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## Impact of Time Constraints on Pedestrian Navigation Information Behavior: Postprint

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### Abstract

**【目的】**To investigate how the presence or absence of time constraints affects users' pedestrian navigation behavior and interaction experience.

**【方法】**A user experimental methodology was adopted, recruiting 20 university students who were randomly assigned to two groups (time-constrained group and non-time-constrained group) to participate in a field navigation experiment, completing two different types of navigation tasks: outdoor navigation and indoor navigation tasks.

**【结果】**Experimental results revealed that time constraints generate time pressure, but do not significantly affect the intensity of this pressure. When users neither know their destination nor its specific location, time constraints significantly impact task completion time, text page dwell time, and swipe frequency. When users search for a location without knowing its specific position, time constraints have no significant impact on navigation behavior. In indoor navigation, time constraints significantly affect zoom frequency and upward swipe frequency.

**【局限】**The experimental user sample size is relatively small.

**【结论】**Time constraints influence users' navigation behavior; under time constraints, users accelerate arrival at the destination by reducing screen operation frequency.

### Full Text

## Impacts of Time Constraint on Information Behaviors in Pedestrian Navigation

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## Abstract

**[Objective]** This study investigates how time constraints influence users' pedestrian navigation behaviors and interaction experiences. **[Methods]** Using a user experiment methodology, we recruited 20 college students and randomly assigned them to two groups (time-constrained and non-time-constrained) to complete three distinct navigation tasks: two outdoor and one indoor pedestrian navigation tasks. **[Results]** The results reveal that while time constraints induce time pressure, they do not significantly affect the intensity of perceived pressure. When users neither know their destination nor its specific location, time constraints significantly impact task completion duration, time spent on text pages, and screen sliding frequency. However, when users search for a known destination without knowing its exact location, time constraints show no significant effect on navigation behavior. For indoor navigation, time constraints significantly influence zooming and upward sliding operations. **[Limitations]** A limitation of this study is the small sample size. **[Conclusions]** Time constraints affect user navigation behavior, prompting users to reduce screen operations to reach their destination more quickly.

**Keywords:** Time Constraint; Time Pressure; Pedestrian Navigation; User Information Behavior

**Classification Number:** G250

With the development of mobile networks and improvements in mobile map functionality, pedestrian navigation has provided tremendous convenience for daily travel. According to the "2016 Q3 China Mobile Map (Navigation) Market Research Report" released by Bigdata-Research [1], the active user base of mobile maps (navigation) reached 301 million in Q3 2016, with a user penetration rate of 46.1%. Among these users, route navigation is the most frequently used function (utilized by over 80% of users), followed by location search and public transit inquiries. This demonstrates that mobile map usage has permeated all aspects of daily life. Ishikawa et al. [2] define navigation as planning a route and moving through space to reach a destination. Pedestrian navigation refers to reaching a destination on foot, encompassing both outdoor and indoor scenarios. Pedestrian navigation information behavior comprises various interactions between users and navigation systems during this process. Teevan et al. [3] found that nearly 50% of users will promptly travel to a location after conducting a mobile search, making navigation a critical subsequent behavior to map searching in everyday usage. Users employ mobile map tools for searching and navigation across various contexts, which determine their navigation purposes, tasks, and interaction patterns with map systems. The concept of context encompasses numerous factors including environment, task characteristics, user knowledge, search skills, and cognitive styles. Time represents a crucial contextual factor. Savolainen [4] summarized research on time as a contextual factor in information seeking, identifying three approaches: treating time as a basic attribute of the information seeking context or environment, as a constraint on information acquisition, and as an indicator of the information seeking process.

Crescenzi et al. [5] demonstrated that time pressure is an important and independent contextual factor, noting that the relationship between time pressure and other environmental variables (such as task duration, number of queries, and page turns) constitutes a vital yet underexplored research area. Sawhney [6] observed that mobile users typically face time constraints, leading them to prefer simple interactions for communication. However, limited research has examined how time constraints affect mobile navigation information behaviors. This study selects time constraint and task type as primary factors to investigate their impacts on users' pedestrian navigation information behaviors and whether these effects differ across three navigation task types.

