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# *A cognitive model for non-linear learning in hypermedia programmes*

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**Abstract**

In the past decade, hypermedia programmes have gained attraction for the purposes of teaching and learning. These programmes provide students with freedom of navigation. On the other hand, students are required to develop learning paths by themselves. Empirical evidence indicates that not all of learners can benefit from hypermedia learning. In particular, they have problems to deal with non-linear learning. Research into individual differences suggests cognitive styles have significant effects on student learning in hypermedia programmes. In this study, a cognitive model is presented to illustrate how students with different cognitive styles react to non-linear learning within hypermedia programmes by analysing the findings of previous studies. Implications for the design of adaptive hypermedia learning programmes are also discussed.

## Introduction

The use of hypermedia as a learning medium has been attracting much research in the field of educational technology. The basic rationale behind hypermedia is that information can be presented in a non-linear format. Learners can make their ways through such an information-rich and highly interconnected programme in their own self-directed manner, instead of having to follow passively some form of pre-defined linear access (Farrell and Moore, 2000). In other words, the development of hypermedia programmes provides learners with many opportunities to explore and discover according to their own individual needs.

However, the freedom offered by hypermedia learning programmes may come at a price because flexibility increases complexity (Ellis and Kurniawan, 2000). There are problems that are specific to the organisation of hypermedia. Some learners who are


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uncertain of how to deal with non-linear learning programs may meet disorientation problems, so their learning achievement may be disrupted to better outcomes. Therefore, it is necessary to see how different learners perceive the features of hypermedia learning. Empirical evaluation of learners' individual differences become paramount because such evaluation can provide concrete prescriptions for developing student-centred programmes that can match with the particular needs of each learner.

In the past decade, many studies have shown evidence of individual differences and their significance in hypermedia learning, ranging from gender differences (Leong and Hawamdeh, 1999), system experience (Reed and Oughton, 1997), to cognitive styles (Kim, 2001). Among these differences, cognitive styles are especially related to the manner in which information is acquired and processed. Ford and Ford (1993) found that when given considerable freedom and lack of teacher direction in the way they went about learning; the students displayed distinct learning strategies that are remarkably similar to cognitive styles.

Therefore, exploration of the relationships between hypermedia's non-linear features and individuals' cognitive styles is needed if designers would like fully to utilise the features of such applications to benefit individual learners. It also becomes essential to build a robust model to show the needs of students with different cognitive styles within hypermedia learning programmes. In this vein, the study presented in this paper aims to present a cognitive model that illustrates the effects of cognitive styles on student learning in hypermedia programmes by using the evidence of previous research as a base. In particular, the evidence will focus on how different cognitive style groups react to non-linear interaction, which is the main feature of hypermedia programmes. In addition, this study proposes to apply adaptive hypermedia techniques to support Field Dependent learners, who meet more problems in non-linear navigation.

**Cognitive styles**

Cognitive style refers to an individual's preferred and habitual approach to organising and representing information (Riding and Rayner, 1998). Within the area of cognitive styles, Field Dependence versus Field Independence has emerged as one of the most widely studied dimensions with the broadest application to problems of education (Messick, 1976; Witkin and Goodenough, 1977), because it reflects how well a learner is able to restructure information based on the use of salient cues and field arrangement (Weller *et al*, 1994).

The concept of Field Dependence originated in laboratory studies on perception by Witkin and Asch (1948) and Witkin (1950). Field Dependence describes the degree to which a learner's perception or comprehension of information is affected by the surrounding perceptual or contextual field, that is, "the extent to which the organization of the prevailing field dominates perception of any of its parts" (Witkin *et al*, 1971). The distinction between Field Dependent and Field Independent individuals is similar to that differentiating Holists and Serialist (eg, Jonassen and Grabowski, 1993; Riding and Cheema, 1991). Field Dependent individuals typically see the global picture, ignore

the details, and approach a task more holistically. Field Independent individuals tend to discern figures as being discrete from their background, to focus on details, and to be more serialistic in their approach to learning. It seems that Field Dependence is bi-polar, value neutral, consistent across domains, and stable over time (Goodenough, 1976; Messick, 1976; Witkin *et al*, 1977; Witkin and Goodenough, 1981). Their different characteristics are:

1. Field Dependence: the individuals are considered to have a more social orientation than Field Independent persons since they are more likely to make use of externally developed social frameworks. They tend to seek out external referents for processing and structuring their information, are better at learning material with human content, are more readily influenced by the opinions of others, and are affected by the approval or disapproval of authority figures (Witkin *et al*, 1977).
2. Field Independence: the individuals tend to exhibit more individualistic behaviours since they are not in need of external referents to aide in the processing of information. They are more capable of developing their own internal referents and restructuring their knowledge, are better at learning impersonal abstract material, are not easily influenced by others, and are not overly affected by the approval or disapproval of superiors (Witkin *et al*, 1977).

