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Cognitive style, hypermedia navigation and learning

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Abstract

This study examined the influence of cognitive style, spatial orientation and computer expertise on hypertext navigation patterns and learning outcomes when participants interacted with a hypermedia presentation. A sample of 306 undergraduates was pre-tested both on their cognitive style and on their self-reported frequency and ability in using computers. From the initial sample, 40 students were selected to form four groups with the following characteristics: (a) 10 high computer users – sequential thinkers, (b) 10 high computer users – holistic thinkers, (c) 10 low computer users – sequential thinkers and (d) 10 low computer users – holistic thinkers. All participants completed a self-report questionnaire measuring spatial orientation and were then requested to browse freely a hypermedia presentation on the ancient Mayan civilisation. Finally, the students completed a post-test to assess the recall of the hypermedia presentation and the cognitive organisation of the acquired knowledge. The results indicated that hypermedia navigation behaviour was linked to computer skills rather than to cognitive style and that learning outcomes were unaffected by cognitive style or by computer skills. However, learning outcomes were positively affected by specific search patterns, that is by re-visiting hypermedia sections and visiting overview sections in the early stages of hypermedia browsing. Further, navigating overview sections and holistic processing fostered knowledge representation in the form of maps. These findings suggest that individual differences can affect hypermedia navigation even though their role in learning is complex and the impact of cognitive style on learning outcomes was proved to be less important than initially predicted.

Keywords: Hypermedia; Learning; Cognitive style; Spatial orientation; Computer expertise

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1. Introduction

It has been suggested that one of the educational benefits associated with hypermedia presentations is that in such tools knowledge is net-structured rather than traditionally linear-structured information, so providing learners with greater flexibility of usage which can in turn reflect the individual's cognitive style (Andris, 1996; Chambreuil, Chambreuil, & Cherkaoui, 1994; Currie, 1995; Douglas & Riding, 1993; Ford & Chen, 2000; Ford & Ford, 1992; Graff, 2003; Lu, Yu, & Liu, 2003; Riding & Grimley, 1999; Terrell, 2002). A number of studies have demonstrated superior learning from hypermedia compared to linearly presented information (Crosby & Stelovsky, 1994; Frey & Simonson, 1994). Further, Baylor (2001) found learning costs if users applied a linear navigation mode (proceeding through the hypermedia as when reading a textbook) on hypermedia content as participants become moderately disorientated. Such disorientation did not occur when navigation took a non-linear format and participants had access to all pages of the hypermedia package. As a result the users in the non-linear navigation mode performed better than those in the linear mode on an incidental learning task. It could be argued that the superiority of the non-linear presentations in these studies was due to increasing familiarity with hypermedia systems. A more sustainable line of reasoning might be that presented by Jonassen (1988, 1991) who argued that hypermedia should facilitate learning because of its correspondence with human associative memory structures, that is with the natural human modality of encoding and retrieving information.

However, it is worth noticing that different learners approach learning tasks in different ways or styles. Such learning styles are considered to be "characteristic cognitive, affective, and psychological behaviours that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment" (Keefe, 1979, p. 4). Since individual learners may approach diverse learning tasks differently, they develop sets of behaviour that they are most comfortable with, although preferred learning styles are not necessarily optimal approaches to learning (Ramsden, 1992; Entwistle, 1981). When a learner is given the opportunity to move freely through a hypermedia presentation, s/he should develop personal navigation patterns whose features mirror his or her own cognitive characteristics. The flexibility offered by hypermedia, it might be argued, should enhance learning as it allows a correspondence between the individual's imposed structure on the materials to be learned and his or her own cognitive profile. Put more succinctly, individual differences in cognitive style should lead to distinctive navigation patterns and these, in turn, should result in differences in learning outcomes (Parkinson & Redmond, 2002). Studies that have established a relationship between cognitive style and learning outcomes in hypermedia environments can be found (see for example Andris, 1996; Korthauer & Koubek, 1994; Weller, Repman, & Rooze, 1994). However, the literature offers only partial support for these claims. Yu Ting and Underwood (1999) reported no significant correlation between style and performance, rather performance outcomes were related to search strategy. This failure to find a connection between learning styles and achievement was also confirmed by Liu and Reed (1994) and by Wilkinson, Crerar, and Falchinov (1997).

One dimension of cognitive style can be described as the extent of field dependency, that is an individual's propensity to discern and to isolate elements embedded in complex contexts. Field-dependent individuals process information overall and rely more on external reference. They thrive in situations where structure is provided for them and tend to solve problems through intuition and trial-and-error approaches (Ayersman, 1993; Riding & Cheema, 1991; Schiff, 1980; Witkin, Oltman, Raskin, & Karp, 1971). In contrast, field-independent individuals are highly analytic and rely more on internal references. They tend to actively structure their own learning by perceiving objects as whole and by finding out the underlying causal relationships of problem situations.

