# Digital Directions: Smartphone Usage while Performing Wayfinding Tasks in Munich's Public Transit System



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***Abstract /***

Wayfinding in spatially complex public transit environments poses unique navigational challenges. Transfers, delays, barriers, and user capacity all influence the usability of a system. Because of the smartphone, how we navigate through these systems, and interact with the surrounding environment is changing. The smartphone provides a spatio-temporal strategy that removes the reliance on our immediate environment and personalizes the wayfinding process — unlike that of transit schedules, signs, and maps. How does smartphone usage influence performance and the wayfinding experience? This paper looks at smartphone usage of twelve participants through a shadowed commented walk, known as a Destination-Task Investigation, in Munich's public transit system. The study provides insights into the role and the influence of smartphones during the wayfinding process. Furthermore, it shows that apps providing integrated spatio-temporal information, such as Google, were used most frequently, especially for confirmation during navigation.

***Keywords /***

Smartphone Technologies; Public Transit; Wayfinding

## INTRODUCTION

The ubiquity of mobile and communication devices today is a result of a rapid societal adoption of new technology over the last few decades. Part of this acceptance of new technologies includes the success story of the smartphone and its advanced level of communication and geo-positioning capabilities on a higher resolution and interactive display (Boulos, et al., 2011; Fullwood, et al., 2017; Perrin, 2017; Melumad, et al., 2019). As smartphones gained popularity, so did the way they infiltrated the many aspects of everyday life — including the way we navigate, particularly focusing on helping us in environments that are unknown, by customizing wayfinding (Schwering, et al., 2017; Melumad & Pham, 2020). This customization can either aid a user, by presenting a concise route and clearly labeled connections, or hinder a user by producing contradictory information compared to their physical surroundings. For example, a smartphone provides a user with navigational options through applications, or apps. These apps are either third-party entities with their own strategic goals, or apps directly controlled by local transit authorities and not always able to capture all scheduling delays, nor provide all different transfer options to the user (Bian, et al., 2021). Quite often the information provided contradicts and/or overlaps with other sources of information provided by other apps or websites, leading to fragmented and incoherent provision of navigation information. This, in turn, results in the user having conflicting advice during their transit experience.

For a quickly growing portion of the population, the wayfinding process now incorporates the use of smartphones. In Germany, like many other Western nations, over the last decade, the smartphone has become more commonplace, as ownership levels have been trending upward and nearing 60% of the total German population by 2019 (VuMa, 2019). With the emergence of extensive availability of WiFi and GPS technologies in public spaces, the opportunity to use one's smartphone has become convenient, and in many cases, more preferred than using one's physical surroundings during navigation.

Wayfinding is a purpose-filled action that includes both a *'decision-making'* and *'decision-execution'* process in order to get to a chosen location (Arthur & Passini, 1992; McDonald & Pellegrino, 1993; Allen, 1999). When individuals are in an unfamiliar environment and wish to better understand their physical positioning, they formulate a navigational plan using their surroundings while moving through the environment. *Wayfinding* can be further understood as the cognitive ability to sense the space one is in, and problem solve to get to one's destination. When viewed through the lens of goal-making and goal-achieving, the success of wayfinding depends on whether the spatial and temporal limitations are met by the individual doing the navigating (Arthur & Pasini, 1992).

The wayfinding process in public transit environments is a spatio-temporal activity with a particular emphasis on the temporal component compared to other forms of wayfinding due to the heavy reliance of transit schedules and timing (Dziekan, 2003; Woyciechowicz & Shliselberg, 2005). The process can be broken into three crucial wayfinding practices: *Preparation*, *Confirmation*, and *Adjustment*, which are stages experienced in one's personal wayfinding (Denis, 1997; Timpf, 2006).



A smartphone provides individuals with both spatial and temporal solutions. Instead of relying on their immediate surroundings, with help from a smartphone, an individual can tailor and personalize their wayfinding experience in public transit. The smartphone has become like a digital "*Swiss Army Knife*" for wayfinding – allowing users to manipulate their wayfinding experiences unlike that of a paper based map and schedule, as it provides users with a dynamic interface, and instantaneous spatio-temporal alternatives (Brakewood, et al., 2014; Melumad, et al., 2019; Bian, et al., 2021).

The readiness of smartphones and their ability to access a wide range of navigational information allows individuals to perform wayfinding tasks using a surplus of information outside of their physical environment. On one hand, this allows for the ability to customize one's wayfinding. On the other hand, competing ontologies increase the complexity of navigational options and conflicting informational intake (Timpf, 2002; Richter et al., 2010). From this, our understanding of expected wayfinding behavior in public transit begins to shift, as the aspect of a step-by-step navigational route summary provided by the smartphone becomes used as a personalized and fragmentary path selection strategy by the user.

