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Investigating the Relation between Users' Cognitive Style and Web Navigation Behavior with K-means Clustering

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Presentation Outline

- Introduction
  - Traditional vs Adaptive Interactive Systems
  - User Modeling Mechanisms
  - Main Challenges
- Bridging the Gap Between Cognitive Factors and Navigation Behavior
- Method of Study
- Results and Limitations
- Conclusions and Future Work

Users are different

- Users do not necessarily share common characteristics and cognitive backgrounds
- Designing usable interactive systems entails understanding the interdependencies among the users':
  - characteristics
  - task
  - device
    - in which human computer interaction takes place

Interactive Systems: One size fits all?

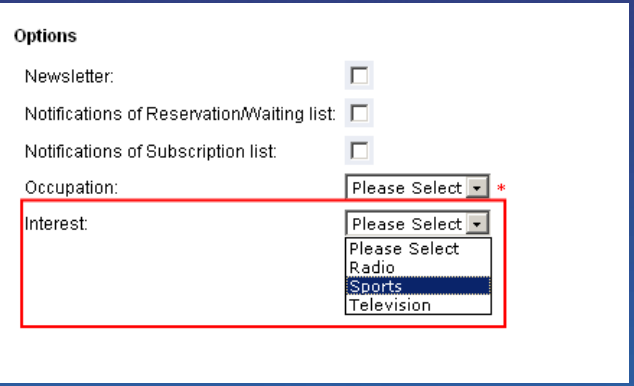
- Traditional interactive systems treat the users the same way
  - Inability to satisfy heterogeneous needs and preferences of users
  - Users become lost or confused by redundant information

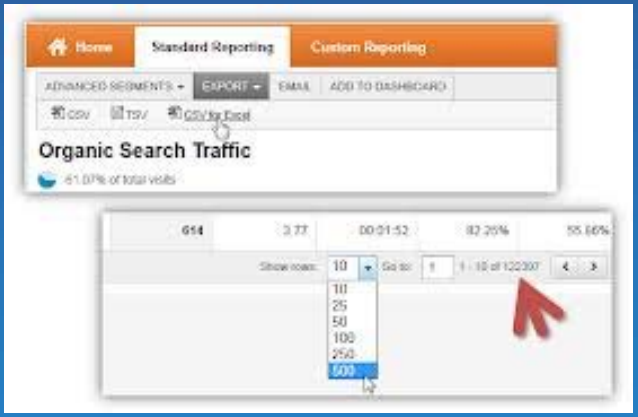
- **Adaptive** Interactive Systems (AIS) offer an alternative

  by adapting content, and functionality according to the users' needs and preferences, in order to improve efficiency, effectiveness and user experience

User Modeling Mechanisms

- User information collection
  - Explicitly, through:
    - direct input via Web forms
    - online questionnaires
    - psychometric tests
  - Implicitly, through:
    - navigation pattern
    - browsing activity
    - browsing history





However… several challenges are identified

- Is user profiling comprehensively approached?
- Are current user profiling methods sufficient?
- Can we take advantage of human factors in the process of user model creation?
- Can clustering methods assist the user modeling process?

The aim of this work is to study whether clustering techniques can identify the relation of cognitive styles with user interaction data

Riding's Cognitive Style Analysis

Individuals have an habitual and preferred way of processing and organizing information. A popular cognitive style theory separates users according to two dimensions (Riding and Cheema, 1991).

CSA Scale	Typology	Description	Web Implications
Verbal/Imager	Verbal	Process information in **textual** form more efficiently	Web content in **text/auditory** form
	Imager	Process **images** more efficiently	Web content in **graphical, visual** representation
	Intermediate	In between the Verbal/Imager scale	No significant difference in preference or information processing
Wholist/Analyst	Wholist	Views a situation and organizes information as a **whole**	**Linear** approach in Web-site navigation
	Analyst	Views a situation as **a collection of parts** and only stresses one or two aspects at a time	**Nonlinear** approach in Web-site navigation
	Intermediate	In between the Wholist/Analyst scale	No significant difference in information processing

Research Hypothesis

- Cognitive styles may correspond ideally to the structure of Web environments
  - the content is essentially either visual or verbal (or auditory)
  - the manipulation of links can lead to a more analytic and segmented structure, or to a more holistic and cohesive environment
- Differences in cognition are likely to be reflected in navigation behavior of users

The study designed aims to understand how cognitive factors affect navigation behavior of users