The degree of field dependency has been shown to impact on learning outcomes produced by exposure to hypermedia. In a multimedia physics environment where text, voice and animation were implemented, beneficial effects were shown only for field-independent participants (Chuang, 1999). Furthermore, field-independent students showed a better visual control in an instructional tools involving animation (Chanlin, 1998), whereas performance in learning from hypermedia by field-dependent students was enhanced by auditory cues (Marrison & Frick, 1994). These findings are consistent with Ghinea and Chen's (2003) results showing that field-independent students enjoyed educational clips including a high number of details while field-dependent individuals' performances were hindered by multimedia tools that required the students to extract cues by themselves. Moreover, field-independent students preferred non-linear browsing, whereas field-dependent learners preferred fixed browsing patterns (Dufresne & Turcotte, 1997). Cacciamani (2002) found that field-independent students outperformed field-dependent peers in learning from hypermedia, regardless of the navigation aid provided (i.e., semantic map vs. alphabetic order). Chen and Ford (1998) showed that, when requested to browse an hypertext, field-dependent users preferred navigational tools such as maps, which provide an overall picture of the contents, whereas field-independent users preferred tools such as an index or find options, designed for searching for specific information (Ford & Chen, 2000). Korthauer and Koubek (1994) reported that the best performances on a hypertext task were associated with a high level of hypertext experience in field-independent participants. Unsurprisingly, level of expertise plays an important part in searching for information on the web. Lazonder, Biemans, and Wopereis (2000) found that students who were unfamiliar with the web were less proficient in locating sites than experienced web users, although no differences in task performance were found when locating information on specific sites. A lack of significant differences between field-dependent and field-independent individuals when learning through hypertext was reported by Ford and Chen (2001), as well as by Shih and Gamon (2002).

Recent research has focused on the interactions between cognitive styles, such as field-dependency and serial versus holistic thinkers, and level of prior experience with standard information technologies. Ford and Chen (2000) have shown that people with different cognitive styles display different learning strategies when they are allowed to navigate in relatively non-linear learning environments. For example, there were differences in the subject categories and navigation tools selected, in the total number of navigational actions, in the numbers of levels visited and the time spent at each level, and in the sequencing of elements explored. However, there is little evidence to show that such navigation patterns impact on learning. This lack of evidence suggests that there is a need to deepen the study of the relationship between a user's stylistic characteristics and hypermedia browsing patterns and its impact on learning outcomes.

Although the current evidence of the benefits of the hypothesised relationship between style and hypermedia navigation is not inconclusive (Chen & Macredie, 2002), it could be argued that previous studies have a number of limitations in that only a restricted set of styles have been investigated, using a single measure with no focus on interaction with other potentially important factors. Hence, this study was designed to investigate the effect of analytical-sequential vs. holistic-intuitive styles of thinking and of hypermedia navigation behaviours on learning performance. Even though the reticular structure of hypermedia leads us to argue that the holistic style is the most suitable in order to browse a network of non-semantically organised content, it can also be argued that the best learning outcomes are achieved when individuals navigate the hypermedia according to their preferred thinking style. Thus, this argument would suggest that no one style will result in better performance: rather, that the best results are acquired by learners whose browsing behaviour is consistent with their own preferred styles.

The study reported here investigates individual differences in hypermedia navigation and the subsequent impact on outcome performance. Specifically, it evaluates the influence of cognitive style and computer experience on the pattern of navigation through the hypermedia. In contrast to much previous research, this study employed: (a) two distinct measures of cognitive style and (b) a general measure of everyday thinking and a specific measure of spatial orientation. The latter was deemed relevant as hypermedia navigation has a strong spatial component. In addition, it was assumed that computer expertise – as suggested by literature (Korthauer & Koubek, 1994; Monereo, Fuentes, & Sanchez, 2000) – would be a contributory factor on performance. Further, it investigated how navigation patterns impacted on two learning outcome perform knowledge retention and knowledge representation.

2. Method

2.1. Participants

The participants in the experimental study (phases 2–4) were 40 undergraduates, ranging in age from 20 to 25 years, selected from an initial sample of 306 students in different universities in Milan, Italy (phase 1). Males–females were equally distributed in the four conditions of the experiment. Mean ages were approximately the same in all conditions.

2.2. Instruments

2.2.1. Computer use questionnaire

Computer use questionnaire (CUQ) is a self-report instrument (Antonietti, 1998; Antonietti, Calcaterra, Colombo, & Giorgetti, 2003) that asks individuals to rate both their frequency of, and their ability, to use computer with reference to the following categories of usage: (a) word processing, (b) calculation and/or statistical programs, (c) educational software, (d) action and strategy video games, (e) web browsing, (f) e-mail, (g) newsgroups and/or chat rooms and (h) programming.