Smartphone technologies in wayfinding have only recently been studied. Bian et al. (2021) provide one of the first systematic literature reviews of existing smartphone transit app research, where they also indicate that more comparative research surrounding the difference between private and public app services is needed. Reilly et al. (2009) approach the topic of shared mobile devices in wayfinding situations – the focus being on social interactions and group navigation with mobile technologies. Several other studies have shown that mobile technologies have shaped the way individuals approach and behave in public transit. For example, Line et al. (2011) point out the significance of how quickly mobile technologies have integrated into daily life, including wayfinding experiences. They further explain how mobile technologies help users to better understand and navigate the uncertainties of public transit by contributing to a *'time-space co-ordination',* further emphasizing the spatio-temporal aspects of wayfinding, (Gollege, 1999; Golledge, et al., 2000; Montello, 2005; Timpf, 2006). This time-space coordination plays an essential role for wayfinding to be successful and for the user to reach their destination goal. The inclusion of smartphone usage in the wayfinding process further adds to the certainty of an individual's time-space coordination, while the complexity of combining the ontologies of both virtual and physical worlds increases uncertainty of their personal process as users struggle to switch between the two worlds (Timpf, 2002; Willis, 2005; Waters & Winter, 2011). Münzer discusses the shortfalls of mobile and computer based navigational systems versus map-based navigation and the implications this has on spatial learning (Münzer et al. 2006; Münzer, et al. 2012). The combination of research about both human wayfinding and public transit is relatively niche, with works such as Fontaine and Denis (1999) looking at route descriptions, and Rüetschi and Timpf (2004) who discuss the description of network (public transit network) and scene space (nodal environments, such as stations and platforms, found within public transit systems), that have formed notable contributions to the state of the art. The addition of smartphone technologies to the niche field of public transit wayfinding systems adds another layer of intricacy, but also helps to connect the two research fields by focusing on an increasingly important aspect of both human wayfinding and public transit design – the smartphone. The 'smartphone usage' in this paper refers to the multitude of functions, including apps, a smartphone provides a user during wayfinding.

The explorative study presented in this paper addresses the gap in literature surrounding smartphone usage in transit wayfinding by observing users' wayfinding experiences. Its main goal is to better understand spatio-temporal changes in the wayfinding process related to customization of wayfinding information by smartphones, and provides implications for how much of a role the smartphone, and subsequent navigational apps, play in human thought process and decision-making. The paper focuses on the individual user experience during the wayfinding journey, as a positive user experience is a central aspect of public transit system mobility.

### *The Setting*

With 1.3 million people, Munich is Germany's third largest city. Its public transit network is made up of two partner transit authorities; the local transit authority (the MVG), and the national Deutsche Bahn (DB) services. Both authorities share some stations and hubs, and transit options occasionally overlap. The entire system is extensive with over 95 km of underground lines, 79 km of tram tracks, and a bus network of 467 km, serving over 1.5 million rides per day (MVG, 2015). In 2015, the MVG surveyed residents' usage of the public transit network and reported that 67% of residents are regular users of U-Bahn, bus, and/or tram at least once a week, and 38% of residents claimed to use the multi-modal network daily. The MVG found that there were over 566 million passengers on public transit in 2015 alone (MVG, 2016).

A third player in the Munich public transport system is the Münchner Verkehrs- und Tarifverbund (MVV), the overarching tariff association integrating MVG and DB services. All three authorities provide wayfinding information which results in overlapping wayfinding systems. With its multitude of transit options and indoor-outdoor transfers, the Munich public transit system provides an optimal location to observe individuals navigating through complex wayfinding situations, and can shed light on underlying theories in wayfinding design and cognitive engineering.

## METHOD

We used qualitative mobile interviewing technology that was able to capture the wayfinding process and practices of individual participants. Mobile interviewing techniques, such as commented walks and participant shadowing, have gained importance with the shift to studying mobility in the social sciences (Sheller and Urry 2006; Büscher and Urry 2009). These methods allow for a participant-centered approach (e.g. Levy 2001 (for main station wayfinding); Holscher, et al. 2007; Kazig & Popp 2012 (for inner-city and main station wayfinding); Meissonier & Dejoux, 2016). They elicit real-life qualitative empirical insights about how users perceive, process, and interact with smartphones in the wayfinding process. Drawing examples of this paradigm, a special Destination Task Investigation (DTI) was developed for the project consisting of two parts:

i. Destination-Task Investigation (*a shadowed commented-walk, and observation of wayfinding behavior of participants while they navigate through the transit system*); *and*

ii. A subsequent interview based on a Cognitive Map (*self-reflection drawing by the participant of the wayfinding experience (Lynch, 1960)*).