Pedestrian navigation primarily occurs when public transportation or driving is unavailable, or when the destination is within walking distance. During mobile navigation, individuals invariably experience time constraints arising from task deadlines or navigation performance limitations. Therefore, this research enhances understanding of user interaction behaviors with navigation systems under time constraints and illuminates the types of system support users require during navigation.

## Literature Review and Hypotheses

Few studies have examined time constraints as a context for mobile interaction. Ordóñez et al. [7] note that deadlines create time constraints, enabling task completion within shorter timeframes. Time pressure reflects the stress induced by time constraints and generates the need to cope with limited time. Thus, deadlines impose time constraints but may not necessarily create time pressure. Crescenzi et al. [8] conceptualize time pressure as individuals' internal response to time constraints. Liu et al. [9] argue that different information needs impose varying levels of time pressure on users. Time constraints and time pressure are inseparable, and as a crucial component of mobile interaction, mobile navigation should exhibit certain characteristics of mobile interaction. Current research on temporal contexts focuses on information search, examining how time constraints affect search behavior primarily through users' subjective experiences, including perceived task difficulty, satisfaction, and other affective measures.

### Time Constraint Effects on User Experience

Crescenzi et al. [8] investigated how time constraints and system delays affect user experience, setting a 5-minute limit per search task. Their findings revealed that time-constrained users experienced significantly greater stress, perceived higher task difficulty, and reported lower satisfaction with their performance. This indicates that time pressure negatively impacts user satisfaction, even when time constraints and task difficulty remain constant. Haynes [10] similarly found that time-constrained users express dissatisfaction with both task processes and outcomes. Time constraints and mobile environmental uncertainties intensify

users' sense of urgency, thereby increasing perceived pressure. Under time pressure, users tend to judge tasks as more difficult and report lower satisfaction.

Therefore, we propose the following hypothesis:

**H1:** Users under time constraints will experience greater time pressure, perceive higher task difficulty, and report lower task satisfaction compared to users without time constraints.

### **Time Constraint Effects on User Search Performance**

Maule et al. [11] found that time pressure increases users' focus but also heightens anxiety, leading them to adopt different strategies to cope with time constraints. Zur et al. [12] noted that time pressure accelerates task performance but reduces quality. Fujikawa et al. [13] examined how search constraints (time, number of queries, and number of browsable documents) affect perception, behavior, and performance, setting a 15-minute time limit that yielded no significant effects. Liu et al. [14] investigated how time constraints and search task types influence user search behavior, finding that time constraints reduce search duration and document writing time while increasing information organization speed. Liu et al. [9] demonstrated that in mobile search, users under low pressure click on more results. In mobile environments, time constraints require users to complete tasks within specified timeframes, leading them to reduce map operations, accelerate interaction speed, decrease search and navigation durations, and consequently shorten overall task completion time.

Therefore, we propose the following hypothesis:

**H2:** Users under time constraints will exhibit shorter task completion times, shorter search and navigation durations, fewer map operations, and longer dwell time on map pages compared to text pages than users without time constraints.

### **User Interaction with Navigation Systems and Spatial Experience**

Aslan et al. [15] found that mobile map navigation users may acquire poorer spatial knowledge. Ishikawa et al. [2] discovered that GPS-based mobile navigation users walk longer distances and make more stops compared to paper map users. Willis et al. [16] observed that GPS-based navigation demands more user attention than paper maps during mobile map navigation. Since attention is limited, time constraints that focus user attention on task requirements and mobile devices inevitably reduce environmental awareness.

Therefore, we propose the following hypothesis:

**H3:** Users under time constraints will exhibit lower environmental perception and attention compared to users without time constraints.