CUQ has been previously administered to a variety of samples of respondents. Scores supported the notion that the questionnaire can discriminate successfully individuals according to their relative frequency of computer use; moreover, correlations among items and factor analysis showed that coherent structures underlie the questionnaire. Similar patterns of responses were recorded in different samples; finally, computer use, assessed through CUQ, was associated in the expected direction with other variables such as gender, computer using skills, and attitude toward computers (Antonietti et al., 2003).

Low, medium and high levels of expertise were designated by computing a total score and by using the 33.3 and 66.6 percentiles of the frequency distribution as the boundary points of the three groups.

2.2.2. Style of learning and thinking questionnaire

The distinction between an analytical-sequential and a holistic-intuitive style of thinking is defined by the tendency of the individual to focus either on details of a situation or the whole picture (Douglas, 1996; Jonassen & Grabowski, 1993; Schmeck, 1988). Analytic individuals here are defined as having focused attention and preferring a step-by-step approach to situations. On the other hand, holistic individuals tend to scan to form overall pictures; their mental schemas involve multiple accessibility of components and varied associations between them. These features of the analytical-holistic style dimension share similarities with the concept of sequential-intuitive style, which states that individuals either: (a) are inclined to do things one after the other, to process items serially, and to reason logically, by considering the relevant elements and by drawing consequences in systematic ways or (b) are inclined to skip steps, to trust feelings and impressions, to identify suddenly and simultaneously the critical aspects of situations, and to ground conclusions on insights (Riding, Glass, & Douglas, 1993; Riding & Rayner, 1998). All these features are encompassed by a construct proposed by Torrance (1988): the left–right style of thinking. The left style is associated with logical-analytical thinking and implies preference for sequential processing of information and systematic approach; right style refers to holistic thinking and implies preference for parallel processing.

The style of learning and thinking questionnaire (SOLAT) questionnaire, a standardised measure of left–right thinking style employed here, is a self-report inventory consisting of 28 paired items, one of which refers to the left and the other to the right style of thinking (Torrance, 1988). Respondents have to place a check mark whether the statement is true of them; they may check one or both of the statements in a pair or neither. Distinct measures for the left and right styles are computed to assess the relative dependence of an individual either on the left (that is, sequential) or on the right (that is, holistic) mode of thinking.

Studies of the validity of the SOLAT report that, for particular characteristics, scores, which withdraw from the norm, do so in the expected direction. Torrance, Reynolds, Riegel, and Ball (1978) found that all the 36 members of an institute for creative problem solving, compared to the population norm, achieved scores significantly higher in the right scale and lower in the left scale. Other researchers have found that students exhibiting right style, in comparison students exhibiting left style thinking, are more creative in mapping learned contents (Torrance & Ball, 1979).

A sample of 171 undergraduates were administered the SOLAT and other psychometric tools by Denny and Wolf (1980): left scale thinking was associated with verbal learning style, logical-analytic style, preference for simplicity, preference for language and scientific disciplines, practical interests, verbal problem solving, converging thinking, accuracy and conservative attitude; right scale emerged as associated with visual learning style, creativity, tolerance for ambiguousness, non-verbal thinking, preference for humanistic disciplines, broad-mindedness, aesthetic interests, intuitive problem solving. Coleman (1979) and Coleman and Zenhausern (1979) underlined relationships between SOLAT and memory processing. They presented some discrimination tasks to a sample of undergraduates: right style subjects performed better in tasks which required parallel-holistic processing of information, while left style subjects scored higher in tasks which needed sequential processing of information.

There are few reports of the reliability of the SOLAT in the literature but Torrance (1987), on a sample of 139 mature subjects, showed the following internal reliability coefficients (Cronbach's alpha): 0.73 or the left scale and 0.57 for the right scale.

From the SOLAT, two scores were computed: the number of left style and of right style statements endorsed by each participant. Low, medium and high levels of left and right styles were assessed by assuming the 33.3 and 66.6 percentiles of the frequency distribution of both scales as cut-off points. Students who obtained a low right style score and a high left style score were classified as showing a preference for the left style of thinking (that is, as sequential thinkers). Similarly, participants who obtained a low left style score and a high right style score were classified as showing a preference for the right style of thinking (that is, as holistic thinkers).

2.2.3. Spatial orientation situational inventory

Spatial orientation situational inventory (SOSI) (Bosco & Scalisi, 2000) is a self-report questionnaire which presents a series of spatial tasks including: (a) way finding (e.g., "You are in the house of a relative of yours. Imagine you want to reach the front door in the dark. What information do you refer to?"), (b) map drawing (e.g., "A friend of yours asks you to draw a map of an important medieval town that you know very well"), (c) direction giving (e.g., "You are in your district. A pedestrian asks you to show him the way to reach a quite far restaurant").

