Cognitive maps, AI agents and personalized virtual environments in Internet learning experiences

R. William Maule

The author

R. William Maule is Associate Professor, Department of Organizational Studies, College of Professional Studies, University of San Francisco, San Francisco, California, USA.

Abstract

This paper develops frameworks to help Internet media designers address end-user information presentation preferences by advancing structures for assessing metadata design variables. Design variables are then linked to user cognitive styles. An underlying theme is that AI methodologies may be used to help automate the Internet media design process and to provide personalized and customized experiences. User preferences concerning knowledge acquisition in online experiences provide the basis for discussions of cognitive analysis, and are extended into structural implications for media design and interaction. The assumption is made that frameworks for the alignment of design metadata with user metacognitive elements may serve as a reference to aid information design for Internet-based media.

Internet Research: Electronic Networking Applications and Policy
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Introduction

Internet online environments enable new and interesting media designs for the support of traditional learning, and for the development of new forms of learning. As Internet bandwidth to the end-user expands, most of the capabilities of previous instructional innovations will be integrated into the environments. Media possibilities will expand as the Internet increasingly supports high fidelity audio, full motion video, and three-dimensional virtual reality. The interactive processes and methodologies for media integration are becoming complex as media possibilities escalate, and as Internet tools evolve from their historical display and presentation agendas to support personalized experiences, intelligent assistance, virtual environments, and multiuser collaboration.

One goal of the Internet community is to create a broadband global digital multimedia conduit which reaches all users within a universal and totally open environment. Ideally, users will be able to access all forms of knowledge and media – in any combination, from any location, at any point in time. This implies considerable complexity in the software design, and a substantial level of intelligence across the systems – from the servers, to the networks, to the user-interfaces. Most of the necessary design and development tools already exist. However, there are implementation issues stemming from different software methodologies – which result in different means of delivering information, different means of providing interaction and human-computer discourse, and different means for creating the overall environments and online experiences.

While the graphical user-interfaces of commercial Internet browsers have somewhat alleviated historical multimedia and hypermedia design problems by standardizing user-input and display processes across platforms, networks, and operating systems, a new series of issues have arisen as media designers must today struggle with several complex options to achieve their objectives. Self-contained multimedia authoring software, Java Integrated Development Environments, Common Gateway Interface solutions for database access, agents and artificially intelligent assistants, and Virtual Reality Modeling Language environment creation and interaction

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

languages all provide new paradigms for information display, representation and interaction. Moreover, for at least the next few years, it is likely that comprehensive solutions will require an integration of many, if not most, of these design tools – and thereby an integration of their methodologies and paradigms. Some frameworks may help guide the application of the media. The predefined and somewhat hierarchical nature of previous generations of computer media have generally limited designs to simple input-output models. The new generation of AI agent technologies, together with the nearly limitless resources of the Internet, create a new paradigm for media development. The limitations of the traditional behavioral approaches are diminishing, neobehavioral constructs are more easily applied, and future directions using advanced intelligence indicate possibilities for mapping user psychological constructs directly to the information designs.

This paper seeks to aid media integration and environment personalization by providing a framework to help assess the cognitive needs, styles and preferences of users. The objective is to shift the design methodologies away from the somewhat stringent requirements supplied by the development tool vendors, and more towards a design independence in which developers instead focus on the cognitive parameters of users. Proposed variables have been compiled through some basic literature and research reviews, and through some derived analysis and assumptions. The author assumes that metacognitive variables may be derived from cognition studies in interface and interactive design, instructional software, Internet services, and online collaboration. A further assumption is that corresponding metadata variables for media design may be derived from these user cognitive variables and applied in information service development. This paper integrates these metadata and metacognitive variables into frameworks for Internet media design. A foundation belief is that Internet media design variables may be superimposed onto cognitive user profiles, via mapping structures, to aid in the creation of personalized virtual experiences.

