Postprint: A Study of Pedestrian Navigation Concerns Using the Think-Aloud Method

Authors: Wu Dan, Lu Liuxing

Date: 2017-11-08T00:00:00+00:00

Abstract

【Purpose】This study investigates users' focus of attention and its changes during pedestrian navigation, examines the applicability of the think-aloud method for studying user information behavior in outdoor real-world environments, and provides improvement suggestions for mobile map applications from the perspective of user focus. 【Method】Three pedestrian navigation experiments were designed in outdoor real-world environments, requiring users to think aloud while operating. 【Results】During pedestrian navigation, users paid more attention to the search system than to external information; throughout the navigation process, users showed high attention to the display of search system results, while their primary focus on external information before, during, and after walking exhibited a shift from "environmental conditions–location–destination conditions." 【Limitations】Data were manually segmented into three time periods, which involves unavoidable errors. 【Conclusion】The think-aloud method is suitable for user interaction research in outdoor real-world environments; optimizing map functions based on both the external information users focus on and the search system itself can provide users with a better user experience.

Full Text

A Study on Pedestrian Navigation Awareness Using the Think-Aloud Method

Wu Dan, Lu Liuxing
(School of Information Management, Wuhan University, Wuhan 430072)

Abstract

[**Objective**] This study investigates users' attentional focus and its changes during pedestrian navigation, examines the applicability of the think-aloud method

for researching user information behavior in real outdoor environments, and provides improvement recommendations for mobile map applications from a user attention perspective.
[**Methods**] We designed three pedestrian navigation experiments in real outdoor environments, requiring participants to think aloud while operating their devices.
Results During pedestrian navigation, users exhibited greater attention to the search system than to external environmental information. Throughout the navigation process, users showed high attention to search result displays, while their primary focus on external information shifted from "environmental conditions" to "location" and finally to "destination situation" across the pre-walking, mid-walking, and post-walking phases.
[**Limitations**] Manual division of data into three time periods introduces unavoidable errors.
[**Conclusions**] The think-aloud method is applicable for user interaction research in real outdoor environments. Optimizing map functionality from the perspectives of both external information and the search system itself can enhance user experience.

Keywords: Think-Aloud Method; Pedestrian Navigation; Awareness

Introduction

With the proliferation of smartphones, mobile map applications have become essential tools for daily travel. According to data from the BigData-Research Data Center, mobile map navigation software exhibits high usage rates, with 59.7% of users using it frequently and 38.6% occasionally. Among mobile map functions, route navigation, location search, and public transportation queries are the three most commonly used features [1]. Since interactivity represents a key aspect of map functionality [2], studying user-map interaction behaviors is crucial for enhancing map functionality. During interaction with mobile maps, users consciously or unconsciously attend to information from either the map or their surroundings to facilitate interaction. Therefore, investigating users' attentional focus during map usage is significant for understanding user-map interaction behaviors and improving map functionality.

Based on map spatial cognition theory [3], users navigating and locating destinations attend to and utilize maps to acquire, recognize, memorize, and employ spatial information for decision-making and action guidance. The user-map interaction process involves complex perceptual, representational, memory, and thinking activities. When users verbalize their thoughts during task completion, a close connection is established between thinking and speech [4]. As a method for studying complex information processing and thinking processes [5], the think-aloud method enables researchers to study users' thought processes or cognitive psychology through their verbalizations. Also known as the think-aloud protocol or verbal protocol method, it requires participants to vocalize their ongoing behaviors and thoughts during information seeking. Researchers

record these utterances using audio equipment to understand user thinking and analyze behavioral motivations [6]. Given that complex thinking activities accompany user-map interactions, using the think-aloud method to study attentional focus during these interactions is feasible.

2.1 The Think-Aloud Method

Research on the think-aloud method itself focuses on its introduction and promotion, validity verification, and comparative studies with other methods or different think-aloud variants. Originating in psychology, the method was first proposed by Duncker et al. [7] in 1945 and was later introduced and promoted in other fields at the turn of the 21st century. During its early adoption in information science, numerous studies addressed the method' s concepts and procedures [8], and it gained prominence across various subfields of information science. In human-computer interaction research, the method' s value for understanding user cognitive processes received full recognition [9] and became widely promoted.

