Human-Centered Public Transportation Systems for Persons with Cognitive Disabilities

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Challenges and Insights for Participatory Design

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ABSTRACT

In this paper, we present a participatory process for designing new socio-technical architectures to afford persons with cognitive disabilities the opportunity to use mainstream public transportation systems. This project faces two unique challenges: (1) there are no true "experts" who understand all facets of public transportation system design, operation, and maintenance; and (2) each person with cognitive disabilities represents a "universe of one," preventing the technology designer from thinking in terms of typical "user classes." Participatory "in-the-world" design is therefore a necessary and critical facet of this research, and the design process must include members from diverse communities. Our design team participants include assistive care specialists and family support organizations, urban transportation planners and managers, hardware and information technology designers, and university researchers. Designing for a diverse user population or a complex system acts as a "forcing function" for using a participatory approach, and it is simply impossible to create a good design without it. This paper will highlight insights from this process that have illuminated our research efforts.

Keywords

participatory design, transportation systems, technologies for persons with cognitive disabilities, caregivers, "universe-of-one," personalization, universal design

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INTRODUCTION

Public transportation systems are among the most ubiquitous and complex large-scale systems found in modern society. In many urban cities, public transportation systems are broadly accepted as the preferred transportation alternative for commuting to work, performing errands, or traveling to social events. But for certain members of society, including persons with cognitive disabilities, the elderly, and the unfamiliar or out-of-town visitor, these systems can be complex and daunting to learn or use. For those with cognitive disabilities and the elderly, the freedom to live independently, socialize, or hold a steady job is tightly coupled with their ability to use these complex systems. Because of shortcomings in current systems, fleets of "special access" vehicles are often dedicated to supplement mainstream systems. While sound in intention, these special vehicles also separate users from mainstream experiences and require advanced reservations, thus preventing flexible ad hoc travel.

PROJECT GOALS

The objectives of our "Mobility for All" research are:

- **Analyze and understand the cognitive barriers in public transportation systems**. Using a participatory design approach [Schuler & Namioka, 1993], public transportation systems will be surveyed to develop a conceptual understanding of the cognitive barriers that exist and must be addressed in current systems. The survey will include field studies to observe occupational therapists and assistive technology specialists as they train persons with cognitive disabilities to use these complex systems. The survey will also explore emerging transportation and information technologies to inform our understanding about infrastructures that could be adapted or leveraged within a near-term time frame.

- **Design a "Mobility for All" socio-technical architecture to reduce cognitive loads in current public transportation systems**. In collaboration with technical experts and support communities, a technical architecture will be designed that addresses the functional needs of transportation users and caregivers, while providing technologies necessary for a reliable, safe, and trustworthy system.
- **Implement and evaluate socio-technical prototypes within a "real world" setting.** In collaboration with public transportation managers, designers, and caregiver communities, technical prototypes will be developed, assessed, and refined within our local university and city transportation systems.

DESIGN PARTICIPANTS

To achieve our project goals, we have assembled a unique consortium of expertise from university, local government, public education, and commercial sectors:

- **University researchers** from the following institutions:
  - **Center for LifeLong Learning and Design** (L^3D; http://www.cs.colorado.edu/~l3d/) a multi-disciplinary research center at the University of Colorado that studies the design of intelligent systems that serve as amplifiers of human capabilities.
  - **Cognitive Levers Research Project** (CLever; http://www.cs.colorado.edu/~l3d/clever/) an L^3D research initiative to develop computationally enhanced environments to assist people with a wide range of cognitive disabilities.
  - **Coleman Institute for Cognitive Disabilities**, a privately endowed research institute at the University of Colorado founded to develop information technologies that address challenges faced by persons with cognitive disabilities and their families.
  - **University of Colorado/BP Center for Visualization**, a unique 3D immersive simulation center for virtual design, test, and evaluation.
- **Assistive technology specialists** from the Boulder County public school district (working part-time in the L^3D Center), and the University of Colorado Assistive Technology Partners (http://www.uchsc.edu/atp/).
- **Transportation system planners, managers, and operators** from the City of Boulder and University of Colorado.
- **Technology developers** including **AgentSheets, Inc.** (http://www.agentsheets.com), a software company formed from an L3D research initiative that develops agent-oriented programming environments; **BEA Inc.** (http://www.bea.com), a software company that provides web infrastructure substrates for enterprise application development and personalization; and **Intuicom** (http://www.intuicom.com), a local developer of high-precision Global Position Satellite (GPS) and mobile communications technologies.
- **Urban planners and designers** from the City of Boulder; and Communication Arts (http://www.commarts-boulder.com/), a Boulder commercial design firm responsible for several award-winning international urban and public transportation system designs.