Metadata design variables for Internet systems utilization

Authors have long been addressing the rise of "online communities" that will be instrumental in the realization of advanced learning societies. Most users today realize this as the Internet and its capacities for learning services which are fluid, evolving, ever expanding, and increasingly personalized. The implementation of personalization services has been advancing rather slowly – due somewhat to difficulties mastering AI software, structural difficulties integrating diverse media, and the general absence of frameworks to help align user cognitive preferences with media design variables. Benefits of personalized information processes in the Internet learning experience may be quite pronounced. In addition to the core knowledge, users may learn valuable professional skills as they acclimate to network-based communications, and modern practices in information access and retrieval. They become aware of data organization and processing issues, and are thereby introduced to current practices in information systems resource design, development and maintenance (Maule, 1997). Internet media designs thereby become a major force advancing the technology of learning – and as with all learning – the experiences are more beneficial if aligned with the learning styles of users. Customization and personalization mean enhanced possibilities for knowledge acquisition and distribution (Caglayan and Harrison, 1997).

AI agents and dynamic customization in Internet media design

One of the greatest impacts of Internet information processing is the distribution of information management responsibilities to give end-users greater power to shape their computing environments and manage their personal information needs. Designers can program their services to enable the user to traverse their own path through the networked information. Software agents have been proposed as a mechanism to help computer users deal with work and information overload (Maes, 1995). Intelligent agents introduce a new paradigm for instruction that is based on the concept of shared abilities and cooperative learning between humans and computers (Kearsley, 1993). AI programmed into user interfaces may enable the system to dynamically personalize applications and services to meet user's preferences, goals and desires (Caglayan and Harrison, 1997). The paradigm has its roots in the content-based

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

approach to recommendation common to the information retrieval community, wherein media are recommended based on a comparison between content and a user profile (Balabanovic and Shoham, 1997).

Historically, WWW information designs have encouraged users to wander through large clouds of information, gathering knowledge along the way. Current initiatives focus on personalization and customization, experiences which feature problem solving, and designs which are structured and constrained to the identified needs of the users. Internet agent technologies and WWW persistent objects are two of the most readily accessible means to develop such capabilities. Emerging standards for dynamic customization and personalization, such as the Open Profiling Standard (OPS), offer specifications for sharing acquired user data among online service providers. For example, the OPS specification indices a unique ID field to enable the site to recognize returning users. Agents, robots, droids and other software modules with AI characteristics that gather information, perform tasks, and interact with other humans and software on behalf of users, can apply this standardized data for Internet searching, filtering and customization (Gaskin, 1997).

Through artificial intelligence, user cognitive preferences may be captured and applied to dynamically coordinate the creative structure of Internet content and presentation. The intelligence may be applied through user models to make assumptions about the user's state of knowledge, which may in turn help determine the user's learning needs (Woolf, 1996). While customization in hypermedia displays via branching and linkages have been a mainstay for many years, for technical reasons, AI implementations have been relatively rare. Many of the advances pioneered in the commercial sector as AI enhancements to distributed database technologies for electronic commerce have direct applications for environment customization for Internet learning experiences. For example, in the commercial sector, AI is being used to advance data mining and data filtering applications. This same technology applied to Internet media may be used for media analysis and personalization. Blankenhorn (1997) has identified some of the prominent AI methodologies which may be applied (Table I). Rule-based Internet AI techniques can generate user profiles or patterns, which may then be transformed into rules to predict user behaviors. Case-based AI techniques can utilize questions based on cases and examples to continually narrow options. Collaborative filtering AI systems can look for user profiles in utilization patterns, which are then matched with other users to produce intelligent/likely recommendations.

The rapid commercial acceptance of AI, agent and mobile object technologies and their programmable and dynamic intelligence has resulted in new opportunities for media designers seeking to align Internet experiences with the cognitive styles and preferences of users. In the commercial sector, this has broad implications for Internet commerce, and for the design of Internet information repositories and warehouses. A typical commercial example of such AI would be the use of agents to help merchants learn the preferences of customers, provide selections based on the user's earlier choices, and notify users of relevant product updates based on the agent's knowledge of the user (Gaskin, 1997). At a systems level, applications such as the PATROL network management product from BMC Software uses intelligent autonomous agents, and loadable libraries of expertise, to proactively manage applications and databases, and to continuously survey the services. Applied to learning environments, this methodology may include the application of agents which collect patterns from the experiences of users. The selection of branching options, and interactive options in simulations, are the most apparent measurement data. The result would be a database of learning options based on the experiences of users. Expert libraries can then be formed to guide future experiences. AI can help adapt the presentation to perceived user needs for individual knowledge (Woolf, 1996). Rather than isolating users (as originally feared), the Internet and agent AIs may provide socialization and continuity between online experiences by grouping those of like interest and allowing multiparticipant interaction, collective experiences, and intimate knowledge-sharing within personalized and customized virtual environments. Thus, at the cognitive level, agent AIs can help make the

