Safety in Pedestrian Navigation: Road Crossing Habits and Route Quality Needs

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Abstract: Still most commercial navigation tools used by pedestrians fail to encompass a comprehensive organization and prioritization of safety-related route qualities and accordant information in the user interface. To support pedestrian route choices to minimize potential dangers, we study in this paper user requirements for an enhanced pedestrian navigation system that considers safety related route quality parameters. Besides effectiveness, related factors of distance and time, safety was highly prioritized to become an explicit requirement for the conceptual design. The acquired data from an online survey provides the basis for pedestrian's classifications and requirements regarding user friendly interfaces for mobile routing and navigation that enhance road safety.

Keywords: Pedestrian Navigation, User Requirements, Road Crossing, Safety.

1. INTRODUCTION

As members of the digital age, pedestrians have come to rely more heavily on mobile navigation as a means to find ones way throughout varying contexts of foot travel. Perhaps the individual is intent upon finding the fastest walking route to work, or a more scenic route to a place of interest, or simply as a means of familiarizing oneself with new surroundings. As a prominent example, in 2013, Google Maps was the most used app worldwide, providing valuable information for pedestrians (Hedencrona 2013). However, available maps often provide rather general information, not tailored to the actual needs of the pedestrian. Still most commercial navigation tools used by pedestrians fail to encompass a comprehensive organization and prioritization of safety-related route qualities and accordant information in the user interface.

It has been stated that poorly designed user interfaces can affect visual attention from the road and decrease road safety. Additionally, cognitively demanding interaction indicates a reduction in the traffic situation awareness (Olaverri-Monreal and Bengler 2011). In a vehicular context, proper in-vehicle warnings and function location that enhances visibility and reduces the distraction potential has been the focus of design by automotive manufacturers (Olaverri-Monreal et al. 2014). However, this has not been extended to mobile devices that are increasingly being used in a road context. As usability is one of the factors to be considered in an ergonomic design, it is crucial to determine the needs of the pedestrians through a user centered approach.

To support pedestrian route choices to minimize potential dangers, route qualities such as e.g. safety (including safe crossing facilities, motor traffic volume and speeds) need to be considered in the design of pedestrian navigation systems (Czogalla and Hermann 2011).

The use of mobile phones by pedestrians (for talking, texting, reading), affects their awareness of the surrounding environment, hence augmenting the risk of incidents. Moreover, it has been stated that pedestrian behavior varies at road crossing (Thompson et al. 2013). Observing pedestrians crossing streets has shown that mobile phone users exhibited more unsafe behavior than other pedestrians. Moreover, mobile phone users are far less likely to recognize crossing opportunities, which results in slower crossing times (Neider et al. 2010). Hence, pedestrian distraction associated with mobile phone usage is a very prominent, contemporary safety issue, particularly relevant in urban environments with high traffic density. However, most mobile solutions rather neglect the risks related to the influence of mobile phone usage in a situation where traffic needs to be considered.

Particularly, pedestrian navigation and routing systems need to be developed in a user friendly manner that enhances road safety and provides an optimal user experience. Additionally, persuasive technologies should be applied into the development of mobile applications to promote more desirable pedestrian behavior and motivate pedestrians to adopt less risky behavior by providing specific information regarding road conditions and possible disturbances on a route (Fogg 2009) such as for example accurate information regarding available access conditions, location and type of near crosswalks.

In this work, we study user requirements for an enhanced pedestrian navigation system that considers safety related route quality parameters:

(1) We determine pedestrians usage routines in relation with existing navigation and route planning tools in urban environments on a daily basis.
(2) Relying on studies of route quality including route safety, comfort, attractiveness and accessibility (Czo-

galla and Hermann 2011), we collected information related to preferences of routes to dissociate between main characteristics of route quality and preferences, and thus allowing for the definition of corresponding pedestrian user groups.

(3) As part of a user centered design process (UCD) consisting of a multi-disciplinary design approach based on the early and continuous involvement of end users we sought a more clear understanding of user requirements relying on related studies (Vredenburg et al. 2001).