In the past ten years, a great number of studies have examined the influence of Field Dependence on hypermedia learning. Such research includes learning in the areas of artificial intelligence (Chen and Ford, 1998), HTML Authoring (Ford and Chen, 2000), information skills (Wood, Ford, Miller, Sobczyk and Duffin, 1996), and development of concept map (Oughton and Reed, 1999). Results from these studies suggested that different cognitive style groups showed distinct reactions to non-linear interaction.

**Non-linear interaction**

The issue of non-linear interaction represents one of the major differences between hypermedia and traditional learning programmes (Lawless and Brown, 1997). Previous studies showed the evidence that Field Dependent and Field Independent learners have been shown differentially to prefer linear and non-linear pathways through a hypermedia programme. Reed and Oughton (1997) examined the relationships among students' characteristics, such as gender, learning style, and various prior computer experiences, and their linear and non-linear navigation patterns. The navigation patterns were analysed at three different stages. The results showed that Field Dependent students took more linear steps than Field Independent students at the early and middle stages. Furthermore, Andirs and Stueber (1996) investigated students' learning patterns in a hypermedia lesson about Geology Laboratory Simulation. Students' cognitive styles were identified with Learning Styles Inventory. The results indicated that Field Independent students preferred the linear tutorial less than their Field Dependent students counterparts. Liu and Reed (1995) examined the effects of students' cognitive styles on learning strategies. Witkin's Group Embedded Figure Test (GEFT) was applied to measure students' cognitive styles. They found that Field Independent students tended to jump freely from one point to another using the index tool, whereas Field Dependent students tended to follow the sequence from the beginning to the end.

A number of studies found that such different preferences to linear and non-linear learning have significant impacts on their learning effectiveness and disorientation problems in hypermedia programmes. The sections below will illustrate these impacts by presenting the results of previous studies.

*Learning effectiveness*

It seems that most of previous studies revealed that Field Independent individuals performed better than Field Dependent individuals in hypermedia learning. Williams (2001) investigated the effects of conceptual model provision and cognitive styles on problem-solving performance in a hypermedia learning programme. Sixty-one undergraduate students participated in the study. The GEFT was used to classify subjects as Field Dependent or Field Independent learners. The results of the study revealed Field Independent subjects performed better in the exploratory learning programme than did Field Dependent subjects on two post-tests. In addition, Field Independent subjects also spent more time engaging with the highly exploratory photography simulation.

Chang (1995) examined the interaction effects between structure of hypermedia documents and individual differences. The GEFT was applied to identify students as Field Dependent and Field Independent students. Hypermedia documents, which introduced Internet navigation tools and methods, represented three types of combinations of structure and menu design, including (a) hierarchical structure signalled by explicit menus and referential links presented by embedded menus, (b) hierarchical structure signalled by embedded menus and referential links presented by embedded menus, (c) referential links presented by embedded menus without structural information. She found that Field Independent users scored significantly higher than Field Dependent users on information searching tasks. Field Independent users especially had advantages over Field Dependent users when structural information was not conveyed through interface design in program.

Moreover, Dufresne and Turcotte (1997) designed a hypermedia program to teach students the use of Microsoft Excel. The GEFT was applied to identify students as Field Dependent and Field Independent students. They found that Field Dependent students who used the free access version of the hypermedia system (non-linear format) spent more time completing the test than those who used restricted version (linear format). Field Independent users consulted the user guide for a longer period than Field Dependent users in the restricted version, while Field Dependent users consulted it longer in the free access version. Another study by Yoon (1994) investigated the effect of instructional control strategies and cognitive styles on the outcomes of computer-based instruction in terms of students' learning achievement and learning time. Eighty-six elementary school students were asked to learn from a computer-based instruction program. Results found Field Independent learners, who had higher ability to engage in independent learning with analytical thought, performed better in non-linear presentation. On the contrary, Field Dependent learners, who are relatively passive and less capable to learn independently, performed better with linear presentation.

