Pedestrian navigation using haptic feedback: Results from a field study to test spatial abilities and memory recall

Ricky Jacob[1], Adam Winstanley[1], Naomi Togher[2], Richard Roche[2]

[1]Department of Computer Science, National University of Ireland Maynooth, Co. Kildare, Ireland
Tel: 353-1-708 3847 Fax: 353-1-708 3848
Email: rjacob@cs.nuim.ie Web: http://www.cs.nuim.ie/~rjacob/
[2]Department of Psychology, National University of Ireland Maynooth, Co. Kildare, Ireland

Summary: Haptic feedback (using the sense of touch) or 'haptics' is a technology that provides forced feedback, vibrations, and/or motions to haptic-enabled user devices. The mobile haptic interaction model for a point to destination pedestrian navigation system is described. The importance of eyes-free, subtle feedback has been highlighted in previous work. This paper reports on the initial findings from the tests carried out to evaluate the user's spatial abilities, navigations skills and memory recall of features seen along the way. Initial results show that the user walks faster to the destination on the second attempt and builds a good mental map of the features seen along the route as haptic feedback ensures heads-up navigation and no interaction with the mobile device (a GPS enabled smart phone) while walking towards the destination.

KEYWORDS: haptics, pedestrian navigation, orientation, spatial ability, mental map

1. Introduction

The word *haptics* is derived from the Greek word *haptesthai*, which means 'of or related to the sense of touch'. In the psychology and neuroscience literature, haptics is the study of human touch sensing, specifically via kinesthetic (force/position) and cutaneous (tactile) receptors, associated with perception and manipulation. The benefit of using the human sense of touch is that it is faster than vision, it is the first sense one develops when born and the last sense to fade at death. Consequently haptic interaction we believe has a much longer 'use life' than traditional interaction methods. Another important feature of this kind of communication is that unlike visual or audio based interaction, this overcomes the language barrier and can thus be extended to other geographies with ease. The use of a non-visual system like this means that the user can query about features by performing pointing and/or scanning gestures and not having to look into the mobile device. Thus such operations can be performed privately by having the phone in the jacket/loose pant pocket and by pointing and waiting for feedback. This insures that the people around are not aware that the user is a stranger to the area and thus serves as a good feature to ensure the user is 'one among the crowd'. In this paper we discuss the results from the haptics based navigation tests carried out to test the spatial abilities (orientation skills and memory recall) of users.

2. Related work

We have seen in Jacob et al (2010), the uses and importance of haptic feedback as a way to convey spatial information to the user. A point to query Haptic Geowand was described in Jacob et al (2011) where distance to point of interest and density of point of interest information was defined using varying vibration patterns. In our previous work in Jacob et al (2011a) we defined the four pedestrian navigation prototypes and the haptic interaction models for them. The authors in Waller et al (2002) examines the degree to which knowledge about the body's orientation affects transformations in spatial memory and whether memories are accessed with a preferred orientation. The participants learned large paths from a single viewpoint and were later asked to make judgments of relative directions from imagined positions on the path. Experiments were later carried out to test their memory recall and spatial orientation skills. In Hegarty et al (2006), we see the various tests like mental rotation and spatial learning has been carried out to measure the spatial ability of the user. In this we paper we test the spatial abilities of the user based on both the navigation performance and also the memory recall of the user to recreate a map of the test region.

