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TRANSITIONAL VOLATILITY IN WEB NAVIGATION

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ABSTRACT

Understanding the specific nature of disorientation in hyperspace will benefit from a battery of characterizations of the space being navigated, the user navigating the space, and their interaction. This study focuses on a particular consideration for understanding the "lost-in-hyperspace" problem, namely "transitional volatility". Metrics investigated in relation to disorientation and Web site mental models include: 1) the navigational and content changes of a Web site's interface in page-to-page transitions, and 2) the users' ability to reorient themselves to these changes. Metrics to relate to disorientation and Web site mental models include the extent to which 1) a navigation session is volatile, 2) a user is typically habituated in navigation patches, and 3) a user can predict navigation support changes at destination pages. The primary concern of the study was the effects of the navigational volatility on disorientation and Website mental models for two common hierarchical navigational schemes: partial overview and local context support.

The results suggest an interesting pattern of interaction effects: When users are provided with partial overview navigation support, navigational volatility predicts increased disorientation, decreased perceived global coherence and decreased ease of navigation. In contrast, when provided with a more locally focused navigation scheme, navigational volatility predicts increased perceived site size and increased perceived global coherence. The results generally supported a model with a direct causal link from navigational volatility to disorientation.

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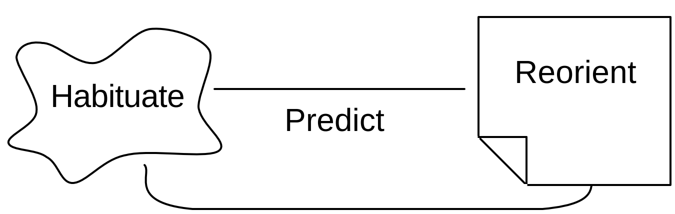
"Volatile" is a telling way to describe both the Web and a user's interaction with it. The Web itself and its individual sites rapidly change (Pitkow 1998), and user interaction with it has been described as "rapidly interactive" (Cockburn and McKenzie 2001), causing navigators to encounter a wide range of design schemes, types of sites, and types of information in small units of time. That is, one can speak of two sorts of ways the Web is volatile: (1) an individual structure (such as a page or site) can change over time, and (2) separate structures can be different in such a way that navigating among them produces a volatile experience.

The latter will be referred to as "transitional volatility"—or the extent to which users encounter changes in the Web interface as they move within or between sites. When they move to a new site or sub-site, they are confronted with new navigation support and potentially different design schemes. These sorts of changes relate to the "flow" of a navigation session, and they are indicative of an old concept in interface design and film production: the extent to which a scene is "visually turbulent" or has good "visual momentum" (Woods 1984). There are a number of reasons that the extent to which interface changes occur during a navigation session might be of special interest for many circumstances on the Web: (1) the page-to-page transitions are generally discrete and invoked by only one primary act on the part of the user, namely hyperlinking; (2) the visual changes are often themselves discrete, but are affected by page loading time, which itself can produce variations on the rendering of a page; (3) the Web is a wide open space in which users frequently encounter vastly different types of sites and vastly different design schemes; and (4) the user is predisposed to look to the content of the destination page (Nielsen 2000), and thus transitional changes on the Web will not necessarily be noticed in the same sorts of ways they are noticed with other interfaces; rather, the volatility of the transition (especially that of navigation support) may often go unnoticed until non-content interface objects are needed.

Page-to-page transitions do not occur in a vacuum, however. The user brings a background of previous engagement with a site into each and every transition. In particular, one may say that the user is more or less habituated within a navigation "patch" (a cluster of pages with similar navigation support), and that attributes of the destination page are more or less predictable. Here is a simple way of looking at the interaction that will drive much of this discussion:



The user becomes habituated within the recent navigation patch. The user predicts content and navigation option changes in page-to-page transitions. The user reorients at the destination page of a transition. The destination page becomes part of the recent navigation patch, continuing the cycle.

One of the great problems in Web navigation is the “behind-the-door” problem: users are often unable to grasp what lies directly behind a hyperlink, let alone what lies further down the path of that hyperlink. Transitional volatility will be thought of largely in terms of its potential contribution to this predictability problem.

TRANSITIONAL VOLATILITY

This study empirically investigates the effects of a volatile navigation session on a user’s level of disorientation and mental models of a site. Transitional disorientation is proposed as a subset of the lost in hyperspace problem resulting solely from hyperlink transitions, with transitional volatility as a possible contributor. Figure 1 shows the proposed contributing factors to both the user’s need and potential for reorientation into a destination page.

In this study, metrics are developed for three factors, with all others being held constant.

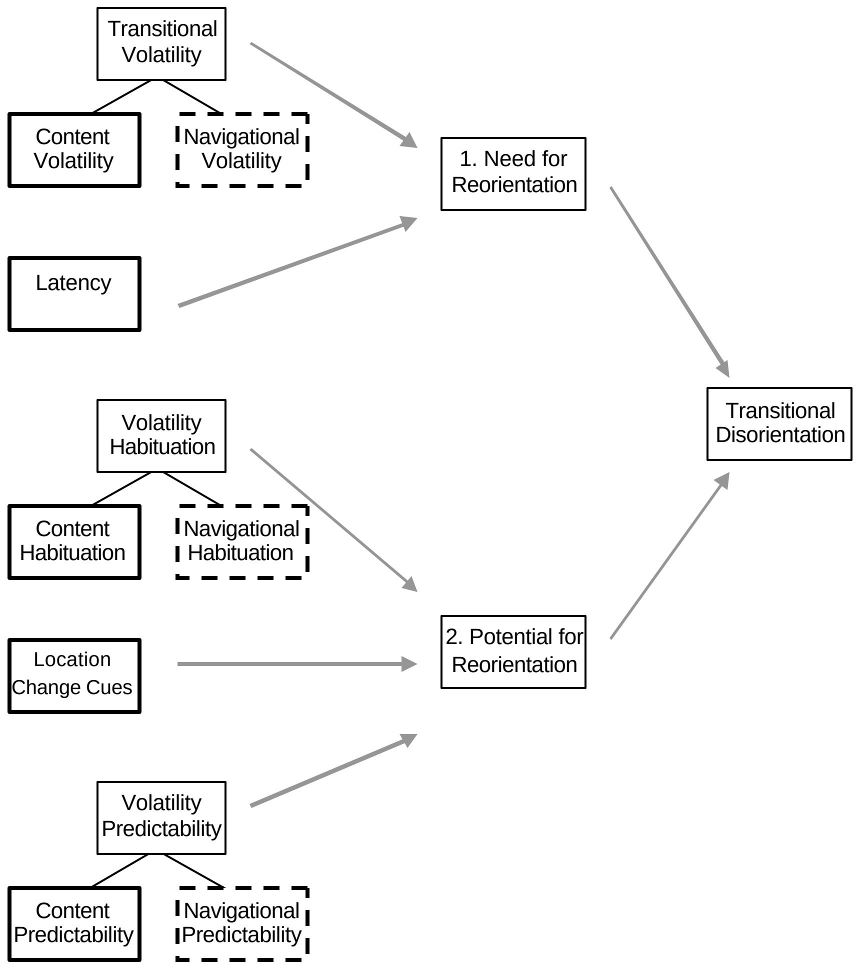
1. *Transitional volatility* refers to the extent to which the Web interface changes as a user moves through a site. Its navigational component simply refers to the extent to which the user is continually confronted with new navigation options, and its content volatility refers to the extent to which the user is continually confronted with new content (where Web page content encompasses all non-navigational interface objects).