Method of Study

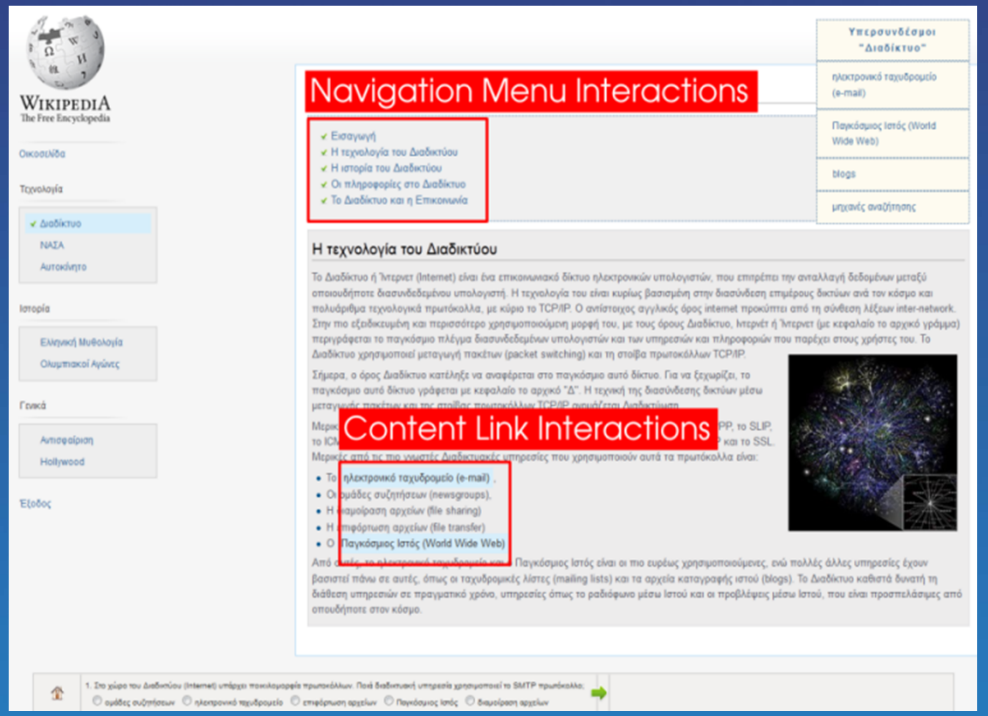
- Participants: 22 undergraduate students
- When: November 2011
- Age: 20 to 25
- Procedure:
  1. Users performed psychometric test
  2. Extract cognitive styles
  3. Users navigated in a controlled Web environment
  4. Extract navigation patterns based on three navigation metrics

Psychometric test

- Utilized Riding's CSA
  - Measured the response time on two types of stimuli and computed the ratio between the response times for each stimuli type in order to highlight differences in cognitive style
- The stimuli types are:
  - statements (i.e., identify whether a statement is true or false)
  - pictures (i.e., compare whether two pictures are identical, and whether one picture is included in another picture)

User's Navigation

- Users freely navigated in a reproduced version of a Web application; Wikipedia
- Navigation patterns were monitored at all times



Navigation Metrics

- Absolute Distance of Links (*ADL*)
  - Low value indicates nonlinear navigation behavior
  - High value indicates linear navigation behavior
- Average Sequential Links (ASL)
  - Low value indicates linear navigation behavior
  - High value indicates nonlinear navigation behavior
- Average non-sequential Groups of Links (*AGL*) visited
  - Low value indicates nonlinear navigation behavior
  - High value indicates linear navigation behavior

Data Analysis

- Data pattern analysis was used to discover knowledge from such complex humanistic and click-stream data
- *k*-means clustering was performed
  - on the answers of the users to the psychometric test
    - Analyst/Wholist dimension
    - Verbal/Imager dimension
  - on the navigation behavior of users (click-stream) interacting with the online encyclopedia system while trying to answer a set of specific questions

Results

RQ 1: Can clustering be utilized to cluster users based on their responses to the psychometric test?

RQ 2: Does this clustering correspond to the theoretic basis of Riding's CSA?