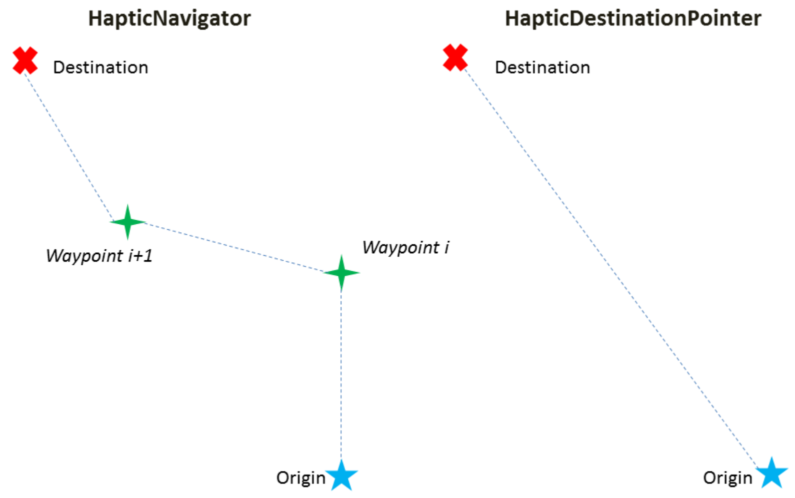

Figure 1. Haptic feedback for HapticNavigator and HapticDestinationPointer

3. Haptic interaction model

The haptic interaction for *HapticNavigator* and the *HapticDestinationPointer* described in our previous work in Jacob et al (2011a) is shown in Figure 1. The *HapticNavigator* provides waypoint by waypoint navigation along the shortest path. The *HapticDestinationPointer* provides haptic feedback when the user points in the direction of the destination. The distance from origin to destination is calculated and divided into three parts as shown in Figure 2. The querying angle is dependent on this distance information of the user from the destination where the angle decreases to a much smaller range as the user is nearing the destination.

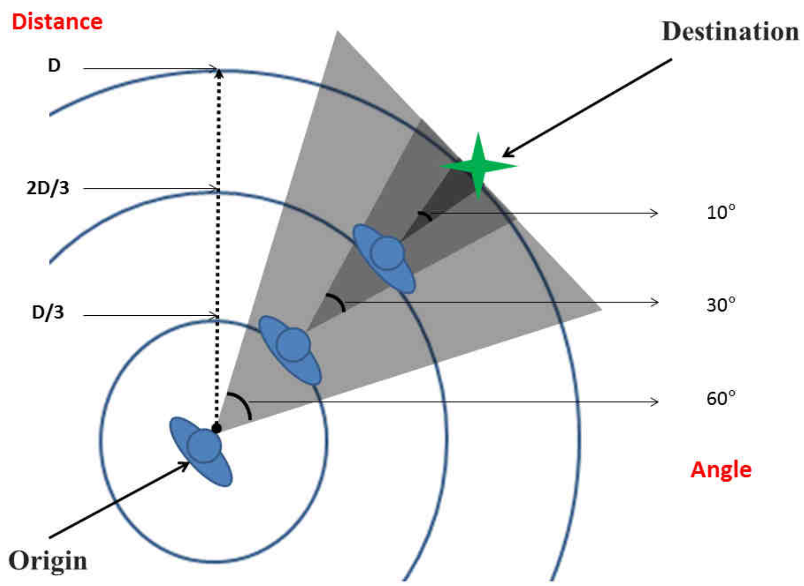

Figure 2. Variation in querying angle based on distance from destination

For any origin, O to the destination, P the straight line distance is set as D. This distance is divided into three parts which form the three main parts of the user's travel. For the walk from the origin to the point D/3 from the origin, the angle range for querying is 60°. The querying angle range for the second part of the walk from distance D/3 to 2D/3 is set to 30°. The last part of the trip when the user is closer to the destination which is between 2D/3 and D, the angle range is decreased to 10°. The user performs the 'scan function' where they hold the mobile device parallel to the ground and move it around them slowly to be alerted of the direction they need to start walking. The user is alerted with a unique continuous vibration feedback when the user reaches within 10 metres of the destination point.

4. Experiments

The experiments were carried out between the three user groups to test spatial abilities of the user. To ensure that all users are at the same level and navigation performance is not biased by better IQ or spatial intelligence, a few tests were carried out before the experiments. The tests carried out before the navigation tasks were – National Adult Reading Test (NART), Trail Making task, Mental Rotation Task and a Cognitive Failures Questionnaire (CFQ). We selected a destination location P and two origin points, A and B. Users were divided into three groups of 10 each. The average age of the users was 22 yrs. The map of the study area is shown in Figure 3 with all the important points marked for the navigation tasks. Memory recall of the users was tested once the users completed the navigation tasks.