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

Table I AI and agent metadata filtering methodologies for intelligent, customized and personalized media selection

	Concept	Technology	Process	Application	Output
Rule-based AI systems	Databases of user profiles	Patterns transformed into assumptions	Online forms navigation paths, actions, if/then scenarios	Rules applied to predict user preferences/ actions	Stored and systematically referenced data
Case-based AI systems	Transform data-bases into cases	Statistical modeling	Questions yield queries, follow-up up questions to narrow options	Users navigate cases via questions which narrow options	Inquiry processing via inferences and case-based reasoning
Collaborative filtering systems	User profiles, preferences	Compare usage and content patterns to peers and collectives	Rank order, yes/no preference lists, likes/dislikes	Relevance determination by peer association, user clustering	Intelligent views/ selections/ recommendations and scenarios

online experience more enjoyable by making users feel more at home. The intelligence can help the system reason about the user's idiosyncratic actions, and help determine problems/ issues to be solved (Woolf, 1996).

Knowledge integration and human cognitive factors

Knowledge management, in an information systems context, is generally considered a layer of abstraction above information management – which is itself a layer of abstraction above data management. The higher the level of abstraction, the more intrinsic the resource, and the more subjective the interpretation (Maule, 1998). Abstractions are an important concept since information representations will trigger different perceptions, metaphors, and analysis based on the user's level of experience with that form of knowledge (Jacobson, 1995). Higher level information abstractions depend on the interpretation of the user, and these interpretations are likely based on cognitive factors. Knowledge management, at a practical level, would thereby address the gathering, filtering and distribution of processed information to create specified cognitive effects in recipients. The Internet, with its wide base of information, is considered a major resource for knowledge acquisition. Agent AIs provide the filtering and processing, and are thereby instrumental in the propagation of ideas. Users contend with new information by adding new ideas to their existing repertoire of ideas, by distinguishing among the variables in the expanded repertoire, and by subsequently restructuring their personal knowledge (Linn, 1996). This abstraction, and the underlying analysis, underpin research in knowledge acquisition and cognition.

The success of representations, whether graphical or textual, depend on not only whether the information meets the user's needs, but the degree to which the representations fulfill the user's information acquisition requirements and are appropriate to the user's task (Petre, 1995). In the commercial sector, information products are often linked to knowledge variables to help determine the specific interests of individuals (Davenport, 1997). From user patterns of interest, over time and in the collective, probable patterns of action, initiative or process may be derived. For example, software vendors may offer products based on user metadata – derived from utilization and interest profiles. The profiles may collectively represent demographics, purchases, inquiries and navigational choices. In a learning environment, the designer might use such profiles to ascertain the cognitive state of the user in specific situations. From this knowledge, the designer might learn about specific human-machine interactions, and the technicalities of interactions between the system and the learner. This concept is certainly not new, and is likely at the basis for much of the cognitive research into technology-assisted instruction. What is new is the client/server environment of the Internet which enables a dynamic interplay between the information repository and the user, the growing prevalence of applied artificial intelligence via the agent technologies of Internet commerce, and the ability to instantly and dynamically gather user

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

cognitive profiles across a very wide user base. The cognitive assessment of multi-user collaboration over the networks is the next step.

