviews were entered and coded in ATLAS.ti, an online application for qualitative-data analysis (ATLAS.ti Scientific Software Development GmbH, Berlin). Our data-analysis process was guided by Charmaz's grounded approach [12]. In it, open coding started as soon as the research team had begun collecting data. The first set of codes was developed from our first three interviewees' data, and the creation of their high-level categories was guided by Keseru et al.'s [32] work, from which we adopted codes including *Duration of Travel (Long/Short)*, *Trip Purpose (Commuting/Business/Leisure)*, and *Activity Type (Work/Leisure)*, among

Table 1: Participant Profiles

ID	Age / Gender/ Ocuupation/ Location	Polychronicity	Prefered Tasks-By-Hand	Shadowing Transit Mode	Shadowing Duration	Semi-Structured Interview Transit Mode	Interview Duration
P01	23/ F/ Student/ Hsinchu	Polychron	Relaxing, Media Use, Mobile Phone Use, Working/Studying, ICT Use, Talking	Bus	30 min	Intercity Bus, Metro, Train	94 mins
P02	24/ M/ Student/ Taipei	Polychron	Relaxing, Media Use, Working/Studying, Other	Intercity Bus	90 min	Bus, Intercity Bus, Metro	91 mins
P03	22/ F/ Student/ Hsinchu	Polychron	Relaxing, Media Use, Playing, Mobile Phone Use, ICT Use, Talking	Bus	20 min	Bus, Intercity Bus, Metro	91 mins
P04	26/ M/ Worker/ Taipei	Polychron	Relaxing, Media Use, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	Metro	20 min	Bus, Metro, HSR	72 mins
P05	24/ M/ Student/ Taipei	Polychron	Reading, Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	Metro	20 min	Bus, Metro, Train	102 mins
P06	24/ F/ Worker/ Hsinchu	Polychron	Reading, Mobile Phone Use, ICT Use, Talking	Bus	45 min	Bus, Intercity Bus, Metro	83 mins
P07	25/ M/ Student/ Taipei	Monochron	Reading, Relaxing, Media Use, Mobile Phone Use, ICT Use, Talking	Metro	15 min	Bus, Intercity Bus, Metro	73 mins
P08	25/ F/ Worker/ Taipei	Polychron	Reading, Relaxing, Media Use, Mobile Phone Use, Working/Studying, ICT Use, Talking	Metro	25 min	Bus, Metro, Train	117 mins
P09	23/ F/ Worker/ Taichung	Polychron	Reading, Relaxing, Media Use, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	HSR	54 min	Bus, Intercity Bus, Metro	102 mins
P10	32/ F/ Self-Employed/ New Taipei	Polychron	Reading, Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	Bus	50 min	Bus, Metro	91 mins
P11	24/ F/ Student/ Taipei	Polychron	Relaxing, Playing, Mobile Phone Use, Working/Studying, ICT Use, Talking	Bus	20 min	Bus, Intercity Bus, Metro	82 mins
P12	22/ F/ Student/ Taipei	Polychron	Relaxing, Media Use, Working/Studying, Eating and Drinking	Intercity Bus	50 min	Bus, Intercity Bus, Metro	81 mins
P13	21/ F/ Student/ New Taipei	Polychron	Relaxing, Media Use, Mobile Phone Use, Working/Studying, Eating and Drinking, Talking	Train	38 min	Bus, Metro, Train	155 mins
P14	24/ F/ Worker/ Taipei	Polychron	Reading, Mobile Phone Use	HSR	100 min	Bus, Metro, HSR	105 mins
P15	24/ F/ Worker/ Taipei	Polychron	Reading, Relaxing, Media Use, Mobile Phone Use, Working/Studying	HSR	110 min	Bus, Metro, HSR	91 mins
P16	22/ F/ Student/ Hsinchu	Monochron	Relaxing, Media Use, Mobile Phone Use, Eating and Drinking, Talking	Intercity Bus	90 min	Bus, Intercity Bus, Metro	84 mins
P17	24/ F/ Worker/ New Taipei	Monochron	Relaxing, Mobile Phone Use, ICT Use, Eating and Drinking, Talking	Train	145 min	Intercity Bus, Metro, Train	84 mins
P18	22/ M/ Student/ Taoyuan	Polychron	Reading, Media Use, Mobile Phone Use, Working/Studying, ICT Use, Talking	Train	30 min	Train, Metro, HSR	93 mins
P19	48/ M/ Worker/ Kaohsiung	Polychron	Reading, Media Use	Metro	30 min	Intercity Bus, Metro, HSR	89 mins
P20	27/ M/ Worker/ Kaohsiung	Polychron	Relaxing, Media Use, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	Metro	30 min	Metro, Train	90 mins
P21	22/ M/ Student/ Taipei	Polychron	Media Use, Mobile Phone Use, Working/Studying	HSR	70 min	Bus, Metro, HSR	70 mins
P22	50/ M/ Worker/ Kaohsiung	Monochron	Reading, Relaxing	Metro	30 min	Metro	42 mins
P23	24/ F/ Worker/ Taoyuan	Monochron	Reading, Media Use, Mobile Phone Use, Working/Studying, Talking	N/A	N/A	Intercity Bus, Metro, Train	81 mins
P24	25/ M/ Worker/ Taipei	Polychron	Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying	N/A	N/A	Intercity Bus, Metro, Train	54 mins
P25	21/ F/ Student/ New Taipei	Polychron	Reading, Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying, ICT Use, Talking	N/A	N/A	Bus, Metro, Train	70 mins
P26	30/ M/ Worker/ New Taipei	Polychron	Reading, Media Use, Working/Studying	N/A	N/A	Bus, Intercity Bus, Metro	67 mins
P27	40/ M/ Worker/ New Taipei	Polychron	Reading, Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	N/A	N/A	Bus, Metro, Train	55 mins
P28	26/ M/ Student/ Nantou	Polychron	Reading, Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying, ICT Use	N/A	N/A	Bus, Intercity Bus, Metro	54 mins
P29	40/ M/ Worker/ Taipei	Polychron	Reading, Relaxing, Media Use, ICT Use, Eating and Drinking	N/A	N/A	Metro, Bus, Train	60 mins
P30	33/ M/ Worker/ Taipei	Monochron	Reading, Relaxing, Media Use, Playing, Mobile Phone Use, Working/Studying, ICT Use, Eating and Drinking, Talking	N/A	N/A	Metro, Train, Bus	57 mins