## Methodology

### Research Method

We employed a user experiment methodology, controlling task duration and navigation task type while recording mobile map interaction behaviors and navigation experiences for data analysis. The experiment comprised four parts: a pre-test questionnaire, pedestrian navigation tasks, a post-test questionnaire, and user interviews. Before the navigation tasks, users completed a pre-test questionnaire about their mobile map navigation habits. The pedestrian navigation tasks required users to complete three real-world navigation tasks using mobile maps. The post-test questionnaire assessed feelings associated with each task process. User interviews were conducted after the experiment. All questionnaires used a 5-point Likert scale to collect subjective responses. The pedestrian navigation tasks controlled task duration and type, with screen recording software (Screen Master and Screen Expert) capturing user interactions with mobile maps (including screen operations and audio). Thirty users participated and completed the experiment as required, randomly assigned IDs N01-N30, with N01-N10 in the time-constrained group, N11-N20 in the non-time-constrained group, and N21-N30 in the non-GPS group. As this study focuses on pedestrian navigation behavior under time constraints, we analyzed data from only the 20 users in the time-constrained (N01-N10) and non-time-constrained (N11-N20) groups, specifically their pre-test questionnaires, screen recordings, post-test questionnaires, and interview data from three navigation tasks.

Data collection involved manual video review to extract duration and frequency information. In addition to basic statistical methods, we employed Mann-Whitney U tests for difference testing and CORREL functions for analyzing correlations between time pressure and relevant variables.

### Navigation Tasks

According to the “2016 Q3 China Mobile Map (Navigation) Market Research Report” by iiMedia Research [17], restaurant information ranked first among mobile map queries at 50.1% in Q3 2016. The Bigdata-Research report [1] indicates that over 80% of users most frequently use route navigation, followed by location search. Both male and female users primarily employ mobile maps for “finding directions and locations,” with 70% opening mobile maps when unable to find their way. Pedestrian navigation environments can be categorized as outdoor or indoor. Navigation contexts mainly involve two scenarios: knowing one’s destination but not its specific location (e.g., finding an exam room), and neither knowing the destination nor its location (e.g., searching for restaurant information).

Based on these scenarios, we designed three pedestrian navigation tasks to test our hypotheses:

(1) **Outdoor Pedestrian Navigation 1 (OPN1):** Starting from Wuhan Shopping Plaza, find the highest-rated Hubei cuisine restaurant nearby (nei-

ther knowing the destination nor its location).

(2) **Outdoor Pedestrian Navigation 2 (OPN2)**: Starting from Wuhan Shopping Plaza, walk to Wuhan Taiyangshen Health Club (searching for a location without knowing its specific position).

(3) **Indoor Pedestrian Navigation (IPN)**: Starting from the entrance of Wuhan New World Department Store, locate the TEENIE WEENIE brand store.

### Experimental Participants

To minimize demographic and search skill differences, we recruited participants from Wuhan's university population through questionnaires, requiring: (1) Android system users familiar with basic Android operations; (2) mobile map usage experience, particularly with navigation functions; (3) unfamiliarity with the experimental locations.

This compensated experiment used external incentives to ensure participant engagement. Twenty participants were selected (12 female, 8 male) and randomly divided into two groups: Group 1 (Time Constraint, TC) and Group 2 (No Time Constraint, NTC). The TC group faced time limits of 35 minutes for OPN1, 25 minutes for OPN2, and 15 minutes for IPN, while the NTC group had no time constraints.

The TC group ranged in age from 22 to 23 years (Mean=22.4, SD=0.49), with over two years of map usage experience and an average navigation frequency of 3.4. The NTC group ranged from 19 to 24 years (Mean=22.4, SD=1.685), also with over two years of map experience and an average navigation frequency of 3.2. Mann-Whitney U tests on pre-test questionnaire data revealed no significant differences between groups, confirming that aside from time constraints, the groups were equivalent.