Each participant brings a unique role and perspective into the project, but all are united by a desire to design future systems that are inclusive and universally accessible for all of society.

METHODOLOGY

Our team has used the methodology seen in Figure 1 to study existing transportation systems.

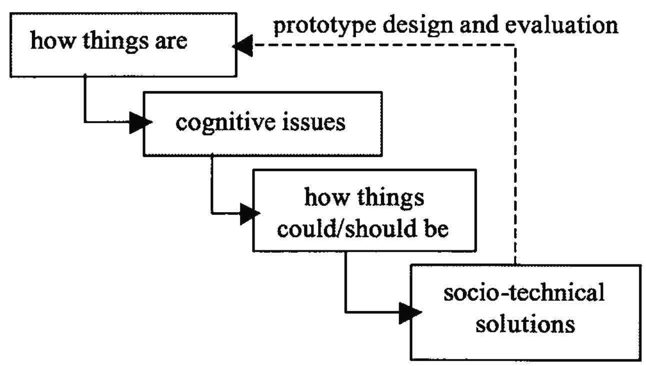

Figure 1: Research methodology

Our assessment of "how things are" began with an analysis of current transportation systems, assistive approaches for learning these systems, and a survey of emerging transportation system technologies. Once real world constraints and cognitive issues were identified, our team developed scenarios and architectures to illustrate "how things could be" and provide a framework for the design of socio-technical prototypes [Ehn, 1989]. Within this methodological context, we will summarize results from our field studies and present some preliminary socio-technical prototypes.

FIELD STUDIES

Our team conducted field surveys of public transportation systems (bus, light rail, and subway) in five major cities including Denver, Milwaukee, Chicago, Washington DC, and Tokyo. Our team has also studied a "next generation" bus system in Vail, Colorado and observed high school students with cognitive disabilities learning to use public bus systems in Ft. Collins, Colorado.

We will now summarize our major findings.

Finding #1: Non-impaired users generally fall into one of two categories:

- **familiar users**: regular commuters who routinely use public transportation systems on one or more routes.
- **unfamiliar users**: infrequent users, out-of-town visitors, or familiar users attempting to learn a new route.

Finding #2: When using public transportation systems, unimpaired users engage in a series of high-level activities that include planning, waiting, and moving. These high level activities can be further decomposed into atomic cognitive steps of: *"reflect→choose→act"* [Schön, 1983]:

For example while waiting, users reflect on where they are in the journey, what connection (bus, train, etc.) they are waiting for, how to identify and select the correct vehicle, and finally where to move and board. In other words, every step – including the appearance of "doing nothing" – imposes cognitive loads.

Finding #3: To use public transportation, it is necessary comprehend, manipulate, and process *"essential navigation artifacts"* [Tufte, 1990]. These artifacts include:

- *maps:* needed to determine one's current location, destination, routing options, and overall trip progress.
- *schedules:* necessary to find a feasible transportation route at a particular time of the day or week.
- *labels and signs:* to identify where to go, which transportation vehicle to take, where to get on and off.
- *landmarks:* to confirm progress and identify locations.
- *clocks:* to synchronize schedules with arriving transportation vehicles.

