

A Tag in the Hand: Supporting Semantic, Social, and Spatial Navigation in Museums

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ABSTRACT

Designers of mobile, social systems must carefully think about how to help their users manage spatial, semantic, and social modes of navigation. Here, we describe our deployment of MobiTags, a system to help museum visitors interact with a collection of “open storage” exhibits, those where the museum provides little curatorial information. MobiTags integrates social tagging, art information, and a map to support navigation and collaborative curation of these open storage collections. We studied 23 people’s use of MobiTags in a local museum, combining interview data with device use logs and tracking of people’s movements to understand how MobiTags affected their navigation and experience in the museum. Despite a lack of social cues, people feel a strong sense of social presence—and social pressure—through seeing others’ tags. The tight coupling of tags, item information, and map features also supported a rich set of practices around these modes of navigation.

Author Keywords

Mobile tagging, museum, experience, presence, navigation

ACM Classification Keywords

H.5.3 [Information interfaces and presentation (e.g., HCI)]: Group and Organization Interfaces---Collaborative computing

INTRODUCTION

The convergence of ubiquitous computing and social applications highlights a key issue for designers of mobile, social systems: what does it mean to navigate? In the domain of information spaces, Dourish and Chalmers speak of spatial, semantic, and social modes of navigation [16]. That is, people use the physical layout of information, relationships between aspects of information objects, and people’s activity around these objects as cues when choosing which information to consume next.

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We see value in using this framework to think about mobile, social systems where spatial navigation involves the physical world and people will want to navigate in all three modes. This may require rapid transition between modes, as with digital tour guides where attention regularly shifts between semantic navigation on the device and spatial navigation in the world. In other situations, people may navigate using all three modes simultaneously, such as when spontaneously coordinating a lunch date with friends who happen to be nearby. In either case, the places where these modes come together (Figure 1) are likely to pose interesting design challenges.

We explore these challenges in the context of MobiTags, a mobile, social system we developed to help people engage with “open storage” museum collections, an increasingly common arrangement where objects that would otherwise be in storage are placed in cases with minimal curatorial information and physical organization. MobiTags integrates social tagging of museum objects, an interactive map, and information about the art to help visitors collaboratively organize and explore these open storage collections.

Below, we report on our deployment of MobiTags in a local museum, interviewing 23 participants and logging their use of the system and their motion through the museum. We found that people use tags for multiple purposes: navigating, thinking about art, and creating a sense of social presence. People valued this sense of presence, but found it sometimes made them unwilling to evaluate others’ tags. People also richly interleaved spatial and semantic navigation, with each influencing the other: some people focused on parts of the semantic space based on their

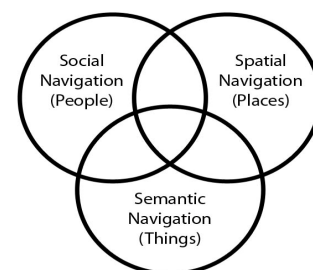


Figure 1. Each individual design challenge is hard, but the real action happens where navigation modes intersect.

current location, while others were led by semantic navigation to move through the museum in ways not suggested by the physical space.

NAVIGATION THROUGH MUSEUMS

Information spaces have always helped people choose appropriate information by exploiting attributes of and relationships between things. Because information goals are a primary concern in museums [18], museums have always used low-tech artifacts such as audio tours and brochures to support navigation. More recent systems add multimedia content [39], guidebooks and personalization technologies [43], and other tools to supplement the “tombstones” of art information placed next to exhibits [1].

Social navigation, using the activity of others to make choices, complements semantic navigation [27]. People watch each other to find quick paths, good restaurants, fashionable clothing, and popular people. Hill et al. extend this idea to computer systems with their work on edit and read wear [26], and a number of systems have exploited this idea to support navigation (e.g., [38,41,44]).

Dividing people and things is rhetorically useful, but in practice social navigation almost always refers to the intersection of people and things. Sometimes this is forgotten, e.g., by social networking systems that de-emphasize things despite theoretical [10] and empirical [8] evidence that things mediate relationships between people. Museum technologies have the opposite problem, sometimes shortchanging social experience because of the dominance of information goals. However, social goals are important for visitors [13,25], and technologies use social information to enrich visits [28] through revealing others’ activity [7,22,23] and reactions to art [14,19,33].

Tagging brings together the ideas of social and semantic navigation by allowing people to label things and places. The *steve.museum* project is exploring how tagging affects people’s use of online museum collections, and elements of ArtLinks are tag-like as well [14,45]. MobiTags extends this, bringing tagging into the physical museum. It also

builds on the handheld tagging of ZoneTag [2], supporting social navigation and interaction through voting on tags.

