

The effects of web-based instruction navigation modes on undergraduates' learning outcomes

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ABSTRACT

The purpose of this study was to examine whether matching navigation mode of a learning environment with learners' preferred navigation mode would facilitate their learning in a web environment. Sixty-eight undergraduate students were randomly assigned to treatments (linear vs. nonlinear navigation mode) and received four criterion tests designed to measure different educational objectives immediately after interacting with the instructional material about human heart. The results suggested that matching or mismatching navigation mode of the learning environment with learners' preference did not lead to significant differences in learning outcomes. However, there were significant differences in achievement between groups with different navigation mode preferences. Our findings indicated that students preferring nonlinear navigation had significantly higher achievement scores on higher levels of learning outcomes. Based on the results of the study, we discussed specific recommendations for instructional designers and the issue concerning matching/mismatching navigation modes with learning preferences.

Keywords

Navigation mode, Undergraduate students, Web-based instruction, Matching/mismatching, Navigation preference

Introduction

Web-based instruction (WBI) has gained considerable popularity in education due to its benefits such as allowing learner control (Laurillard, 1993; Chen, 2002; Alomyan, 2004), providing practice of self-discipline, time-management (Daugherty & Funke, 1998), and 24/7 accessibility (Chuang, 2000). To maximize the educational value of WBI, researchers in this field have been exploring the design and usability of websites. Typical design considerations of instructional websites include navigation tools, response time, credibility, and content (Nielsen, 2000). Among the above considerations, the navigation mode applied in designing navigation tools is an important element since it determines how learners experience the information they need to acquire. It is asserted that the nonlinear capability of the World Wide Web (WWW) has great potential for education because of the opportunities it offers individuals to control their own learning (e.g., Chen, 2002; Alomyan, 2004). Being able to determine what and how to learn also makes the learning experience meaningful to individual learners (Laurillard, 1993). However, some researchers (e.g., Lazonder, Biemans, & Wopereis, 2000) argued that certain learners are not prepared to construct their own learning paths. The question of interest is, "Do all the learners today benefit from the web's nonlinear capability? If not, which types of individuals would or would not benefit from this capability?" Through examining the interaction between web navigation modes and learners' characteristics regarding web navigation, useful suggestions for designing web-based instruction were provided based on the results of this study.

Literature review

Nonlinearity vs. Linearity

Web-based instruction (WBI), taking advantage of the advancement of hypermedia technology, has become a popular alternative to mainstream face-to-face instruction. The potential of WBI has led to the shift of research focus to examining variables that may contribute to the success of this kind of instruction. Research has shown that the

advantage of WBI lies in its affordance of nonlinear interaction (Laurillard, 1993). Nonlinearity of WBI is believed to provide individuals with learning decisions that allow them to control their sequence and pace while learning the target material. In addition, allowing individuals to have control over their learning also makes them more motivated to learn (Keller, 1983).

In a hypermedia/hypertext learning environment, information is organized by various nodes and links. Texts, visuals, or organizational cues are displayed by nodes, while links are used to connect the nodes (Barab, Young, & Wang, 1999). The initial appearance of these nodes and links constitutes a mental cognitive map in learners in terms of the scope and structure of the information to be learned. Linear navigation ensures that the decision relative to information processing is in the hands of the instructional designer rather than the learners. Research has shown that by presenting information more explicitly and structurally, linear navigation presentation makes the material more likely to be assimilated by learners (Dillon & Gabbard, 1998; Meehan & Shubin, 1997).

Hypermedia navigation preference

A large body of research has investigated how individual differences affect students' learning in hypermedia/hypertext environments (e.g., web-based instructional modules) that adopted varied navigation patterns. The individual differences explored include learners' cognitive styles (e.g., Dufresne & Turcotte, 1997; Chen, 2002; Gauss & Urbas, 2003), prior knowledge (e.g., Recker, Ram, Shikona, Li, & Stasko, 1995; McDonald & Stevenson, 1998; Lawless & Kulikowich, 1998; Holscher & Strube, 2000; Last, O'Donnell, & Kelly, 2001), gender difference (e.g., Ford & Miller, 1996; Reed & Oughton, 1997), learner interest/motivation (e.g., Lawless & Brown, 1997; Chou & Liu, 2005), and learners' computer expertise/experience (e.g., Calcaterra, Antonietti, & Underwood, 2005).

In their review examining research on developing a hypermedia learning model, Chen and Macredie (2002) found that cognitive styles played a critical role in affecting students' learning in hypermedia systems. As they also pointed out, *Field Dependence* proposed by Witkin, Moore, Goodenough, and Cox (1977) was the most widely studied example of dimensions of cognitive style—it helps explain learners' preferences in terms of organizing and representing information. According to Jonassen and Grabowski (1993), when encountering information, field dependent (FD) persons tend to accept the existing structure of incoming information, while field independent (FI) persons are more likely to reorganize or restructure the information. Since FIs are more likely and able to impose their own structure, they are more tolerant with ambiguity and uncertainty in learning environments (e.g., nonlinearity in web-based instruction) than FDs. In their study of navigation in hypermedia learning environments, Dufresne and Turcotte (1997) indicated that both FD and FI students found it easier to navigate in linear than in nonlinear environments, given that a linear format was more appropriate for presenting complicated content. However, FD students felt more disoriented than their FI peers, and had problems understanding and remembering information they encountered in the nonlinear environment.