Finding #4: Even "familiar users" make mistakes when using public transportation systems. Mistakes are caused by [Norman, 1988]:

- *system errors:* mislabeled buses; buses not running on schedule, or taking a "detour" from the normal route;
- *user errors:* falling asleep, failing to hear or understand the announcement of an upcoming stop, forgetting to signal intentions to get off at the next stop, getting on the wrong bus, or getting off at the wrong stop.

Unfortunately, our survey did not reveal any transportation systems with fail-safe systems designed to help a user detect or recover from these unexpected errors. When familiar users discovered they had made an error, they often acted like "unfamiliar users" and needed to use *essential navigation artifacts* get back on track.

Implications for persons with cognitive disabilities using public transportation systems.

These field surveys identified cognitive issues facing persons *without cognitive disabilities*. Our analysis of these findings with assistive care professionals led to the following research hypotheses:

- Using public transportation systems involves many subtle complexities. Navigation is a complex and difficult executive function [Kintsch, 1998].
- Cognitively disabled persons face many of the same problems as unfamiliar users (out of town visitors or non-native speakers) who are learning a new system or route [Newell & Gregor, 1997].
- Complex procedural knowledge is also necessary when using the *essential navigation artifacts* found in modern public transportation systems.
- Perturbations (i.e., a detour) or "system errors" require users to (1) recognize the situation and (2) engage in new planning activities. For those with cognitive disabilities, unforeseen events can prevent them from using previously "mastered" routes.
- Common user errors could likewise present significant issues for those with memory or attention deficits.
- If a memory or attention deficit is severe enough, the act of learning a new route may interfere with previously learned routes.

Problems in Transportation Systems for People with Cognitive Disabilities.

Our research team also visited Poudre High School in Fort Collins, Colorado to observe students with cognitive disabilities learning to use public transportation systems. We have also interviewed transition specialists who help people with cognitive disabilities in the "school-to-work" transition.

Key findings from these surveys include:

- Instructors engaged students in the same high-level activities observed with our study of unfamiliar users: planning, waiting, and moving.
- In the classroom, students were introduced to simplified maps and schedules. The instructor discussed the connection between bus schedules and clocks, but it was unclear how many students grasped this abstract concept.
- Once on the street, labels and landmarks were highlighted. Tremendous concentration was needed to understand these *essential navigation artifacts* and only one of eight students demonstrated an ability to track trip progress using a simplified map while traveling.
- Navigation lessons were interleaved with other essential life skills such as social etiquette. These skills are also needed for a student to safely use public transportation, but it creates problems with focus on navigational tasks.

- The ability to successfully use public transportation impacts one's ability to live and work independently. One experienced instructor reflected that approximately one-half of the adolescents in the program eventually learn to use public transportation for routine travel.

PROTOTYPE DEVELOPMENT

From our field research, two major design approaches emerged:

1. design technologies that simplify and contextualize the complex navigational artifacts encountered in public transportation systems; or
2. design technologies that transcend existing navigational artifacts and provide personalized, location-aware, "just-in-time" instructions and prompts for what to do and where to go next.

Our field research showed that current assistive training methods closely approximate the first design approach. For example, assistive teachers often used "analog technologies," such as simple user-colored maps and schedules, to serve as memory aids for their students.

Despite using these simpler artifacts, our field research also showed that (1) there was limited success for those unable to master higher level navigational concepts, and (2) a significant amount of individual training and "confederate tracking" [Newbigging, 1996] (using an unknown instructor follow a person who is traveling alone) is necessary before a person is considered capable of using public transportation without assistance.

Our team has therefore focused on the second design approach – creating technologies that eliminate the need to master complex navigational artifacts. To reduce the burden on caregivers, our team has also considered how technologies could be designed to help privileged individuals (such as caregivers or family members) monitor and assist persons in their care as they learn or use a new route.

As a proof-of-concept, we have developed a technical prototype with two synchronized components (Figure 2):

- a 3D display of the University of Colorado bus system showing the real-time GPS location of all buses and a "virtual person" who responds to prompts from a simulated mobile prompting device; and
- a simulated mobile prompting device that provides personalized multi-modal (pictures, sound, voice, and/or text) "just-in-time" prompts for "what to do" based on real-time GPS bus data.

