Reforms in Human Wayfinding Behavior Based on the Availability of GPS-based Navigation System

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Abstract

Recent advances in location finding and smartphone technologies help us to access necessary information including location and navigational assistance. At the same time, there are demands for more efficient and seamless navigation tools as the use of location aware mobile devices grows. The question then remains, as it has from the first introduction of GPS, as to whether or not we truly need navigation tools beyond maps and verbal communication. If innovative navigation tools such as GPS can help humans reach a destination efficiently and reduce anxiety, what are the benefits in using such a tool and how can we maximize our navigation performance? What are the implications of using a form of assistance that might not be reliable? There is currently a lack of information regarding how such navigation tools impact human abilities to navigate and process spatial knowledge. Navigation or experience is altered based on the availability of navigation tools while navigating. The purpose of this study is to examine the difference in human spatial behavior based on the availability of the navigation system during wayfinding. We examined the impact on human navigation based on with or without the navigation system as well as the impact of varying the levels of availability of such tools (not available, partially available, or full availability).

Background and Relevance

Map and verbal communication have played a major role in how we share and accumulate spatial information and develop knowledge (Ishikawa, Fujiwara, Imai, & Okabe, 2008). However, the quality and accuracy of acquired spatial knowledge is often inconsistent between individuals, as well as, between different places for the same individual (Golledge, 1999). Since geographic knowledge relies on an individual's memory and ability to understand the environment, there is a potential risk of miscommunication when one shares spatial knowledge verbally. In contrast, a map is a more effective method to deliver geographic knowledge to others. Maps can store a great deal of spatial and non-spatial information through systems of geodesy, symbology, generalization, and communication (Goodchild, 2007). However, a map cannot contain all spatial observations and therefore necessarily represents a simplified and often specific view of the world.

The landscape of our community has been expanded in both physical and social dimensions (Bell, 2006). Recent advances in Global Positioning System (GPS) and complex functionalities in many mobile devices have put a wealth of geographic and navigation information in our hand (Bell, Jung, & Krishnakumar, 2010; Jung, Bell, Petrenko, & Sizo, 2012). These technological advances could reduce our spatial anxiety in unknown environments and prevent us from becoming lost. GPS-based navigation assistant aids update dead-reckoning information for the users. Furthermore, with integrated network data, Global Positioning System (GPS) can show the current location of a user with small dot on the mobile display and deliver turn-by-turn navigation information based on integrated geographic information, including metric distance, time, heading direction, and speed along a selected route. Some advantages of using a GPS-based device include not needing to learn about the environment prior to travel and even if we take an off-route, this system could deliver an alternative route to reach destination. These technologies represent the most recent in a long line of innovations that have altered the navigation and wayfinding process (Bell & Saucier, 2004).

Navigation systems are positively able to assist human wayfinding in various environments and tasks (Allen, 1999). But, if we rely on a particular navigation system for our wayfinding needs, it is important to understand how the availability, or the presence of a GPS device during navigation, can impact and modify our navigation patterns and behaviors. Many researchers studied human spatial activities through currently available positioning systems (Field, O'Brien, & Beale, 2011; Ishikawa et al., 2008; Speake & Axon, 2012). Unfortunately, there is a lack of information about the ways such navigation tools directly impact peoples abilities to navigate and process spatial knowledge in the same environment. At the same time, there are demands for more efficient and reliable navigation tools as the use of location aware mobile devices grows (i.e. cellphones, smartphones, laptops, and other mobile devices). The question remains as to whether or not we truly need navigation tools beyond maps and verbal communication. If innovative navigation tools can help humans to find a destination efficiently and reduce disorientation, what information needs to be communicated to humans before and after use? And what are the implications of using a form of assistance that might not be reliable?

The purpose of this study is to examine the differences in human spatial behavior based on availability of a navigation system during wayfinding. This research examines the impact of technology on human navigation, both with and without a navigation system, with varied levels of availability of such tools (not available, partially available, or fully availability). Navigation tools may result in a transition of navigation from active (that which is done with a full understanding of their orientation) to passive (that which is done without sufficient critical reasoning). It is also beneficial to evaluate the usefulness of the navigation assisting system for use in complex urban settings (i.e. determining a correct route and reducing disorientation problems). This research also examines how humans react to and acquire geographic knowledge when navigational tools are both available and unavailable (or unreliable).