Matching versus mismatching

The era of hypermedia and the development of advanced technology have empowered web-based instructional designers to design learning materials/environments that would optimize students' learning by accommodating various learner differences. Instructional websites with such capabilities were encouraging and attractive in their own right, but the extent to which the custom design can actually be tailored to meet learners' needs remains unclear. Most importantly, learning effectiveness that can be attributed to the design is still open to questions. Past research has suggested that presenting knowledge to learners with an expert's knowledge structure in a hypertext system seems to be beneficial in assisting learners in processing and acquiring that knowledge (Shapiro & Niederhauser, 2003; Su & Klein, 2006). However, an inflexible mapping of expert knowledge structure on learners did not always lead to desirable learning outcome in learning contexts that did not account for individual differences, background, prior knowledge, and other characteristics that usually accompany learning effectiveness and efficiency. On the other hand, learning style (used interchangeable with cognitive style in this paper) and experience also entail problems when the learning environment allows students to proceed at their own pace. Learners might not be experienced enough to choose the most effective routes to go about learning the targeted knowledge (Gall & Hannafin, 1994; Su & Klein, 2006).

Until today, it is still a dilemma for instructional designers creating web-based instruction regarding whether or not the presentation of instructional material should be in accordance with students' learning styles. Although researchers and educational practitioners have urged and promoted the ideas of incorporating differences/preferences of individual users into instructional design tasks, the core issue concerning matching or mismatching of learning and instructional presentation styles should be given top priority over other instructional decision-making considerations.

Pask's work dated back to the 1970s remained to be the most consistent and systematic exploration of the topic concerning matching or mismatching of instructional presentation style and students' identified cognitive styles. In a detailed review of Pask and his associates' studies, Ford (2000) indicated that Pask et al. studies were important because they found consistent and dramatic effects of learning performance that strongly favored the matching of presentation style of material with learners' cognitive style. Pask (1976) identified two approaches that people generally adopt in the learning processes, i.e., holists and serialists. The former learners are more inclined to take a global approach to learning. They develop an overall and general understanding of the scope and structure of learning tasks at hand and gradually shift attention to details that fill in the structure. Serialists, on the other hand, would tackle individual details first, or take so-called "local learning approach" (Ford, 2000, p. 543), connect the separate topics, and finally form the overall picture.

Using complex academic subject matter, including biological taxonomies, the operon, reaction kinetics, and Henry VIII's reign, and two complex as well as learner-demanding tests (i.e., free-learning and teach-back to identify learning styles), Pask's studies found high correlation between matching and mismatching of teaching style and learning style. Pask (1976) concluded that people tended to "... consistently prefer a particular type of learning strategy..." if given a choice and that "... if the teaching strategy is matched to the same type of learning style... the student will learn more quickly and retain the information for longer" (p.132). On the other hand, a mismatched condition tends to result in unsatisfactory performance.

Ford and Chen (2001) explored the relationship between matching and mismatching of instructional presentation styles with students' cognitive styles. The presentation styles included breadth first (a Holist strategy) and depth first (a Serialist strategy); cognitive styles included field dependence and field independence. In their matched conditions, field-independent students worked with the depth-first version of the learning materials while field-dependent students worked with the breadth-first version. The participants in their study were 73 postgraduate students engaging in a task of creating Web pages using HTML. The results suggested that the matched-conditions group had better performance than the mismatched-conditions group only for male students. To some extent, this study provided support for the effect of matching condition on learning outcomes.

Ford (1985) conducted a study to explore if experienced and successful learners, e.g., postgraduate students, identified as having holist or serialist learning style can learn equally well from material designed specifically to suit serialist and holists respectively. Contrary to Pask's instruments used to identify learning style, Ford used a quick and easy questionnaire measure termed "Study Preference Questionnaire." The results agreed with Pask's work. Students, even though as experienced as the ones in Ford's study, cannot be expected to learn equally well from material designed to suit holists or serialists respectively if their learning styles were contrary to the instructional presentation style.

In another study, Ford (1995) investigated the relationship between levels and types of mediation in instructional material and individual differences. Thirty-eight participants were first tested for field dependence/independence using Cognitive Style Analysis (CSA) and then learned a computerized version of Pask and Scott's instructional materials designed to suit either holist or serialist learning strategies. The study found that students in matched conditions performed significantly better than those in mismatched conditions, consistent for both holists and serialists.

In this study, we focused on examining whether matching navigation mode of the learning environment with learners' preferred navigation mode would facilitate their learning in a web environment. The preferred navigation mode was used as an indicator of learners' cognitive style in this research. We selected undergraduate students as participants due to the increasing number of web-based courses for undergraduate students, hence the need to provide instructional design suggestions for web-based courses for this specific population. Additionally, the instructional material used in this study was enriched with animation since it is becoming popular for its capability of enhancing learning in today's web-based instruction.

Specifically, this study aimed to answer following research questions:

1. Is there a difference between matching and mismatching assigned navigation modes in web-based instruction with learners' preferred modes on their learning outcomes?
2. What is the effect of assigned navigation mode (linear vs. nonlinear) of web-based instruction on learning outcomes?
3. What is the effect of learners' preferred navigation mode (linear vs. nonlinear) on their learning outcomes?

Methods

Research Design

This research employed a two-way MANCOVA design. The two independent variables were assigned navigation mode (nonlinear vs. linear) and preferred navigation mode (nonlinear vs. linear). Four criterion measures – drawing test, identification test, terminology test, and comprehension test were utilized to assess the effect of the intervention on the different criterion measures. Participants' prior knowledge of physiology, measured with a 36-item test, was used as a covariate to control for its effect on learning performance. Figure 1 presents a graphic illustration of the experimental design.