2. *Volatility habituation* refers to the extent to which a user expects a lack (or low level) of transitional volatility as a result of a page-to-page movement, based on a recent lack (or low level) of transitional volatility. Navigational habituation and content habituation are analogously defined.

3. *Volatility predictability* refers to the extent to which a user is able to anticipate interface changes at the destination page of a transition. Volatility predictability, in general, relies on a navigator’s ability to recognize hyperlink attributes with predictive power and to map them to interface changes from the source page to the destination page. This predictive power is distinguished from destination prediction (of where in the site a hyperlink will take the user) and information prediction (of specific content at the destination page). Navigational predictability and content predictability are analogously defined.

Variables based on user exposure to a Web site (volatility habituation and volatility predictability), joined with actual transitional volatility, are proposed as contributing to the perceived transitional volatility of a navigation session, as in Figure 2.

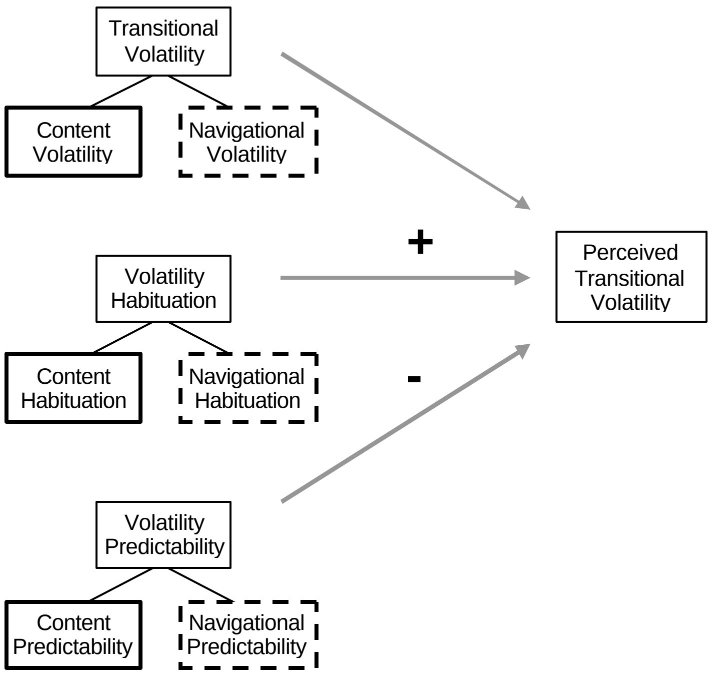
FIGURE 1: EXPERIMENTAL MODEL OF TRANSITIONAL DISORIENTATION



Proposed factors that contribute to (1) the user's need to reorient into the destination page of a transition, and (2) the user's potential for reorientation into the destination page. Metrics (leaves with dotted lines) are developed for three factors that vary from navigator to navigator: navigational volatility, navigational habituation, and navigational predictability. Other proposed contributing factors (leaves with solid lines) are held constant.

The user's experience with the Web site should be a cause of discrepancy between actual and perceived transitional volatility. In particular, habituation should lead to overestimation of actual transitional volatility, and predictability should lead to underestimation of actual transitional volatility.

FIGURE 2: MODEL OF PERCEIVED TRANSITIONAL VOLATILITY



Actual (measured) transitional volatility, volatility habituation, and volatility predictability are proposed as contributing to a user's perception of the extent to which interface changes occur as a result of page-to-page transitions, measured by post-navigation reports. Volatility habituation should lead to users assigning a perceived transitional volatility rating which overestimates actual transitional volatility (+); volatility predictability should lead to users assigning a perceived transitional volatility rating which underestimates actual transitional volatility (-).

Mental models: This study investigates the relationships between the described volatility concepts and behavioral and attitudinal data, specifically regarding disorientation, or "lostness," and mental models of the stimulus Web site. A mental model is generally taken to be an internal, symbolic representation of some part of the external world (Johnson-Laird 1983, 1991). Mental models on the Web are primarily *about* sites. Much attention has been paid to mental models of a site's connectivity; this study is concerned with: (1) users' perceptions of the site's size and complexity, (2) their model of their own exploration of the site (i.e., the extent to which they have explored its sub-sites), and (3) the extent to which they view the site as a congregation of tightly (or loosely) related topics. Measure (3) is referred to as *perceived global coherence*. Understanding large-scale connections between many nodes within an information space demonstrates global coherence (Thüring et al. 1991). In this study, the concern is not with users' *actual* understanding, but rather their perception of such understanding—that is, the extent to which they *perceive* that they see connections between the site's topics.

EXPERIMENT

This study investigated transitional volatility in Web navigation, collecting and analyzing both the behavioral and attitudinal variables in Figure 1; exact wordings of the questions and measures of the variables are shown in Table 2. The intent of the study was to investigate the effects of navigational volatility *within the Partial Overview and Local Context conditions*, rather than to compare the relative usability of the three differing navigational schemes.

Navigational volatility, navigational habituation, and navigational predictability were approximated with metrics, while other proposed contributing factors were held constant (or minimized). For example, latency was minimized, to prevent page loading time differences both within and between subjects, including lack of graphics, appropriate for low word count pages (Ivory et al. 2001). The stimulus site was also kept on a local machine to minimize latency, a subject of primary concern in effective Web design (Byrne et al. 1999; Nielsen 1999). Session and post-navigation questionnaire data together assessed efficiency, effectiveness and subjective satisfaction, because one cannot assume these to be correlated (Nielsen and Levy 1994; Frøkjær et al. 2000).

Participants: A total of 30 Stanford University students aged 18 to 33 were randomly assigned to one of three experimental conditions (half female and half male within each condition). Previous analyses of age effects suggest these participants would be more efficient navigators than a fuller age sample (Meyer et al. 1997).

Stimuli: The stimulus site contained text from a government "self-help" legal information site for the California court system. It was constructed to control design aspects and contained 100 pages, including a home page. The site was hierarchically structured and organized into five main sections, each containing between 18 and 21 pages and two levels of hierarchical structure. Limiting the maximum hierarchical depth from the home page to three levels should help limit the age effects mentioned above (Zaphiris and Ellis 2000). The site depth is appropriate given that Web navigators rarely traverse more than two layers before returning to a hub page (Catledge and Pitkow 1995). Moreover, the stimulus site follows Chimera and Shneiderman (1994), in that its structure was "well-formed" down to the third level, such that "…each of the two upper levels' items always had subordinates, and no item at the third level had any subordinates." Chimera and Shneiderman acknowledge that many real-world overviews are not well-formed, but the use of a well-formed structure may help "…account for performance differences attributable to interface design."

