Addressing Map Interface Usability: Learning from the Lakeshore Nature Preserve Interactive Map

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These are exciting days for cartography, as emerging technologies have greatly expanded the possibilities of online, interactive maps. These developments, however, now require cartographers to think about issues that only a few years ago fell solely in the domains of human-computer interaction (HCI) and web design. Further, given how fast these changes have occurred, there are few tried-and-true guidelines for building digital maps. This paper reports on the design, development, and evaluation of the University of Wisconsin-Madison Lakeshore Nature Preserve Interactive Map (www.lakeshorepreserve.wisc.edu) and outlines many of the insights gleaned from this process. The purpose of this article is to strengthen the important bridge between cartography and usability evaluation (i.e., how we study the way in which users interact with their maps and how we measure the success of those interactions) so that the efforts of a team of developers and stakeholders can be coordinated in a way that ensures the map works equally well for all potential end users. We outline the relative merits of two broad categories of evaluation techniques, arguing that there is no single, correct evaluation technique appropriate for all evaluation scenarios, and then detail the specific strategy adopted for evaluation of the Lakeshore Nature Preserve Interactive Map. We conclude by offering four design guidelines for online, interactive maps revealed during the evaluation of the Lakeshore Nature Preserve Interactive Map: two positive strategies we recommend for consideration when designing map interfaces (inclusion of cascading interface complexity and provision of map browsing flexibility) and two pitfalls we caution to avoid (minimalist design of interface widgets and employment of a lorem ipsum map during development).

Keywords: map interaction, interface design, usability evaluation, cascading information-to-interface ratio, map browsing flexibility, ipsum lorem map, Lakeshore Nature Preserve Interactive Map

INTRODUCTION

The pervasiveness and rapid maturation of personal computing devices combined with decentralized, network-based, and wirelessly accessible geographic information are creating new opportunities for cartographers. These developments are part of larger, far-reaching changes in how and by whom geographic data is *generated* (e.g., volunteered geographic data), where and how it is *accessed* (e.g., on a cell phone, or on large multi-touch screens), where and how the computing work is *performed* (perhaps as a collection of disparate Web services that are connected via a thin client running locally), and how a map reader *interacts* with the maps and how we measure the success of a map-use session. Given unprecedented (and unregulated) progress and diversification of these areas in just the

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past year or two (with new map innovations occurring almost weekly now), there is feeling among those of us who develop online, interactive maps that we are trying to build the plane while it's flying. Worse, we're not even sure where the plane is headed or what tasks it may be asked to perform in the future. While these are exciting days for interactive and web-based mapping, mapmakers are now faced with new challenges that fall far beyond the traditional boundaries of cartography and that were previously addressed by the domains of human-computer interaction (HCI) and web design.

It is the final development—how users interact with maps and how we can measure the success of those interactions—that is the focus of this article. Central to this development is the concept of *usability,* an area of research concerned with improving both the usefulness of a set of interface tools for completing a map-based task and the ease of use of the map interface itself. The challenge of usability is to tap into established map interface conventions in order to improve the transparency of the interface, yet to remain innovative and creative in design and to avoid the propagation of inefficient interface solutions. These are still pioneering days for online, interactive mapmaking and we should be exploring new ideas, yet from a usability perspective there are obvious advantages to having some level of consensus about user-map interactions so that people do not have to learn entirely new skills for each map they encounter (much as desktop software has coalesced around similar keyboard shortcuts, e.g., copy, print, save).

"The challenge of usability is to tap into established map interface conventions in order to improve the transparency of the interface, yet to remain innovative and creative in design and to avoid the propagation of inefficient interface solutions."

Usability evaluationUsability evaluation is addressed using the case study development process of the Lakeshore Nature Preserve Interactive Map (www.lakeshorepreserve.wisc.edu) by the University of Wisconsin-Madison Cartography Laboratory. The online, interactive map, built entirely in the Flash authoring environment, marks the most significant effort to date by the University to establish an online presence for the Preserve, enhancing public appeal and legitimizing the often-contested boundary demarcations. Figure 1 provides an overview image of the map interface. The Lakeshore Nature Preserve Interactive Map follows the strategy of other exhibit-like websites such as the Theban Mapping Project (http://www.thebanmappingproject.com) and Monticello Explorer (http://explorer.monticello.org), using a central map to organize a variety of spatial and historical themes about a place or region. The purpose of this class of maps is not simply to provide a viewer for disjoint data layers overlapping in a particular spatial extent, as is the case for many of the mash-up mapping websites currently available on the Internet, but instead to tell a series of detailed, interwoven geographic stories via maps that are necessary for complete understanding of the complex characteristics and discourses concerning a given place or region.

The paper begins with a review of usability evaluation, drawing heavily from the literatures of HCI and web design. Following a brief description of the Lakeshore Nature Preserve Interactive Map, a synopsis of the usability evaluation strategy is provided, detailing both the informal evaluation conducted during development and the structured verbal protocol analysis (VPA) administered on the beta release. The paper concludes with the enumeration of several design guidelines for developing online, interactive map applications not currently offered in the cartographic literature. This set of guidelines is by no means implied to be exhaustive, nor appropriate for usage for all applications; rather, these guidelines summarize our experiences from the Lakeshore Nature Preserve Interactive Map project that may be of use for future cartographers when preparing for similar undertakings.

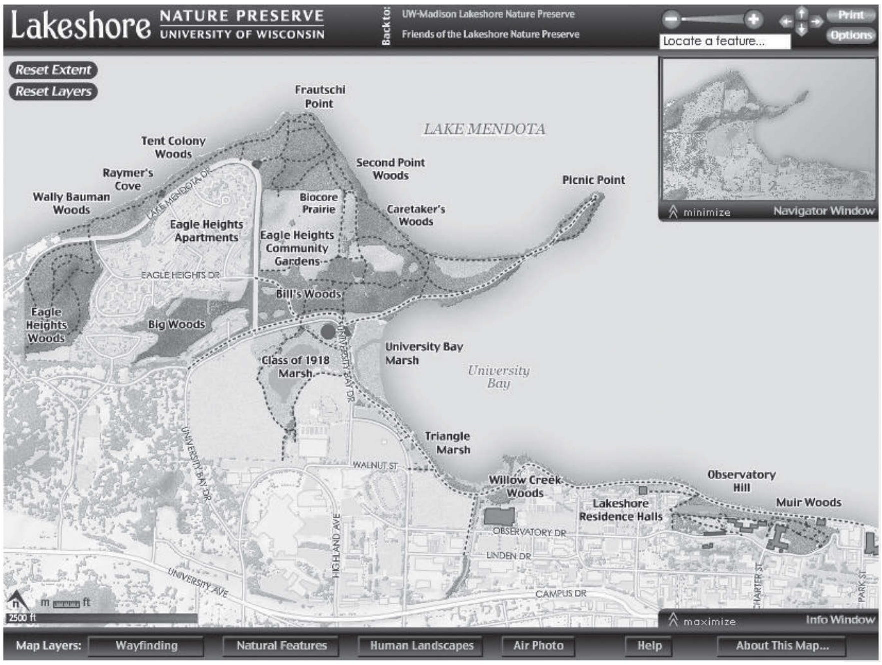

Figure 1. The Lakeshore Nature Preserve Interactive Map (www.lakeshorepreserve.wisc.edu). (see page 90 for color version)

