Exploring the Relation Between Sense of Direction and Spatial Anxiety in Everyday Mobile Map App Use

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Abstract

Many studies have examined the effect of GPS reliance on individual spatial abilities and emotional disposition. Yet, how those individual differences relate to everyday mobile map interactions in the wild is poorly understood. Hence, we empirically studied the effect of users' sense of direction and spatial anxiety using mobile map apps in their everyday lives by deploying an ecologically valid approach to recording phone-based touchscreen interaction. We operationalised touchscreen interactions as switching patterns for mobile maps and other app categories. We hypothesised that users with a better sense of direction would spend less time on mobile map apps and show increased switching patterns between mobile map apps and other apps compared to users with a worse sense of direction. Conversely, users with higher levels of spatial anxiety would spend more time on mobile map apps and show decreased switching patterns. Our results contradicted our hypotheses. We did, however, find gender-specific trends: Women with higher spatial anxiety switch more often from different categories of apps (for all apps, not specifically map apps) in a phone session. Contrary to our hypothesis, men with a better sense of direction tend to spend more time on mobile map apps. This research reveals insights into the effect of users' spatial abilities and emotional dispositions on everyday users' touchscreen interactions with mobile map apps. It provides ground for mobile map app interaction design on accounting for individual-related differences.

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1 Introduction

A vast body of research has highlighted the significant role that individual differences in spatial abilities play in our daily interactions with physical and social environments [7]. These abilities are a combination of psychological attributes (such as emotional dispositions like spatial anxiety) and spatial cognitive skills (such as spatial visualisation, sense of direction, and working memory) [5, 11, 4, 6, 7]. Individual differences play a crucial role in everyday tasks, such as navigation. Recent research has shown the need to acknowledge these individual

differences in the design of mobile maps for navigation systems [15, 12]. This is also supported by emerging evidence suggesting that GPS-based navigation practices might negatively affect navigation skills, spatial learning, and knowledge acquisition [6, 14, 12]. Specifically, these studies have found that higher reliance on GPS use has been associated with a worse self-reported sense of direction but higher spatial anxiety [4] or has shown long-term negative effects on mental rotation and perspective-taking skills [13]. Additionally, studies have found that reliance on smartphone GPS use is associated with higher inaccuracy in route retracing when compared to using paper maps [14] and a lower ability to learn new environments [6].

Despite these significant advances in understanding the effects of GPS use on cognitive abilities, most studies rely on either indoor or outdoor controlled experimental designs [6, 14] and on self-reporting to quantify GPS use [13], limiting the generalisation of findings in complex real-world settings. For instance, self-reports of GPS use may affected by over-or-under estimations as they are based on an individual's perception, beliefs or attitudes rather than actual use. This data can thus differ from daily, on-device use data collection. This discrepancy indicates a significant research gap in understanding how spatial abilities and emotional dispositions are linked to smartphone-based navigation.

Addressing this gap requires a method that ensures privacy and accurately captures everyday interactions with mobile map apps. Due to the challenge of collecting mobile app data of high ecologic validity, the relationship between these interactions and users' differences in spatial abilities or emotional traits remains largely unexplored. Interestingly, a recent line of research in cognitive neuroscience has been deploying touch-event sequences (i.e., taps) recorded on the smartphone screen to investigate various human behavioural and cognitive processes [1]. These investigations range from sleep pattern analysis to cognitive test performance and considerations of smartphone dynamics by age [1, 2] and demonstrate that smartphone interactions in the wild offer unique insights into cognitive processes.

However, the relationship between spatial abilities and emotional traits in smartphone interactions has yet to be studied. Indeed, studies that rely on collecting data in the wild to explore mobile map app use have been limited to a general understanding of map app use based on the frequency of taps for different categories of mobile map apps at different distances from users' homes [17, 16] but not retrieving those specific to navigation apps. Therefore, current research has yet to fully address how spatial abilities and emotional traits might influence mobile map app use patterns when employed for navigation.