TABLE 1: STIMULUS SITE WORD COUNT ANALYSIS

Mean word count for each of the three levels of the stimulus site hierarchy, with progressive word count increase at lower levels.			
	Pages	Mean	SD
Level 1 ("Top Level")	5	74	51
Level 2	19	137	108
Level 3	75	219	116

The site contained 19,411 words (including a 46-word site introduction at the home page), with the common progressive increase in amount of content at lower levels of the hierarchy, as shown in Table 1. The word counts place the page lengths in the low to medium range in the Ivory et al. (2001) analysis. Diaper and Waelend (2000) reported that graphic content significantly affects information extraction on Web pages by novice users, but not by experienced users. Lack of graphics may therefore limit potential Web expertise effects.

Conditions: The stimulus site was presented with the three different design schemes, as illustrated in Figure 3, varying the navigational support provided, each representing an experimental condition that was evaluated rather than contrasted:

1. *Full Overview:* hyperlinks are provided (at each node) for all pages in the site

2. *Partial Overview:* hyperlinks are provided (at each node) to the five top-level pages and to all pages within the sub-site of the current node

3. *Local Context (or "Sibling-Child"):* hyperlinks are provided (at each node) to the five top-level pages and to the siblings and children of the current node

These conditions represent a range in navigational support common to hierarchically organized information spaces. The Partial Overview and Local Context conditions will allow for evaluation of metrics for navigational volatility, navigational habituation, and navigational predictability. The Full Overview condition is not contrasted with conditions 2 and 3, but rather allows for the investigation of the effects of other transitional factors (such as the hierarchical relationship between the source and destination pages) while minimizing navigational volatility. This capability will allow for the evaluation of potential causal models in the Discussion section below. It is again important to emphasize that the intention of the study is not to evaluate the relative effectiveness of the three conditions, but to observe their correlates.

The content of the site was exactly the same in all conditions. In addition to their unique navigational mechanisms, each condition shared three mechanisms: (1) a "Self-Help Center Home" link at the top-left corner of the screen, (2) a "breadcrumb list" just below the page title, and (3) an associative list mechanism ("see also" links) located below the body text.

The site was presented in 800x600 screen resolution in all conditions. An effort was made to apply exactly the same design and font specifications to all conditions. All navigational mechanisms (except the breadcrumb and associative lists) were presented in modules with differentiated background color. Left column mechanisms spanned 200 pixels of horizontal screen space, and the content area spanned the remaining 600 pixels (with some room for the browser attributes). These specifications led to a line of body text spanning about 75 characters, a reasonable length to support online reading (Lesk 1997).

The appearance of navigational mechanisms as vertical, left-column modules, and their differentiated background color from the page content were appropriate specifications for supporting visual search performance (van Schaik and Ling 2001), and follow the common practice of "yellow fever" (Nielsen 2000).

Horizontal scrolling was never necessary, given the above specifications. Vertical scrolling was not required for structural navigation support in either the Partial Overview or Local Context conditions, but content did appear below the scroll line for higher word count pages. The Full Overview navigational mechanism, in Chimera and Shneiderman's (1994) classification, was in the low-end medium size range. The Partial Overview navigational mechanism was in the small size range, fitting in one screen display.

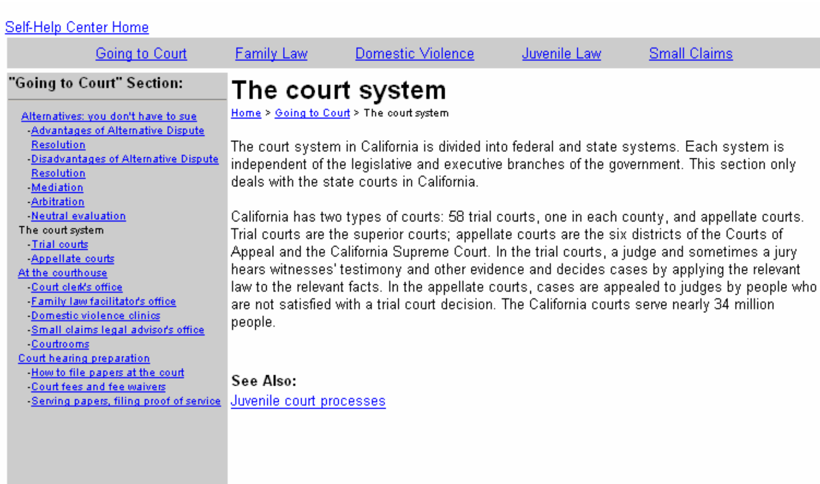
Figure 3 shows a sample page for each of the three conditions.

Questionnaire, tasks and procedures: The study included a post-navigation questionnaire, collecting the following variables for correlation:

1. Participant estimates regarding the size of the site (in number of pages) and the extent to which it and each of its main sections had been explored. These estimates were used to measure users' ability to accurately estimate their exploration of the site and its sub-sites.
2. Usability ratings, using 1-10 agree/disagree Likert scales for statements such as "I generally knew where I was in the Web site," one of three measures of disorientation.
3. The user's understanding and model of the condition's design scheme.
4. Perceived global coherence of the site, measured by asking the user to rate the relatedness of 15 page-title pairs from the site. Pairs were split evenly according to familial relationship (each hierarchical relationship being represented) and location of the pages. Perceived global coherence of the site was also assessed by asking the user to rate the extent to which a sample of nine page titles from the site were central to the site's

FIGURE 3: EXPERIMENTAL CONDITION EXAMPLE: AN EXAMPLE PAGE IN THE (A) FULL OVERVIEW, (B) PARTIAL OVERVIEW AND (C) LOCAL CONTEXT CONDITIONS

(A)



(B)

(C)

main topic, with three pages coming from each of the three hierarchical levels.

This study was concerned with directed search, or low complexity fact-finding missions, using a set of 25 randomly ordered information-seeking tasks. (Participants were not expected to complete all tasks.) An example task was "Where can you get information on local department locations and court hours?"

Experimental sessions were separated into three sections. First, participants were given information regarding the general nature of the study, and instructions for participation.

Second, participants navigated the stimulus site for 15 minutes, with screen monitor output being recorded for later viewing and coding. This procedure is believed to be less invasive than many other recording options. All participants used the same PC, with a wheel scroll mouse. The experiment began with the participant clicking on a link to the home page of the stimulus site (therefore originally entering the site through the front door). Participants attempted to complete one information-seeking task at a time, with the option of abandoning a task if they did not believe they would find the answer (but could not return to previously abandoned tasks). After participants completed or abandoned tasks, they clicked on an "ANSWER QUESTION" or "SKIP QUESTION" link in the browser to stamp the completion, and returned via the home page to begin the next task. (The procedure of returning to the home page after each task is methodologically similar to Otter and Johnson (2000), who point out that such practice ensures that all participants start tasks from the same point in the site).