A Primer on Usability Evaluation

Understanding the user's needs and expectations of a map application is essential for effective and transparent interface design (Cooper and Reimann 2003). Consideration of these needs and expectations during development has been termed *user-centered design* (Norman 2002) and relies heavily upon an iterative process of interface evaluation at all steps of development (Krug 2000). More broadly, evaluation is not only a way to determine the success of a single application, but it is also a necessary step in the application of theory, producing the three-part validation system of theory, applications, and evaluation for interactive and web-based cartography (Figure 2). User-centered design and evaluation specific to usability testing borrow heavily from the disciplines of human-computer interaction (HCI) and web design, although there is a quickly growing body of research on usability within GIScience, particularly for geovisualization applications (see Slocum et al. 2003, Fuhrmann et al. 2005, Harrower and Sheesley 2005, and Robinson et al. 2005, for example).

The literature discriminates between user testing and controlled experimentation as the two modes for conducting interface evaluation (Haug et al. 2001, Plaisant 2004, Saraiya et al. 2004). As Plaisant (2004, 2) writes, "Usability testing and controlled experiments remain the backbone of evaluation." This research defines the term *evaluation* to describe any implementation of usability testing or controlled experimentation that "is about understanding, stating, and serving user needs" (Greinstein et al. 2003, 606). *Controlled experimentation* follows the traditional positivist model of science, where a task is simplified to allow for the isolation and control of independent variables and the quantitative measurement of dependent variables (Kerlinger and Lee 2000). The results of controlled experiments are generalizable to any situation with similar control conditions and repeatable in any location, at any time, and by any investigator (Castree 2005). In order to achieve generalizability and repeatability,

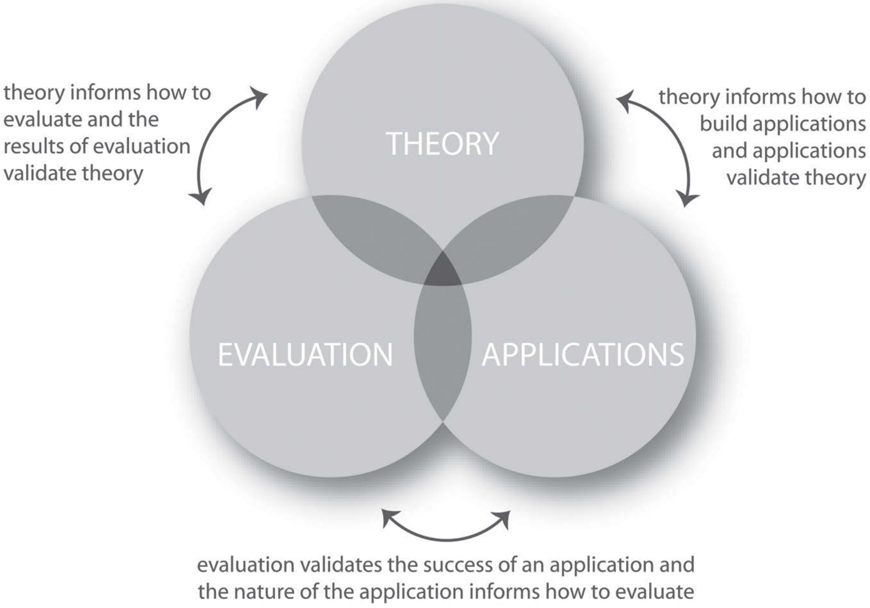

Figure 2. The three-part validation system of theory, applications, and evaluation for interactive and web-based cartography. Evaluation serves the dual purpose of validating the general theory-of-use described in the literature and the success of a particular application.

such controlled experimentation requires an extremely large sample size and testing in an often artificial environment. In contrast, *usability testing* (also referred to as usability assessment, usability inspection, or user testing) requires a much smaller sample size, typically between three to ten participants (Shneiderman and Plaisant 2006) and relies on the collection of qualitative data in a realistic, perhaps even real-world, setting for the purpose of improving a single application (Krug 2000). There is growing consensus that this second type of evaluation is superior to the first, with Shneiderman and Plaisant (2006) arguing that the transition to the study of a small number of individuals in greater depth reflects the broader transition to a post-positivist model of science.

When comparing different descriptions of usability testing and controlled experimentation, it becomes clear that there is no clear dividing line between the two methodologies; rather, particular methods fall along a continuum between strictly controlled experimentation and in-depth usability testing. Figure 3 illustrates this continuum and, for reference, positions along it many commonly used evaluation methods. The antipodes of the continuum hold several opposing characteristics that are useful for placement of methods along the continuum. First, this continuum represents the transition from quantitative methods, designed to generate summary statistics concerning the influence of an independent variable on the usability of an application, to qualitative methods, designed to collect detailed, personalized accounts of user experience with the interface. It is important to note that several of the methods along the center of the continuum can generate both quantitative and qualitative data. Second, the continuum represents a transition from a large sample size, possibly in the hundreds or thousands, to a sample as small as perhaps only one individual (e.g., Robinson et al. 2005). Small sample sizes are appropriate for usability testing due to the diminishing returns provided by additional subjects when looking for fatal interface errors and the budget limitations of an iterative approach to evaluation (Krug 2000). Third, the continuum

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portrays a movement from a detached and hidden investigator to one that is salient and directly engaged with the participants in their natural environment. Fourth, the continuum illustrates the shift in the research goal from *universal usability* (Plaisant 2004), or generalizable design guidelines applicable to all mapping projects, to one focused solely upon revision of a single application. Results from usability testing can still be used to inform design decisions on other projects, but they cannot do so with the same degree of predictability awarded controlled experimentation.

Finally, the continuum represents a shift from summative evaluation to formative evaluation (Gabbard et al. 1999, Robinson et al. 2005). The purpose of *summative evaluation* is to provide an overall ranking on aspects of usability after construction is completed, allowing for direct comparison with similar applications (see Kobsa 2001, for example). Examples of summative evaluation on interface workload include the NASA TLX (Task Load Index) Worksheet (Hart and Staveland 1988) and GOMS (Goals, Operators, Methods, Selection rules) (Card et al. 1983). In contrast, the purpose of *formative evaluation* is to ensure that interface prototypes are meeting user needs and expectations. In formative evaluation, both the usability (i.e., how easy it is to use) and the utility (i.e., how useful is it) are evaluated (Grinstein et al. 2003). Formative evaluation is administered multiple times throughout the development process, improving the prototype iteratively (Krug 2000, Fuhrmann et al. 2005). As Robinson et al. (2005, 253) remark, "The evaluative effort must mirror the development effort, in that it should be constant throughout the progress of the project." Slocum et al. (2003) offer a framework for an iterative design process, illustrating the importance of evaluation at each stage of development.