In the commercial sector, Internet-based groupware applications have begun to serve as a primary knowledge gathering and distribution mechanism. In collaborative learning, distributed expertise and multiple perspectives enable users to accomplish tasks and develop understandings beyond what anyone could achieve alone (Edelson *et al.*, 1996). Users' beliefs expand in ways that serve to organize what they know and to identify gaps in their understanding. In an Internet virtual learning environment, the relationships found in online collaborative partnerships may help structure the cognitive designs and information options. Agent technologies and intelligent filtering systems enable users to model their personal cognitive profiles which can be applied to information repositories to derive customized knowledge. This intelligence may be automated as either user-specified criteria, or simply provided as a support mechanism and collected through traditional AI information gathering techniques – such as case- or rule-based reasoning, collective filtering, pattern matching, etc. For the resource designer, the identified interests may indicate cognitive patterns, and output as visual relationships. The identified relationships may, in turn, be tested through any number of statistical modeling, quantitative analysis, or pattern matching techniques. The pattern recognition of modern data mining tools, sometimes built on neural networking methodologies, would be a practical example. An initial step in this process is to develop frameworks to help apply the cognitive variables and their paradigms and methodologies.

Correlating software design variables and cognitive learning patterns

Internet communications are pervasive, reaching into the daily activities of users wherever they reside. Users access the resources for any number of reasons – but these reasons are generally tied to matters of personal and professional interest. Anticipating the needs of the situation via cognitive maps/profiles of the users has long been a mainstay in automation. Cognitive maps have been used in knowledge elicitation/engineering for expert systems development, and for analysis and assessment processes to help in the automation of managerial communications (Schwartz, 1992; Te'eni *et al.*, 1992). In developing the resources, designers collect and structure materials to reflect their personal understanding of the users, and in anticipation of the user's possible interests, needs, or ability to comprehend the interrelated content (Marshall and Shipman, 1995). Cumulatively, and over time, a monitoring of the user-media interactions will provide data for program-planning as developers become more knowledgeable about the target population – and as users become more deeply involved in directing information development and presentation (Maule, 1998). Since the communications are Internet-based, and able to utilize the distributed reasoning available through AI agents and the Internet, the designs may create dynamic knowledge – drawing resources from static information repositories. Until recently this was a difficult proposition. Over the past few years, cognitive scientists have gained a deeper understanding of the needs of developers and users, and designers have gained a deeper understanding of cognition and the mental aspects of programming (Stacy, 1995). A framework to help assess the likely direction of the human-machine exchanges may include categorizations by the probable types of cognitive processes triggered during the interactions. The following discussion argues that metadata design variables may then be derived from these cognitive variables and used to help guide future media development.

Cognitive science and metacognitive mapping strategies in Internet media

Cognitive science addresses mental constructs as advanced by the disciplines that study the human mind, including cognitive psychology, epistemology, linguistics, computer science, AI, mathematics, and neuropsychology (Reber, 1985). In cognitive science, comprehension is often characterized as the construction of a mental model that represents objects and semantic relationships (Thuring *et al.*, 1995). Metacognition considers the mindful engagement of the user in a task, and addresses the knowledge and control the user has over his cognitive processes (Lopez, 1997). Metacognition deals with awareness, observation,

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

reflection and analysis. The cognitive map is often presented as the best available means for structuring cognitive and metacognitive variables. Psychologists believe that users intuitively seek to create a mental analog of a real map as they traverse electronic information. Cognitive theorists even believe that the cognitive map (a term coined by E.C. Tolman) is fundamental to human mental processing. Users form the map by chaining experiences, mentally drawing spatial relationships, and subsequently drawing inferences, preferences and judgments (Reber, 1985). Recent studies of Web site design have found that users prefer to see an overview or map of an information resource to help them make judgments about content and navigation (Abels *et al.*, 1997). One suggestion is that humans build and use mental models to solve problems and understand situations (Stacy and MacMillian, 1995). Mental events and representations are extended into mental constructs of consciousness – such as schemas, ideas, strategies, memories, ideas, beliefs, intentions and other decision-making criteria. A goal of the designer is thereby to assist users in the construction of their mental models, strengthening factors that support the design processes, and weakening those that impede it (Thuring *et al.*, 1995).