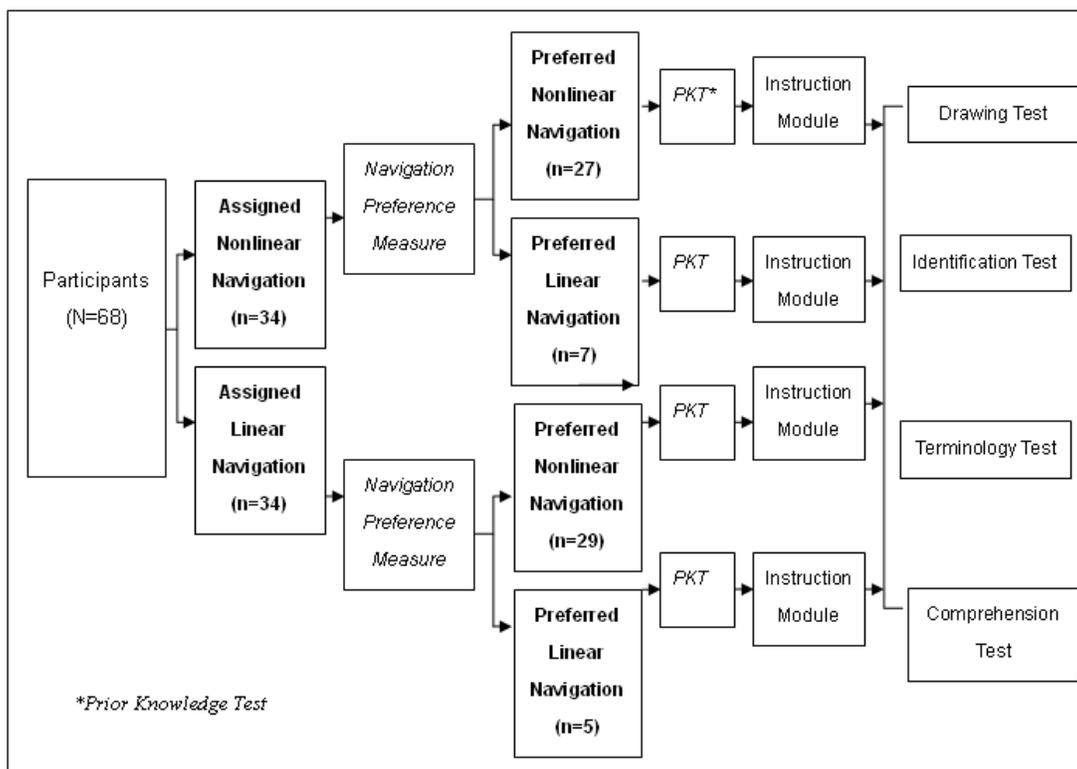


Figure 1. Research design

Instructional material

The instructional material used in the study was an 1821-word unit on the parts of the heart and its functions (Dwyer, 1978). The original materials were developed into a web-based instructional format accompanied by animated visuals to facilitate students' learning of the material. Various animation techniques were used to provide dynamic illustration of concepts that were difficult to comprehend. Some examples are progressive reveal, motion, pop-in verbal, motion, contraction, and expansion. Students were allowed to review the animated visuals as many times as needed by clicking on the "Play Animation" button.

The instructional module consisted of five units: 1) The heart's structure; 2) The veins and arteries; 3) The valves of the heart; 4) The blood flow through the heart and 5) The phases of the heart cycle. Content for each unit was presented in several subunits, with one subunit per webpage. There were a total of 20 subunits for the entire instructional module. Animations were displayed on the right-hand side of the screen to complement the text to their left. The respective navigation treatments employed in the study are described in the following section.

Assigned navigation mode

Linear navigation

A navigation menu with hyperlinks showing “back” and “next” was placed beneath the major content text on each webpage. This menu was the only tool that learners could utilize to proceed in the web-based instruction. The navigation design was extremely linear in that learners could only proceed in a predetermined way. The major unit titles on the left side of the screen indicated students' current progress in this module. Moreover, only unit titles were presented along with corresponding content text. The subunit titles for each unit were not presented for more detailed overview as were in the nonlinear mode (see below). This difference was meant to be a difference between both modes, since the design of the linear module was intended to keep learners focusing on immediately available content on each page. Figure 2 provides a screenshot of the linear-navigation treatment.

