A WEBSITE INTERFACE DESIGN FRAMEWORK FOR THE COGNITIVELY IMPAIRED: A STUDY IN THE CONTEXT OF ALZHEIMER'S DISEASE

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ABSTRACT

Bodies such as the World Wide Web Consortium and the US Congress have advanced recommendations intended to make Information Technology more accessible to impaired users. These include guidelines specifically intended for the cognitively challenged, such as people with Alzheimer's disease (AD). However, there is little research evidence to date demonstrating the value of complying with these guidelines. In this paper, we introduce a four-element, theoretical framework and outline a research agenda that identifies important considerations for developers of website interfaces for those with AD. This Website Accessibility Framework may be used as the basis for investigating the impacts of interfaces with differing degrees of guideline compliance, ranging from no compliance to full compliance, on people with AD.

Keywords: Alzheimer's disease; Cognitive impairment; Website accessibility; Web Content Accessibility Guidelines; Website Accessibility Framework

1. Introduction

A critical issue of our times is the welfare of the aging and the aged in society. The US Census Bureau's Census 2000 report estimates that currently there are thirty-five million Americans aged sixty-five and over. This figure is projected to exceed eighty million by the year 2050 when the worker/retiree ratio shrinks to two. With this "graying of America", the treatment and cure of disabilities that arise out of aging have assumed center stage in the medical and policy-making fields. Today, we have several highly focused, well-funded medical research groups concerned with various facets of the diagnosis and treatment of ailments associated with aging. Examples include the Geriatric Research, Education, and Clinic Centers and the Alzheimer's Disease Research Centers. Likewise, national policymakers are also cognizant of the importance of this issue as reflected by legislation (e.g., the Medicare Prescription Drug, Improvement and Modernization Act of 2003 [Centers for Medicare and Medicaid Services 2003]) implemented with the aim of safeguarding the interests of older adults.

A particularly debilitating impairment that affects Americans and others worldwide is Alzheimer's disease (AD). The Alzheimer's Disease Education and Referral Center, established by the National Institute on Aging, estimates that up to 4 million Americans have been diagnosed with AD. This includes about 3 percent of the approximately 18.5 million men and women aged 65-to-74 and nearly half of the about 4.5 million individuals aged 85-and-older (those in the 75-84 age group constitute much of the remainder). Whereas the risk of AD does increase with age, AD is not a normal part of aging. Increasingly, younger individuals – even those as young as 30 -- are being diagnosed with "early onset" AD and it is now believed that the disease can be inherited. It is estimated that by the year 2050, more than 14 million Americans – over thrice the current number -- will be diagnosed with AD. The socio-economic ramifications are tremendous. Currently, the total annual societal costs attributable to AD are estimated at about $100 billion [President and Fellows of Harvard College 2002]. As of today, there is no effective

cure for the disease. The course of the disease and its acceleration vary from person to person. On average, AD patients live from eight to 10 years post diagnosis, although longevity extends to as much as 20 years in some cases. Given this grim scenario and the peculiar features of the disease, it is essential that AD patients receive especially tailored care and facilities to both enhance the quality of care received and their quality of life.

The quantum leaps that have been made in the field of computer, communication, and information technologies and the integral roles that such technologies play in our everyday lives are well established. Consequently, there is emerging interest in harnessing computer-based technologies to further enhance the quality of care provided to Alzheimer' patients (e.g., the use of tracking technologies). Regrettably, the same is not true of making Information Technology (IT) more accessible to such individuals as one means of enhancing their quality of life in today's heavily IT-reliant society. System developers have hitherto focused, perhaps unintentionally, on the research and development of interface designs for the young and the healthy, although research concerning designs for the older and less able sections of society is emerging [Dailey 2004; National Institute on Aging 2002]. Thus, despite the national proliferation of internet access for business and non-commercial use, we are quite likely to face an unprecedented "intra-national digital divide," one where a significant, growing population chunk is isolated from effectively harnessing the Net due to inappropriate interface design.

This state of affairs is indeed lamentable, as IT can also be used to more effectively meet a primary objective of patient care, viz., "resurrecting the self." This phrase refers to the development of quality programs that seek to understand each person's capabilities and interests and plan activities that seek to enhance a patient's daily existence. There is prior research evidence that the Web is capable of fostering cognitive engagement in healthy users [Agarwal and Karahanna 2000]. We contend that, with suitable website re-design, this trait could be exploited to benefit the cognitively impaired as well.

