

# Augmented Cognition: An Approach to Increasing Universal Benefit from Information Technology

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## Abstract

Complex information technology (IT) is available to a wide audience; however, it is not designed typically to serve the needs of users from diverse populations. As part of the Universal Benefit from Information Technology Research Program, we have examined the design of IT in several areas. Our aim is to identify and mitigate cognitive breakdowns that can occur in the design or the use of IT. We provide an overview of our efforts to augment cognition in the areas of web site design, user assistance, and graphical image translation. For each project, we describe our approach to augmenting cognition, the project's current status, and findings that are relevant to other researchers who are interested in these areas. We think that a focus on resolving cognition breakdowns, as well as usability and accessibility issues, can produce solutions that enhance cognition and benefits from IT.

## 1 Introduction

The rapid expansion of the Internet, the ubiquity of home and office computers, and the proliferation of mobile computing devices (i.e., small, portable computers) in the last decade has made complex information technology (IT) available to a wide audience. Despite its prevalence, IT has not served the needs of users from diverse populations (e.g., people who have visual or learning impairments) in an equitable and effective manner (Shneiderman, 2000; Stephanidis, Akoumianakis, Sfyarakis, & Paramythis, 1998). Typically, underperforming IT, such as a web site or software application, is attributed to usability or accessibility issues; thus, improvement efforts aim to make it easier for users to use technology. We assert that, in many cases, we can also attribute ineffective IT to breakdowns in cognition (i.e., comprehension, perception, etc.) on the designers' or developers' end (e.g., not understanding how to produce beneficial web sites), the users' end (e.g., not understanding how to complete a task on a web site), or both. By not recognizing that IT deficiencies can result from cognition breakdowns, we miss opportunities to enhance cognition and possibly benefits from IT. Augmented cognition, the identification and mitigation of specific bottlenecks, is one way to address breakdowns that can occur in the design or use of IT.

In this paper, we provide an overview of research efforts that we are undertaking as part of the Universal Benefit from Information Technology (u b i t) Research Program at the University of Washington. The u b i t program aims to enable all people, regardless of their abilities, backgrounds, or experiences, to benefit from IT in all areas of their lives. To achieve this aim, currently, we are exploring ways to augment cognition in the areas of web site design, user assistance (i.e., help systems), and graphical image translation. We are conducting empirical studies and developing solutions to assist: (1) web site designers with developing and evaluating sites, (2) users with locating information to resolve IT problems, and (3) tactile graphics specialists with creating tactile forms of graphical images (i.e., representations of bar charts, line graphs, and illustrations that can be touched and read by people who are blind). We discuss these three efforts in this paper. For each project, we describe our approach to augmenting cognition, the project's current status, and findings that are relevant to other researchers who are interested in these areas.

## 2 Web Site Design and Evaluation

The Web enables broad dissemination of information and services; however, many web sites are inadequate with respect to usability or accessibility (Forrester Research, 1999; Jackson-Sanborn, Odess-Harnish, & Warren, 2002). This problem arises due to the site's designer being unfamiliar with effective design practices or inexperienced with producing effective sites. In our examination of the work practices of 169 web practitioners, we discovered that 96

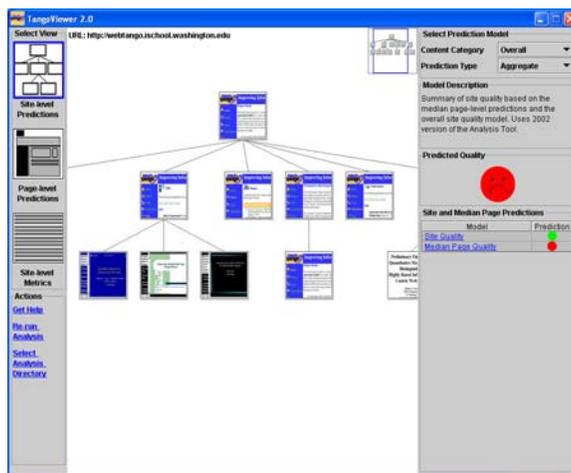
percent of them always or sometimes used guidelines to inform their work during the site's design or evaluation process (Ivory, 2003). We conducted four experiments to understand the problems that designers face when they attempt to follow prescriptive guidance. Results of the first three studies demonstrated that novice and professional designers find it difficult to apply guidelines during both the design and evaluation processes and that training is required to make them accessible, especially to novice designers (Chevalier & Ivory, 2003b; Ivory, 2003). The fourth study examined the effect of a short training program in applying usability criteria and recommendations on the evaluation and improvement of a web site (Chevalier & Ivory, 2003a). Although training novice designers to apply guidelines improved their ability to do so, it did not help them to produce sites that did not have problems.