The potential to monitor cognitive variables is increasingly available due to the prevalence of agent technologies which use artificial intelligence. These technologies provide new capabilities for media designers, and provide a useful means to evolve media from the somewhat behavioralistic design traditions of conventional practices (measurable responses, activities, reactions, movements, processes, operations, etc.). The structural processes advanced by the neobehaviorists help provide a continuity between the internal (psychological) and external (behavioralistic) design strategies by addressing intrinsic states and intervening cognitive variables. Patterns of behavior obviously influence knowledge-seeking behaviors. It is argued that these may be tied to the cognitive development of users, and the variables serve as a guide for addressing programmatic goals and objectives in the knowledge acquisition process (Table II). Issues to be addressed include strategies for dealing with ambiguities, matters of context, recognition-to-recall progressions, recognition skills, relationships in hierarchies of media, structural modeling, and cognitive strategies for exploration (Jacobson, 1995). At the practical level, this can be achieved through the advancement and testing of hypothetical constructs and mediational processes against outcomes. Prior to the commercial advances of AI, such analysis was generally beyond the reach of most media developers. Today, AI agents, and advances in Web-based virtual reality, enable designers to more fully control environmental and cognitive variables.

One of the tenets of AI concerns the ability to have a machine or program make judgments on the basis of incomplete knowledge. Internet agent technologies may accumulate knowledge based on user experiences and preferences, categorize this information, and apply it proactively during online sessions to anticipate user interests and assemble virtual and customized experiences. This may even be accomplished dynamically as programs make some rudimentary judgments based on a user's preferences and prior actions (Caglayan and Harrison, 1997). An underlying tenet is that a knowledge of the users' cognitive processes will enable media selection criteria based on the users' cognitive style. This may be a relatively straightforward advance from existing AI and agent research, and may be realized through a comparison of the cognitive maps of users with the systems map of the services. This line of thinking assumes that the foundation variables and media structures follow some basic constructs. First, is that the appropriate cognitive theories may be tested through an analysis of the structure of the software and the user's interaction with that structure. At this point, the user is actively engaged in the program and the design agenda is focused on structural matters, including program sequencing, information linkages, visual designs, and interactive capabilities. Personalization and customization may then be addressed via a comparison of the cognitive map of the users with the elements influencing the systems design (Table III). The user's cognitive map would be graphed against the systems map of the service – delineating linkages, browsing options, and the user's navigation strategy as a means to test specific cognitive and metacognitive variables. There is an historical basis for this stream of thought.

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

Table II General framework for mapping programmatic and knowledge metadata design variables with metacognitive interpersonal usage elements

Variables	Data	Metadata	Cognitive	Metacognitive	Output
Program purpose	User access, user criteria	Relevance, interests	Information agendas	Coherence and purpose	Fulfillment of goals, objectives
Tangible objectives	Test results, models	User profiles proficiencies	Knowledge attributes	Sequencing, synchronization	Demonstrated interests, ideas
Intangible objectives	Sense data clues	Sensations, interpretations	Memories, concepts	Ambitions, reflections	Comprehension mental effort
Knowledge systems	Learning of facts	Memory, recall, application	Learning techniques	Discovery processes	Context, interdependencies

Since the early works of Pavlov and Thorndike, learning theory has been characterized by experimental investigation and interpretive theories. Pavlov advanced his theories of classical conditioning to explain a user's association between a stimulus and a response, with the objective of determining higher order nervous skills activated by environmental stimuli. Thorndike studied intelligence by investigating the degree to which patterns of behavior are selected by their consequences or probable outcomes. Media designers, either implicitly or explicitly, have until relatively recently used learning theory as a design methodology and means to gauge user reactions to media variables. The reintroduction of artificial intelligence via Internet agents will enable the next generation of media designers to more specifically target media variables and user reactions to those variables. Models of motivation, using a design-based approach with artificial intelligence, may help to determine variables related to physiological needs and emotional reactions to learning stimuli (Aube, 1997). Over time, as the agents and designers learn about the users, the assembled knowledge may enable the production of personalized media based on individual learning/cognitive styles. Hopefully, the framework advanced in this paper will help in the categorization of the variables, and help provide a basis for analysis of the relationship between the environment and user reactions.

