Accessible Science Museums with User-Activated Audio Beacons *(Ping!)*

Ellen Giusti and Steven Landau

BACKGROUND

According to the 2000 U.S. census, millions of Americans live with visual disabilities that can interfere with their full participation in the cultural activities currently offered by museums. A number of organizations are working toward a future in which these underserved potential museum visitors have greater opportunities to benefit from the educational experiences taken for granted by the sighted population.

In 1997, the New York Hall of Science pioneered the use of audio tours in a science museum for visitors who are blind or have low vision. Director Alan Friedman's goal was to expand its audience by offering specially crafted audio tours "to our potential public that had seen no value in visiting us —or, for that matter, any other museum—because so much of the experience had previously been inaccessible to them" (Friedman, 2000). Evaluation showed that the tours could provide science content previously unavailable in a hands-on setting to visitors with low vision or who are blind. However, we also learned these tours lacked important wayfinding information that could provide much-valued independence and enable visitors who are blind to navigate the exhibit floor.

Inventor Steven Landau and his colleague, accessibility consultant Ellen Rubin, who is blind, are working on a system of user-activated audio beacons (working title, *Ping!*) that addresses both content and wayfinding needs. Cell-phone-based technology, a ubiquitous technology used by most people who are blind or have low vision, can enable people with visual disabilities to independently navigate in museums by following paths of "sonic breadcrumbs" to locate individual exhibits and other destinations in the museum. When they reach their chosen destination, the system then provides content and directions for using an exhibit.

EVALUATION DESIGN

Early stage prototype tests of *Ping!* proved that it effectively enabled visitors who are blind or have low vision to tour a museum under controlled, experimental conditions. The next step was to test the system's effectiveness under more naturalistic, real-life conditions, that is, with several blind or low-vision users simultaneously interacting with the system when other visitors were in the museum. The National Science Foundation awarded the project an implementation grant to further develop the system and test its efficacy.

Developers intended to answer the following questions:

1. Can a visitor who is blind or has low vision distinguish his or her personal "*Ping!*" sound from others when several are in use at the same time?
2. Will the presence of other visitors adversely affect users' ability to navigate successfully? Can audio beacons be heard with the typical ambient noise level in the museum?
3. Can users reach distant destinations using a sequence of audio beacons as "stepping stones" between starting point and destination?
4. Are frequent, high-pitched sounds from the beacons distracting for other visitors?
5. Once users reach their destination, does the interpretation effectively enable them to engage with hands-on science exhibits?
6. Would the presence of a user-activated audio-beacon system make it more likely that people who are blind or have low vision will visit museums?

The New York Hall of Science, which is fully ADA compliant, was selected as the test site. There are obstacles—exhibit components and stools—but individuals who are independent travelers (using a long cane or a dog guide) should be able to navigate around them.

PROCEDURE

The principal investigator (PI), New York Hall of Science staff and the evaluator selected appropriate hands-on exhibit elements and audio beacons were installed at them.

A diverse sample of people who are blind or have low vision were solicited for participation and screened to determine eligibility based on the following criteria: the person must be an independent traveler using a cane or a dog, 12 years or older, fluent in English and able to use a touch-tone telephone.

In return for trying out the system, eligible participants were offered transportation, a $20.00 honorarium and lunch. The task was described

Technology can enable people with visual disabilities to independently navigate in museums by following paths of "sonic breadcrumbs" to locate individual exhibits and other destinations in the museum

and they were apprised of their right to privacy and told that they could quit at any time. They were told that when they finished trying the system, they would be asked some questions to help the developers improve it. Participants and parents of minors signed a Letter of Informed Consent.

The PI and evaluator introduced participants to the equipment (the telephone) and instructed them on how to use it to find their way around the museum. Participants were introduced to museum staff (Explainers) who would be available to assist them at all times, if needed. (Explainers are college students hired by the museum's Education Department to assist visitors with exhibits. Four Explainers were trained by the evaluator and accessibility consultant in specific skills needed for the trials.)

Participants selected a personal ping sound from among nine choices. Participants could choose a destination from a menu of 11 options: the exhibit entry point, 6 exhibits, 3 services (cafeteria and men's or women's restrooms) and the museum entry desk. They were instructed to activate their sound as frequently as needed. To reach more distant destinations, participants used a sequence of audio beacons as "stepping stones."

