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Enhanced Turning Point Displays Facilitate Drivers' Interaction with Navigation Devices

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ABSTRACT
Recently, the use of in-vehicle navigation devices, such as PNDs (Personal or Portable Navigation Devices) has become pervasive, and the device functions have been rapidly expanded and updated. Unfortunately, drivers often have considerable difficulty using these complex technologies. To improve and optimize PND user interfaces, the present study suggested several display improvements for the turning point, which is one of the critical usability issues. *Advanced Turn-By-Turn Display* and *Spatial Turning Sound* were suggested to facilitate the preparation of the next turns. *Leading Tones for Turning* was also presented to help drivers tune the timing of their turns. We evaluated these new concepts with domain experts in three countries, and improved the details of the functions. We are currently implementing those features and looking forward to demonstrating new displays on the real product in our presentation at the Automotive User Interface conference.

Categories and Subject Descriptors
H.5.2. **[Information Interfaces And Presentation (e.g., HCI)]**: User Interfaces – graphical user interfaces (GUI), interaction styles (e.g., commands, menus, forms, direct manipulation), user-centered design

General Terms
Design, Human Factors, Performance

Keywords
Advanced Turn-By-Turn Display, AUI, GUI, IVTs, Leading Tones for Turning, PND, Spatial Turning Sound

1. INTRODUCTION
Driving is one of the most attention-demanding tasks in modern everyday life, with dangerous contexts and complex human-system interactions. Driving is even more challenging when the driver simultaneously uses in-vehicle navigation devices such as Personal or Portable Navigation Devices (PNDs), because it requires multi-tasking and can result in additional distraction from the primary driving task. Not surprisingly, this inattention to the driving task has been identified as one of the leading causes of car accidents. Research has pointed out that the increasing provision of a range of types of complex in-vehicle technologies (IVTs) means that the problem of driver inattention is likely to become even worse [1, 5, 9].

To compensate for this risk, the latest generation of PNDs has adopted more sophisticated navigation features including 3 dimensional maps, a quick spelling, and voice recognition [17, 18]. On the other hand, these new devices also have extended non-navigation functions involving music, movies and telephone. Despite the pervasive use of PNDs (which should make users more familiar), and updated technology (which has been done in an attempt to make the interaction better), users still complain about the difficulty of using PNDs. Even the most basic functions (e.g., entering an address, or learning when to make the next turn) are still in need of considerable research and enhancement. For example, various vendors have begun to support a 3 dimensional display as well as a bird's eye viewing angle, but this does not seem to help users identify the precise time or place to make a turn. Rather, it causes information pollution by conflicting 3D image with text on it. Previous research has shown that a visually optimized navigation system can decrease the total map fixation time and the number of glances needed to interpret the display [8]. This type of benefit using abstracted information properly illustrates how we can overcome the naïve realism in display design [13], but it often remains to be implemented effectively in real devices.

In order to provide a more effective display and safer use of PNDs, we focused on improving the way to present information pertinent to turning points, which is the most fundamental display problem of navigation devices.

2. ISSUES WITH CURRENT TURNING POINT DISPLAYS
Once driving starts, the PND provides visual and auditory information regarding turning points. The use of both visual and auditory cues makes a lot of sense, since it allows the driver to listen to cues while driving, when necessary. From a more theoretical perspective, models of multimodal information processing, such as Wickens' Multiple Resources Theory [16], have led many researchers to study this multimodal approach, particularly in terms of the use of spoken turning commands

from the navigation system [3, 6, 14, 15]. Typically, better results are obtained with the multimodal navigation system than with visual-only PNDs. However, there remain considerable issues still to overcome.

2.1 Turning Point Planning and Preview

The first category of usability problems with turning point displays relates to the planning of routes, and the planning and previewing of upcoming turns.

Memory Capacity Issues.

Before getting started to drive, drivers can check all of the routes to their destination on the PND. They can trace the route with using a simulation function. They can also get an overview of important turning points with turn-by-turn list. These functions are clearly helpful in preparing for driving because they can form a schema on the entire route. Nevertheless, they cannot memorize all the directions where they have to go in every single road. What they can memorize are just overall destination direction and a few intersections. It is necessary to provide directions in sequence, and preferably in such a way that the driver need not look down at the list of turns, or navigate from map view to list view.

Advanced Planning.