The early works of James Gibson Locke became a staple for behaviorists, learning theorists, and cognitive scientists. Locke (1690) postulated that ideas originate in experience, and are comprised of sensations and reflections. Sensations arise through the observation of external objects, and reflections through observations of the operations of the mind. Visual data such as color, size and shape lead to outputs which include perceptions and their reinforcements. In a more modern context, the

Table III General framework for mapping perceptual and subjective metadata design variables with metacognitive interpersonal usage elements

Variables	Data	Metadata	Cognitive	Metacognitive	Output
Interactive capabilities	Environmental choices	Self-assessment criteria	Visual responses to stimuli	Perceptions, analysis	Dynamic customization
Program sequencing	Path schema	Personal usefulness	Understanding, consistency	Orientation, predictabilty	User objectives design goals
Information linkages	Path structures, complexity	Navigational usability	Option assessment	Interests, strategies	Stuctural analysis
Visual design	Visual art, visual experiences	Aesthetics structure	Mental representations	Mental events judgment, ideas	Scene objectives
Service design	Usability, architecture	Models, views, characteristics	Perception, perspectives	Influences, preferences	Visual art, spatial layout

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

manner in which visual input stimuli are presented and represented by the Internet media designer will be directly responsible for specific understandings in the user (Jain, 1997; Gupta *et al.*, 1997). At a cognitive level, these may include desires, sensations, responses, perceptions – and other variables which directly influence the information transfer. Perceptions are complex and comprised of variables both concrete and abstract. A stimulus will illicit different levels of cognitive abstraction, and thereby produce different outcomes. AI techniques may thereby help delineate the linkages between cognitive variables based on user preferences, and the metadata influencing the presentation of the Internet experiences. AI Internet agents can help guide development by controlling the variables through the learning experiments and exercises. Recent advances in virtual reality for the Internet will likely enable most environmental and sensory elements of the learning experience to be customized to the needs of users.

Virtual environments, metadata, and intelligent interfaces

An important facet of the customization and personalization process involves the service interface and the overall environmental setting of the online experience. It is commonly known that users react differently to different mixes of aesthetic and sensory input, e.g. audio, visual and textual elements. Some users absorb more knowledge through the audio channel, while others through reading or watching. The visual layout and design of the media are an important facet. Industrial applications in distributed artificial intelligence have often targeted sensory data as a means to facilitate interpretation, planning, and other cognitive resources involved in tasks and actions (Chaib-draa, 1995). The ability to control these media options is important since it may reduce the cognitive “overhead,” or the additional and unnecessary effort and conceptualization which limits capacities for human information processing (Thuring *et al.*, 1995). In a purely practical sense, the emerging Cascading Style Sheets and XML Web standards will enable Internet media designers to tightly and dynamically control many of the design variables, and to dynamically customize an entire online experience.

Schemas and representations can all be isolated and tested against the user’s perceptions of those events. Advances in the AI research area addressing “fuzzy” reasoning will lead to further refinements of the capabilities of AI agents to make judgments about users and control media variables, likely through the selection of linkages and the automation of path options. Agents may dynamically reconfigure presentation and branching options to route users into agent-selected branches. The central theoretical construct in AI is representation (Boden, 1977), and the manner in which the system adapts and uses stored knowledge to interpret user preferences, and to then modify its behavior to represent the needs of the users, will determine the effectiveness of media delivery. The result is that AI-assisted Internet media may become more subjective, entirely functioning via these compiled views of the world (Boden, 1977). Learning experiences may use background knowledge to construct explanations of experiences, which may be compiled into rules to anticipate similar situations (Langley and Simon, 1995). The practical application of this intelligence may counteract the somewhat dehumanizing effects of the mechanistic approaches to media design of the past.

Neilsen (1993) defines usability as addressing ease of access for the user, and the degree to which the resources support user interaction. Users have different interface preferences, and these can be documented by tracking user behaviors. Agents can observe the user and memorize the kinds of interactions the user has had with the environment, and even offer suggestions (Maes, 1995). Some guidelines for the pertinent design variables are well established and have an historical basis. Typical forms of computer-mediated communication have been classified as immediate- or dynamic-interactive (e.g. teleconferencing); static- or delayed-interactive (e.g. reference or knowledge search); and simulated or experiential (e.g. virtual reality or online gaming) (Maule, 1997). Groupware and multiparticipant capabilities enable one or more users to simultaneously engage in these activities – should the user prefer the shared experiences, and the designers provide these options. Agents may be active throughout this process – engaging in user dialogs, and through these interactions instantiating rules to help determine the scope of the pertinent environmental variables (Dillenbourg, 1996). Research indicates that users enjoy environments in which there are agents or other phenomena with which they may form an emotional relationship (Maes, 1995). In essence, the AI agent becomes a "coach" acting on the user's profile to help the user in the learning process to advance from one knowledge state to another (Chambreuil *et al.*, 1994; McGraw, 1994). It may then be possible to assume that clusters (object patterns) may be identified to help correlate the tangible media elements with the foundation metacognitive attributes – to help in the creation of virtual and personalized experiences (Table IV). Environmental variables may also be categorized by user's interactive and emotional preferences – as evidenced by the services sought and the cognitive variables triggered in these sessions.