When a participant reached a selected exhibit, he or she was asked to press one of the telephone numbers to hear pre-recorded information about the exhibit and how to use hands-on elements. The participant could spend as much or as little time as s/he chose, visiting as many or as few of the possible destinations as s/he liked. Participants were asked to try reaching the museum entry from the exhibit floor—the farthest destination—using the "stepping stone" feature.

Trials were conducted over a weekend in July 2003 when the museum was open to the general public. Three users were scheduled during each morning and afternoon—four trial periods in all—for a total of 12 participants.

Three types of data were collected during and after the trials:

1. The system tracked the destinations selected, the number of times the beacon was activated to reach destinations, and time spent at each destination.
2. Museum staff trained in observation techniques by the evaluator observed and kept notes on participants' ability to navigate the museum floor and level of engagement with exhibits.
3. Participants were interviewed about their experience. Post-participation evaluation questions were read aloud and responses written down by museum staff.

The data were analyzed to determine the overall feasibility of the system. Data analysis focused on the following measures:

- degrees of success with which the participants found their way around the museum
- participants' anecdotal responses about the value of the experience
- overall effectiveness of the system as reported by both museum staff and the participants.

Participants were warned in advance to expect "glitches," and were told that their input was essential to help developers improve the system. Participants were assured that any problems that might occur with the equipment were not their fault.

PARTICIPANTS

The 12 participants (7 female, 5 male) represented a range of visual impairments, as shown in Table 1.

Table 1. Participant assessment of their vision
n = 12

BEST DESCRIBES YOUR VISION	
Blind, no useful vision	7
Very limited useful vision	1
Some useful vision	2
Considerable useful vision	2
VISUAL IMPAIRMENT BEGAN	
From birth to 2 years	5
Between 3 to 5 years	3
Teens to 30 years	4

continued on page 18

One participant navigating on the exhibit floor.

All participants were able to travel independently, 9 used a long cane and 3 had dog guides. Three participants indicated that they had mild additional impairments: 1 hearing, 1 physical/ motor and 1 print.

English was the primary language for 11 participants, Spanish for 1 (who was fluent in English). All participants said they were able to use a touch-tone phone. Participants ranged in age from 14 to 56.

FINDINGS

Overall, the trials proved that a user-activated audio-beacon system can provide wayfinding information and exhibit interpretation under naturalistic conditions, that is, when several users are simultaneously interacting with the system during a time when other visitors are in the museum. Equipment malfunctions occurred during the trials (as might be expected in a prototype implementation study), however, all participants were able to successfully follow their personal *Ping!* sound, reach selected destinations and interact with exhibit components.

Effectiveness of individual sounds

Can a visitor who is blind or has low vision distinguish his or her personal sound from others when several are in use at the same time? The answer is yes: 100% of the participants were able to hear, distinguish and follow the *Ping!* sound they had selected. Everyone started off from the "exhibit entry point" close to the exhibit floor. Destinations were listed in the order of closeness to the user. Starting out, most users selected the closest destination first, all attempting to reach it at the same time.

The other sounds don't bother you as long as you can remember your own!
Participant 103

We found that multiple sounds playing at the same time (even from different nearby locations) caused significant confusion, so a signal was blocked from playing if another sound was already playing at that moment. Some of the sounds were shortened to make them fit within .5 seconds; this was done to reduce the problem of one user having to wait for another's *Ping!* sound to finish before he or she could trigger a sound. However, another form of confusion arose: when a sound failed to play, users assumed that their *Ping!* was not functioning properly. This lag time needs to be spelled out for future users.

Participants suggested ways of improving the beacons' effectiveness:

- Users should be able to adjust volume of *Ping!* sound for greater flexibility, such as accommodation of hearing loss or crowded museum conditions.
- If user is accidentally logged off the system, s/he should be automatically reassigned the same sound after logging back on.
- Instructions should indicate where beacons are in relation to exhibit components, such as, "beacon is located below the counter" or "overhead."

The presence of other visitors did not adversely affect users' ability to navigate successfully. Likewise, the other visitors in the exhibit hall were not distracted by the beacons: they appeared to associate the *Ping!* sounds with the ubiquitous beeps and chirps of the interactive museum exhibits (which did not adversely affect *Ping!* users).