Additionally, a short, guided introductory interview was employed at the beginning of the DTI to understand how the participant prepared for the DTI, their use of the public transit system, and their opinions towards public transit in general. This information was important during the

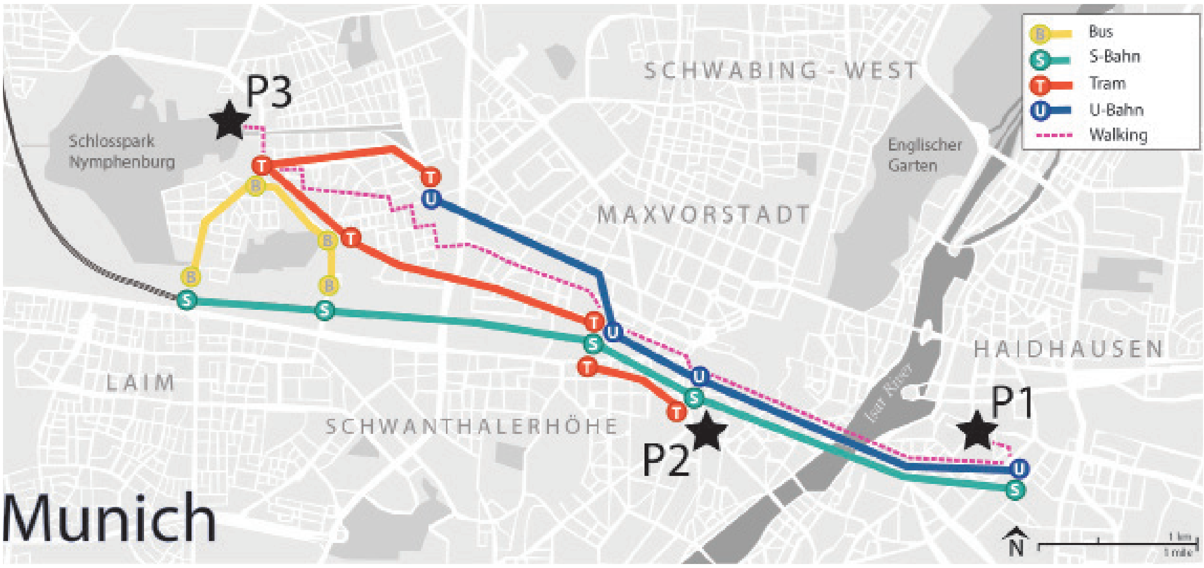


*Figure 1 /*

The route (including P1, P2, and P3) and mode options participants had during the DTI

interpretation process as it enabled us to better understand the behavior and navigational choices of the participants during the DTI experience. The structure of the DTI made it possible to investigate the first-hand transit experience of participants in transit hubs, transfer stations, and so called 'scene spaces' (Rüetschi and Timpf, 2004), and helped to shed light on participant smartphone reliance and behavior.



### Destination-Task Investigation

The study consisted of twelve participants (seven men and five women) between the ages of 25 and 45, all of whom have lived in the Munich region at least one year. Participants were selected on the basis of being familiar with Munich's transit sytem. All participants had used Munich public transit before. Some participants were already familiar with the destinations in the DTI, but, as the focus of this study was on public transport usage in everyday mobility, this was not a significant issue. Furthermore, due to the scope of the study, newcomers and tourists were not included. Additionally, all participants had an advanced knowledge of English as the DTI and interviews were conduced in English. Some homogeneity within the study group was established through this decision, which was appropriate given the scope of the study. Data collection was carried out between June 2019 and January 2020. Participants were selected through recommendations of colleagues. As all participants were tasked with finding the same pre-determined destinations, this helped guarantee the researcher was able to observe the participant experience through multiple mode changes. The DTI route [Figure 1], began in the eastern part of Munich (Haidhausen– P1), and took participants 9.1 km (5.65mi), to the western side of the city (Nymphenburg-Neuhausen – P3), with a mid-point at a transit hub, near the city's center (Karlsplatz/Stachus – P2).

The origin-destination locations were chosen due to their distance from one another, with the intention that an individual cannot travel to these locations directly and must transfer between modes to get there. The mid-point stop was added as a safeguard, to guarantee to the researcher a transfer would occur during the DTI.

The researcher sent the participants the meeting point and destination information 24 hours before the DTI started, to reflect more authentically real-life mobility preparation from the participant. Figure 2 gives an overview about the participants and their individual background.

| Participant | Age/ Gender Identity | Public Transit Frequency | Frequented Modes | Preferred Mode | Preferred Navigation Tool | Prepared for DTI | Familiar with Route |
|---|---|---|---|---|---|---|---|
| Lita | 29, F | Daily | U S B | S-Bahn | S X | Yes | No |
| Samuel | 33, M | Daily | S T | S-Bahn | S | Yes | Yes |
| Marek | 35, M | Monthly | B T | U-Bahn | L S X | No | No |
| Tobias | 33, M | Daily | U S B | U-Bahn | M S | No | Yes |
| Amy | 30, F | Daily | U S B T | Tram | I S | No | Yes |
| William | 43, M | Daily | U B | Tram | S | Yes | No |
| Trevor | 32, M | Monthly | U S | U-Bahn | M S X | No | No |
| Felix | 29, M | Daily | U S B T | S-Bahn | S | No | Yes |
| Mina | 31, F | Weekly | U B | Tram | S | Yes | Yes |
| Serena | 31, F | Daily | U B | U-Bahn | L M S X | No | No |
| Raye | 32, F | Seasonally | U | Tram | I L M | Yes | No |
| Simon | 28, M | Daily | U B | None | I S | Yes | No |
| | M=Male<br>F=Female | | U=U-Bahn<br>S=S-Bahn<br>B=Bus<br>T=Tram | | I=Intuition/Feeling<br>L=Landmarks<br>M=Maps<br>S=Smartphone<br>X=Signs/Arrows | | |