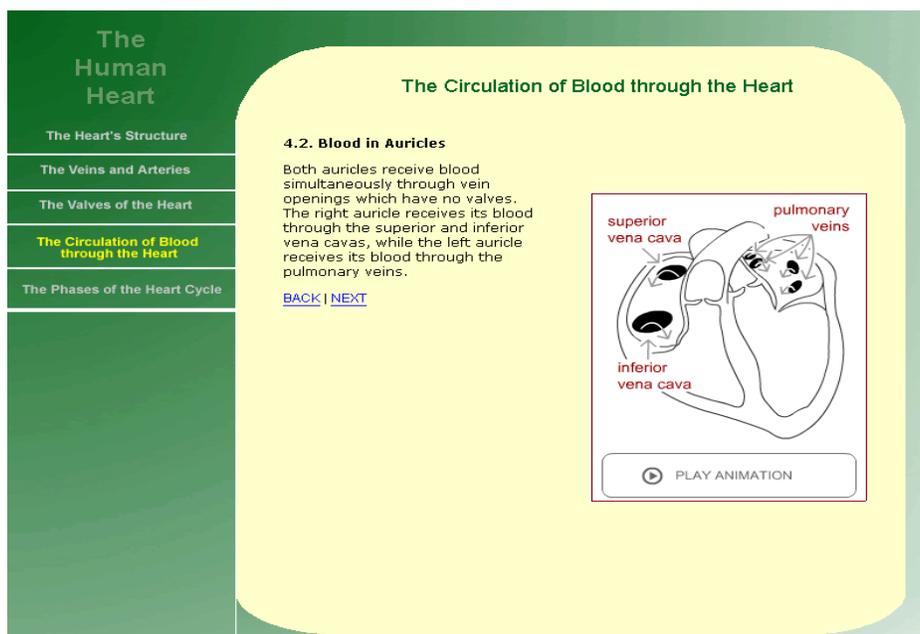


Figure 2. A linear version webpage

Nonlinear navigation

The instructional content in the nonlinear navigation treatment is exactly the same as that in the linear version. However, the navigation menu beneath the text, which allows students to move back and forward, was eliminated (see Figure 3). Instead, this nonlinear navigation design allows learners to navigate the 20-page instructional material at their own pace and in unarranged sequence using an interactive dropdown menu on the left side of each webpage. The treatment was designed to be in great contrast with the linear counterpart. In this nonlinear version, the participants have immediate access to any webpage at any time by placing the cursor over any one of the five major units that display automatically the titles of the subunits (see Figure 4). To access a sub-unit of their choice, learners could mouse over and click the sub-unit title, which then brought them to the desired unit.

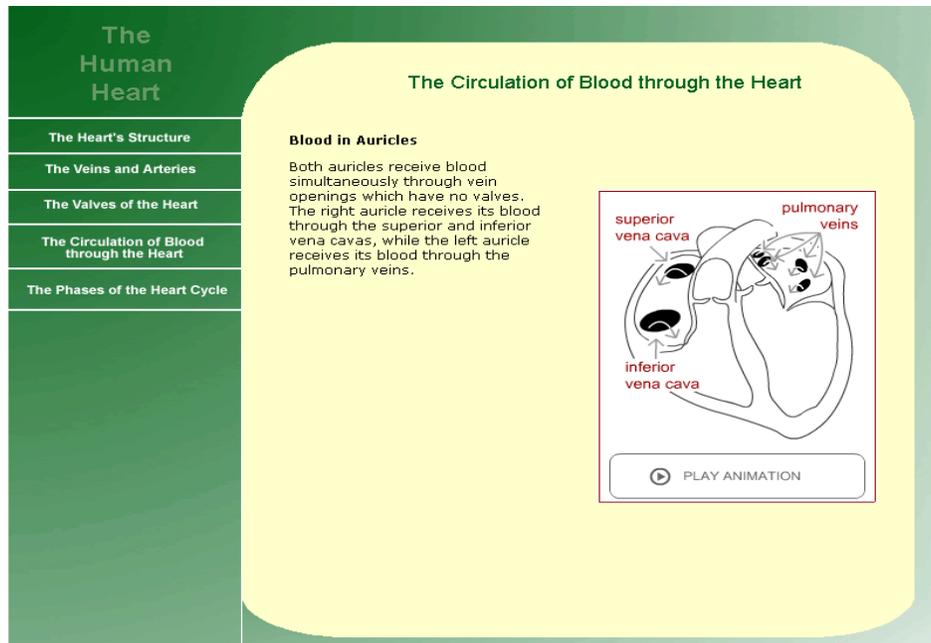


Figure 3. A nonlinear navigational webpage without dropdown menu

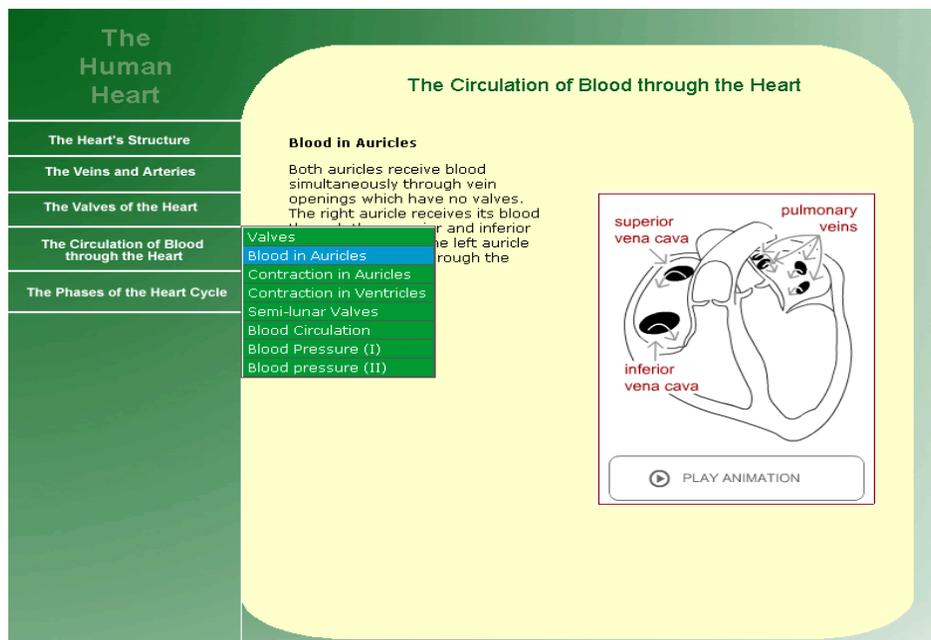


Figure 4. A nonlinear navigational webpage showing drop-down menu

Navigation preference measures

Instead of identifying students' cognitive style on the field dependence dimension that is related to individuals' preferences in navigation, a 10-item navigation preference measure was adopted to directly identify participants' preferences for specific web navigation modes (Hsu, 2006). In this measure, there were 10 pairs of websites (i.e., one pair per item) for students' review. Each pair of websites included both linear and nonlinear navigation material that contained the identical content and subcategories, with the only difference being navigation mode (i.e., linear vs.

nonlinear). Each module was labeled as either A or B respectively on top right corner of the page (e.g., Figure 5 and Figure 6).