Methods and Data

Measuring the difference in human spatial behavior based on availability of navigation tools was conducted with 60 participants. Each participant was randomly assigned one of 4 navigational groups (all navigation occurred on the University of Saskatchewan campus):

1. Navigation Condition 1 (Active Navigation): No navigational support for the entire navigation experiment.
2. Navigation Condition 2 (Active to Passive Navigation): No navigational support in the first half of the navigation experiment with navigational support in the second half of the navigation experiment
3. Navigation Condition 3 (Passive to Active Navigation): Navigational support in the first half of the navigation experiment with no navigational support in the second half of the navigation experiment.
4. Navigation Condition 4 (Passive Navigation): Full Navigational support for the entire navigation experiment.

The primary concern of this experiment was to investigate the consequences of two navigational situations; consistent navigational status or a change in the navigational status (gain or loss of access to the GPS device) during navigation. The research was conducted in three steps. In the first step, the mental rotation, object memory, and SBSOD tasks took place in a quiet room with participants receiving directions via iPad (SaskEXP application). In the second step, modification in human navigation was investigated based on the availability of a GPS-device in outdoor environments. Two routes were developed for the experiment since two of the navigational conditions switched from 'Active' to 'Passive' and vice versa (Figure 1).

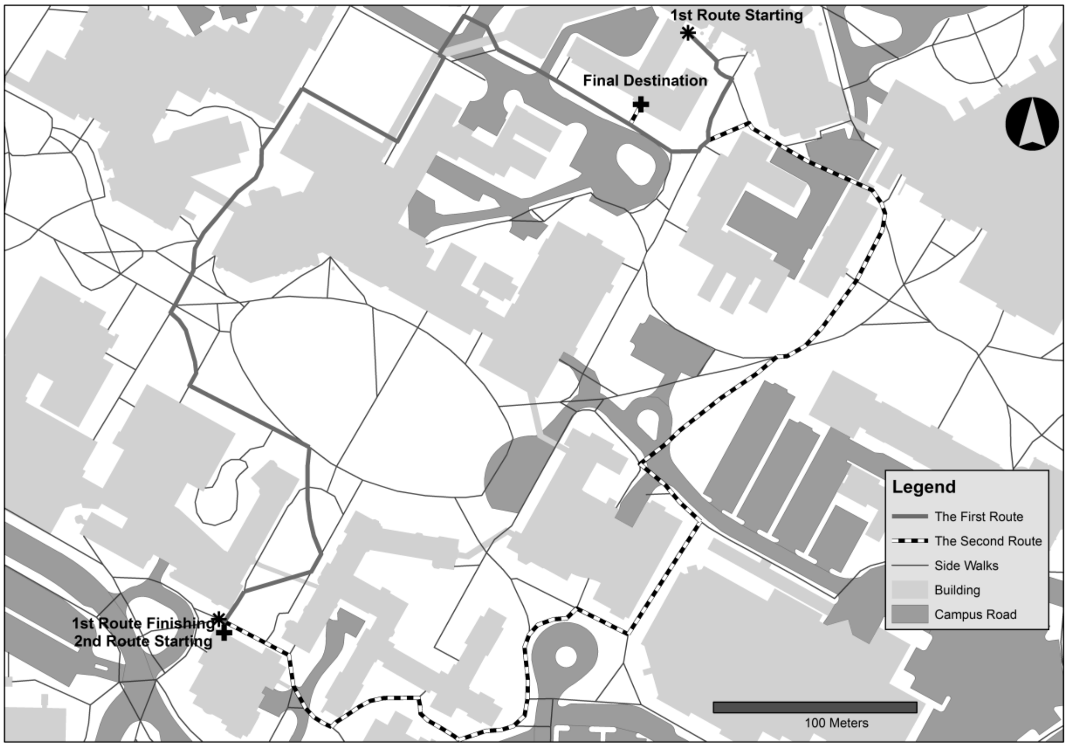


Figure 1. Experimental paths in the University of Saskatchewan

The route in which a gain or loss of GPS assistance took place transpired as such: a preliminary 700m route, followed by a second 740m route, each consisting of 10 turns. All trials began at the same location and finished at the same building but different entrances. This experiment was performed between May and August of 2012. During this time there were no high traffic volumes on the selected paths. Furthermore, no experiments were performed during inclement weather, meaning most participants were assumed to navigate experimental conditions with a similar route, exposed to similar weather conditions.

