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Cognitive Styles within an Exploratory Search System for Digital Libraries

1. Introduction

Significant amounts of cultural heritage material are now available through online digital library portals to users with varying levels of expertise and ability to find, navigate, interpret and use such information. Increasingly, the providers of cultural heritage (i.e., libraries, museums and archives) are seeking to make their content more widely accessible and in innovative ways. Cultural heritage institutions are seeking to provide richer user experiences that support connectivity between people, content and applications, to support writers as well as readers, and to enable collaborations with and between users. For example, a new generation of cultural heritage portals is encouraging user participation through the tagging of resources and making recommendations to other users (Carmagnola et al., 2008; Trant, 2009). However, this vast amount of material from libraries, museums and archives can also be overwhelming for many users who are provided with little or no guidance on how to find and interpret this information (Johnson, 2008; Skov and Ingwersen, 2008; van den Akker et al., 2013). Potentially useful and relevant content is hidden from the users who are typically offered simple keyword-based searching functionality as the entry point into a cultural heritage collection. The situation is very different within traditional mechanisms for viewing cultural heritage (e.g., museums) where items are organised thematically and users guided through the collection.

In this work we recognise that users of cultural heritage portals have diverse information needs and exhibit highly individualistic information seeking behaviours, which are not well supported by the functionalities offered by standard search interfaces. Recent trends in information access services have recognised the necessity of providing support for more exploratory and serendipitous search behaviours if services are to be effective in helping users with discovering and assimilating knowledge (Eaglestone et al., 2007; Foster and Ford, 2003; Ford 1999; Marchionini, 2006; White and Roth, 2009; Wilson et al., 2010). This article describes and makes use of a novel prototype system (the PATHS system) that seeks to support users with accessing information from digital cultural heritage collections and assisting broader information activities, such as learning and exploration (Stevenson et al., 2013). A key aspect of the system has been the integration of ‘paths’ (collections of artefacts organised around a theme) to assist users with navigating and interpreting the content. Pathways and trails have previously demonstrated an effective approach for guiding users through online digital collections (Shipman et al., 2000) and items displayed in physical museums (van Hage et al., 2010; Grieser et al., 2011).

Following a lab-based evaluation, user-system interaction data and user feedback have been utilised to study the relation between the user’s cognitive style and their interaction behaviour. In particular, we focus on the wholist/analytic dimension of cognitive styles (Riding 1991). Our hypothesis is that these styles affect the way that users interact with the prototype system when presented with various tasks involving collections accessible via the system. We postulate that users search with the system in different ways, produce different results when asked to create their own paths from the collection, and also evaluate their own experiences differently. To test this theory we analysed a number of detailed experiments in which users were presented with a number of tasks to accomplish using a large digital library, including various types of search and exploratory tasks and also that of creating their own path using items from the library. Our studies lend support to the hypotheses that users with different cognitive styles will: (i) exhibit different navigational behaviours; (ii) assign different levels of value to the various navigational features offered by the system; and (iii) require different kinds of support when interacting with the system. The aim of this work is to provide a basis for future work in which we can predict the cognitive styles of users based on the way that they interact online and tailor their search experiences accordingly.

The work described here differs from previous work on the analysis of cognitive styles in a variety of ways, including the following. Multiple analysis techniques are adopted in the study (transaction log analyses, lab-based evaluation and user feedback). The navigation system offers the user a range tools for exploring the collection, allowing them to adapt the way in which they interact with the system to the one that is most appropriate for their cognitive style. A significant amount of analysis has been carried out on the digital library to which the system is applied and this information is used to support navigation. This level of analysis would not be possible for some collections (e.g. the web).

The remainder of the paper is structured as follows. Section 2 provides a summary of related work; Section 3 describes the prototype PATHS experimental system used to investigate the interaction behaviours of how different users interact with a system; Section 4 outlines the research problem and methodology used to gather and analyse data; Section 5 presents the main results and analysis of the main findings; Section 6 discusses the results in light of previous research and proposes a tentative model describing unexpected differences between users' attitudes and search behaviours; finally we conclude the paper in Section 7, together with providing suggestions for future work.

2. Background

Adapting cultural heritage to the digital age

Cultural heritage institutions hold an enormous and rich variety of digital content covering a broad range of subjects: natural history, ethnography, archaeology, historic monuments, fine and applied arts which often cross national and linguistic boundaries. There is strong motivation to bring together content from different cultural institutions into aggregated portals, which have typically offered access services based on traditional catalogues used in libraries, museums and archives. Search services have been geared towards subject specialists and experienced users; yet the environment in which users and digital library services are operating has changed. People come to digital libraries with experience of using the web and with new expectations (Connaway, 2009).

Cultural institutions wish to be able to offer users of their portals an experience that is continuous with the way people experience the web. They are seeking to enable richer user experiences that support connectivity between people, content and applications, to support writers as well and readers, and to enable collaborations with and between users. A new generation of cultural portals is encouraging user participation by offering people with opportunities to interact with content (for example encouraging them to tag resources) and to make recommendations to other users (Carmagnola et al., 2007; Trant, 2007). Institutions are looking for ways to recreate in the digital information space the opportunities that visitors to libraries, museums and archives have of sharing books, objects and ideas with each other. They would like to be able to personalise the experience for their digital library users, for example suggesting content that is more likely to be of interest based on their profile and highlighting associations between related items (Bowen and Filippini-Fantoni, 2004). Issues related to user-adaptivity, such as controllability, trust, privacy, obtrusiveness, predictability, transparency and breadth of user's experience are also important (Jameson, 2003).

Cognitive Styles

"Human individual differences" have now been the subject of considerable research efforts for a number of decades, particularly in the fields of psychology and education (Jonassen and Grabowski, 1993). More recently, information behavioural aspects of such differences have been the focus of a research in library and information science (Bawden and Robinson, 2011). The range of human differences studied from an information perspective has included demographic factors such as age and gender (Ford, Miller and Moss, 2005) as well as cognitive features such as personality types (Heinström, 2011), levels of search experience (Kim, 2011), and cognitive styles.

A cognitive style is a characteristic way in which an individual tends to approach a cognitive task, such as learning or problem-solving. "Learning styles" or "problem solving styles" are examples of a cognitive styles applied to particular activities. Examples of cognitive styles include field dependence/ independence (Witkin et al., 1977); impulsivity/reflectivity (Kagan, 1965); holist/serialist (Pask, 1976a; 1976b; 1979; 1988); leveler/sharpener (Holzman and Klein, 1954); simultaneous/successive (Das, 1988); and divergent/convergent (Hudson, 1966). The dimension of cognitive style selected for this study is that of wholist/analytic (Riding and Cheema, 1991; Riding, and Rayner, 1998), also known as field-dependence/independence (Witkin, 1976; Witkin and Goodenough 1981, Witkin et al., 1977). This style has been the focus of research study for over 40 years, and has been found to influence a wide range of human activity, from basic perception to career choice. Riding's "wholist" and "analytic" is used in preference to Witkin's "field-dependent" and "field-independent", though as Riding and Cheema (1991) note, the constructs are essentially equivalent.

Witkin et al (1977) published a detailed review of research describing the essential features characterising the two dimensions and their educational implications. Essentially, analytic individuals are more adept at structuring and analytical activity when compared with their wholist counterparts. Wholist individuals thrive more in situations where learning is structured and analysed for them. They tend to prefer a 'spectator' approach to learning rather than the hypothesis-testing approach favoured by more analytic learners. They operate with a relatively external frame of reference, as opposed to the greater "inner directedness" of the analytic individual. Wholists tend to be more socially oriented than analytics, and this may even be reflected in the type of academic study and employment they choose and in which they excel. Essentially, as their name suggests, relatively analytic individuals tend to experience the components of a structured field analytically, as discrete from their background, and to impose structure on a relatively unstructured field. By contrast, relatively wholist tend to be less good at such structuring and analytic activity, and to perceive a complex stimulus globally as a gestalt.