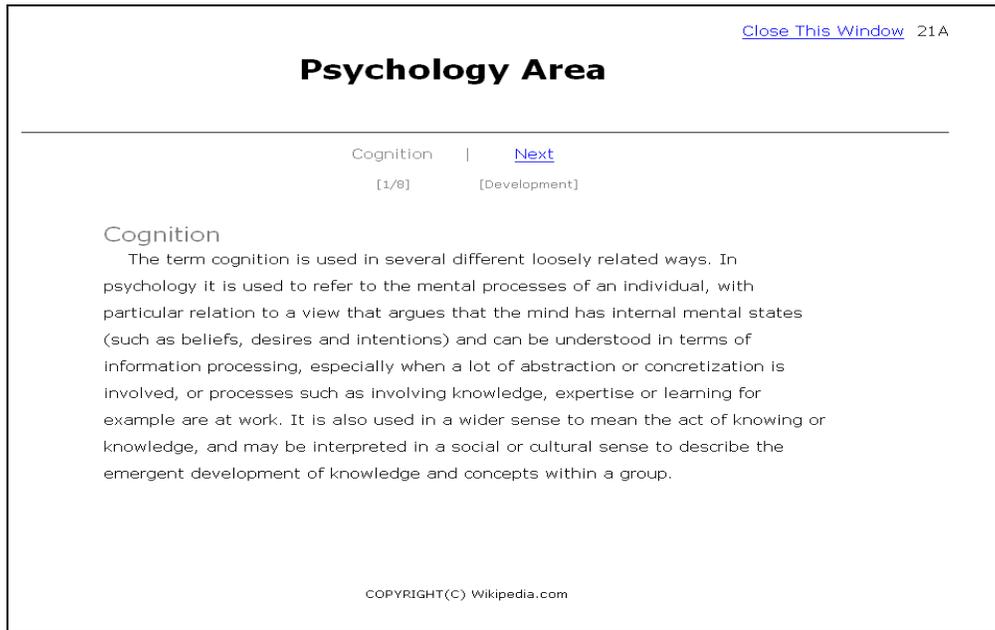


Figure 5. Navigation preference: Screenshot of a linear navigational webpage

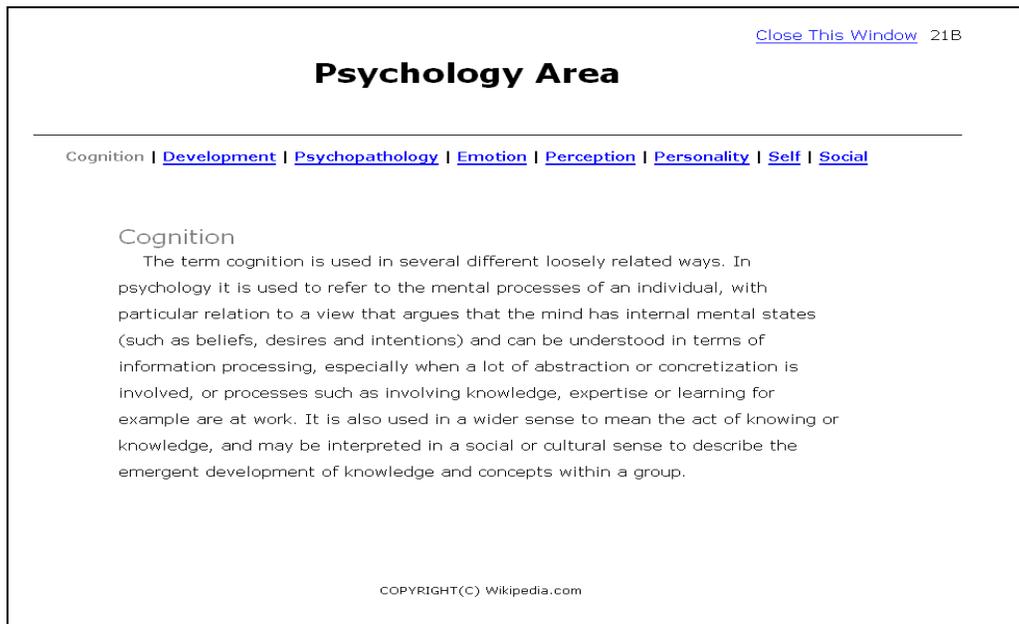


Figure 6. Navigation preference: Screenshot of a nonlinear navigational webpage

On each “choice” page (e.g., Figure 7), the participants were asked to click on a radio button to indicate their navigation preference immediately after they viewed each pair of navigation prototypes. It has to be noted that the letter A or B is not associated with a specific navigation mode and was used randomly to label either linear or nonlinear presentation.