One of the most important reasons why drivers need more information for further directions while driving is that they should prepare for turns in advance. Although the current turning arrow display can make drivers expect the next direction and prepare for it, it is not sufficient. What if they have to turn again just after the next turn? If a driver needs to turn left just after right turning, she must change lanes immediately after the right turn. Drivers have to decide which lane they will turn into, depending on the next turning direction after the current one. The importance of advanced planning in the dynamic context has been stressed in various fields. For instance, expert musicians play even unknown scores well, because they read the next several notes in advance, which allow them to prepare for the next whole sequence of movements [12]. For drivers, multi-turn planning needs to be part of the instructions, and presented before the first turn, in order for adequate sequencing of sub-goals.

Decision Making.

Even with a PND, drivers in an unfamiliar locale have a high possibility of missing the correct turning point. Even though they listen to the voice guidance, they might not have confidence to turn when directed. Part of the problem is trust in the technology, and part of the issue is a mismatch between the instructions and the view out the window. Visual displays on the small screen are confusing and distracting, and do not have realistic images. Improving the context of the instructions can help enhance the match between system and street, and thus increase the driver's recognition of the correct turning location, and therefore trust in the system. As an example, Reagan and Baldwin [11] suggested that when voice instructions included a *salient landmark*, driving performance was significantly improved. For example, a voice prompt that says, "Turn right in five miles *at the police station*" should lead to better results than a prompt that does not include the police station landmark.

2.2 Cue Sound Location

Typical turning point instructions include a series of prompts, progressively closer to the turn. For instance, listeners may hear a voice prompt at 3km, 1km, and 500m before the turn. While this may help planning to some degree, to date all of these sounds are recorded (or synthesized) and played in mono, via a single speaker on the PND, or via both stereo channels of the car stereo system. This has the effect that the sound cues appear to originate either very near to, or in front of the listener (driver). While this may not be detrimental, per se, it is generally regarded as more congruent to have the sound cue originate from the same side as the required action. That is, a right turn could be cued by a sound coming more from the right side.

2.3 Turning Synchronization

At the first stage of using the PND, many people complain that they cannot know exactly when or where they are to make a turn. Even experienced users experience the same problem because the tuning of their timing is different from the system timing. Some people simply give up using a PND before they become familiar with it. Though PNDs currently present various ways to inform the user of the precise turning point, individual differences between users will always be a big obstacle to overcome. Clearly, there is a need for some way for the PND to overcome the timing-synchronization issue, in order for users to achieve the fast acclimation and adjustment to the timing of the various turn prompts.

3. REDESIGN OF TURNING POINT DISPLAYS AND BENEFITS

Based on these issues, this paper presents several solutions in terms of visual and auditory displays. Solutions involve two separate display timing points. One is preparing for the current turn in advance. The other one is just within a measurable distance of turning i.e., just before turning. For this purpose, visual and auditory components are added to each context.

3.1 Advanced Turn-By-Turn Display

First, to predict and prepare for turnings more properly, we created *Advanced Turn-By-Turn Display*, which could display the next several turning directions on the map screen. If the route requires a second turn soon after the first turn, the PND automatically displays a piece of additional turning information beside the current turning arrow. Moreover, if users touch the arrow, they can check additional turning points (see Figure 1). Once users touch it again, it will disappear. Otherwise, it automatically disappears in a few seconds.

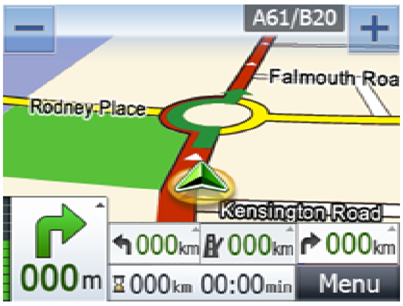

Figure 1. Screen capture of *Advanced Turn-By-Turn Display*. It shows several next turning points from left to right.

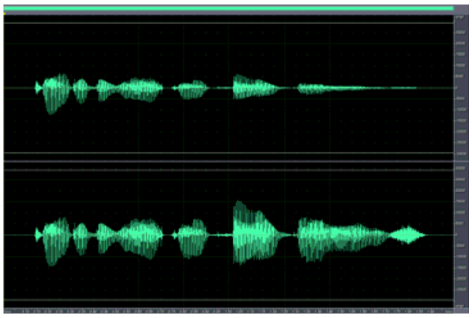

Figure 2. Screen capture of redesigned voice prompt. *Spatial Turning Sound* pans from the center to the right.