What, then, of spatial navigation: helping people choose and locate places—or exhibits? Orientation and wayfinding is a common task for museum visitors that technologies support with tools such as maps [40,42], virtual reality experiences of the space [11], and even robotic guides [32].

But spatial navigation is not just about space. People define spaces through the ways they use and experience them, an idea researchers have explored both computationally [50] and conceptually [24]. Technologies that monitor the location of children [37] or parolees [46] affect their navigation through space because of the constraints imposed by authority. Tools such as the Social, Location, Annotation, Mobility (SLAM) framework [15] explicitly recognize the link between social and spatial navigation, combining them to support group awareness and activity.

In museums, tools that relate social and spatial navigation are rare, though [12] provides recommendations based on proximity and [21] provides cues about people’s locations. We believe this is fertile ground for museum technologies to explore because social activity influences how people move through and experience museums [5,13,25,33]. Further, people can set the mood of a museum both through their presence and through mediating technologies such as the Hunt Museum’s “Room of Opinion” [19], guestbooks [22], and other technologies that collect and display users’ opinions [14,43]. MobiTags’ interface provides some elements of mood-setting by helping people find themes and form impressions of exhibits through others’ tags.

The end goal is for mobile, social systems to effectively support rich interaction between spatial, semantic, and social modes of navigation. Research systems such as GeoNotes [17], comMotion [36], and PlaceMail [35] allow people to attach semantic information to places through tags and list-making; these annotations can then be used as fodder for social and semantic navigation in the world. Museum technologies do not generally integrate all three modes of navigation, though systems like CoolTown [20,31] and PEACH [43] are moving in that direction with features that support spatial orientation, provision of extra semantic information about objects, and recommendations.



Figure 2. Our open storage collection. At left is the Workshop, normally a classroom. The middle picture shows the view from the Workshop, past the Lobby Case, to the African Corner at the far end. At right is a closeup of the African Corner.

MOBITAGS: DESIGN FOR INTEGRATED NAVIGATION

MobiTags attempts to integrate social, spatial, and semantic navigation, allowing us to study how people move between these modes in mobile, social systems while improving their experiences in open storage museum collections.

The specific context of MobiTags is a relatively small open storage collection at the Johnson Museum of Art at Cornell University. This collection includes 51 objects scattered across three sets of glass cases on one floor of the museum: the Workshop, the Lobby Case, and the African Corner. The cases are pictured in Figure 2 and spatially arranged as shown in the map in Figure 3. The Workshop is used for classes and is not generally open to visitors. The Lobby case is just outside the Workshop's door. The African Corner is located at the opposite end of the lobby some 100 feet away from the other two cases. The art objects are mostly ancient cultural artifacts such as weights, vessels, bowls, masks, and totems. Thumbnails of a number of the objects are shown in Figure 3.

MobiTags helps people experience this collection while giving visitors more control over their visit than a typical guided tour. It explicitly supports semantic, social, and spatial navigation through tight integration of art information, tags contributed by visitors, and a map representing the physical space. It runs as a web application on an iPod Touch, using the CIUI JavaScript library to provide feedback through animated navigation and caching to improve response times. Below, we focus on three issues we encountered around supporting multiple modes of navigation on a handheld device.

Big information, little screen

One key challenge was supporting effective semantic navigation on a small screen. Figure 4 shows the three main views available for an individual object. The default view of an object (left) shows a condensed overview of an object's information. Clicking the "more info" link provides additional curatorial information when available, broken into sections with a table of contents (center). The "choose

tags" button opens an interface for using, voting on, and adding tags (right).

Many of our choices were compromises for the small screen. A picture for each object supports orientation both on the device and in physical space [49], but had to be small enough to fit the overview screen and, as we will see, drew attention away from the exhibits for some visitors. Putting all of the "more info" on one page requires users to scroll, but an earlier version with a separate page for each question was hard to navigate. Our tag cloud uses color instead of size to show tag frequency, and only shows how often the tag had been applied to the given object, rather than how many objects the tag had been applied to. We would have liked to show both, but it resulted in a display so cluttered that it was unusable.

Social navigation and presence through tags

We allow users to vote on and contribute tags to increase social awareness, social navigation, and engagement. Voting on tags is low cost and also invites consideration of the person who provided the tag (for instance, someone tagged an ancient game board "beer pong"). Figure 4 (right) shows the tagging interface. Votes take effect immediately and update the popularity meters, giving people immediate feedback that they contributed to the system. Users can also add tags using a text box with an auto-complete feature backed by tags already in the system, as suggested by [2].