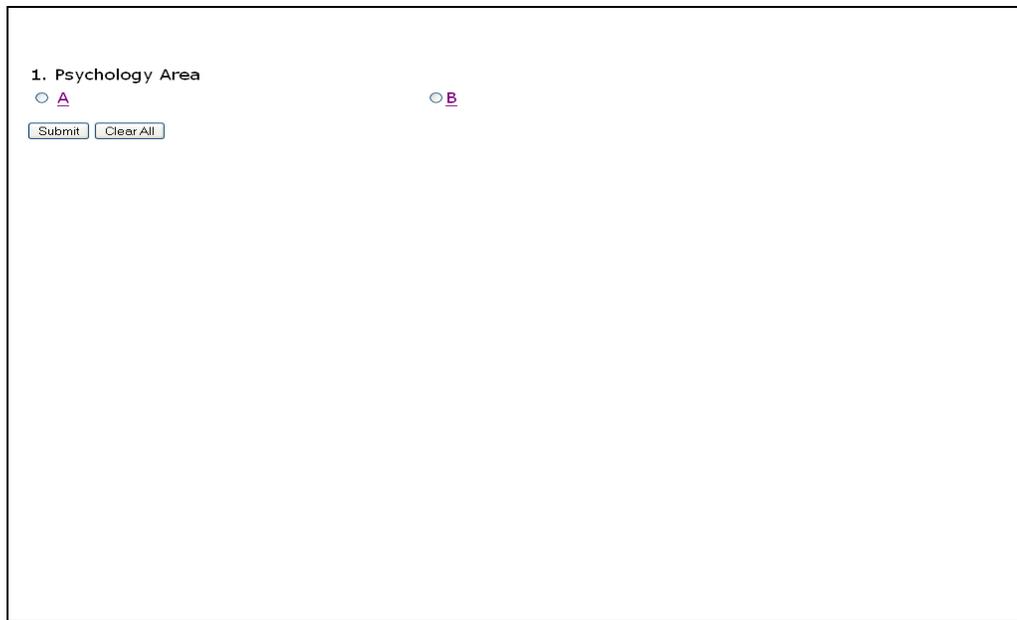


Figure 7. Navigation preference measure

A scoring scheme was employed to classify participants into two different navigation preferences. Using the preference for nonlinear navigation as the coding standard, participants who identified their preferences for nonlinear navigation in 6 or more pairs (i.e., possible score: 6 to 10) were categorized as “Preferring Nonlinear Navigation,” while those who identified their preference for nonlinear navigation in 5 or fewer pairs (i.e., possible score: 0 to 5) were categorized as “Preferring Linear Navigation.” This navigation preference measure has a high reliability (KR-20 = .94), that is, participants who preferred a specific navigation mode tended to consistently select that mode. In fact, only 3 of the 68 participants scored 5 (i.e., middle range), others scored either 4 and below or 7 and above. Also, it is worth mentioning that the KR-20 reliability values reported in this paper were calculated based on the participants’ scores on each measure/test in this study.

Instruments

The study employed four tests, drawing, identification, terminology and comprehension test, to assess treatment effects, and a physiology test to evaluate students’ prior knowledge related to the learning content. The instruments were evaluated by a panel of content experts when they were developed in the 1960s and had undergone several revisions. The current version of instruments has been used in more than hundreds of experimental studies (Canelos, 1987), systematically manipulated making use of other independent variables related to instruction, and facilitated systematic explorations of visualized web-based learning environments. The following is a description of each individual test.

Physiology prior knowledge test

A 36-item test (KR-20 = .63), validated by content experts, was presented in a multiple-choice format to evaluate students’ prior knowledge of general physiology (Dwyer, 1978). The purpose of using this test was to control for the effect of the prior knowledge related to the content of the instructional material on students’ posttest performance.

Criterion measures

Four criterion measures, also developed by Dwyer (1978) and validated by content experts, were used to assess learning outcomes of the instructional treatment designed specifically for this research. The four tests were: 1)

drawing test (KR-20 = .93); 2) identification test (KR-20 = .87); 3) terminology test (KR-20 = .87); 4) and comprehension test (KR-20 = .84). The total score for each test is 20. A composite score (KR-20 = .96) adding scores of the aforementioned four scores was used to measure each student's overall achievement on learning from the instructional material. The four tests are briefly described as follows.

The drawing test

This test was designed to evaluate student ability to construct and/or reproduce items in their appropriate context. This test provided the students with a numbered list of terms corresponding to the parts of the heart discussed in the instructional presentation. The students were required to draw a representative diagram of the heart and place the numbers of the listed parts in their respective positions. For this test the emphasis was on the correct positioning of the verbal symbols with respect to one another and with respect to their concrete referents.

The identification test

The test was designed to evaluate students' ability to identify parts or positions of an object. This multiple-choice test required students to identify the numbered parts on a detailed drawing of a heart. Each part of the heart, which had been discussed in the presentation, was numbered on a drawing. The objective of this test was to measure students' ability in using visual cues to discriminate one structure of the heart from another and to associate specific parts of the heart with their proper names.

The terminology test

This test consisted of items designed to measure knowledge of specific facts, terms, and definitions. The objectives measured by this type of test are appropriate for all content areas, while assuming an understanding of the basic elements is a prerequisite to the learning of concepts, rules, and principles.

The comprehension test

Given the location of certain parts of the heart at a particular moment of its functioning, the students were asked to determine the position of other specified parts of the heart that are functioning at the same time. This test required that the students have a thorough understanding of the heart, its parts, its internal functioning, and the simultaneous processes occurring during the systolic and diastolic phases. The comprehension test was designed to measure a type of understanding in which the individual can use the information being received to explain some other phenomenon.

Participants

Convenient sampling was used in this study. Sixty-eight ($N = 68$) undergraduate students were recruited from an entry-level statistics class from a northeastern research university in the U.S. to participate in this study. Among the 68 students, there were 25 males and 43 females, while 86.7% of them were 19 to 20 years old. The students received extra class credit for their participation.

