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AUTHOR Hall, Richard H.; Balestra, Joel; Davis, Miles
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ABSTRACT

The purpose of this experiment was to assess the effectiveness of a comprehensive model for the analysis of hypermap navigation patterns through a comparison of navigation patterns associated with a traditional linear interface versus a non-linear "hypermap" interface. Twenty-six general psychology university students studied material on bipolar disorder, in which the home page was displayed in either an outline or hypermap format. The pages students went to, the time spent on each page, and the order of their traversal were all recorded. Cardinal (number of hits), temporal (time on page), and structural (pathfinder network) navigation measures were examined. The two groups did not differ on the cardinal navigation measure, but the temporal and structural measures differed markedly. Those in the hypermap groups spent significantly more time on the home page. Further, the structure of the navigation for those in the list group was more consistent with an outline than with a map structure, as would be expected. However, the navigation pattern of those in the hypermap group was no more consistent with an outline structure than it was with a map structure. The results indicate that a comprehensive analysis of navigation patterns can provide useful insight into hypermedia processing. Contains 19 references. (Author/MES)

A Navigational Analysis of Linear and Non-Linear Hypermedia Interfaces

Richard H. Hall
Dept of Psychology and Instructional Software Development Center
University of Missouri-Rolla

Joel Balestra
Depts of Psychology and Computer Science
University of Missouri-Rolla

Miles Davis
Altera Corporation

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Abstract

The purpose of this experiment was to assess the effectiveness of a comprehensive model for the analysis of hypermap navigation patterns through a comparison of navigation patterns associated with a traditional linear interface versus a non-liner "hypermap" interface. Twenty-six general psychology students studied material on bipolar disorder, in which the home page was displayed in either an outline or hypermap format. The pages students went to, the time spent on each page, and the order of their traversal were all recorded. Cardinal (number of hits), temporal (time on page), and structural (pathfinder network) navigation measures were examined. The two groups did not differ on the cardinal navigation measure, but the temporal and structural measures differed markedly. Those in the hypermap groups spent significantly more time on the home page. Further, the structure of the navigation for those in the list group was more consistent with an outline than with a map structure as would be expected. However, the navigation pattern of those in the hypermap group was no more consistent with an outline structure than it was with a map structure. The results indicate that a comprehensive analysis of navigation patterns can provide useful insight into hypermedia processing.

A Navigational Analysis of Linear and Non-Linear Hypermedia Interfaces

Hypermedia-based instructional tools have become ubiquitous in classrooms at all stages of education in the last decade (e.g., Dillon & Gabbard, 1998; Kumar & Sherwood, 1997; Wilhelm, Friedmann, & Erickson, 1998). This is most dramatically exemplified by the incredible popularity of the World Wide Web as an instructional tool (e.g., Khan, 1997; Owston, 1997; Windschitl, 1998). Despite the widespread use of these methods, there has been a surprising lack of research on hypermedia tools, and as a consequence, researchers have called for more systematic research into the effectiveness of these approaches in general, and the conditions under which they are most effective (Dillon & Gabbard; Oweston, 1997; Jacobson, 1994). In particular, there is a need for studies that examine the way in which students use these tools (Barab, Fajen, Kulikowich, & Young, 1996; Dillon & Gabbard, 1997).

Hypermedia Navigation Measures

The first purpose of this research was to carry out such an examination through the analysis of hypermedia navigation patterns. There are a number of potential advantages to such an approach. First, analysis of traversal through hypermedia is much less time consuming (Kelly & O'Donnell, 1994) and intrusive (Barab, Fajen, et al., 1996; Kelly & O'Donnell, 1994) than other methods of assessing on-going processing. Further, these approaches have been touted as examples of a measure that capture the dynamic nature of processing (Barab, Fajen, et al., 1996). Such techniques have great potential for use in research, instruction, and hypermedia design (Gay & Mazur, 1993).