Wholist/analytic cognitive style differences have been observed in relation to a wide range of human activity. Indeed, this dimension would seem to extend from perceptual through to intellectual and social functioning. Witkin et al. (1977) published an extensive review of studies of the constructs, which appear to underlie a wide range of human activity, from the way people perceive, to problem-solving and social interaction. As Witkin et al. (1977:8) note:

> "Extensive evidence, accumulated over the years, shows that the styles we first identified in perception manifest themselves as well when the person is dealing with symbolic representations, as in thinking and problem solving. The individual, who, in perception, cannot keep an item separate from the surrounding field-in other words, who is relatively field dependent-is likely to have difficulty with that class of problems, and, we must emphasise, only with that class of problems, where the solution depends on taking some critical element out of the context in which it is presented and restructuring the problem material so that the item is now used in a different context."

At a perceptual level, relatively analytic (field independent) individuals are more adept at perceiving a shape embedded in a more complex figure. They are also more analytic in their learning and problem-solving, but are less socially oriented than their more wholistic (field-dependent) counterparts. Thus the dimension would seem to extend from basic perception, through learning and problem solving to social interaction.

Ford et al. (2002) found that analytic researchers were more active and analytic than their wholist counterparts, based on assessments of their problem-solving and information-seeking behavior. The finding that analytic individuals report clearer, more focused thinking is in line with the greater analytical competency associated with them in the research literature. There would seem to be some evidence to support the notion that analytic individuals take a less passive, less reproductive approach to research than their wholist counterparts. They report more of Ellis's (Ellis, 1989; Ellis and Haugan, 1997) "engaged differentiating" activity, and the higher reported levels of change in perception of the problem they are working on are compatible with the more active transformational engagement with, and questioning of new information characteristic of the relatively analytic person.

Cognitive styles and effects on search and navigation

A study by Chen and Ford (1998) investigated hypertext navigation. Twenty postgraduate students were tested using Cognitive Styles Analysis (CSA), then learned from a hypertext system designed to give an introduction to the field of artificial intelligence. Navigation patterns were logged for analysis. It was found that relatively wholist individuals made significantly greater use of the main menu, their more analytic counterparts making more use of the relatively sequential previous/next buttons. Analytic students thought the structure of the hypermedia program was clear, while wholist students experienced more disorientation problems. Similar results were also obtained in Kim's (1997) study, which found that wholist users appeared more to become lost and to be distracted on the Web.

Ford and Chen (2000) also found significant differences in navigation strategies used by wholist and analytic individuals in a hypermedia learning environment. Analytic learners made greater use of the index to locate a particular item. Conversely, wholist learners preferred to use the map to get the whole picture of the context. Chen and Macredie (2002) reviewed a number of studies of the wholist/analytic dimension in relation to information processing. They concluded that the research suggests that global individuals prefer more structured linear pathways while more analytic learners prefer freer more exploratory nonlinear pathways through hypermedia systems (Andris (1996); Chang (1995); Durfresne and Turcotte (1997); Reed and Oughton (1997). They also concluded that wholist individuals had a greater need to be provided with structure and guidance.

There is also evidence that the styles of the web users affected their information search strategies. Studies by Ford et al (1994) and Wood et al (1992), for example, revealed significant links between global/analytic differences and search behavior. Postgraduate students conducted searches on Silver Platter's CD ROM-based Library and Information Science Abstracts (LISA) database on subjects related to their coursework. Their searching strategies were classified in terms of relative breadth and depth. A high use of the word OR to link keywords represents a relatively broad strategy: a high use of 'AND' a relatively narrow strategy. Other measures of the breadth or narrowness of search included truncation and generic descriptors (which broaden a search), and use of date or language qualifiers (which tend to narrow a search). Relatively global individuals used significantly broader search strategies than their analytic counterparts.

In a study by Kim (1997), relatively analytic individuals tended to use search engines, the find option, and URLs more frequently to reach the desired Web sites for information. On the other hand, relatively wholist individual students tended to use the home or back/forward keys more frequently. This implies that analytic individuals tend to engage in search tasks with more active and analytic strategies. In contrast, relatively wholist individuals do not feel comfortable with using tools for moving between different nodes and navigating the Web in a linear mode. This finding is similar to those of Liu and Reed's (1995) study.

Wang et al. (2000) investigated cognitive and affective aspects of Web searching by 24 Masters students. They found interactions between cognitive style and both difficulty and confusion. Wholist students experienced more difficulty and confusion than their analytic counterparts. Levels of anxiety were linked to negative feelings, which in turn, could affect levels of persistence in searching.

Palmquist and Kim (2000) studied the effects of both experience and cognitive style on Web searching. They investigated searching by undergraduate college students of a university Web site when conducting factual and topic searches. They found that cognitive style interacted with experience of on-line database searching. Wholist novice searchers took longer and traversed more nodes in locating relevant information than analytic novices. Wholist novices also made greater use of embedded links. The authors explained that wholist users prefer a well-structured set of stimuli, and do not enjoy imposing a structure by themselves, so they tended to follow links prescribed by the authors of Web pages. They suggested that wholist users, especially for those who had little or no experience with online databases, might need special attention from the interface designers. No significant cognitive style differences were found among experienced searchers.

In a study by Chen et al (2005), wholist and analytic users displayed different preferences relating to the presentation of subject categories in a web directory. Relative to analytic users, wholists: (i) preferred more main categories with fewer levels of subcategory; (ii) preferred web pages that presented subcategories first, followed by the corresponding results, in comparison with analytics who preferred to have results presented first, followed by subcategories; and (iii) where categories and subcategories were presented before specific results, preferred main and subcategories to be presented on separate pages, whereas analytics preferred both to be presented on the same page. These preferences may reflect wholists' greater concern early to establish a global overview of the information space rather than begin by targeting more specific detail.

Adapting information systems navigation features to individuals' cognitive styles

The cognitive style literature suggests that stylistic differences in individuals may affect not only the strategies people adopt in learning or information seeking, but also the nature and effectiveness of the results of these cognitive processes – whether in learning (Ford, 1985; Ford & Chen, 2001; Pask, 1988; Witkin et al., 1977) or information seeking (Ford, 2001). Insofar as stylistic differences may affect the nature and effectiveness of the results of cognitive processing, these constructs are potentially relevant to designing information systems capable of helping individuals optimiseoptimize their information seeking performance, such as the PATHS system reported here.

It appears that wholist individuals learn better when adopting a breadth first exploration of an intellectual space. Ford (1995) conducted an empirical study, in which students' cognitive styles were identified with Riding's CSA. Students were asked to learn from computerized versions of a set of teaching materials designed to match wholist and analytic learning styles. He found that learning found in matched conditions was significantly superior to that found in the mismatched conditions. Wholist individuals had higher test scores in their matched learning condition, and analytic individuals obtained higher test scores in their matched condition.

Similar results were reported by Ford and Chen (2001), who examined the effects of matching and mismatching on student learning. Two versions of hypermedia learning systems were designed entailing breadth-first and depth-first explorations. The material was classified into seven levels in depth. In the depth-first version, each topic was presented exhaustively before the next topic, which was presented in the same way (i.e., it was matched to an analytic cognitive style). In contrast, the breadth-first version gave an overview of all of the material prior to introducing detail (i.e., it was matched to a wholist cognitive style) and included 12 categories in breadth. Their results showed that students whose cognitive styles were matched to the design of hypermedia learning systems attained higher post-test and gain scores.

Wholist learners in the breadth-first version performed better than those in the depth-first version. Conversely, analytic students outperformed wholists in the depth-first version. The studies imply that analytic individuals are more adept at adopting a strategy in which they pay early attention to relatively detailed lower level content when processing information in a learning context (Pask, 1976b, 1979). The findings also provide support for the notion that matching and mismatching can have significant effects on learning outcomes.

In summary, different individuals may have different predominant navigational styles. These appear to be linked to more fundamental cognitive styles. High academic achievers, as well as less academically achieving people, may still have a predominant style. These navigation styles translate into different navigation paths.