Ayersman and Minden (1995, p. 372) suggest "hypermedia has the capacity to accommodate individual learning style differences". However, the aforementioned studies indicated that non-linear learning is closely related to students' cognitive styles. Not all learners appreciate non-linear learning, particularly when taking into account their cognitive styles. Field Independent students are relatively capable of setting the learning paths by themselves in hypermedia programmes with non-linear presentation. Conversely, Field Dependent students seem to prefer to have a regular path to follow in a hypermedia learning programme. It may be due to the fact that Field Independent learners tend to be more analytical, imposing their own structuring more on the situation, and to be relatively less passive in their behaviours. On the other hand, Field Dependent learners prefer some externally provided structure in the presentation of material (Ford, Wood and Walsh, 1994), because they tended to rely on external stimuli in approaching a task and have much more difficulty in separating the individual parts within a whole (Witkin *et al*, 1977). These differences suggest that different cognitive style groups have different learning requirements for hypermedia programmes.

*Disorientation problems*

Disorientation problems are recognised as one of the key issues in hypermedia navigation (Gupta and Gramopadhye, 1995). Non-linear interaction provides learners with freedom of navigation. Nevertheless, there is a danger to some learners, who become lost in hyperspace because of lacking any clear signposts as to where they are going. Several studies reported that Field Dependent students felt disoriented or lost in hypermedia learning programmes. Wang, Hawk, and Tenopir (2000) examined users' interaction with the hypermedia programmes. The Embedded Figures Test (EFT) was applied to identify students' cognitive styles. Their results revealed that individuals with a strong Field Dependence tendency might find it more difficult to navigate on the hyperspace and might get confused more easily than those with a strong Field Independence tendency.

Furthermore, Palmquist and Kim (2000) investigated the effects of cognitive style on hypermedia learning. The GEFT was administered to identify subjects' cognitive styles. They found that Field Dependent novices tended to follow links prescribed by the designers and experience more disorientation problems. As the result, they suggested that Field Dependent learners, especially when novices, might need special attention from the interface designers and those who are in charge of student training. The similar results were obtained from the study conducted by Chen and Ford (1998), in which a hypermedia program was presented with non-linear formats to give students an introduction to artificial intelligence. Riding's Cognitive Styles Analyses (CSA) was administered in order to assess each participant's level of Field Dependence. Their results indicated that Field Independent students thought the structure of the hypermedia program was clear. On the other hand, Field Dependent students experienced more disorientation problems.

The aforementioned studies suggested that Field Dependent individuals tend to have greater difficulty in learning when the learner himself/herself is required to provide

organisation as an aid to learning (Witkin *et al*, 1977). Davis and Cochran (1989) explained this phenomenon as Field Dependent learners are more reliant on salient cues in learning. Conversely, Field Independent students were more comfortable navigating autonomously in hyperspace. This may be because Field Independent individuals employ more active approaches and are better at transferring concepts to new situations. However, Field Dependent students prefer to be guided in their learning processes (Chou and Lin, 1997). This issue is also consistent with Witkin, Moore Goodenough, and Cox's view that Field Dependent learners tend to employ a less analytic approach to learning (Witkin *et al*, 1977). Again, this suggests that there is a need to provide them with instructional guidance, which can help them in finding out the relevant and meaningful information to reduce disorientation.

In summary, non-linear interaction may be suitable to Field Independent learners, who rely on internal gravitational cues and prefer a discovery approach. However, Field Dependent learners, who rely on external references and prefer structured presentation of learning material, may have more difficulties in non-linear learning within the hypermedia program and they still prefer linear format representation. These findings echoed the previous research (Witkin *et al*, 1977) that in comparison to Field Independent people, Field Dependent people have difficulties dealing with confusion and complexion, such as hypermedia programmes. Thus, extra guidance might be useful in assisting Field Dependent people in interacting with a complex-structured system. Designers of hypermedia learning programmes should consider different system requirements for these two cognitive styles groups.

**Cognitive model**

As discussed in the previous sections, Field Dependent and Field Independent individuals showed different learning experience in interacting with hypermedia programmes. Field Independent individuals had a preference for flexible non-linear structure. On the other hand, Field Dependent individuals might benefit from learning programs with fixed linear paths. Figure 1 presents a cognitive model, which illustrates Field Independent and Field Dependent students' characteristics and their learning pattern in hypermedia programmes. The implications of this model are illustrated below by the characteristics of different cognitive styles.