We could have chosen other tools to support social interaction, such as guestbooks. However, tags have many advantages in a mobile, social system. Apart from being low-cost, people have a number of motivations for tagging [3]. And although lack of expertise can cause people to fear commenting on artwork [22], *steve.museum* shows that people are willing to contribute tags despite not talking about art in the way experts do [45]. The resulting folksonomy provides visitors with access points to the collection that would be missing with expert-only information—and is especially important in open storage collections, where visitors' tags may be the primary source

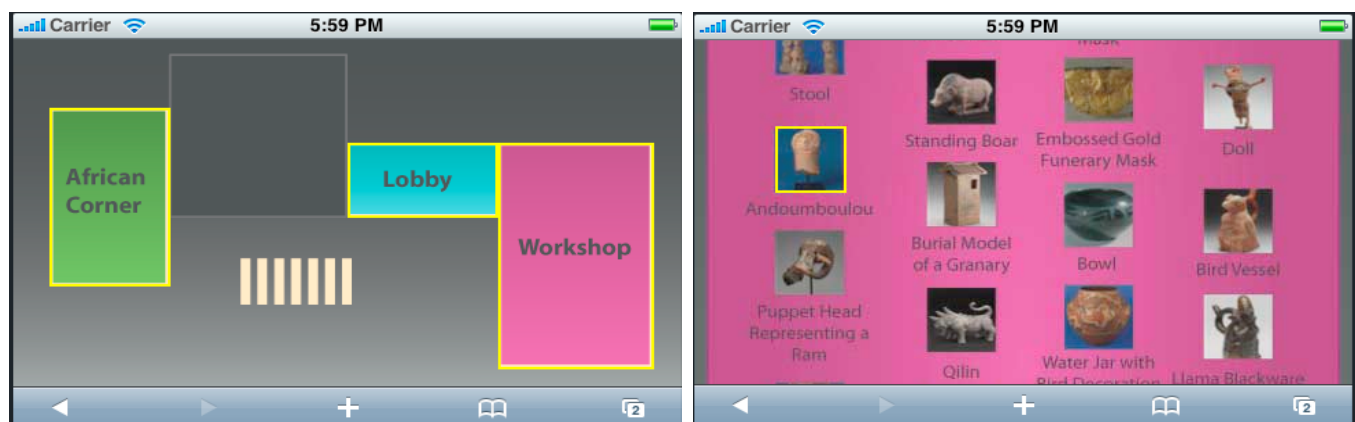


Figure 3. Maps in MobiTags. Left shows the three sub-collections. Right is the section view of the Workshop; the currently selected object (here, Andoumboulou), or set of objects with a given tag is highlighted. Selecting an object loads its details in portrait mode.

of information about objects. Finally, we hoped tagging objects would lead not just to changes in how people navigate through a space, but to a deeper understanding of the art and awareness of other people in the museum.

Spatial navigation and seamless transitions

A potential problem with mobile, social systems is that they can dissociate people from the physical space. This may interfere with navigation and distract from the physical world (in our context, the artwork). We took advantage of the orientation sensors on the iPod Touch to provide parallel, linked views of the collection. Portrait mode, shown in Figure 4, provides semantic and social information about an object, as well as a home screen (not pictured) that presents a list of tags commonly applied to objects. Figure 3 shows the map overview (left) and section view (right) that result from rotating the iPod sideways. From general pages such as the home screen, the map view provides an overview of the space; from an individual object, the map zooms to the section of the collection that contains the object. Users can zoom in and out in the map.

In either orientation, the iPod shows relevant information about the user's current location in the semantic space. If an object is selected, it is highlighted in section view. If a tag is selected, all the objects with that tag would be highlighted in section view, while in map view the number of objects with that tag would be shown in each section. Selecting an object in section view causes its details to load in the background in portrait mode. The correspondence between views in both directions is designed to ease transitions between spatial and semantic navigation.

EVALUATING MOBITAGS

We deployed MobiTags at the museum from August 4-15, 2008, recruiting from the population of museum patrons who visited during our period of testing each day. We gave participants an overview of MobiTags and started each person at a screen with the list of the 20 most commonly applied tags. Participants were asked to use the system however they chose and to stop when they were done.

We observed participants from a distance and took notes on how they interacted with the iPod and the art, as well as where they moved in the museum. MobiTags logged device use, including spatial elements such as opening and closing the map, semantic actions around choosing tags and objects, and social aspects of voting on and adding tags. After participants finished using the system, we conducted brief interviews and administered a questionnaire. Combining this qualitative and quantitative data enabled us to create a rich picture of how people used MobiTags.

RESULTS

A total of 23 museum patrons (15 female, 8 male; 11 aged 18-25, 5 aged 26-35, 2 aged 36-45, 3 older than 45, and 2 unknowns) participated. Of those, 16 agreed to participate in the post-interview and 22 completed the questionnaire.