Although previous works have targeted the classification of users of pedestrian navigation tools (i.e. Wen et al. 2013), there is still an important need to elaborate a comprehensive typology that aligns user preferences to different route quality parameters provided by todays navigation tools. Therefore, this work focuses on the assessment of self-reported habits toward different types of road-crossing behavior (i.e. optimal, distractive, risky) in Austria, to uncover less visible attitudes and routines related to the use of mobile tools in traffic related areas.

2. RELATED WORK

According to a study from Thompson et al. 2013, 29.8% of 1102 pedestrians performed a distracting activity while crossing the road. The specific activities were distributed in the following way: 11.2% listened to music, 6.2% were involved in a phone conversation holding the phone and 7.3% were texting. The crossing time was longer during the texting activity and the eyes were also diverted from the road, indicating these results that texting was the most dangerous activity compared to the other two.

These results were confirmed by the authors in Schwebel et al. 2012 that also compared the same dual task situations: crossing while talking on the phone, crossing while texting, crossing while listening to a personal music device, with crossing without performing other tasks. Their results suggested that although all three situations caused attention to deviate from the road, texting and listening to music while crossing were considered to be more dangerous than talking on the phone.

In Neider et al. 2010, results from several simulator tests showed that pedestrians are less likely to cross a road without being involved in a road accident when talking on a phone (in a hands free situation) than when listening to music. Phone users are also less likely to recognize crossing opportunities. These dual task situations seem to be especially challenging for older people (Neider et al. 2011, Hatfield and Murphy 2007).

Furthermore, other works intended to improve safety for pedestrians in situations where they were particularly exposed to danger while crossing, due to simultaneous tasks that deviated attention from the road. For example, the Android application WalkSafe (Wang et al. 2012), aims to improve safety by using the phone's back-camera in order to detect approaching vehicles and alerting the user in case of an unsafe situation.

In the same context the authors in Chen et al. 2012 notified users via a smart phone app when they were about to cross a potentially dangerous street. They conducted tests in a simulated environment and found out that users were more careful and waited longer before crossing when they received a warning.

An additional work tackled crime related safety issues for pedestrians focusing on assessing the safety of sidewalks by using light sensors for the generation of safety efficient routes (Matsuda and Arai 2014). In accordance with the Japan Security Systems Association the authors stated that brightness of street lights may improve safety. They also suggested including information from crime reports for generating routes.

Illumination was also the target of the work by Miura et al. 2011. Relying on the deployment of a network of sensors, the authors gathered information about road illumination conditions to incorporate them in pedestrian navigation systems.

3. DATA ACQUISITION

As part of UCD process, we designed and developed an online survey that we later deployed among potential subjects within Austria, addressing them directly and attaching the link to the questionnaire. The survey was organized according to the following thematic categories:

3.1 Mobility Routines

The first part of the survey dealt with the collection of mobile users daily walking routines regarding typical ways and routes to reach specific destinations that for example included ways to work, duties (running errands or attending appointments (i.e. visiting public authorities, going to special events, kids school, etc.), as well as leisure activities (e.g. meeting friends, sports, cinema, theater, etc.).

3.2 Experience with Routing and Navigation Tools

In relation with mobility patterns we investigated whether pedestrians make use of (public) transportation means to effectuate their daily routes. Previous experience with (pedestrian) navigation/ routing systems was addressed, i.e. users were asked to report type and use frequency of their preferred (mobile) navigation tools.

We particularly focused on the use of navigation tools for specific route sections in combination with some mean of transportation and specifically asked to enter information related to origin destination matrices such as: from the origin to a public transportation station or from a point of transfer to the destination.