The implication for the work reported here is that it may be possible to optimise users' performance using an information system if that system is capable of adapting to individuals' cognitive, and consequently navigational, styles. Adopting a navigation path that matches one's predominant style can influence the *effectiveness* of the resultant learning. Where an individual navigates using a path that mismatches their predominant style their learning may be disrupted; matching a navigational path may enhance learning (for a given learning task). However, these results have been found in experimental rather than more natural learning conditions.

Navigation paths adopted by individuals may also vary according to their level of *subject expertise* in the area being navigated. Different paths may also be more, and less appropriate for achieving *different types of goal/task* (e.g., relatively convergent fact-finding versus more divergent creative exploration).

Individuals also vary in the extent to which they thrive in navigational conditions characterised by external mediation (guidance) versus autonomy. This difference appears to be linked to fundamental cognitive style. Relatively wholist individuals are more likely than their more analytic counterparts to be more interested in engaging early in broad exploration in order more quickly to establish a conceptual overview, as opposed to narrower investigation of details; be less independent in their thinking and more reliant on structuring and guidance from others; and be more socially oriented.

3. The PATHS System

Within the context of the EU-funded PATHS (Personalised Access To cultural Heritage Spaces) project[1], we have developed an experimental system to assist users in their exploration of digital cultural heritage (Hall et al., 2014). Navigation in the PATHS system is based around the metaphor of pathways (or trails) through the collection, an approach that has been widely explored as an alternative to standard keyword-based search (Furuta et al., 1997; Reich et al., 1999; Shipman et al., 2000; White and Huang, 2010). Pathways are collections of artefacts organised around a theme, which form access points to the collection. Although the PATHS system could be applied to any document collection, our focus has been on Cultural Heritage since pathways are particularly useful in this context. Users accessing these collections are often unfamiliar with their content, making keyword-based search unsuitable since they are unable to formulate appropriate queries (Wilson et al., 2010). Search interfaces utilising functionalities that go beyond keyword search have shown to be more suitable for exploratory search (Marchionini, 2006). Pathways support this exploration by echoing the organised galleries and guided tours found in museums.

The PATHS system has been applied to a range of cultural heritage collections including Europeana, a commercial photographic archive, and an archive of fairground memorabilia. Our experiments focus on Europeana, the largest collection to which PATHS has been applied. Europeana[2] is a web-portal that acts as a single access point to collections of cultural heritage artefacts provided by a wide range of European institutions. It currently provides access to over 20 million artefacts including paintings, films, books, archival records and museum objects, provided by around 1,500 institutions, ranging from major institutions, including the Rijksmuseum, the British Library and the Louvre, to smaller local museums. Europeana contains information in a variety of European languages. The majority of content available in English is provided by Culture Grid[3] and this was used for the PATHS system. Culture Grid contains information about artefacts from 40 UK content providers such as national and regional museums and libraries. The collection contains around one million items but we found that many of them had insufficient detail to be of general interest. Items lacking sufficient metadata were filtered out to leave around half a million items (Agirre et al., 2013).

The interface for the PATHS system[4] has three main areas:

1. Search, which supports discovery of both artefacts and pathways via keyword search.

[1] http://www.paths-project.eu
[2] http://www.europeana.eu
[3] http://www.culturegrid.org.uk
[4] Development of the PATHS prototype followed two iterations cycles of design, prototype and evaluate. The work reported in this paper uses the initial or first prototype system; experiments with a second and more enhanced version of the system are left for future investigation.

2. Paths, which enables users to navigate via previously (manually) created pathways.
3. Explore, which enables users to explore the collections using different types of overview.

We now describe each of these areas in more detail with a focus on the aspects of the functionality that are incorporated in the analysis described later. More details about the design of the interface can be found in (Hall et al., 2014).

Search

This area allows users to search for artefacts and pathways using standard keyword-based search**.** The search screen includes single free-text search field, as well as a list of keywords users can select from and a scrolling field of sample content thumbnails representative of the contents of each of the keywords. These keywords provide useful suggestions for users who are not familiar with the content of the collection or are unable to formulate suitable queries. Figure 1 shows an example of the search screen. The search box is towards the centre, keywords on the left-hand side and sample content towards the bottom. In the search results, each item is presented with a title, short description, thumbnail (if available) and metadata, such as the content provider, location and subject.

[FIGURE 1]

Paths

This area (Figure 2) provides users with access to artefacts from Europeana through pathways or trails. These are manually generated sets of artefacts arranged as a sequence, which are designed to showcase the content available to the user in an organised way. They are created by users and can be published for others to follow. When a user chooses to follow a path and they are shown a set of items in the collection. The PATHS system also provides a workspace area, which supports users who wish to create their own paths. Users have the option of adding an item to their workspace when they view them, and can then organise these into a path and provide some descriptive information, such as a title, brief descriptions, and tags. The screenshot in Figure 3 shows the interface when a user follows a path. It displays the current item in the path (‘enamel advertisement’) together with information about the path towards the left of the screen. Following the “My Paths” and “Workspace” links to the right of the screen invokes the path building environment in which the user can create their own paths. (This is available in all parts of the interface).

[FIGURE 2]

[FIGURE 3]

Explore

This area allows users to explore the collection without having to rely on keyword-based search by providing two functions. The first of these shows a slideshow from the collection, providing the user with a random selection of content to explore. The second function, the tag-cloud, provides users with an overview of the collection presented in a visual format. Each item is represented by a thumbnail image, which can be clicked for the users to explore. An example of one of these visual tag clouds is shown in Figure 4. Users can get further information about the items by clicking on them[5].

[FIGURE 4]

4. Methodology

Data Collection

Data collection for this study was carried out during user evaluations of the PATHS system using a comprehensive Interactive Information Retrieval (IIR) style protocol, under controlled conditions in a laboratory environment. The study was completed by 22 users who were recruited according to three scenarios: regular museum visitors who use cultural heritage information for leisure purposes; students who use it in the course of their degree; and, professionals (curators, teachers, researchers) who use cultural heritage materials in their work. These scenarios relate to the primary user groups identified in an earlier user requirements study (Goodale, et al, 2011). Participants were required to use PATHS to complete a number of simulated information and work tasks, including four simple 5-minute information seeking tasks (examples given in Table 1), arranged using a Latin square design, and a longer (30-minute) more complex path creation task. Tasks were derived from a review of the literature on information seeking in cultural heritage (e.g., Skov and Ingwersen, 2008; Clough et al., 2008) and from interviews with cultural heritage expert users during an earlier user requirements gathering study (Goodale et al., 2011). Each user completed all four of the information seeking tasks (rotated according to the Latin square), and the path creation task, with a scenario aligned to their user group (leisure, student, work). The path creation task allowed participants a degree of freedom of interpretation, providing an approximation of a real world task according to the user profile.

[TABLE 1]

Data was collected via (i) a user profile questionnaire, (ii) the CSA cognitive style test (Riding 1991), (iii) observations of the tasks undertaken (screen-recording and transaction logs), (iv) a feedback questionnaire on the tasks, (v) a feedback questionnaire on the overall session, and (vi) a think-after interview for qualitative reflections on the path creation task and the PATHS system in general. Observation data from the screen-recordings provides more fine-grained detail than the transaction log data in some parts of the PATHS system; for example, the extended path creation activity, which takes place in a single screen, but incorporates multiple interactions over several minutes. Transaction log data provides quantitative data that can be more easily analysed for sequences of interactions. Feedback on all tasks comprised responses to three 7-point semantic differential scales (familiarity with the topic, ease of task completion, how enjoyable was the task), and a free text comment box.

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[5] In a second version of the system we provided more advanced exploration functionalities, including a taxonomy and map-based visualisation of concepts in the collection.

Additional feedback on the path creation task included the user's own rating of their path, and comments on what they would do to improve the path they created, given more time and resources. Session feedback relating to the experience of using the PATHS system as a whole comprised a set of sixteen 7-point semantic differential scales to rate how well the system supported a variety of information seeking and related tasks (Likert scale). Participants were also asked to),rate each primary feature of the system according to three 7-point semantic differential scales (easy to use, useful, inventive), a rating of likeliness of using different features of the PATHS system, and comments on how these features could be improved.