In the future, blind system users should be told that frequent activation of the beacons does not adversely affect sighted visitors. Audio beacons could be heard when there was typical ambient noise level in the museum. There were occasions when the ambient noise exceeded normal levels, at which times the ability to control the *Ping!* sounds' volume would be desirable.

Effectiveness for wayfinding

The system tracked the number of *Ping!* sounds needed to reach each destination. The average was 22, varying from a low of 7 to a high of 84. Some users triggered their *Ping!* almost continually as they traveled. Others used them much more sparingly, pressing the key and then thinking a bit before moving.

Overall, participants had no trouble following their *Ping!* sound. People who are blind or have low vision typically use auditory cues and are sensitive to them when moving about. A participant who was less accustomed to traveling on her own had greater difficulty following her *Ping!* sound. Table 2 illustrates participants' assessment of how easy or difficult it was to use the system for wayfinding.

Table 2. Wayfinding system's ease of use

WAYFINDING	POST-PARTICIPATION INTERVIEW *n=12*	SYSTEM-ADMINISTERED INTERVIEW *n=11*
Easy	8	6
Both easy and difficult	4	3
Difficult	1	2

Table 3. Use of beacon "stepping stones" for wayfinding

STEPPING STONES	POST-PARTICIPATION INTERVIEW *n=12**	SYSTEM-ADMINISTERED INTERVIEW *n=11*
Easy	5	7
Both easy and difficult	5	-
Difficult	2	4

*Responses based on Explainers' observation reports

Users were able to reach more distant destinations using a sequence of audio beacons as "stepping stones" between starting point and destination. The farthest destination on the list was the museum's main entry desk. Reaching it required ascending a flight of stairs, passing through a reception area, and finally, ascending another short flight of steps. All of the participants were asked to attempt this trip and to give their feedback on the ease or difficulty associated with it.

All participants were able to make the trip, but with varying levels of confidence and ease. In some cases the beacons were not working properly at the intermediate points. Several participants noted that the instructions did not indicate clearly where they were on the route. As users reached a point en route, the narration referred to "the next point along the route" and "the next *Ping!* beacon." Users wanted to know the number of beacons required to reach the destination and exactly which beacon they had arrived at. For example, "You are at the Cafeteria, beacon #3, on route to the main entrance; 2 more beacons to your destination." Users needed clarification about location of stairs they were expected to ascend or descend.

Directions to the main desk should clearly state that you will need to go up the stairs to the first beacon, and up another 3 steps to the last beacon. Participant 202

One participant commented that the "stepping stone" beacons that were on the same floor were too close together, making it more complicated to reach her destination.

The post-participation interview asked participants to rate their experience, choosing excellent, good, fair, poor or very disappointing. Results are in Table 4.

Table 4. Rate experience with system *n=12*

Excellent	2
Good	6
Fair	2
Poor	1
Very Disappointing	-

Participants' suggestions for changes
Suggestions for improvement, not surprisingly, began with "fix technical malfunctions." Other suggestions were:

- Allow user to have more volume control of narrator's voice (5 people)
- Expand the system to include more exhibits (2 people)
- Locate beacons closer to exhibit, let user control volume (2 people)
- Offer a better earpiece for hands-free option (2 people)
- Make it possible for user to speed up narration (2 people)
- Make it possible to use own phone or make better equipment available (2 people)
- Improve "stepping stone" approach (2 people)
- Make it easier to "find yourself" when confused
- Add a "replay" feature, so user can hear instructions again
- If user is disconnected from system, should be able to get same *Ping!* when reconnected

continued on page 20

System navigation issues

Participants suggested that the system should offer more flexible menu options. Several people asked for the ability to return easily to the list of destinations. Participants wanted to be able to repeat or replay a segment of narration if they had not heard it clearly.

Because blind system users must use a long cane or dog guide to avoid obstacles, one hand is always occupied. If they must use the other hand for the phone to activate the beacons, how can they take advantage of hands-on exhibits? The system's voice activation feature did not function effectively: whenever a user spoke, the narration was cut off. Voice activation was sensitive to ambient noise as well, also interrupting the narration.

After the first morning session, voice activation was modified so as not to interrupt narration. If users chose to use voice activation, they had to wait until the segment of narration was complete; if they wanted to interrupt the narration, they must press a key.