Moreover, a recent study found that smartphone use is fragmented, with frequent app switching throughout the day and that users overestimate time spent on apps, leading to discrepancies in perceived versus actual app use [3]. By examining how much time we spend on mobile map apps and how often and why we switch to or from mobile map apps during navigation, we can gain insights into how these specific interactions fit into our broader smartphone use habits. For instance, distinct behaviours such as switching from a map app to another app category (social or communication apps, for example) or returning to a map app during overall phone use could provide valuable insights into the role of mobile maps in daily life and the impact of smartphone integration in our navigation routines. In our study, we address these research gaps by applying tappigraphy, a cutting-edge method developed for the non-intrusive and continuous recording of app use sourced from touch events on the smartphone screen similar to [1].

Our research aims to uncover patterns of interactions with mobile map apps in the wild and how spatial abilities and emotional traits might influence these use patterns. To this end, we formulated two main hypotheses: (1) A better sense of direction correlates with less time spent on mobile map apps during a phone session and more switching between mobile map

apps and other apps. This would suggest a lesser reliance on mobile map apps, which in turn would support increased spatial learning and more engagement with other apps. (2) Higher levels of spatial anxiety correlate with more time spent on mobile map apps during a phone session and less switching between mobile map apps and other apps. This would suggest greater reliance on map apps for navigation, which may lead to reduced spatial learning and less engagement with other apps.

2 Methods

This study has been reviewed and approved by the UZH PhF Ethics Committee with protocol Nr. 23.03.24 [1]. We gathered data from 61 participants from March to June 2023 using the MapOnTap app. All participants were assigned a randomised ID code, and demographic details, such as gender and age group, were collected. Participants downloaded the MapOnTap app from the Google Play Store and installed it on their Android smartphones.

The app, originally developed by QuantAction AG, operates in the background and begins logging data when users unlock their phone until it is locked again (creating a phone session). Data collected included the total touch events (i.e., taps) per phone session, session duration, apps used and their category, the participant's randomised ID, and the device ID. The app could also log GPS coordinates if the user permitted, capturing latitude, longitude, and altitude through the phone's location sensors. Additional data from light sensors, magnetometers, and accelerometers were also collected if permitted.

Participants were instructed to use their smartphones as usual while running the MapOnTap app for two weeks. Participants were also asked to fill in three questionnaires. We employed the Santa Barbara Sense of Direction (SBSOD) scale to measure each participant's self-reported sense of direction. To self-assess spatial anxiety (SA) [11], we used the SA scale as modified in [4]. We collected the experience and frequency of using three distinct navigation systems, including pedestrian, in-car and paper-based maps as in [14]. Participants were compensated with a digital voucher.

This short paper showcases preliminary results from our comprehensive data collection by leveraging tappigraphy and focusing on selected features relative to our hypotheses, as outlined in the pre-processing steps. It does not consider GPS data, other sensor data, or self-reports on the experience and frequency of the three navigation systems.

2.1 Data Pre-Processing

Data pre-processing involved several key steps for data analysis. Initially, we filtered the dataset to retain only phone sessions with at least one navigation-related app. This criterion includes user touch events within apps in the Google PlayStore categories of "Maps & Navigation" (MN) and "Travel & Local" (TL) that specifically address navigation. These two categories include map apps, traffic apps, or travel apps for local public transport, where real-time information and route optimisation are also essential for navigation.

We extracted selected features from touch events. These variables included the frequency of app switches, defined as the number of times a user switches from one application category (e.g., "Communication") to another (e.g., "Social") while using their phone. Additionally, we calculated the proportion of map-related application switches, which is the ratio of switches

[1] "Ethik in der Forschung", University of Zurich, last accessed 18 March 2024, `http://www.phil.uzh.ch/de/forschung/ethik.html`

from MN and TL-related applications to any other category compared to the total number of all application switches during a phone session. Lastly, we measured the overall duration of the phone session, recorded in seconds, and the time spent (also in seconds) in specific categories like MN and TL within a phone session. More detailed information is provided in Table 1.

Consequently, we applied a logarithmic transformation to the right-skewed data distribution and normalised the variables using a min-max scaling approach, i.e., for each individual participant, we rescaled the data to a [0, 1] range. Finally, for smartphone-derived variables, we considered the median distribution. We conducted correlation analyses to explore the relationships between general phone use and specific maps as referenced in Table 1 with spatial anxiety and sense of direction.