Overview of MobiTags Usage

Excluding an outlier who used the tour for over an hour, the average duration of MobiTags use was 20 minutes, with a standard deviation of 7 minutes. People used MobiTags' navigation features a total of 1822 times. Again, leaving out a 205-event outlier, people averaged taking 70 actions on the device with a standard deviation of 33 actions. Table 1

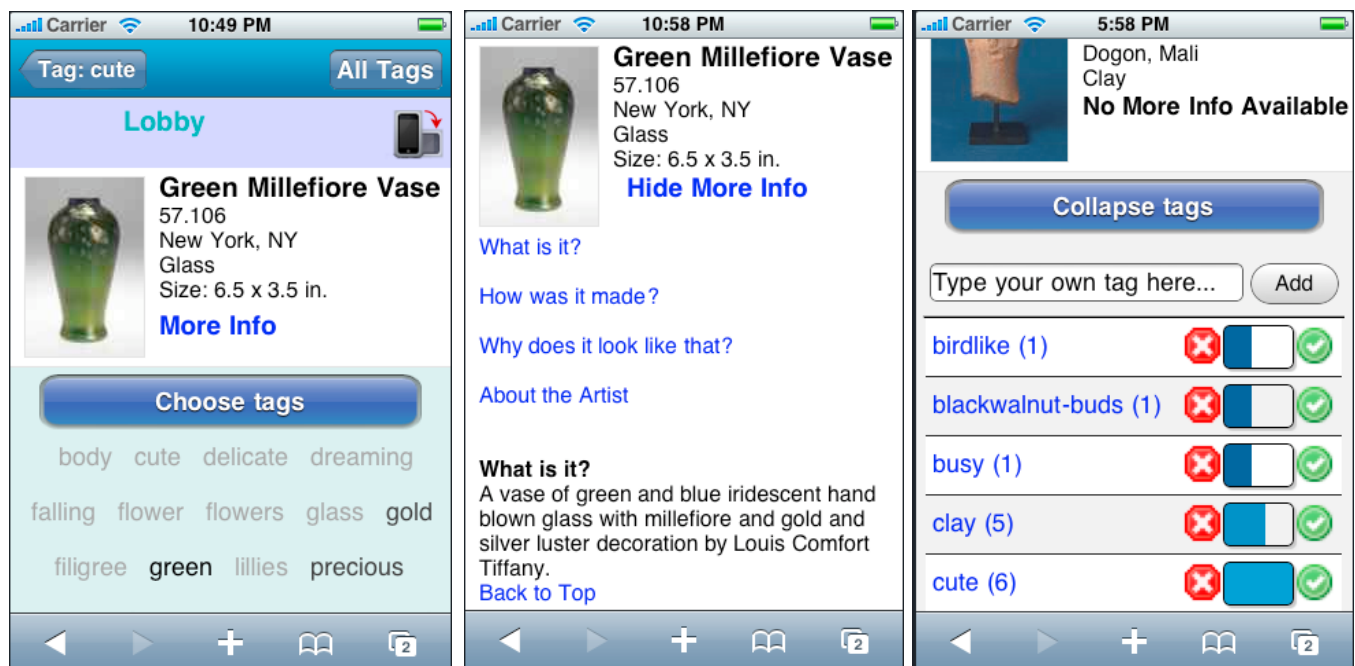


Figure 4. In portrait mode, the iPod Touch shows semantic information: an overview (left), expanded information on the item page (center), and the interface for exploring, adding, and voting on tags (right).

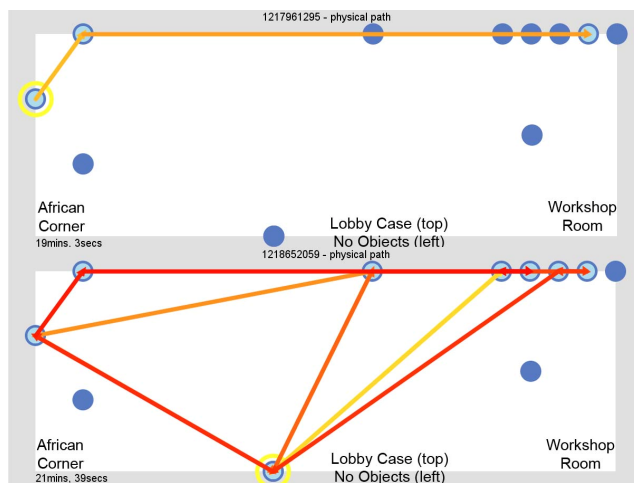


Figure 5. Representative examples of infrequent, linear motion and frequent, less linear motion through the museum.

gives an overview of how people used the navigation features in MobiTags. Each row presents a single feature, how often people used that feature, and the three actions they were most likely to take next.