Results

GPS did not make drastic improvement in human navigation but it did have a similar effect on participants that were subjected to the same navigational performance / experience. Participants who navigated without GPS had an actual travelled distance similar to other conditions but their travelled route was highly associated with off-route spaces (Table 1 & 2).

Table 1. Analysis of Route Metrics in the First Path

	No GPS (NC 1&2)	GPS (NC 3&4)
Travelled Distance (Mean)	689.72	732.86
Travelled Distance (Std)	60.6	47.48
Travelled Distance (Max)	918.6	816.4
Travelled Distance (Min)	640.2	670.1
Exceeded Travel Distance (%)	-1%	5%
Off-route Taker (%)	100%	73%
Off-route Distance (Mean)	189.06	63.63
Off-route Distance (Std)	98.54	29.74
Off-route Distance (Max)	380.55	110.62
Off-route Distance (Min)	23.11	14.45

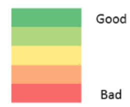
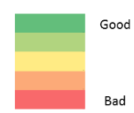


Table 2. Analysis of Route Metrics in the Second Path

	No GPS (NC 1)	Gain GPS (NC 2)	Lose GPS (NC 3)	GPS (NC 4)
Travelled Distance (Mean)	827.35	769.06	882.37	777.04
Travelled Distance (Std)	92.56	38.16	125.03	59.08
Travelled Distance (Max)	1018.7	858.1	1179.9	981.4
Travelled Distance (Min)	671.2	725.9	725.9	738.8
Exceeded Travel Distance (%)	12%	4%	19%	5%
Off-route Taker (%)	100%	53%	100%	33%
Off-route Distance(Mean)	239.95	45.69	222.86	17.6
Off-route Distance (Std)	137.1	27.19	139.64	9.76
Off-route Distance (Max)	479.88	99.33	476.76	24.32
Off-route Distance (Min)	71.28	19.77	21.65	5.52



These off-routes were often a shortcut but they could also be a path that resulted in a further distance travelled. GPS assistance helped to reduce the hesitation during recall of the correct route and destination since GPS could continuously deliver adequate spatial information for during navigation. When participants did not have GPS, they experienced more difficulty in finding their final destination or find correct headings. Specifically, if participants did not have GPS assistance during the second route, 50% of the participants often travelled in an incorrect direction.

Travel movement was recorded with GPS for all participants. These tracking records allow us to visually compare resulting navigation performance (Figure 2). When participants did not use GPS, the resulting route selection became highly deviant. For these conditions, overall tracking records were wider and tended towards messier distributions (Table 1). When participants had GPS available to them, their tracking records tended to be more concentrated within a narrow region, as GPS was able to guide participants to travel within designated routes. Interestingly, GPS support associated with the second route (NC2 & NC4) resulted in better navigation performance over GPS support associated with the first route (NC3 & NC4). This may be attributed to a higher level of familiarity with the GPS device, after using it for an extended period of time (NC4). In combination, as participants became more familiar with the experimental environment, their navigation experience with GPS could be maximized.