Analysis

Three types of analysis are performed on the data generated from evaluating the PATHS system. First, analysis of task performance and interactions based upon screen-recording observations and related responses in the feedback questionnaires gives a broad understanding of the differences in information seeking behaviour. Second, more fine-grained analysis of the transaction logs generated from the task activity provides additional detail on the sequence of interactions. Third, analysis of attitudinal data from the feedback questionnaires provides further insight into user preferences. All of these analyses are segmented by users' cognitive style on the wholist-analytic (WA) dimension of the Riding CSA test. Scores on this test can be used in two ways. Raw scores can be used to determine an individual's position on a bipolar dimension from analytic to wholist. Alternatively, a classification recommended by the author of the test can be used to group ranges of scores into three categories - analytic / intermediate / wholist. Given a relatively small sample size, the majority of the analyses are based upon cross-tabulations against the three categories. In addition, however, where there was sufficient data available, raw scores on the CSA are used in Spearman's Rank correlation analyses.

5. Results and Analysis

In this section we present the raw findings from the user evaluation, with analysis by users' cognitive style on the wholist/analytic dimension, along with discussion on the meaning of these findings in the light of the research questions. The findings are presented in three sections: (i) task performance, in terms of time taken, and level of engagement (path creation task); (ii) user interactions, conducted via an analysis of the transaction logs; and (iii) participant feedback based upon an analysis of the session feedback questionnaire.

5.1 Analysis of Task Performance

Participant performance in terms of time taken on each task was analysed overall, by task, and by the wholist/analytic dimension of their cognitive style. Time taken is a common measure of performance in studies of usability and information seeking and gives an indication of how easily the task was completed, although for browsing and exploration tasks a longer time taken does not necessarily indicate relative failure, due to the higher levels of engagement that may be involved. Time taken to complete the different tasks was measured from the screen recordings and was found to vary by both task type and by cognitive style. For the information seeking tasks, time allowed was capped at 5 minutes; whilst for the path creation task participants were allowed 30 minutes.

Information seeking tasks

Analysis of time taken of the four short 5-minute information seeking tasks (Table 2) shows that the extended fact-find task had a lower mean (4.07 minutes, lowest mean for all tasks), than the simple fact-find task (4.53), and the mean for the exploration task (4.36) was lower than the mean for the open-ended browsing task (4.78, highest mean for all tasks). Whilst the reason for the difference between the fact-finding tasks is unclear, we may infer that the information need for the exploration task was satisfied more quickly than the information need for the browsing task, on the basis that for the former the requirement was to find one suitable item, and for the latter, the number of items required to complete the task was open to interpretation.

[TABLE 2]

When analysed by cognitive style, there is a difference in the time taken between the wholist/analytic types, with analytics exhibiting the lowest mean time taken (4.33 minutes), and wholists exhibiting the highest mean (4.79); an increase of almost 11% time taken by wholists compared to analytics. This greater amount of time taken by wholists is consistent with the hypothesis that they will exhibit a higher degree of dependence, and consequently lower levels of confidence in undertaking tasks in a novel environment. From analysing the proportion of participants who were prompted to end the task at the 5-minute time limit, it is found that prompting was required overall for 71.4% of tasks, most often for the browsing task, and least often for the extended fact-find task. Analysing the data by cognitive style, it is also found that wholists were more likely to be prompted to end their task (75.0%), than analytics or intermediates (both 68.8%), again, supporting the hypothesis that wholists are more dependent and less confident in completing tasks in a novel environment. Time taken on the short 5-minute information seeking tasks is found to be negatively correlated with the numerical ratio score for the wholist/analytic cognitive style dimension (r=-0.30, n=56, p=0.25, 2-tailed), indicating that time increases, the higher the score on the wholist/analytic scale. This confirms the significance of the finding that wholists, being more dependent, are likely to take more time on information seeking tasks in a novel environment.

However, despite variations in the amount of time taken per task, ratings on the 7-point semantic differential scales for easy/complicated and enjoyable/unenjoyable are broadly similar across all three wholist/analytic categories, and a positive correlation was found between the two scales (r_s=0.498, n=88, p=0.000, 2-tailed), i.e. independent of cognitive style, if tasks are found to easier, they are found to be more enjoyable. Positive correlations are also found between time taken on the information seeking tasks, and each of the semantic differential scales; easy/complicated (r_s=0.390, n=88, p=0.000, 2-tailed), and enjoyable/unenjoyable (r_s=0.247, n=88, p=0.20, 2-tailed), indicating that tasks that are easier and/or more enjoyable, take less time to complete. It may also be inferred therefore, that since wholists take more time on the tasks overall, that they are likely to find the tasks more difficult to complete and less enjoyable.

Path creation task

A longer, more complex path creation task was undertaken by all participants, with a time allowance of 30 minutes, incorporating elements of sense-making and creativity (see Goodale, et al., 2014, for further analysis). As with the shorter tasks, the mean time taken increases with higher wholist scores, indicating a higher degree of dependence than analytics, and a greater degree of learning required to complete this relatively novel task (not generally supported in other digital libraries), within a novel system. However, the standard deviation for wholists is somewhat lower, and so conversely it is also found that these participants were less likely to use the full 30 minutes (33% prompted) than analytics and intermediates (50% each). This may indicate that wholists 'gave up' more quickly on the task than their analytic counterparts, or that they are less 'analytic' in their behavior, and approached the task in a more simplistic way, thereby reaching a state of task completion before the allocated time had fully elapsed. Conversely, analytics exhibited more analytical and complex behavior, and were therefore more likely to keep working on the task for the full time allocation.

In contrast to the shorter information seeking tasks, user differences are found in the semantic differential ratings by user category for the path creation task. Whilst an overall positive rating of at least 50% was given by all user types for both easy/complicated and enjoyable/unenjoyable, analytic users are much more likely to give a negative rating on both scales than intermediate and wholist users. This ties in with their more analytical approach to the task, and their tendency to keep working on it, fine-tuning the path in an attempt to achieve a more satisfactory outcome.

Analysis of individual elements of the path creation task was undertaken based upon the task feedback responses and screen-recordings, providing insight into the depth of engagement and task success achieved by users at different points on the wholist/analytic dimension. First, users were asked to rate the quality of their path on a scale of 1-10. A negative correlation is found between the rating given and CSA numerical score for the wholist/analytic dimension (r_s=-0.679, n=23, p=0.000, 2-tailed) verifying the greater time spent on the task by wholists, as noted above. Inspection of the data by categories shows that ratings were given from 1-7, and further, that only 10% of analytic users gave a rating for their path greater than 5, compared with 40% of users in the intermediate category and 50% of users in the wholist category. This finding shows that analytic users find it more difficult to create a path that matches their exacting standards and indicates a more analytical and detailed approach to the task. It may also indicate that analytic users find it harder to complete more creative tasks, as they are seeking accuracy and completeness, rather than a good overall impression and aesthetic quality that is favoured by wholists.

The number of items added to paths reveals that users in the analytic category are more likely to create shorter paths (75% adding less than 10 items), than intermediate users (50%) or wholist users (33%). This tends to indicate a greater degree of precision in the paths created by analytic users, with more careful selection of items, and in fact, closer inspection of the screen-recordings shows analytic users have a tendency to delete items from their path as they fine-tune the content.

User differences are also found in the strategy used to find items to add to the path. Following inspection of the screen-recordings and log files, interactions were classified in four different modes: serial searching (successive search reformulations, few search results viewed); serial browsing (few searches, many pages of search results viewed); exploration (use of tag cloud and other exploratory features); or, combination (an even mix of two or more of the previous categories). Analytic users exhibited an even split between serial searching and serial browsing strategies, and intermediate users between serial searching and combination strategies, whilst the dominant mode for wholist users (67%) is serial browsing, with no evidence of serial searching strategies in this group. Given their higher levels of dependence, this finding indicates that wholists are less comfortable with searching in a novel system, and in a task which is less prescriptive, relying instead on browsing strategies to find suitable items. It may also indicate a more creative approach to the task, with wholists looking for pleasing images, rather than the more specific, representative items that may be located via searching strategies, as favoured by analytic users.