The four studies revealed two key cognitive breakdowns: (1) understanding and applying guidelines to the design of a site and (2) understanding and applying guidelines to the evaluation of a site. To address the design bottleneck, we are developing a tool to generate effective web sites, specifically for classroom based courses (as opposed to distance based courses) that are offered within university settings (Heines, Ivory, Borner, & Gehringer, 2003). To address the evaluation bottleneck, we developed an automated evaluation methodology to help designers to conform to effective design patterns (Ivory & Hearst, 2002). We discuss these two efforts in the remainder of this section.

## 2.1 Automated Web Site Evaluation

We developed an automated evaluation methodology and software prototype to assist designers with determining whether or not their designs employ practices that are used on effective web sites. As the assessment basis, we used 157 highly accurate, quantitative page- and site-level measures; we identified the measures from an extensive survey of the web design literature and relevant empirical studies. The measures assessed many aspects of web interfaces, including the amount of text on a page, color usage, and consistency. We used these measures (computed for thousands of interfaces) along with ratings from Internet professionals (writers, designers, editors, etc.) to build statistical models or profiles of high quality (usable, accessible, etc.) web interfaces. In essence, the models predicted whether an evaluated page or site is consistent with interfaces that were rated highly, moderately, or poorly by the Internet professionals.

We deployed the models via two applications: (1) a web-based service that enables designers to submit an automated evaluation request for their site and (2) a desktop application that enables designers to explore the results of their site's automated evaluation. Figure 1 depicts the application for viewing evaluation results; the application shows results from various models and rationales for predictions. Rationales can help designers to improve their understanding of how to apply design guidance and help to mitigate cognitive breakdowns that occur during the design and evaluation processes. A small user study demonstrated that novice designers could use the prototype to modify designs and that users preferred pages and sites modified based on the statistical models over the original versions (Ivory, 2003); differences were significant in both cases.



**Figure 1:** Application for Viewing the Results of an Automated Web Site Evaluation

There are several novel aspects to this methodology: (1) the use of quantitative measures, (2) the use of empirical data to develop guidelines, (3) the use of profiles as a comparison basis, and (4) the ability to build models that are context-sensitive (i.e., based on the content category of the site or the functional type or size of a page). The context-sensitive aspect is critical, because it enables us to adapt assessments to the context in which interfaces are used.

## **2.2 Automated Web Site Generation**

After extensive work on automated evaluation, we shifted our focus to the web site design process. To narrow the scope of our work, we focused on the design of sites that instructors use as resources for their classroom based courses. First, we developed a systematic heuristic evaluation methodology (i.e., an expert reviews a site to see if it meets predetermined criteria) (Nielsen, 1994), relevant heuristics, and a toolkit to facilitate evaluations (Ivory, 2004). We then applied the approach to 79 sites that we selected randomly for courses offered at the University of Washington. We found that most sites were of average quality. Sites did well on aspects like visual layout, usability, and performance, but poorly on aspects like accessibility, content organization, and navigation structure. We found that the development environment that an instructor used to create a site has inherent problems (usability or accessibility). Furthermore, even with development tools, instructors needed to expend considerable effort and possess some design and technical expertise to produce sites.