3.3 Road Crossing Behavior

To gather further insight on road crossing behavior, we presented selected statements to respondents which exemplified certain road crossing situations such as texting or reading text on the smartphone or scampering among traffic to cross a road. To this end, we asked participants to complete a modified 10-item version of the Self-Report Habit Index (SRHI), self-report instrument to measure habit strength, which collects data from the features which display a history of repetitive behaviors, the difficulty of controlling behavior, the lack of awareness, efficiency, and the identity element (Verplanken and Orbell 2003). Respondents had to indicate to what extent they agreed to

a certain behavior on a 5-point-Likert scale, by which low scores denoted a more frequent behavior and high scores a less frequent behavior. Based on this, we calculated the mean scores of the SRHI.

3.4 Sense of Direction

Spatial abilities are involved in most of our daily orientation tasks in two and three dimensional surroundings (e.g. reading maps, using navigation tools). Beside psychometric approaches such as mental rotation tests, self-assessed sense of direction such as the Santa Barbara sense of direction scale (SBSOD) (Hegarty et al. 2002), has shown to provide valuable insights to a person's spatial skills. We relied on the SBSOD scale in order to determine the environmental spatial ability of our subjects and investigated possible relationships between individual sense of direction, gender and safety.

3.5 Pedestrian Route Quality Criteria

Previous work on pedestrian quality needs (Methorst 2010) stated the existence of different route quality criteria that influence route choices in pedestrian navigation. In order to determine the factors influencing route selection, we additionally investigated the prioritization of quality parameters based on the classification in Czogalla and Hermann 2011. Furthermore, we asked in our survey to select the main reasons for not using a certain route.

4. RESULTS

4.1 Sample

175 participants correctly completed the survey. The final sample was nearly equally distributed in terms of gender (90 female (51,4%), 85 male (48,57%)). The youngest participant was 19 years; the oldest was 64 years old, while the average age was 37,2 +/- 11 years. The majority of respondents (84%) lived in cities with more than one hundred thousand inhabitants. 101 respondents (57,7%) were fully employed, 29 (4,6%) partly employed, and 21 (12%) currently at university.
Regarding experience with mobile phones and navigation tools the sample turned out to be homogeneous: 171 respondents (97,7%) were experienced in using digital maps, route planning or navigation systems, while 148 users (84,6%) answered to use mobile internet services on a regular basis (at least once a day). One participant used a wheelchair. No other participant stated to use any walking aid.

4.2 Mobility Routines

According to the results regarding the mean of transport (multiple answers allowed) people used regularly, 157 (89,7%) named public transport and 103 (58,8%) selected private cars. Private bicycles (72; 41,14%) seem to be also quite popular. Fig. 1 depicts the means of transportation by number of respondents.
Regarding the daily use of the different mean of transport, results showed the choice strongly depended on the nature of the trip. 59,5% of the respondents said they used