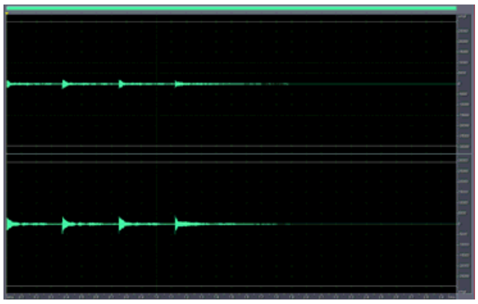

Figure 3. Screen capture of redesigned *Leading Tones* just before the turning. It consists of a series of leading sounds.

Suppose that the drivers stop at the crosswalk on the red light, they might want to check the next few turning points. Previously, for this, drivers had to enter the menu and navigate several depths more in order to reach the Turn-by-Turn list. After checking the list, they had to return to the current map display. In contrast, by using the *Advanced Turn-By-Turn Display*, they can check it by only one touch of the map screen and they can also leave it on the screen. This means drivers might feel that the *Advanced Turn-By-Turn Display* requires navigating a shorter physical and psychological distance and is more approachable than the current Turn-by-Turn list in the menu. Therefore, it can provide drivers with advanced awareness of future required lane changes and further turns, and can allow them to be free from our typically limited memory capacity that might otherwise be a problem when driving a route.

3.2 Spatial Turning Sound

To enhance any potential benefits of cue-response compatibility, we devised a *Spatial Turning Sound* (see Figure 2). If the next turn is right in a mile, the PND may say, "Turn right in one mile." To date, it has been generated in mono. In this newer version, the sound is provided in stereo. That is, if the next turn is to the right, the sound generates from the right speaker.

Spatial Turning Sound uses the basic perception principle of spatial sound. It would affect users' anticipation of the turning direction. Even if users cannot know it consciously, it might render a type of subliminal perception like a framing effect. Users can obtain additional information from the acoustic properties of sound (such as spatial location) before they interpret the meaning of the words. This can clearly lessen the information processing load for drivers. Even if users miss the message of the voice prompt due to a dialogue with passengers or radios, they could identify the next turn direction from the spatialized location of the audio cue. According to Ho and Spence [7], spatial attention is attracted more efficiently when information presented to multiple senses originates from approximately the same spatial region. Thus, *Spatial Turning Sound* may play a role in terms of attracting drivers' attention.

3.3 Leading Tones for Turning

Finally, the sound presented just before turning was redesigned. This *Leading Tones for Turning*, generates tones of increasing duration and pitch, like "Pip.. Pip.. Pip.. PiiiiP" (see Figure 3). Adding contextual sounds before the exact moment might help users sense the appropriate timing.

Even though the current concept of presenting a short sound like an earcon [2] just before turning has been recently added to many PNDs in order to help turn timing, it still tends to make users miss the correct timing because the processing from 'perception' to 'behavioral reaction' requires a certain time. Drivers still need anticipation and preparation for the precise turning timing. *Leading Tones for Turning* can let users perceive where the next turn is more accurately, and be ready to turn appropriately. Furthermore, through *Leading Tones*, users are able to compute the accurate turning timing by using all of the series of sounds.

Both these two auditory displays are easy to make and implement because the device can always use the same files in each situation. Vision is the most heavily taxed sense in driving, even though driving requires integration of information coming from multiple modalities [4]. Thus, the workload of the visual modality could be lessened by using the additional auditory modality. Further, all of these new features might help users in terms of decision making. Based on this additional information for turning point display, drivers can more conveniently decide whether to make a turn at a particular time or not.

4. FGI & DESIGN IMPROVEMENTS

We conducted several Focused Group Interview sessions for gathering experts' feedback and improving these newer display design concepts, in the U.S.A., Hungary, and Germany.

4.1 Participants

Seventeen participants (all male) participated in the FGI sessions. They ranged from telematics system providers and car audio specialists to salesmen at electronic goods stores.

4.2 Materials & Procedure

For the *Advanced Turn-By-Turn*, a simple movie clip was created in Flash 8.0. For the auditory display features, we composed wave files using Cubase SX 3.0 and played them via Microsoft Power Point 2003. Total seven FGI sessions (the U.S.A. and Hungary = 2, Germany = 3) were conducted including one to four participants in each Focused Group. FGI sessions were held at our office or the participants' office in each country. At first, a coordinator introduced the new display design concepts, using the Power Point slides for visuals, and playing sounds via stereo desktop speakers. Another interviewer simultaneously took notes of the participants' comments using a laptop computer.