*Internal/external directed*

The results of previous studies showed that students' cognitive styles have significant effects on the attitudes toward non-linear learning. Field Independent learners enjoyed working on their own paths, but Field Dependent learners felt confused with which options to choose. This may be attributable to the fact that Field Independent learners operate more from internally defined goals; conversely, Field Dependent learners rely on externally provided cues (Reiff, 1996). Therefore, flexible paths are beneficial for Field Independent learners who engage in learning with internal references, and hypermedia learning programmes should provide them with multiple routes, free choice, and visual control so that they can decide the learning strategies by themselves.

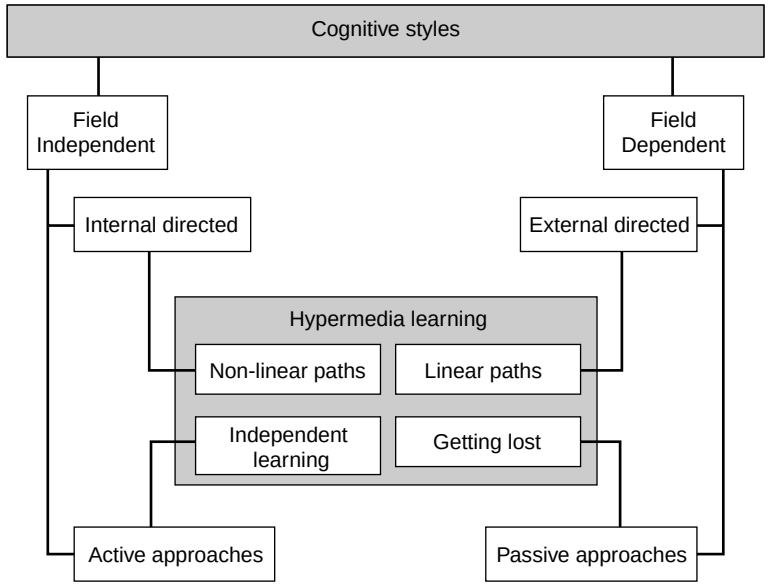


*Figure 1: Cognitive model of hypermedia learning*

On the other hand, fixed paths are helpful for Field Dependent learners, who prefer to be guided in their learning process (Chou and Lin, 1997). Providing guided routes can help them gradually to learn the hyperspace. One of the solutions is to provide visual paths, which can be displayed by means of cues to indicate how far students are along a path or by giving some conceptual description for the possible sequences. Along with having visual paths, providing clear labels for the pages will also aid Field Dependent learners. Since Field Dependent learners tend to rely on salient cues that the system provides, labels that clearly indicate the role of a particular page may help them to decide the appropriate coherent path (Lewis and Polson, 1990). The other way is that hypermedia learning programmes can provide them with written directions that can appear in separate areas or windows to the information required to learn the underlying concepts (Hedberg, Harper and Brown, 1993).

*Active/passive approaches*

Hypermedia learning programmes provide students with freedom of navigation. On the other hand, students are required to work in an independent way, which is considered as a congruent and congenial approach for Field Independent students, because they tend to take an active approach and are able to extract the relevant cues that are necessary for completion of a task (Goodenough, 1976). Conversely, Field Dependent students tend to take a passive approach and attend to the most salient cues regardless of their relevance (Davis and Cochran, 1989). That is probably the reason why they appeared to experience more disorientation problems.

Elm and Woods (1985) suggested that "not knowing where to go next, how to get there, and where they are in the overall structure" are the major factors leading to the "lost in hyperspace" phenomena (Marchionini, 1988). In this situation, user interface, which serves as the major medium for such engagement of the learners (Hildreth, 1995), is a major determinant of effective communication (Sims, 1988). Highlighting the context is a possible approach to reduce the disorientation problems that Field Dependent learners meet. Proper use of font sizes and background colours may also facilitate them to identify the part of the information being explored and the relative position in context. In addition, screen elements of the user interface should be a well-organised layout that draws attention to the important pieces. Clear, consistent icons, graphic identity schemes, and graphic or text-based overviews can give learners confidence that they can find what they are looking for without wasting time.

It is also possible to solve the disorientation problems by providing effective feedback, which is essential for a hypermedia learning system in helping learners to identify the system's structure and to learn across the system effectively (Jones, 1997). For example, hypermedia learning programmes can make an indication to the location when they reach these navigation buttons. In this way, learners can be better informed and may feel comfortable with using different navigation buttons. In addition, the unnecessary navigation routes can be reduced. Alternatively, showing pagination in each page (eg, "*Page 4 of 10*") may help them decide where they want to go and how to decide navigation paths effectively.