A number of experiments have been conducted, which have examined student's hypermedia traversal. For example, one approach is to classify pages in a given hypermedia space based on some criterion and then to count the number of times a user goes to a certain type of page (e.g., Kelly & O'Donnell, 1994; Lawless & Kulikowich, 1996; Barab, Bowdish, Young, & Owen). Another, less common, approach, is to analyze the order of the user's traversal through pages or the pattern of interconnection of links among the pages (Barab, Bowdish, et al., 1996). The present project will extend this previous research by considering many of these approaches within a single context, within an overriding framework. We will take into account measures aimed at assessing the number of times a page is accessed (cardinal), the time on pages (temporal), and the pattern of linking (structural). It is our belief that such an approach will lead to an overriding model of tracking behavior. Such a model-based collection of techniques would allow for the development of techniques that would be robust enough to apply across domains and flexible enough to be easily modified for a specific domain.

In order to assess the effectiveness of this approach we will compare students' traversal through hypermedia pages that underlie two fundamentally different single page interfaces. If such a navigational approach is effective, the measures should differentiate between navigation patterns associated with the two interfaces, and should provide useful and insightful information about the nature of students' traversal.

HyperMaps

In order to provide an ecologically valid examination of these navigation measures, we selected a "linear" interface in the form of a traditional outline, which is a way in which links to pages are often displayed on the World Wide Web (see Figure 1). As a contrast we created a non-linear *HyperMap* interface (Figure 2). This *HyperMap* interface is the product of the integration of a tool found effective in non-hypermedia experiments (Hall & O'Donnell, 1996; Patterson, Dansereau, & Newborn, 1992; Rewey, Dansereau, & Peel, 1991), within the domain of hypermedia. Therefore, a secondary purpose of this experiment was to extend research on non-linear text displays, by assessing the effectiveness of such displays as interfaces for displaying a group of hyperlinked pages.

Method

Participants

Twenty-six students in an undergraduate Physiological Psychology class at a medium sized Midwestern technologically oriented public university participated in this experiment for extra class credit.

Materials

A *HyperMap* interface was developed to represent a description of the Bipolar I disorder, as presented at the Internet Mental Health Web Site (Long, 1998) (see Figure 2). In addition, a corresponding traditional linear interface was developed for the control group (Figure 1). Ten pages were selected from the site. Nodes on the *HyperMap* and a list of page titles for the list group were hyperlinks to these ten pages. Thus, the hypertext space for each group consisted of eleven pages including the main-interface page.

In addition, a questionnaire consisting of nine Likert and an open-ended item, and a fifteen item multiple choice quiz were created to assess students subjective reactions and objective recall of the information.

Procedure

Participants were randomly divided into map and list groups. Students studied the information on the bipolar 1 disorder for thirty minutes, after which they completed the quiz followed by the questionnaire. The test and questionnaire were both forms on the World Wide Web.

A *WebTracking* program was created for this experiment, which recorded the pages that students went to while studying and the time they arrived at and left a given page.

Results

Navigation: Cardinal

The analysis of tracking data began with a two-way mixed analysis of variance on page hits. Group (map vs. text) served as a between subject independent variable, Page (1 through 11) served as a within subjects independent variable, and the number of times a student went to a page ("hits") served as the dependent variable. A main effect for Page was found $F(10,260) = 12.11, p < .001$. Post hoc analysis consisted of all possible comparisons among these pages collapsed across groups. The number of hits for the main-interface page was significantly higher than all other pages. The other pages did not significantly differ among themselves. No other effects were significant.

Navigation: Temporal

A two way, Group X Page, mixed analysis of variance was performed with average-time-on-page as the dependent variable. Again, a significant main effect for page was found $F(10,250) = 26.47, p < .001$. Since a significant Group X Page interaction was also found $F(10, 250) = 4.47, p < .001$, a post hoc analysis of the main effect was not carried out. In order to further examine the interaction effect, Tukey's HSD tests were computed to compare groups on average time on page for each of the eleven pages. The descriptive statistics associated with this interaction, and the results of the post hoc tests are in Table 1. In addition, the means for the four pages on which the groups differed significantly are displayed in Figure 3.