To mitigate the cognitive burden that is inherent in creating effective course sites, we are developing an intelligent site generation system. Our vision is that the instructor will use a simple text based mechanism, which does not require HTML authoring expertise, to maintain the site's content. Unlike existing content management, portal, or site generation systems, our envisioned site generator would use machine learning algorithms to automatically map the text based content into an effective page layout and integrate it into the site. Such functionality would also support the automated transformation of documents (PDF, Word, etc.) into web pages, such that the pages are consistent with the rest of the site and do not require the use of plug-ins. The system would be responsible for all aspects of a site's design (e.g., navigation, layout, consistency, etc.), except for content creation; the instructor would be responsible solely for creating content for a site. The system will also provide the instructor with guidance on content organization or presentation; the feedback mechanism will build upon our earlier automated evaluation approach. Finally, the system will enable the instructor to safely control some design aspects, such as color schemes, font sets, headers, logos, etc., so that a site conforms to effective design patterns, despite these changes. Automated layout and feedback mechanisms can help instructors to improve their understanding of how to apply design guidance and help to mitigate cognitive breakdowns that occur during the design process.

As a first step toward realizing this vision, we created a prototype site generator and have used it to provide web sites for undergraduate- and graduate-level courses. Figure 2 depicts a site created with the generator prototype. The current prototype does not support text based content entry, perform automated content mapping to layouts, or provide feedback to instructors. We developed it mainly to explore ways in which to conform to the heuristics that we used to evaluate sites. For instance, the prototype organizes content in a logical manner, maintains consistent navigation, displays resources like readings in a contextual manner, enhances accessibility, and helps students to stay informed of classroom activities. Informal feedback from students has been promising.

We are currently completing the first phase of this study in which instructors and students complete online questionnaires about their experiences with course web sites. During the second study phase, we will conduct focus groups to gather more insight into course web site experiences and formal feedback on the prototype generator.

## **3 User Assistance**

Users need help systems (e.g., manuals, online content, and wizards) to support their use of complex IT, but often they find these systems difficult to use. We conducted a study to assess the current state of help systems and to identify ways in which to improve them (Martin, Ivory, Megraw, & Slabosky, 2005). We administered an online questionnaire to a diverse population of 107 IT users. The 45-item questionnaire probed users' perceptions and use of help systems that are within PC applications, web sites, and mobile computing devices. Unlike prior studies, our study examined help efficacy in the broadest sense (i.e., across applications, computing environments, and user populations). We identified three groups of users who differed based on their preferred help-seeking strategies and satisfaction with help. We showed that previously documented help system issues, such as incomprehensible



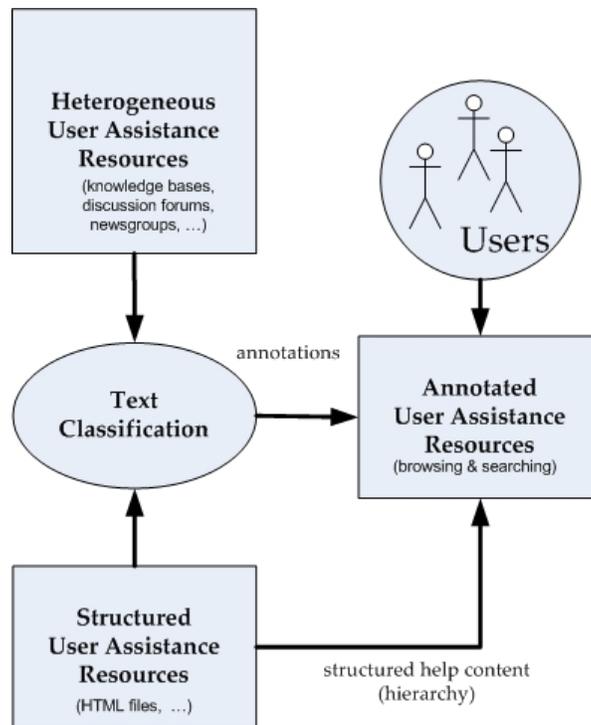
Figure 2: Screen Snapshot of a Site Created with the Site Generator Prototype

terminology and inadequate content, still exist. Furthermore, these problems seemed to be more pronounced in newer technology like web sites and mobile computing devices than in PC applications. Due to inadequate language, content, and search functionality, over two-thirds of users seemed to turn to the Web to resolve IT problems.

