Introduction

While hypertext and the ideas surrounding it have clearly been around for decades (see Bush, 1945; Nelson, 1965), the recent and unprecedented growth of contemporary technologies has afforded and necessitated their exploration, development, and deployment (McKnight, Dillon, & Richardson, 1991). Current estimates of the World Wide Web, the most prominent manifestation of hypertext today, indicate that it is comprised of over 60 million servers housing more than 11.5 billion indexed pages (Gulli & Signorini, 2005). This estimate does not account for content that is not indexable by search engines (e.g., Google), sometimes called the “invisible Web,” which likely exceeds the amount of indexed content by 400 to 550 times (Lyman & Varian, 2000). These statistics reflect a startling 60,000% increase in quantity in less than 10 years.

In conjunction with the exponential expansion of hypermedia content afforded by the Web, there is also an increasing trend in Internet usage. Well over one billion people worldwide actively participate in online activities (Internet World Stats, 2006). The fastest growing segment of the population to embrace the Web is children ages 9 to 17. Internet usage by children and adolescents of elementary and high school age has intensified, rising from about one third of 9- to 17-year-olds in 1997 to about two thirds in 2001 (U.S. Department of Commerce, 2002) to nearly 74% in 2005 (Pew Internet and American Life Project, 2005). Further, survey research shows that 94% of students ages
12 to 17 with home access to the Internet used the Internet for homework. Nearly 71% used the Internet as the primary source for information on their most recent school report or project, while only 24% reported using standard library materials for the same task (Pew Internet and American Life Project, 2001). These statistics indicate not only that the Internet is a prominent learning tool within the classroom but also that digital resources are rapidly overtaking their more traditional counterparts as the primary information sources in K–12 settings.

Combined, the massive explosion of information available as digital resources and the increasing ubiquity of these resources within the classroom have created a shift in what it means to be literate in today’s knowledge society. The computer is more than a medium for the digital transformation of printed resources (J. R. Hill & Hannafin, 2001). Rather, it is a new and ever-evolving context for learning that accommodates a greater variety of learning goals and resources for constructing meaning (D. J. Leu, D. D. Leu, & Coiro, 2005). Citizens in the 21st century must not only know how to decode and comprehend information as they have in the past, but they are also now responsible for efficiently and effectively finding and evaluating information as well as quickly adapting goals in response to the complexities of the environment (Alexander & Fox, 2004; Grabinger, Dunlap, & Duffield, 1997). As such, it becomes clear that online learning both calls on and develops cognitive skills and strategies in addition to those learning apparatuses that are more traditional require (Kozma, 1991; Mayer, 1997; Shapiro & Niederhauser, 2004).

Many have posited that the key to understanding how we learn from hypermedia environments rests within unpacking the mechanisms through which a user selects one link over another to build a path through the terrain of a hypermedia system—in other words, navigation (Alexander, Kulikowich, & Jetton, 1994; J. R. Hill & Hannafin, 2001; Kozma, 1991; Lawless & Brown, 1997). Although navigational skills are critical for 21st-century learning, there is relatively little research compared to other areas in learning. As stated by McKnight et al. (1991), “For an activity that is routinely performed by all of us, navigation is not a well-studied psychological phenomenon in the same way that reading is” (pp. xx–xx). The existing research spans a number of disciplines and methodological approaches, which have shared little cross-pollination. Moreover, each study utilizes environments that vary in terms of domain, structure, and affordances that make transfer of findings difficult.

This chapter attempts to cull these disparate research domains and genres, extracting common findings concerning navigation and its impact on learning. While previous reviews have looked at specific aspects of navigation (C. Chen & Rada, 1996; Dillon & Gabbard, 1998; Lawless & Brown, 1997), the intent of the present analysis was much more broadly defined. Our goal is to provide the reader with a multidimensional review of the continuum of research conducted on navigation across a sundry of digital environments. Using schema...
theory as a framework, we view navigation as an active, constructive process. It is affected not only by learners’ internal knowledge structures but also by the external constraints of the learning environment as well (Kozma, 1991). The following sections of this chapter examine how different internal learner characteristics (e.g., prior knowledge, self-efficacy, and interest) and different external constraints (e.g., learner control, instructional design, and level of control) influence the navigational process. In an effort to extend this research area, we have included a discussion of burgeoning research trends in navigation and their implications for the design and implementation of nonlinear, digital learning environments. Finally, we conclude by providing some recommendations for future research that will help us better understand the skills and strategies involved in navigation and their impact on learning and instruction.

What Is Navigation?

As Whitaker (1998) stated,

> Navigation is a term that describes activities ranging from the first tentative exploration by an infant to the sophisticated calculations and planning which successfully placed a man on the moon. Navigation in its narrow sense means to move through space; in its broader sense, navigation also includes virtual movement through cognitive space made up of data and the knowledge emerging from those data. (p. 63)

Drawn as a parallel between human movement about the physical world and user engagement with electronic environments (H. Kim & Hirtle, 1995), navigation has become the principal metaphor adopted to connote how we interact with hypermedia, the Web, screens of video games, and other immersive and nonimmersive virtual environments (Gamberini & Bussolon, 2001). This basic spatial metaphor has an important influence on how we envision digital environments, what we do when we are using them, and how we design them for others.

The theoretical foundations of the spatial navigation metaphor have their roots in a number of fields. In architecture, the term *wayfinding* has been used synonymously with navigation to account for an individual’s understanding of how to move about the physical space of buildings to select a route, monitor progress along this route, and recognize when the target has been reached (Benyon, in press; Downs & Stea, 1973). Similarly, effective navigation through virtual environments also requires users to know where they are, where they need to go, how to get there, and when they have arrived. Navigation, conceived of in this manner, describes not only the behavioral actions of movement (e.g., locomotion from one destination to another) but also elements of cognitive ability (e.g., determining and monitoring path trajectory and goal orientation; Bowman, 1999; Darken, Allard, et al., 1999; Passini, 1984).
The underlying principles of navigation can also be traced back to early empirical work in cognitive psychology. Tolman (1948) introduced the concept of cognitive maps as a way to interpret experimental findings that rats used some form of internal spatial representation in path selection behaviors. Without cognitive maps, Tolman (1948) argued, rats would not be able to extract relevant cues and ignore the extraneous stimuli to complete navigational tasks successfully. In much the same way, it is hypothesized that humans develop a cognitive map or schema for virtual environments (Dillon, McKnight, & Richardson, 1990). These mental maps contain both generic and situation specific information that facilitate movement and progress, help implementation of appropriate problem-solving strategies, and aid in knowledge acquisition and comprehension (Brewer, 1987).