Navigation Structural

Scoring. In order to create a structural navigation score for each participant, an adjacency matrix was created that represented the number of times that two pages had been "linked" during the given participant's traversal. Thus, all the pages were represented on both axes of the matrix and a given cell represented the intersection of two pages. The cell contained a 1 or a zero, depending on whether the pages were contiguous in a students navigation or not (Figure 4 is an example of how the adjacency matrix was created). Two prototypical adjacency matrices were also created, representing the prototypical map vs list structure. To create the list prototype, a given cell in the matrix received a one if the two pages were in the same group, and a zero if they were not. For the map prototype, the matrix was created in a similar manner, except that the grouping was different based on the structure of the map. Figures 5 and 6 illustrates how the adjacency scores were created for these prototypes. For each participant, a map and list score were created by correlating the participant's matrix with the appropriate prototype, using the *Knot* Program (Interlink, 1999), based on Schvaneveldt's Pathfinder approach (Schvaneveldt, 1990).

Analysis. A 2 X 2 repeated measures analysis of variance was computed with group (map vs list) as a between subjects independent variable and prototype (map vs list) as a within subjects independent variable. Prototype correlations served as the dependent variable. A main

effect for prototype was found $F(1,26) = 3.81, p < .05$. The descriptive statistics for the map and list prototypes respectively were $M = .18$, $SD = .13$ and $M = .26$ and $SD = .15$. The group X prototype was also marginally significant $F(1,26) = 3.81, p = .06$. (The means associated with this interaction are displayed in Figure 7).

Group Comparisons on Quiz and Questionnaire Responses.

This analysis began with a series of t-tests, comparing the two groups (map vs. text) on quiz score and on each of the nine Likert items on the questionnaire. The groups differed significantly in response to question #3 $t(26) = 2.84, p < .01$; #5 $t(26) = 2.31, p < .05$; and #6 $t(26) = 3.01, p < .01$. Those in the map group found the pages to be more helpful for learning the information ($M = 6.38$, $SD = 2.84$ vs. $M = 3.80$, $SD = 1.94$); in aiding them to remember information for the quiz ($M = 4.77$, $SD = 2.65$ vs. $M = 2.77$, $SD = 2.02$); and found the thirty minutes to be a more positive learning experience ($M = 6.92$, $SD = 2.18$ vs. $M = 4.80$, $SD = 1.86$). None of the other t-tests yielded statistically significant differences.

An examination of students' responses to the open-ended question at the end of the questionnaire was consistent with the results of the Likert scale question analysis. In general students in the HyperMap group were more positive about the interface than students in the text group. Representative comments from students in both groups are displayed in Table 2.

Discussion

An examination of the analyses of the three tracking dimensions taken together, provide a rich insight into the nature of the differences in hypertext traversal in the map vs the list group. The cardinal analyses indicated that the groups did not significantly differ in terms of the number of times they visited the different pages. Both groups relied heavily on the interface page as an anchor point. Most likely the students returned to the page regularly as a gage of where they had been. However, the average-time-on-page analysis indicated that the groups differed markedly in how they actually used the interface page. Apparently, those in the list group spent very little time on the actual page. They simply went to it for some sort of orientation, and quickly moved to another page. They appeared to do the bulk of their actual studying on a few content pages (see Figure 3). However, those in the HyperMap group apparently used their interface, not only as an anchor, but also as a study aid, and as a graphical tool for the integration of the to-be-learned information.

The analysis of the navigation provided further insight into group differences. The group by prototype means (Figure 6) indicate that the structural navigation patterns for those in the list groups were much more consistent with their (list) prototype than with the map prototype as would be expected. However, the structural navigation pattern for those in the map group was no more consistent with the map prototype than for the list prototype. This finding adds further support to the explanation posed above, that those in the list group used their prototype more as a navigation aid, as opposed to a study tool. Taken together, these results provide support for the

utility of these navigation analyses as discriminating between different types of hypermedia designs, and providing insight into processing.