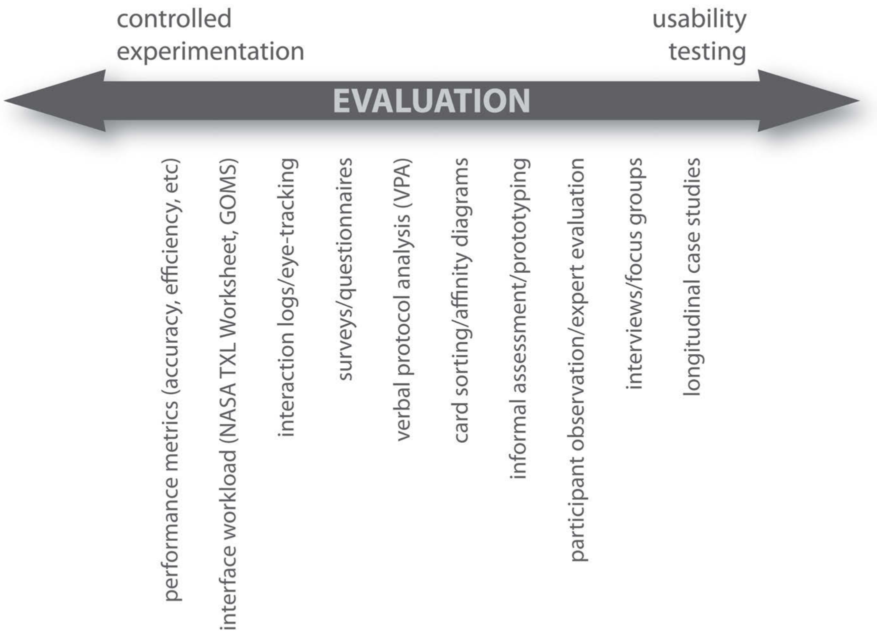

Figure 3. A continuum of evaluation methods, with strictly controlled experimentation and in-depth usability testing forming the antipodes. The positions of the more common evaluation methods are approximated along the continuum for reference. The positioning of these methods may change slightly depending on the specific binary used for ordering (quantitative versus qualitative, large versus small sample size, hidden versus salient investigator, universal usability versus improvement of a single application, and summative versus formative evaluation).

Usability Evaluation of the Lakeshore Nature Preserve Interactive Map

Description of the Lakeshore Nature Preserve Interactive Map

The University of Wisconsin-Madison Lakeshore Nature Preserve is a 300-acre continuous stretch of land along Lake Mendota, forming nearly one-third of the total campus area. The Preserve is the amalgamation of multiple donations from private landowners to the university over the past 150 years and is comprised of a mosaic of forest, prairie, and wetland ecosystems. The vision of the Lakeshore Nature Preserve Interactive Map was to offer multiple readings of the Preserve's physical and cultural landscape through various map layers. Each map layer provides a spatial overview of the many individual features important to a particular reading of the Preserve. The map interface acts as a catalogue for all of the spatial and attribute content about the Lakeshore Nature Preserve, allowing users to first see only several attributes of each map feature instance (its location in the Preserve and a label) and then request additional information if desired.

Navigation begins with selection of a map feature displayed on the map or with input of a feature name in the search box. After selecting a feature, the map user receives additional information about the theme and how it applies to the selected instance. This additional information, in the form of text, photographs, and diagrams, is populated in the information window along the right side of the application. From the information window, the user can then jump out of the map interface to the main website for a complete account of the selected feature. Figure 4 illustrates the navigation of the map interface during the browsing of content with a focus of providing more detail as the user drills down to a feature of interest. This navigation design permits the user to quickly filter out a vast majority of the available information, following Shneiderman's (1996, 337) mantra of "overview first, zoom and filter, then details-on-demand." Such design allows the user to "get lost in the content" and provides a new reading of the Preserve, and therefore a different experience, each time the user visits the website.

The Development Process and Informal Assessment

Evaluation for the Lakeshore Nature Preserve Interactive Map was conducted in two stages: informal assessment iteratively throughout the development process and a verbal protocol analysis (VPA) on the beta release of the application. Informal assessment occurs when a small group of stakeholders provide input on unpolished prototypes and offer comments, questions, and design ideas for their improvement (Robinson et al. 2005). Typically, the application developers conduct the informal assessment themselves, coupling each development step with an evaluation step, although project supervisors, outside consultants, and important end users may also be asked to participate in this formative evaluation. Teams responsible for the development process and informal assessment may be separated completely in large-scale, well-funded projects. Informal assessment is unstructured and often conducted in a brainstorming meeting or via email. The goal of informal assessment is not to provide detailed usability analysis at regular intervals during development for tracking the improvement of a summative usability metric, but rather to ensure that prototypes are following the original vision, to gain valuable input from stakeholders at all stages of design, and to avoid the obvious "head slappers" that could become fatal to the map if left unchecked (Krug 2000).

Most of the formative evaluation for the Lakeshore Nature Preserve Interactive Map occurred during the informal assessment stage. Stake-

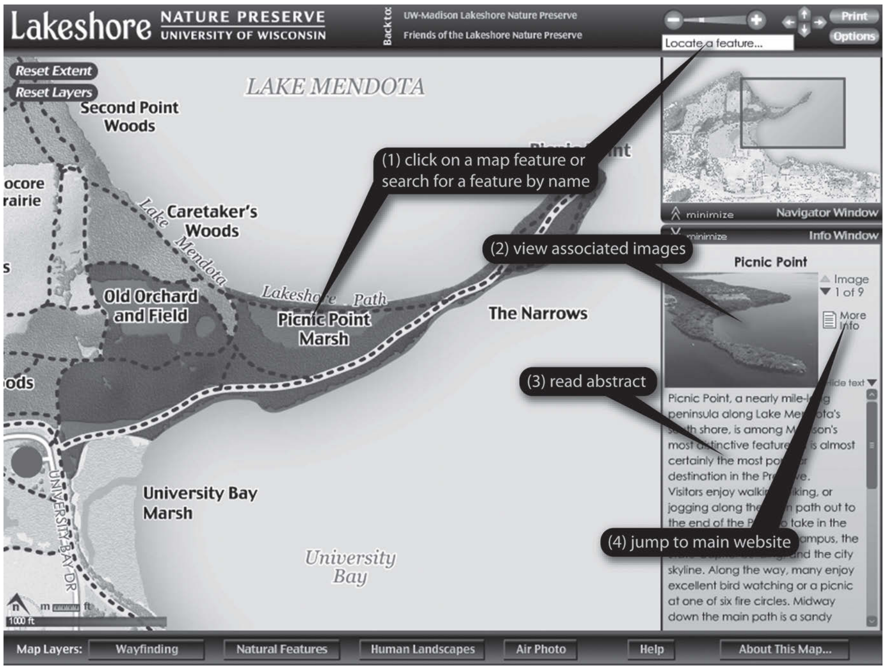

Figure 4. Navigation for the map interface, following Shneiderman's (1996, 337) "overview first, zoom and filter, then details-on-demand" mantra. (see page 91 for color version)