Pre-test questionnaires revealed that Baidu Maps was most popular (55% of users), followed by Amap (40%) and Tencent Maps (5%). The iiMedia Research report [17] similarly showed Baidu Maps held the second-largest market share at 29.7% in Q3 2016. Based on usage patterns, we selected Baidu Maps for this experiment. All participants had mobile navigation experience, with frequency=3 being most common, indicating our sample effectively represented typical mobile map users while including both heavy and novice users. The top five most-used functions were location services, public transit queries, pedestrian navigation, address search, and offline maps—aligning with the iiMedia report [17]. For route starting points, 70% used GPS positioning (current location), while 95% typed destination inputs (0% used voice input). Regarding voice input frequency, 95% of users scored below 2, indicating a preference for conventional input methods. The average frequency of enabling turn-by-turn guidance was 2.45, increasing to 3.55 in unfamiliar locations, suggesting users rely more on guidance when disoriented.

## Data Analysis and Findings

### Hypothesis Verification

**H1** examines whether time constraints affect perceived time pressure, task difficulty, and satisfaction across different mobile contexts, as shown in Table 1 .

Time pressure was measured through self-report using a 5-point Likert scale after each task. No significant differences emerged between TC and NTC groups in time pressure, task difficulty, or satisfaction for OPN1, OPN2, or IPN, leading us to reject H1. Interestingly, for OPN2 and IPN, the NTC group reported slightly higher average time pressure than the TC group.

**H2** tests whether time constraints affect task duration, search time, navigation time, map operations, and dwell times on map versus text pages across contexts, as presented in Table 2 .

For OPN1, significant differences appeared in task duration and text page dwell time, with the TC group showing shorter times than the NTC group. The TC group also reported higher time pressure (2.6) than the NTC group (2.4), suggesting that despite greater perceived pressure, time-constrained users completed tasks faster and perceived lower difficulty. No significant differences emerged between TC and NTC groups for OPN2 or IPN across any temporal or operational measures.

As Table 3 shows, for OPN1, the TC group exhibited significantly fewer sliding operations than the NTC group ( $U=7$ ,  $P=0.001$ ), indicating that time constraints significantly reduce sliding frequency—users with lower time pressure tend to slide more frequently to examine route directions and orientation. For OPN2, the NTC group showed more sliding and zooming but fewer clicks than the TC group. For IPN, the TC group performed significantly more zooming operations than the NTC group ( $U=22.5$ ,  $P=0.037$ ). Notably, despite shorter average task duration (333.3s vs. 350.1s), TC users performed more screen zooms than NTC users, who exhibited more slides but fewer zooms and total operations.

Table 4 reveals that for OPN1 and IPN, the NTC group performed significantly more upward slides than the TC group, with no other significant differences. NTC users under lower time pressure conducted more upward slides, and in OPN1, more slides in all directions. For IPN, despite reporting lower time pressure (2.2 vs. 2.4), NTC users performed more upward slides. No significant differences emerged between groups for OPN2 across any sliding direction.

As shown in Table 5 , for IPN, the TC group performed significantly more zoom-in operations than the NTC group ( $U=20.5$ ,  $P=0.024$ ), with no significant difference in zoom-out operations. Similar to the upward slide pattern in IPN, TC users with lower time pressure performed more zooms overall. Combined with task duration data, this indicates that in indoor navigation, TC

users performed more screen zooming operations under lower time pressure and within shorter timeframes. No significant differences appeared between groups for OPN1 or OPN2 in zoom-in or zoom-out operations.

**H3** examines whether time constraints affect the number of landmarks selected and their perceived salience across contexts, as shown in Table 6 .

No significant differences emerged between TC and NTC groups in landmark quantity or perceived salience for OPN1, OPN2, or IPN, leading us to reject H3. For landmark quantity, the NTC group selected more landmarks than the TC group in OPN1 but fewer in OPN2 and IPN. For landmark salience, NTC users perceived landmarks as more prominent in OPN1, while TC users reported higher salience in OPN2 and IPN. This suggests that in OPN1, NTC users tended to select more landmarks as reference points and perceived them as more noticeable.

### Correlation Analysis Between Time Pressure and Variables

Using Excel's CORREL function and SPSS for Spearman correlation tests (with significant correlations marked by “\*”), we analyzed relationships between time pressure and relevant variables.