We recorded an average of 9 locations per person. The distribution was bimodal: people tended to exhibit either high or low motion in the physical space. Figure 5 shows representative examples of people's low and high motion through the physical space on a stylized diagram of the space (compare to the map overview in Figure 3). Circles represent individual display cases in each area; the circle at the bottom represents not being near any display case.

Below, we report our main findings, again organized around the themes of semantic, social, and spatial navigation, and how they came together in use.

Semantic navigation: use of more information

People liked the idea of having the detailed object information available on the item page, and found the information easy to access and absorb at their own pace. Seven participants reported that having more information was helpful. Log data, however, showed that they did not actually access it as often as it was mentioned, only about twice on average per person (49 times total).

The relative lack of actual use might be because only 29 objects out of 51 had detailed information available, leading people to stop trying to access information—and leading four participants to want more objects to have information. (Though note that this is still more information than would likely be available in a typical open storage context.) People may also have valued knowing that depth was available even if they didn't access the information. In either case, providing information supported people's expectations of learning from museums [4,9,30].

Action	Total	Common next actions
Vote On Tag	401	Vote on tag (285); Collapse tags (35); Map Section (23)
Choose Item	297	Choose Tags (96); List Items w/Tag (41); Close Map (41)
List Items w/Tag	249	Choose Item (133); List All Tags (55); List Items w/Tag (30)
Choose Tags	151	Vote on Tag (94); Add Tag (22); List Items w/Tag (11)
Map Section	139	Choose Item (90); Close Map (15); List All Tags (11)
List All Tags	129	List Items w/Tag (72); List All Tags (14); Open Map (11)
Open Map	125	Close Map (59); Map Section (30); Choose Item (25)
Close Map	123	Open Map (26); Choose Tags (22); Choose Item (21)
Collapse Tags	50	Choose Tags (15); List Items w/Tag (11); Map Section (9)
More Info	49	Choose Tags (17); Map Section (14); List Items w/Tag (7)
Add Tag	48	Vote on Tag (20); Map Section (7); List Items w/Tag (6)
Index	36	Open Map (16); List Items w/Tag (15); Search Tags (2)
Search Tags	25	Search Tags (10); List Items w/Tag (9); List All Tags (5)

Table 1. How people used MobiTags' navigation features, with total use of each feature and the most common next actions.

Semantic aspects of tag use

People extensively used tags as a semantic navigation tool. They viewed the list of objects with a given tag 249 times and chose an item to view from that list 133 times. Six participants reported using tags to see relationships between exhibits that were not captured by the physical layout, such as looking at all the religious objects in the collection.

The constraints of the small screen and the power-law distribution of tag popularity (of 698 distinct tags, 502 were applied only once) both shaped people's use of the tags as a semantic navigation tool. Table 2 shows the top 20 tags that appeared in the "all tags" screen. These tags accounted for about 87% of all tag navigation events, suggesting that tags that were applied to relatively few objects provided little value for semantic navigation.

However, people also used the tags to form impressions of objects. In the summary tag cloud view for each object, they tended to notice darker tags (those applied more often) first, but they were also interested in less popular tags. Some participants reported that the tags helped them think about the art in new ways or notice things they had overlooked. Evaluative or uncommon tags often revealed a novel perspective about the art.



Figure 6. King Dedede and the bird pot tagged "Dedede". Coincidence... or is it? (Dedede image taken from Wikipedia.)

"It was very interesting to see how some of the things have been tagged that I haven't necessarily thought of. That was good." (Female, age 18-25)

Not all tags were useful for navigation or for forming impressions. Four participants, who voted some tags down that they found silly and unhelpful, suggested either a filtering system or a way to receive tags from more knowledgeable people. This is related to the *steve.museum* project's observation that lay and expert visitors use different vocabularies to describe objects [45]. Still, straightforward descriptive tags such as "ceramics" and "mask" served a purpose: sixteen participants said these descriptive tags were helpful in searching for objects.

Participants also added a number of new tags, about as often as they sought more content on an object (48 times). Motivations to add new tags varied: to help others, to gain personal benefit, and to make the semantic information on *MobiTags* more complete and interesting.

"Sometimes when you see the boring ones [objects], you are like, let's zazz it up a bit." (Male, 26-35)

Social navigation: feeling the presence of other visitors

Tags which connected one piece of art to another also served as ties to connect visitors. Twenty of the 23 participants reported feeling a sense of social presence through seeing others' tags. Although participants thought that descriptive tags were useful to search for art, they found that subjective tags (such as "beautiful" and "scary") made them feel connections to earlier visitors.