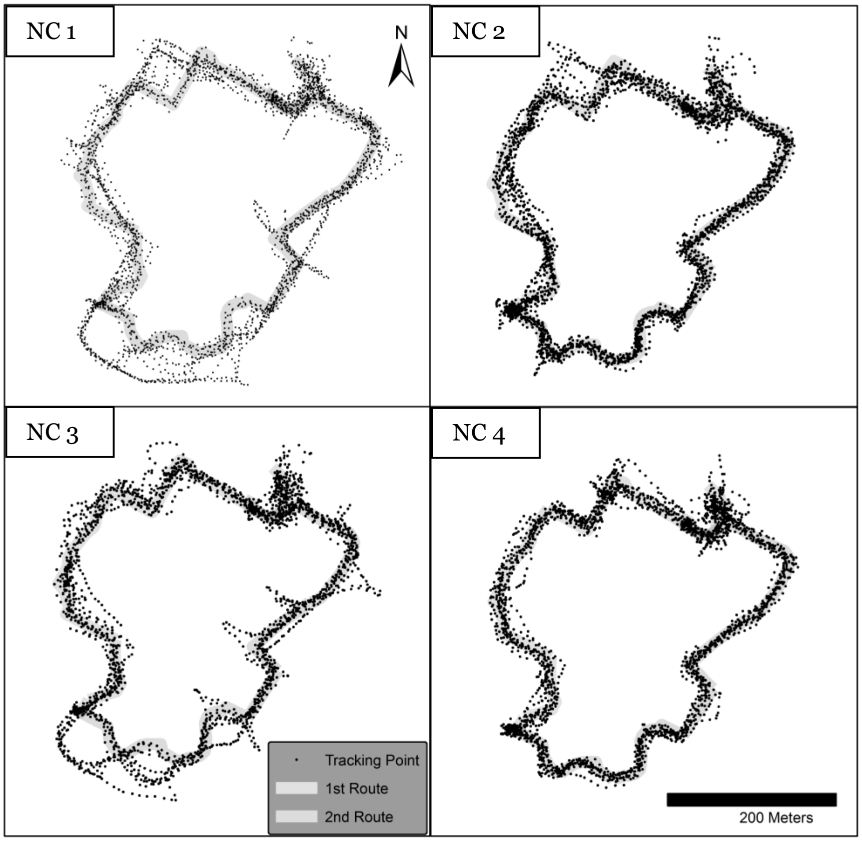


Figure 2. Raw tracking results comparison for individual participants

Table 3. Overall taken path width for each condition

	NC 1		NC 2		NC 3		NC 4	
Overall Taken Path Width in Metres (Mean)	**9.60**		**5.30**		**7.98**		**4.51**	
1st path / 2nd path	7.76	11.43	6.66	3.94	6.56	9.41	5.47	3.55
Overall Taken Path Width in Metres (Std)	**11.26**		**5.92**		**9.64**		**4.18**	
1st path / 2nd path	8.68	13.83	7.60	4.24	7.02	12.27	4.92	3.45

Conclusions

Both active and passive navigation modes have the potential to benefit for our daily navigation experiences, however it is important to understand how these modes of navigation are associated with us and what primitive requirements must be satisfied in order to maximize our navigation experiences (Table 2). Individuals can accomplish successful and efficient navigation without GPS but if participants make any mistakes or bad decision during their travel the overall distance could be increased and the time needed to determine the correct heading also swell. However, participants need to familiarize themselves with the surroundings before traveling in any novel environments. GPS assistance may help people to save time although it may not assure the navigation performance is opportune, it is capable of reducing the chance of disorientation and unnecessary travel, such as taking alternative paths. In order to have a successful navigation experience with GPS navigation, we need to be familiar with guidance style of the GPS or have a spatial knowledge of the environmental surroundings.

Table 4. Impact of the availability of GPS assistant on human navigation

	Active (No GPS)	Passive (GPS)
Critical Requirement	Degree of familiarity with ***surroundings***	Degree of familiarity with ***navigation system***
Positive Impact	Dynamic navigation strategy (high flexibility for route selection)	May result in increased navigation performance over time
Negative Impact	May result in decreased navigation performance over time	Fixed navigation strategy (less flexibility for route selection)
System Availability	If experiencing GPS loss: anxiety level may increase	If experiencing GPS gain: high familiarity with surroundings may correlate with low familiarity with the navigation system

In addition, one of our current studies suggest that when an individual has a positive experience in terms of location accuracy with a navigation system, the individual's trust of the navigation system may increase (Wei & Bell, 2012). So we may need to examine in more detail how the availability of a navigation system will be impact an individual's trust of the system, such as in group NC 3, which modeled this experience by taking their GPS away without warning before the start of Path 2.

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