holders for informal assessment of the interactive map included the team of developers (responsible for initial development, evaluation, and revision), a group of supervisors, and an important set of end users involved in maintenance of and fundraising for the Lakeshore Nature Preserve. Meetings were held on a bimonthly basis, with smaller subgroup meetings taking place when needed. While the face-to-face meetings were used to clarify feedback and solidify future development directions, much of the informal assessment concerning specific map features or interface tools took place via email between bimonthly meetings. An online collaborative environment called DocuShare (http://docushare.edutech.org) was used to share and store documents during the informal evaluation, although actual communication via DocuShare was infrequent. Initial informal assessment focused upon determining user needs and identifying the list of core functionality for the application. It is reported in the literature that allocating ample time and resources for finalizing a carefully thought-through feature list is essential for avoiding *feature creep*, the requesting of additional features from the client related to working features that are available, and *feature loops*, features that require the development of additional, unforeseen features (37signals 2006). Central to this process was the "activity of getting to know the characteristics of people who will later use the software" (Henry 1998, 250). Materializing from the first several bimonthly meetings was a series of documents itemizing the features necessary for completing core user tasks, an estimation of the difficulty in implementing each feature, and a rough timeline for completion of these features. Amendments or clarifying descriptions of the map layers and interactivity included in the feature list were circulated through email.

After solidification of a feature list, interface mockups were prepared for informal commenting and revision. Initial interface mockups of interface widgets and layouts were generated using pen and paper. The *paper sketch* approach allows for immediate and rapid prototyping, providing a means for stakeholders to externalize their conceptualizations on how par-

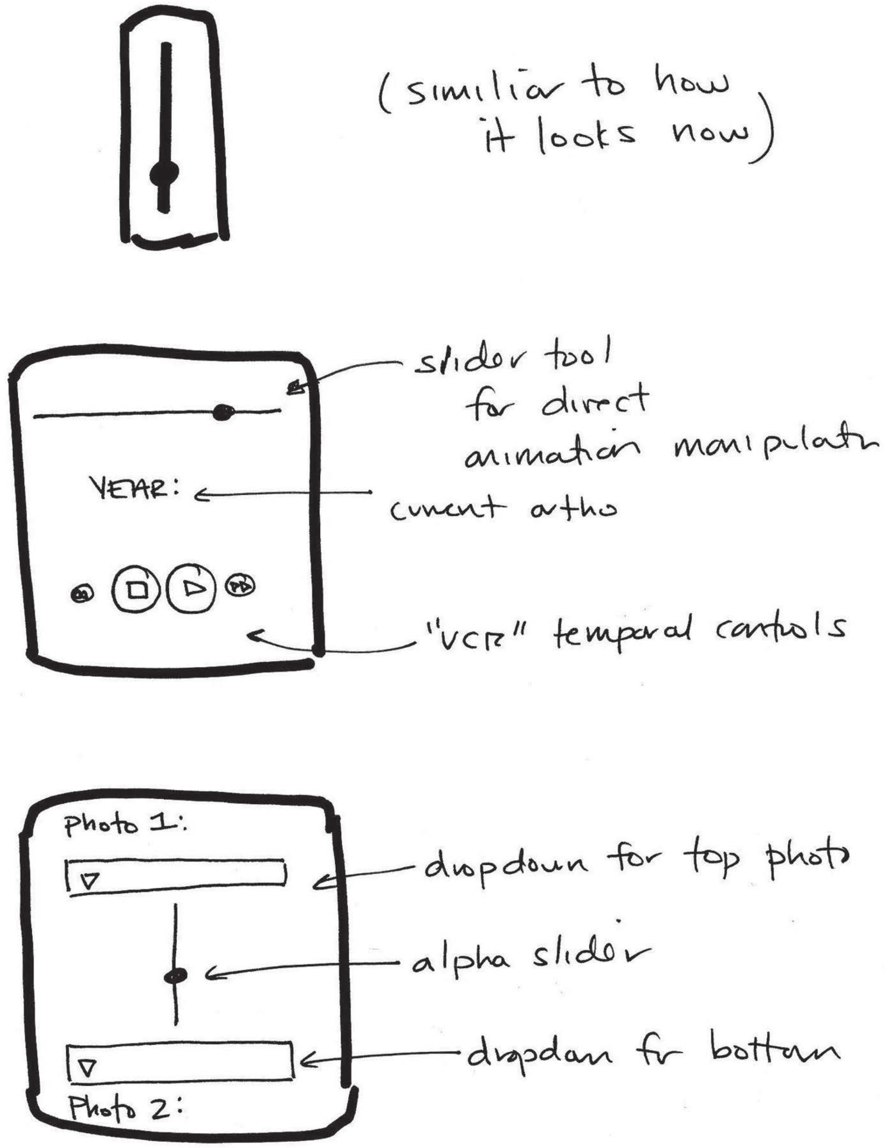

Figure 5. Paper sketch mockups for the air photo interface widgets that were circulated during the informal assessment stage. The top image shows a mockup for the transparency slider, the middle image shows a mockup for the historical orthophoto animation controls, and the bottom image shows a mockup for the analytical comparison tool.

ticular features should look and function without requiring any familiarity with graphic design programs (37signals 2006). Figure 5 shows several paper sketch designs for the air photo interface with descriptions of how the components function, and Figure 6 shows a paper sketch positioning these widgets in the application layout. During the bimonthly meetings, copies of the paper sketch mockups were distributed to everyone in attendance to allow for direct annotation when explaining design revisions and were collected when concluding the meeting. Once design ideas were formalized, the paper sketches were recreated using the graphic design program Adobe Illustrator and then exported to Flash for insertion into the application. A primary function of the email communication between bimonthly meetings was to relay annotated or corrected mockups discussed during the meetings. Figure 7 portrays the revisions to the future vegetation layer stemming from one such email thread.

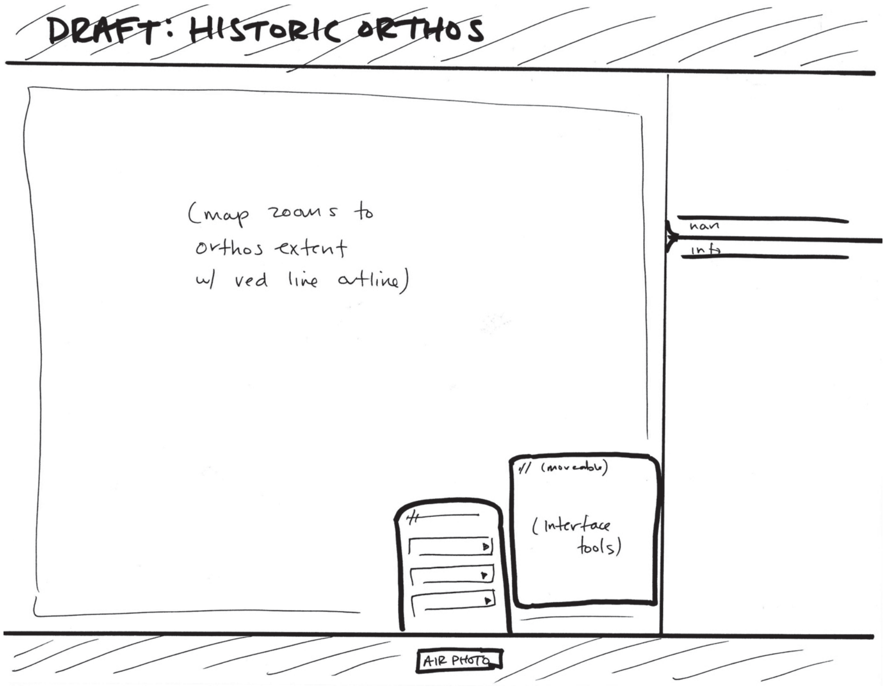

Figure 6. A paper sketch mockup showing the positioning of the air photo interface widgets in the larger application layer.