Table 1 Summary of variables derived from smartphone use. These variables highlight general smartphone use, specific map app use, and the proportion of map use variables over the general app use in a phone session.

Variable Category	Description
App switches frequency	
All app switches	Total count of all switches from a different category in a phone session
Switches **from** maps	Total count of switches from map category to another app category in a phone session
Switches **to** maps	Total count of the switches from another app category to a map category
All map switches	Sum of switches from maps and switches to maps
Proportions of map switches	
Proportion of map switches	Proportion of all map switches overall app switches
Proportion of switches from maps	Proportion of switches from maps overall app switches
Proportion of switches to maps	Proportion of switches to maps overall app switches
Time spent (duration)	
Time spent on map	Time spent on map apps in seconds inside a phone session
Overall time	Total duration of phone session in seconds
Proportion of time on maps	Time spent on map over overall time

2.2 Data Analysis

We conducted correlation analyses on the entire dataset and divided subgroups by gender. The rationale for dividing our dataset into male and female subgroups stems from evidence suggesting differences in navigation confidence and spatial anxiety between genders. Studies generally report a better sense of direction for men than for women [10], and women experience more navigation-related anxiety than men [11]. To further refine our analysis, we also considered age by dividing participants into age groups: 18–24, 25–34, and 35–64. Due to the uneven distribution of data across age groups, when dividing subgroups by gender, we specifically focused our analysis on the most substantially represented age group for both females and males: those between 25 and 34 years old. Throughout our analyses, we maintained a significance level (alpha) of 0.05 to determine the statistical significance of our findings.

3 Results

This section shows the paper's main findings, reporting the correlations between smartphone-derived user variables, as in Table 1, with SBSOD and SA. The results highlight significant insights from our data, including gender-specific analyses.

Our final dataset included 4,326 phone sessions, encompassing 420 unique apps across 32 distinct Google Play Store app categories. Among these, our navigation-related subset included 26 apps that we assumed had a direct relevance to navigation. Additional information on the apps selected is found in the supplementary materials.

The participant pool for our final dataset included 56 individuals (25 females, 31 males). For gender subgroups, we focused on the largest age group, 25–34 years old (38 participants). This group was followed by 18–24 years (10 participants) and 35–64 years (8 participants). We employed Pearson (r) and Spearman (r_s) correlation coefficients to assess positive or negative relationships. The choice between r or r_s was based on Shapiro-Wilk test outcomes, which describe the normality of data distribution for each variable. Across all participants, self-reported SBSOD was negatively correlated with SA, as indicated by $r = -0.33$, $p = 0.0131$, and 95% $CI[-0.55, -0.07]$. Correlations related to all our variables are found in the supplementary materials.

Next, when splitting our dataset of the chosen age group 25–34 into gender subgroups, we found that, within the male subset, the SBSOD was positively correlated with the total time spent on a mobile map in a phone session, $r_s = 0.48$, $p = 0.046$ and 95% $CI[0.02, 0.77]$. The effect is not found for females, where $r_s = -0.40$, $p > 0.05$, 95% $CI[-0.72, 0.52]$. Figure 1 depicts the correlations for males and females between SBSOD and time spent on a mobile map app for the age group 25–34. Conversely, within the female subset, the total number of app switches found in a phone session is positively correlated with an increase of spatial anxiety, $r = 0.51$, $p = 0.021$, and 95% $CI[0.09, 0.78]$ as shown in the Figure 1. In the male subset we observed no correlation, $r = 0.086$, $p > 0.05$ and 95% $CI[-0.40, 0.53]$.

4 Discussion

This study analysed the relationship between individuals' sense of direction and spatial anxiety when interacting with mobile map apps. Behavioural data was extracted from phone sessions where navigation apps were used.

The study was structured around two main hypotheses: (1) Individuals with a better sense of direction would likely show less dependence on mobile map apps, as evidenced by decreased usage time and a greater tendency to switch between these and other apps within a single phone session. (2) Individuals experiencing high levels of spatial anxiety would show an opposite pattern of behaviour, characterised by prolonged use of mobile map apps and a lower frequency of app switching.