The system-administered interview asked users if they preferred to press keys on the phone or speak a number: 10 of the 11 users who responded to the question said that they preferred to press the keys. However, during face-to-face interviews respondents mentioned the difficulty of using their free hand to press keys. If the voice activation feature could be perfected, it would be preferable to key pressing.

Participants reiterated many times that they do not want to be treated as "special" because of their disability, or be conspicuous. A voice-activated system needs testing because blind users say they do not want other visitors to think that they are talking on their cell phones instead of attending to exhibits.

Exhibit interpretation

Once they reached a destination, the interpretation effectively enabled participants to engage with hands-on science exhibits. Like sighted visitors, visitors who are blind or have low vision have a range of interests that predispose them to enjoy some exhibits more than others. As shown in Table 5, every user interacted with at least one of the hands-on exhibits on the system; the majority used most or all of them.

A museum like this has hands-on exhibits and the phone system gives people a more detailed tour of the museum. Without it, it's difficult to interact with the exhibits. For example, the Euglena *cutout—you can sit down and feel it but you wouldn't know what you were feeling if it wasn't for the phone system.*
Participant 102

Table 5. Number of exhibits participants used *n=12*

Number of exhibits used	
All or most (5 or 6)	5
3 or 4	4
Just a few (1 or 2)	3

I don't find the exhibits interesting at the Hall of Science....If they had a Ping! *system at art exhibits that blind people can feel, I would be more inclined to visit.*
Participant 201

The 6 exhibits on the tour were: Build a Molecule, How Many Molecules, Odor Molecules, The Big *Euglena* model, The Smaller *Euglena* and Germs in the Nose. The latter was the overwhelming favorite, as shown in Table 6.

Table 6. Users' exhibit preferences

PREFERRED EXHIBIT	POST-PARTICIPATION INTERVIEW *n=12*	SYSTEM-ADMINISTERED INTERVIEW *n=11*
Germs in the Nose	8	5
Odor Molecules	2	1
Euglena model	1	1
Build a Molecule	1	2
How Many Molecules	1	0
None	1	1

Numbers add up to greater than 12 because more than 1 exhibit was cited.