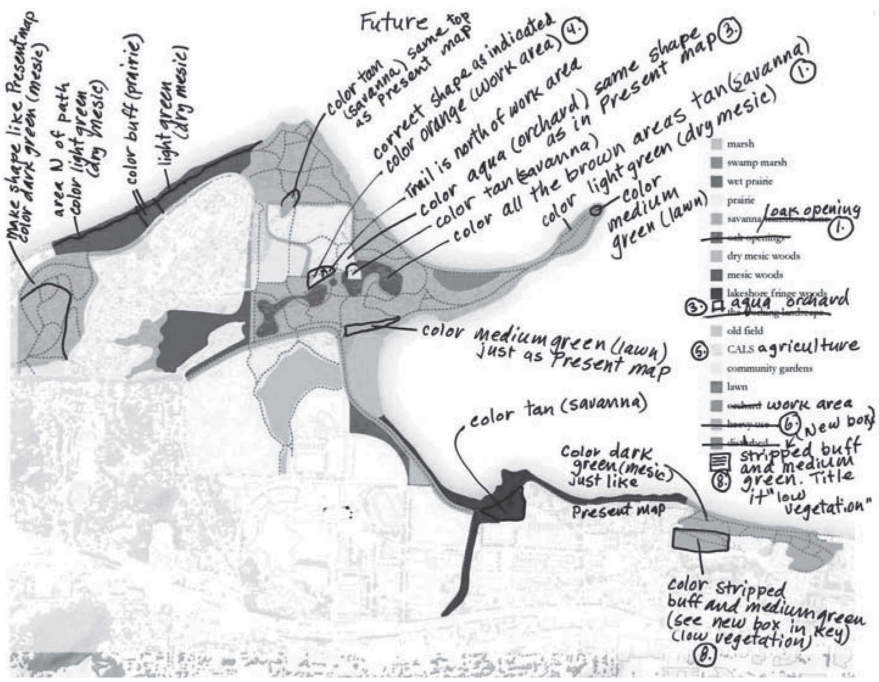

Figure 7. An annotated mockup circulated in an informal assessment email showing revisions and comments to the future vegetation layer. (see page 92 for color version)

Once development begins, feedback is received through a series of application releases. There are two release stages prior to the full product release: the alpha stage (composed of numerous pre-alpha and alpha releases) and the beta stage (and associated beta releases) (van der Hoek et al. 1997). Features are added to the application during the alpha stage of development and are debugged and polished during the beta stage of development. *Pre-alpha releases* of the application are those that are not feature complete, but offer an initial implementation of a particular functionality. Prototype versions that include the full feature set, but are unstable and untested, are termed the *alpha releases*. Generally, pre-alpha and alpha releases are closed versions of the application, viewable for evaluation only to the group of stakeholders, while the *beta releases* are opened for evaluation by a broader group of end users in real-world settings. This software release cycle allows for continued usability evaluation from the beginning of development through product release.

The final wave of informal assessment was upon pre-alpha and alpha releases of the application. For the Lakeshore Preserve Interactive Map, pre-alpha releases were demonstrated in the bimonthly meetings for feedback and circulated privately via email to the group of stakeholders when available. In sum, a total of sixty-five pre-alpha and alpha releases were evaluated either internally by the developers or by the entire group of stakeholders. During informal assessment of the pre-alpha and alpha releases, a running list of necessary revisions was maintained to document both usability issues and programming bugs as feedback was attained. The revision database logged the date the problem was identified, the date the problem was fixed, the person who identified the problem, a description of the problem, the person who fixed the problem, and a description of the solution. Table 1 displays several examples from the revision database. We continued to maintain this revision database during the beta releases and even after the product release, causing the developers to spend one week on revisions and updates approximately four months after the product release.

Verbal Protocol Analysis

Formal evaluation was completed on the beta release of the interactive map using verbal protocol analysis (VPA). VPA, also called talk aloud or simply protocol analysis, is a method for determining knowledge bases and problem solving strategies of users by asking them to speak aloud as they complete pre-determined tasks with the interface and is a common method for usability evaluation (Ericsson and Simon 1993, McGuinness 1994, Howard and MacEachren 1996, Haug et al. 2001, Saraiya et al. 2004, Fuhrmann et al. 2005, Robinson et al. 2005). VPA is triumphed as a method for moving beyond the recording of interaction outcomes, as with interaction logging, and instead generates data that describes the cognitive process itself (Ericsson and Simon 1993). Although VPA may be used for cognitive testing to examine how previous experiences and mental schemata are employed to solve complex problems (Howard and MacEachren 1996), VPA is also valuable for allowing "participants [to] subjectively comment on the prototype, [supporting] the identification of flaws and errors in the user interface" (Fuhrmann et al. 2005, 562).

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During VPA, participants are given a series of tasks to complete and are asked to describe what they are thinking as they attempt to solve them. Reflection from the user on what they are trying to accomplish provides insight into the expectations of the application (Robinson et al. 2005), allowing for recognition of widgets that are transparent and those that are not. Transparent interfaces allow users to focus upon the task at hand, rather than on learning how to manipulate the provided widgets correctly (Cooper and Reimann 2003). This difference in cognitive focus between the actual task and interface manipulation should be evident during VPA, highlighting which feature implementations are inefficient or unclear.

Eight subjects were recruited for participation in the VPA on a beta release of the map. The participants were purposefully selected to reflect

Date Added	Logged By	Date Fixed	Fixed by	Description	Solution
8/14	Mark	8/25	Andy	The larger images need to load in their own html window, outside of Flash, to speed their delivery.	Added getURL script
8/16	Bill	8/16	Rob	The eye icon needs to be changed to the words "on/off" to remove ambiguity.	Graphics adjusted
8/18	Mark	8/21	Rob	The user needs to be able to reset the layers and the view extent separately.	Added two interface buttons called "Reset Layers" and "Reset Extent"
8/18	Rob	8/25	Andy	Include tool tips to reduce the ambiquity of small interface widgets by adding textual instructions for use.	Tool tip system added for all interface widgets
8/21	Cathy	8/21	Rob	Need the ability to see both legends when using the analytical comparison tool.	The legend now comes up in the top left corner after a new polygon layer is selected in the dropdown menu.
8/21	Bill	8/21	Rob	There is an error in the position of Edward Young House. A document in the email reflects its appropriate position.	Repositioned accordingly.