Contrary to our predictions, the empirical data did not confirm these hypotheses in the population investigated. Nevertheless, the analysis replicated the negative correlation between spatial anxiety and sense of direction, supporting studies that emphasise that a worse sense of direction is related to increased spatial anxiety and poorer performance in small- and large-scale spatial skills [4, 14]. This result supports the idea that individuals with high spatial anxiety might seek more support from mobile maps for tasks such as navigation. This behaviour potentially deprives them of the critical experience of spatial learning, thus perpetuating a cycle of reduced navigational skills [6, 7] and, more likely, increased levels of spatial anxiety. By subdividing the population by gender and selecting the age group 25–34 years for more robust analyses, our results again contradicted our initial hypotheses. In particular, contrary to the expected pattern of behaviour, in which a better sense of direction is correlated with less time spent on mobile map apps, we observed that males with a better sense of direction tended to spend significantly more time using map apps. This unexpected finding departs from previous studies that associated good spatial skills with less reliance

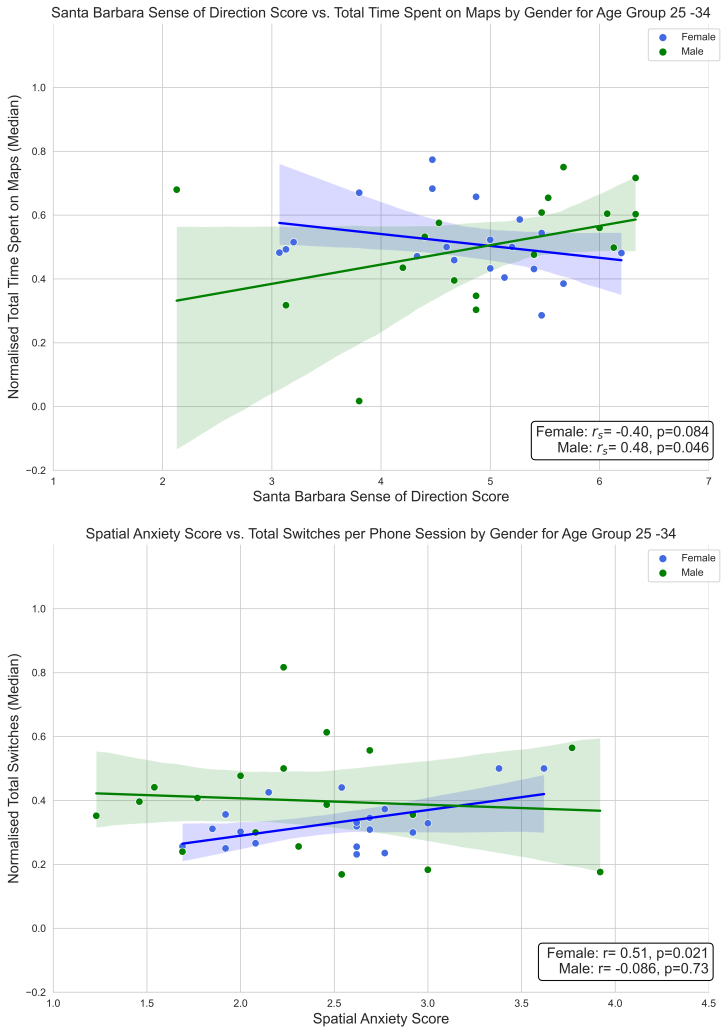

Figure 1 Gender-specific correlations for the age group 25-34. For males (left), there is a significant positive correlation between the total time spent using a mobile map per phone session and SBSOD ($r_s = 0.48, p = 0.046$, $95\%CI[0.02, 0.77]$). For females (right), there is a significant positive correlation between the number of app switches per phone session and increased SA ($r = 0.51, p = 0.021$, $95\%CI[0.09, 0.78]$).

on GPS navigation aids [13], suggesting that individuals with a better sense of direction may still find significant advantages in the offered mobile map app functionalities, such as real-time transport and traffic data or route optimisation. This insight suggests a broader relevance of mobile map tools beyond simple compensatory uses for navigation deficiencies or a worse sense of direction.