others. The first three transcriptions were coded by the first author and three co-authors. Throughout the coding process, new code category such as *Challenge* were added. Another two co-authors would join each time a transcription was compiled to discuss the current state of our codes and synchronize the team'sunderstanding of coding semantics. The codebook was then iteratively revised by the research team until all team members agreed with all of its content. The remaining transcription data were then coded by all six researchers separately using the codebook, and they met regularly to discuss any questions so as to guarantee consensus on the codes.

When new codes or revisions to codes were proposed, they were also examined against existing data. When a circumstance that was challenging to code arose, the researchers replayed the interview recording file and attempted to comprehend the context of what the participant had said. At this stage, improving the code was our main priority. For instance, the previously mentioned code *Activity Type* was eventually renamed *Task Feature*, and extra features were added to it, e.g., Concentration/ Duration/ Expectation/ Importance/ Operation/ Urgency/ Complication. During this process, we wrote memos and drew diagrams to depict the relationships among the codes and code categories. This revealed that both the dynamics of the environment and the reasons behind the participants' multitasking on public transit had profound influences on their multitasking practices, choices, adaptation to the environment, and challenges. This led us to focused coding [12], a process whereby we started establishing our theoretical codes and categories by focusing on participants' motivations for multitasking, multitasking behaviors, task performance, challenges, and coping strategies. Based on those theoretical codes and categories, we then recruited the second wave of participants to assess saturation, as explained above.

4 FINDINGS

In this section, we present our key findings regarding the participants' multitasking practices and challenges on public transit. For simplicity's sake, we use the term travel task to refer to actions whose ultimate purpose is safe, timely arrival at one's destination. Typically, a travel task's subtasks include monitoring the progression of the journey, preparing to disembark from the vehicle, actually doing so, and so forth. The term *task-at-hand*, in contrast, is used to refer to any non-travel-related task that a participant engaged in during his/her journey. Travel-based multitasking [32] is thus the process whereby participants performed a travel task and a task-at-hand simultaneously; and we regarded their travel-based multitasking experiences as successful only if both these classes of tasks were satisfactorily completed.We did not adopt Kenyon's [29] primary vs. secondary task classification in our study because, in the context of travel-based multitasking, the travel task can always be considered primary in theoretical terms, whereas some travelers might view it as a secondary task, e.g., because it is part of a familiar routine. Thus, looking at travel tasks vs. tasks-at-hand both aligns better with travelers' subjective perceptions and enables us to discuss task types with greater precision than if Kenyon's typology were used.

The first of the following subsections describes the four travel-multitasking behavioral patterns we identified, which are distinguished from one another by differences in motivation. Subsections 4.2 and 4.3 then explain the challenges the participants encountered, including those that arose due to interference between their travel tasks and their tasks-at-hand, and those resulting from the dynamics of the public-transit environment.

4.1 Four Multitasking Patterns on Public Transit

As noted above, classifying multitasking patterns according to the participants task motivations and the meanings they assigned to tasks resulted in a four-part typology. However, they also differed in their choices of tasks-at-hand, levels of concentration on them, insistence about engaging in particular ones, persistence in completing them, and expectations regarding the completed ones' quality. These differences, in turn, resulted in the participants exhibiting variation both in their levels of receptivity to environmental stimuli and in the task challenges they experienced. Each of the four patterns is described in turn below.

4.1.1 *Habitual Behavior, Part of the Daily Routine.*

This travel-based multitasking was characterized by the participants' lack of intention to accomplish a particular task-at-hand; rather, they just habitually performed such tasks while traveling, without much regard for whether they would be completed. Probably because of this, when we asked them in interviews about the multitasking behaviors we had observed while shadowing them, the participants who followed this pattern usually told us that their task-at-hand choices were habitual, spontaneous, and without particular intention; and some did not recall what they had done during their journeys. For example, during the shadowing study, P05 was observed browsing a stock-trading app, but he seemed to be unaware of this when he asked about it in the debriefing interview. *"I probably have checked some stock stuff at that time. [...]. It just occurred to me that I haven't done this today and so I did it"*. Then, when asked about browsing social-media apps during this time, he commented, *"It's probably just an unconscious thing, for no particular reason"*.

However, some participants who followed this multitasking pattern expressed much greater awareness that their tasks-at-hand were parts of their daily routine, e.g., catching up with news or incoming messages during the morning commute, applying makeup before arriving at work, accumulating reward points, and so on. Importantly, those participants whose tasks-at-hand were habitual reported that they were not committed to them, and could start, stop, and resume them at any time.

4.1.2 *Making the Most of Travel Time.*

This pattern of multitasking was motivated by utilizing one's time fully, regardless of task-at-hand type. Interestingly, the participants who exhibited this multitasking pattern expressed their motivations both negatively (e.g., avoidance of idleness) and positively (e.g., seeking a feeling of being productive). Unsurprisingly, given that their main aim was simply to fill dead time, these participants were quite open both about task choices and task outcomes. That is, they were neither insistent nor persistent about undertaking a particular task-at-hand, but rather, were open to switching to other tasks, as long as doing them helped them fill the time. As P10 told us, *"I am a person who can't tolerate being idle [...] I feel that I just had to find something to do, even including playing games"*. Similarly, P05 commented, *"It is extra time that is freed up where I had nothing to work on but do want to do something to leverage it."* In light of such motivations, members of this class of participants did not have high expectations about the quality or progression of their tasks-at-hand. As P23 put it, *"I usually post what I ate today and comment on it on Instagram [during the after-work commute...]. Some typos in there are okay, not work you need to be serious about."* This attitude freed these participants to intermittently shift their attention to the environment and to monitoring the progression of their travel tasks.