Table 1. Several sample entries in the revision database.

the broad intended audience of the map, ranging greatly in age (15-83) and technical expertise. The VPA was also conducted in the subject's natural setting, providing evaluation on multiple operating systems, internet browsers, and screen resolutions. None of the subjects had any previous interaction with the interactive map or any part in the informal assessment, although all subjects were familiar with the Lakeshore Nature Preserve. The VPA began by allowing the participants several minutes to get comfortable with the map, encouraging them to explore core features without any direction from the investigator. After the participants reported feeling acclimated to the interface, they were given a series of tasks to complete using the map and asked to articulate what they were thinking as they worked through each task. The complete VPA protocol is provided in Table 2. Completion of the tasks required participants to interact with both simple and complex widgets, representing the full range of task difficulty associated with the application. The facilitators asked follow-up questions related to the tasks when the participants had difficulty verbalizing their thoughts or when they completed the tasks with unusual or

Task #	Task
Opening	Just explore the map for a few moments on your own to get a feel for it.
#1	Click on Picnic Point on the map. How many children are in the 5th photo about Picnic Point?
#2	What is the soil type at the eastern end of the Howard Temin Lakeshore Path (near Science Hall and the Union)?
#3	Change the scale of the map (zoom in or out).
#4	Using the search engine to answer this (it says "Locate a Feature"), how many fire circles are there at Picnic Point?
#5	Reset the map (make it look like it did when you arrived).
#6	Turn-on the 2004 air photo (make it visible).
#7	Click on Raymer's Cove on the map to zoom into it. Without changing the scale of the map, recenter on Willow Beach.
#8	Within the "Wayfinding" menu, turn-on (make visible) all of the visitor amenity features (phones, benches, etc.).
#9	What year did the Blackhawk Lodge close?
Cognitive Interview	OK, let's talk! Any general comments? Concerns? Ideas?

Table 2. The VPA protocol.

unexpected solutions. The number of tasks in the protocol was limited to ensure that the testing session was less than thirty minutes in length.

The usability assessment concluded with a *cognitive interview*, a practice similar to debriefing (McGuinness and Ross 1995). The cognitive interview allows the participant to discuss his or her experience after the completion of all tasks, allowing the user to share more general comments concerning multiple tasks or specific suggestions not mentioned during the VPA. The cognitive interview was unscripted and optional for the participant. Howard and MacEachren claim that the use of a cognitive interview is an effective approach to usability assessment, "perhaps especially when combined with protocol analysis" (1996, 17). Results from the VPA and cognitive interviews were then analyzed by the developers, informing a final round of revisions to the application. Following Krug (2000), only legitimate interface problems were corrected following the VPA; suggestions for additional features or major reworkings of current features were not undertaken during the final stage of development. The following section summarizes four of the larger design issues revealed by the VPA.

Discussion – Design Guidelines for Usable Online, Interactive Maps

Providing a Cascading Information-to-Interface Ratio

One objective of the project was to develop a map interface that would equally attract new visitors to the Preserve, educate casual visitors on the little known riches of the Preserve, and provide avid visitors and researchers analytical tools that encourage new ways of thinking about the Preserve. During development, these categories of intended users were referred to as the "newbie," the "regular," and the "researcher," respectively. The primary differentiation among the three groupings was the expected level of user motivation. Note that taking an approach based upon motivation is different from one that is based upon level of expertise (e.g., focusing upon either domain knowledge of the Preserve or technical familiarity with online, interactive maps). Saraiya et al. (2004) acknowledge the importance of initial user motivation on the quantity and quality of insights gained from use of the application. We contend that users with low levels of motivation are not necessarily incapable of gleaning large amounts of rich insights from a map application, but rather that they simply do not want to do so. Further, we take the position that it is the duty of the developer to accommodate a large range of potential motivation levels when the expected audience is so varied, rather than filtering potential users by their level of motivation. In this regard, using the map to look up a wayfinding point of reference in the Preserve is an equally justified task to support as using the map for its more complex functions that provide a richer reading of the Preserve.

Understanding how to design for varying levels of user motivation is informed by the concept of information-to-interface ratio. The total screen pixels dedicated to the browser is termed the *screen real estate* (Nielson 2000). The screen real estate can be dedicated to either information content or interface widgets, generating a measure for interface complexity termed the *information-to-interface ratio* (Harrower and Sheesley 2005). In this research, a component that contains information but is also interactive (as in the case of a map that can be directly manipulated) is counted towards the information pixel total, rather than the interface pixel total. Harrower (2002) theorized that there is a direct relationship between the user's level of motivation and a successful degree of interface complexity. This work can be extended to assume that users with low motivation seek a map with a high information-to-interface ratio (i.e., an interface that is not complex), while users with high motivation will tolerate a map with a low information-to-interface ratio (i.e., an interface that is highly complex) to access the accompanying increase in functionality. Figure 8 illustrates the relationship between user motivation and interface complexity.

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The VPA reflected a varying signal on preferred interface complexity, with several subjects suggesting that there were so many interface controls available that it was unclear where to begin and others requesting additional interface functionality. This finding reflects the variation in self-reported motivation of the participants, with subjects matching most closely with the "newbie" category desiring a streamlined interface with an obvious entry point to the map, and subjects matching most closely with the "researcher" category desiring a more complex interface and advanced features. The VPA reports the two potential failures shown in Figure 8: a situation where the user is unmotivated and the interface is too complicated, and a situation where the user is highly motivated and the interface is too simple. To compensate for this variation, the final redesign attempted to provide a *cascading information-to-interface ratio*, or an interface that provides ascending levels of interface complexity that relate to ascending expected levels of user motivation. A common example of a cascading information-to-interface ratio is in the availability of a regular versus expert mode in software (Cooper and Reimann 2003).

To provide an initial high information-to-interface ratio for the "newbie," all extraneous views (the information window, layer menus, layer legends, etc.) were hidden upon first viewing the map, and the position of the search box on the visual hierarchy was improved. This design ensured