***Figure 2 /***

Participant Overview

After the introductory interview, participants were set up with recording equipment (both audio and video) for their DTI. Participants were instructed that they could use any form of help or assistance during the DTI. Emphasis was made that they were to do what they would normally see fit for navigating through the public transit network. For example, if they felt they wanted to ask for directions, look at a map, or use their smartphone, then they were encouraged to do so. Participants were to make their own navigational decisions with no interference from the researcher—accepting the fact that the presence of the researcher in itself brings along some interference. A main principle of the commented walks is that they are not so much organized by questions as by settings. This means that participants were asked to think aloud during the task: to speak about everything they perceive, decide, or do. The main objective of the researcher was to encourage spontaneous comments on the wayfinding process, but maintain no influence over a participant's decisions. The researcher would interject with questions when he felt he needed a better understanding of a certain navigational decision, but only when said question would not interfere with the participant's process. The shadowing allowed the researcher to observe a participant's immediate experience, which permitted the observation of performance and behavioral outcomes. This revealed further details of the wayfinding experience that would otherwise be overlooked through survey and questionnaires (Thibaud 2004; Popp 2018).

At the mid-point destination, seven of the participants were given a "rush factor" (for getting from P2-P3) from the researcher, stating there was a hypothetical individual impatiently waiting for them at P3. This rush factor was given to spot behavioral differences in participants in comparison with those who were not given any form of time pressure. At the end of the trip, both the participant and the researcher sat down at a local café and completed the subsequent interview and cognitive map portion of the investigation. Each DTI plus introductory interview lasted between 40 and 120 minutes.

The subsequent interview and cognitive map portion took another 15 to 30 minutes. All interviews took place during day time and with no rain – to further foster comparability of the trips.

### *Subsequent Cognitive Map Based Interview*

While the DTI itself captured the immediate wayfinding experience and practices in situ for the journey, the perspective was changed in the subsequent interview. Here, a reflexive analysis of the journey was undertaken. The interview took place at a local café at the DTI end destination. The café was chosen for its casual and relaxed atmosphere – as the intention was to remove the participant from the DTI activity. Participants were asked to draw their experiences, as a cognitive map and to mark each section of their drawing with green, yellow, or red to indicate positive, neutral, or negative wayfinding experiences in the corresponding section of their drawing. The intention behind expressing their experience through drawing was to allow for an exploration of emotions and communication (Reason, 2010). Building on these drawings, participants were asked to verbally communicate to the researcher their wayfinding experiences out loud, and in as much detail as they could remember, to reflect on their actions during the journey.



### *Data Collection and Analysis*

After completion of the DTI and the subsequent interview, all verbal materials were transcribed verbatim and coded for analysis using MAXQDA. For the coding scheme, the division of the wayfinding process practices of Preparation, Confirmation, and Adjustment were used to organize the protocols. The data was visualized through a modified Customer-Journey Map (CJM) by the researcher, which allows for a general overview and summary of a participant's journey (Bucolo & Matthews, 2011; Van Lierop et el., 2019). Observational notes were also taken by the researcher during and after the DTI. Interpretation of the modified CJM was based on coded transcripts, audio and video recordings, cognitive maps, and the documentation of observational findings. Specific participant experiences elicited through the study are organized along basic wayfinding practices of *Preparation, Confirmation, and Adjustment.*

## RESULTS

### *Overview*

Four transit modes (U-Bahn, S-Bahn, Bus, and Tram) were used during the DTI where most participants used between two or three modes [Figure 3]. For the first section of the DTI (P1-P2) participants were able to travel by S- or U-Bahn as the other options provided only indirect connections, which was considered too inconvenient by the participants. For the second section of the DTI (P2-P3), participants had access to more mode options and were also able to combine modes to reach P3.

Although not required for the study, all participants owned and brought their smartphone with them. In 11 of the 12 of the DTI journeys, the smartphone had influence in how a mode or route was chosen. The smartphone was an important navigational tool, as all 12 participants referred to it during their journeys. Between the 12 participants, there were 195 verbal indications

| Participant | Mode Choice *(P1-P2)* | Rush | Mode Choices *(P2-P3)* | | |
|---|---|---|---|---|---|
| Lita | S-Bahn | | Tram | | |
| Samuel | S-Bahn | | Tram | | |
| Marek | S-Bahn | | Tram | | |
| Tobias | S-Bahn | | Tram | | |
| Amy | S-Bahn | | S-Bahn | Bus | |
| William | S-Bahn | | S-Bahn | Bus | |
| Trevor | S-Bahn | | S-Bahn | Bus | |
| Felix | S-Bahn | | S-Bahn | Bus | |
| Mina | U-Bahn | | S-Bahn | Bus | |
| Serena | U-Bahn | | S-Bahn | Bus | Tram |
| Raye | U-Bahn | | Tram | | |
| Simon | U-Bahn | | Tram | | |