Faced with the prospect of a new digital-divide dilemma, the World Wide Web Consortium has advanced the Web Content Accessibility Guidelines (WCAG 1.0) [World Wide Web Consortium 1999a] and the User Agent Accessibility Guidelines (UAAG 1.0) [World Wide Web Consortium 1999b], as part of its Web Accessibility Initiative (WAI) [World Wide Web Consortium 2000]. Likewise, the US Congress has enacted the Rehabilitation Act (Section 508) [Architectural and Transportation Barriers Compliance Board 2000] to make IT more accessible to those with cognitive, visual and/or auditory impairments. Specifically, subpart B (Technical Standards), section 1194.22 of the Section 508 guidelines entitled "Web-based intranet and internet information and applications" lay out the standards that directly relate to Web sites. These, again, are based on guidelines developed by the World Wide Web Consortium. However, the vast majority of systems and websites (including governmental sites) fail to conform to such recommendations [Loiacono 2004] and it is not entirely clear to what extent adherence to such guidelines/laws will be helpful to those with AD, particularly those in the early stages of the disease where enhanced IT accessibility will likely offer the greatest dividends.

We contend that the development of "Alzheimer's patient-friendly" website interface designs is of paramount importance and this is the ultimate product that we envisage flowing out of this research. In this paper, we advance the theoretical framework that identifies important considerations for developers of such system interfaces: the Website Accessibility Framework. The principal contribution of this framework is its provision of a theoretically grounded means for systematically exploring the access efficacy of alternative website designs for users with AD. Moreover, the Website Accessibility Framework identifies technical and behavioral factors that should guide a consideration of features to incorporate into the design of websites that accommodate the cognitively impaired. While the framework relates specifically to coping with dementia arising out of AD, we suggest that it may be extended to apply to other forms of cognitive disabilities including Attention Deficit Disorder, Dyslexia, Down Syndrome, and general, short-term, memory loss due to aging [World Wide Web Consortium 2004].

Given this overview and our underlying motivations, the remainder of this paper is organized as follows. Section 2 provides a quick review of a medical categorization scheme called the Cognitive Dementia Rating scale used to characterize those with AD. An understanding of this scheme is necessary to help design experiments utilizing AD patients and our proposed framework. Section 3 introduces key elements in effective website interface design for the healthy. These elements may be divided into those that design technocrats typically focus on and those that behaviorists believe influence user perceptions about systems. Both groups seek to enhance system accessibility but the focus has been, at least implicitly, on the young and the healthy. In Section 4, we present and discuss the Website Accessibility Framework. This framework forms the basis for an examination, in Section 5, of the impacts of the existing UAAG 1.0 / WCAG1.0 / Section 508 guidelines, taken both in isolation and in conjunction with one another, on enhancing accessibility by the cognitively impaired. Section 6 presents concluding thoughts.

2. Characteristics of Alzheimer's disease

A trait common to all Alzheimer's Disease patients is memory loss and associated cognitive and learning impairments with regard to a number of traits -- personality, abstract thinking, judgment, language use, the ability to perform complex tasks, and the ability to recognize objects or people [President and Fellows of Harvard College 2002]. From a medical perspective, an AD patient is customarily characterized as belonging to one of five stages or levels on a Clinical Dementia Rating (CDR) scale [Alzheimer Disease Research Center 2003]. The assignment is based on assessments spanning six domains of cognitive and functional performance, namely, Memory, Orientation, Judgment & Problem Solving, Community Affairs, Homes & Hobbies, and Personal Care. The assessment includes both information gathered by a clinician via a semi-structured interview using a standard CDR worksheet and that obtained from a reliable collateral source such as a caregiver or family member. The rating for each domain is combined into an overall CDR level value using an algorithm. Table 1 [Alzheimer Disease Research Center 2003] describes characteristics associated with each domain at each stage of the disease.

As the table indicates, CDR-0 individuals are essentially able-bodied, healthy individuals. CDR-0.5 connotes people in the very early stages of AD with "very mild" or "questionable" dementia. They display slight impairments with regard to virtually all dimensions barring personal care. CDR-1.0 corresponds to "mild" dementia. They display moderate levels of impairment in all domains including personal care. Stages CDR-2 and CDR-3 correspond to the advanced AD stages with impairments ranging from the severe (for CDR-2) to debilitating (for CDR-3). With the onset of AD, patients progress from stage to stage over time, as there is no stopping this decline with present-day treatment. This has lead to widespread concern with trying to improve an AD patient's quality of life, to whatever extent possible, over the course of the disease. Whereas an individual at CDR-3 is likely too far advanced in dementia to be a productive website user, website redesign attempts could perhaps help improve quality of life at some or all of the preceding stages.