One of the strengths of hypermedia is that it enables designers to present content in different contexts (Marshall and Shipman, 1995). The various interfaces presented throughout the online experience are often key. Interface designs may be evaluated by whether they address intrinsic or extrinsic elements. Examples of the former would include cognitive factors addressing the aesthetics of the presentation, including such elements as color, arrangement, warmth and the overall feel of the environment. Extrinsic elements may consider the linkages, branches, input/output elements, and the degree to which structural variables correlate with the cognitive style of the user. Structures address the nodes, their object properties, and media/object interrelationships (Johnson, 1995). A limitation of first generation hypermedia presentations was the relatively small number of user options which could be programmed into the software. Designers faced immediate physical limitations to the number of options available on permanently stored media, such as CD-ROM. While intelligence could be programmed into the software, options for dynamic customization were rather limited due to the requirements for predefined content, and the difficulty in providing new and dynamic options based on user actions. The tracking of user behaviors, and the relay of these parameters back to the programmers, was quite delayed or non-existent.

Internet-based media have a different set of design limitations, mostly based on physical attributes such as bandwidth and delivery speed. However, designers no longer need suffer from an inability to align media behaviors with the cognitive styles of users. They can create customized and virtual experiences. Intelligence may be programmed into both the client and the server to enable a very close tracking of both tangible and intangible factors. Usage patterns may be identified, and media linkages more closely attached to the cognitive variables of users. In essence, the prominent learning variables are more tightly controlled. The control of the user's explorations through an information space can help structure the presentation to convey precise experiences and thereby support tasks requiring deep understanding and learning (Thuring *et al.*, 1995). The vast resources of the Internet, coupled with AI agents, provide a potent means for the creation of these dynamic virtual experiences. This flexibility in design

Table IV General framework for mapping environmental and experiential metadata design variables with metacognitive interpersonal usage elements

Variables	Data	Metadata	Cognitive	Metacognitive	Output
Environmental aesthetics	Presentation effects	Architectural preferences	Awareness, visualization	Feelings, desirability	Identification, linkages
Interface design	Registration data	User experience, demographics	Familiarity, interests	Comfort level, analogies	Dynamic personalization
Sensory motor tasks	Speed of performance	Actions, physical agility	Mental agility	Awareness, observations	Task knowledge, usability data
Skill acquisition	Experimental results	Practice, repetition traits	Attention, focus visualiztion	Internalization, perception	Sensory/motor designs

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

structure, and resultant great freedom for the user, also mean new research opportunities for the analysis of media and structures, and the testing of these variables with the metacognitive attributes of users. Metadata design frameworks are a means to delineate types of media, relationships between the media, and structural linkages across an environment.

Discussion

This paper proposes that Internet media designers seeking to provide personalized, customized and intuitive online experiences may benefit from an alignment of the cognitive maps of the users with the design maps and flowcharts of the information service. To test the designs, specific cognitive elements of targeted user populations may be manipulated and analyzed for their impact on the design variables for each reference point of the service (e.g. the nodes of the directed graph). Since the cognition of users is more likely a neural representation than a hierarchical model, as feasible the directed graph of the service may be conceptualized as a neural network and stress relationships which are more spatial and interactive. This is admittedly difficult given present design tools, but the analysis in this paper may help define some of the pertinent variables. Perhaps, neural networks and other pattern matching techniques may use the concept of the node as a self-contained intelligence, and thereby a point of reference for information processing. These nodes may serve as cognitive markers to help align the user's neural map with the neural map of the service. This is an interesting area for future research, and one likely to evolve with the technology. Typical online activities, such as computer conferences, bulletin boards, chat services, and electronic games all provide variables for the analysis of user cognition in electronic environments – and thereby provide viable environments for further research. The study of group and multi-participant software may be considered the next step and tested as a means to provide data on the interpersonal aspects of electronic learning environments.