The analysis of student quiz scores indicated that students did not significantly differ in tests over the content of the information studied. This finding is in marked contrast to the significant differences between the groups in their perception of the pedagogical effectiveness of the two different interfaces, as represented by questionnaire responses. These analyses indicated that those in the HyperMap groups found the interface to be substantially more effective. This inconsistency may be explained by the fact that the bulk of the information that students studied (i.e., the content pages) was the same for both groups. The questionnaire, on the other hand, was specifically aimed at comparing the interfaces. Further, the nature of the multiple-choice quiz consisted of specific questions, principally at the basic knowledge level, as most multiple choice tests do (Woolfolk, 1998). It is very possible that students were accurate in their subjective judgement of the effectiveness of the HyperMap interface, but the objective outcome measure used may have been insensitive to this effectiveness.

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Table 1
Average Time On Page (in seconds) as a function of Group and Page

page	Group			
	HyperMap		List	
	M	SD	M	SD
Main/Interface Page*	60.86	26.42	17.70	11.90
Major Depressed Episode*	81.76	38.77	112.32	57.78
Hypomanic Episode*	53.73	18.54	78.74	47.72
Manic Episode*	54.70	27.58	94.88	109.81
Mixed Episode	28.82	11.15	33.25	34.70
Single Manic Episode	36.58	15.46	34.70	17.44
Most Recent Episode Depressed	25.06	19.53	23.35	8.66
Most Recent Episode Hypomanic	29.10	26.68	35.68	29.10
Most Recent Episode Manic	67.46	29.50	58.67	34.27
Most Recent Episode Mixed	70.31	34.67	90.06	66.79
Most Recent Episode Unspecified	51.91	37.86	53.46	29.17

*significant mean difference (Tukey's Post Hoc Tests)

Table 2
Representative Comments

HyperMap Group

- I found the main page effective because it gave an overview picture of how the different most recent episodes are linked to the different types of episodes. Being a picture helped me to remember it more.
- The main page was very useful, I found that I would keep referring to it to get an overall view of the material presented. I thought it was useful, in that, I could return to it after each reading of the different sections and see it in context with the rest of the material.
- I found the main page to be most helpful in reviewing the material. After I completed studying the pages, I returned to the main page to use it to test my recall of the information in the other pages. However, presenting the figure on the main page first thing was some what intimidating, but once I read the material the figure was much easier to follow and understand.
- I did not initially understand the main page but after studying the written material and coming back to the diagram it proved to be very helpful.
- I found the main page to be effective because it displayed an overview of the entire material.

List Group

1. I thought the main page was rather static and contained little information on the web site, where I was going, how to navigate. It is confusing to enter a web site that doesn't have any sort of site map that tells you where you are and where you're going
2. I found the main page to be effective in giving me an outline of what was enclosed in the lesson. As far as helping me learn the material I don't think it helped me that much.
3. The main page was all right as a sort of table of contents. The only reason I would go back to it though is because I had finished the bulk of my studying in 15 minutes and was just looking around verifying to myself that I knew all of the information. I think that the links within the text were more than enough for me to get by.
4. The main page helped to organize a little bit but it still did not help to connect the material.
5. The main page was effective in outlining what topics were going to be studied. However, the main page did not relay any information about the topics and how the different topics related to each other. This fact made it more difficult to learn the material.