The study revealed two key cognitive breakdowns: (1) understanding help content and (2) understanding the right type of help resource to use. To address the first bottleneck, we are developing a help portal system to aggregate various help resources that are available on the Web and organize them in an intelligent manner so that users can have access to multiple perspectives on the same problems. This solution will also streamline help seeking via search engines. To address the second bottleneck, we propose the development of a help matching system to connect users with the right type of help resource in an intelligent and unobtrusive manner. We discuss these two efforts in the remainder of this section.

### 3.1 Help Portal System

Our study showed that users are increasingly turning to the Web (search engines in particular), when they need assistance with IT problems. Simply put, the help content that users find most useful and understandable does not always exist in a structured help system. We borrow the term “annotation” to indicate a link from a structured help source to an unstructured help source (e.g., discussion group posting, knowledge base article, or FAQ) which contains useful and relevant content (Marshall, 1998). We wish to take the content from structured help systems and annotate it with links to useful, unstructured help content (Figure 3). By doing so, users’ information retrieval processes can be streamlined and simplified. As annotations become part of the structured help system itself, a user can query and locate this information just as they would locate structured help content. Annotations may also implicitly bridge the jargon barrier by automatically associating structured, jargon-heavy help content with unstructured help content that is expressed with everyday language and mitigate cognitive breakdowns that occur during the help-seeking process.



**Figure 3:** Architecture of the Proposed Help Portal System

We are developing text corpora to examine the use of existing or the development of novel text classification algorithms to annotate structured help with unstructured content. Our corpora include structured and unstructured help content for three email applications that are used within three different computing domains (PCs, Web, and mobile computing devices); it consists of help content taken from Web based (newsgroups, vendors' knowledge bases, and discussion forums) and Windows help sources. Once we complete the corpus, we will conduct text classification experiments. By comparing results across structured help systems and computing domains, we intend to determine how the volume and hierarchical nature of structured help content affects the success of our text classification techniques. Another aim is to use the experiments to possibly provide guidance to help content authors and architects who may wish to support automated retrieval of their unstructured help content.

We view the annotation system as part of a Web based user assistance portal. To explore our portal concept, we constructed a prototype to demonstrate its interface and to describe its envisioned functioning (Figure 4). We are soliciting feedback from help users. Preliminary, informal feedback confirms that users prefer a help system which integrates unstructured sources to one which does not. We will continue to develop the portal prototype and evaluate it during our future focus groups with help users, help developers, and technical support specialists.

### 3.2 Help Matching System

Our study revealed that users expect help to follow a continuum based on their experience levels (i.e., novice versus expert) or help-seeking preferences (e.g., use tutorials or search). Users suggested the need to support three levels of proficiency (beginner, intermediate, and advanced) by: (1) offering different types of help resources and (2) organizing help content by proficiency level. Even if this continuum is supported, connecting users with the right type of help resource in an intelligent and unobtrusive manner is a major research problem. In future work, we will conduct additional studies to determine appropriate help resources for a wide variety of situations and use results as input to machine learning techniques so that we can build a model to predict useful help resources for a specific context. We will also investigate ways in which to deploy the model. A wizard, which users can invoke as needed, may be a desirable solution; the wizard would ask users a few questions and then recommend the appropriate resource for the context. The help matching system can help to mitigate cognitive breakdowns that occur during the help-seeking process, in particular for less experienced users.