In validity verification studies, scholars examined whether the method affects certain populations' work performance, such as working time and efficiency [10], to explore its effectiveness for specific user groups. Think-aloud methods have several variants, primarily including traditional think-aloud, active listening think-aloud, and active intervention think-aloud, distinguished by the experimenter' s role throughout the process. In traditional think-aloud, experimenter-participant interaction is minimal, with the experimenter only reminding participants to continue thinking aloud after prolonged pauses, without engaging in conversation. In active listening think-aloud, the experimenter plays an intermediate role. Since participants often use filler words to indicate thinking during pauses [11], experimenters can repeat participants' last statements with questioning intonation to maintain naturalness similar to normal communication [12]. Active intervention think-aloud involves deeper experimenter-participant interaction, with experimenters questioning participants about their think-aloud content to understand the purposes or reasons behind behaviors and thoughts [13].

Due to these variations, comparative studies of different think-aloud types have become a research focus, including comparisons between traditional and instructed think-aloud [14], and between concurrent think-aloud (thinking while performing tasks) and retrospective think-aloud (thinking after task completion) [15], aiming to understand how different think-aloud types affect task performance.

2.2 Application of Think-Aloud Method in User Interaction Research

In user interaction research, scholars have focused on using think-aloud to study information seeking behavior, product usability evaluation based on users, and interactive interface design. User information seeking behavior research typi-

cally employs traditional think-aloud, conducted in laboratory settings where search topics or tasks are designed. Participants are required to search for needed information while verbalizing their operations and thoughts, which are recorded by experimenters who remind participants to continue thinking aloud. These studies are often combined with other data collection and analysis methods, primarily applied to: (1) research on user information seeking strategies and processes, exploring strategies and processes when users search for specific information online to build theoretical models [16]; (2) research on cognitive processes of information seeking, examining web browsing behavior patterns and analyzing cognitive dimension influencing factors [17]; (3) research on factors affecting information seeking behavior, analyzing influences on different populations' information seeking behaviors [18] or impacts of different task types on user information seeking behavior [19].

Research on product usability evaluation and interactive interface design primarily employs active listening and active intervention think-aloud. These studies involve participants using products or operating on interfaces while thinking aloud, with experimenters asking questions about operations or utterances, such as "What operation are you performing?" or "Why did you do that?" [20] to gain deeper understanding. In usability evaluation, users employ think-aloud to evaluate specific products (websites, software, etc.), analyzing product development factors from the user perspective to provide improvement basis [21]. In interactive interface design research, think-aloud is used in specific interactive systems, such as clinical computer systems and online shopping website interfaces, to analyze how different interfaces affect user experience or work performance, thereby informing design [22-23].

Currently, think-aloud research on user interaction behavior primarily focuses on web information search behavior, with few studies examining mobile map navigation behavior or attentional focus during pedestrian navigation. Therefore, this study focuses on using think-aloud to investigate attentional focus during pedestrian navigation.

Methodology

Route navigation is one of the three most frequently used mobile map functions [1]. As a type of route navigation, pedestrian navigation helps users locate destinations on foot, providing daily convenience and thus being frequently used. This study designed three pedestrian navigation tasks to investigate user behavior:

1. Starting from Wuhan Shopping Mall, search for and walk to the highest-rated Hubei cuisine restaurant nearby.
2. Starting from Fuke Mall in Wuhan, search for and walk to the Wuhan Taiyangshen Modern Health Center (Xudong Branch).
3. Starting from the entrance of Wuhan New World Department Store (Xudong Branch), search for and walk to the TEENIE WEENIE brand

store in that mall.

All three tasks were conducted in real outdoor environments. Thirty university students experienced with Baidu Maps were recruited (participants N01-N30). Each participant independently traveled to the outdoor starting point. The experiment consisted of four parts: pre-test questionnaire, pedestrian navigation experiment, post-test questionnaire, and user interview. The pre-test questionnaire collected basic information about navigation habits before the navigation experiment. The navigation experiment involved completing the three real-environment navigation tasks. The post-test questionnaire gathered participants' experimental experiences. The interview was conducted online after all tasks and questionnaires were completed. Since this study focuses on attentional focus during pedestrian navigation, we used the think-aloud data from 30 participants performing three navigation tasks.