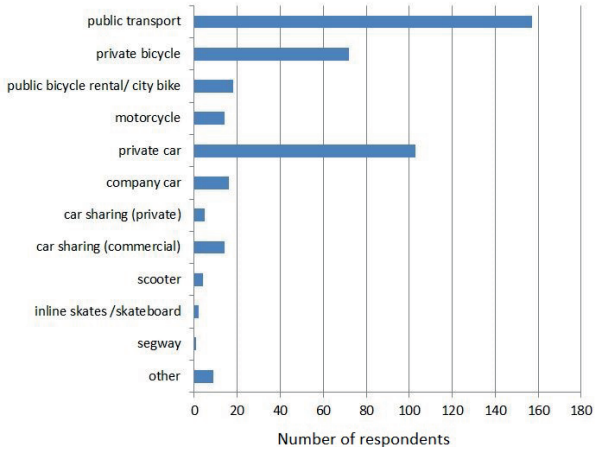

Fig. 1. Preferred mean of transport by number of survey participants

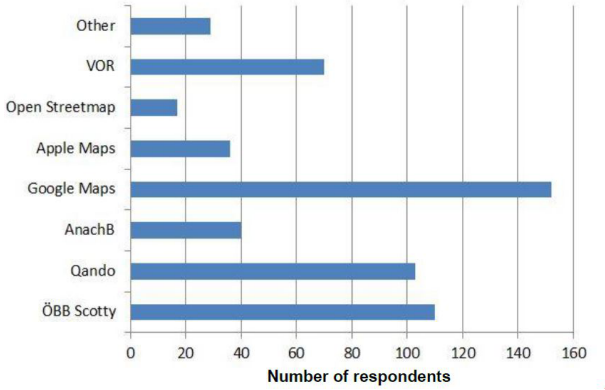

Fig. 2. Preferred navigation apps by number of survey participants

public transportation to go to work, while only 15,8% preferred their car. When asked about duties such as running errands or attending appointments, the results were similar: 50% used public transportation while 37,5% walked and 125% used their private vehicle. According to the results of our survey, 60,7% of the participants preferred go shopping by foot. In their free time, 44,1% of the respondents stated to regularly walk to their target destination and 44,1% indicated to use public transport.

4.3 Experience with Routing and Navigation Tools

The most used navigation apps indicated by the survey participants are depicted in Fig. 2. Google Maps was with 81,7% the most popular, followed by the services provided by the national railway company "ÖBB Scotty" (57,1%) and the local public transport routing assistant named "Qando" (53,7%). Also mentioned but not included in the figure were brands such as "TomTom" (by 5 respondents) and "Garmin" (by 2 respondents), as well as further services from public transportation providers in Austria (i.e. "Wiener Linien" (by 4 respondents)).
Regarding trips in which public transportation was used in combination with navigation tools, our results showed that people use navigation tools mostly to find their way from their starting point to the bus or railway station or from the latter to their final destination (outdoor navigation).

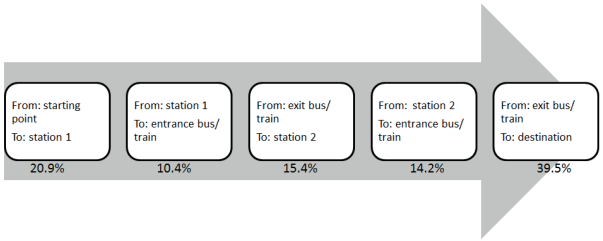

Fig. 3. Transition while traveling using public transport and walking

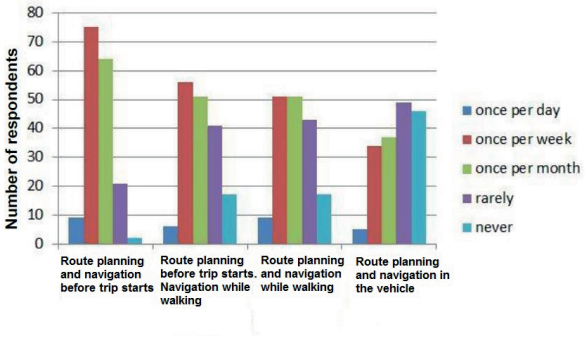

Fig. 4. Route planning strategy by number of respondents

Using navigation to find the way to the train transfer is far less common. Only a small number of people use their navigation system to find their way within a train station, to find out where the train stops (Fig. 3). With regard to the planning of trips, we found that not all the users plan their trips spontaneously while traveling even though 84,6% of the respondents affirmed to use mobile data connection on a daily basis. As a result, planning a route in advance is still very popular (Fig. 4).

4.4 Road Crossing and Pedestrian Behavior

With respect to self-assessed risky behavior, low scores in the SRHI index reflect a strong habit and high scores represent a less frequent behavior. Results indicated that respondents very often crossed the road while vehicles were approaching (M = 2,2; SD = 0,7), while crossing the road at crosswalks was not a strong habit (M = 3,5; SD = 0,9). Finally, respondents indicated to usually avoid texting or reading text on the mobile device during road crossing (M = 4,0; SD = 0,9), and being consequently not exposed to distraction sources that could jeopardize their safety.
However, looking closely at the data, we could examine differences related to age and habits. According to the Spearman's rank correlation coefficient, there was a significant relationship between age and distractive behavior at road crossings (P = -.333; p<.001), revealing that younger pedestrians were more often exposed to distraction sources such as texting or reading on the mobile device while crossing a road than older pedestrians (Fig. 5).