**Time Pressure and Task Difficulty/Satisfaction:** As Table 7 shows, for OPN1 and OPN2, time pressure correlated significantly and negatively with task satisfaction in the TC group ( $r=-0.67$  and  $r=-0.65$ , respectively), indicating that greater time pressure reduces satisfaction. No significant correlation emerged between time pressure and perceived task difficulty, except for a negative correlation in the NTC group for OPN1.

**Time Pressure and Task Duration:** Table 8 reveals that for OPN1, TC group task and navigation durations correlated positively with time pressure (greater pressure associated with longer times), while NTC group durations correlated negatively. TC group search duration correlated negatively with time pressure (greater pressure associated with shorter search time), while NTC group search duration correlated positively. For OPN2, both groups showed similar patterns: positive correlations for task and navigation durations, negative for search duration. For IPN, both groups showed positive correlations between task/navigation durations and time pressure, while search duration correlated positively for TC and negatively for NTC.

**Time Pressure and Map Operations:** Table 9 shows that for OPN1, both groups exhibited negative correlations between sliding frequency and time pressure (greater pressure associated with fewer slides). TC group click and zoom frequencies correlated positively with time pressure, while NTC group correlations were negative. For OPN2, both groups showed negative correlations between clicks/zooms and time pressure; TC group sliding correlated positively while NTC group sliding correlated negatively. For IPN, TC group clicks and slides correlated positively with time pressure (NTC group negative), while zooms

correlated negatively (NTC group positive).

## Discussion of Experimental Results

Based on the premise that time constraints generate time pressure, this study employed time constraint as an independent variable in a controlled experiment to verify its effects on user-map interactions across different navigation task types.

**Impacts of Time Constraints on Indoor vs. Outdoor Navigation:** Time constraints affect indoor and outdoor navigation differently. For outdoor navigation, time constraints primarily influence duration, operation frequency, and satisfaction perception, with particularly pronounced effects in OPN1. For indoor navigation, time constraints mainly affect screen operations. Specifically, in outdoor navigation, time-constrained users demonstrated significantly shorter task durations and text page dwell times, with substantially fewer sliding operations, particularly upward slides. In indoor navigation, time-constrained users performed significantly more zooming operations, especially zoom-ins, while non-time-constrained users performed more upward slides.

Regarding environmental perception, although not statistically significant, time constraints differentially affected indoor and outdoor navigation. In outdoor navigation, time-constrained users selected fewer landmarks and perceived lower salience, suggesting visual attention focused more on system interaction. They reduced unnecessary map operations and external environmental attention to reach destinations faster. In indoor navigation, time-constrained users selected more landmarks with higher perceived salience, indicating attention divided between the map and physical environment. This aligns with the immaturity of indoor navigation technology, which cannot provide pre-planned routes but only floor layouts and current location. Consequently, indoor navigation users performed more zooming operations than outdoor users.

Even within outdoor navigation, time constraints more strongly affected OPN1 performance. OPN2 provided a specific destination name enabling direct navigation, whereas OPN1 required users to explore and identify the target first, demonstrating that time constraints more significantly impact complex information tasks. This parallels findings from web search research: Slone [18] found that with 30-minute limits, users focused on goal-directed tasks like bill payment and shopping, but with extended time, they engaged in exploratory searches like job hunting. Another controlled study [19] showed that under time constraints, users collected significantly more information for comprehension tasks than fact-finding tasks. Thus, whether web search or outdoor navigation, time constraints affect information behaviors more substantially during complex tasks.

**Relationship Between Time Constraint and Time Pressure:** Liu et al. [20] found that while time constraints did not significantly affect perceived task difficulty, they significantly impacted search confidence and effectiveness evaluations. Crescenzi et al. [8] demonstrated that time constraints increased

perceived difficulty and reduced satisfaction, with significant differences in perceived time pressure between constrained and unconstrained groups. These findings suggest that time constraints' effects on task perception depend on the magnitude of time pressure they induce. In our study, time pressure correlated significantly with satisfaction but not difficulty. However, perceived time pressure differed between time-constrained and unconstrained groups without statistical significance, indicating that time constraint is not the decisive factor in time pressure intensity. This confirms that time pressure, not time constraint, directly influences information task perceptions.