Some participants in this category mentioned that they usually thought about or even planned what they would do while waiting to arrive at their travel destinations. This helped them feel *"productive"* (P09). *"I'd think about what I was going to do before I took public transit. [...] It was sort of dependent on where I was going and how many things I could do during this time. I'd quickly walk through them before I took it"* (P09). According to several participants, this type of planning sometimes occurred many days before their travel, or even before they had determined what mode of transportation they would be using. For instance, P18 had a tendency to seek optimization, and therefore, when using an expensive mode of transportation such as high-speed rail, he planned carefully how he was going to leverage the travel time to make the expense worth it. As he put it, *"Mostly I see taking high-speed rail as a luxury, so I would hope to be productive when I do it, like making PowerPoints or something. [...] It's like the extra amount of money could let you stay in a coffee shop. So I will try my best to make this worth it."* He even stated that he was willing to buy additional hardware to optimize his tasks-at-hand in light of high-speed trains' table-size constraints: *"I try not to use a mouse on the high-speed train, but sometimes I still have to use it, which is troublesome. I may buy a small mouse in the future."*

4.1.3 Completing Last minute Work or Clearing Work Backlogs.

This pattern of travel-multitasking was motivated by the participants having heavy workloads and wanting to complete them during the travel. Often, people in this category needed to deliver completed tasks very soon after their travel, or even immediately upon arrival at their destinations. This pattern differed sharply from the two described above, insofar as the importance assigned to completing tasks-at-hand was very strong, even when performing them caused discomfort or was otherwise ill-suited to the public-transit environment. For example, P02 was a student who needed to prepare for an upcoming meeting on the day we shadowed him. Despite the intense vibration of the bus, he worked on his laptop during the trip, writing reports and responding to emails, and at one point, zooming in to read small text. Later, he told us that, despite being aware that the movement of the bus might negatively affect his vision, *"making progress on this [task-at-hand] was way more important than my health. I felt that if I didn't do this well, I'd have a mental breakdown. It's like I wanted to borrow a little health from the forty-year-old me for this moment"*. Similarly, P15 reported squatting down among a crowd of fellow passengers in a moving train to use her computer: *"There happened to be some urgent business to deal with at that time. I had to turn on the computer to send a document to a client because there was no way to use my phone to do this. But I was standing in the Metro. All the seats were occupied, so I had to squat down and take out my computer, find a space, and then put the computer on my knee to do my work. It was not an ideal situation. Very crowded, but I had to do it."* On other occasions, when the train was not crowded but she also felt it was urgent to work, she moved to areas where she thought fewer people would go: *"The area where cars are connected [...] is very unstable, and there are usually not many people standing there, so the space is relatively large"*. She also told us that she wished the Metro service would provide a work-friendly area so that people with similar needs could have a more comfortable and safe environment in which to perform their tasks.

P02 told us that he had worked on a last-minute report using his computer while standing up: *"There was still a little bit of the task left. It was extremely difficult. I thought my computer would bend and break. But that was the only way to do this. [...] It was hard to use the mouse and it was very crowded"*. The same participant also told us that the urgency he felt about finishing his task-at-hand on time made him be willing to run the risk of his computer falling.

4.1.4 Performing Tasks Suited to Public Transit's Rhythm or Environment.

This pattern of travel-multitasking involved choosing tasks the participants perceived as especially well-suited to public transit's temporal rhythm or environment. Several participants mentioned that they intentionally deferred certain tasks until they were on public transit because they preferred to perform them there. Participants who mentioned this motivation were highly familiar with the temporal rhythms of the public transit they took: i.e., not only its duration, but also the time intervals between each pair of stops. This familiarity enabled them to allocate tasks that fit into the time available. P15, for example, reported a preference for listening to podcasts during her commute on the Metro. *"I usually commute on the MRT from Monday to Friday. I use this time to listen to podcasts related to my work. [...] Most podcast shows are thirty to forty minutes long, and the commute time is the same, so I have this clear schedule in which I need to do this. But if I'm not commuting, like taking a walk, my behavior is less predictable and so I wouldn't want to listen to podcasts during that time."* In addition, P15 commented that the unpredictability of the Metro environment enhanced her alertness, enabling her to pay more attention to podcast content: *"I think when I'm in the office listening to a podcast for thirty or forty minutes, it's hard to focus and ensure that I'm paying attention the whole time. [... But on the MRT] you have to keep your eye on the situation. So many things are happening around you. [...] Your attention is always drawn back to your current environment, and this makes you also quite alert and attentive to what is on the podcast."*

P11, on the other hand, was observed using the short intervals in her commute to quickly respond to messages, and commented: *"If I spend all my [non-travel] time replying to messages, I feel like it is a waste of time [... So] I usually do not reply until I'm waiting for the bus or commuting."*

Interestingly, the desire to perform specific activities while traveling influenced some of these participants' transportation choices. P09, for example, anticipating that she would rather take a rest during her journey than arrive at the destination earlier, chose to take the normal train instead of high-speed rail. As she explained: *"Although the train takes a long time, I feel that if I'm not in a hurry, taking the train is pretty nice, because I can rest and eat in an easy way, and feel that 'Oh! I'm able to do so many things on the train'."*

To sum up, the four travel-multitasking patterns we discerned were linked to different motivations as well as variation in their task choices and expectations of their completed tasks' quality. Such variation, in turn, affected their levels of concentration on tasks-at-hand and their ability to monitor the progress of their travel tasks, as explained below.