4.5 Pedestrian Route Quality Criteria and Needs

Results regarding the prioritization of quality parameters based on the classification in Czogalla and Hermann 2011 are depicted in Fig. 6. The figure shows the ranking of the quality criteria and needs from most important (1) to less important (5).
Furthermore, Table 1, shows the factors influencing pedestrian route selection and behavior and its relationship to the quality criteria in Czogalla and Hermann 2011. As the main reason for a decision to not use a certain route, 100 respondents (72%) classified long distance as the leading quality factor for route choice. The second most relevant criteria was being in a hurry, which is directly related to the distance. More than 40% of the respondents ranked safety as the third factor, parameters included insufficient illumination of the environment or record of criminality, decisive for the selection. Less participants but a still considerable amount of users (36,6%) named overly crowded streets as a parameter to select one or another route. Comfort was not a decisive parameter for routing.

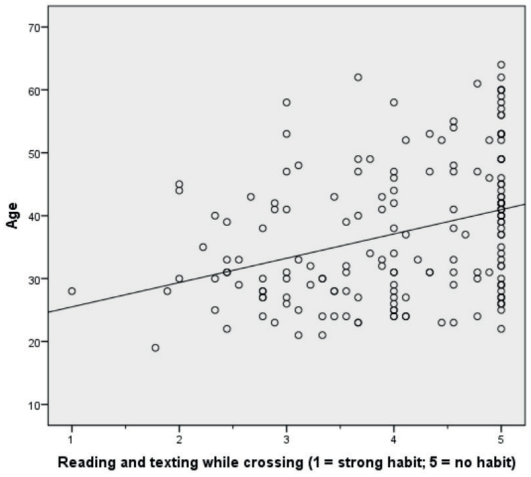

Fig. 5. Relationship between age and distractive behavior at road crossings.

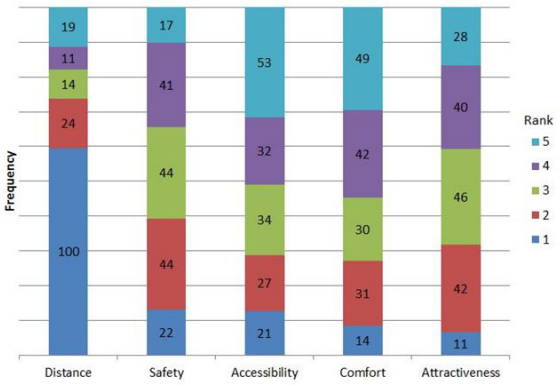

Fig. 6. Prioritization of route quality parameters for pedestrians route choice (1 more important, 5 less important)

4.6 Sense of direction

Our results showed that there were statistically significant differences in the perceived sense of direction between genders (t(173) = -3,1, p = 0.002), being the mean Santa Barbara-score for men 5,12, SD = 0,8 and for women 4,69, SD = 0,9. Regarding the relationship between safe or risky crossing habits and sense of direction no statistically significant differences could be found.

Factor	Selections#	%	Category
Long distance	126	72,00%	Distance
Short of time /hurry	108	61,71%	Distance
Unsafe route (crime)	87	49,71%	Safety
Poor street lighting	71	40,57%	Safety
Too crowded	64	36,57%	Comfort/Safety
Pavement	41	23,43%	Accessibility
Habits	37	21,14%	Other
Unfamiliarity	28	16,00%	Other
Illegible signage	21	12,00%	Accessibility
Missing guidance	17	9,71%	Accessibility
Missing shelter	16	9,14%	Comfort
Poor infrastructure	15	8,57%	Comfort
Stairs existence	15	8,57%	Accessibility
Steep ramp	13	7,43%	Accessibility
Lacking experience	13	7,43%	Attractiveness
Other	6	3,43%	Other

Table 1. Factors influencing pedestrian route selection

5. DISCUSSION

The survey presented in this work depicted early investigation of mobility and safety related aspects in pedestrian navigation as part of a user-centered design process. We investigated usage routines with pedestrian navigation tools, self-reported habits in relation with road crossing behaviors as well as criteria and barriers for route choice decision.