Figure 3. The map of the area with the destination and the two origin points along with the waypoints

4.1 User trials

User group 1 were provided with panoramic images of the destination (P) before they started from the origin A. Once they reached the destination they were taken to origin B and were asked to again make their way to the destination P. User group 2 were provided with the mobile device running the

HapticDestinationPointer application. A 5 minute briefing about the working of the haptic system was provided to the user. The user had to walk from origin A to the destination P using haptic feedback. Once the user reached destination P, the user was taken to the origin point B and the user had to perform the same task by walking to the destination P. User group 3 were provided with the mobile device running the *HapticNavigator* application. After a quick briefing about the working of the waypoint-by-waypoint navigation system, the users were asked to go from the origin A to the destination P. Once the user reached the destination P, they were taken to the origin point B and were asked to again find their way to the destination (P). Information about the distance walked and time taken along with the chosen path for all the users were recorded.
For all the three user groups, once the users reach the destination, they were provided with a sheet with just the main road around the study area drawn. The final task for the users now was to mark on this map the two origins and destinations and all the features (buildings, bins, lamp posts, etc.) that they remember seeing along their path. The users were not informed about this final task at the beginning of the experiment so as to ensure that the user doesn't memorise the features while doing the tests before reaching the destination but rather try to recall what they remember seeing. The steps for the user trials are described in Figure 4.

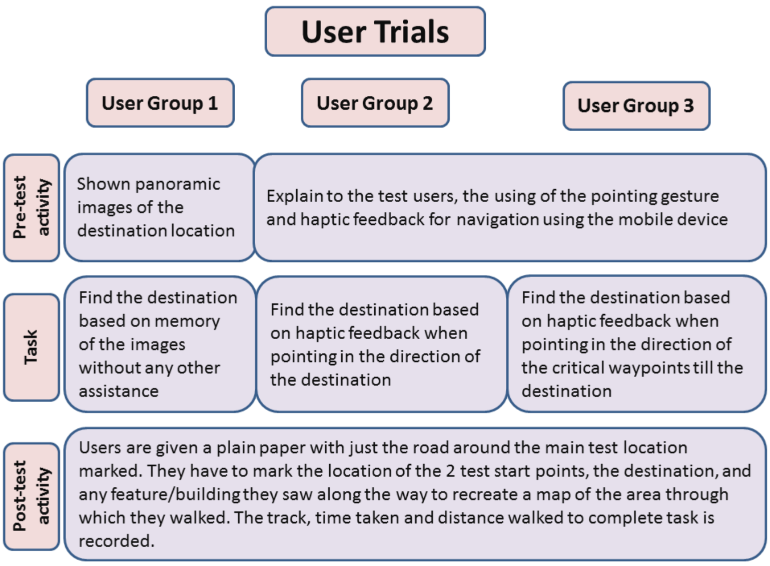

Figure 4. User trials for three different groups

4.2 Results

The users of all the three groups successfully reached their destination. While walking to the destination from the origin point B, almost all the users walked faster and with more certainty as they now had a better understanding of the environment. On reaching the destination the users marked features what they saw along their way. The users were given points based on the features marked, especially building polygons.

4.2.1 User group 1

All the users in the group 1 reached the destination successfully. The navigation performances of the users are shown in Table 1. All users excluding user 4 chose the same route (route 1) to get from origin A to destination P. User 1 chose route 3 and took longer time and walked a longer distance to get to the destination from origin B. The routes taken by the users are shown in Figure 5.