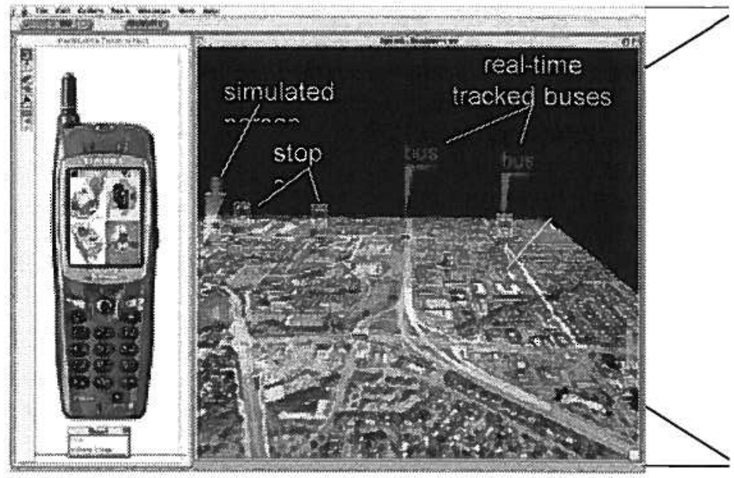

Figure 2: Agent-based prototype showing a mobile prompting device synchronized with a 3D real-time display of the University of Colorado bus system.

FUTURE WORK

This prototype provides an "object to think with" as we progress toward our goal to design a mobile platform that provides personalized, location-aware prompts and instructions. Other project plans include:

- a schedule and activity management system so caregivers can easily create personalized itineraries and offer help while people travel.
- infrastructure mechanisms to support sharing generalized itineraries and routing options among caregiver communities;
- communication-augmentation systems to support essential dialogs between persons with cognitive disabilities and transportation system operators;
- automated error detection, recovery, performance feedback, and if necessary, caregiver notification systems;
- dynamic, knowledge-based infrastructure technologies to make travel more safe, enjoyable and comfortable. For example a computational "routing agent" might facilitate a serendipitous meeting between two friends by routing them through a common bus stop on an itinerary.

IMPLICATIONS FOR PARTICIPATORY DESIGN

Designing systems for persons with cognitive disabilities in the complex domain of public transportation provides unique insights for participatory design:

- No single perspective can yield a satisfactory solution. The unique needs and abilities of our users must be juxtaposed with the complexity and constraints of modern public transportation systems, making collaborative partnerships essential [Fischer, 2000].

- Complex socio-technical systems cannot easily be studied and designed in a laboratory [Nardi, 1997]. Problems such as people falling asleep or buses not running on time are likely only to be seen in the world, and not in a lab.
- There are no "silver bullet" technologies that can replace caregivers. However, we believe socio-technical solutions can be designed to (1) provide mobility and independence options contextualized to the person and situation [Fischer, 2001]; (2) augment memory, focus attention, and offer help; (3) allow caregivers to tailor support to suit the needs and abilities of each individual; and (4) deliver prompt, personalized assistance when needed.
- Participatory design should not be viewed as an additional step or burden on existing domain practices, but a catalyst to inform, enhance, and possibly transform existing practices [CTSB, 1997].
- When designing for persons with disabilities, participatory design is not optional, but essential. What is unique and challenging about design in this domain is that another group (the assistive care community) often acts as a proxy so any new assistive approaches must ultimately be tested, assessed, and refined in-the-world with real users.

CONCLUSIONS

Understanding the needs of people with cognitive disabilities poses unique challenges for participatory design, but it has the potential to provide unique insights. The significance of our research effort is that (1) it addresses the needs of an under-represented and often non-vocal sector of society within the context of a technically complex system; (2) it requires the participation of disparate communities for a common goal; (3) it could change the methods and practices of participants, and influence the way future designers and engineers are educated; (4) it has the potential to improve public transportation systems for everyone through the adoption of universal architectures and prototypes that promote universal access.

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