Respondents have to choose (among three options) the strategy they would employ to carry out the task described, that is:

1. *Route* (e.g., "You try to remember what there is on the right and on the left as you proceed towards the main entrance").
2. *Survey* (e.g., "You try hard to remember the image of the map as you saw it").
3. *Non-spatial* (e.g., "You try to remember some events that happened when you were at that restaurant, in order to remember some helpful elements to find the shortest way").

Further they have to evaluate their own ability to perform the strategy on a five-points scale, ranged from 0 (*low ability*) to 4 (*high ability*).

The route or sequential strategy allows individuals to acquire and store spatial relationships, for example how to go from A to B. The picture of reference of these spatial relationships is self-centred with the goal of assessing the route distance between two nodes. The survey or holistic strategy fosters an immediate and partially analogical representation of spatial relationships referring to the elements arranged in the space by means of an aerial view of the environment. These two strategies, the memory of a route versus the overall picture of a familiar neighbourhood, are distinct forms of spatial mental representation (Tversky, 1991). The final strategy considered here was the non-spatial orientation strategy regards a particular mode of orientation task solving which is neither a route nor a survey format. Bosco and Scalisi (2000) have assessed the validity and reliability of the SOSI.

Total scores were computed either for whole orientation ability by summing ability scores given to each item and for each of the three individual strategies by counting the number of items where the respondent choose that strategy. On the basis of these scores, students were classified, respectively, as either low or high in orientation ability using the median of total ability score as the boundary point and as showing a preference for the route, the survey or the non-spatial strategy by a highest score criterion. The median was considered the cut-off point since the distribution of total scores suggested that two distinct groups of participants could be identified within the sample according to their orientation ability; the highest score criterion was employed to assess the preferred orientation strategy since choices among strategies were mutually exclusive and the inspection of the three scores obtained by each participant showed that there was always a score markedly higher than the two other scores.

2.2.4. Hypermedia

The experimental task was to learn about Mayan culture by exploring only a part of an hypermedia package on the ancient Mayan civilisation, specifically, sightseeing tour of the *Chichén Itzà* town. The hypermedia package provided students with the following sections: (a) An *Introduction* constituted by textual notions, (b) a *Flight over* the town, (c) the *Virtual Reality* reproduction of the Mayan town to be freely navigated, (d) a series of *Architectures* (that is, three-dimensional shapes which can be rotated) accompanied by short expository texts, (e) a gallery of *Photos* accompanied by explanatory notes and (f) a series of short *Videos*.

2.3. Procedure

2.3.1. Phase 1

A sample of 306 students attending university courses in different faculties were administered the CUQ and the SOLAT. Questionnaires were administered individually in various locations across the university campus during non-teaching time by the first author. They were presented to the subjects one after another without break. Even though there was no time limit for completion of the tests, each of them required 10 min on average to be filled in.

From this sample, 40 students were selected by considering scores in CUQ and SOLAT questionnaires, so that the following groups were constituted: (a) 10 high computer users – sequential thinkers, (b) 10 high computer users – holistic thinkers, (c) 10 low computer users – sequential thinkers and (d) 10 low computer users – holistic thinkers.

2.3.2. Phase 2

The 40 selected students completed all the subsequent tasks (phases 2–4) in the cognitive psychology laboratory of the Department of Psychology of the Catholic University of Milan.

2.3.3. Phase 3

Students were requested to explore the hypermedia presentation of the Mayan civilisation freely for 15 min. Before they started browsing, students were provided with detailed written instructions containing: (a) Information on the computer controls for each section (that is, how to move the mouse cursor, where to click or which function key to hit in order to carry out certain actions, such as to speed up browsing, rotating or enlarging objects, jumping) and (b) a short introduction to the acquired knowledge test which was to follow directly after the exploratory phase. Students were not informed that the SOSI questionnaire was to be administered on completion of the recall test.

Behaviour when navigating the hypermedia was recorded and analysed by considering the following parameters for each section of the hypermedia:

1. Time in seconds spent in navigating the whole section and each of its elements.
2. Rank Order Score from 1 to 2 and so on (according to which the sections were navigated).
3. Zooming (that is, enlarging or reducing the apparent distance between the observer's point of view and the observed object or scene).
4. Changing the perspective (that is, varying the apparent visual angle from which the object or the scene was observed and, if allowed, navigated).
5. Mouse movements (e.g., direction, speed, continuous vs. jumping movements).
6. Return (that is, navigating the same section again).

For parameters 3–6 students received: (a) one point if they never showed that navigation behaviour, (b) two points when they sometimes (twice or less) utilised it and (c) three points when that particular browsing pattern appeared often (more than twice).