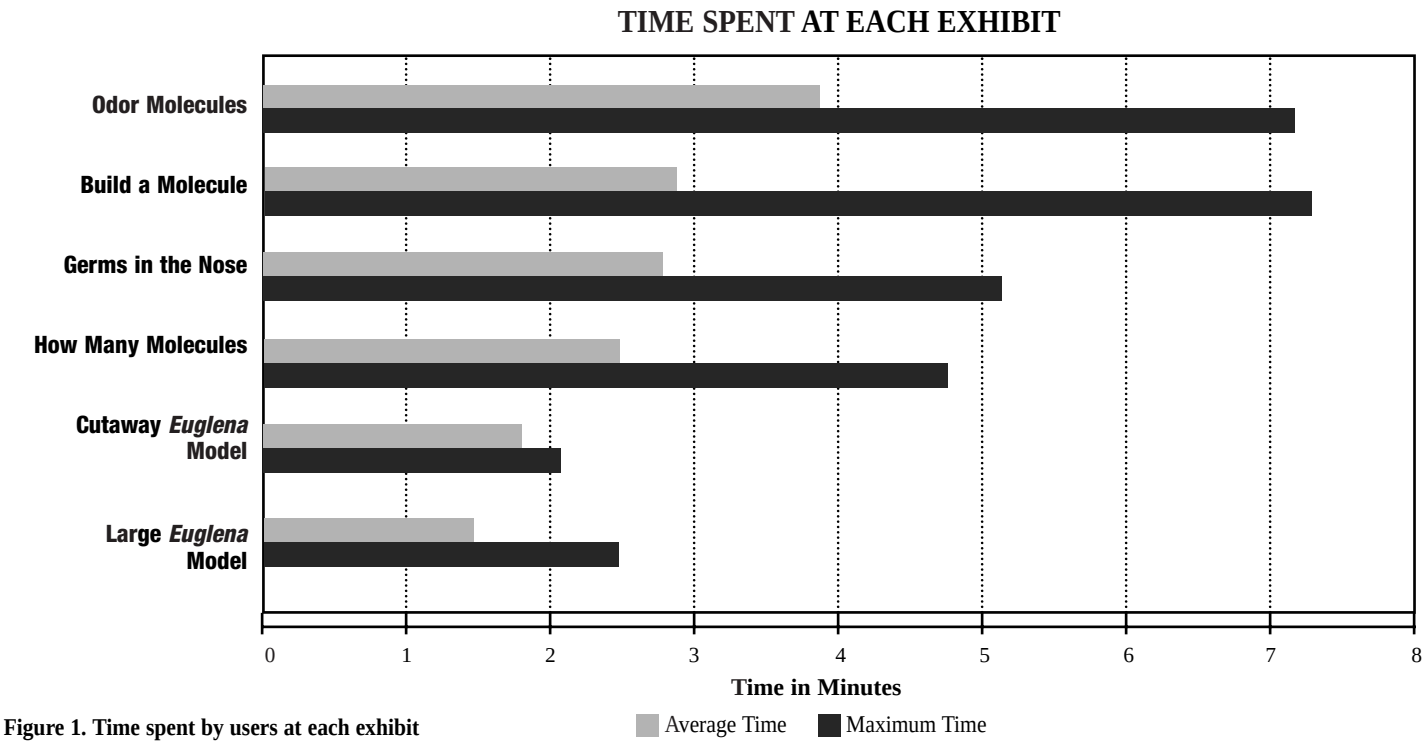

Figure 1. Time spent by users at each exhibit

A participant interacting with an exhibit element at Odor Molecules.

Participants' reasons for their preference were

1. Offered the most interaction/ hands-on, or
2. Gave immediate, gratifying response to a correct interaction.

Which exhibit did participants like least? "How Many Molecules" was the only exhibit mentioned by more than one person. It was disliked because it failed to deliver its answer through the phone due to a computer malfunction.

Figure 1 illustrates the average and the maximum time spent at each exhibit element.

Participants' suggestions for improving interpretation included:

1. Quality of the recording was poor on occasion, and difficult to understand; better quality receivers could remedy this.
2. Related to the sound quality, some users wanted the narration's volume increased when the ambient noise level became louder.
3. Some users wanted to be able to speed up or cut short the narrated interpretation to reach the next interpretive segment. Some users needed less explanation to understand scientific phenomena or the expected interaction with the exhibit.

Museum visitation

Only 1 of the participants is a frequent museum visitor: her work as an accessibility consultant brought her to museums 10 or more times in the past year. The others, regardless of their level of interest in a museum exhibit's content, did not visit at all in the past 12 months (4 participants) or visited between 1 and 4 times (7 participants).

continued on page 22

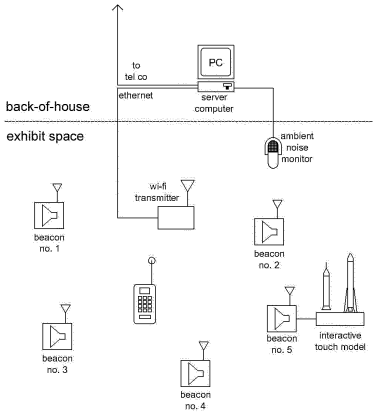

Exhibit Space Schematic

Why don't people who are blind visit museums more frequently? What are the barriers that prevent them from attending museum exhibitions? The most frequent response was that there is nothing for them, nothing accessible or hands-on. The next most frequent response was their inability to find their way in museums or find out which, if any, facilities were accessible.

Would the presence of a user-activated audio-beacon system make it more likely that people who are blind or have low vision will visit museums? All participants said they would be more likely to visit a museum if it had a similar system (particularly if "the bugs" were eliminated). A teenage boy said it would depend on the type of museum.

If the system is put into effect I will still use it even with the glitches.
Participant 102

[I would be more likely to go because] it would show that the museum cares by reaching out to blind people.
Participant 203

Would participants recommend the system to a friend with a visual impairment? Again, 100% said they would (when malfunctions are minimized).

How does the system compare to visiting with a sighted friend? All participants said the system was preferable.

- System gives more independence, freedom and control.
- System user can go at his or her own pace, as opposed to the companion's pace.
- System is designed for specific wayfinding and interpretive needs of a blind person, where a sighted friend can only give his/her perspective.
- Interpretation given by system is more knowledgeable and accurate than a friend might be capable of providing.