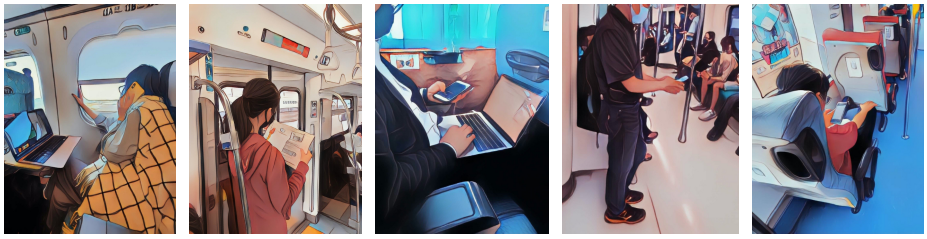

Figure 1: Images of travel multitaskers engaged in travel multitasking on different modes of public transit

4.2 Challenges to Carrying out the Travel Task and the Task-at-Hand Simultaneously

When multitasking, the participants divided some of their attention, or switched their attention quickly, between their task-at-hand and their travel task: in particular, monitoring cues indicating how much time was left before they needed to disembark. Such monitoring can be challenging at times irrespective of one's other activities or the lack thereof. As we will see, however, it can be especially difficult when multitasking, because the sharing of cognitive resources for processing information between two tasks can result in low receptivity to travel-progression cues, especially when people are highly engaged in their tasks-at-hand. This interference becomes more severe when the cues are hard to perceive, which can be for a variety of reasons including their unavailability, low clarity, low salience, and/or low reliability, as well as the difficulty of mapping them onto key journey timings. Below, we explore each of these challenges in turn.

4.2.1 Unavailability of Clear Cues. Sometimes, the cues participants used to rely on for journey-monitoring, such as those delivered by public-transit stop-announcement systems, were simply not present. Even when they were, however, a variety of environmental constraints made them unclear and/or not salient enough for participants to notice or understand clearly. For example, when relying on visual information such as LED displays of stop names, one commonly mentioned obstacle was the distance between the passenger and the signal source. On buses, P04 told us, *"the place where it shows the information is too far away. There is only one place that shows the information, and that is above the driver"*. Other participants mentioned that crowding on public transit not only made the displays difficult to see, but also hard to move closer to. *"Sometimes I don't really want to look at that map on the Metro, because there may be too many people standing in front of it. Or every time I look at it, I have to tell other passengers to let me go through"* (P13).

When relying on auditory information from stop-announcement systems, noises in the environment commonly interfered. This was especially challenging when the participants' tasks-at-hand were also auditory in nature, e.g., listening to a podcast, as P18 noted: *"You need to pay attention to the podcast when it's noisy, and you don't know where you are, especially when you need to wear headphones [... as doing so] makes you unable to hear the Metro announcements. Then you miss the stop."* To overcome this challenge, some participants developed strategies such as trying to sense changes in the flow of the crowd. Others reported that they simply had to abort their tasks-at-hand: *"The bus is quite noisy, and then the volume of the station announcement is very low, so if it's rush hour, I can't hear clearly, so I will watch the electronic scroll"* (P14). Such obstacles caused some participants to be uncertain about when to disembark, causing them to become anxious and, in some cases, to choose to complete their tasks-at-hand immediately and exit the vehicle sooner than was strictly necessary. And most of the time, the participants had to expend extra effort to seek other, clearer cues; and this additional effort negatively affected the quality of their tasks-at-hand. As P02 told us, *"I had to look out the windows. Some buses don't broadcast [stop announcements], don't know why, maybe it's broken, so I can't focus on listening to the radio."* Others felt they had to check the scroll frequently, which was burdensome and did not allow continuous task focus, making trips especially stressful for participants with urgent tasks.

4.2.2 Receptivity. Even when the cues they relied on were available and clear, our participants were not always receptive to them, normally because they were concentrating on their tasks-at-hand. Many reported that this was especially common when the task-at-hand was urgent, leading them to be so focused on it that they did not notice whether the vehicle was emitting journey-monitoring cues or not. P02, for example, told us: *"When I arrived at the station, I was like, 'Oh my God! I got here!', and I grabbed all my belongings and threw them into the bag. But it turned out that I had missed my stop."* Some said they concentrated so hard on their tasks-at-hand that they often missed opportunities to get off the vehicle in time, even when they had noticed their stop being announced. *"I heard that we were about two stops away from where I should get off, and I thought I should wait and listen to the announcement for two more stops before preparing. It turned out that I exceeded three stops. I'm like, 'Oh no! I didn't hear that'"* (P06).

Travel monitoring became particularly difficult when the modality of travel-porgression cues overlapped with that of the participants' tasks-at-hand. Some even adjusted their task choices to keep their cue receptivity high. As P10 explained, *"I choose not to play games that require my concentration."* P04, on the other hand, said that he purposefully made himself uncomfortable to avoid failing to notice announcements. *"I prefer to stand now. Standing itself is not that comfortable and costs you more effort. This makes you more alert and so less likely to miss stops."* Some participants, however, were able to use pre-planning to balance tasks-at-hand and travel tasks without anything being sacrificed. For example, anticipating that she would have to concentrate on her work while taking the Metro, P08 set a phone alarm to remind her it was time to leave.

"When I'm so focused on work, I don't pay attention to the time on my phone, I don't want to pay attention to whether there is anyone around me who wants me to give up my seat, or how crowded it is, or what everyone else is doing. I don't care about things like that. That's when I [...] estimate the time and set the alarm to remind myself to get off."