2.3.4. Phase 4

Students completed individually a post-test of the knowledge provided they had acquired during the exploration phase of the study. There was no time limit for the completion of this test but students took on average 15 min to complete it. Thirteen questions assessed: (a) the recall of verbal and also visual information, (b) the recall of information presented in a mixed visual–verbal format, (c) inferences drawn from declarative knowledge provided and (d) completeness of the number of screen shots and the amount of elements reproduced by participants. The 14th question asked participant to represent with a schematic diagram the structural organisation of the acquired knowledge.

The post-test scoring was as follows. For each of the 13 questions, students received: (a) no point if they did not give any answer, (b) one point when their answer was wrong, (c) two points if their reply was either imprecise or incomplete and (d) three points when they answered correctly. Layouts were categorised as *map* (score 1) (if the abstract, overall and reticular structure of the hypermedia was reproduced), *picture* (score 2) (if the linear chain of the visited sections was constituted by images) representation, or *discursive* (score 3) (if the elements were reproduced through strings of words in a linear-narrative format which mirrored the sequence in which the sections were browsed).

Separate scores for each kind of question and a total score were computed; respondents were classified as low or high learners by assuming the medians of the score distributions as cut-off points (also in this case distributions suggested such a criterion).

Finally, the SOSI was administered individually with no time limit for completion (it required 25 min on average).

3. Results

Our initial research question was: "Do individual differences in cognitive style and computer experience influence hypermedia navigation, and if so what is the impact on learning"? Thus, the following relationships were analysed:

1. Relationships between left–right style and expertise and orientation style.
2. Relationships between left–right style and expertise and navigation.
3. Relationships between orientation style and navigation.
4. Relationships between navigation and learning outcomes.
5. Relationships between left–right style and expertise and learning.
6. Relationships between orientation style and learning.

To test such relationships the following statistical indices were computed: (a) $\chi^2(2, n = 40)$ test as regards to variables association, (b) both Spearman's *Rho* coefficient ($n = 40$) and Pearson's product-moment ($n = 40$) as far as variables' correlation is concerned and (c) ANOVA analysis referring to the thorough investigation of any possible significant effect between variables.

Only results supported by significant statistical values or by consistent trends are reported.

3.1. Relationships between left–right style and expertise and orientation style

No significant correlations (Spearman's *Rho*) and associations (χ^2-test) between SOLAT and SOSI responses emerged. However, high orientation ability students scored higher than low ability students in the right scale of SOLAT ($M = 15.11$, $SD = 6.38$ vs. $M = 14.43$, $SD = 6.37$). Low ability students scored higher than high ability students in the left scale of SOLAT ($M = 8.33$, $SD = 5.72$ vs. $M = 6.95$, $SD = 4.95$). Thus, the following relationships tended to emerge: (a) right style – high orientation ability, and (b) left style – low orientation ability.

A significant relationship between computer expertise and orientation ability (low-high) was recorded ($\chi^2 = 4.91$, $p < 0.05$). This was supported also by: (a) a significant correlation between CUQ total scores and SOSI ability scores ($Rho = 0.55$, $p < 0.001$) and between CUQ total scores and non-spatial strategy scores ($Rho = -0.42$, $p < 0.05$); (b) a significant effect, $F(1, 38) = 10.57$, $p < 0.005$, of expertise on SOSI ability scores (low expertise: $M = 35.55$, $SD = 6.90$; high expertise: $M = 42.35$, $SD = 6.10$). Students classified as having high expertise tended to privilege the survey strategy, low experts the route and non-spatial strategies (see Tables 1 and 2).

3.2. Relationships between left–right style and expertise and navigation

Detailed analysis of the navigation behaviour (carried out through ANOVA and χ^2 procedures) – not reported here for the sake of space – showed coherent patterns of relationships within each section of the hypermedia and between the Virtual Reality and Architectures sections (that is, the sections which involved similar browsing modalities such as zooming and changing the

Table 1
Preferred orientation strategies of students with different computer use expertise

Orientation: preferred strategy	Computer expertise	
	Low (%)	High (%)
Route	55	40
Survey	25	40
Non-spatial	15	5
No preference	5	15

Note. Percentages are represented for column.

Table 2
Orientation strategy scores of students with different computer use expertise

Orientation: strategy score	Computer expertise		$F(1, 38)$
	Low	High	
Route	7.50 (2.21)	6.80 (1.58)	1.32
Survey	5.15 (2.32)	7.40 (2.16)	9.68**
Non-spatial	3.35 (2.30)	1.80 (1.77)	5.44*

Note. The scores represent the mean values (with standard deviations in parentheses).
* $p < 0.05$.
** $p < 0.005$.

perspective). For instance, both in the Virtual Reality and Architectures sections, right thinking style students tended to rotate objects and to choose scenes using a top-down approach; moreover, they preferred to test all browsing options provided by the hypermedia.

Left–right style and expertise did not influence the mean time spent in navigating any section of the hypermedia, as revealed by 2 (left vs. right style) $\times$ 2 (low vs. high computer expertise) ANOVA, even though expert students tended to spend less time in navigating the sections of the hypermedia (see Table 3).