3.1 Research Questions

Users attend to map or environmental information to varying degrees during pedestrian navigation. Therefore, studying their attentional focus and changes aids understanding of user-map interaction behaviors. Based on this, this study addresses two main questions: (1) What are users' primary attentional foci during pedestrian navigation? (2) How do users' attentional foci change during pedestrian navigation?

3.2 Research Methods

(1) Data Collection Method
Numerous data collection methods exist for user information behavior and interaction research, including questionnaire surveys, interviews, observation, experiments, and think-aloud methods [24]. Compared to questionnaires, observation, and experiments, think-aloud enables deeper understanding of user behavior, offers flexible operation, allows free thinking around specific topics, involves less experimenter influence than interviews, and is cost-effective—making it effective for understanding user cognition and behavioral processes. Since this research was conducted in real outdoor environments, we used think-aloud to collect user data to deeply understand thinking and cognitive processes. Due to constraints preventing experimenter-participant interaction during experiments, we adopted traditional think-aloud to design the experiment and collect verbal data. During the three navigation tasks, all participants used pre-installed screen recording software on their phones to record the entire process and operations. They were required to speak loudly into their phone screens about any operations or thoughts, recording their map operations and think-aloud content.

(2) Data Analysis Method
Participants' verbal data during walking were transcribed into text, yielding 745 utterances. Using NVivo 8 content analysis software, we applied grounded theory' s hierarchical coding approach. Coding is a process of analyzing, under-

standing, and defining data. Grounded theory provides three coding methods: open coding, axial coding, and selective coding [25], which some scholars term first-level, second-level, and third-level coding [26]. Although Chinese literature uses different names for these three coding types, their meanings are identical. To reflect the hierarchical nature of coding in this study, we adopted the "first-level coding," "second-level coding," and "third-level coding" nomenclature to study users' primary attentional foci during pedestrian navigation. Additionally, based on the hierarchical coding results, we divided each participant' s navigation duration into three equal parts—early, middle, and late walking stages—and extracted think-aloud data from each period to examine changes in attentional focus.

Results

4.1 Primary Attentional Foci in Pedestrian Navigation

(1) Coding Results

First-Level Coding

First-level coding involves labeling any codable sentences or fragments from raw interview data—a process of breaking down, conceptualizing, and recombining data [27]. During coding, researchers can choose word-by-word, sentence-by-sentence, or event-by-event coding [25]. Since participants uttered one or several sentences during specific time periods, we adopted sentence-by-sentence coding. To minimize personal bias, we followed previous qualitative research methods [25], using participants' original words as first-level codes whenever possible. When original words could not accurately express concepts, we abstracted relevant nouns or concepts while adhering to the original meaning. After continuously comparing and summarizing participants' raw utterances, extracting concepts, and processing all 745 utterances from 30 participants, we obtained 14 first-level codes, as shown in Table 1 .

Second-Level Coding

Second-level coding involves merging and categorizing first-level codes. For example, "indoor temperature" and "weather" were categorized as "environmental conditions," representing specific states of temperature, humidity, wind, and rain that users perceive in outdoor or indoor environments. "Time display," "distance display," and "landmark display" were categorized as "search result display," representing content shown in the result interface after users input queries. After clarifying internal connections among all first-level codes and merging related or identical categories, we obtained 8 second-level codes.

Third-Level Coding

Third-level coding involves further determining core categories through induction, merging, and summarization of second-level codes [25]. During this process, we found that users' attentional foci during pedestrian navigation could be summarized into two dimensions: "external information" and "search system." "External information" refers to information in users' real environment,

including "environmental conditions," "location," "time," "traffic conditions," and "destination situation." "Search system" refers to all information and services provided by Baidu Maps, including "search result display," "system prompt services," and "system positioning." Our first-level, second-level, and third-level codes are shown in Table 2 .

As shown in Tables 1 and 2, users primarily focused on external information and search system content during pedestrian navigation. Total attention frequency to external information was 99, while attention to the search system reached 202, indicating greater focus on the search system. Within external information, "environmental conditions" received the most attention (28 times, approximately 30% of external information attention), as human senses are sensitive and users can most directly perceive temperature and weather phenomena. Within the search system, "search result display" received the most attention, particularly "landmark display," because map landmarks help users determine correct directions and choose proper routes.