***Figure 3 /***

DTI Mode choice for sections P1-P2 and P2-P3. Participants highlighted in gray experienced a rush factor during their DTI

| Participant | Preparation | Confirmation | Adjustment | Total Smartphone Usage |
|---|---|---|---|---|
| Lita | 2 | 5 | 3 | 10 |
| Samuel | 1 | 1 | 1 | 3 |
| Marek | 1 | 0 | 0 | 1 |
| Tobias | 1 | 0 | 1 | 2 |
| Amy | 0 | 0 | 0 | 0 |
| William | 1 | 3 | 2 | 6 |
| Trevor | 2 | 4 | 1 | 7 |
| Felix | 0 | 1 | 1 | 2 |
| Mina | 2 | 6 | 3 | 11 |
| Serena | 2 | 11 | 5 | 18 |
| Raye | 1 | 7 | 2 | 10 |
| Simon | 2 | 1 | 0 | 3 |
| | | | | |
| **Total** | 15 | 39 | 19 | 73 |

***Figure 4 /***

DTI smartphone indications and usage per participant, including the usage breakdown based on type of wayfinding strategy



of smartphone usage, and 73 smartphone usage events during the DTI. The analysis of the data indicated that smartphone usage occurred during *Preparation, Confirmation, and Adjustment* practices of the wayfinding process. Of those smartphone usage events, 15 fell into the Preparation category, 39 into Confirmation, and 19 into Adjustment [Figure 4]. The results help to reinforce the idea that Confirmation is a very important step in the wayfinding process. This reiterates the findings of Denis (1997), Allen (2000), and Schwering, et al. (2017).

### *Smartphone as a Comfort*

Participants were more likely to use their smartphone as a navigational aid due to higher levels of stress, uncertainty, confusion, or perceived complexity during the DTI which often took place in the *Confirmation* and *Adjustment* practices. For example, a participant may enter an unfamiliar corridor and indicate they feel lost or stressed, they then use their smartphone to help pacify and get them out of that particular situation, regardless if the smartphone was able to provide such detailed navigational information. If a participant struggled to find navigational information in their physical surrounds, they knew they were still able to access route details through their smartphones, helping to appease any navigational stress. This was also discussed by Brakewood et al. (2014) and Melumad & Pham (2020) who found that users have a tendency to gravitate towards their smartphones over any other form of technology to find comfort in stressful situations.

### *Smartphone Mobility Culture*

Every participant referred to their smartphone as a form of navigational or wayfinding aid at some point during their DTI which underscores the role of the smartphones for transit wayfinding situations, regardless of signage given throughout the system. Smartphones provide a customized wayfinding approach for participants, which felt benefitted their navigational experiences. Customization includes GPS guidance, route calculations, updated schedules, and mode/connection options. Participants indicated they prefer the smartphone in transit wayfinding situations over any other navigational tool, due to their ability to provide instantaneous information and that they themselves are familiar with their own smartphones, therefore know where and how to request information quickly. A user's preference to customizability and preference to use their own smartphone device was also found by Kaplan et al. (2017), Melumad et al. (2019), and Melumad & Pham (2020).

How participants used their smartphones depended on their individual need. For many it provided a spatial locator which helped them navigate through unknown environments. For example, many participants utilized the GPS maps and compass apps on their device, or accessed navigational apps, such as: Google Maps, and Apple Maps, or alternative navigational map apps, like Maps.me, and Citymapper. For others, local transit authority apps, including the MVG Transit App, MVV Transit App, and the DB Transit App provided participants with a temporal strategy through both timetables, delays, and real-time transit arrivals. The usage of the app type varied between participants according to their needs, as each app provided participants with different navigational tools for different aspects of their journeys. The preferred app by participants in the three wayfinding process practices was by far Google. Apps such as the local transit authorities (MVG, MVV, and DB), were mentioned as useful by participants, but when put into practice were not used as much as Google. The reasoning behind this may be due to Google's dynamic platform (both static and real-time data) which allows a user to plan their route through both spatial and temporal functions which leads to increased flexibility and a wider scope of route options for the user. The local authority apps provide a more limited approach, which typically only allows users to plan for routes through a temporal lens of wayfinding. In contrast, alternative app choices, such as Maps.Me, provide more spatial and location focused services, often leaving out temporal transit information. This shows that multi-functionality of the smartphone in terms of *time-space coordination*, and the ability to personalize wayfinding and aid in decision making, was a positive benefit for participants through the DTI. Smartphones have become vital for many individuals in terms of their time-space-coordination and increased ability to personalize one's public transit experience (see also Line et al. (2011); Kaplan et al. (2017); Narimoto et al. (2018); Melumad & Pham, (2020); and Bian et al. (2021).