However, if we consider the order in which the sections of the hypermedia were navigated with higher means indicating later access, we notice that right style students, as compared to left style students, chose to navigate the Introduction section later ($M = 3.00$, SD = 2.45 vs. $M = 1.15$, SD = 0.67), $F(1, 38) = 10.52$, $p < 0.005$. No other significant differences were found.

High computer users showed, in comparison to low users, faster movements measured in Number of moves in the Virtual Reality section ($M = 0.55$, SD = 0.76 vs. $M = 0.01$, SD = 0.31), $F(1, 38) = 5.83$, $p < 0.05$; a significant correlation between CUQ scores and speed scores was recorded ($Rho = 0.36$, $p < 0.05$).

3.3. Relationships between orientation style and navigation

Differences between low and high orientation ability students in each navigation measure were tested. During navigation high orientation ability students scored higher than low ability students: (a) in the numbers of jumps in the Virtual Reality section (mean value = 1.16, SD = 0.69 vs. mean value = 0.67, SD = 0.66), $F(1, 38) = 5.32$, $p < 0.05$; (b) in the frequency of zooming in the Virtual

Table 3
Navigation mean time of students with different computer use expertise for each hypermedia section

Hypermedia sections	Computer expertise	
	Low	High
Introduction	87.55 (55.42)	66.70 (33.96)
Flight over	101.45 (38.70)	91.80 (38.81)
Virtual Reality	211.75 (164.75)	190.75 (108.73)
Architectures	178.06 (82.42)	171.75 (60.61)
Photos	98.00 (40.66)	85.00 (37.31)
Videos	191.53 (64.54)	186.22 (52.13)

Note. The scores represent the mean time in seconds (with standard deviations in parentheses).

Table 4
Navigation mean time of students with different orientation style for each hypermedia section

Hypermedia sections	Orientation style	
	Survey	Route
Introduction	66.23 (44.63)	81.00 (41.80)
Flight over	109.62 (37.61)	86.42 (36.94)
Virtual Reality	178.00 (66.70)	233.74 (181.15)
Architectures	165.54 (67.23)	183.35 (85.06)
Photos	85.08 (27.23)	103.50 (42.72)
Videos	188.65 (55.54)	190.75 (59.43)

Note. The scores represent the mean time in seconds (with standard deviations in parentheses).

Reality section (mean value = 0.42, SD = 0.77 vs. mean value = 0.05, SD = 0.22), $F(1,38) = 4.56$, $p < 0.05$; (c) in the frequency of zooming in the Architectures section (mean value = 1.32, SD = 0.89 vs. mean value = 0.74, SD = 0.87), $F(1,38) = 4.12$, $p < 0.05$. No other significant differences were found.

Analyses were carried out by considering the route-survey style distinction as the independent variable. Differences about mean times spent in navigating the sections of the hypermedia are shown in Table 4. Survey style students zoomed more frequently than route students ($\chi^2 = 6.27$, $p < 0.05$) and made faster movements ($\chi^2 = 5.01$, ns) in the Virtual Reality section, whereas route students scored higher than survey students in the numbers of mouse movements (movements on the left: $\chi^2 = 2.86$, ns; movements on the right: $\chi^2 = 1.20$, ns; movements at the bottom of the screen: $\chi^2 = 3.51$, ns) and number of continuous movements ($\chi^2 = 2.12$, ns) in the Virtual Reality section.

3.4. Relationships between navigation and learning outcomes

Relationships between browsing patterns and knowledge acquisition from the hypermedia were assessed by analysing both differences between low and high achievers in the measures concerning navigation and associations between level of learning (low vs. high) and the frequency (on a 3-grade scale) of the navigation behaviour recorded. High learners spent more time in navigating the Introduction, $F(1,38) = 19.67$, $p < 0.001$ (see Fig. 1), and re-visited the Architectures a higher number of times, $F(1,38) = 4.23$, $p < 0.05$, (see Fig. 2), than low learners. No significant differences in time spent visiting the other sections between low and high learners were found.

In general, re-navigating the sections of the hypermedia tended to be associated with best learning outcomes. In particular, the following results were found: (a) 67% of participants who re-visited the Introduction section achieved high learning rates ($\chi^2 = 4.81$, $p < 0.05$); (b) 63% of participants who re-visited the Architectures section obtained high learning rates ($\chi^2 = 3.99$, $p < 0.05$).

High learners performed, in the Virtual Reality section: (a) Lower numbers of mouse movements (cursor-reporting: $\chi^2 = 1.72$, ns; movements on the left: $\chi^2 = 2.16$, ns; movements on the right: $\chi^2 = 1.67$, ns; movements at the top of the screen: $\chi^2 = 4.55$, ns; movements at the bottom of the screen: $\chi^2 = 3.31$, ns) and of continuous movements ($\chi^2 = 2.04$, ns); (b) a higher number of changes of perspective ($\chi^2 = 3.71$, ns).