Third, participants completed the post-navigation questionnaire materials, lasting approximately 20 minutes.

Behavioral data collection and metrics: Navigational click-stream data was collected for analysis from recorded screen output. For each navigational act, the following attributes of the page visit were recorded:

1. Node code, which uniquely identified the page visited in the site hierarchy.

2. Navigational mechanism used to arrive at the destination page (i.e. Full Overview, Partial Overview, Top-Level Links, Sibling List, Child List, Breadcrumb List, Associative List, Back button, etc.).

3. Time of arrival (starting from zero seconds).

Task completion or abandonment and site reentries via the home page were also recorded, but they were treated separately from other navigational acts. Note that the collected click-stream data allowed for a measure of the user's frequency and proportion of "top-level switches," defined in this study as movements between pages within different main sub-sites. This measure will be important in examining the effects of navigational volatility on disorientation, in the Discussion section. For the Partial Overview and Local Context conditions, each participant's click-stream data resulted in indexes for (1) navigational volatility, (2) navigational habituation and (3) navigational predictability. Structural mechanism hyperlinks stayed the same for all navigational acts in the Full Overview condition, and so the same analyses were not appropriate. This condition served to evaluate potential causal models for transitional volatility.

1. For each transition, *navigational volatility* was defined as the number of hyperlinks appearing on the destination page that did not appear in the same screen location as on the source page. The participant's volatility score was the mean navigational volatility across all navigational acts during the experimental session.
2. For each transition, *navigational habituation* was defined as the number of previous consecutive pages the participant had visited within the same main sub-site; that is, habituation was based upon how long (in terms of page visits) the navigator had remained within the same navigation patch. (This metric works well when pages within the same sub-sites have similar navigational support, which is common in hierarchically organized sites, and was the case in this study.) Measuring habituation in terms of number of transitions rather than seconds was preferable since much of a user's time is presumed to be spent on extraction tasks rather than focusing on navigation support. (A metric for *content* habituation, on the other hand, would more appropriately attach weights to each transition according to duration of page stay.) The participant's habituation score was the mean navigational habituation across all navigational acts during the experimental session.
3. For each transition, *navigational predictability* was defined as the number of times the user had previously used the same navigational mechanism as the mechanism being used for the transition in question. The participant's predictability score was the mean navigational predictability across all navigational acts during the experimental session.

Each time a task was completed, the navigational habituation of the next transition was measured at zero (the start of a new habituation patch). Regardless of the number of previous times a user invoked an associative hyperlink, the predictability of such a transition was always given a zero value, in the spirit of the commonly-agreed-upon unpredictable nature of associative hyperlinks (DeRose 1989; Otter and Johnson 2000). Back-button clicks were not assigned a predictability score, as any such score was difficult to justify. (Future similar work might attempt to develop and empirically validate a predictability score for Back-button clicks accounting for their likely special nature.)

RESULTS

A total of 1730 navigational acts and 2400 page visits (including task completion/abandonment and site reentries) were recorded. This section reports experimental results regarding the metrics for navigational volatility, navigational habituation and navigational predictability. Correlation analyses for the Partial Overview and Local Context conditions are done within condition; the effects of the metrics used are found to vary according to the design scheme used. Condition comparisons would not provide information regarding the effects of transitional volatility, since disorientation and mental model metrics could be influenced by other characteristics of each individual design scheme. Results for the Full Overview condition, as mentioned above, are used to evaluate the causal models examined in the Discussion section below, in light of the correlations reported in this section. More detailed results and discussion may be found in Danielson (2002a).

Metric overview: Across Partial Overview and Local Context participants, the mean navigational volatility scores of 3.9 and 4.2 were not significantly different. However, they were for both habituation and predictability. Partial Overview participants had a mean habituation score of 1.0, while Local Context participants had a mean score of 1.9, which was significantly higher (t-test, $p < 0.05$). Thus, Local Context participants tended to stay within navigation patches more than Partial Overview participants. Local Context participants had a mean predictability score of 7.9, while Partial Overview participants had a mean score of 16.7, here significantly higher (t-test, $p < 0.001$). Thus, Partial Overview participants tended to use navigational mechanisms repeatedly more than Local Context participants—not surprising since the navigational scheme in that condition was composed of one less mechanism than that of the Local Context condition, as shown in Figure 3.

Navigational volatility: Navigational volatility correlates in the Partial Overview and Local Context conditions are shown in Table 2.

Within the Partial Overview condition, navigational volatility had significant effects on disorientation, perceived global coherence and ease of navigation. Navigational volatility significantly predicted two disorientation measures ($p < 0.001$, $p < 0.01$), and approached significance for the third ($p < 0.1$). Navigational volatility significantly predicted two perceived global coherence measures ($p < 0.01$, $p < 0.05$), and a sign test for the six perceived global coherence measures (including centrality ratings for both top-level and lower-level page titles), shows a significant negative relationship ($p < 0.05$). Navigational volatility significantly predicted one ease of navigation and site organization measure ($p < 0.01$), and a sign test for the five measures shows a significant negative relationship ($p < 0.05$).

With Partial Overview navigational support, a high navigational volatility score predicted increased disorientation, decreased perceived global coherence and decreased ease of navigation. Its effect on site size perception and accuracy of the user's exploration model within the Partial Overview condition is not conclusive; more measures will be needed in future work to determine whether there is mounting evidence of an effect.

Within the Local Context condition, navigational volatility had significant effects on subjective site size perception and perceived global coherence. Navigational volatility significantly predicted the subjective site size measure, but surprisingly was not predictive of the user's actual size estimate in number of pages. Navigational volatility significantly predicted the rated centrality of top-level page titles ($p < 0.01$). However, the extent to which centrality ratings measure perceived global coherence is unclear (discussed further in the Discussion section). If one chooses not to rely heavily or solely on such measures (as might be reasonable), a sign test for the six measures shows a significant positive relationship between navigational volatility and perceived global coherence ($p < 0.05$).

With Local Context navigational support, a high navigational volatility score predicted increased site size perception and increased perceived global coherence of the site. Its effect on the accuracy of the user's exploration model within the Local Context condition, as with the Partial Overview condition, is not conclusive.

Across both the Partial Overview and Local Context conditions, increased navigational volatility predicted decreased reported ease of navigation, correlating negatively with "The site was easy to navigate" ($r = -0.57$, $p < 0.01$), and increased disorientation, correlating negatively with "I generally knew where I was in the Web site" ($r = -0.53$, $p < 0.05$), negatively and approaching significance with "When I felt lost, it was easy to reorient myself" ($r = -0.41$, $p < 0.1$), and positively, but not approaching significance, with "I felt lost and needed to reorient myself" ($r = 0.32$).