Table 1. User group 1 navigation performance results

User	From Origin A to Destination		From Origin B to Destination	
	Route taken	Time taken (in minutes)	Route Taken	Time taken (in minutes)
1	1	2.37	3	4.16
2	1	2.39	4	2.55
3	1	2.49	4	3.57
4	2	2.16	4	2.55
5	1	2.34	4	3.22

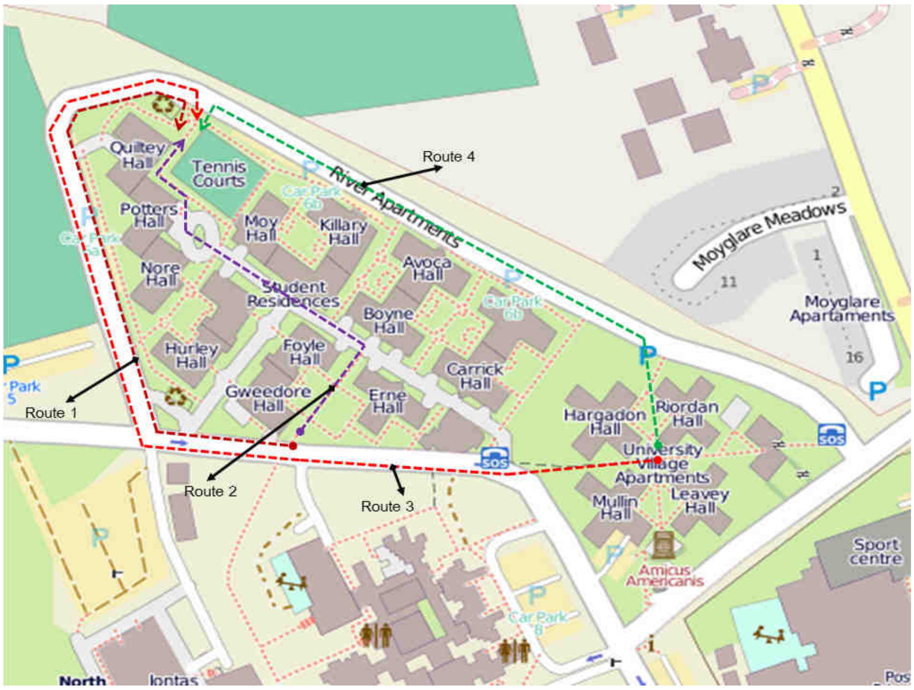

Figure 5. The 4 distinct routes taken by the *User Group 1* during the tests

4.2.2 Haptic user trials

User groups 2 and 3 used the pointing gestures on the phone and were provided with haptic feedback to get to the destination. All users of group 3 took the same routes to get to the destination from both origin A and origin B as they were guided by haptic feedback towards the waypoints till they reach the destination. The paths are shown in Figure 6. All users in group 2 chose the same route to get to the destination from origin B like group 3. The group 2 users choose an alternative route to the waypoint by waypoint route to get from origin A to the destination P as shown in Figure 6.