4.2.3 Cues Not Reflecting the Actual Situation. In some cases, participants were not confident that a travel-progression cue reflected the actual progress of their trip. This was mainly for two reasons. First, some participants did not find it easy to map the cues they received onto their actual travel task. For instance, the scenery outside the window was sometimes used as a reference for when to get off a bus, but some participants noted that this was only useful when they were familiar with the route. As P12 said, *"I'm not familiar with the route. During the bus ride, it's hard to tell when I will arrive. I can't identify where I am now by the change of scene."* This prompted them to actively seek other cues, especially when they suddenly realized that they might have already missed their stop. Second, some participants mentioned that certain cues, such as information on both in-vehicle displays and bus-tracking apps, tended to be unreliable or inaccurate, or that the information provided by different sources was inconsistent. This not only worsened their task-at-hand performance at the moment of its occurrence, but also had a long-term influence on their activity choices and transportation-mode preferences. The unreliability of one cue source tended to prompt the participants to expend extra effort on cross-validating its information using multiple sources. As P10 explained, *"There are two ways to display arrival information on the bus in Taipei. One is an electronic scroll placed in the front of the bus, showing only the next stop. The other is an electronic board that tells you the estimated time of arrival at each place. Normally, the scroll is not accurate, so I usually don't rely on it. But if there is a board that tells you the arrival time of the coming bus, I will accept it."* Even so, however, P10 said she was prone to using GPS information from Google Maps to identify when to get off. She also noted that having to cross-validate the progress of her journeys via multiple platforms and information sources fragmented her attention, and thereby rendered her task-at-hand performance lower than expected.

4.3 Concerns and Challenges Arising from Public Transit's Dynamic Environment

Last but not least, challenges arising from the constantly changing environment of public transit itself also impacted our participants' travel multitasking practices and performance. Details of these challenges are presented below.

4.3.1 Unstable and Vibrating Vehicles. The most frequently mentioned transit-environment challenge was executing tasks-at-hand in moving vehicles beset by heavy vibration, which at best had a slightly negative impact on task quality, and at worst, placed the participants in danger. Specifically, although not all participants' tasks on their phones were influenced by vehicular vibration, some mentioned that they often needed to perform tasks that required precision and care. As P06 noted, *"Making slides requires more skills. You must precisely move the cursor to a certain location."* In addition, several participants mentioned that, because of vibration, they had to hold onto handgrips/handrails to keep their balance, with the result that they could only perform a limited range of tasks. P11, for instance, commented, *"I could only do things that were convenient to do while holding a mobile phone with one hand, like replying to messages."* However, using one hand was still perceived as less efficient, as P08 noted: *"I didn't have any door nearby, and worse, nothing to lean on. All I could do was grab the handrail, and you just swing with the carriage. I could thus only use my left hand to scroll the phone, but it was slower."*

Additionally, participants mentioned that vehicular vibration made it difficult to keep track of their progress when reading. To help themselves track it, they had to highlight text constantly, as P02 explained, *"When the intercity bus wobbled, it would make me suddenly unable to find which line I was reading [...]. So, I had to highlight the line I'm reading, so I can know if I lose my place later, I'll know where to continue reading from."* Others mentioned that when vehicles shook severely, they had to cease their tasks, as persisting would have made them feel uncomfortable, or even nauseated: *"I don't stare at the screen while the vehicle is moving or vibrating. [...] It keeps wobbling and makes me dizzy"* (P12). To overcome this challenge, P19 said, he *"bought a small tool with clips at both ends, one for the phone and the other for the handle of the chair. [...] When the bus vibrates or is unstable, the phone and clips move with the bus and me simultaneously so you won't feel nausea."* However, in vehicles that vibrated so severely that the participants perceived a risk of falling, they had to pause their task-at-hand until the vibration stopped (e.g.,P18).

4.3.2 Concerns about Constantly Changing Passengers and Close Contact with Them. The high turnover rate of passengers in the small and constrained public-transit environment led many participants to express concerns about multi-tasking in such environments. These concerns involved their property, health, and safety, and arose due to their awareness that other passengers were constantly changing and that there were many strangers with whom they might come into physical contact. These concerns not only influenced participants' seat choices but also distracted them from their tasks-at-hand, as they felt they had to increase their alertness to their surroundings to facilitate quick reactions if needed. For example, P18 mentioned that when he was reading, being surrounded by a crowd of people made him worry about his personal belongings being stolen. This worry made it difficult for him to concentrate on the task-at-hand because he had to repeatedly check his belongings: *"When you're focused, you would fear things being taken away. [...] Like your phone or keys, you put them in a place where your backpack can be locked, but when there are many people, you're still afraid of things being stolen, so you will still check again. [...] I had to put them where I could easily touch them."*

Several participants mentioned that due to the COVID-19 pandemic, they had become more protective of their personal health. For example, P13 mentioned that she would change her seat or stand away from a crowd of people, which influenced whether she had a seat in which she could undertake her task-at-hand. *"I want to avoid people who are sneezing, and if they don't cover their mouths, I'm more likely to be infected. So, I used to stand at the end of the car because I didn't want to be exposed to this kind of cough or sneeze."* P09 also considered health issues when choosing a seat

on high-speed rail: *"If alone, I prefer to pick a window seat, since it makes me feel less in contact with other passengers."*

Several others mentioned the Taipei Metro attack in 2014 [1], and particularly, how it had led to them developing the habit of intermittently checking their surroundings and reminding themselves not to concentrate too much on their tasks-at-hand on public transit. *"Since that incident happened, I'll be more aware of the environment while watching a video [on my phone]. I'll watch the video a little bit and then look around at what's happening nearby, and I'll be less focused on what I'm doing. I tend to focus more on observing people around me, like fifty-fifty, to see if there are any weird people"* (P06). Similarly, when shadowing P04 on the MRT, we noted that he regularly looked up and watched people getting on and off at every stop. In his debriefing interview, he told us that he raised his head frequently because he wanted to be alert to any potential dangers or unexpected situations. *"I like to see what the other passengers look like, to avoid danger [...]. I assume what they might want to do or if they have an emergency. Just in case, I'll take a look. [...] I wanted to wait until the door was closed"*. This tendency had accustomed him to switching his attention whenever the vehicle arrived at a stop, and as a result, we observed that his attention to his task-at-hand was never longer than two minutes.