A review of the augmentation of paths with annotations and keywords reveals further user differences, which overall, were used less by users in the wholist category. For example, all of the analytic and intermediate users added a description to their paths, compared with only 67% of wholist users. All analytic users added tags (keywords), compared with 75% of intermediate users and only 50% of wholist users. Descriptions could also be added to each item in the path, which demonstrates a similar pattern of behaviour, with 75% of analytic users adding description to all or most items, compared with 50% of intermediate users, and only 33% of wholist users. A tendency to overlook, or not attempt to use these more complex elements of the path creation task is compatible with the expectation that wholist users are more dependent, requiring more direction or instruction in what is required. It is also illustrates that wholists are less detail-focused and potentially more creative, interested more in the images and overall composition, than in adding detailed annotations and descriptions.

In summary, relative to their analytic counterparts, the activities of wholists include: spending more time on the tasks; needing prompting to end the task (information seeking tasks); finding the path task easier and more enjoyable; producing longer paths; they rated their paths more highly; displaying more serial browsing (few searches with many pages viewed) as opposed to serial searching (many search formulations with few pages viewed) (path creation task); and producing fewer descriptions and tags for their paths.

5.2 Analysis of User Interactions

To measure if there was any difference in interaction between users identified as wholist and those identified as analytic an analysis of transaction logs was undertaken. Each log comprises a sequence of query URLs generated as users navigated through the web pages while undertaking the evaluation tasks. Each URL effectively corresponds to a different interaction e.g. creating a path, searching by query etc. The analysis in this section relates to the volume of interactions by type, and interaction sequences, excluding the path creation section of the system, which cannot be analysed in detail from transaction logs.

We first investigated whether search/browse behaviour was different between wholist and analytic users. Table 3 shows a breakdown of the frequencies of actions for each type of user. The figures show that wholist users used the tag-cloud feature (12.9%) more than analytic users (0.9%). They also show that analytic users performed more search queries (32.4%) than the wholist users (20.6%). This fits our hypothesis that wholist users more likely to want to get an overview of the whole collection of items rather than immediately focusing in with specific queries. Interestingly, analytic users also preferred to use the facet function (11.3%) more than wholist users (2.7%). This may also suggest that these users were more likely to want to narrow in on more focused data using the facets compared to the wholist users who were happy to view the whole data set. It is also worth noting that the data for the intermediate users fell between the wholist and analytic users for each of these metrics which lends support to these observed patterns.

[TABLE 3]

Next we analysed search behaviour related to the use of the workspace. If the user adds an item to the workspace it suggests that this item is of interest and may possibly be added to a path. We looked at the action that immediately preceded that addition of the item to the workspace. There were three main options: (1) Add the item directly from the search results page, (2) Click on the item to view detailed information before deciding to add the item, and (3) Add the item from a pre-existing path. The breakdown for these actions is shown in Table 4.

[TABLE 4]

It appears that analytic users are somewhat more likely to view items before adding to their workspace: 39.1% of analytics viewed an item before adding it to the workspace, compared with 30.9% for wholists. This supports our hypothesis that these users have a greater tendency to drill down into the data. In contrast, wholist users are more likely to add items to their workspace directly from a path or from search results, where only the thumbnail and title are visible, which suggests they only want a broad overview of items before selecting which to add to their path. Again, the data for the intermediate users fit between the WA groups, supporting this pattern.

Next we looked at the number of pages viewed before an item was added to the workspace. The results of this again show a clear pattern. Wholists seemed to be willing to browse through many pages before selecting items to add to the workspace. The distribution curve for the analytic users shows a far steeper curve, with a large majority of users adding items from the first page, with 6 as the maximum number of pages visited. Again the distribution curve for the intermediate users falls between these two groups, adding supporting evidence for the hypothesis that analytic users have a greater tendency to drill down into the data.

[TABLE 5]

A similar investigation analysed how many search results pages users visited before viewing the detailed record for an item. The results are similar as for the previous investigation with wholists more likely to view more search results pages than analytic users.

[TABLE 6]

In summary, the analysis of transaction logs showed that wholist users tended to use exploratory functions, such as the tag-cloud, more than analytic users suggesting that they prefer to see an overview of the data before focusing in on particular topics. Conversely analytic users performed more specific query searches and used the faceting functions, perhaps demonstrating an eagerness to quickly focus in on the items of interest.

Analysis of the how users found items to add to their workspace showed that wholist users added items directly from the search path while analytic users viewed items first before adding them. This supports the view that wholist users want to put together a broad overview of items before constructing a path. Analysis of the number of page views before looking at items or adding items to a workspace showed that wholists tended to visit far more pages than analytic users, again fitting in with the idea that wholists want to get a good overview of the data while analytics prefer to drill down into specifics quickly, doing more search queries if they don't find what they want straight away.

5.3 Analysis of User Feedback

A correlation analysis was conducted on the data from the session feedback questionnaire to establish whether there were any significant relationships between aspects of people’s reactions to using the system and their attitudes towards it. A number of significant correlations were found, which are summarised in Figure 5.

[FIGURE 5]

In order to maximise the sensitivity of the correlational analysis, raw scores on the wholist/analytic dimension of the Cognitive Style Analysis measure were used, rather than categorising respondents into discrete categories. This approach has been adopted in previous studies (e.g., Ford et al., 2005), and it enables the identification of correlations between user behaviour and the strength of the extent to which an individual is wholist or analytic. This is a bipolar dimension, meaning that the stronger one scores as a wholist, the proportionately weaker one scores as an analytic, and vice versa.

Behaviour that correlates positively with a wholist cognitive style also correlates negatively with an analytic style. Thus, in Figure 5 (top left), the significant *positive* correlation between considering the Explore function in PATHS to be inventive and having an *analytic* style implies that there is also a significant *negative* correlation between considering the Explore function in PATHS to be inventive and having a *wholist* style. Only the correlations between user behaviour and having an analytic style are shown in Figure 5 since in each case the converse correlation with having a wholist style is necessarily implied. Links between boxes show a significant positive Spearman correlation at $p<0.05$ (2-tailed). The one exception is the broken arrow, which indicates a trend just under the probability threshold at $p=0.053$.

As can be seen from Figure 5, the more analytic (as opposed to wholist) the cognitive style, the more positive ratings of the PATHS system were on a number of dimensions, namely considering that PATHS is: inventive; good at supporting serendipity/discovery; good at supporting the development of new ideas; good at finding items related to a topic; good at supporting communication with other people; and the explore function was rated more highly (in terms of inventiveness, usefulness and ease of use). Possible reasons, and implications of the discrepancy between the relationships hypothesised between cognitive style and attitudes and those found are discussed in the following section.

6. Discussion of the Findings

In this work we have tested the hypothesis that the behavior and attitudes of individuals to the navigational features of the PATHS system would differ according to cognitive style, as suggested in previous literature (Bawden & Robinson, 2011; Chen & Ford, 1998; Wang et al., 2000). For the questionnaire survey of user attitudes towards the various PATHS features, statistically significant differences were found. In the case of the experiments into user behavior, the sample size was too low to establish statistical significance. However, differences were found in behavior relating to cognitive styles, and the direction of these differences was consistent with that suggested in the hypotheses. We have interpreted these findings as indicative of a trend worthy of further systematic investigation.

The notion that wholists are more likely to want to establish a clear overview of the topic they are exploring prior to drilling down to detail was positively supported. Specifically, wholist users, relative to their analytic counterparts: (i) displayed a higher use of the tag cloud feature; (ii) made fewer specific as opposed to more general queries; (iii) reported a higher preference for using the faceting function; (iv) viewed items less often before adding them to their workspace (as opposed to wholist users' tendency to add items directly from a path or from search results); (v) browsed through more pages before selecting items to add to the workspace. These findings all lend support to the proposition that wholists are more preoccupied than their analytic counterparts with establishing a clear overview of a topic they are exploring, analytics being more concerned with focusing more narrowly on detailed aspects of the information space.