(2) Coding Consistency Check

In qualitative research, validity can be verified by comparing whether different analysts independently produce consistent results when analyzing the same data –i.e., reliability assessment, primarily expressed through inter-coder agreement indices. Inter-coder agreement refers to the percentage of identical coding categories out of total categories, calculated as CA = 2S/(T1+T2) [28], where S represents the number of agreements and T1, T2 represent each coder' s total codes. CA values approaching 1 indicate higher consistency.

To verify coding consistency, we invited another researcher experienced in qualitative analysis but not part of our team to code independently. Since coders might use different words for identical or similar concepts (e.g., one coded "road construction situation" while another coded "road condition" for the same utterance), we unified semantically identical codes after independent coding and discussion. Following this approach, we standardized codes with identical meanings while preserving distinct ones, then calculated inter-coder agreement without changing either coder' s total count. The resulting inter-coder agreement index was CA = 0.77 > 0.5, indicating good consistency.

4.2 Changes in Attentional Focus During Pedestrian Navigation

After dividing participants'verbal data into early, middle, and late walking stages and conducting coding statistics, Figure 1 [Figure 1: see original paper] shows that attention to the search system exceeded attention to external information throughout navigation. We further analyzed second-level codes for "external information" and "search system" across the three time periods.

Figure 2 [Figure 2: see original paper] reveals that within "external information" second-level codes, attention to "time"remained relatively stable, while attention to "environmental conditions," "location," and "traffic conditions" decreased over time, and attention to "destination situation" showed a fluctuating upward

trend. In the early walking stage, "environmental conditions"dominated external information attention; in the middle stage, "location" became primary; and in the late stage, "destination situation" emerged as the main focus. Thus, users' primary external information attention shifted from "environmental conditions → location → destination situation."

Figure 3 [Figure 3: see original paper] shows that within "search system" second-level codes, attention to "search result display" remained consistently high, peaking in the middle walking stage.

4.3 Discussion of Experimental Results

Analysis of think-aloud utterances from 30 participants using Baidu Maps for pedestrian navigation, using grounded theory hierarchical coding, reveals attentional foci and their changes.

(1) Attentional Foci and Changes in Pedestrian Navigation
When using mobile map apps for pedestrian navigation, users attend to both external information and search system content. In the early stage, after confirming routes on the map, users develop a general understanding and easily notice surrounding environments when starting to walk. Notably, if participants previously used public transportation (subway then bus) from the experimental starting point (Qunguang Plaza) to the shopping mall, they paid more attention to environmental conditions in the early walking stage because the significant difference between indoor subway environments and outdoor conditions created strong sensory impressions.

In the middle stage, users frequently encountered intersections or previously selected landmarks, requiring location confirmation to determine subsequent directions, thus increasing location information attention. In the late stage, when near destinations, if maps indicated proximity but users couldn' t locate destinations due to outdated map information, they focused more on destination situation, confirming destination orientation and surroundings to verify locations. Additionally, users often selected prominent place names or buildings displayed on maps as reference points or landmarks for direction judgment, making landmark display particularly important throughout navigation.

Throughout pedestrian navigation, attention to the search system consistently exceeded attention to external information. Moreover, as users approached destinations, the ratio of search system to external information attention increased from 1.6:1 in the early stage to 2.2:1 in the middle stage and 2.5:1 in the late stage. This increasing focus on the search system reflects users' growing concentration on map interaction to reach destinations, while decreasing external information attention reflects reduced environmental influence as map interaction intensified.

(2) Application of Think-Aloud Method in User Interaction Research
Previous think-aloud user interaction research was primarily conducted indoors.

Based on the Web of Science "Information Science & Library Science" category, we selected 25 most relevant articles (retrieved April 8, 2017). Among these, 23 studies on user interaction behavior (including search, browsing, and other interactions with information system interfaces and functions) used think-aloud methods in indoor environments. For example, the most highly cited study (191 citations) by Fidel et al. [29] examined high school students' web information search behavior in school computer labs using think-aloud and observation methods. In the most recent study by Brett et al. [30], think-aloud was used to collect usability test and evaluation data on the University of Houston Library's Primo interface to provide improvement recommendations.