4.3.3 Concerns about Privacy and Personal Image. Finally, some participants also expressed concerns about their privacy and personal image when they were aware of the presence of many other people on public transit, and told us that such concerns affected their task choices. For example, P26 said, *"If I need to pay with a credit card for online shopping, I will try to use it at home, because I have no way to fully ensure my privacy on public transportation"* (P26). He later noted that, *"as a journalist, I would try not to let other people see the content of my interviews and the issues I am preparing before publishing."* Indeed, above a certain level of crowdedness, some participants chose not to perform any tasks-at-hand at all, not because they did not want to, but because they perceived that their action might negatively affect other passengers. As P13 explained, *"if it is crowded, taking out my phone might lead to me accidentally hitting people, so sometimes I avoid this kind of action, and then I think it's better to do nothing."* P02, on the other hand, preferred to only undertake simpler tasks-at-hand to avoid spending too much time packing when someone needed his seat. *"If I want to give my seat to someone else but have to pack up a lot of stuff, by the time I'm done, he may have passed out or he'd be really pissed off."*

Interestingly, however, some participants regarded the presence of many other people on public transit as positive pressure to perform tasks-at-hand, and said they would deliberately engage in certain activities on a vehicle to present a positive image to its other passengers. P14, for example, mentioned one occasion on which she wanted to project a diligent attitude toward learning: *"I have some strange insistence, that is to be perfect in front of strangers, so that people next to me will think, 'Oh, this young lady is so hard-working, she is not looking at the people around her but at her books.' Anyway, at that time, I forgot to get out of the [train and...] was late for my event because of this."* P18 also noted that he *"rarely read books in daily life, but do so on public transit. [...] Reading books looks cool, I think [laughter]."*

[1] https://en.wikipedia.org/wiki/2014_Taipei_Metro_attack

5 DISCUSSION

5.1 Motivation is Key in Travel-Based Multitasking

As noted in our literature review, prior research on travel multitasking has largely focused on the activities people engage in during their journeys to leverage the travel time [52], and the effects on those activities of factors predetermined by the researchers [32]. However, none seems to have explored the influence of motivations behind travel multitasking behaviors. Our results suggest that such motivations are deserving of considerable attention – indeed, more attention than multitasking activities themselves – because the former more clearly reflect travel multitaskers' support requirements.

Specifically, we have shown that these motivations played the key role in determining how insistent the participants were about performing a specific task-at-hand (vs. changing to a different one); how strongly they concentrated while performing it (vs. being easily distracted); and how much task progress they expected to make, and how high they expected the quality of their work to be (vs. no expectations). All of these factors influenced their receptivity to cues/signals relevant to their travel tasks, their task-at-hand performance, and their ability to adapt their tasks-at-hand to their public-transit environments. Thus, while Axtell et al. concluded that people would adapt both their tasks and contexts to overcome obstacles to working while traveling [3], our results instead suggest that whether public-transit passengers change their task choices may depend chiefly on their motives for multitasking.

Consequently, to the best of our knowledge, the current study is the first to have analyzed and recognized the underlying motivations of travel multitasking; and, based on its results, we argue that recognition of such motivations has important implications for design. We discuss those and other implications in the next subsection.

5.2 The Mixture of Influences on and Challenges to Multitasking on Public Transit

Our observational and interview data both indicate the variety of influences on participants' multitasking practices and performance while on public transit, and that these influences arose both from environmental dynamics, and personal motivations. However, what makes the challenges of travel multitasking distinct from those of multitasking in other contexts such as the workplace [11, 43] is that travelers all share the same primary task – arriving at their destinations – which not only requires them to take actions at very specific timings that are beyond their control, but also can be disrupted by varying, and sometimes unpredictable, changes in the public-transit environment. Thus, when the participants found themselves losing track of the progression of their journeys, and also perceived that missing their stop would be costly (whether in terms of delaying their subsequently scheduled events, or losing face in front of other passengers), nearly all of them assigned a higher priority to their travel tasks than to their tasks-at-hand, sacrificing the quality and/or progress of the latter.

However, these conflicts were not rare. Many participants in our study had experienced rushing to disembark or even missing their station/stop because cues about when to exit the vehicle were unavailable, not salient, non-straightforward, or unreliable, and thus failed to help them establish awareness of their journey's progression. These cues were especially crucial to participants who had become immersed in their tasks-at-hand. Additionally, some such cues were delivered in modalities that overlapped with those of the participants' tasks-at-hand, while others had lost the participants' trust due to their past unreliability, and cross-validating their information was a further distraction from tasks-at-hand. For many participants, the trade-offs between the travel task and the task-at-hand that resulted from the aforementioned challenges and issues could have been avoided, if the public-transit systems they were using had provided cues that were more readily perceivable, more reliable, and delivered at more opportune moments.

Finally, the fact that the characteristics of Taiwanese public-transit contexts varied rapidly and profoundly further complicated and hindered multitasking. Environmental and social challenges – including vehicle vibration and lurching, crowdedness, fellow passengers' unpredictable behavior, and the participants' own desire to sustain their personal images – could arise at any time during journeys on any of our five categories of public transit. While some of these challenges did not have direct negative impacts on tasks-at-hand, they heightened participants' concerns about their personal safety and well-being, and this in turn distracted their attention from such tasks.

It is noteworthy that, although the literature on travel multitasking has mentioned some of these or similar challenges, including the need for privacy [3, 62], social perceptions [10], and personal security [45], none appear to have been investigated in depth; and therefore, questions about their effects on travelers' multitasking practices have long remained unanswered. Through the identification of challenges to travel multitasking in this study, we hope to draw transit-service providers' and other relevant practitioners' attention to ways in which the infrastructure and environment of public transit, as well as novel mobile services, could better support this increasingly prevalent behavior.

5.3 Which Task Should I Pay Attention to? The Potential Influences of Familiarity and Transportation

Not all participants appeared to have encountered the same level of conflict between travel tasks and tasks-at-hand, and thus, the amount of attention-switching they reported also varied sharply. While various factors play a role in attention-switching, we found its major drivers in the context of travel multitasking were 1) people's familiarity with the travel task and/or the task-at-hand, and 2) how concerned they were about changes during the journey that were specific to the mode of transportation they had chosen.