- Diagnostic Criteria For Bipolar I Disorders
  - Bipolar I Disorder, Single Manic Episode
  - Bipolar I Disorder, Most Recent Episode Hypomanic
  - Bipolar I Disorder, Most Recent Episode Manic
  - Bipolar I Disorder, Most Recent Episode Mixed
  - Bipolar I Disorder, Most Recent Episode Depressed
  - Bipolar I Disorder, Most Recent Episode Unspecified
- Criteria For Mood Episodes
  - Major Depressive Episode
  - Manic Episode
  - Mixed Episode
  - Hypomanic Episode

Figure 1. Linear (List) Interface

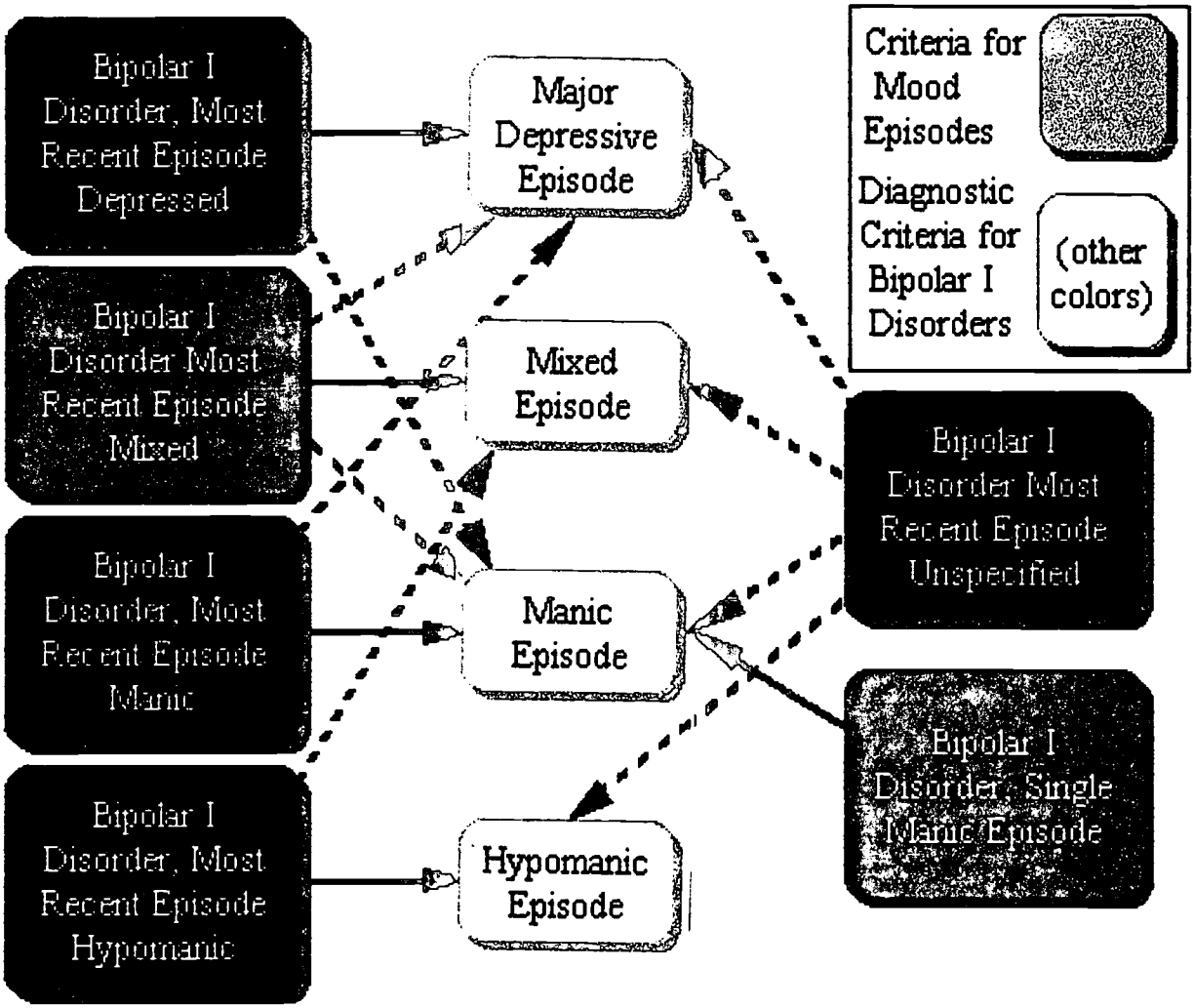

Figure 2. Non-Linear (*HyperMap*) Interface

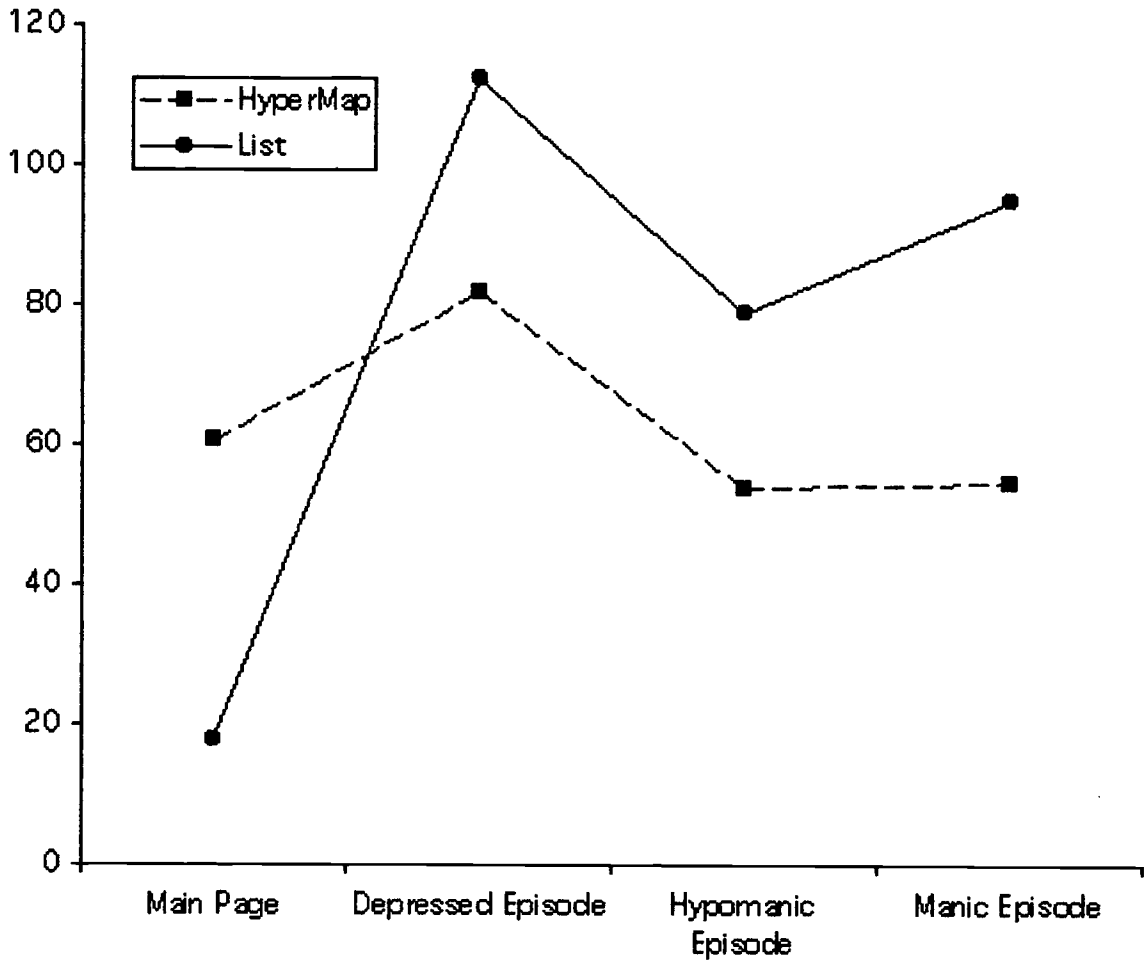

Figure 3. Mean Time on Page (seconds) as a Function of Group