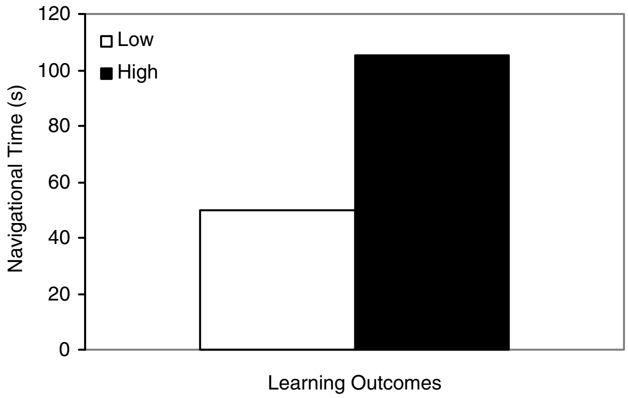

Fig. 1. Time (in seconds) spent in navigating the Introduction section of the hypermedia by students with different learning outcomes (low vs. high).

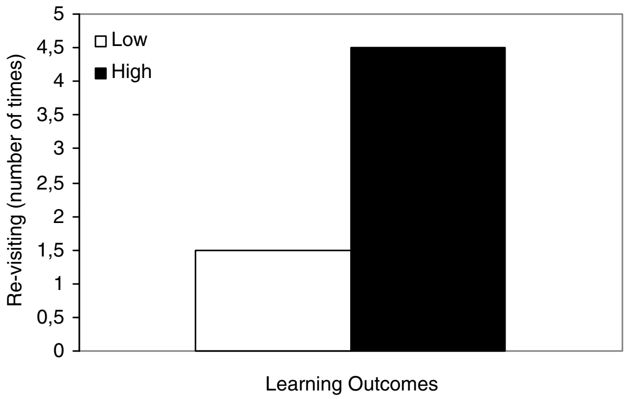

Fig. 2. Re-visiting (number of times) the Architectures section of the hypermedia by students with different learning outcomes (low vs. high).

As far as the mode of representation of the acquired knowledge was concerned, students who represented the whole acquired knowledge in a holistic way (e.g., with a map) spent more time in navigating the Flight over section than students who derived a discursive representation (both kinds of students did not differ significantly from students who represented knowledge through pictures), $F(1,38) = 3,14$, $p < 0.05$ (see Fig. 3).

Thirty-five per cent of the sample represented the acquired knowledge through maps. Such a representation occurred more frequently for students who re-navigated sections of the hypermedia, as shown in Table 5. Moreover, 100% of students who navigated the Flight over section first reproduced knowledge through a map. In short, re-visiting overview sections hinted at representing knowledge through maps.

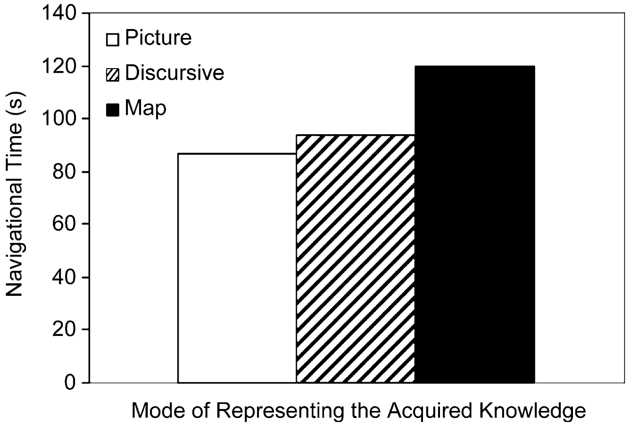

Fig. 3. Time (in seconds) spent in navigating the Flight over section by students with different mode of representing the acquired knowledge through hypermedia (picture vs. discursive vs. map).

Table 5
Percentages of participants who re-visited hypermedia sections according to the mode of representing the acquired knowledge

Hypermedia sections re-visited	Knowledge representation		
	Picture (%)	Discursive (%)	Map (%)
Flight over	24	33	43
Virtual Reality	35	23	42
Architectures	27	27	46
Videos	19	28	53

Note. Percentages are represented for row.

3.5. Relationships between left–right style and expertise and learning

A 2 (sequential vs. holistic) $\times$ 2 (low vs. high computer expertise) ANOVA showed that neither left–right style nor expertise influenced learning rates, respectively, $F(1,38) = 1.69$, ns, and $F(1,38) = 2.31$, ns.

3.6. Relationships between orientation style and learning

No consistent relationship between orientation style and learning outcomes emerged. Only the following tendency was found: when students were asked to provide an overview of the sum of their learning from the hypermedia experience, 45% of the survey students used maps to present their knowledge but only 25% of the route students chose this form of knowledge presentation.