Specifically, according to our observations and our participants' self-reports, some participants seemed to manage disembarkation well without having to frequently check the progress of their trips, despite performing tasks-at-hand, whereas others frequently self-interrupted to check such progress, or even paid attention to the travel task most of the time. These data resonate well with the concept of a multitasking continuum [54], with one end being concurrent multitasking (in which there is no need to frequently switch attention) and the other being sequential multitasking (in which frequent attention-switching is absolutely necessary). Specifically, we found that in cases where the participants reported being highly familiar with the critical timings of their travel tasks, including when to pack up and/or when to disembark, such tasks did not demand much in the way of attention and other cognitive resources; and thus, they were able to undertake the two tasks concurrently and successfully. Likewise, when participants' tasks-at-hand were simply habitual, they were also able to perform both tasks concurrently and effectively. In contrast, if the participants perceived that both tasks demanded their attention, time, or cognitive effort, they tended to adopt sequential multitasking behavior: i.e., switched their attention between the two tasks. Because many of the participants' motivations for travel multitasking were not to kill time but to make progress on or complete specific tasks that demanded their cognitive resources, their familiarity with the journey became crucial to whether and to what extent they could concurrently multitask; and therefore, whether they had to frequently switch their attention between their two tasks. As noted by Salvucci et al. [54], when performing sequential multitasking, retrieving a representation from memory takes time, and attempts to do so are not always successful. In this vein, some of our participants who engaged in sequential multitasking told us that their task-at-hand performance was not as expected because they had needed to pay too much attention to changes in their external environments. Yet, while such difficulty might make some people change their task choices [18], it is important to recognize that, as our results have shown, people are often strongly motivated to undertake specific tasks-at-hand that lead (or indeed force) them to sequentially perform those tasks and their travel tasks. As a result, we deem travel multitaskers who are unfamiliar with their routes as most in need of technological assistance to make their travel multitasking more effective.

Another notable factor was the participants' concern about journey unpredictability. For example, they seemed to generally perceive that buses/shuttles were more unpredictable than other forms of public transit, not only in their fluctuating schedules, which are easily affected by traffic conditions, but also in their jolting and vibration that can be caused unexpectedly by poor road conditions. Due to such unpredictable variations, many of our participants felt that they needed to be more alert in general and to pay more frequent attention to the progression of their trips when taking buses or shuttles than they would otherwise. The Metro was regarded as largely free of the same unpredictable factors, but had its own, in the form of constantly changing passengers. Though of course bus passengers also change regularly, the participants perceived that, on the Metro, they encountered much larger and more diverse crowds of strangers, whom they were also more likely to be physically close to.

It is noteworthy that, while our participants felt a need to increase their alertness and had switched their attention away from their task-at-hand on both buses and the Metro, the target to which they switched their attention, and the reason for which they switched it, differed in each case. This difference might suggest a different set of design implications for the different classes of public-transit service providers involved. Unfortunately, however,

our qualitative data do not allow us to make quantitative comparisons of these aspects. Therefore, we encourage future researchers to extend our investigation to the question of how the presented challenges and concerns differ quantitatively across different modes of transportation.

5.4 Design Implications

By their sheer quantity, our findings about challenges imply that there is considerable room for improvement in the technological facilitation of multitasking on public transit. Our first high-level recommendation is therefore to take people's motivations for travel multitasking into account when designing or redesigning public-transit infrastructure. Specifically, future technology designed to support multitasking on public transit should be context-aware and employ techniques to either collect or autonomously learn individuals' primary or frequent motivations. This information can be collected through profile-building during onboarding or prompted questionnaires. Alternatively, the information can be learned through training a machine-learning model based on features extracted from people's patterns of task choice, task length, task switching, and sensor data from their devices, among others.

In addition, prompted questionnaires can be utilized to gather labels for task sessions. Prior research has successfully characterized app sessions [64] and distinguished moments when people are bored [48] or "killing time" [13]. We believe that a motivational model of travel multitasking can be built upon these previous studies. Once individuals' motivations are recognized, trip-planning apps or public-transit services can provide suggestions of tasks or locations tailored to them, according to whether the motivation is related more to the available time or to the task itself. For example, passengers who have an explicit need to complete a specific task, such as catching up on urgent work, will be more likely to accept location suggestions than task suggestions. In addition, travel multitaskers motivated by the urgency of work are likely to concentrate strongly on their tasks-at-hand, to the extent that they might miss their stops. As such, they may need more salient cues reminding them to disembark than passengers with other motivations do.

Second, we learned from our participants that when travel multitaskers were familiar with both the temporal and environmental characteristics of their journeys, they could – and often did – plan their tasks-at-hand in advance. Therefore, our second high-level recommendation is to enhance travel multitaskers' awareness of the characteristics of their upcoming public-transit journeys, including their overall durations, the lengths of the intervals between stops, noise levels, the spatial distribution of seating and standing areas, the locations of stop-announcement displays, etc. Such information can be supplied either directly by public-transit services or via crowdsourcing, which has already been leveraged to obtain public-transit crowdedness information [49].

Third, we have shown that travel multitaskers confront three main types of challenges to their travel tasks, and that their worries about losing track of their journey progression – and, in particular, about missing their stops – repeatedly and negatively impact the progress and quality of their tasks-at-hand. Thus, our third high-level recommendation is that travel multitaskers should be supported in tracking their journey progression by addressing all of those challenges.