With respect to digital environments, the spatial navigation metaphor has become widely adopted by researchers and designers. Today, many sites contain site maps and other scaffolds to aid users’ wayfinding and development of cognitive maps. A number of notable differences exist between geographic and electronic worlds that undermine the utility of space as a metaphor for navigation (Boechler, 2001; Dahlbäck, 2003). Physical environments contain a number of useful landmarks that provide information on location and future direction that are often lacking in hypertext. There is also a significant distinction between the notion of distance and scale in the physical world and the digital world. This issue is highlighted when one visualizes the differences in stability and permanence between spatial relationships and conceptual relationships. In the physical world, the Washington Monument will always be situated between the Lincoln Memorial and the Smithsonian Air and Space Museum. The same cannot be said of hypermedia systems, where the landscape is continually changing and new links can arbitrarily be created, making previously distal informational nodes adjacent to one another.

Further, as Dillon and Vaughn (1997) highlighted, “Navigation through semantic space is more complicated than simply acquiring a sense of physical place” (pp. xxx–xxx). That is, the issue of movement through the structure of information presented in a digital environment is not the same thing as finding meaning through the semantic space represented in the author’s discourse. Although these two navigational processes are not entirely disparate, clearly, if we are to understand navigation as a skill/strategy, it has to be tied to both a users syntactic information of navigation behavior (e.g., link selection and sequence) and semantic information during meaning making (e.g., evaluation of information, what and how it is processed; Juvina & van Oostendorp, 2004).

Patterns in Navigation

A handful of studies has attempted to use navigational data (e.g., audit trails, dribble files, and weblogs) to answer the question, How do people move
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around in digital worlds (see Borges & Levene, 1999; Catledge & Pitkow, 1995; Lawless & Kulikowich, 1996). These contributions originate from a variety of disciplinary fields (e.g., psychology, education, computer science, and e-commerce) and span the methodological continuum from qualitative to quantitative. Whether these data have been presented in graphical format or analyzed numerically, it appears that, regardless of the age of participants, the domain of study, or the nature of the digital environment implemented, there are common approaches to navigation. In other words, there are navigational profiles that can be used to describe the movements of subsets of people interacting in hypermedia systems.

Horney and Anderson-Inman (1994) developed a hypermedia environment to supplement the language arts curriculum for at risk learners in two eighth-grade classrooms. The digitally supported text included resources, vocabulary definitions, background information, text glossaries, graphic overviews, pictures, sounds, and self-monitoring comprehension questions. From navigational data of 31 students, event graphs were constructed that provided a visual overview of each student’s interactions with the computer. Classification of these graphs revealed three common reading patterns, or patterns of interacting with the computer and its various resources. Participants reflecting the book lover profile typically read everything in linear form, moving from one screen to the next, and used available resources sparingly. When later interviewed, all of these students expressed a preference for reading from traditional printed texts over the computerized medium. Like book lovers, the studier profile, also viewed every screen. However, these individuals employed additional navigation techniques such as backward navigation for reviewing and checking and more frequent use of comprehension monitoring resources. These students indicated that the resources facilitated their understanding of the material. Finally, the last type of hypertext reader was coded as a resource junkie. Students of this type reported being excited by the resources provided, particularly by computer-generated speech. It is the resource junkie whose navigation patterns and strategies were the most varied and complex.

Lawless and Kulikowich (1996) used a cluster analytic technique to reduce navigational data into three profiles: (a) knowledge seekers, (b) feature explorers, and (c) apathetic hypertext users. Knowledge seekers characterized those users who pursued information related to the content topic, typically navigating toward screens that contained material that would enhance comprehension. These navigators tended to be more strategic, in that they selected logical sequences of screens, acquiring information in a systematic manner. Feature explorers spent a disproportionate amount of time interacting with the bells and whistles within the environment such as the sound effects, movies, and animations. These individuals invested more time in understanding what kinds of features the environment contained than in trying to gather important information aiding comprehension. Finally, the apathetic hypertext
users engaged with the environment on a very superficial level. They spent very little time navigating and visited a limited number of screens. Their navigational paths tended to be very linear, and indicated that they took the quickest and shortest route through the environment. In subsequent replications of this investigation, which varied in terms of education level of students (Lawless & Kulikowich, 1998), domains of study (Lawless, Mills, & Brown, 2002), and complexity of the computerized environment (Barab, Bowdish, & Lawless, 1997), similar navigational profiles emerged.

MacGregor (1999) triangulated data sources including navigation selections, verbal report and video transcriptions of 10 students (4 seventh graders and 6 eleventh graders) interacting with a science-based, instructional hypermedia system. Using a constant comparative approach, MacGregor (1999) isolated three navigational profiles that were labeled sequential studier, video viewer, and concept connector. However, although each student had a dominant profile that lead to their classification, most of the students used one of the other navigational styles at least once during their session. The sequential studier methodically selected all of the nodes on a particular screen, usually from left to right or top to bottom, before moving onto the next screen. In addition, the sequential studier spent more time on average with each object within the environment than other types of navigators. By contrast, video viewers were primarily interested in the video nodes (still or full motion). These individuals spent about 83% of their time in the environment viewing such resources with little cross-linkage of other modalities. The concept connector was the most flexible navigational profile. These students read carefully at times, skimming at other times, and moved back and forth between text and graphic objects. MacGregor (1999) concluded that only some learners were able to take advantage of the nonlinearity and resources offered by the hypermedia format and that the patterns revealed different motivators attracting students as they navigated through the medium.