Finally, the analysis of female participants with high spatial anxiety revealed an increase in the overall number of apps and switches between them, again departing from our initial hypothesis. This observation aligns with previous research identifying higher spatial anxiety in the female population [11] but challenges the second hypothesis by demonstrating that increased spatial anxiety does not necessarily translate into increased map app use or decreased app switching. Instead, the high frequency of app switching among spatially

anxious women reflects the general switching pattern inside a phone session. This result may reflect a more generalised pattern of fragmented interaction with the smartphone, not specifically related to mobile map apps, as also pointed out in human-computer interaction research [3] and that this fragmentation is higher for a generally more anxious, and not only spatially anxious, population.

5 Conclusion and Future Studies

Our study sheds light on the complexity of app use within the context of navigation, illustrating that individual differences in spatial abilities and emotional dispositions influence everyday mobile map app interactions. By leveraging tappigraphy, this research adds a new dimension to the existing knowledge on spatial cognition and mobile map usage patterns in everyday life.

It is important, however, to acknowledge the limitations that may impact the generalisability of our results. Our study was correlational, and we cannot establish any direction for the relations we reported. Moreover, our participant pool displayed limited diversity in age demographics. For this reason, we selected only the age group of 24–35 years in our correlation by gender subgroups.

Our study's scope was limited to analysing app switching counts and self-reported SBSOD and SA measures to address spatial abilities. Future research should incorporate sequence analyses to further dissect app use patterns during navigation and general smartphone use. Additionally, it should address spatial cognition more comprehensively by including other critical tests for assessing spatial abilities, such as spatial working memory with the Corsi Block-Tapping Test [8] and spatial orientation abilities, including perspective-taking tasks [9].

This study did not extend its analysis to include GPS data, such as analysing distance travelled while engaging with navigation apps. Subsequent research should integrate these data points, examining the relationship between users' speed and distance travelled with their mobile map navigation data to provide a more comprehensive understanding of users' in-the-wild interactions. Nevertheless, this study illustrates the complex dynamics of the interplay between individuals' spatial skills, emotional responses, and mobile map app use in-the-wild, and supports, considering these individual differences, mobile map app design for navigation.

References

1 J. N. Borger, R. Huber, and A. Ghosh. Capturing sleep–wake cycles by using day-to-day smartphone touchscreen interactions. *npj Digital Medicine*, 2(1):73, 2019. doi:10.1038/s41746-019-0147-4.

2 E. Ceolini, R. Kock, G. P.H. Band, G. Stoet, and A. Ghosh. Temporal clusters of age-related behavioral alterations captured in smartphone touchscreen interactions. *iScience*, 25(8):104791, August 2022. doi:10.1016/j.isci.2022.104791.

3 T. Deng, S. Kanthawala, J. Meng, W. Peng, A. Kononova, Q. Hao, Q. Zhang, and D. Prabu. Measuring smartphone usage and task switching with log tracking and self-reports. *Mobile Media & Communication*, 7(1):3–23, January 2019. doi:10.1177/2050157918761491.

4 C. He and M. Hegarty. How anxiety and growth mindset are linked to navigation ability: Impacts of exploration and GPS use. *Journal of Environmental Psychology*, 71:101475, October 2020. doi:10.1016/j.jenvp.2020.101475.

5 M Hegarty, D. R. Montello, A. E. Richardson, T. Ishikawa, and K. Lovelace. Spatial abilities at different scales: Individual differences in aptitude-test performance and spatial-layout learning. *Intelligence*, 34(2):151–176, March 2006. doi:10.1016/j.intell.2005.09.005.

6 T. Ishikawa. Satellite Navigation and Geospatial Awareness: Long-Term Effects of Using Navigation Tools on Wayfinding and Spatial Orientation. *The Professional Geographer*, April 2019. Publisher: Routledge.

7 T. Ishikawa. Spatial thinking, cognitive mapping, and spatial awareness. *Cognitive Processing*, 22(1):89–96, September 2021. doi:10.1007/s10339-021-01046-1.