Table 3 summarizes the effects of navigational volatility found in Table 2. It can be seen that with partial overview navigation support, increased navigational volatility predicted increased disorientation, decreased perceived global coherence and decreased ease of navigation, with no effect being found on perceived site size or users' ability to accurately estimate the extent to which they explored the site and its sub-sites. With Local Context navigation support, increased navigational volatility predicted increased perceived site size and increased perceived global coherence—with no effect being found on disorientation, site exploration model accuracy, or ease of navigation.

TABLE 2: NAVIGATIONAL VOLATILITY CORRELATES, PARTIAL OVERVIEW AND LOCAL CONTEXT CONDITIONS

	Partial Overview		Local Context	
Disorientation	*r*		*r*	
"When I felt lost, it was easy to reorient myself in the site"	-0.91	**	0.37	
"I generally knew where I was in the Web site"	-0.82	**	0.14	
"I felt lost and needed to reorient myself"	0.60		-0.12	
Perceived Site Size	*r*		*r*	
"The site seemed large"	0.52		0.66	*
"The number of navigation options (links) was overwhelming"	0.33		0.35	
Site size estimate (in number of pages)	-0.11		0.33	
Perceived Global Coherence	*r*		*r*	
"The information in the site seemed to be tied together and well connected"	-0.84	**	0.38	
"Topics in the site were related to one another and pertained to one coherent topic"	-0.40		0.47	
Perceived global coherence metric (mean topic relatedness rating)	-0.53		0.45	
Relatedness ratings for "distal" site topics	-0.65	*	0.22	
Centrality of site topic ratings (mean for sample)	-0.13		0.48	
Centrality of top-level site topic ratings	-0.23		0.80	**
Exploration Model	*r*		*r*	
Section exploration error	0.45		0.37	
Ease of Navigation (and Site Organization)	*r*		*r*	
"The site was easy to navigate"	-0.83	**	-0.18	
"The information in the site was well organized"	-0.56		0.14	
"The navigation options (links) were well organized on the page"	-0.49		0.28	
"It was easy to return to pages I had previously visited"	-0.36		0.36	
Rated usefulness of navigation options	-0.31		0.21	

*p<.05 **p<.01

Navigational volatility correlations with disorientation (3 measures), site size perception (3 measures), perceived global coherence (6 measures), the site exploration model (1 measure) and perceived ease of navigation and site organization (5 measures) for Partial Overview and Local Context condition participants. The statements in quotes were rated on a 1-10 agree/disagree scale.

Navigational habituation and predictability: Users provided an agree/disagree rating for "The navigation options (links) seemed to stay the same as I navigated," assessing perceived (lack of) navigational volatility. Recall that navigational habituation and navigational predictability were proposed as causes of discrepancy between actual and perceived navigational volatility. In the Local Context condition, the regression equation for perceived (lack of)

TABLE 3: SUMMARY OF RELATIONS IN TABLE 2

	Partial Overview	*Local Context*
Disorientation	⬆	–
Perceived site size	–	⬆
Perceived global coherence	⬇	⬆
Exploration model accuracy	–	–
Ease of navigation	⬇	–

⬆ *Positive relationship with navigational volatility;* ⬇ *Negative relationship; – No effect found*

navigational volatility with predictors being actual navigational volatility, navigational habituation and navigational predictability was:

$$(Lack\ of)\ Volatility_{perceived} = 8.9 - 1.6*Volatility_{actual} - 1.1*Habituation + 0.65*Predictability\ (R\text{-}sq = 36\%)$$

In the Partial Overview condition, the regression equation, with the same predictors, was:

$$(Lack\ of)\ Volatility_{perceived} = 14.3 - 1.3*Volatility_{actual} - 2.7*Habituation - 0.07*Predictability\ (R\text{-}sq = 53\%)$$

In both conditions, then, navigational habituation led users to overestimate navigational volatility. In the Local Context condition (but not in the Partial Overview condition), navigational predictability led users to underestimate navigational volatility.

The extent to which a navigator tended to remain within navigational patches was generally not predictive of attitudinal data or site perceptions. Across the Partial Overview and Local Context conditions, the navigational habituation metric correlated positively with “It was easy to understand where in the site clicking on a link would take me” ($r = 0.45$, $p < 0.05$). Not surprisingly, navigational predictability scores significantly predicted a decreased proportion of Back-button clicks ($r = -0.68$, $p < .001$).

It can be seen that perceived (lack of) navigational volatility appears at least promising in capturing the notion of predictability during the navigation session. The user rating for perceived (lack of) navigational volatility, “The navigation options (links) seemed to stay the same as I navigated,” correlated positively with each of the three predictability reports by participants. The relationship was significant with “It was easy to predict where in the site clicking on a link would take me” (destination prediction) ($r = 0.56$, $p < .01$), approached significance with “The (underlined) link titles well summarized the information they led to” (information prediction) ($r = 0.41$, $p < 0.1$), and was positive (but not significant) with “It was easy to understand how the page would change when I clicked on a link” (transitional volatility prediction) (r =

0.33). Perceived (lack of) navigational volatility also correlated negatively, but not significantly, with a validated sign of low predictability, Back-button usage (r = -0.35).

Duration of page visit: Across conditions, there was a significant effect of hierarchical direction of movement on duration of page visit, with downward movements resulting in the most time spent at the destination page (1-way ANOVA, $p < 0.001$). Similarly, navigators spent more time at pages deeper in the site hierarchy (1-way ANOVA, $p < 0.001$). Both findings are linked to the effect of page word count on duration of visit, as summarized in Table 4. Positive correlations between a given page's word count and mean time spent at that page were found regardless of the page's hierarchical level or experimental condition. (Note that in some cases, a Web page was never visited by any of the 10 participants within a condition.)

Across conditions, non-Back-button transitions resulted in a mean time spent at the destination page of 11.7 seconds (SD = 11.3), and Back button clicks resulted in a significantly lower mean of 5.7 seconds (SD = 7.0) (t-test, $p < 0.001$). Distal and non-distal movements in the site hierarchy did not result in significant differences in time spent at the destination. Top-level switches (movements between pages within different main sub-sites) were also not predictive of duration of page stay. Moreover, across the Partial Overview and Local Context conditions, neither navigational volatility nor navigational predictability of a transition correlated with the amount of time spent at the destination page.

DISCUSSION

This section discusses relationships between the navigational metrics used in this study and disorientation, site size and complexity, users' models of their own site exploration and perceived global coherence.

Disorientation: Across the Partial Overview and Local Context conditions, a volatile navigation session and reported disorientation correlated positively. Within the Partial Overview condition the relationship was especially strong. Possible causal relationships are now considered.