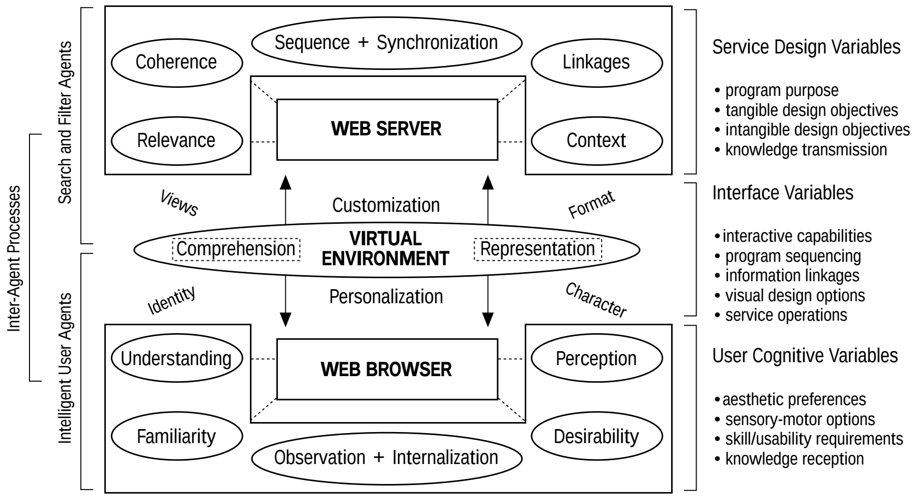
Applied artificial intelligence, via agent technologies, provides a means to realize the objectives of Internet personalization and customization. The fields of AI and agents are well established and quite comprehensive. A detailed discussion of these areas is well beyond the scope or intent of this paper. Rather, the objective herein is to present agent technologies as the enabler through which Internet personalization and customization become feasible for the average Web developer. Historically, artificial intelligence programming required a very detailed understanding of specific AI languages. This made AI a very specialized profession. Agent technologies are delivering a new/repackaged form of AI which is more focused, easier to access since it is application-level programming, and thus more available for use in daily Web operations. With such personalization and customization available to the Web designer, the focus turns to the means to effectively apply this capability. More specifically, the means to align the media designs with the cognitive traits and interests of users. Agents, and their applied AI, are the practical means to realize these design objectives. This integration process is modeled in Figure 1. Depicted are variables addressed in Tables I-IV, and a general structure to map an information service design with a user's cognitive map to help achieve personalization and customization. Future research in this area might address those agent technologies which provide options for media personalization and dynamic customization, which AI processes or techniques they are employing, and the propensity of the given technologies to help map media characteristics against user profiles and cognitive maps.

Conclusion

Internet-based media and distribution, for most forms of electronic information, seems probable given current trends toward network computing. The Internet will prove to be a powerful adjunct to traditional computer learning environments due to its capacities for a nearly limitless supply of information, and the applied intelligence needed to make customized knowledge from the media. As with all products, the effectiveness of the endeavors (programmatic information) will depend on the degree to which the information presentation and distribution processes are congruent with the needs of the users. Services will likely need to be integrated into the daily

Internet Research: Electronic Networking Applications and Policy
Volume 8 · Number 4 · 1998 · 347–358

Figure 1 Proposed mapping between a user's cognitive map and an information service



informational agendas of participants, and closely tied with user's personal attributes. For optimal impact and influence, the needs of the users will probably be satisfied through complex mixtures of media. This paper has argued that the guiding framework for media alignment should be the cognitive preferences of the users, and that it may be possible for this information to be translated into the types of metadata design variables usable by developers. Frameworks were presented to help address some of the pertinent elements and variables. Systems-level metadata was advanced as a means to provide a structure for the programming of the software. Agent and intelligence-gathering software was referenced as a means to provide insight into the types of cognitive variables which may be applied to provide end-user customization and personalization. Future research may help to determine the proper mix of the resources and interactive elements for online virtual learning, and to draw insight into the impact of Internet-based communications on both traditional media design practices, their supporting information structures, and their underlying design processes.

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