### *Overall Infiltration of the Smartphone into Everyday Wayfinding*

How participants navigated in public transit also reflected a high degree of infiltration of smartphone culture into everyday life or even a dependence on the smartphone. The language used by all participants, regardless of active smartphone usage, continuously held reference to the smartphone. Overall, participants gave verbal indication of their smartphones 195 times during the DTI, ranging from 7 times (Marek), to 36 times (Serena). When mentioning their smartphones, participants would refer to it as an information guide, such as: *"I'll ask for an update,"* or referring to the smartphone as an assessment of their own wayfinding behavior, e.g. *"If I look at my phone, it'll tell me I'm wrong,"* or as a type of foreshadowing, *"I feel like Google probably wouldn't do it this way."* Additionally, the smartphone played both positive and negative emotional roles in participants' experiences. Positively, it was able to offer a sense of reliability to a participant and contributed to an increase in a participants' positive emotions by providing navigational solutions. In contrast, when there was no data or WIFI available, or when the smartphone battery was low, this contributed to negative emotional experiences for several participants which resulted in increased negative emotions throughout their DTI journeys. This type of language and user behavior further demonstrates a shift in navigational and wayfinding culture, and emphasizes the ubiquity and reliance of mobile technologies in public transit as also reported by Line et al. (2011), Brakewood et al. (2014), Kaplan et al. (2017), and Narimoto et al. (2018), and further reported by Melumad & Pham (2020) as a general phenomenon in society.

### *Spatio-temporal Strategies of Smartphone Usage in the Wayfinding Process*

Spatio-temporal strategies involving the smartphone during the DTI were found in the three wayfinding practices, *Preparation, Confirmation, and Adjustment.*

**(a) Preparation**

Preparation is the strategy-building, or "ground work", participants have done on their smartphone immediately *before* they commence their journey (Denis, 1997; Timpf, 2006; Padgitt & Hund, 2012). This particular phase of wayfinding is an important one, as it sets the tone for the remainder of the journey by lining the participant up with route landmarks and milestones – helping the participant to create a cognitive map of their route and increasing the legibility of their surroundings (Lynch, 1960). The smartphone is beneficial in this case, as it provides an easily accessible, handheld plan based on a familiar platform for the individual.

During the DTI, 10 of the 12 participants used their smartphone for preparing their route to both P2 and P3 (participants Amy and Felix did not find the need to use preparation as they both were very familiar with the chosen route) [Figure 5].

Participants who were less familiar with the area chose to use spatial guidance features (like a GPS map) to help them navigate towards the destination. In contrast participants who were more familiar with the area often chose a temporal guidance feature (like a transit schedule) to get them to the destination, as they could mentally visualize the route, and used the temporal guidance to gauge the distance and speed of walking. Overall, participants preferred a macro-overview of their journey in order to prepare mainly using Google. This was due to its ability to combine both spatial and temporal factors into a single visualization. Having both spatial and temporal features of a journey highlighted allowed the participants to feel greater autonomy to personalize their route choices, and the ability to factor in any personal preference in mobility. The importance of user preference in smartphone personalization during navigation was previously discussed by Shaheen et al. (2016), Kaplan et al. (2017); and Narimoto et al. (2018).

| Participant | Preparation | App Choice During DTI |
|---|---|---|
| Lita | 2 | Google→Google |
| Samuel | 1 | Google |
| Marek | 1 | Google |
| Tobias | 1 | Google |
| Amy | 0 | 0 |
| William | 1 | Google |
| Trevor | 2 | Google→Google |
| Felix | 0 | 0 |
| Mina | 2 | Google→Google |
| Serena | 2 | Google→Google |
| Raye | 1 | Maps.me |
| Simon | 2 | Google→Google |

***Figure 5 /***

Number of times participant used Preparation during the DTI, and their choice of app for each event

Serena, a DTI participant, explained her process: *"So, this is a route I'm not very familiar with. The first thing I would do is use Google Maps and look for every step I have to take to get to my destination."* Without using her previous knowledge of the public transit system, Serena immediately looked at her smartphone for guidance.

Participants were more inclined to take the route and mode suggested by their smartphone app – regardless if they had previously indicated they were somewhat familiar with the route or uncomfortable with a certain mode. Similarly, Lita, another DTI participant, explained that when she prepares for her journey, she relies on her smartphone. She incorporates the idea of *Preparation* into her routine so that she has a sense of awareness of her surroundings later on. When asked if there are any modes of transit she typically avoids, Lita responded with the S-Bahn, *"I used the S-Bahn less frequently just because I find it less convenient."* However, when given a choice, Lita used the S-Bahn during her DTI. When asked why she chose the S-Bahn, Lita responded that she used her smartphone to prepare for the journey, and she implied that Google had given her the directions and the suggested modes of transit and therefore she contradicted her own mode preferences and followed the suggestions of the smartphone. This shows the high impact of mobile technologies on decision-making in wayfinding as virtual instructions are given priority to the detriment of the user's learned spatial knowledge. The smartphone's ability to provide a user with a detailed route overview gives it a semblance of authority. A user may view the advice given by the smartphone and compare it to their existing spatial knowledge and may discover that there are more efficient or quicker routes to reach a destination than they previously knew. This creates a positive reinforcement between the user and the smartphone; the more the user turns to the smartphone to solve a navigational problem, the less they are inclined to use their own spatial knowledge, and therefore form a user-smartphone dependency. The discussion surrounding smartphone dependency and influence on user behavior has been previously found by Münzer et al. (2006); Münzer et al. (2012); Richter et al. (2010); and Waters & Winter, (2011).