Although correlations between time pressure and task duration/map operations were not significant, detailed data reveal patterns. In the “unknown destination and location” scenario (OPN1), 50% of time-constrained users reported time pressure  $>3$  (average=3.6), with average task duration of 1,181.6 seconds (116.2s longer than their group mean) and operation frequencies above group averages (except sliding). In indoor navigation, 60% of time-constrained users reported pressure  $<3$  (average task duration=255.7s, 77.6s below group mean), with operation frequencies below group averages (except zooming). This suggests that users experiencing greater time pressure actually performed more operations and took longer, contrasting with time-constrained users who performed fewer operations and finished faster. This discrepancy confirms that time constraint and time pressure are distinct concepts: time constraint is an objective temporal limitation, while time pressure is a subjective emotional response. Benson et al. [21] distinguished them as: (1) available time being less than required time, and (2) users having to complete tasks within available time. Due to individual differences, identical time constraints produce varying pressure perceptions. Clarifying this distinction better illuminates how temporal factors influence information behavior.

**Design Recommendations for Mobile Navigation Systems:** Time-constrained users demonstrated shorter task durations and fewer interactions, indicating higher efficiency. Since improving efficiency is a universal system design goal, mobile navigation systems could artificially create time-constrained scenarios to promote efficiency. However, as time pressure generates negative emotions that degrade experience, such artificial constraints should motivate rather than pressure users. Systems could ask users before navigation whether they wish to challenge themselves to complete the task within a time limit, offering rewards (e.g., points) for success. This gamified approach would make time pressure a positive efficiency factor. Existing systems like Baidu Maps and Amap already provide social features; integrating challenge games with social functions—similar to WeChat’s step-count leaderboards—could attract users to social features while improving efficiency and enhancing overall experience.

Our results show time pressure correlates negatively with satisfaction, suggesting navigation systems should help reduce time pressure. The most effective method is helping users reach destinations quickly with accurate time estimates. The former requires unobstructed routes, potentially through user comments

providing real-time route condition updates (e.g., “User A (1 hour ago): Road construction ahead, detour required”). The latter can be achieved by calculating current speed to update estimated arrival times (e.g., “At current speed, you will arrive in 10 minutes”). Furthermore, since time constraints more strongly affect complex information tasks, mobile navigation systems should provide additional support for time-constrained users searching for nearby services.

In mobile pedestrian navigation, time constraints generate time pressure but do not significantly affect its intensity. When users neither know their destination nor its location, time constraints significantly impact task duration, text page dwell time, and sliding frequency. Greater perceived time pressure leads to fewer screen operations and faster arrival. Indoor navigation shows the opposite pattern: time constraints affect map operation frequency—greater time pressure correlates with more screen operations but fewer zooms. No significant differences emerged in environmental perception. When searching for an unknown location, non-time-constrained users spent less time but performed more screen operations with lower environmental awareness, though not significantly.

In real life, individuals perceive time differently; even under identical time constraints, their experienced time pressure varies. Future research should therefore deeply investigate the relationship between time pressure and time constraints, expanding sample sizes when possible.

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## Author Contributions

**Wu Dan:** Designed the research framework, proposed the research topic and ideas, revised the manuscript, and finalized the paper.

**Li Yi:** Collected, cleaned, and analyzed data; drafted the initial manuscript.

**Dong Jing:** Revised the final version of the paper.

## Conflict of Interest Statement

All authors declare no conflict of interest.

## Supporting Data

Supporting data is available in the online version of the journal at <http://www.infotech.ac.cn>:

[1] Wu D, Li Y, Dong J. jcsj.xls. Basic data.

[2] Wu D, Li Y, Dong J. xgxjysj.xls. Correlation test data.

[3] Wu D, Li Y, Dong J. bzwtsj.xls. Landmark statistics data.

[4] Wu D, Li Y, Dong J. qcwjjg.xls. Pre-test questionnaire results.

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