More recently, resurgence in the study of user navigation has emerged from the fields of information and computer science. Juvina and van Oostendorp (2004) examined the behavior traces of users’ navigation through a personal finance Web site. Using an automated technique for extracting navigation data (e.g., path length, time deviations, etc.), a principal component analysis yielded a four-component solution explaining approximately 86% of the variance in navigational scores. The first of these navigational styles was dubbed flimsy navigation. Users with high scores on this component visited very few pages and did not venture far from the homepage. It was described as a very parsimonious navigational profile, revealing little exploration or nonlinearity. Those individuals that aligned with the content focus approach were deemed the readers, selecting pages with a large amount of text-based content. Furthermore, these individuals not only sought out those types of pages but also allocated time to process them in depth. Laborious navigators intensively
used the navigational options availed to them. They were characterized by the high number of back buttons and page revisits selected. Finally, Juvina and van Ostendorp (2004) identified a fourth profile, divergent navigation. These navigators were the explorers, visiting the highest number of unique pages with little or no revisitation to previous sections. In a follow-up study, Herder and Juvina (2004) isolated similar navigation profiles and indicated that understanding these profiles and accounting for them in the design of an environment is a promising means of alleviating a user's sense of perceived disorientation in cyberspace.

While each of the studies previously summarized varied in terms of participants, digital environment explored, and methodological approach taken, the findings combine to reveal a common trend highlighting the existence of multiple dominant navigational profiles among users. Across all studies, researchers found one group of navigators that focused on comprehending information, one group that played with the special features, and one group that forced a linear structure onto the nonlinear environment. What is curious about this common finding is that only one study, conducted by Lawless and Kulikovich (1996), included a reference to another in the set (Horney & Anderson-Inman, 1994). This fact may be interpreted by some as an indicator of convergent validity, multiple studies conducted in isolation from one another revealing the same findings. However, one may interpret the lack of cross-referencing among these studies as an indicator of poor communication across academic disciplines conducting research in navigation. This not only narrows our understanding of navigation, but it also clearly contributes to a large amount of redundancy in research efforts.

**Influences on User Navigation**

While research pertaining to navigation confirms the existence of common navigational patterns, it fails to provide an empirical explanation as to why these different profiles emerge. Knowing that a particular navigational pattern exists does not mean that we understand its impact on task completion or learning from a hypermedia system. The volume of constructs that explain variability in navigational performance and its mediating impact on learning is overwhelming (Juvina & van Oostendorp, 2004). To a certain extent, however, they converge around three primary components: (a) attributes of the user, (b) characteristics of the environment, and (c) features of the learning activity or context. Each of these dimensions is delineated in greater detail in the sections that follow.

**User Attributes**

Individuals vary in their aptitudes for learning, their willingness to learn, and the styles or preferences for how they learn if they choose to do so. These cognitive and affective differences impact both the learning process and outcome
for each student. That is, learner traits determine, at least to some degree, if and how well any individual is able to learn (Grabowski & Jonassen, 1993).

**Prior knowledge.** Prior knowledge can be defined as any related knowledge that an individual brings to a learning situation that may or may not aid in acquiring information or understanding (Alexander & Judy, 1988; Anderson & Pearson, 1984). A very large pool of research examining the influences of prior knowledge on learning from print-based resources has indicated that learners with greater preexisting knowledge about a topic generally understand and remember more than those with more limited prior knowledge do (Chi & Ceci, 1987; Glaser, 1984; Schneider & Pressley, 1997). Prior knowledge has further been shown to bias the learning of new material and significantly influence one’s actions in a given learning situation (Dochy, Segers, & Buehl, 1999; Thompson & Zamboanga, 2003).

When examining the impact of prior knowledge on navigation, similar trends are apparent. More knowledgeable users within a domain tend to focus on specific topics within a system (Carmel, Crawford, & Chen, 1992; Dillon, 1991), explore these topics in greater depth (Chen & Ford, 1998) and move more nonlinearly through the information space (Eveland & Dunwoody, 1998; Lawless, Schrader, & Mayall, in press; Recker, 1994). By contrast, individuals with less prior content knowledge tend to navigate toward the bells and whistles of the system (Lawless & Kulikowich, 1996), rely more heavily on navigational aids (Barab et al., 1997; McDonald & Stevenson, 1998) and are more predisposed to be being disoriented or becoming lost (Hammond, 1989; Last, O’Donnell, & Kelly, 2001; Rouet & Levonen, 1996). Combined, it appears the novices within a domain often lack the conceptual structure of the content area needed to orient their interaction or mediate their navigation (S. Y. Chen, Fan, & Macredie, in press).

It is also important, however, to remember that there are multiple domains of prior knowledge that can influence a user’s navigation. How much a user understands about a particular environment, how it works, and what information it contains can all have an impact on what selections are made within that environment, in some cases, even more so than domain expertise (J. Hill & Hannafin, 1997; Mitchell, Chen, & Macredie, 2005). Lawless and Kulikowich (1998) measured both prior knowledge of the content domain as well knowledge of hypermedia. They found prior knowledge of the content significantly contributed to the knowledge seekers profile, while knowledge of the technology predicted the feature explorers group (see the previous section for a description of these profiles). Other research has illustrated that technology-based prior knowledge is directly related to the nonlinearity of the navigation path (Gerdes, 1997; J. Hill & Hannafin, 1997; Pazzani, 1991; Reed & Oughton, 1998). That is, as one’s knowledge of the system increases, the greater the flexibility in movement through the environment.
Research has further indicated that, because of the relationship between prior knowledge and navigation, learning outcomes are influenced (Lawless, Brown, Mills, & Mayall, 2003; Lawless & Kulikowich, 1998; Lawless et al., in press). A number of studies have illustrated that individuals with greater domain expertise not only adopt different navigational styles than less knowledgeable learners but that their selections are also more efficient and effective, resulting in better comprehension of material (Dee-Lucas, 1999; McDonald & Stevenson, 1998; Mohageg, 1992; Wood, Ford, Miller, Sobczyk, & Duffin, 1996). Similar findings have been documented with respect to prior knowledge/experience with computers. Borgman (1986) found that training a user on a system’s architecture prior to use allowed the user to develop a better mental representation of the information space leading to greater success in completing learning tasks. These findings are consistent with the long history of research on traditional learning environments, indicating that more prior knowledge one has, the better this individual can employ strategies that lead to successful learning outcomes (Alexander, 1992; Alexander & Judy, 1988).