Cluster	# Users	Wholist-Analyst Range	# Users	Verbal-Imager Range
1	8	[0.786, 1.030]	6	[1.121, 1.248]
2	12	[1.099, 1.424]	7	[0.958, 1.040]
3	2	[1.776, 1.853]	9	[0.832, 0.941]

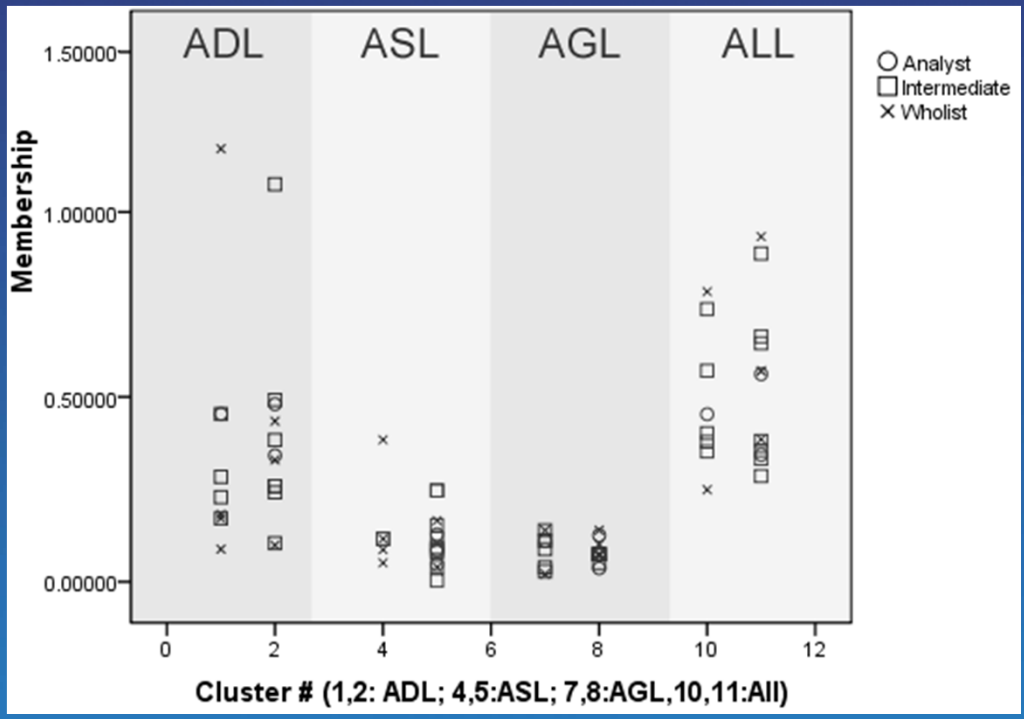
Ratio of Cognitive-based Profiles of Clustered Users from the Psychometric Test

- clustering performs very well in grouping users based on their response to the psychometric test
- clustering resulted in balanced groups of users which correspond to the ranges proposed in theory

Results

RQ 3: Can clustering differentiate users based on their navigation behaviour?

- our method used to capture users' navigation and the metrics proposed to measure linearity were both successful
  - since they can effectively group users in two distinct clusters (with significantly different values and mean values) following linear and nonlinear navigation



Findings

- *k*-means clustering could be applied effectively on the data extracted from cognitive-based psychometric tests for highlighting differences in users' cognitive styles by assigning the users into cognitive-based clusters
  - Clustering mechanisms can be used as an alternative method for forming groups of users with particular cognitive style, handling the uncertainty and fuzziness of the information available (e.g., ratio) to extract optimum groups of users, rather than using a strict rule-based mechanism that highlights differences in cognitive style based on specific thresholds

Findings

- The clusters formed using the users' navigation behavior showed that the three proposed metrics (measuring linearity in their interaction) can distinguish users with similar navigation behavior
- The users of the same cluster group although had similar navigation behavior (i.e., linear or nonlinear), their respective cognitive style was variant
  - This is maybe due to potential weaknesses of the reproduced version of Wikipedia at a design level which needs to be further studied

Limitations of the study

- Participants were undergraduate students aged between 20 to 25 years (narrow sample)
- Carrying out a single assessment of users' cognitive style might not fully justify the users' classification into specific cognitive style groups
  - Thus, further study needs to be conducted in order to reach to more concrete conclusions

Future work

- Conduct further studies investigating the relation of cognitive styles of users with other types of navigation behavior than the ones investigated in this work (i.e., linear/nonlinear)
- Capture and study the users' interactions with other Web objects (e.g., drop down lists, drag and drop tools, Web forms)
- Investigate the effect of users' navigation behavior during collaborative and sharing activities as well as evaluate the proposed approach and metrics in other Web environments (e.g., social networks, collaboration platforms)

Thank you for your attention

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