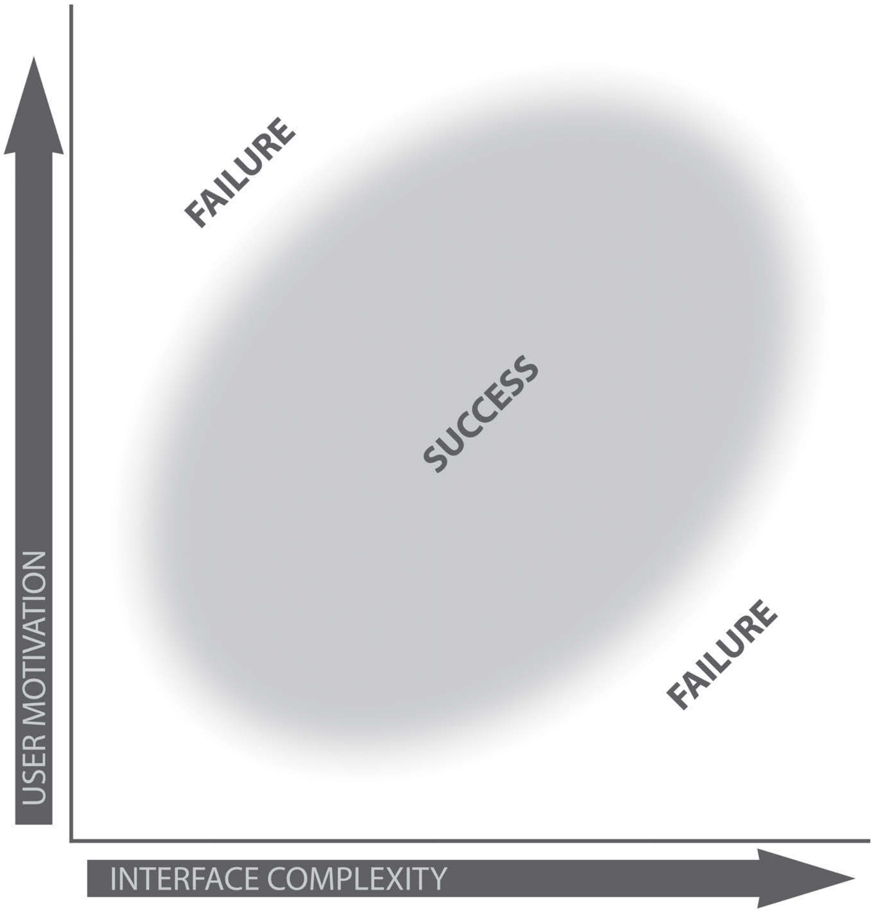

Figure 8. The relationship between a user's motivation and a successful level of interface complexity as described by Harrower (2002).

the largest possible footprint for the central map; comments from the VPA recommend a large map footprint as the default view when unmotivated users are expected to use a map. The "regular" is then able to access additional functionality by clicking on map features, automatically re-centering the map and opening the information window. Finally, the most complex functionality designed for the "researcher," presenting the lowest information-to-interface ratio, was hidden deeply within the bottom menu structure. This cascading information-to-interface ratio strategy implemented in the Lakeshore Nature Preserve Interactive Map is plotted atop Figure 9 as a piecewise function.

Providing Map Browsing Flexibility

A second interesting result of the VPA was the inability to identify a universal method for map browsing that was understood by all participants. *Map browsing* is the combination of panning and zooming of a map document that is too large or too detailed to be viewed by the available screen real estate, and is related to the HCI research on browsing of an information space too immense to be displayed in a single window (Cockburn and Savage 2003). *Panning* is the repositioning of the map document to view sections of the document space not currently visible or to center on a map feature of interest, while *zooming* is the act of changing the scale of the map, effectively shrinking or enlarging the map image onscreen; the two are often implemented in tandem (van Wijk and Nuij 2003). Harrower

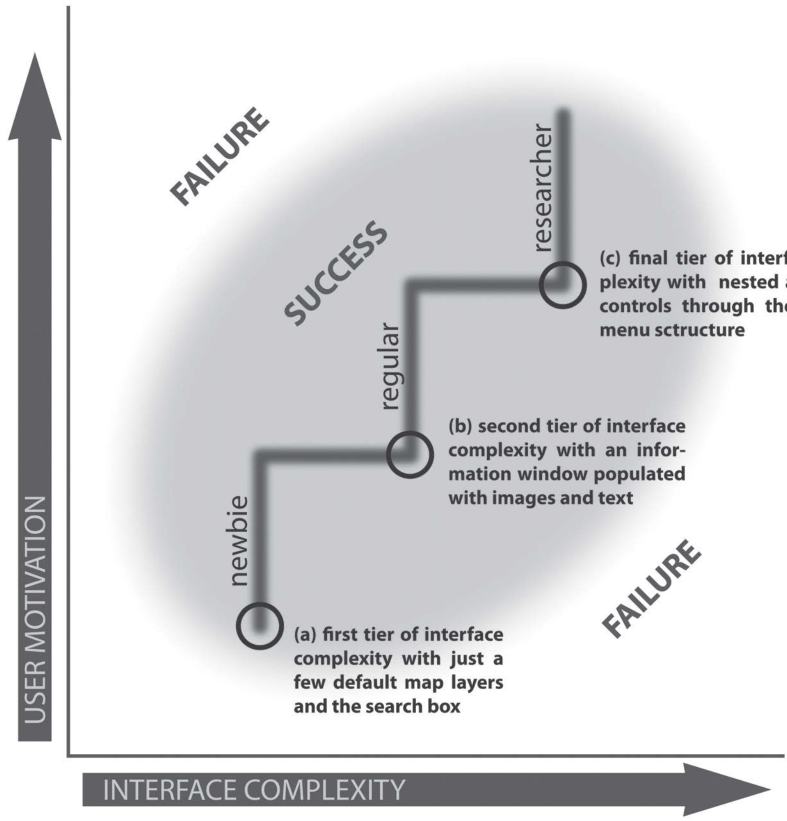

Figure 9. The cascading information-to-interface ratio strategy implemented in the Lakeshore Nature Preserve Interactive Map is modeled as an abstracted piecewise function atop this graph. The new image reflects the three tiers of interface complexity and their associated target users. This path reflects a hypothetical pairing of user motivation to interface complexity in the Lakeshore Nature Preserve Interactive Map; deviation of "newbies" from the simple interface is not only hoped for and expected, but, more importantly, would show that the initial positive experience with the simple interface has increased motivation to use the site.

and Sheesley (2005) identify nine different solutions for map browsing: 1) directly re-positioning the map ("grab and drag" or "direct manipulation"), 2) smart scroll bars, 3) rate-based scrolling, 4) keyboard controls, 5) zoom and re-center under mouse click, 6) navigator tabs/interactive compass, 7) navigator window, 8) specify explicit coordinates or scale, and 9) zoom box (for simultaneous pan and zoom). While explanation of each of these is outside the scope of this paper, it is important to note that preliminary research suggests that the appropriate implementation of map browsing depends on two factors: the map browsing task and the size of the document to be browsed (Cockburn and Savage 2003). In short, there is no ideal, context-independent method of map browsing.

The beta release of the application included three map browsing implementations: 1) direct manipulation of the map, 2) zoom and re-center under mouse click, and 3) a navigator window. According to Harrower and Sheesley (2005), these three methods exhibit the lowest interface workload and highest information-to-interface ratio and were therefore assumed by developers to be the most important to include. The VPA demonstrated that, while these methods did prove to be highly efficient, they were not entirely self-evident. All participants discovered the zoom and re-centering functionality after some exploration with the interface, but the majority did not directly manipulate the map to pan, and no participant used the navigator window as an interface widget. This finding presents a third constraint to finding a single, ideal method of map browsing: given previous experience with map interfaces, users may or may not be aware of particular implementations of map browsing that are not visually obvious. *Flexibility* is the provision of multiple interfaces by the application to the user to complete a single task, allowing for task completion through multiple paths (Cooper and Reimann 2003). This insight from the VPA caused developers to increase map browsing flexibility by adding two additional methods: 4) navigator tabs in the form of an interactive compass and a zoom slider bar and 5) keyboard shortcuts.