It was also expected that wholist users would express greater preference for: (i) the PATHS facility to support serendipity/discovery (since they are more oriented towards this aspect of exploration); (ii) the facility of the PATHS system to support inventiveness and the development of new ideas; (iii) finding items related to a topic; (iv) communicating with other people (since they are more socially oriented than analytic people); and (v) the PATHS 'explore' function. Significant correlations were found between cognitive style and Likert measures of these attitudes, but in a contrary direction to that hypothesised. All of the preferences listed above correlated significantly and consistently with cognitive style, but with analytics as opposed to wholists.

Thus, paradoxically, whilst in their observed behaviour using the PATHS system corresponded with expectations based on the cognitive styles literature, in their attitudes (what they thought rather than what they did) they displayed the converse of what might be expected. In their attitudes, analysts considered the PATHS system to be strong in supporting the activities in which one would expect them to be most weak: exploring, engaging in relatively divergent (as opposed to more convergent) thinking in the form of being inventive, developing new ideas, discovering things, experiencing serendipity, relating ideas (finding items related to topics) and being socially communicative. This is an interesting paradox; however, can be explained by a descriptive model, such as that shown in Figure 6.

[FIGURE 6]

According to the model, users display *behaviour* which accords with their habitual cognitive style. However, it may be that users display more positive *attitudes* to those aspects of PATHS that support those aspects in which they are *weaker*. In those activities in which they are strongest, they may have less need for, and accord less value to, those features of the PATHS system that support them. Conversely, they need and value features that support them in relation to activities in which they are naturally weaker. We argue that this study has provided at least a *prima facie* case for further investigation of the effects of cognitive style on user in large digital libraries navigation patterns using larger samples. If the model proposed here is supported by more robust evidence, a number of implications for system design would follow.

The wholist/analytic dimension of cognitive style would appear to be worthy of further investigation in the context of personalisation research. The dimension maps well onto meaningful patterns of search and navigation, linking conceptually with the notion of levels of creativity. A number of studies, including that presented here, have found empirical evidence of links between this dimension of cognitive style and users' search and navigation patterns. Furthermore, findings from matching/mismatching studies suggest that matching aspects of user interface design to individuals' style may impact the effectiveness with which they process information in a learning context.

7. Conclusions

In this paper we have investigated the effects of users' cognitive style on their use of a prototype system for exploring digital collections of cultural heritage. Much of the research literature has focused on the notion that individuals display behaviour in accordance with their cognitive style, and in instructional contexts on matching the style of information presentation to each individual's style. There has been less emphasis on individuals' attitudes towards system features designed to support the matching process, and support designed to compensate for the weaknesses of each style, as opposed to matching information presentation and navigational affordances to an individual's style. The present study provides further evidence of links between style and search/navigation behaviour to support other studies, but in the context of an experimental interface to a large cultural heritage digital library. It also offers a significant contribution to research into cognitive styles by proposing a model suggesting a converse relationship between behaviour and attitudes to support: individual users displaying search/navigation behaviour mapped onto the strengths of their cognitive style, but placing greater value on interface features that support aspects in which they are weaker. This distinction is worthy of further investigation and will be our focus of upcoming investigation with a second version of the system that incorporates a richer set of features for exploring and navigating digital collections of cultural heritage.

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TABLES

Paper: Cognitive Styles in Digital Library Navigation: An Educational Informatics Perspective

Task Type	Example
Simple fact find	Which artist painted 'The Blaydon Races'.
Extended fact find	Identify at least six English towns in which trams were once operational.
Open-ended browsing	Find several items illustrating aspects of daily life during war-time Britain, and save to your workspace.
Exploration	Find an artwork you would like to display in your own home'
Path creation (student user)	Imagine you need to create a path as part of a university assignment. You have been asked to use primary source materials to create a mini online exhibition suitable for a target group within the general public and/or school visitor categories. Your goal is to introduce a historical or art-focused topic in a popular, accessible way, and to encourage further use and exploration of cultural heritage resources.

Table 1: PATHS System Evaluation, Examples of Tasks

Time taken	Task / Cog Style	Mean	Max	Min	Std Dev
By task type	Simple fact-find	4.53	5.00	2.83	0.72
	Extended fact-find	4.07	5.00	1.83	1.04
	Open-ended browsing	4.78	5.00	2.28	0.63
	Exploration	4.36	5.00	2.34	0.99
	Tasks A-D	4.44	5.00	1.83	
Information seeking tasks by cognitive style	Analytic	4.33	1.83	5.00	1.11
	Intermediate	4.59	2.21	5.00	0.82
	Wholist	4.79	2.28	5.00	0.58
Path creation task by cognitive style	Analytic	25.64	15.43	30.00	6.94
	Intermediate	25.88	20.82	30.00	4.82
	Wholist	26.64	19.36	30.00	4.18

Table 2: Time taken on PATHS evaluation tasks, by task type and cognitive style

Interaction	Analytic	Intermediate	Wholist
search-query	32.4	28.5	20.6
search-query-paginate	15.7	17.1	19.8
search-query-facet	11.3	8.8	2.7
search-query-facet-paginate	5.3	3.8	7.0
search-index	11.6	9.5	9.7
search-facet	1.3	0.0	0.6
item	20.1	26.1	23.5
explore	1.3	2.2	3.2
tag cloud	0.9	4.0	12.9

Table 3:Percentage of interactions with the PATHS system by cognitive style

Action preceding workspace-add	Analytic	Intermediate	Wholist
search	55.1	57.4	61.1
item	39.1	36.2	30.6
path-follow	1.4	4.3	6.9

Table 4: Actions preceding 'add to workspace'

Search results pages visited	Analytic	Intermediate	Wholist
1	78.3	64.5	67.6
2	6.7	15.8	6.7
3	10	6.6	3.8
4	3.3	9.2	1
5	0	0	3.8
6	1.7	0	1

7	0	2.6	1
8	0	1.3	0
10	0	0	1
11	0	0	2.9
12	0	0	2.9
13	0	0	1.9
14	0	0	2.9
15	0	0	1
16	0	0	1
28	0	0	1
40	0	0	1

Table 5: Distribution (%) of search results pages visited before adding items to the workspace

Search results pages visited	Analytic	Intermediate	Wholist
1	81.1	75.6	87.2
2	10.8	9.2	1.4
3	4.1	2.3	2
4	2.7	10.7	0.7
5	0	0	3.4
6	1.4	0	0.7
7	0	0	0.7
8	0	1.5	0
11	0	0	2
20	0	0.8	0
38	0	0	2

Table 6: Distribution (%) of search results pages visited before viewing a detailed item record

FIGURES

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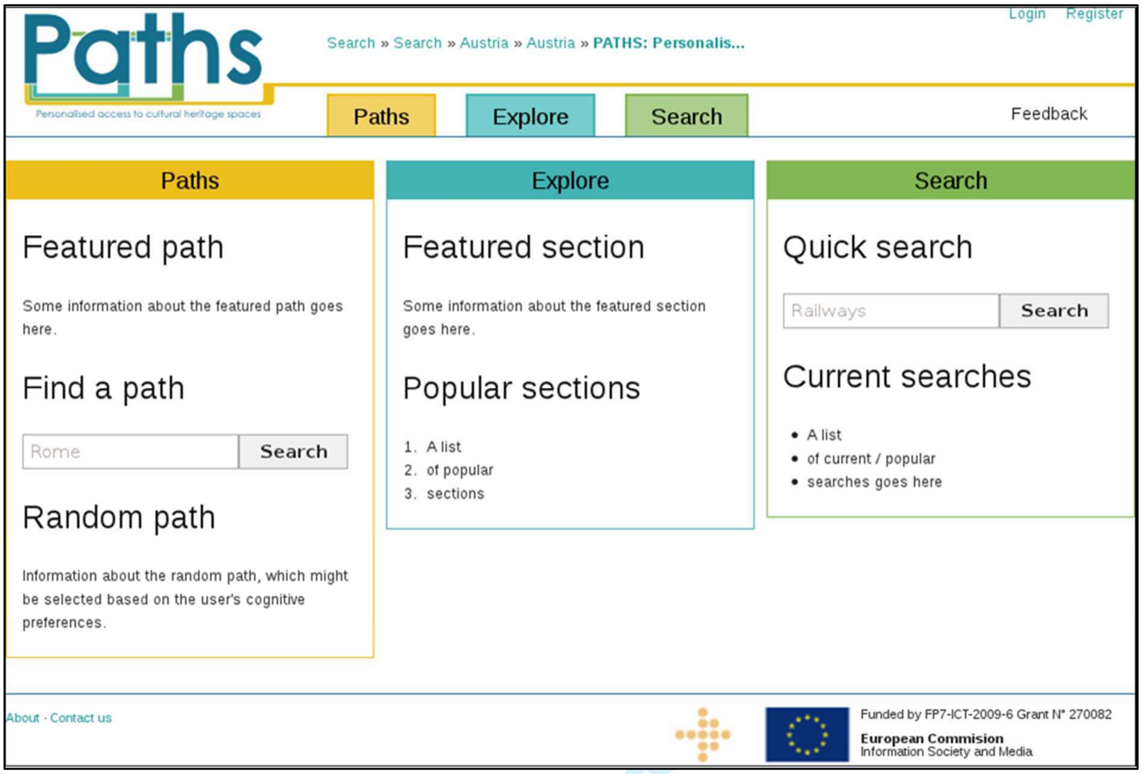