This study applied think-aloud in real outdoor environments for actual search and navigation experiments using mobile map apps. The research demonstrates that think-aloud is not limited to indoor user interaction studies but is also applicable to outdoor real-environment user interaction research, such as mobile map interaction studies, thus providing examples for future outdoor think-aloud research. Since think-aloud data collection can be limited by external environmental factors, users might hesitate to think aloud or do so less frequently without experimenter supervision outdoors. Therefore, when using think-aloud in real outdoor environments, researchers should provide adequate training, emphasizing the importance and necessity of thinking aloud outdoors to overcome users' hesitation or concerns. Additionally, before participants depart for outdoor experiments, researchers should ensure normal and smooth data recording by checking screen recording and audio tools to avoid experimental failure due to equipment issues. When possible, experimenters can accompany participants, though they must not guide think-aloud. They can supervise, assist with equipment issues, or use active listening or active intervention approaches to question participants about operations or thoughts for deeper behavioral understanding.

(3) Recommendations for Enhancing Mobile Map User Interaction Experience

Based on findings that users paid considerable attention to "environmental conditions" in the early stage, "traffic conditions" in the middle stage, and "destination situation" in the late stage, we propose corresponding recommendations for improving mobile map interaction experience.

Since users focused on environmental conditions including temperature in the early stage, mobile map apps could provide voice reminders or display current temperature at appropriate interface locations before navigation begins, helping users prepare mentally or take necessary measures. Since users also focused on traffic conditions in the middle stage, mobile map apps should update walking route conditions in real time, promptly alerting users to detours or safety precautions when encountering traffic jams, congestion, or road construction ahead, reducing unnecessary detours due to unknown conditions. In the late stage, users' increased attention to destination situation stemmed from outdated map information that failed to remove demolished business information, preventing destination location. Therefore, mobile map apps should leverage user partic-

ipation by placing problem feedback entry points prominently in destination information interfaces and providing rewards for users who report outdated information, encouraging active participation in database updates to remove obsolete information and add correct information.

References

[1] Bigdata-Research. Research Report of the 3rd Quarter of 2016 China Mobile Map (Navigation) Market [R/OL]. (2016-11-06) [2016-12-25]. http://www.cnit-research.com/content/201611/11430.html.

[2] Harrower M. A Look at the History and Future of Animated Maps [J]. Cartographica, 2004, 39(3): 33-42.

[3] Wang Jiayao, Chen Yufen. Theoretical Cartography [M]. Beijing: PLA Press, 2000.

[4] Ericsson K A, Simon H A. How to Study Thinking in Everyday Life: Contrasting Think-Aloud Protocols with Descriptions and Explanations of Thinking [J]. Mind, Culture, and Activity, 1998, 5(3): 178-186.

[5] Ma Jie. Using "Think Aloud" Method to Acquire Expert' s Decision Tacit Knowledge in Enterprise [J]. Information Science, 2007, 25(6): 944-948.

[6] Huang Lihong. A Review of the Methodologies Used by User' s Information-Seeking Behavior on the Web in Foreign Countries [J]. Information Science, 2009, 27(11): 1747-1752.

[7] Duncker K, Lees L S. On Problem-Solving [J]. Psychological Monographs, 1945, 58(5). http://dx.doi.org/10.1037/h0093599.

[8] Someren M W V, Barnard Y F, Sandberg J A C. The Think Aloud Method - A Practical Guide to Modelling Cognitive Processes [J]. Information Processing and Management, 1995, 31(6): 906-907.

[9] Nielsen J, Clemmensen T, Yssing C. Getting Access to What Goes on in People's Heads?: Reflections on the Think-aloud Technique [C]// Proceedings of the 2nd Nordic Conference on Human-Computer Interaction, Aarhus, Denmark. 2002: 101-110.

[10] Gill A M, Nonnecke B. Think Aloud: Effects and Validity [C]// Proceedings of the 30th ACM International Conference on Design of Communication. 2012: 31-36.

[11] Boren T, Ramey J. Thinking Aloud: Reconciling Theory and Practice [J]. IEEE Transactions on Professional Communication, 2000, 43(3): 261-278.

[12] Bruun A, Stage J. An Empirical Study of the Effects of Three Think-Aloud Protocols on Identification of Usability Problems [C]// Proceedings of the 15th IFIP TC13 Conference on Human-Computer Interaction. 2015: 159-176.