8 R. P. Kessels, M. J. van Zandvoort, A. Postma, L. J. Kappelle, and E. H. de Haan. The Corsi Block-Tapping Task: standardization and normative data. *Applied neuropsychology*, 7(4):252–258, 2000. Place: United States. doi:10.1207/S15324826AN0704_8.

9 M. Kozhevnikov and M. Hegarty. A dissociation between object manipulation spatial ability and spatial orientation ability. *Memory & Cognition*, 29(5):745–756, 2001. Place: US, Publisher: Psychonomic Society. doi:10.3758/BF03200477.

10 L. T. Kozlowski and K. J. Bryant. Sense of direction, spatial orientation, and cognitive maps. *Journal of Experimental Psychology: Human Perception and Performance*, 3(4):590–598, 1977. Place: US, Publisher: American Psychological Association. doi:10.1037/0096-1523.3.4.590.

11 A. Lawton. Gender differences in way-finding strategies: Relationship to spatial ability and spatial anxiety. *Sex Roles*, 30(11):765–779, June 1994. doi:10.1007/BF01544230.

12 I. Ruginski, N. Giudice, S. Creem-Regehr, and Toru I. Designing mobile spatial navigation systems from the user's perspective: an interdisciplinary review. *Spatial Cognition & Computation*, April 2022. Publisher: Taylor & Francis.

13 I. T. Ruginski, S. H. Creem-Regehr, J. K. Stefanucci, and E. Cashdan. GPS use negatively affects environmental learning through spatial transformation abilities. *Journal of Environmental Psychology*, 64:12–20, August 2019. doi:10.1016/j.jenvp.2019.05.001.

14 M. Sugimoto, T. Kusumi, N. Nagata, and T. Ishikawa. Online mobile map effect: how smartphone map use impairs spatial memory. *Spatial Cognition & Computation*, April 2022. Publisher: Taylor & Francis.

15 T. Thrash, S. Lanini-Maggi, S. I. Fabrikant, S. Bertel, A. Brügger, S. Credé, C.T. Do, G. Gartner, H. Huang, S. Münzer, and KF. Richter. The Future of Geographic Information Displays from GIScience, Cartographic, and Cognitive Science Perspectives. In Sabine Timpf, Christoph Schlieder, Markus Kattenbeck, Bernd Ludwig, and Kathleen Stewart, editors, *14th International Conference on Spatial Information Theory (COSIT 2019)*, volume 142 of *Leibniz International Proceedings in Informatics (LIPIcs)*, pages 19:1–19:11, Dagstuhl, Germany, 2019. Schloss Dagstuhl – Leibniz-Zentrum für Informatik. doi:10.4230/LIPIcs.COSIT.2019.19.

16 D. Zingaro, M. Bartling, and T. Reichenbacher. Exploring Map App Usage Behaviour Through Touchscreen Interactions. In Roger Beecham, Jed A. Long, Dianna Smith, Qunshan Zhao, and Sarah Wise, editors, *12th International Conference on Geographic Information Science (GIScience 2023)*, volume 277 of *Leibniz International Proceedings in Informatics (LIPIcs)*, pages 95:1–95:6, Dagstuhl, Germany, 2023. Schloss Dagstuhl – Leibniz-Zentrum für Informatik. ISSN: 1868-8969. doi:10.4230/LIPIcs.GIScience.2023.95.

17 D. Zingaro and T. Reichenbacher. Exploratory analysis of mobile app usage in relation to distance from home. In *Zingaro, Donatella; Reichenbacher, Tumasch (2022). Exploratory analysis of mobile app usage in relation to distance from home. In: LBS2022, Munich / Augsburg, Germany, 12 September 2022 - 14 September 2022, 59-67.*, pages 59–67, 2022. doi:10.5167/uzh-224336.

18 Donatella Zingaro, Tumasch Reichenbacher, Mona Bartling, and Sara Irina Fabrikant. Exploring the Relation Between Sense of Direction and Spatial Anxiety in Everyday Mobile Map App Use. Supplementary Tables (visited on 2024-08-22). URL: https://doi.org/10.17605/OSF.IO/KB5M8.