**(b) Confirmation**

*Confirmation* refers to the way in which people utilize their smartphone to help them navigate a journey. This is ultimately tied with preparation, as one attempts to follow the path provided at the beginning of the journey (Dennis, 1997; Allen, 2000; Schwering et al., 2017). When orienting with a smartphone during the journey, participants have two options: they can confirm and continue on their path, or they can correct and redirect themselves. *Confirmation* focuses on the former – confirming and continuing. Often, participants required a reminder, to double-check, or confirm, that they were heading in the right direction. The key element to this strategy is that, when looking at their smartphone, participants are reminding themselves of their initial path to reach their end destination.

Participants used smartphones during *Confirmation* more (39 times) than *Preparation* (15 times) and *Adjustment* (19 times), and would confirm with their smartphones during both highly active moments, as well as during lulls in their journey. Typically, a participant would use the smartphone for timing of scheduled departure and dead-reckoning to situate themselves in the physical environment and to help point out landmarks along their chosen path to their destination. The number of times a participant needed to confirm their navigational choices [Figure 6] ultimately depended on their familiarity of the mode choice and chosen route, personal characteristics, such as their ability to memorize route data, or a general confidence in their own navigational abilities.



In the DTI, three participants did not use their smartphone for *Confirmation*, this was due to their familiarity of the environment, as well as their ability to use their physical surroundings to orient themselves within the transit system. During *Confirmation*, a participant is either searching for spatial information, temporal information, or

| Participant | Confirmation | App Choice During DTI |
|---|---|---|
| Lita | 5 | MVG→Google→Google→Google→Google |
| Samuel | 1 | Google |
| Marek | 0 | 0 |
| Tobias | 0 | 0 |
| Amy | 0 | 0 |
| William | 3 | Google→Google→Google |
| Trevor | 4 | Google→Google→Google→Google |
| Felix | 1 | Google |
| Mina | 6 | Google→Google→Google→MVV→MVV→MVV |
| Serena | 11 | Google→Google→Google→Google→Google→Google→Google→ Google→Google→Google→Google |
| Raye | 7 | Maps.me→Maps.me→Maps.me→MVG→MVG→MVG→MVG |
| Simon | 1 | Google |

***Figure 6 /***

Number of times participant used Confirmation during the DTI and their choice of app for each event a combination of both to help guide them through a situation of uncertainty. The smartphone is able to provide this information to a user through one or sometimes two apps, depending on their needs. Google, again, proved to be the most popular choice among participants. The dynamic combination of spatio-temporal information allowed for quick confirmation and reduced user uncertainty in stressful situations, as well as allowed the user to preemptively avoid stressful situations by following the route guidance provided by the smartphone.

For example, Serena, while sitting on the U-Bahn to P2, stated that when she is uncertain of a route, she primarily focuses on spatial factors of navigation. She would continuously follow the path given to her by her smartphone app, *"I checked my phone because…it's not a route I use every day."* The route provided by the app gave her a general step-by-step overview of the path. This shows that an individual's need for locational reassurance during *Confirmation* is important. The need for an individual to verify direction during orientation was also found by Schwiering et al. (2017) who stressed 'Wayfinding Through Orientation', a concept that navigational systems should support users through orientation, spatial learning, and cognitive mapping.

Raye, another DTI participant, was relatively familiar with the transit system, but she mentioned her need to confirm and reconfirm her path during her DTI to check the timing. Following the exact instructions from the app allowed her to slip in and out of both virtual and physical worlds. In doing this, Raye's attention for physical cues became less important, as the need to orient herself was emphasized by the time pressure she experienced. This shows that temporal aspects in an individual's navigation are also valuable in the wayfinding process. Since Raye did not use Google, but Maps.me (primarily spatial), and the MVG app (primarily temporal), her need to check between apps and double-check the information provided by the apps underscores the advantage of the Google app in *Confirmation* situations. User desirability and positive response for app customization has been found by Shaheen et al. (2016) too, however, the comparison of app customizability of spatio-temporal features has not yet been thoroughly researched.

### (c) Adjustment

*Adjustment* requires a situation to occur that forces the participant to reorient themselves from the initial route (Fontaine & Dennis, 1999; Narimoto et al., 2018). For example, when a participant found signage or station design unreadable and difficult to navigate, it led them to feeling lost or confused and required them to change their initial route plans and redirect themselves. During the DTI, several participants found themselves in situations where they indicated they felt "lost" or turned around, or they found themselves in situations where they simply misread a navigational cue along the way. William, for example, often deferred to the smartphone when he made a wrong turn, or missed a connection: *"I have to take bus... which I just missed. I'll ask for an update."* William implemented an adjustment to his original plan and the smartphone provided him with subsequent alternatives to taking the bus. If participants realized they were no longer following their original plan, most of the times they would adjust their route with their smartphone. Even though Google was still a popular choice for participants, app choice varied more during the Adjustment stage compared to *Confirmation*. Here, problem-moments that participants found themselves in often only involved either a spatial or a temporal issue, which reduced the necessity to use an app that integrates spatio-temporal information, such as Google. [Figure 7].