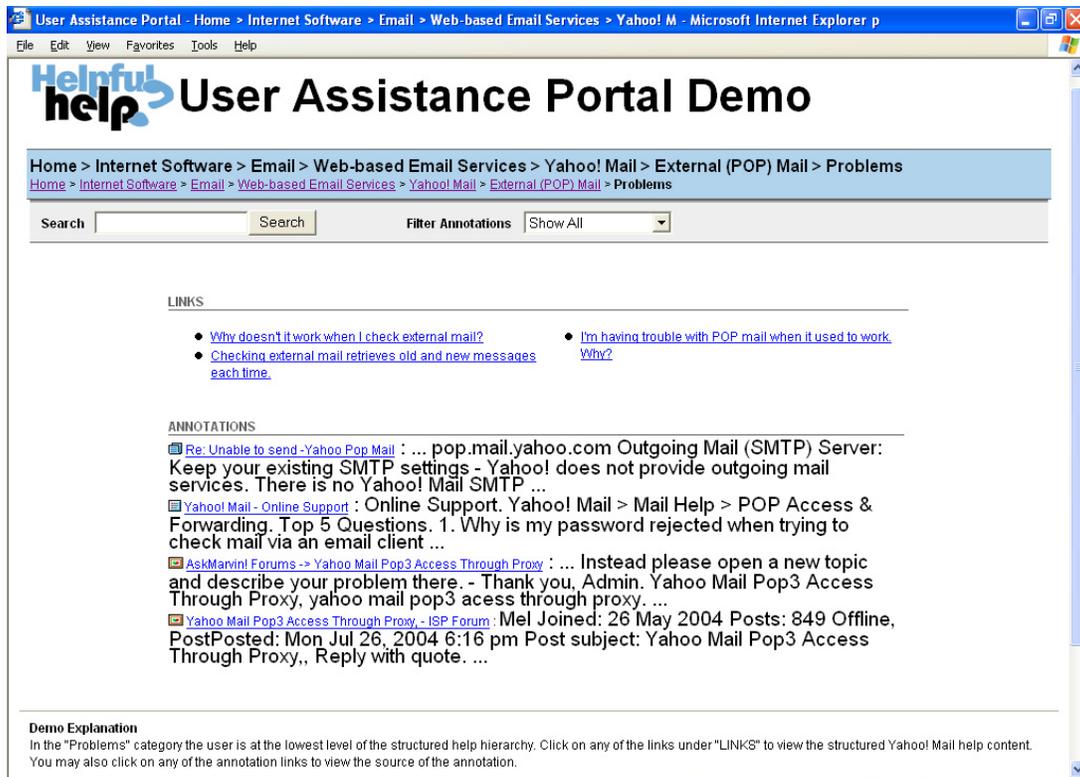


Figure 4: Screen Snapshot of the Proposed Help Portal System

## 4 Graphical Image Translation

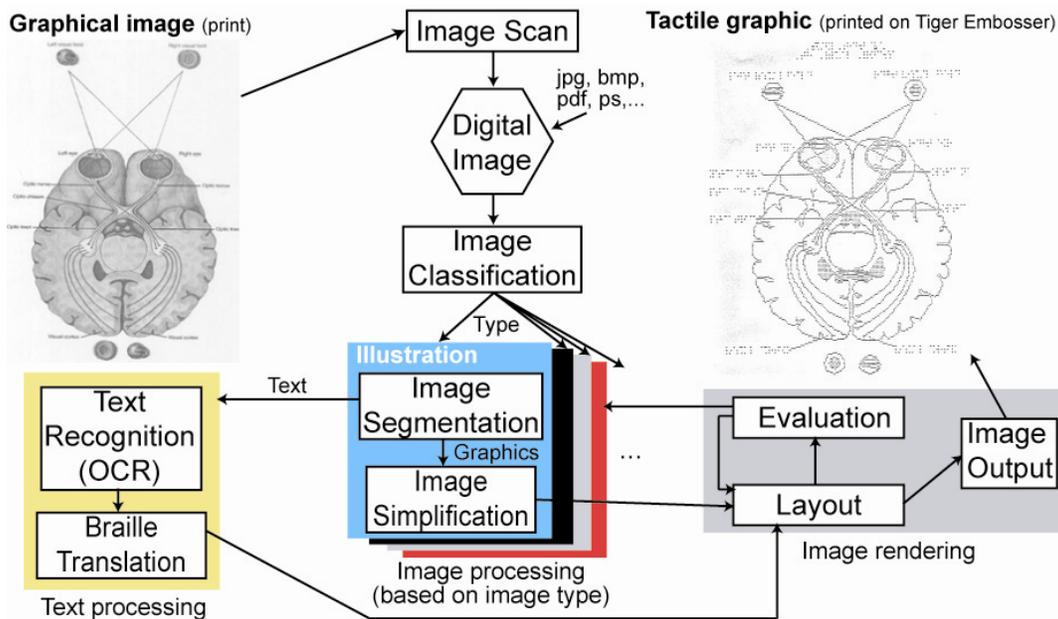
Historically, blind students have been denied access to important graphical materials which their sighted counterparts can access. It is easier and less costly to simply leave images out of a textbook than to have a tactile version (i.e., raised image that is designed to be read by the fingers) created by a tactile graphics specialist. During the manual translation of a graphical image into a tactile form, a tactile graphics specialist, by hand, makes a line drawing or sketch of the graphical image, either on paper or with a drawing package like Visio or Corel Draw. There is an editing program, the BrlGraphEditor (Batusic & Urban, 2002), which supports drawing 2D graphics and printing them on certain Braille printers; however, there is no automated processing of graphics. When completed, these handmade drawings can be used as a master for producing tactile graphics.