[13] Dumas J F, Redish J C. A Practical Guide to Usability Testing [M]. Greenwood Publishing Group Inc., 1999: 1505-1506.

[14] Mcdonald S, Petrie H. The Effect of Global Instructions on Think-aloud Testing [C]// Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. 2013: 1549-1558.

[15] Willis L M, McDonald S. Retrospective Protocols in Usability Testing: A Comparison of Post-session RTA Versus Post-task RTA Reports [J]. Behaviour & Information Technology, 2016, 35(8): 1-16.

[16] Li Peng, Han Yi. Case Study about Relevance in Collaborative Information Seeking & Retrieval Based on the Grounded Theory [J]. Library and Information Service, 2013, 57(19): 24-29.

[17] Geng Qian, Yang Qian. Study on Web Browsing Behavior and Cognitive Influential Factors Based on Three-dimensional Model [J]. Library and Information Service, 2015, 59(15): 87-93.

[18] Madden A D, Ford N J, Miller D, et al. Children' s Use of the Internet for Information-Seeking: What Strategies do They Use, and What Factors Affect Their Performance? [J]. Journal of Documentation, 2006, 62(6): 744-761.

[19] Thatcher A. Web Search Strategies: The Influence of Web Experience and Task Type [J]. Information Processing & Management, 2008, 44(3): 1308-1329.

[20] Makri S, Blandford A, Cox A L. This is What I' m Doing and Why: Methodological Reflections on a Naturalistic Think-aloud Study of Interactive Information Behaviour [J]. Information Processing & Management, 2011, 47(3): 336-348.

[21] Ganglbauer E, Fitzpatrick G, Subas Ö, et al. Think Globally, Act Locally: A Case Study of a Free Food Sharing Community and Social Networking [C]// Proceedings of the 17th ACM Conference on Computer Supported Cooperative Work & Social Computing. 2014: 911-921.

[22] Jaspers M W, Steen T, Van Den B C, et al. The Think Aloud Method: A Guide to User Interface Design [J]. International Journal of Medical Informatics, 2004, 73(11-12): 781-795.

[23] Majid R A, Hashim M, Jaabar N A A. An Evaluation on the Usability of E-Commerce Website Using Think Aloud Method [A]// New Perspectives in Information Systems and Technologies [M]. Springer, 2014: 289-296.

[24] Cao Mei, Zhu Xuefang. A Preliminary Study on the Research Method of User Information Behavior [J]. Information Studies: Theory & Application, 2010, 33(1): 37-40.

[25] Ke Ping, Zhang Wenliang, Li Xining, et al. A Grounded Theory Research on Public Librarians' Perception of Organizational Cultures [J]. Journal of Library Science in China, 2014, 40(3): 37-49.

[26] Chen Xiangming. How Teachers Make Qualitative Studies [M]. Beijing: Education Science Press, 2001.

[27] Wang Ping, Ru Jiayi. Influencing Factors on Domestic Teenagers' Satisfaction of Library Service: An Exploratory Study Based on the Grounded Theory [J]. Library and Information Service, 2015, 59(19): 41-46.

[28] Xu Jianping, Zhang Houcan. Testing Intercoder Reliability by Multi-approaches in Qualitative Research [J]. Psychological Science, 2005, 28(6): 1430-1432.

[29] Fidel R, Davies R K, Douglass M H, et al. A Visit to the Information Mall: Web Searching Behavior of High School Students [J]. Journal of the Association for Information Science and Technology, 1999, 50(1): 24-37.

[30] Brett K R, Lierman A, Turner C. Lessons Learned: A Primo Usability Study [J]. Information Technology & Libraries, 2016, 35(1): 7-25.

Author Contributions

Wu Dan: Proposed research questions and framework, revised manuscript, finalized version.
Lu Liuxing: Collected and analyzed experimental data, drafted and revised manuscript.

Conflict of Interest Statement

All authors declare no conflict of interest.

Supporting Data

Supporting data is available in the journal's online version at http://www.infotech.ac.cn.
[1] Wu D, Lu L. think-aloud data.xlsx. Think-aloud data.

Received: 2017-02-07
Revised: 2017-04-14

Note: Figure translations are in progress. See original paper for figures.