## Adaptive hypermedia

As indicated by the results of previous studies, Field Dependent students meet more problems in non-linear learning within hypermedia programmes. They may need special attention from system designers. In addition to the solutions presented in the previous section, the alternative way is to develop adaptive hypermedia learning programmes for them. Adaptive hypermedia learning programmes can tailor information to individual users by taking into account a model of the user's goal, interests, and preferences (Paterno and Mancini, 1999). Basically, adaptive hypermedia techniques can provide four types of navigation support: direct guidance, links hiding, annotated links, and link ordering. Among these four types, the first three types can be applied to support the needs of Field Dependent students.

### *Direct guidance*

Direct Guidance is the simplest technology of adaptive navigation support. It can decide what is the next "best" page for the students to visit according to their goal and other factors (Brusilovsky, 1998). To provide direct guidance, hypermedia learning programmes can outline visually the link to the "best" page or present an additional dynamic link (called "next" or "continue") that is connected to the "best" page. Field Dependent students seemed overwhelmed by the number of choices offered by non-linear test. Direct guidance is a possible solution to find their way through the hyperspace.

*Linking hiding*
The technology of navigation support through hiding is to restrict the navigation space by hiding links to irrelevant pages. A page can be considered as irrelevant for several reasons. Perhaps it is not related to the users' current goal (Vassileva, 1996) or it may present material that the user is not yet prepared to understand (Perez *et al*, 1995). Links hiding can help Field Dependent students easily to identify which concepts and nodes should be visible at the given moment and which should not (Brusilovsky, 1998). In this way, students can be protected from the complexity of the unrestricted hyperspace and their cognitive overload can be reduced.

*Annotated links*
Adaptive annotation augments the links with an extra comment or visual cues (Hohl, Böcker and Gunzenhauser, 1996). The use of annotated links aims to provide students with more information about the destination of a link prior to selection. Annotations can take the form of text and icons or can be encoded by colours, different font sizes or typefaces. There are several types of annotation. Among these annotation techniques, history-based annotations can work as a means to help Field Dependent students to know whether a link has been visited or not. Prequistite-based annotation can be applied to provide Field Dependent students with information on the background relevant to the concept being learned. These techniques can help students to reduce disorientation problems in the hyperspace by providing them with more appropriate mental maps to follow.

## Conclusions

The findings of previous research provide the evidence that hypermedia learning programmes may not be suitable for all learners as a learning technology. Instructors must be aware of individual differences such as cognitive styles possessed. Some learners, eg, Field Dependent learners, may need greater support and guidance from the instructors, while others may be able to follow hypermedia learning programmes relatively independently. Thus, instructors should not assume that every student would benefit equally from hypermedia learning programmes in educational settings. There remains the need for guidance to ensure that all learners attain their learning potential.

Implementing hypermedia learning programmes is a complex process. The empirical evidence showed that designers need to pay close attention to how hypermedia learning programmes can accommodate different learning preferences. Although hypermedia learning programmes have tremendous flexibility in providing dynamic learning, this quality seems to be a double-edged sword. It seems that when "too much" freedom is provided to learners, some learners, eg, Field Dependent learners, may become confused to decide their learning paths. On the other hand, if the freedom is limited, some learners, eg, Field Independent learners, may not be able to develop their own learning strategies. Therefore, versatility is important in the design of hypermedia learning programmes to allow for use by a variety of individuals, rather than a particular user group. It suggests that there is a need to conduct further research to examine how to integrate non-linear and linear learning into a single hypermedia learning programme.

To accommodate different learning preferences, this study develops a cognitive model to illustrate the learning patterns of Field Dependent and Field Independent learners within hypermedia programmes. In addition, some suggestions are presented for the improvement of hypermedia learning programmes. Therefore, further studies are needed to investigate whether hypermedia learning programmes, incorporating the cognitive model and the suggestions presented in this study, could tailor the preferences associated with each cognitive style or whether differences in students' learning would remain.

The results showed by previous research indicate that Field Dependent students tend to have more problems in hypermedia learning programmes. This study suggests three adaptive hypermedia techniques, ie. direct guidance, links hiding, and annotated links, to solve their problems. Empirical studies are also needed to identify whether these three adaptive hypermedia techniques can improve their learning or whether the problems still exist. It raises another question whether adaptive hypermedia techniques can also be applied to enhance the learning experiences of Field Independent learners even though they feel confident in non-linear navigation.

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