One should recognize that in the Partial Overview condition, the extent to which users are confronted with new navigation options, as they move from one page to another, is heavily influenced by how frequently they make "top-level switches," or movements between pages within different main sub-sites. In order to understand the probable causal relationships, one should consider these movements. Consider the following causal model:

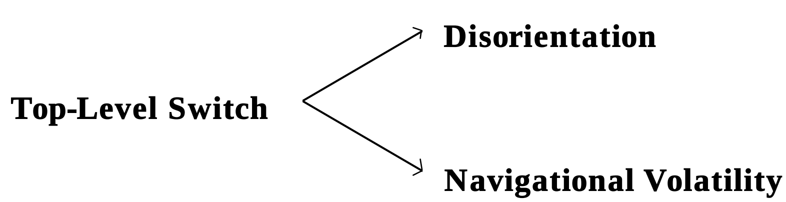
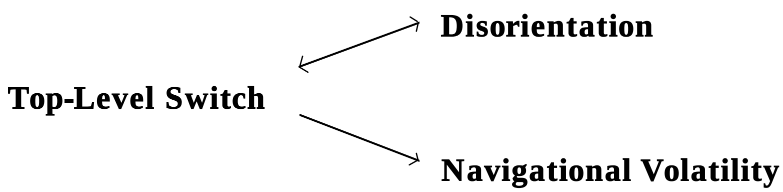


TABLE 4: WORD COUNT AND DURATION OF VISIT

	Pages	r
Across Level/Condition	95	0.47
Level 1	5	0.64
Level 2	19	0.75
Level 3	70	0.40
Full Overview	75	0.36
Partial Overview	89	0.43
Local Context	81	0.43

Correlations between page word count and mean time spent, across all page visits and within hierarchical level and condition.

"Top-Level Switch → Navigational Volatility" is true just by the definition of the two terms and consequence of the design scheme. In the above model, top-level switches cause both disorientation and, as a by-product, navigational changes in the Web interface. One might extend this model to include a causal influence of disorientation on top-level switches, creating a potentially ugly cycle:

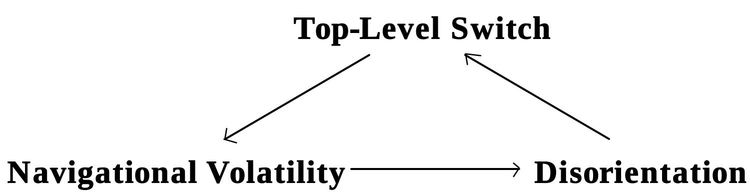


This additional causal relationship is at least plausible; top-level nodes are reorienting nodes, and may be viewed that way by navigators. A cycle like this might explain why the correlations between disorientation and navigational volatility were so high; the disoriented user seeks reorientation in top-level switches, which cause more disorientation, leading to more top-level switches, and all the while the cycle includes increased navigational volatility.

However, in saying that top-level switches cause disorientation, one ought to be able to say what it is *about* a top-level switch—as opposed to transitions within the same sub-site—that might give such transitions their causal power. The stimulus site was stripped down in such a way as to eliminate or minimize any differences between inter- and intra-sub-site transitions (other than their differences in navigational volatility, as determined by the navigational scheme of the condition). They differ in one other way: the extent to which the specific information in the source and destination pages of the transition are likely to be related. Although lostness appears to occur independently of a navigator's content domain expertise (Elm and Woods 1985), disorientation nonetheless could be an effect of moving from one kind of information (assuming users have some grasp of the sort of information space they are in) to another (assuming they notice on some level, by the specific content, that they are "not in Kansas anymore").

But if the "Top-Level Switch → Disorientation" portion of this causal model is believable, one would expect that in the Local Context condition (where the top-level mechanism was also available), a relationship between top-level switches and disorientation would be found. However, neither frequency nor proportion of top-level switches predicted any of the three disorientation measures in the Local Context condition. The same is true of the Full Overview condition, where, in fact, the relationship between top-level switches and "I generally knew where I was in the Web site" approached a significantly *positive* relationship ($r = 0.59$, $p < 0.1$). Moreover, consider that distal movements—by the same presumption made regarding top-level switches—are between source and destination pages with less-related information topics than local transitions. Neither frequency nor proportion of distal transitions predicted any of the three disorientation measures, in both the Full Overview and the Local Context conditions. In short, all of this evidence points to one conclusion: moving among unrelated information topics in the Web space appears not to have been related to disorientation. More importantly for the purposes of this discussion, top-level switches do not, in and of themselves, cause disorientation—giving good reason to consider the two models above implausible.

Consider another potential causal story: "Disorientation → Top-Level Switch," as part of the larger picture, "Disorientation → Top-Level Switch → Navigational Volatility." Note that this model is not inconsistent with navigational volatility causing disorientation. One could, rather, be faced with another potentially ugly cycle in Web navigation:



One might simply argue that disorientation causes navigational volatility directly, although this seems slightly less plausible. Notice that predictability now plays a role. In order to accept "Disorientation → Navigational Volatility", one would need to accept that disoriented users consciously recognize the hyperlinks that will lead to navigational changes (navigational predictability), and then decide that such change is desirable, leading to a transition. In this study, all hyperlinks within the same mechanism had homogenous volatility (led to similar navigation support changes), and under such circumstances a direct causal link from disorientation to navigational volatility becomes more plausible.

However, if disorientation has any such causal power, one ought to be able to explain why it flexed it only in the Partial Overview condition and not the Local Context condition. (One could explain why it did not in the Full Overview condition, which did not include a top-level links mechanism, by stating that without such a homogenous mechanism, users were less able to make hyperlink decisions that would predictably move them to another sub-site—or at least a distal page.) If the top-level hyperlinks significantly "invite" disoriented users, one would expect the extent to which users invoke that particular mechanism to predict disorientation. Neither frequency nor proportion of top-level mechanism clicks predicted any of the three disorientation measures in the Local Context condition. (Note here that "I generally knew where I was in the Web site" *did* correlate negatively with both the frequency ($r = -0.68$, $p < 0.05$) and proportion ($r = -0.64$, $p < 0.05$) of *home page hyperlink clicks*. Thus, it was the home page link in the top-left corner of the page, just as one might have expected, that was "inviting" disoriented users, not the top-level hyperlinks.)

Thus, it appears implausible that top-level switches cause disorientation, or vice versa. A causal relationship between navigational volatility and disorientation now appears more plausible: "Navigational Volatility → Disorientation." But one still needs an explanation as to why navigational volatility flexed *its* causal power so strongly in the Partial Overview condition but not in the Local Context condition.

The simple and crucial observation is that the distributions of navigational volatility in the two conditions were quite different. In the Partial Overview condition, users encountered a sort of all or nothing change in their navigation options during the experimental session. In making local transitions, the Breadcrumb List mechanism would be altered slightly for a small navigational volatility score, while in making distal movements between sub-sites, the left-column Partial Overview mechanism would present a whole new set of navigation options. In the Local Context condition the changes were more subtle and spread out. Usage of the Sibling List mechanism resulted in a new set of child node hyperlinks, with distal movements resulting in lesser change than in the Partial Overview condition.