Figure 1: PATHS Prototype 1, Home Page

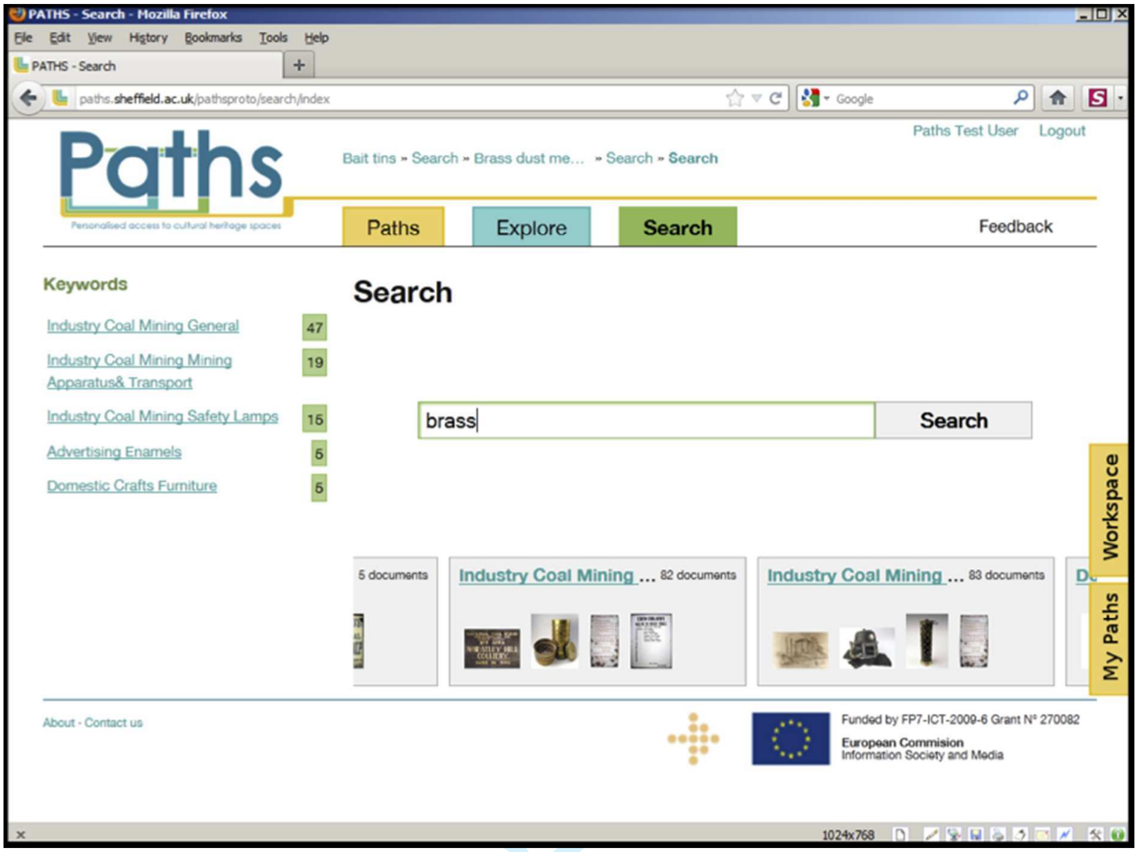

Figure 2: PATHS Prototype 1, Search Page

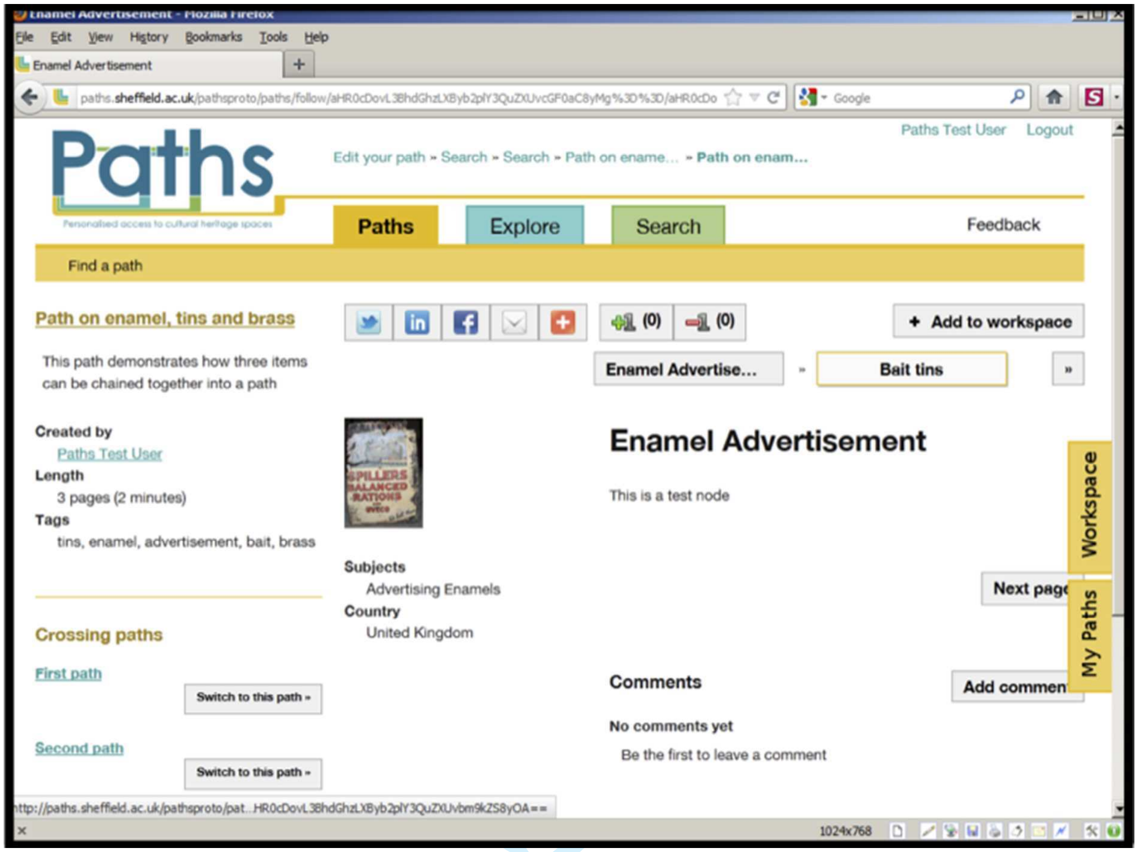

Figure 3: PATHS Prototype 1. Path Node Page

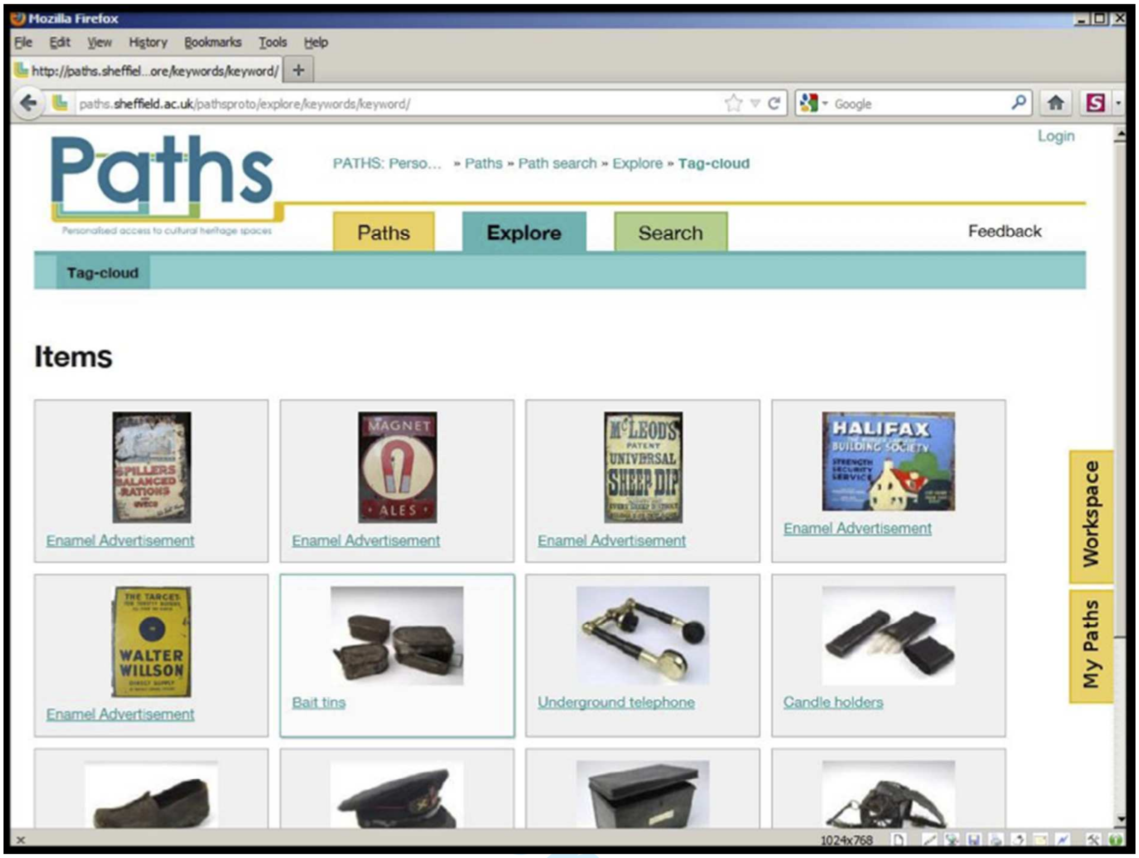

Figure 4: PATHS Prototype 1, Explore Page