Metacognition. Conklin (1987) contended learning within a hypermedia system depends not only on individuals’ prior domain or system knowledge but also on the learners’ ability to successfully allocate and monitor cognitive resources. Learners must understand how to get from one location to the next; they must figure out and remember the navigational tools used; and they must read, comprehend, and be able to use the information they apprehend in order to complete a task or direct navigation toward that end. While the freedom to derive a personal path through hypermedia is touted as one of the great strengths of the medium over print-based resources, some have suggested that this places an added level of cognitive burden on learners (Patterson, 2000; Shapiro & Niederhauer, 2004). This added level of complexity demands greater use of comprehension and regulatory learning strategies to ensure success (Jul & Furnas, 1997; Marchionini, 1988). Yet, students often lack sufficient metacognitive awareness and comprehension monitoring skill to make effective navigational choices (J. Hill & Hannafin, 1997).

While numerous authors have alluded to the link between metacognition and navigation (e.g., Astleitner & Leutner, 1996; Dillon, 1991; Lawless & Kulikowich, 1996; Shapiro, 1998), we could only isolate one study examining individual differences on navigational tasks that directly measured metacognitive skill as a correlate of navigation. Using a metacognitive awareness inventory, Schwartz, Andersen, Hong, Howard, and McGee (2004) found a positive and significant correlation between metacognitive ability and successful navigational outcomes. In turn, both variables were significant predictors of performance on outcome measures of recall. In addition to the Schwartz et al. (2004) study, numerous studies have tested potential metacognitive cueing techniques for aiding navigation, without a direct measure of metacognition
itself. Because these studies are tied to manipulations of the learning environment rather than a user attribute, we will address them in greater detail later within the section pertaining to characteristics of the hypertext environment.

Spatial ability. Because the primary lens for understanding hypermedia usage is based on a spatial metaphor, many researchers have also examined the link between spatial ability (a cognitive characteristic which offers a measure of an individual’s ability to conceptualize the spatial relationships between objects) and navigation through a host of digital environments ranging from large information spaces, database systems, hypermedia, and virtual reality-based environments (C. Chen, 2000). Unlike evidence on other user attributes, findings from this collection of research are not entirely consistent. In their meta-analysis, C. Chen and Rada (1996) found a medium-large effect for spatial ability on efficiency, indicating that spatial ability increased the efficiency of navigation. Others have found that spatial ability predicts more than just efficiency, but also how users move about virtual spaces. Campagnoni and Ehrlich (1989) and Benyon and Murray (1993) independently reported that users with good spatial ability accessed deeper levels of information nodes and implemented more complex navigational strategies than users with lower spatial ability. However, other findings refute these claims. Baylor (1999) hypothesized that spatial-holistic ability would influence perceived disorientation, but the data supported no such link. Similarly, Calcaterra, Antonietti, and Underwood (2005) found no relationship between learning outcomes, spatial ability, and an assortment of navigational constructs (e.g., time spent during navigation, nodes accessed, etc.).

One possible explanation for these incongruous results could be the manner in which spatial ability was operationally defined in each of these studies. For example, Zhang and Salvendy (2001) utilized a battery of factor-referenced cognitive tests to evaluate spatial ability. By contrast, Calcaterra et al. (2005) relied on scores from a self-report questionnaire as a surrogate for spatial ability. From a psychometric perspective, it is difficult to equate these forms of measurement. In order to resolve the issues related to spatial cognition and navigation, more constrained research needs to be conducted that utilizes common measurement techniques.

Cognitive style. Complementing efforts with respect to spatial attributes, researchers have conducted extensive research on the cognitive styles of learners (Calcaterra et al., 2005; S. Chen, 2002; S. Y. Chen & Macredie, 2002; C. Chen & Rada, 1996; Chou & Lin, 1998; Graff, 2005; K. Kim, 2001a, 2001b; Shapiro & Niederhauser, 2004). Predominantly, researchers have defined cognitive style in terms of field dependence and field independence. Field dependent learners are said to rely on social or external frameworks for structuring and processing information. By contrast, field independent learners exhibit
more autonomous behaviors and are more able to develop internal referents and knowledge structures.

S. Y. Chen and Macredie (2002) asserted that there is a significant relationship between cognitive style and nonlinear learning, learner control, and navigation. From their findings, field independent learners were better able to construct meaning in unstructured environments. Further, field independent learners are also able to create their own internal representations of the knowledge space with greater facility than field dependent learners, leading to more focused navigational techniques. On the contrary, field dependent learners lack the necessary cues and structure to perform well in these types of environments, and often exhibit more disorientation. In a meta-analysis of empirical studies on navigation, C. Chen and Rada (1996) found a small overall effect for cognitive styles on effectiveness and efficiency, indicating that cognitive style does influence navigation along these dimensions.

Motivation and affect. As Pintrich and Schrauben (1992) reminded us, learners are not coldly cognitive. Both a person’s internal and external motivations for learning in a particular domain or instructional environment can greatly affect their performance (Alexander et al., 1994; Krapp, Hidi, & Renninger, 1992; Schiefele, 1992) and have been found to influence the amount of time and attention a student will devote to a particular learning exercise (Garner, Gillingham, & White, 1989; Hidi & Baird, 1986; Tobias, 1994). With respect to navigation, Dillon (1991) found that an individual’s navigation decisions aligned with their self-reported areas of interest. This relationship between navigation and field specific interest has been replicated in several other investigations (Barab et al., 1997; Lawless et al., 2002; Mills, Lawless, Paper, & Kulokowich, 2002).

A set of studies by Lawless and Kulikowich (1993; 1996; 1998) highlighted the influence of situational interest (e.g., interest in external, transient features of the learning context) on navigation. They posited that the additional features of a computerized text, such as movie and sound effects, would be highly situationally arousing. Results indicated that those students with the highest situational interest ratings had the lowest recall scores. The authors attribute this finding to the fact that these readers spent considerable time interacting with digitized embellishments in the environments at the expense of informational nodes required for comprehension of the material. As computers are becoming more widely used for instructional delivery, however, motivation that results from these novelty effects will likely disappear (Keller, 1997; Keller & Suzuki, 1988; Song & Keller, 2001).