A reasonable conclusion seems to be that the all-or-nothing nature of users' navigational volatility distributions in the Partial Overview condition were more noticeable, and more disorienting, than the more subtle and graded changes typically encountered with a Local Context navigation scheme. Moreover, this study provided a way of confirming the noticeable nature of the navigational changes: in the Local Context condition, actual navigational volatility did not correlate significantly with perceived (lack of) navigational volatility, assessed by user agree/disagree ratings for "The navigation options (links) seemed to stay the same as I navigated" ($r = -0.13$, $p = NS$), but *did* in the Partial Overview condition ($r = -0.65$, $p < 0.05$). A key point is: the navigational scheme used will affect the extent to which navigational volatility plays a role in disorientation, based upon the sorts of volatility distributions one can expect as a result of the scheme. The navigational changes, when dramatic enough, make a difference. Notice that navigational habituation now plays a role. The extent to which a user is habituated in a navigation patch may make the changes seem even more dramatic when they do occur, as discussed below.

Site size and complexity: The study results suggest that navigational volatility leads to increased site size perception, but that it has no effect on complexity perception. The result was significant in the Local Context condition, but not in the Partial Overview condition.

Recall that navigational volatility appeared to go relatively unnoticed in the Local Context condition. However, one must distinguish between (1) noticing changes in navigation support, and (2) as a result of those changes, being exposed to a greater variation of information topics in the site, bringing one into the territory of perceived global coherence. One might predict that a site which seems smaller would, conceptually, seem to have a more "compact" set of information topics that are tightly related, and vice versa. However, this is not what happens. A significant effect was not found linking perceived global coherence to perceived site size. Surprisingly, the user's perception of the broad ranging nature of the site, which might be captured by the mean centrality ratings of the post-navigation questionnaire, also failed to predict site size perception.

Model of exploration: Although within and across the Partial Overview and Local Context conditions navigational volatility correlated positively with the extent to which users were in error in estimating their own exploration of the site's main sections, a significant effect was not found. Lateral movements and total unique page visits led to more accurate models, perhaps suggesting that breadth-first strategies have a positive effect.

In general, exploration models are emphasized here as an important area for future research. It is reasonable to believe that the behind-the-door problem remains one of the more crippling effects of poor navigation design. Users will undoubtedly benefit substantially from more accurate models of what paths they have followed and the extent to which they have followed them. Research regarding the extent to which a user's navigation session is volatile appears to be a promising start in this direction.

Perceived global coherence: Interestingly, navigational volatility predicted a low level of perceived global coherence in the Partial Overview condition, but predicted a high level of perceived global coherence in the Local Context condition. The explanation for the Partial Overview condition result was expected, since a highly volatile navigation session, when noticeable, presumably leads users to recognize connectivity differences amongst pages in the space. This in turn may lead them to believe the information topics of these pages are likely less related (in the same way that two people who know different groups of people probably don't know each other).

The results in the Local Context condition are trickier. Distal pairs of Web pages in a site hierarchy typically have relatively different navigational support—that is, relatively different connectivity. Yet the exposure to different navigational support was predictive of increased perceived global coherence; users tended to view the site topics as more tightly related anyway. The most plausible explanation is that exposure to the navigational differences (navigational volatility) allowed users with Local Context support to see connections between distal pages they otherwise would not have seen—and so led them to view such pages as more related. In the Partial Overview condition, such volatility was not necessary to view many of the distal pages as connected, since the Partial Overview mechanism displayed many distal hyperlink pairs together as it was.

Note that the extent to which a navigator views page titles as central to the main topic of the site may measure users' mental models of the site *structure* more so than their perceived global coherence. Participants tended to rate page titles higher in the site hierarchy as more central, perhaps relying on their memory of where pages appeared in the site. Relatedness ratings for pairs of site topics appears to be a more suitable metric, and it is recommended for future studies assessing the concept.

Navigational habituation and predictability: The reader may recall the suggestion that the user's experience with the Web site should be a cause of discrepancy between actual and perceived volatility. Specifically, habituation should lead to overestimation of actual volatility, and predictability should lead to underestimation. The metrics for habituation and predictability did exactly as expected in the Local Context condition. In the Partial Overview condition, habituation did as expected, but navigational predictability did not lead to an underestimation of actual volatility.

The reader will also recall that Partial Overview participants had significantly higher predictability scores than Local Context participants (because they were provided with fewer navigational mechanisms, and therefore were more likely to repeatedly use any given mechanism). A possible explanation is that, given the higher level of predictability of a navigational scheme with a persistent overview, it is not clear a designer could cause users to further underestimate the navigational volatility of their experience with the site. The extent to which users do in fact become habituated within navigation patches and have predictive power at the source pages of transitions remains an open area for research.

Duration of page visit: Although no claims can be made regarding online reading and scanning behavior based solely on click-stream data, the word count of a Web page had a clear impact on the duration of page stay, with longer word count pages resulting in more time spent. Consistent with previous work (Danielson 2002b), users tended to spend less time on a page visited via the Back button, likely due to rapid, successive backtracking and "hub and spoke" behavior (Catledge and Pitkow 1995).

The reader may recall that the design schemes used in this study were presented such that transitional attributes other than navigational volatility were accounted for. Likely as a result, distal movements and top-level switches did not result in more time being spent at the destination page, unlike previous work in which such movements included other visual changes such as new color coding and different content presentation (Danielson 2002b). This study suggests that navigation option changes that occur as a result of a page-to-page transition do not, in and of themselves, cause longer page stays. A possible explanation is that page stay depends more prominently upon initially recognized (i.e., at time of arrival) visual changes, and it has been argued that users tend to look to the page content when first arriving at a destination page (Nielsen 2000).

Generalizability: The applicability of results from this Web navigation study can be considered among four factors:

1. *User*. Participants likely had generally high Web expertise, were not domain experts, and were likely more efficient information seekers than a wider age sample would be. Moreover, the results may be restricted to Western culture, given the heavy use of left-column navigational mechanisms (van Schaik and Ling 2001).
2. *Task*. This study investigated directed search tasks with low complexity. The navigation session imposed some time pressure.
3. *Site*. This study applies to hierarchically organized, relatively small sites, or sub-sites of larger ones. The study may not apply to sites with very similar sub-sites; for example, a university site might have department sub-sites with similar sub-sections (courses, research labs, etc.), and such homogeneity may influence navigational predictability.
4. *Design scheme*. The design schemes used in this study were common to hierarchically organized sites, had generally homogenous screen real estate usage, and were not subject to slow download times. Note that design scheme decisions were generally "by the book," based upon previous research in the field. Sites that deviate heavily from the basic and tested design principles will not necessarily be informed by these results.

These specifications, nonetheless, are indicative of a fairly common circumstance on the Web: general Web experts need specific information on a topic they are generally unfamiliar with, and they navigate within a small hierarchical site or sub-site.