Overall the results of our survey provided useful insights into pedestrians routines in urban areas regarding the use of navigation tools. As the final sample turned out to be rather homogeneous in terms of the main characteristics (e.g. frequency of use of public transportation, pedestrian usage of navigation tools) certain limitations must be considered in the interpretation of the data from a methodological point of view. As a consequence, the results of the conducted survey are not to be generalized for all pedestrians. However, the sample serves to elaborate on the requirements and design concepts of future safety-enhancing navigation systems.

The study was conducted in metropolitan areas in Austria. As the public transportation in these areas is very good, results regarding the combination of public transportation with walking over using a personal vehicle are not surprising.

Continuous advancements of mobile navigation aids in general aim at enhancing overall effectiveness and comfort in pedestrian mobility. However the use of such mobile technologies in the streets might be a compromising thread for pedestrian safety. Our survey results show that despite all the new technological advances regarding internet connection on smart devices, pedestrian routes are calculated in advance, before leaving the starting point, which hamper safety measures and lead to potentially distracting situations while the navigation tool is being employed. In the case pedestrians were still need to spontaneously check the route several times while walking in traffic areas, future navigation systems could incorporate strategies to motivate the users to calculate routes in advance to foster awareness toward navigation behavior.

Results on road crossing habits showed a higher tendency of younger adults to adopt risky and distractive behavior (i.e. texting during road crossing) than older respondents. Whereas not reflected in our data, previous research identified the effect of age as predictors of unsafe crossings, considering factors such as walking speed, start-up delay, safety margins and subjective walking time estimation of the pedestrians (Holland and Hill 2010). Hence it is assumed that the likelihood of unsafe crossing increases with age. The mentioned work also uncovered the effect of gender on unsafe road crossing decisions in adult pedestrians. With increasing age, women were shown to make more unsafe crossing decisions, to leave small safety margins and to become poorer at estimating their walking speed. However, our results did not reveal any significant effect of gender in reported road crossing habits.

Mobile navigation systems could be used to support users in their appraisal of a crossing situation by e.g. providing alerts for using larger safety margins, planning more accurate walking time for the road crossing etc. Users need to become aware of potential dangers related to their own behavior. Raising the awareness regarding unsafe crossing behavior might reveal better risk perception and behavior change towards a safer crossing.

The Table 1 showing the factors influencing pedestrian route selection and behavior includes a mapping to the quality criteria in Czogalla and Hermann 2011. This mapping is a first ad hoc approximation, that needs to be further tested. Particularly the quality factors “too crowded” and “poor street lighting” are relevant factor for user experience in terms of perceived safety and decisive to select one or another way.

6. CONCLUSION AND FUTURE WORK

The acquired data from the online questionnaire provides the basis for pedestrian’s classifications and requirements regarding user friendly interfaces for mobile routing and navigation that enhance road safety.

Beside effectiveness related factors of distance and time, safety was highly prioritized to become an explicit requirement for the conceptual design. Accessibility (and comfort) were not decisive parameters for selecting a route. This can be explained by the fact that except one respondent only people without mobility related aids completed the survey. Furthermore, being that most of the respondents were employed fulltime, their main activity of on foot navigation was arriving at their respective place of work, comfort along the route was of low priority.

Further research will focus on the elaboration of concrete design concepts and development and testing of prototypes relying on the acquired knowledge, focusing on raising pedestrian users awareness of risky crossing situations in order to reduce risky behavior. It is through this end, that pedestrian users will be steered toward less distraction and safer navigation in the streets.

ACKNOWLEDGEMENTS

This work was supported by the Perron Project - Enhanced Pedestrian Routing and Navigation as well as Walkability Assessment of Pedestrian Ways, funded by European funds through the Flagship Call 2013 Future Travelling, ERA-NET TRANSPORT III.

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