"It's more interesting to see the tags that are describing emotion, or something like that. It tells me a little more about the piece or about how someone felt about the piece." (M, 26-35)

"...that bird over there had [a tag] like 'Dedede', and I don't even know what that means, but I look at the bird and it seemed perfect for describing the bird. So it was actually kind of interesting because it was an interaction with someone else who made up a word and ... we kind of understand what they mean by that." (M, 26-35)

There is an interesting twist to the Dedede story. Although the participant believed someone had made up the word to describe the bird pot, the actual motive for the tag was based on the bird pot's resemblance to the Nintendo character "King Dedede" (Figure 6). If tags are just a tool for semantic navigation, this would be a problem. Here, however, it supported meaning-making and interpretative flexibility [6], a useful outcome around art.

Top 20	mask, black, small, face, detailed, shiny, wooden, ornate, red, smooth, wood, cute, gold, green, hair, unique, woman, pot, clay, round
Rare	alarm-clock, beads, charcoal, crocodile, fat, headdress, impractical, indistinct, Japan, Japanese, lavender, religious, story, swords, symmetrical, tan, top-heavy, tribal, ugly, wink

Table 2. The top 20 tags by number of objects, along with 20 rare tags that people voted on relatively frequently.

Relating semantic and social navigation

Semantic and social navigation came together when visitors voted on tags they agreed or disagreed with. Participants often opened the detailed view of an object's tags (151 times) and the most common activity on the device was to vote on a tag, which happened 401 times. Further, voting was often sequential: the most frequent activity after voting on a tag was to vote on another tag (285 times), sometimes going back and forth on voting the same tag up or down.

Participants used voting on tags to express their opinion on tags added by previous visitors, and to help future visitors navigate among the collection. It is interesting that people voted tags up four times as often as they voted tags down. The dominance of upvoting relative to downvoting behavior highlighted an important tension that might affect social voting systems more generally. Twelve participants were confused by some tags because they found them distracting. However, only four people actually voted others' tags down, which could mean that people refrain from downvoting because they felt pressure to respect others' opinions and/or to allow the system to reflect everyone's thought.

Spatial navigation: use of the map

Participants made extensive use of the map as a navigation tool. In total, they opened the map 125 times. About half the time (59/125) they then immediately closed the map, suggesting that they were orienting themselves. About 25% of the time, they zoomed in on a specific section, and 20% of the time they chose an item using the map. People also used individual sections of the map quite often, a total of 139 times; about 65% of the time their next action was to select or look at an item.

Participants thought that the map was useful as a general overview of the collection. The map was used to navigate, to orient, and to find a specific object's location in the museum. Although two participants used the map function very little, most of them combined the tag and map functions to different degrees in order to navigate.

Relating semantic and spatial navigation

People exhibited a number of strategies for interleaving spatial and semantic navigation. Three participants reported being willing to go wherever the device took them, moving freely through space to find objects they had chosen

through tag searches. They also used an object's tags to find related objects; 8 participants reported this was a common strategy, and log data shows this happened over 130 times.

Some participants used spatial considerations to instigate semantic navigation. Four reported using the map to find an object they had chosen in the physical space, or choosing objects from the section view of their current location. Spatial considerations also limited semantic navigation: if no objects with a chosen tag were nearby, people sometimes chose a different tag.

Looking at people's paths through both the physical space of the museum and the semantic space of items in MobiTags gives further insight into their diverse navigation strategies. We visualized these paths in virtual space analogously to the physical paths by defining "moving to a section of the museum" as choosing an item on the device.

Figure 7 shows the physical and virtual paths of a particular visitor who tended to look at items near their physical path. For some visitors, including this one, people's paths through both spaces were fairly similar; for others, the paths are quite different, as shown in Figure 8. To investigate these differences, we created these paired visualizations for each of the 23 participants and characterized their spatial and semantic navigation paths.

We first categorized each participant's motions through both physical and semantic space as either "linear" or "nonlinear". "Nonlinear" meant that people doubled back to a section of the collection they previously visited (e.g., they entered the African Corner or chose an item in it, moved to or chose an item in another part of the museum, and then returned to the African Corner).

People were more likely to navigate nonlinearly in the virtual space (11 of 23) than in the physical (6 of 23). This is not surprising, as spatial navigation imposes a higher cost than semantic navigation. Of the six participants who had nonlinear physical paths, five were among the ten people

who spent the most time using the tour. This suggests that extended semantic navigation affected people's spatial navigation, leading them to move in ways not implied by the physical layout of the museum. Nine participants said MobiTags made them move with more jumps or random patterns than they might otherwise:

"If I was walking around I would just go look at all the things in one room, then go to the next. Not look at everything people said was interesting." (F, 18-25)

Though semantic navigation made it easier for people to navigate to arbitrary parts of the collection, it had consequences for people's experience of the physical space. Seven participants were surprised to see that they spent more time on MobiTags than they thought, and four mentioned that it slowed them down in the museum.