Order of Pages Accessed = 1-2-4-3-4-1

adjacency matrix

Page	1	2	3	4	5
1	-	1	1	0	0
2	-	-	1	1	1
3	-	-	-	0	0
4	-	-	-	-	1
5	-	-	-	-	-

Figure 4. Example of creation of adjacency matrix from Order of Pages Accessed

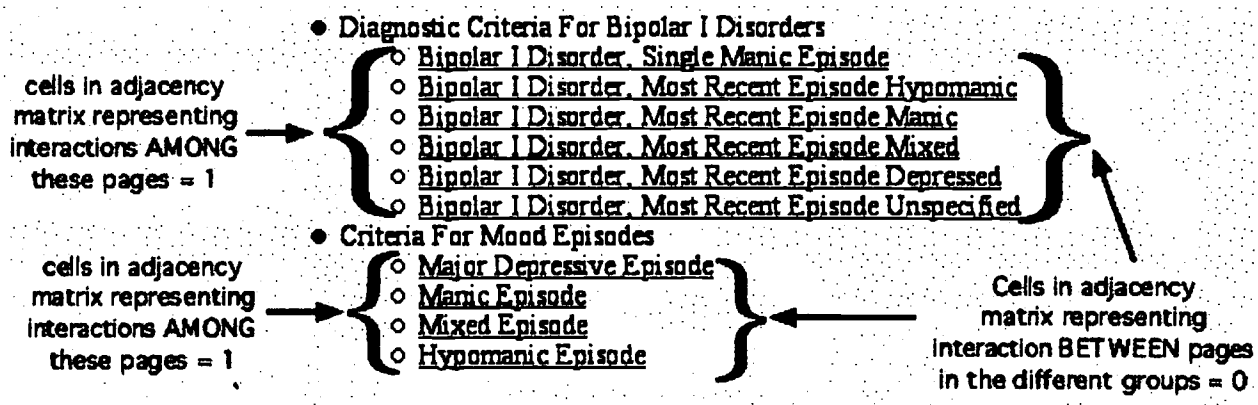

Figure 5. Creation of List Prototype Adjacency Matrix

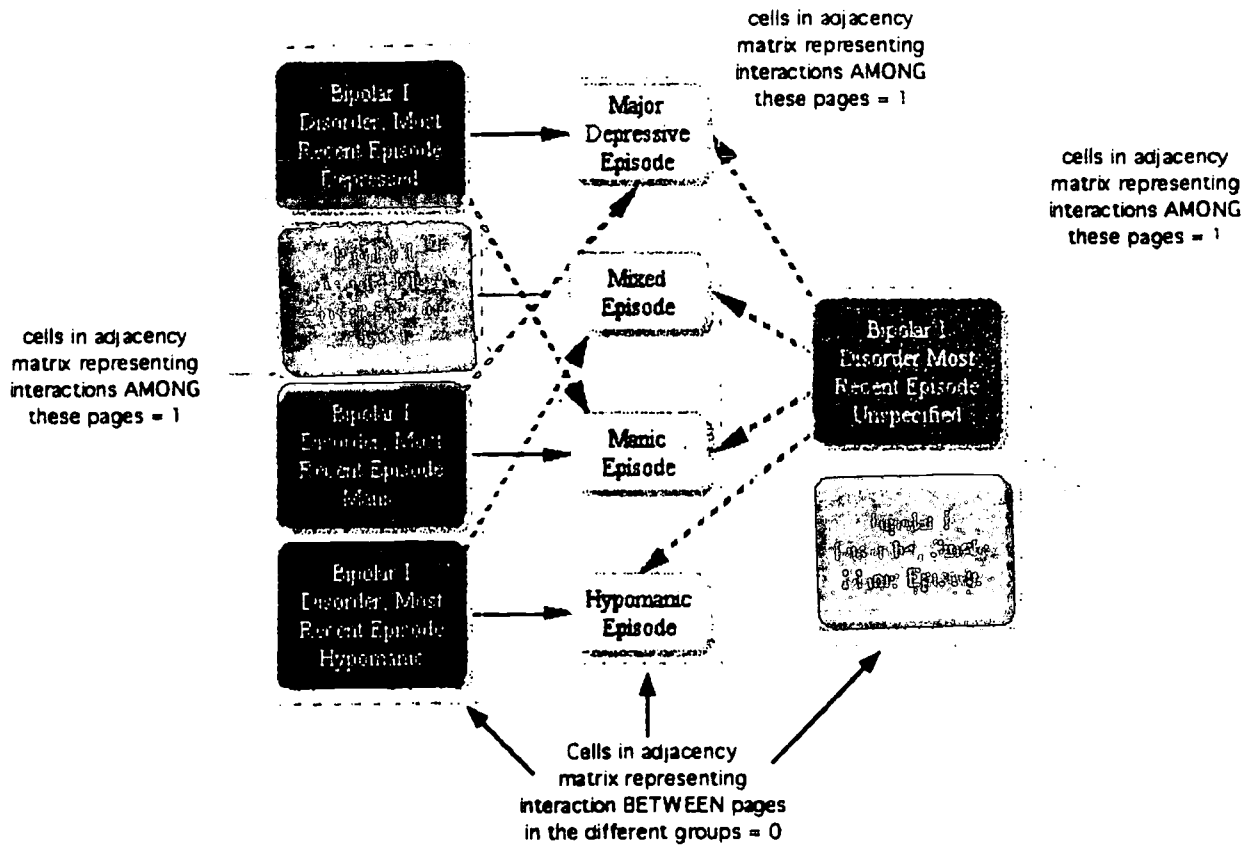