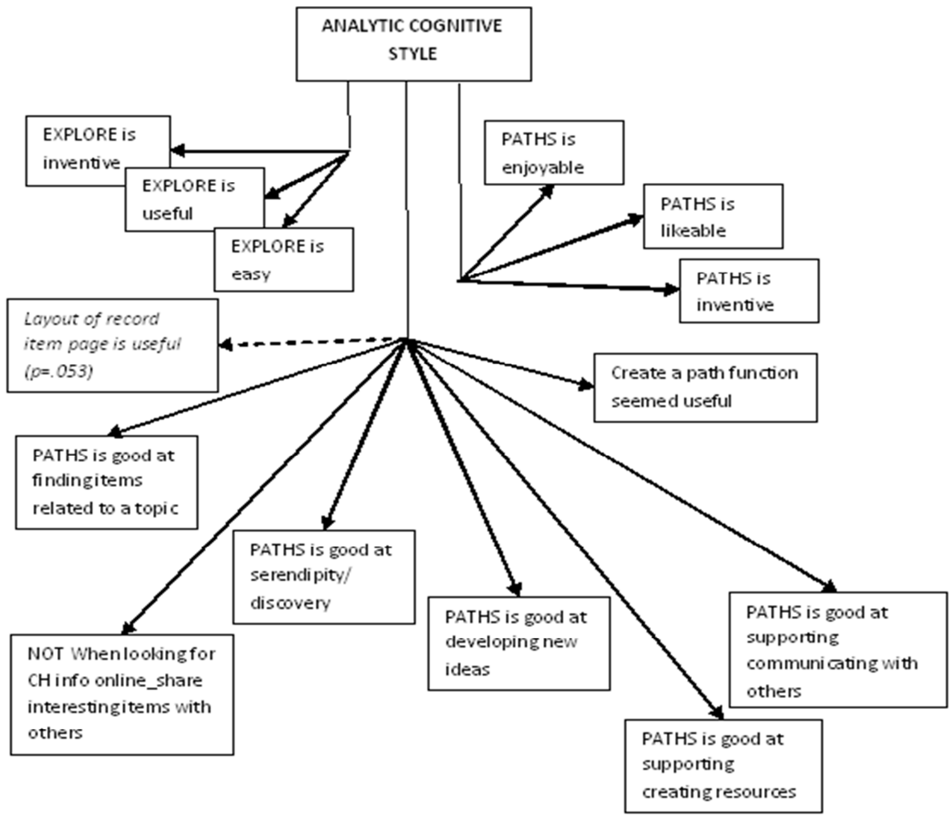

Figure 5: Significant correlations between cognitive style and attitudes to using the PATHS system

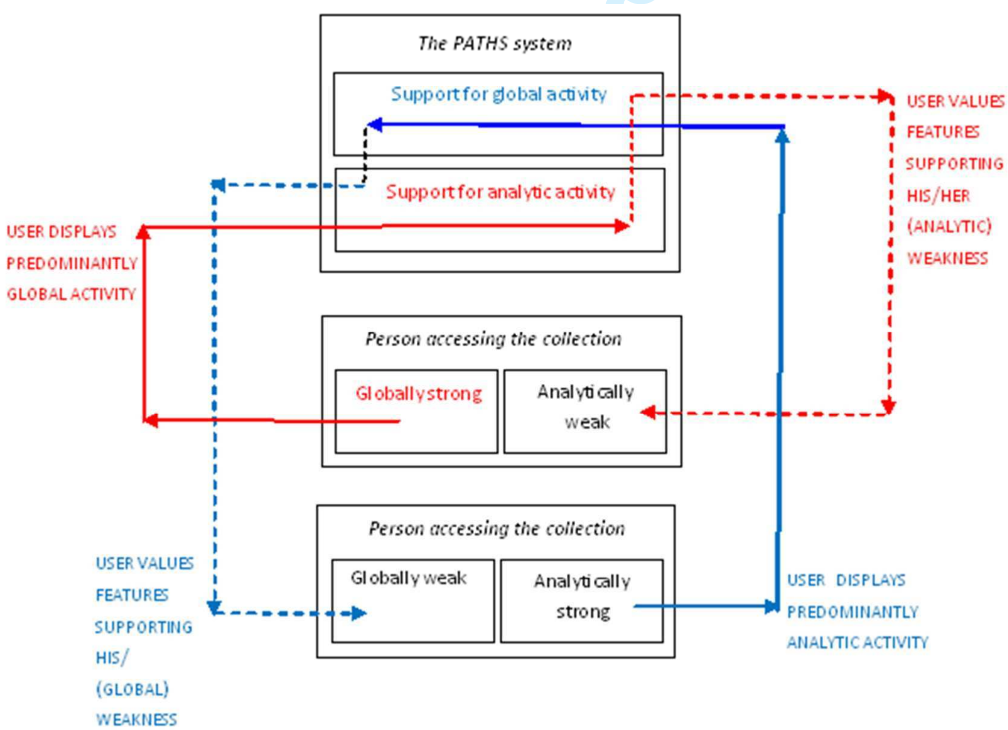

Figure 6: Interactions between cognitive style and interface support features