4. Discussion and conclusions

This study was designed to investigate the effect of analytical-sequential vs. holistic-intuitive styles of thinking and of hypermedia navigation behaviours on learning performance. Background

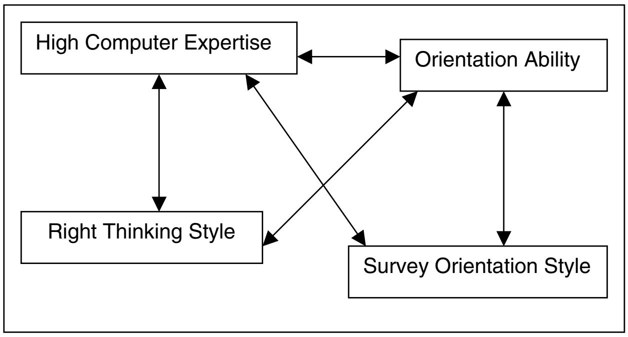

Fig. 4. Framework of relevant relationships among factors involved in browsing the target hypermedia.

data showed that high levels of computer expertise were positively related to orientation ability and the preference toward the survey strategy. Further, high levels of computer expertise were associated with the holistic style of thinking (see Fig. 4).

Although we had predicted that right style thinking would be related to preference for using the survey strategy, this prediction was not supported by the data. Styles of navigation through a hypermedia package do not appear to draw on the sequential vs. intuitive division outlined by Riding et al. (1993) and Riding and Rayner (1998). One explanation for this might be that the act of "jumping back" to the hypermedia overview sections, which might be viewed as operating non-sequentially, is in fact a logical attempt not to get lost. It is therefore a good strategy that the sequential thinkers would want to adopt.

In general, hypermedia navigation behaviour was linked to skills rather than to styles. It emerged that expert computer users and high orientation ability students showed dynamic browsing patterns, that is, a high number of mouse movements, changes of perspective, zooming. However, the students exhibiting sequential-holistic and route-survey styles showed no distinct browsing paths except for the fact that holistic thinkers prioritised the navigation of overview sections of the hypermedia.

Higher performance outcomes were associated with: (a) re-visiting the hypermedia sections, (b) visiting overview sections first, (c) and changing the perspective. They were not associated with time spent during navigation. This result replicates Yin's (2001) results, which suggested that the amount of time spent using a computer-based presentation program in a multimedia-learning environment does not predict performance on the post-test. Contrary to our expectations, learning outcomes were affected neither by styles nor by abilities. We detected only this effect: as far as the particular mode of knowledge representation is concerned, students who privileged the holistic sections and who showed preferences toward holistic processing tended to develop map (that is, holistic rather than linear-sequential) representations of the acquired knowledge. Based on our initial assumptions concerning the relationships between thinking styles and hypermedia navigation, we can conclude that the results of this study showed that:

1. The instruments employed succeeded in evidencing stylistic differences and in revealing consistent patterns of stylistic features that characterise students. Moreover, stylistic differences appeared to be associated with different levels of computer expertise.

2. Recording of the hypermedia navigation allowed observers to identify behavioural differences, for instance in the number and kind of changes of visual perspective (partially depending on the mouse movements), in the choices of the sections to be surfed first, in the order according to which they were inspected, and in the decisions to re-visit them.
3. Post-navigation test highlighted differences in the learning outcomes, measured both in terms of amount and accuracy of information retention and of information elaboration and in terms of privileged form of representation.

What do the findings suggest about the relationships between these three issues? The link between the issues 1 and 2 mentioned above appears to be weak. Stylistic differences were not associated with navigation patterns; only the relationship between right thinking style and preference toward using the overview sections of the hypermedia was supported by the data. More evidence was provided in favour of the link between issues 2 and 3: it is clear that specific browsing behaviour – for example, re-visiting some parts of the hypermedia, examining overview sections, changing the viewing perspective – induced a better acquisition of the information given. As far as the link between issues 1 and 3 is concerned, the impact of stylistic tendencies was not apparent. They did not predict students' specific browsing strategies, nor did they produce differences in rates of information retention, although style did influence the format of the acquired knowledge. In short, browsing behaviour affects learning from an hypermedia, but such behaviour is not influenced by thinking style, which, therefore, cannot affect learning.

Thinking styles seem to play a minor role in modulating personal hypermedia navigation and hence have limited impact on learning from this media. While there is evidence that individual factors do affect hypermedia navigation, their impact on learning is not simple. We have found a complex picture of relationships, whose outcomes seem to be difficult to foresee. Thus, the results of this study cast doubts on the advantages predicted of accessing knowledge according to the individual's preferred cognitive style. It also questions whether hypermedia experiences actually give such an opportunity.

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