Finally, self-efficacy, or one’s belief about his or her ability to plan and execute a specific behavior (Bandura, 1997) and has been shown to be an excellent predictor of student achievement across a sundry of domains (Owen & Froman, 1992; Schunk, 1989) including learning with and from computers.
(Smith, 2001; Webster & Martocchio, 1993). With respect to navigation, macrolevel findings indicate that higher levels of computer self-efficacy are linked to navigational persistence (Murphy, 1988), ease of navigation (Agarwal, Sambamurthy, & Stair, 2000; Ventatesh, 2000) and the selection of more efficient and appropriate navigational strategies (M.-J. Tsai & C.-C. Tsai, 2003). Taking a more microlevel lens, self-efficacy has also been shown to predict the types of individual nodes a user selects, with low-self efficacious navigators displaying an overreliance on the help and support features in a digital information space to aid their navigation (Barab et al., 1997).

**Text Characteristics**

It has been long argued users’ individual experience depends on the configuration of the digital environment (Alexander et al., 1994). In addition to variability among users, each unique arrangement of content, organizational scheme, and enabling scaffolds also impacts the nature of navigational artifacts. In fact, design considerations have often been found to counteract or neutralize many of the individual differences among learners with respect to quality and ease of navigation.

**Domain structure.** Several researchers have highlighted that the manner in which individuals acquire and process information in well-structured domains is different from the way individuals accomplish these tasks in more ill-structured domains (Lawless & Kulikowich, 1996, 1998; Spiro & Jehng, 1990; Spiro, Vispoel, Schmitz, Samarapungavan, & Boerger, 1987). Well-structured domains, such as mathematics or statistics, for example, tend to be more algorithmic or rule based in nature (Alexander, 1997; Kulikowich & DeFranco, 2003). By comparison, domains like psychology and history have been termed *ill structured.* They tend to employ heuristics as procedures and exist as multidimensional composites of other domains. Spiro and Jehng (1990) purported that the more ill structured a domain the more nonlinear the cognitive processing will be (Spiro et al., 1987). This hypothesis is based on the notion that these individuals must acquire associations between different pieces of information in a flexible environment so that connections between disparate schemata can be formed. As such, learners need to be able to explore a domain strategically, from multiple perspectives, in order to study potential relationships (Wittgenstein, 1953). It follows that students would navigate a digital environment representing an ill-structured domain more strategically, seeking out information-based nodes, and comparing and contrasting related screens, in an attempt to discover information linkages and build mental representations.

Some research has supported this view (Lawless & Kulikowich, 1998; Niederhauser, Reynolds, Salmen, & Skolmoski, 2000). However, Spiro et al. (1987) offered cautionary notes on implementing design manifestations of this principle. While an ill-structured domain may lend itself more to easily to
nonlinear digital exploration, too many navigational demands on the subject
can lead to increased disorientation and too few can lead to misconceptions
that arise out of oversimplification. Developers must attend to not only the
structure of the domain but also to the overall organizational structure and
complexity of the digital representation of the content as well.

Site maps and overviews. Researchers have evaluated several methods to enhance
available tools used to interact with and organize information in the digital
context (Boiling et al., 1998; Calisir & Gurel, 2003; Chou & Lin, 1997, 1998;
Cress & Knabel, 2003; Danielson, 2002; Jonassen & Wang, 1993). Much of
this research has been conducted under the premise that a reduction in cog-
nitive load effectively decreases metacognitive demand on the user, thereby
improving such factors as navigational performance (speed, accuracy, number
of pages accessed, and recall) and comprehension. Typically, in the literature,
navigation behavior, navigational errors, and disorientation have been used as
proxy measurements of cognitive load (Astleitner & Leutner, 1996; Brünken,
Plass, & Leutner, 2003).

Cockburn and Jones (1996) argued that the majority of navigational issues
derive from contextual inadequacies. To counteract this, many designers have
introduced navigational scaffolding techniques (e.g., site maps; Chou & Lin,
1997, 1998; Danielson, 2002; Puntambekar, Stylianou, & Hubscher, 2003;
Schroeder, 1994). Cockburn and Jones (1996) suggested that site maps or
other visual aids are invaluable in minimizing memory load, enriching the
development of a global mental model of the information space depicting the
relationships between pages and their content. As a result, researchers have
investigated the link between various forms of site maps (e.g., visual, hierar-
chical, spherical, and dynamic) and their theorized value to user orientation,
wayfinding, and learning.

Schroeder (1994) found that users had difficulty internalizing the structure
of the site map and exhibited lower levels of performance when using embed-
ded text links. Schroeder asserted that this might explained by the novelty of
the Web combined with the need for some level of navigational expertise or
at least proficiency. Considering the findings of later studies, this seems to be
the case. For example, Chou and Lin (1998) found that within the context of a
complex hypermedia system, site maps had a significant positive influence on
performance (e.g., search steps, efficiency, and task completion).

Puntambekar et al. (2003) incorporated external graphical and text-based
navigation prompts into a hypertext system pertaining to scientific concepts.
The cues (concept maps) updated dynamically as the user navigated through
the system and were intended to increase a user’s metacognitive awareness.
Puntambekar et al. found that the support structure facilitated students’
detailed investigation of content. Although there was no significant difference
in overall knowledge, students examined adjacent and adjoining information
with greater frequency and depth. Similarly, de Jong and van der Hulst (2002) found no significant difference in declarative knowledge across three treatment conditions—(a) visual, (b) hints, and (c) control—but reported significant gains in procedural knowledge and overall knowledge of the system and structure. They argued that graphical map participants did not necessarily show better recall of the content, but exhibited enhanced knowledge of the overall structure and quality of navigational decisions beyond the gains normally attributed to the intervention.

Providing users with a bird’s-eye view of the information space has also been found to facilitate information seeking tasks, prompted deeper investigation, diminished the use of the backward navigation (back button), improved local branching, and offered a better conceptual indication of their location (Danielson, 2002). Further Danielson’s findings suggested that the integration of a site map allowed users to understand content in their immediate virtual vicinity and allowed them to circumvent redundant visits to content.