A lot of potential. Without the bugs it'll be great!
Many participants

It worked better than I expected. I didn't expect to like it; now I wish it was available. I love the idea of going to the museum alone, getting the Ping! *system and then meeting a friend there.*
Participant 401

The beacons with the Ping! *sounds were a dream—very easy to follow.*
Participant 202

RECOMMENDATIONS FOR FURTHER STUDY

Study participants' overwhelmingly positive responses to the user-activated audio-beacon concept to increase museum accessibility for people who are blind strongly suggest that the system should be implemented. Technical issues must be worked out and a longer technical evaluation period scheduled to test functionality.

In addition, the following formative trials are recommended:

- "Stepping stones" need additional testing on several fronts. Test the ideal distance between beacons necessary for "stepping stones" so that they are not too close nor too far apart. Test scripting ideas to make sure users understand where intermediate stops are located, how many intermediate stops there will be, where they are at each juncture, where there are stairs to ascend or descend.
- Test with a larger group of participants to see if personal *Ping!* sounds can be distinguished and whether a larger number of users can navigate effectively at the same time.
- Test portions of the script to ensure that each clearly explains navigation and exhibit interaction instructions the way a person who is blind or has low vision would interpret them.
- Test hands-free feature so that it can be optional for users. For example, it might be implemented while user is interacting with exhibit and turned off during navigation when key pressing may be more efficient. Some participants recommended earphones that cover both ears so the interpretation could be heard more clearly over ambient noise. They said that headphones could be pushed away from the ears when

Why don't people who are blind visit museums more frequently? What are the barriers that prevent them from attending museum exhibitions? The most frequent response was that there is nothing for them, nothing accessible or hands-on.

the user was following his or her *Ping!* sound through the museum. This should be tested.

- Test *Ping!* sounds with users to select the ones that are not only the easiest to hear and follow, but also the most appealing. Test a user-controlled beacon volume adjustment. Participants noticed that *Ping!* sounds on the phone are different from those coming from beacons. Users became more proficient at following *Ping!* sound after a few minutes practice. For the next phase, test the efficacy of a trial run close to the launching area.
- Evaluate equipment that may have better sound quality. Test volume levels of recorded narration.
- Convene a group of people who are blind or have low vision to advise on appropriate hands-on exhibits to add to the system. There should be exhibits that appeal to a variety of interests and education levels. Would an optional, in-depth information level for more advanced interpretation of science concepts or "behind the scenes" details appeal to *Ping!* users?
- Develop and test a large print and Braille instruction brochure that users can carry with them to access during their visit. Exhibit destinations included in the tour could be described with their numbers to expedite choices. Instructions could be available in print as well for easy reference.
- Develop and test more interactions between the system and interactive computers in exhibits.
- Destination menu gives only the destinations nearest the user. Add and test a feature to allow user to hear a list of destinations that are further away. For example, "press 1 if you would like to hear the next 10 destinations."
- Large, open museum exhibit floors with considerable ambient noise can be disorienting for visitors who rely on sound to navigate. Participants occasionally needed to repeat or replay the last recorded message to understand instructions. Users need a way of figuring out their location. Features such as "find yourself" or "the computer needs to locate where you are" need further development and testing.

THE FUTURE OF *PING!*

The National Science Foundation awarded the project a three-year implementation grant. The PI is working on the technical issues, including installation in the New York Hall of Science and extensive user testing will begin during autumn 2004.

REFERENCES

Friedman, Alan. (2000). Expanding Audiences: The Audio Tour Access Project at the New York Hall of Science. *ASTC Dimensions*, July/August, 7-8.

THE AUTHORS

Ellen Giusti has a degree in museum education from Bank Street College of Education, and has been the in-house evaluator at the American Museum of Natural History since 1990. She is a past Chair of AAM's Standing Professional Committee on Audience Research and Evaluation (CARE) and is currently a board member of the Visitor Studies Association. egiusti@amnh.org

Steven Landau, Director of Research for Touch Graphics, Inc., received an undergraduate degree in Art from Oberlin College and a Master of Architecture from Harvard University. He spent 12 years as a professional architect before forming Touch Graphics, Inc., a for-profit company carrying our federally financed R&D on new products for the blindness and visually impaired market. He was recently named a Tech Awards Laureate for his work on the Talking Tactile Tablet. sl@touchgraphics.com