Results

The average prior knowledge test score of the 68 students was 21.12 ($SD = 4.08$) out of the total possible score of 36, with the lowest score of 11 and the highest score of 32. As for the students' preference for navigation modes, 56 students were identified as preferring nonlinear navigation (preference score: $M = 9.61$, $SD = 0.89$), while 12 as preferring linear navigation (preference score: $M = 2.33$, $SD = 2.31$). Table 1 shows the descriptive statistics of assigned and preferred navigation modes on the criterion measures.

Table 1. The learning outcome means by navigation modes

Criterion Measure ^a	Assigned Navigation			
	Nonlinear		Linear	
	Preferred Navigation			
	Nonlinear (n = 27)	Linear (n = 7)	Nonlinear (n = 29)	Linear (n = 5)
Drawing	13.11 (5.47) ^b	11.29 (7.70)	13.31 (4.90)	8.00 (9.38)
Identification	16.11 (3.82)	14.29 (5.19)	15.34 (4.64)	12.60 (5.08)
Terminology	13.67 (4.54)	10.57 (5.59)	13.21 (5.24)	10.20 (5.36)
Comprehension	11.59 (3.96)	8.14 (3.63)	12.07 (4.47)	6.00 (6.36)
Total Score	54.48 (15.86)	44.29 (20.63)	53.93 (17.62)	36.80 (24.67)

^a the maximum score for each criterion measure is 20.

^b value in parentheses indicated standard deviation.

We further analyzed learning outcomes by comparing participants who received treatments either suited or contrary to their preferred web navigation style. The analysis revealed that 32 participants received navigation tools suited to their preferred navigation style (i.e., matched group: nonlinear-preference students receiving nonlinear treatment; linear-preference students receiving linear treatment), and 36 students were assigned navigation tools contrary to their learning preference (i.e., mismatched group: nonlinear preference students receiving linear treatment; linear preference students receiving nonlinear treatment). Table 2 shows the means and standard deviations for each criterion measure of the matched and mismatched group.

Table 2. The learning outcome means by matching groups

Criterion Measure	Matching	
	Matched (n = 32)	Mismatched (n = 36)
Drawing	12.31 (6.33)	12.92 (5.48)
Identification	15.56 (4.15)	15.14 (4.69)
Terminology	13.13 (4.76)	12.69 (5.33)
Comprehension	10.72 (4.76)	11.31 (4.55)
Total Score	51.72 (18.22)	52.06 (18.34)

The omnibus test of one-way MANCOVA, using “matching” as the independent variable and controlling for prior knowledge of general physiology, indicates there was no significant difference between the matched and mismatched groups on the learning outcomes ($F(4,62) = 1.15, p = .344$).

We further conducted a two-way MANCOVA, controlling for prior knowledge of general physiology, to investigate the interaction between assigned navigation mode and preferred navigation mode and found that it was not statistically significant at the .05 level ($F(4,60) = 1.255, p = .298$). As a result, the main effects of respective assigned navigation modes and preferred navigation modes were examined. The results indicated that students’ learning outcomes was not significant for the assigned navigation mode at the .05 level ($F(4, 60) = .387, p = .817$), but significant at .05 level for the preferred navigation mode ($F(4,60) = 2.94, p = .028$).

Table 3. The learning outcome means by preferred navigation modes

Preferred Navigation (N)	Criterion Measures ^a				
	Drawing	Identification	Terminology	Comprehension	Total
Nonlinear (n = 56)	13.21 (5.14) ^b	15.71 (4.24)	13.43 (4.88)	11.84 (4.20)	54.20 (16.64)
Linear (n=12)	9.92 (8.20)	13.58 (4.98)	10.42 (5.25)	7.25 (4.81)	41.17 (21.64)

^a the maximum score for each criterion measure is 20.

^b value in parentheses indicated standard deviation.

Since the MANCOVA test revealed the main effect of preferred navigation modes on the students’ learning outcomes, the dependent variables were then considered separately. The only difference reaching statistical

significance was the comprehension test ($F(1,63) = 10.856, p = .002$), with the nonlinear preference group receiving higher average scores ($M = 11.84, SD = 4.20$) than the linear preference group ($M = 7.25, SD = 4.81$). Table 3 shows the means and standard deviations of scores obtained by students identified as preferring different navigation modes.

Discussion and conclusion

Our study revisited the effects of matching/mismatching of cognitive styles and presentation styles on learning by investigating the matching/mismatching of one's preferred navigation mode (arguably indicating one's cognitive style) and assigned navigation mode in the web-based learning environment. Students were assigned to one of the two treatment groups—a linear navigation group or a nonlinear navigation group, after taking a test on their website navigational preferences. Treatment effects were assessed with four criterion tests that address lower level factual/descriptive knowledge as well as more complex intellectual skills.

Results indicated there was no significant difference in learning performance between the matched and mismatched groups in all four criterion measures. That is, we could not conclude that matching navigation mode of web-based instruction with one's preferred navigation mode provide participants advantages in learning over their counterparts receiving mismatched navigation mode. The findings of our research did not support those in past research studying the effect of matching (i.e., Pask & Scott, 1972; Pask, 1976, Ford 1985; Ford, 1995) which suggested leaning performance in matched conditions was significantly superior to that in mismatched conditions. One plausible reason for our finding might be that "... human beings are highly adaptable it may be possible for an individual with any sort of competence to learn, in the end, according to any teaching strategy..." as indicated by Pask and Scott (1972, p. 221), although Pask et al. also emphasized that "... the rate, quality and durability of learning..." might depend on whether or not the teaching strategy matches the individual. Our finding suggested that matching instructional style to learners' preferred learning style specifically in navigation tools in a web-based environment might not be a critical issue that needs to be taken into design consideration, if the aim of instruction is to facilitate learning achievement.