Fourth, it should also be borne in mind that travel multitaskers can be at various places within a vehicle and perform tasks involving a variety of information modalities, and that our participants frequently switched their attention among many displays, including but not limited to the devices they were using for their tasks-at-hand and vehicle-mounted electronic scroll screens. As such, we recommend that public-transit services recognize this increasingly prevalent second-screen phenomenon [39, 40] and diversify the channels whereby real-time updates about a vehicle's current location, speed, and/or upcoming destinations can be accessed by its passengers. This could be accomplished via browsers, official transit-service apps, third-party apps, and vehicle-mounted physical displays of existing and new types. This would allow passengers flexibility in accessing the required information across channels, and reduce the unnecessary attentional cost of switching between devices.

Fifth, we recommend that passengers be enabled to set their own time- and/or position-based reminders, which would alert them to travel-progression information via the same devices on which their tasks-at-hand are being conducted. Such alerts should allow configuration of their dismissability, among other forms of customization to be established by future user research. A countdown feature, for example, might usefully be included to give passengers a sense of urgency [36] about wrapping up their tasks and packing their belongings.

If adopted, the above design recommendations can reasonably be expected to promote less attention-switching between travel tasks and tasks-at-hand. However, we would like to stress that such recommendations should not be taken as encouraging people to devote all their attention to their tasks-at-hand. Rather, based on our observations that some participants concentrated so hard on their tasks-at-hand that they seemed to become totally unaware of their surroundings, our sixth and final high-level recommendation is to enhance travel multitaskers' awareness of potential dangers around them. Specifically, real-time safety and security information and warning alerts could be provided via transit services, according to the location of the vehicle or the direction it is heading in, based on governmental statistics and/or crowd-sourced information about the relevant areas.

5.5 Research Limitations and Future Work

There are several limitations of this research that could negatively influence the generalizability of our paper's findings and/or the strength of its claims. First, as it is a qualitative study based on shadowing and interview data, its results do not allow us to make quantitative claims about the impact or prevalence of specific factors we have identified as impacting travel-multitasking practices, or about such factors' interrelationships. Thus, although our participants mentioned certain challenges and concerns more often when discussing some transportation modes than others, and some travel-multitasking situations than others, we cannot draw any firm conclusions about frequency from those data. Additional quantitative research is therefore needed to address questions of how the factors we have identified – such as transportation mode [16], familiarity/novelty of the route [18], and companions [63, 65, 67] – are correlated to the motives, challenges, and concerns identified in our study.

Second, our data-collection approaches, including shadowing and interviews, primarily focused on lone-passenger scenarios. As a result, the extent to which our results apply to multitasking behavior that occurs when passengers are traveling in pairs or groups remains unclear.

Third, our results might have been affected by recall bias [50], insofar as a considerable proportion of our findings were derived from the participants' recall of their previous public-transit experiences. Additionally, because our research was conducted in the midst of the COVID-19 outbreak, some participants had not used public transit for a long time prior to their interviews, and this time-lag would have tended to magnify such an effect. Although a key strength of interviewing as a method is that it enables researchers to obtain people's in-depth reflections on their motivations, needs, attitudes, and feelings, as well as details of their specific experiences, multitasking behaviors are nonetheless situated behaviors, and one's own *in situ* reactions to environmental stimuli are often infeasible to recall. To address this limitation, future researchers on this topic should consider including relatively more introspective methods such as experience sampling [35] and participant observation [4] to record people's public-transit travel experiences *in situ*.

Fourth, the durations of our observations of the participants' behavior via shadowing were quite limited in duration. Specifically, each participant was only shadowed on one trip lasting between 15 and 145 minutes. This prevented us from observing their behavior across multiple trips, trip purposes, transportation modes, times of day, and times of year. As a result, we had to rely on their self-reports in interviews to obtain such data. In addition, during shadowing, the presence of researchers might have influenced the participants' decisions about what tasks to perform, and/or other aspects of their behavior. Although we told the participants that they should behave as they would normally do, and that we would not interfere with them and try to stay out of their lines of sight, two participants told us in their debriefing interviews that they were unable to ignore the fact that they were being shadowed. Although the majority of the findings were based on participants' reflections, this limitation could have prevented us from observing some natural multitasking behaviors.

Finally, in terms of generalizability, the majority of our participants were selected as having high levels of polychronicity. So, despite the targeted population of the current study being travel multitaskers, our findings should not be assumed to be generalizable to all public-transit passengers. In addition, our sample size of participants was small and limited to people in one Asian country. The participants' age-range was also fairly limited, with none under age 21 or over 50, and an average age of 26.7. Although we can discern similar patterns of travel multitasking behavior between the participants in our study and those in previous studies conducted in other countries, it is unclear whether our findings can be generalizable to travel multitaskers who are older or younger, and/or who live in countries where public-transit infrastructure and/or health-and-safety policies differ sharply from ours. Moreover, given that the current study was conducted against the backdrop of the COVID-19 pandemic, it is likely that the participants were engaging in social distancing, further limiting the generalizability of our results to periods without infectious-disease epidemics. That being said, however, we believe the results of the current study, though preliminary, are an important step toward drawing research attention to the complex focal phenomena.

6 CONCLUSION

This qualitative research on multitasking behavior on public transit makes three main contributions to the literature. First, it appears to be the first study to identify and discuss the influential role of travel-multitasking motivations, for which it provides a novel four-part typology. It shows how differences in these motivations shape travel multitaskers' task choices, expectations about their tasks' progress and outcomes, and receptivity to travel-task-related public-transit cues. Second, it delineates the three main types of challenges to travel tasks and tasks-at-hand caused by these two task classes' mutual interference. And third, it identifies three additional types of challenges arising from instability and rapid variation in public-transit systems' physical and interpersonal surroundings. In addition to these contributions, we have offered five practical high-level design recommendations for public-transit services and other service providers who hope to improve people's travel-multitasking experiences.

ACKNOWLEDGMENTS

We greatly thank all of our study participants. This project is supported by National Science Technology Council, Taiwan (110-2222-E-A49-008-MY3, 111-2221-E-A49 -164), as well as the Higher Education Sprout Project of National Yang Ming Chiao Tung University and Ministry of Education (MOE), Taiwan.

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