Hypertext structure. The organization and intratextual linkage of information is one salient feature of hypermedia that has prompted researchers to explore the nature of navigation performance within the scope of specific hypermedia and encompassing contexts. The structure of information and context evidently are of seminal importance, and as a result, much of the research has been dedicated to understanding the influence of hypermedia structure on navigation and learning (Shapiro & Niederhauser, 2004).

A recurring theme in the literature seems to be that nearly all of available hypermedia structures are appropriate, at least some of the time. For example, Donald and Stevenson (1996) found that users that had experienced the linear hypermedia structure outperformed users of a nonlinear hypermedia environment. In contrast, Barab, Young, and Wang (1999) suggested that among other things, a nonlinear or generative hypermedia (one that requires user input) is more conducive to the users’ goal formation, which in turn, positively influences problem solving and self-determination. In their review of the literature, Shapiro and Niederhauser (2004) expanded on this topic considerably. It follows that like so many other issues associated with hypermedia, there is no consistent, universal design strategy that meets the navigational needs of a true heterogeneous population. Even so, many commonly applied educational contexts demonstrate benefits of one structure over another.

One such context is a hierarchical site structure and similarly designed navigational tool evaluated by Zhang and Salvendy (2001). Zhang and Salvendy examined the site and tool as it interacted with visualization ability pertaining to navigation and information access. They found that both high- and low-visualization participants showed a significant increase in navigational efficiency (identified items and fewer steps) when using the hierarchical site structure. The nature of the task in Zhang and Salvendy’s experiment pertained to
performance and memory organization when participants performed information search tasks. In this context (e.g., the retrieval of information), evidence supports the use of hierarchical structures for this and similar tasks.

Shapiro (1998) conducted an investigation of 72 undergraduate students as they used one of three hypermedia digital book formats (control or traditional text, loosely structured, and highly structured). She found that the internal representations were significantly influenced because of the hypermedia system. The results indicated that navigators of a loosely structured hypermedia system showed a significantly better recall on an essay posttest than those in a highly structured context. However, Shapiro indicated that there were no significant increases in knowledge gains among the groups.

The issue and relevance of hypermedia structure increases in complexity when individual user differences are taken into account. For example, Calcaterra et al. (2005) found a link between cognitive style, hypermedia structure, and navigation. Specifically, verbalizers visited more pages in a hierarchical condition whereas imagers visited more pages in a relational condition. In an independent study, Lin (2003a) found that older users of the Web experienced more disorientation and navigation difficulty when using referential and mixed hypermedia structures. Lin (2003b) argued that this was due to the overwhelming degree of control over more complex hypertext systems and that for older users a hierarchical structure was superior in facilitating navigational decisions. In addition to age and cognitive style, Schoon and Cafolla (2002) showed significant differences between the ways males and females navigate loosely structured Web sites. Specifically, females on average exhibited greater difficulty in locating closed-task information within Web sites constructed using an ambiguous or arbitrary structure. However, Schoon and Cafolla acknowledged that although experience was not shown to be a significant factor in navigation, the females in the study reported less experience with the Web than their male counterparts did.

Although the empirical research seems at odds with itself, these findings demonstrate important consistencies with the literature on support strategies (site maps and overviews). The results associated with support strategies indicate that the nature of the support system has little bearing on declarative knowledge but has a significant influence on knowledge structures and deep contextual meaning. Similarly, research on system structure indicates that while there is little evidence to support an influence on factual knowledge (declarative), there is a significant influence on the learners’ ability to arrive at a deeper contextual meaning. Taken collectively, the literature suggests that for differential goals, a complementary set of structures and support strategies is appropriate.

**Design issues.** Although disheartening with respect to a single design principle, the previously mentioned findings indicate that hypertext developers are some-
what better equipped to construct meaningful, virtual learning environments. Further research into the nuances of hypertext design has been conducted. From a microlevel, there is ample opportunity to manipulate the hypertext environment in terms of button placement, text cues, the addition of sound, or other changes intended to facilitate navigation. We have already reviewed some of these changes on the scale of menu and text structure. Those findings indicate that global changes are not advised unilaterally without regard for the target population or the context in which learning takes place. Research on microlevel design decisions reveals similar findings of interest, although it is evident that designers do not always agree.

A relatively early pair of studies conducted by Boiling et al. (1996) examined the functional difference between abstract, text based, and mixed navigational cues. In their first study, Boiling et al. examined a sample of buttons from 130 readily available HyperCard stacks and designers’ disposition to those navigational functions. They found that designers of shareware were at times highly consistent and at times very inconsistent in their use of buttons for navigation. For example, there was 100% agreement when an arrow pointing right was used to indicate a next function. There was, however, considerably less agreement (46%) what an up arrow signified. In their second study, Boiling et al. examined different classes of buttons (concrete or abstract) on a group of 1st-year graduate students. Participants exhibited significantly fewer errors in navigation when using concrete iconic representations as the button strategy (miniatures of the target destination) when compared to participants using an abstract strategy (arrows).

In a subsequent investigation, Boiling et al. (1998) contrasted representations of navigation buttons commonly found in hypertext and hypermedia programs. Each button (e.g., back, main menu, next, quit, etc.) was displayed in one of three conditions, text only, pictorial only, or pictorial and text. Boiling et al. found that in contrast to their earlier study, combining text and pictorial representations corresponds had a significant influence on navigation. Participants who used buttons with text only and text and pictures made significantly fewer errors than participants who used pictorial navigation alone. Taken collectively, these studies indicate that designers should utilize concrete semantic representations for buttons to facilitate navigation.