The results also show that the ability of the smartphone to give navigational guidance does not guarantee a successful result by the participant. After exiting the S-Bahn on her way to P3, Serena was looking for a bus station, but was unable to physically locate its position. She felt the signage was difficult to find and the design of the station confusing: *"I found the sign, but it's not on the street … but it should be here because it says so and my Google Maps says so as well."* At that particular moment, she realized she had been led astray (whether by her own doing or the app's instruction is not clear); regardless, due to the discrepancies in information on her phone and at the station, she missed her connection. Serena ended up getting on the wrong bus and travelling in the wrong direction, only noticing it was wrong by comparing the smartphone to her surroundings.

| Participant | Adjustment | App Choice During DTI |
|---|---|---|
| Lita | 3 | MVG→Google→Google |
| Samuel | 1 | Google |
| Marek | 0 | 0 |
| Tobias | 1 | Google |
| Amy | 0 | 0 |
| William | 2 | Google→Google |
| Trevor | 1 | Google |
| Felix | 1 | Google |
| Mina | 3 | MVV→MVV→MVV |
| Serena | 5 | Google→Google→Google→Google→Google |
| Raye | 2 | MVG→MVG |
| Simon | 0 | 0 |

*Figure 7 /*

Number of times participant used Adjustment during the DTI and their choice of app for each event

### *Avoiding the Smartphone*

The smartphone was prominent in personal navigation for participants of the DTI and its big role in transit navigation has been discussed in detail so far. However, looking at how and when smartphones are not used also can help to better understand human-smartphone behaviors and wayfinding needs of users. Some participants refused to use their smartphones for more personal reasons. Simon, for example, referred to his sense of safety when navigating with a smartphone, *"I don't really like to use my cell phone when I am walking … I feel like I will bump into people, or sometimes I might run into a car or a tramway if I don't pay attention to the … environment."* Simon saw the smartphone as a distraction from the surrounding environment, something that could end up unintentionally harming him. He also spoke about his detachment from smartphone as a sense of freedom (and was the only participant to do so), *"I don't like to be controlled by the cell phone. Sometimes I also believe in … getting lost in the city."* This idea of deciding his own path gives him a sense of responsibility and control which is an appealing factor to him as it helps to increase his sense of discovery. This indicates that not all users view the smartphone as positive addition to their navigational experiences. The smartphone can also be seen as an unsafe distraction as the user must navigate the physical world through virtual instruction, which can also take away the user's sense of autonomy. This contradicts the findings by Brakewood et al. (2014), where it was found that smartphones increased a sense of perceived safety in transit systems.

## CONCLUSION

The smartphone has become a preferred and convenient navigational tool not only for motorized traffic, but also for public transport. No longer are people restricted to static physical information such as schedules, maps, and signage in order to aid in their wayfinding tasks but they now have a conduit to an instantaneous data stream of navigational information that influences their wayfinding process in many ways. Most importantly, the dynamic spatial and temporal information is provided in a single hand-held device which allows users to easily access immediate directional recall to understand their spatio-temporal positioning and, in turn, helps to personalize their route (Golledge et al., 2000).

The goal of the explorative study presented in this paper was to better understand smartphone usage in terms of wayfinding experience and performance. It clearly shows that throughout the DTI, smartphone usage strongly influenced all stages of participants' wayfinding processes: *Preparation*, *Confirmation*, and *Adjustment*. However, smartphones are most often used for confirmation issues which points to deficits in signage and readability of the transit environment and the integration of the digital and the physical environment. The study also reveals that in the Preparation and Confirmation phase, apps which provide integrated spatio-temporal informational guidance, such as Google, are clearly preferred whereas users tend to use apps with a clear spatial or time focus (e.g. apps created by public transit authorities) when Adjustment is needed.

. In general, using the smartphone helped participants to appease navigational stress. However, smartphones did not always facilitate wayfinding, but sometimes also became a distraction for participants. The more they relied on the smartphone, the more they had to balance between virtual and physical worlds. This brings along new design challenges to understanding how individuals behave in public transit settings and how to synchronize smartphone information with information cues from the physical environment including the wayfinding system.

As technological improvements are made to the smartphone and access to the technology reaches larger numbers of individuals, a better understanding of the integration of smartphone usage and user behaviors in wayfinding is paramount to effective public transit design. As an exploratory study, this provides a good starting point for future research in smartphone-to-user interactions in public transit wayfinding settings.

Further studies with a larger number of participants including elderly people and/or other social groups not covered in this study, will allow for greater validity. Moreover, future studies in different transit environments with different signage systems and travel modes can help to broaden our understanding of smartphone assisted wayfinding in transit environments as well as help to better grasp smartphone reliability and users' reliance on them. The DTI provides a sound method to investigate transit user behavior and to learn more about smartphone assisted wayfinding performance. This will lead to a better understanding of the functionality of our designed transit spaces in times of smartphone use.

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The authors declare no conflict of interest.

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