4.3 Design Improvements

As a result of subsequent FGI sessions, we gained a couple of critical improvements as well as the preference of the most of participants (domain experts). Among them, the present paper describes two major points pertinent to each display design. The first one was related to the compatibility issue of the *Advanced Turn-By-Turn Display*. Some said that the top to bottom order of the turning point display is congruent with typical reading flow, but some preferred the bottom to top because it is compatible with the moving direction of the vehicle. This meant that regardless of which design we implemented, about half the users would have an incongruent display. To solve this compatibility issue, we changed it into the left to right order. The leftmost arrow means the nearest turning point and the rightmost arrow denotes the farthest turn. Since in most of countries except some at the Middle East, people read from left to right, we could expect that it would work well.

The next suggestion enhanced the *Spatial Turning Sound* presentation. It was suggested that if the sound moves to either side, the dynamic sound should be more compelling and more commanding of attention [10]. For these reasons, we developed new dynamic turning cues to move from the center out to directed side.

5. CONCLUSION & FUTURE WORKS

This paper presented the visual and auditory display concepts for facilitating drivers' interaction with a navigation device and potential users' benefits. Subsequent FGI results showed that experts favored those features and improved the details. These optimized turning point displays might dramatically decrease the driver's perceptual and cognitive load during navigation tasks which would lead to increased safety for drivers with use of IVTs. Despite this promising expectation, work is still needed to further validate those concepts in the context of real driving with normal traffic sounds. Therefore, future research is planned to evaluate one of our new models which incorporates those features.

6. REFERENCES

[1] Ashley, S. (2001). Driving the info highway, *Scientific American, 285(4)*, 52-58.

[2] Blattner, M. M., Sumikawa, D. A., & Greenberg, R. M. (1989). Earcons and icons: Their structure and common design principles. *Human-Computer Interaction, 4,* 11-44.

[3] Burnett, G., & Joyner, S. (1997). An assessment of moving map and symbol-based route guidance systems, *Ergonomics and safety of intelligent driver interfaces*, 115-136.

[4] Deblasio, J. M., Jeon, M., Walker, B. N., & Nees, M. (2009). Designing an auditory display: Report on a case study for in-vehicle use. Georgia Institute of Technology Sonification Lab Technical Report, 2009.

[5] Dukic, T., Hanson, L., & Falkmer, T. (2006). Effect of drivers' age and push button locations on visual time off road, steering wheel deviation and safety perception, *Ergonomics, 49(1),* 78-92.

[6] Gish, K., Staplin, L., Stewart, J., & Perel, M. (1999). Sensory and cognitive factors affecting automotive head-up display effectiveness, *Transportation Research Record: Journal of the Transportation Research Board, 1694(1)*, 10-19.

[7] Ho, C., & Spence, C. (2005). Assessing the effectiveness of carious auditory cues in a capturing a driver's visual attention. *Journal of Experimental Psychology: Applied, 11(3)*, 157-174.

[8] Lee, J., Forlizzi, J., & Hudson, S. E. (2005). Studying the effectiveness of MOVE: A contextually optimized in-vehicle navigation system. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 571-580. NY: ACM Press.

[9] Patten, C., Kircher, A., Ostlund, J., & Nilsson, L. (2004) Using mobile telephones: Cognitive workload and attention resource allocation," *Accident Analysis and Prevention, 36(3),* 341-350.

[10] Polkosky M. D., & Lewis, J. R. (2001). The function of nonspeech audio in speech recognition applications: A review of the literature, IBM Voice Systems Technical Report TR 29.3405, 2001.

[11] Reagan, I., & Baldwin, C. L. (2006). Facilitating route memory with auditory route guidance systems. *Journal of Environment Psychology 26*, 146-155.

[12] Sloboda, J. A. (1982*). The musical mind.* Englewood Cliffs. NJ: Prentice-Hall.

[13] Smallman, H.S. & St. John, M. (2005). Naïve realism: Limits of realism as a display principle. *Proceedings of the Human Factors and Ergonomics Society 49th Annual Meeting,* 1564-1568.

[14] Srinivasan, R., & Jovanis, P. (1997). Effect of selected in-vehicle route guidance systems on driver reaction times, *Human Factors, 39(2),* 200-215.

[15] Streeter, L., Vitello, D., & Wonsiewicz, S. (1985). How to tell people where to go: Comparing navigational aids, *International Journal of Man-Machine Studies, 22(5),* 549-562.

[16] Wickens, C. D. (2002). Multiple resources and performance prediction. *Theoretical Issues in Ergonomics Science, 3(2),* 159-177.

[17] www.mybecker.com

[18] www.tomtom.com