Context/Task Characteristics

Research with traditional learning environments has shown that the nature of the task and the goals and personal intentions that a user adopts, all set the context for how a user interacts with an instructional resource (RAND, 2002). The research reported in the following section highlights that these findings also influence what, when and how a user accesses online resources, impacting their overall navigational strategy.
Task goals. In classroom settings, students’ engagement with electronic information spaces such as online catalogues or the Web are often dictated by a teacher or instructor and are typically limited to one of two tasks: searching or browsing (Lawless & Brown, 1997). Searching is characterized as a process in which a user enters a request via a query and the system must locate information that matches or satisfies the request (H. Chen, Houston, Sewell, & Schatz, 1998). The success of the search process is directly related to the efficiency of the information acquisition. As such, search based exploration is limited to techniques that positively impact the success of the search (Binder, 1989), and have the tendency to be much more linear (Lawless & Brown, 1997). Navarro-Prieto, Scaife, and Rogers (1999) indicated that users with more search experience plan in their searching behavior while novice searchers hardly plan at all and are driven by what they see on screen at any given moment in time.

Behavior characterized as browsing affords more freedom to explore areas of personal interest. Marchionini (1995) delineated between two types of browsing: directed and undirected. Directed browsing occurs when the user is systematic, focused, and directed by a specific object or target (e.g., scanning a list for a known item). Like searching, navigation with a directed browsing goal tends to be direct and linear; there is a clear objective to be obtained from the inquiry activity. By contrast, undirected browsing is characterized by the lack of any particular goal or focus (e.g., Web surfing). The open-ended nature of undirected browsing necessitates a great deal of self-management to help determine which selections will heighten comprehension. As such, navigational sequences from these tasks can appear to be haphazard and random (Kozma, 1991; Park & Hannafin, 1993) and are reflective of little prior planning (Marchionini & Shneiderman, 1988). While skills necessary for query-based searching tend to require considerably more experience to perform well (Pollock & Hockley, 1997), skills related to browsing individual Web sites seem to be available to users with minimal training (Hurtienne & Wandtke, 1997).

To study the effect of task selection on navigation, Barab et al. (1996) randomly assigned participants to one of two treatments with differing learning goals: a general study goal linked to post test performance and a problem-solving goal linked to finding an appropriate solution to a particular scenario. Both groups of users interacted with the same hypermedia system. Analysis indicated that navigational variables such as time, number of screens visited, and order of selection successfully predicted treatment group membership. The problem-based group approached navigation efficiently and comprehensively when compared to the group with a general learning goal. Based on the findings, different tasks restrict the affordances and utility of links and nodes within the environment and elicit unique patterns of navigational selections.
Curry, as part of the Hypertext Research Group (1999) found that a task goal also affects a user’s mental representation of the global information space. Participants received either a general browsing goal or a problem-solving goal that required the identification and synthesis of several distinct bits of information. After interacting with a hypermedia environment based on Lyme disease, participants provided a concept map of their mental representation of the information space. Participants’ concept maps generally fell into two distinct structures: hierarchical and relational. Hierarchical maps contained main idea nodes with subordinate ideas listed in the following section (replicating the actual environment), whereas relational maps contained unique links between nodes that did not exist in the original text (representing mental associations between information units). The problem-solving group constructed significantly more relational links than the learners with the general browsing goal. Thus, participants with a specific learning task seem to be better able to make their own unique connections within the material. With respect to navigation, those in the problem-solving task tended to be more nonlinear than the browsing group. These results would seem to indicate that, in the absence of a learning goal, readers’ conceptualization of an information space and resulting navigational selections are less integrated than users operating under a specific goal.

**Personal intentions.** Unlike user attributes and text characteristics, which are primarily static, learners’ intentions are continually created and revised during the process of knowledge acquisition and problem solving and arise from the interaction of the individual and the environment (Young, Kulikowich, & Barab, 1997). A change in users’ intention corresponds with shifts in navigational strategies, influencing the direction of linking behavior (Bates, 1989). The navigational path can be thought of as an in situ manifestation of a user’s moment-to-moment intentions. Users act on hyperlinks, images, or other navigational objects that are perceived as being most similar to the representation of their current intention (Kitajima, Blackmon, & Polson, 2000). For example, when navigating through a hypertext, an individual can discover a particular node that peaks their interest and maintains their attention. Known as the serendipity effect (Kuhlen, 1991), this increased motivational state makes the user likely to change their navigation strategy and to lose sight of their prior intention (Cress & Knable, 2003). While the serendipity effect may increase incidental learning, it tends to weaken the efficiency of navigational processes and can lead to disorientation. Further, with higher levels of task difficulty, less distractibility can be observed, whereas for low levels of task difficulty the presence of a competing intention leads to an increase in error rates and the amount of time spent on irrelevant information (Gerjets & Scheiter, 2003).
The Future of Navigation in Cyberspace

While the learner has a certain degree of control in a hypertext environment (e.g., over their path), the author is given ultimate control over the design and implementation of the navigational framework by predetermining the intratextual and intertextual links between nodes (Beasley & Waugh, 1995; S. Chen, 2002; Lawless & Kulikowich, 2006). Implementing a unilateral, intracetable navigation structure across heterogeneous populations of users can be viewed as nothing short of problematic. As reviewed in the earlier sections, variables like prior knowledge, field dependence, spatial ability, and experience have been shown to influence the construction of meaning in hypertext environments (Calcaterra et al., 2005; S. Chen, 2002; Lawless & Brown, 1997; Shapiro & Niederhauser, 2004). As a solution to these and other issues, researchers have begun to investigate adaptive navigation schemes that track (actively or passively) the differential abilities and needs of users while customizing a page’s navigational support tools (Brusilovsky & Maybury, 2002; S. Chen, 2002). The overall goal of adaptive navigation is to improve usability of hypertext by building “a model of goals, preferences and knowledge of the individual user and use this throughout the interaction for adaptation of the hypertext to the needs of that user” (de Bra, Brusilovsky, & Houben, 1999, p. 2). In essence, its intent is to help relieve cognitive load placed on learners by dynamically supporting navigational decisions.

Work on adaptive navigation within the human-computer interaction (HCI) community has also experimented with social navigation algorithms (Brusilovsky, 2004). Social navigation is an approach to categorizing, collecting, and filtering information on the Web. It is based on propagating word-of-mouth opinions and recommendations from trusted sources about the qualities of particular items (Malone, Grant, Turbak, Brobst, & Cohen, 1987; Maltz & Ehrlich, 1995; Shaldanand & Maes, 1995). For example, if deciding on a new restaurant, one would probably ask friends or look at a restaurant guide. This same premise applies to social information filtering and holds promise for constraining and facilitating navigational choices (Maltz & Ehrlich, 1995; Shaldanand & Maes, 1995).