CONCLUSIONS

Navigational volatility, navigational habituation and navigational predictability have been empirically investigated in relation to disorientation and user mental models of a Web site, with the effects of these concepts appearing to interact with the navigational support provided. This study suggests that investigating the extent to which navigation options change as a user moves through a site is at least promising in better understanding the lost in hyperspace phenomenon and Web site mental models.

In order to assist information designers in producing more usable Web navigation support, we must better understand the specific nature of a number of phenomena, particularly: (1) the behind-the-door problem, (2) user models of their own previous exploration of a Web site, and (3) the lost in hyperspace problem.

Prediction of navigational volatility "behind the door" of a hyperlink is only one piece of a larger predictability picture, which includes the extent to which users may predict (1) specific information at a destination page (information prediction), (2) the structural relationship between the source and destination of a hyperlink (destination prediction), (3) specific navigation options at the destination (navigation prediction), (4) the content and design structure of the destination page (content prediction) and (5) content and other design scheme changes from source to destination (content volatility prediction).

The perceived level of transitional volatility appears promising in capturing a general notion of hyperlink predictability. The broader goal may be to precisely determine the set of factors affecting a navigator's ability to map hyperlink attributes at a source page to characteristics of the hyperlink's destination page. As this investigation shows, the factors will not be limited to hyperlink attributes (such as what the link's text snippet itself says), but, rather, will extend to broader contextual factors, such as the sorts of volatile transitions the user has already been exposed to.

One can further anticipate that various types of expertise will play a role in predictability, although the precise role and the extent to which expertise will impact predictive power is not as clear, making for interesting future research. For example:

1. *General web navigation expertise* may allow users to make predictions based upon knowledge of how Web sites are typically organized and designed. For example, they might predict that by clicking on a hyperlink in a top-level navigational mechanism, the local context hyperlinks along the left column of the page will change, since many hierarchically organized sites are designed this way.

2. *Content domain expertise* may allow users to make predictions based upon knowledge of how information in the domain is

structured and interrelated. For example, they might predict that clicking on a "Lost in hyperspace" hyperlink would likely lead to information about disorientation and possibly links to information about navigation design, based on knowledge of the subject.

3. *Site domain expertise* may allow users to make predictions based upon knowledge of how a particular class or genre of sites are typically organized and designed. For example, they might predict that clicking on the name of an author at a bookstore site would lead to a page with a list of books for sale by that author, since many bookstore Web sites are designed this way. (This type of expertise likely overlaps with content domain expertise insofar as the organization and design of a class of sites typically match domain experts' models of the content domain.)

4. *Within-site expertise* may allow users to make predictions based upon previous interaction with a specific Web site. For example, they might predict that within a particular site, clicking on a proper name will open an email editor, since other proper name hyperlinks within the site have done the same.

Attacking the "behind-the-door" problem will likely, in turn, improve user models of their own previous exploration of a Web site. By helping navigators answer questions such as "Where in the site will this link take me?", "How will the page change when I click on it?", and "What information will be available at the page behind it?", it is reasonable to believe we will in turn help them better answer questions such as, "Have I already been there?" and "How much of the path leading from this link have I already seen?"

Predictive power and models of site exploration are primarily combatants to perhaps the oldest (and arguably the most devastating) problem of Web navigation: disorientation. This study suggests that navigational volatility, when noticeable, contributes to the lost in hyperspace phenomenon, and that the perception of such volatility may be affected by users' tendencies to either remain within or frequently move between navigation patches, and by their predictive power at the source pages of invoked hyperlinks.

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APPENDIX A: BEHAVIORAL AND ATTITUDINAL VARIABLES

Behavioral (Click-Stream) Data and Metrics

Variable	*Description*
Navigational Volatility	For each page-to-page transition, the number of hyperlinks appearing on the destination page that did not appear in the same screen location as on the source page. A user's navigational volatility score was the mean navigational volatility across all transitions during the experimental session.
Navigational Habituation	For each page-to-page transition, the number of previous consecutive pages the user had visited within the same main sub-site. A user's navigational habituation score was the mean navigational habituation across all transitions during the experimental session.
Navigational Predictability	For each page-to-page transition, the number of times the user had previously used the same navigational mechanism as the mechanism being used for the transition in question. A user's navigational predictability score was the mean navigational predictability across all transitions during the experimental session.
Total page accesses	Total number of pages visited (including site reentries after task completion).
Unique page accesses	Number of unique pages (out of 100 in the site) visited during the experimental session.
Page revisits	Number of page revisits and the user's revisitation rate (percentage of total page accesses that were revisits).
Duration of page visits	For each page-to-page transition, the amount of time spent at the destination page.
Navigational acts	Number of hyperlink actions taken.
Task completion and abandonment	Number of tasks completed and abandoned.
Navigational mechanism use	Frequency and proportion of navigational acts that were invoked by each navigational mechanism. For example, the number of Back-button clicks and the percentage of the total navigational acts that were Back-button clicks.
Source-destination direction of movement	Frequency and proportion of navigational acts that were: "up" (to a higher hierarchical level in the site), "down" (to a lower hierarchical level in the site) and "lateral" (to the same hierarchical level in the site).

Source-destination relationship of movement	Frequency and proportion of navigational acts for each hierarchical relationship between source and destination: siblings, parent and child, grandparent and grandchild, or "distal" (outside of the immediate hierarchical family).
Hierarchical level of page accesses	Frequency and proportion of page visits to the home page, top hierarchical level, second hierarchical level and third hierarchical level of the site, and the total amount of time spent at each hierarchical level.
Sub-site exploration	The proportion of pages within each of the site's five main sub-sites that were accessed.
Top-level switches	Frequency and proportion of navigational acts for which the source and destination pages of the transition were located in different main sub-sites.

Attitudinal Data

Variable	*Description*
Disorientation	3 agree/disagree scale measures (see Table 3)
Perceived site size	3 measures: two agree/disagree scale measures (see Table 3); and one actual user estimate of the site size (in number of pages).
Perceived global coherence	6 measures: two agree/disagree scale measures (see Table 3); two site topic relatedness measures (user rating for how related a pair of site topics were); and two site topic centrality ratings (user rating for how central a sample of page topics were to the main topic of the site).
Sub-site exploration estimates	User estimates of the proportion of pages within each the site's five main sub-sites that they visited.
Exploration model error	The mean difference between actual sub-site exploration and estimated sub-site exploration for each of the five sub-sites.
Ease of navigation and site organization	5 measures: four agree/disagree scale measures (see Table 3); and one navigation usefulness measure (user rating for how useful the available navigation options were).
Perceived (lack of) navigational volatility	Agree/disagree scale measure for "The navigation options (links) seemed to stay the same as I navigated."
Perceived hyperlink predictability	3 agree/disagree scale measures for: "It was easy to predict where in the site clicking on a link would take me" (destination prediction); "The (underlined) link titles well summarized the information they led to" (information prediction); and "It was easy to understand how the page would change when I clicked on a link" (transitional volatility prediction).