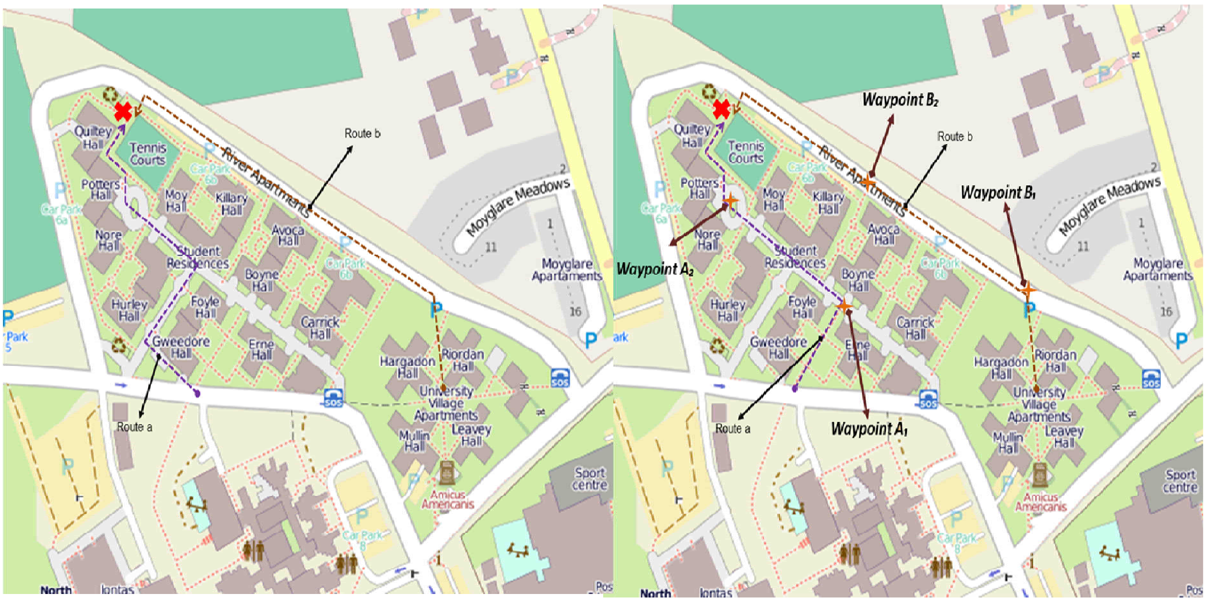

Figure 6. The routes taken by the *User Group 2* and *User Group 3* during the tests

4.3 Key findings

All the users marked the destination point and the points of origin. All the users walked faster while going from origin point B to the destination. Some users marked buildings and bins. Most users marked the tennis court near the destination location. The map drawn by one of the user soon after the user completed the navigation task is shown in Figure 7. The user has marked the destination and the origin points and included buildings, tennis court and bins. Based on the time recorded, it is seen that users who were provided with the panoramic images of the destination (group 1), reached the destination faster as compared to the users of group 2 and group 3. Since the participants of group 1 knew what the destination point looked like, they were able to quickly walk to the destination when they reached within sight of destination P. Group 2 and group 3 users did not have any idea where the destination point was and how it looked and thus took time to get to the exact spot although they were within sight of the destination P. But it has been noted that users of group 2 produced the best maps once they completed the navigation tasks.

Figure 7. The map of the area on OpenStreetMap versus the map drawn by one of the user after completion of the trials

5. Conclusion

Haptics ensures eye-free interaction as there was no visual display which the user was dependant on while performing these navigation tasks. The users of group 1 who were provided with panoramic images of the destination completed the navigation task the quickest. We tested the memory recall after the user has carried out navigation tests by having the user map the area based on memory from the navigation experiments. Most users marked the origin and destination points well. Some users remembered the buildings and bins along the way and included them in the map when asked to draw. We find that the users of group 2 produced the best maps suggesting they were able to look around and see features around them as the device would guide them to the destination. Thus we notice that the users are able to interact with the real-world and remember features along the way when they were provided with subtle feedback guiding them towards the destination. In future tests we wish to compare the user navigation and memory recall performances by comparing haptics with map based systems on mobile devices. We believe that haptics can be an added modality by integrating it with vision based systems for pedestrian navigation. Thus during conditions when navigation using vision based systems cannot be used, haptics can be used for the same tasks.

6. Acknowledgements

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8. Biography

Ricky Jacob is a 3rd year PhD student at the Department of Computer Science at NUI Maynooth. He is part of the StratAG project working on Geo-spatial technologies. His primary focus is on integrating non-visual interaction techniques using mobile devices to pedestrian navigation systems.

Adam C Winstanley is Professor and Head of Department Computer Science at NUI Maynooth. He is one of the PI of the StratAG project. His primary research interests include pedestrian navigation, real-time bus tracking, and location based services for environmental monitoring.

Naomi Togher is a 2nd year Undergrad student at the Department of Psychology at NUI Maynooth. Her research interests include spatial abilities, memory recall and spatial navigation skills.

Richard Roche is a Lecturer in Psychology at the Department of Psychology at NUI Maynooth. His research interests include the neurocognitive processes underlying human spatial navigation and representation, and the neurocognitive mechanisms underlying memory consolidation and reconsolidation.