In general, social filtering systems approach the problem by estimating the desirability of items under consideration. Desirability can be inferred explicitly by directly soliciting data from users about the quality of items through rating scale items (Herlocker, Konstan, Borchers, & Riedl, 1999), but it may also involve detailed annotations about the resource (W. Hill, Stead, Rosenstein, & Furnas, 1995) and general user demographic information. Desirability estimates can also be inferred implicitly by leveraging information collected for other purposes, usually as a by-product of user navigational actions (Herlocker et al., 1999). For example, the system might infer that desirable items
are used more frequently or more recently (Recker & Pitkow, 1996). By providing pointers to certain links or object based on explicit or implicit metadata generated from a group of like-minded users, the cognitive burden associated with the overwhelming amount of resources and navigational decisions are reduced. This in turn, increases the likelihood of finding quality resources and makes effective and efficient navigation more feasible.

The concept of social navigation is still relatively new, however, and a number of issues need to be resolved before its techniques can be implemented on a larger scale across a greater number of communities of practice. For example, the research community is still trying to understand how much and what type of data is necessary to provide pointers that have genuine value to users. Furthermore, social navigation systems are not appropriate for all domains. They tend to be more useful in recommending resources and navigational decisions in fields where a subjective rating is more helpful than an objective rating (Gupta, Digiovanni, Narita, & Goldberg, 1999; Herlocker et al., 1999), where unconstrained search and navigation is not a feasible option (Recker, Walker, & Lawless, 2003), and where a critical mass of users can be culled (Breese, Heckerman, & Kadie, 1998).

While several adaptive and social navigation models have been developed and implemented in small pilot tests, very little work has evaluated their utility for facilitating navigational burden on a large scale (Hoeoek & Svensson, 1999). As programming and design of these techniques become more pervasive, a closer look at how they function, for whom, and under what circumstances must become a more central focus.

Conclusion

For 6 decades, views regarding hypermedia navigation have driven design and research efforts. This chapter has reviewed much of this research, culling together findings from seemingly disparate disciplines. While not exhaustive, a breadth of constructs examining how an individual interacts with these environments to locate, link, and comprehend information has been presented and provides us with a strong foundation for the continued exploration of navigation and its effect on learning. However, we acknowledge that modern incarnations of hypermedia are becoming more complex, involving highly dynamic, changing contexts and 3-D worlds that reside in intricate intertextual niches. These current developments reconceptualize hypermedia and invite new challenges to learning and navigation. As a research community, we must appreciate that these technological evolutions will not stop and that research on these technological advances alone will not be sufficient to garner an understanding of the implications they hold for instruction and assessment. As described by D. J. Leu and colleagues (D. J. Leu, 2004; D. J. Leu, Kinzer, Coiro, & Cammack, 2004; D. J. Leu, D. D. Leu, & Coiro, 2005), we must also strive
to understand the ways in which the 21st century citizen adapts in response to
the complexities of these environments.

While we have accrued a substantial fund of knowledge in the area of navi-
gation, there is still much that we do not know. For example, we have little
evidence of the combined impact of user and text attributes on navigational
ability or how these relationships may vary based on the task in which the user
is engaged. An integrated model of navigation needs to be developed that can
serve as the basis for assessing and comparing navigational performance. By
better being able to determine what a user’s capabilities are, we will be better
situated to build learning environments and instructional interventions focused
on facilitating and improving users’ navigational skills and strategies.

We also do not know how much of the closed-media research reviewed here
will readily transfer to more open environments like the Web. Research has
indicated that there are new and inherent differences between the closed and
open media (Burbules & Callister, 2000; Coiro & Schmar-Dobler, 2004).
While a CD-ROM, once authored, is immutable, the landscape of the Web
can be altered instantaneously (Dahlbäck, 2003). Further, within a closed envi-
ronment, authorship is limited to one author or a group of authors working
in collaboration. With respect to the Web, however, no unitary regulating body
specifies a set of interface specifications or authorship standards across sites.
Finally, with the increasing ubiquity of embedded frames, pop-up windows,
advertisements, and synchronous communications on the Web, navigational
tasks become demanding multimodal and intertextual activities. Though sig-
nificantly more challenging and dependent on sophisticated tracking tech-
nologies, research must move in this more naturalistic direction, capturing
navigation in the context of authentic use rather than controlled, contrived
environments and tasks.

We must also take a less insular approach to the presentation and use of
research findings. Most of the fields that impinge upon navigation research
have worked primarily in isolation from one another. This lack of commu-
nication across disciplines has impeded research efforts by separating theory
from design, instruction from programming, and system management from
real world implementations. Future investigators need to be aware of the full
range of contributions other disciplines have made regarding navigation and
make a greater attempt to share findings across academic boundaries. If we
are to understand navigation as a multidimensional construct, we need to be
significantly more aggressive in initiating collaborative efforts that exploit the
core areas of expertise among these diverse disciplines.

Finally, a better understanding of how navigation links to learning outcomes
is imperative. While there have been numerous studies examining learning
from hypermedia environments in general (e.g., reviews by C. Chen & Rada,
1996; Dillon & Gabbard, 1998; Shapiro & Niederhauser, 2004), few studies
directly link navigational strategy to an outcome. Where studies have done
this, the unit of assessment has typically been limited to the identification of a particular piece of information as a product of a search task with navigation measured in terms of speed and accuracy (e.g., Bilal & Kirby, 2002; Chou & Lin, 1998; Hölsher & Strube, 2000). Others have used information recall as an indicator of learning (e.g., de Jong & van der Hulst, 2002; Lawless & Kulikowich, 1998; Schwartz et al., 2004). While search success and information recall are important outcomes, they are very simple proxies, not necessarily indicative of the robust levels of knowledge acquisition and learning that hypermedia environments can foster. Because navigation is such a complex enterprise, such basic assessment techniques will not likely help capture the true nature of the relationship between process and product. In the future, we need to be more creative and adventurous in developing outcome measures that encapsulate a much broader definition of learning.

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Research on Navigation in Digital Environments


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