Table 6. Creation of *HyperMap* Prototype Adjacency Matrix

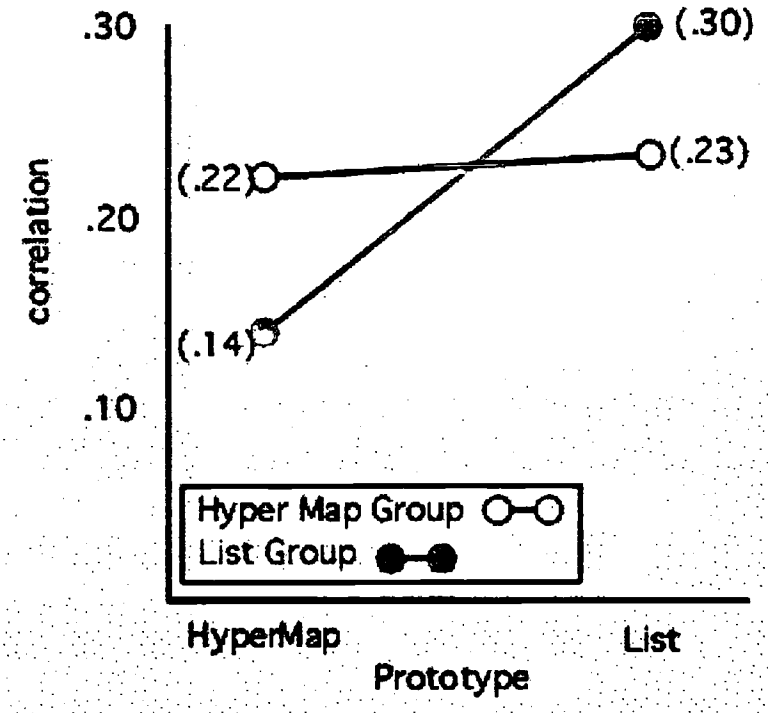

Figure 7. Correlation with Prototype Matrix as a Function of Group and Prototype

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	E-Mail Address: ~~rhall~~ rhall@umr.edu Date: 6/5/2000

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