"It made me slow down. Which was good, to stop and read about the various bits of information. It made me notice things that I perhaps otherwise wouldn't actually have...not necessarily things I'd looked up. But reading through it made me go oh, that's quite interesting as well." (F, 18-25)

People may have felt slowed down when their semantic and spatial navigation diverged. Nine participants had semantic paths that looked considerably different than their physical paths. That is, they were spending time in a "space" that did not correspond to their movement in the museum, and this likely changed how they experienced the physical space.

Technology versus art

As with many museum technologies, MobiTags faced the challenge of providing information while not distracting people from the art itself, a common problem [22,29,42,49]. This problem was especially acute for MobiTags because interactions such as searching for and voting on tags consume more attention than a typical audio tour. This led to criticism from some participants about having to balance looking at the artwork and the device. Including pictures of the art helps people re-orient when moving between the

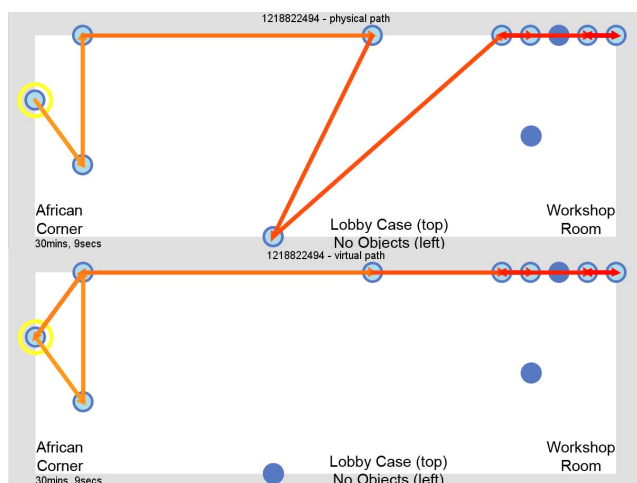


Figure 7. One person's navigation through the physical and semantic spaces. The two parallel each other closely.

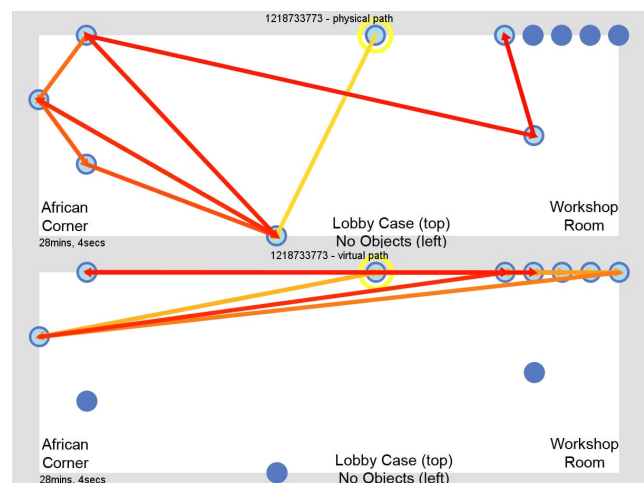


Figure 8. A person whose paths through the physical and semantic space were quite different.

spatial and the semantic [49], but explicitly invites people to focus on the device. A few visitors failed to physically visit all three art cases:

"I felt in some instances that I could just look at the picture and decide whether or not the tag was right without even having seen it for myself, which is NOT a cool thing." (F, 26-35)

Overall effects on experience

Despite these problems, people valued MobiTags. Over two thirds of participants rated their enjoyment of MobiTags as 4 or 5 on a five-point scale, and only two rated it below 3. People liked having detailed information about objects and being able to choose the information and objects they wanted to see using the semantic tools in MobiTags. They also liked using tags for both semantic and social purposes. This was not just about the technology: some participants stated that although they were initially disinclined to use the system due to being unfamiliar with the device, tags, and/or maps, as they learned how to use MobiTags they found it interesting and useful on a number of dimensions:

Interactivity. "I had an absolutely dreadful audio guide that took me around various places that I've been to, but nothing like [MobiTags]. That was very new. [...] This is very interactive which I like." (F, 18-25)

Control. "You have more options of moving around, because when you play it [audio] you can't really stop it so you're customizing your tour here." (F, 18-25); "I can choose what I want to do whereas a sort of a standard technological guide [like] a program book is one sided." (F, 18-25)

Social experience. "It becomes an experience of interacting with people who've seen it before" (M, 26-35); "A different way of appreciating it, different insights to the art, what different people see." (F, 36-45)

Interpretation. "I kind of like [the device] a little better [than a personal tour guide or an audio tour] because you can read it on your own so I feel it's a little more an active process than just walking by... You can kind of make your own interpretation of it through reading it." (M, 18-25)

In short, MobiTags provided effective social, semantic, and spatial support for navigation and experiencing museums compared to most other museum technologies.