Through the use of an on-line questionnaire (administered to 51 people) and 16 in-depth observation sessions, we examined how tactile graphics specialists produce tactile graphics for blind students and how they use software applications during the production process. We found that tactile graphics specialists shy away from using applications, even though their production methods are labor and time intensive. Half of the participants did not use a computer at all and those who did, relied upon simple drawing functionality, such as Microsoft Word's drawing tools, as opposed to fully featured drawing systems like Adobe Photoshop or Illustrator. Participants considered fully featured drawing systems to be cumbersome, non-intuitive, and overkill for their needs. Nonetheless, these tools have valuable image processing algorithms, which could help them to streamline their work practices. For instance, image-editing programs can make automated transformations to simplify the image, such as detecting edges, filtering out noise, thickening lines, or removing unimportant elements.

The study revealed a key cognitive breakdown—understanding how to carry out translation tasks in fully featured drawing software. To address this bottleneck, we are developing the Tactile Graphics Assistant to assist tactile graphics specialists with translating graphical images. We discuss this effort in the remainder of this section.

## 4.1 Tactile Graphics Assistant

We are developing software to support the work practices of tactile graphics specialists. The software will be a plugin for fully featured drawing packages like Adobe Photoshop or Illustrator. Figure 5 depicts the automated, step-by-step process for translating a graphical image into a tactile graphic. Once the tactile graphics specialist loads a digital image, the software will identify the type of the image (e.g., bar chart, line graph, or illustration). We need to classify images so that similar images can be tactilized using the same image processing steps. Example image processing steps include: segmentation into text and non-textual elements, edge detection, color reduction, resolution reduction, label placement, and so on. After applying the appropriate image processing techniques, the software will assemble graphical and textual image components into an effective layout. Determining an ideal layout could be an iterative process between producing a layout and evaluating it in an automated manner. Tactile graphics specialist can use the final layout as a master for producing a tactile form.



**Figure 5:** Process for Converting a Graphical Image into a Tactile Graphic

We have used machine learning techniques to develop a highly accurate model for classifying images into three classes: bar charts, line graphs, and diagrams. We have also developed image processing algorithms which can extract text from the image and convert it to ASCII, remove colors, and rescale images. In future work, we will explore the use of machine learning techniques to identify the appropriate image processing steps to apply to an image based on its predicted type. The envisioned automated translation system can help to mitigate cognitive breakdowns that occur during the use of image-editing software to create tactile graphics.

## 5 Conclusions

During the use or design of IT, there can be cognitive breakdowns on the designers' end, the users' end, or both. We have identified cognitive breakdowns that can occur within three areas: web site design, user assistance, and graphical image translation.

- In web site design, designers have difficulty with understanding and applying guidelines to the design or evaluation of a site. We have developed automated evaluation and web site generation tools to help designers to mitigate these problems.
- In user assistance, users have difficulty with understanding help content or identifying the right type of help resource to use. We are developing a help portal system and a help matching system to help users to mitigate these problems.

- In graphical image translation, tactile graphics specialists have difficulty with understanding how to carry out translation tasks in fully featured drawing software. We are developing an automated translation system to help tactile graphics specialists to mitigate this problem.

By focusing on cognitive breakdowns in addition to usability and accessibility issues, we think that our efforts will produce solutions that enhance cognition and benefits from IT.

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