Avoiding Minimalist Design of Interface Widgets

A third issue that was reported during the VPA concerned the graphic design of many of the interface icons. We attempted to follow Tufte's (1983) concept of data-ink maximization when designing small interface icons. The *data-ink ratio* is a measure of the amount of ink devoted to actual information in the graphic compared to the total ink used for the graphic, and *data-ink maximization* is the process of improving this ratio by subtracting unnecessary marks. These concepts challenged the developers to design basic, yet elegant, interface widgets, removing as many embellishments as possible to limit the footprint of the widget. Figure 10 illustrates the initial designs for the layer visibility, the menu tear-away, and window minimize/maximize buttons. However, most attempts at minimalist design were lost upon at least one of the participants in the VPA. In these cases, the simplistic widget design did not provide enough affordances for the user to infer its function. An *affordance* is a visible property of an object and is useful for creating mental mappings between an object's appearance and its functionality (Norman 2002). By extending Tufte's (1983) principle of data-ink maximization to interface widget design beyond its intended application of information graphics, affordances that are necessary for making sense of the interface are inappropriately removed.

"By extending Tufte's (1983) principle of data-ink maximization to interface widget design beyond its intended application of information graphics, affordances that are necessary for making sense of the interface are inappropriately removed."

Figure 10. Initial designs for the layer visibility button (top-left), the tear-away menu button (top-right), and the minimize window button (bottom). *(see page 93 for color version)*

This finding from the VPA is confirmed in both the HCI and web design literature. Ware writes that "adding marks to highlight something is generally better than taking them away" (2004, 153). Krug adds, "In general, if you're a designer and you think a visual cue is sticking out like a sore thumb, it probably means you need to make it twice as prominent" (2000, 75). The failure of our minimalist interface buttons caused a fundamental graphical redesign for all widgets. In many cases, explanatory words were added next to the button for clarity (e.g., "minimize") or the icon was completely replaced by text (e.g., "on/off"). In situations where space did not permit textual descriptions, extra graphical affordances were added, making the widgets either larger or more complex. A system of tool tips also was developed to provide added instruction when a user pauses over an interactive portion of the application. Figure 11 illustrates the redesigns for the menu close, menu tear-away, and window minimize/maximize buttons based upon recommendations from the VPA.

Figure 11. Redesigns for the layer visibility button (top-left), the tear-away menu button (top-right), and the minimize window button (bottom) added words to explain the function of the widget and sometimes did away with the vague icon altogether. Tool tips (top-right, in yellow) also appear after pausing over a widget for one second to further prompt the user about the widget's function. (see page 93 for color version)

It is important to note that a call for added affordances does not necessarily have to contradict our recommendation to provide a large information-to-interface ratio upon initial entry into the map. While designing for a particular information-to-interface ratio is a holistic way of determining an appropriate number and collective size of interface widgets onscreen, the Tufte critique and the concept of affordances refer to the design of interface widgets on an individual level. We concede that one way to reduce the collective size of the map interface, and thus to improve the information-to-interface ratio, is to remove affordances from individual widgets in such a way that reduces their pixel footprint. However, given the feedback for the VPA, we recommend the removal of widgets in their entirety before the removal of affordances if a higher information-to-interface ratio is desired. In short, when designing for a high information-to-interface ratio, it is better to provide only a few, essential widgets that are immediately obvious and easy to use than have an abundance of ambiguous and difficult-to-understand ones.

Avoiding the Lorem Ipsum Map

The final design concern revealed by the VPA and subsequent cognitive interviews addressed the look and feel of the application. Multiple comments were offered regarding the contemporary or modern feel of the interface "shell" compared to the natural and historic feel of the map itself. Such comments were not unfounded, as the look and feel of an interface should mimic the look and feel of the content that is being accessed (Cooper and Reimann 2003). The mismatch between map content and surrounding interface shell was a result of the development team's beginning programming on common map functionality before the full feature list was produced. The deviation from appropriate workflow required usage of a *lorem ipsum map*, a dummy map used during interface development as a placeholder. The employment of a placeholder lorum ipsum map for development of the interface is evident in the generic look and poor usability of most GoogleMaps mash-ups, as the user interaction was developed without an understanding of the end content.

Krug (2000) warns about designing the interface structure of a website using placeholder content. It is common for web designers to fill components with the lorem ipsum text string, a series of words resembling Latin but not intended to have an implied meaning, during the development process. Krug (2000) argues against this practice, stating that it reduces usability, as designers never think about the kind of content that will be populating the components. Instead, the content should be developed first, and the interface should be designed around it second. This design approach is similar to the concept of *epicenter design*, where the most important content is first established and peripheral user interaction is then added around it (37signals 2006). Designing the map content first would not only have provided a consistent look and feel between the map and the interface shell, it would have also helped inform how the interface widgets in the shell should function.

CONCLUSION

If we want our interactive maps to work well, we must place the user front and center throughout the entire development process and gather input from them at all stages of work, not merely as an after-thought once the system is built. By only asking for feedback after development is complete, user input can do little more than confirm or challenge decisions which would be too expensive to change (and make us kick ourselves for not seeking that feedback earlier). The "feedback loops" we built into development of the Lakeshore Nature Preserve Interactive Map strongly shaped both what the map does (its purpose) and how it behaves (its functionality). As we have shown here, feedback can range from initial brainstorming sessions from a small group of invested stakeholders (who can represent their constituency of end users) to a more structured verbal protocol analysis with a sample of end users.

From the user's perspective, the usability of the map interface is absolutely crucial. No matter how interesting and robust your data may be, the map will not succeed if the user cannot figure out how to access the data or understand what the data is saying. Minimizing usability problems should be the keystone of any development approach. Although this commitment to user-centered design and continuous evaluation appears to be both time-consuming and expensive, it instead accelerates development by allowing the design team to quickly focus their energy on core functionality and reduces the cost of a project by minimizing wasted work hours implementing functionality that is later altered or removed. The Lakeshore Nature Preserve Interactive Map was built, start to finish, including all research, programming and evaluation, in only three months with mostly student part-time labor, offering anecdotal evidence that constant evaluation improves development efficiency.

Perhaps a difficult fact to accept is that the basic metric for determining the success of an interface is not whether we, the developers, think the design of the map is brilliant (or even if we receive accolades from our peers for this brilliant design), but whether the target audience understands the map—both the content and the interface to that content—and if they enjoy using the map. One example from the development of the Lakeshore Nature Preserve Interactive Map was the need to redesign the clever, yet minimalist interface icons in such a way that made them immediately obvious. While we still like our original icons and feel that they are a more elegant way of connecting form to function, we did not hesitate to eliminate them when our testing showed they just did not work. This concern makes early and ongoing evaluation even more important, as it is only human nature for the developers to become increasingly partial to and defensive of their own designs with time. If cartographers only seek feedback following completion of the application, it will be difficult for us to ever see our online, interactive maps for what they may actually be: useless and unusable.

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