DISCUSSION

We hope this work contributes to the conversation around designing mobile, social systems. It presents one of the first studies of how people consume tags, along with a novel, effective interface for allowing people to use and contribute tags in a small-screen format. The technique of visualizing motion through physical and virtual spaces may be useful to designers. Finally, our work shows that a system like MobiTags has real promise for supporting open storage exhibits in museums. Our experience also suggests several design implications for mobile, social systems in general.

Support the many uses of tags. Tags are not just about semantic navigation and categorization [3, 47]. People used

tags not just to select objects, but to think about them. Tags also called to mind the presence and experience of other people, and provided a way (though voting) to collaboratively understand the collection. People wanted different tags at different times, and wanted to contribute tags for many reasons: expressing themselves, improving the system, and helping others navigate. And, as the "Dedede" story indicates, even unintended uses of tags provided value to visitors in this context.

Designers should support these multiple ways to use tags and not necessarily privilege informational aspects of tag use. When applying or voting on a tag, seeing the other items that tag applies to and the people who applied them would help to create connections between people and things. Allowing people to design tag displays for an object may also be useful, based on the popularity of ManyEyes' [48] artistic Wordle tag clouds and people's desire to make—and see others'—imprints on the museum [7].

Manage the tension between device and world. Adding technology to current practices changes people's experiences. Some MobiTags users felt a disconnect between the semantic and the physical worlds, aligning with other studies of museum technologies [22,29,42,49] and navigation technologies more generally [34]. Close correspondence between representations of space and the actual space should help, as should tight integration of navigation modes.

Devices should also explicitly direct people's attention to the world. MobiTags might include explicit instructions to attend to the artwork when presenting "more information": "Look at the pot's texture..." More ambitious designs could place semantic information in the world, using screens embedded in public spaces, projecting images, or other augmented reality techniques to provide the information in a way that naturally invites attention to the art. Such techniques could also support new, interactive artforms that tightly combine existing works with visitors' perceptions.

Provide tight, but flexible, coupling of navigation modes. MobiTags' tight relationships between spatial and semantic features supported multiple navigation strategies. With few restrictions on how to move between these modes, MobiTags allowed people to develop strategies that suited them personally, including strategies we did not anticipate. The ties could be even stronger: three participants suggested that showing tags in the map view would encourage them to move more in the physical space. Displaying others' traces in the semantic and spatial representations of the world would also more tightly integrate social navigation with the other modes [7].

Support social presence and manage social pressure. People felt a strong sense of the presence of others through their tags despite an almost complete lack of social indicators in the interface. Other work has outlined designs with explicit representations of other visitors that help

people feel social presence [7,14]. Here, this feeling of presence arose spontaneously; further, people liked it.

With social presence came social pressure. Unlike social news aggregators such as digg, where people often down-vote content they dislike, in MobiTags many people were reluctant to down-vote others' tags because they wanted to ensure that all opinions were heard. This might negatively affect the utility of tags for semantic navigation. One answer would be to personalize the social presence of each visitor's experience. The system might highlight tags contributed by people a given visitor agrees with, or make the people who contributed the tags first-class elements that visitors could then choose to listen to or ignore.

CONCLUSION

This work could be extended in a number of directions. How do people's navigation patterns with MobiTags compare to patterns generated by people who went through the collections without it and to patterns generated by people who used MobiTags without moving through the museum?¹ Do people change their navigation strategies during the course of their tour, changing from physical-first to semantic-first or vice versa, and how might that affect MobiTags' design? Would it work in larger contexts like a campus or city? How would people react as the size of the space grows and the density of social activity drops? Would they be willing to tag places as ardently as they tagged art? These are all open questions that could inform the design of mobile, social systems.

It is important to address these questions. As the infrastructure for ubiquitous computing continues to grow, and people's expectations increase around using social data on the go, issues around designing mobile, social systems will become increasingly important for the CHI and CSCW communities to consider. We believe that understanding how people interleave social, semantic, and spatial navigation will lead to better designs and outcomes for the people who use them. Our work here provides designs and analysis tools that we hope will help other designers and researchers attack these issues with gusto.

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¹ We had hoped to do this here, but in a testament to Murphy's Law, the museum closed the exhibit area for the second half of August to add a new installation.

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