Moreover, our criterion tests, assessing knowledge ranging from facts to comprehension, were in a format of multiple-choice questions. Assessment of this kind was quick and easy to administer and score; nonetheless, they might not be sufficiently discriminative to reveal differences in learning effectiveness from matched and mismatched conditions. One probable reason for the difference in results between ours and those in Pask was that students in Pask's study were required to go through the program repeatedly until an error-free run had been achieved before they can take the tests, i.e., students accessed the program in a way similar to programmed instruction. In our study, we did not impose such mechanism, and students were, instead, encouraged but not required to review the material to a certain degree of mastery before they proceeded to take the tests.

Furthermore, our results indicated that linear and nonlinear navigation modes had equal effects on learning outcomes, which concurred with Dufresne and Turcotte's (1997) findings, but contradicted those of Baylor's (2001). Baylor found that nonlinear navigation was more effective in facilitating task performance in the form of example and main point generation, and that linear navigation actually led to more disorientation than nonlinear navigation. The result of our study suggested that the expected differential effects of nonlinearity and linearity navigation tools were not distinctive and therefore might not be an important consideration in web-based instructional design. It is far from clear why the nonlinear approach, as preferred by most students in our study, did not result in more learning gain when compared to the linear version. However, it must be noted that the authors did not collect the en-route of students' learning process. The experimental material used in the study was developed into an online version from an original text-based booklet that was designed to be studied in a linear mode of progression. It was possible that, students receiving the nonlinear navigation might have accessed the material in a predominantly linear fashion as the linear students did. There might not be expected differences in achievement should both groups of students study the material in the same or similar way.

The most astounding finding of our study was that learners preferring nonlinear navigation had significantly better performance on relatively higher order learning objective (i.e., comprehension measure in this research) than their counterparts preferring linear navigation. This finding was contrary to Wang and Beasley's (2002) study in which they found hypermedia preferences did not have a significant main effect on cyber-students' task performance in web-based learning environment. While there is no direct evidence suggesting that nonlinear preference learners are

better learners of intellectually more challenging task from our study, it seems plausible to argue that these students might share certain characteristics of FI individuals, considering FIs' preference for nonlinear navigation. As Jonassen and Grabowski (1993) pointed out, FIs are more likely than FDs to "... reorganize, restructure, or represent information to suit their needs, conceptions, or perceptions" (p. 87), it would also be fair to argue that FIs might engage in deeper information processing and deeper learning, hence having better learning performance. Previous studies did suggest that FIs performed better than FDs on tests measuring different educational objectives (Dwyer & Moore, 1995) in certain subject domains, for example, mathematics, natural science, and social science (Tinajero & Paramo, 1997), and on technical courses in an information management program (Murphy, Casey, Day, & Young, 1997). With the characteristics shared by FIs and those preferring nonlinear navigation, it is likely that nonlinear preference individuals engage in deeper information processing during learning, hence obtaining better performance, especially on relatively higher order cognitive objective that requires deeper information processing.

Educational implications and suggestions for future research

The implications of our study could be reported and interpreted as follows:

1. Presenting material indiscriminately to a class of mixed learning preferences regarding navigational tools provided is warranted at least to the extent that those received material that is not matched with their navigation preference would not perform any worse than those receiving matched material.
2. Navigation tools, either linear or nonlinear, led to equal learning effects in a web-based learning environment, suggesting that navigation mode might not be a critical factor for consideration while designing web-based instruction. Other factors such as cost of material development and learning efficiency concerning time-on-task might be priorities instead.
3. Students favoring nonlinear navigation have a tendency to achieve higher-order learning objectives regardless of the presentation format of the material. Special attention must then be paid to those preferring linear navigation. Enhancement strategies might need to be embedded in the linear material to scaffold and in turn, improve learning.

This study has reactivated the discussion concerning whether the matching or mismatching of instructional presentation to student cognitive style would result in improved performance. Additionally, this research also expands our understanding of such issue, in particular, in an enriched online environment with animation. As the research findings were inconsistent with those in some of the past studies, more conclusive and consistent evidence is needed to determine the roles of matching instructional presentation with students' cognitive style, and the extent to which they impact learning (e.g., students' motivation, time on task), in order to design the online environment more effectively.

However, it should be noted that qualitative data on students' navigation patterns were not collected in this study. Muller, Hobbs, and Moore (2002) have indicated that examining a learner's navigation patterns could inform us their ability to perform specific kinds of tasks. More research complemented with qualitative analysis is encouraged to help develop a deeper understanding of the interactions between learners and teaching material, in which other factors such as gender, prior knowledge, forms of learning, and subject domains may interact to various degree to affect learning (Ford & Chen, 2001).

Meanwhile, our study included only 68 participants and the sizes of navigation preference groups were unequal, which might have limited the generalizability of the research findings. It is suggested that larger scale studies be conducted to provide additional empirical evidence. Moreover, merely two simplified versions of navigation modes were included in the web-based instructional modules in this study. They should be viewed as examples of contrasted navigation modes rather than the norm of websites. Future research could be conducted to examine various types of website organizations/structures regarding the effects of assigned and preferred web navigation modes on different levels of learning outcomes.

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