Of particular interest are the Memory, Orientation, and Judgment and Problem Solving dimensions. These are paramount considerations in navigating through a website interface to a desired end state. Further, because an individual's social and professional interests also affect his/her approach to website usage, the two dimensions of Community Affairs (concerned with occupation, shopping, volunteer groups, etc.) and Home and Hobbies (pertaining to casual, recreational, and intellectual interests) play key roles.

We next review existing literature on website interface design. Prior work has focused essentially on design for those with no disabilities of any kind; at least, that appears to be the implicit assumption. Our review seeks to isolate key design features that we believe could play a role in enhancing accessibility by the cognitively impaired.

3. Perspectives on Website Interface Design

From the perspective of interface design technocrats, website interface design broadly deals with three inter-related elements: Usability, Visualization, and Functionality [Vertelney et al. 1989]. Usability refers to how intuitively or easily a user can navigate a system (is concerned with flow, sequence, instructions, and download time). Visualization refers to creating visually interesting and aesthetically pleasing interfaces while avoiding potentially distracting or unnecessary "bells and whistles." Functionality pertains to the usefulness of the interface in terms of supporting a task it is intended to support.

The fact that multiple design elements, in a variety of combinations, can be used to achieve these three goals has given rise to an extensive "how to" or prescriptive "best practices" literature base in this area. Key recommendations include:

- avoiding large graphics [Balas 1999; Conger and Mason 1998; Nielsen 2000; Powell et al. 1998],
- avoiding numerous graphics [Lightner and Eastman 2002; Powell et al. 1998; Vertelney et al. 1989],
- avoiding lengthy pages [Balas 1999],
- offering navigation support [Balas 1999; Karvey 1996; Nah and Davis 2002; Nielsen 2000],
- considering browsing effects [Karvey 1996; Nielsen 2000; Powell et al. 1998; Smith 1998],
- simplifying websites [Balas 1999; McCune 1998; Nielsen 2000],
- avoiding complex URLs [Balas 1999; Nielsen 2000; Powell et al. 1998],
- making content succinct and relevant [Conger and Mason 1998; Lee and Kim 2002; Smith S. 1998],
- updating content in a timely manner [Balas 1999; Conger and Mason 1998; McCune 1998; Nielsen 2000], and
- soliciting user feedback [Balas 1999; Conger and Mason 1998; Nielsen 2000; Powell et al. 1998].

Notwithstanding the technical perspective, a separate stream of behavioral research has identified three key influencing interface elements that ultimately impact a user's cognitive processes, perceptions, and performance when using a site. These are:

- the structuring of the site's hyperlinks (Navigation Structure),

- the task that must be performed using the site (Knowledge Acquisition Task), and
- the extent to which the content material of a site matches the values, beliefs and experiences of a user (Content Compatibility).

Table 1. Clinical Dementia Rating (CDR) [Alzheimer Disease Research Center 2003]

CDR Score	**0** **Healthy**	**0.5** **Very Mild Impairment**	**1** **Mild**	**2** **Moderate**	**3** **Severe**
Memory	No memory loss or slight inconsistent forgetfulness	Consistent slight forgetfulness; partial recollection of events; "benign" forgetfulness	Moderate memory loss; more marked for recent events; defect interferes with everyday activities	Severe memory loss; only highly learned material retained; new material rapidly lost	Severe memory loss, only fragments remain
Orientation	Fully orientated	Fully orientated except for slight difficulty with time relationships	Moderate difficulty with time relationships; may have geographic disorientation elsewhere	Severe difficulty with time relationships; usually disorientated in time, often to place	Orientated to person only
Judgment Problem Solving	Solves everyday problems and business affairs well; judgment good in relation to past performance	Slight impairment in solving problems, similarities, differences	Moderate difficulty in handling problems, similarities, differences	Severely impaired in handling problems, similarities, differences	Unable to make judgments or solve problems
Community Affairs	Independent function at usual level in job, shopping, volunteer and social groups	Slight impairment in these activities	Unable to function independently at these activities though may still be engaged in some	No pretense of independent function outside home Appears well enough to be taken to functions outside a family home	No pretense of independent function outside home Appears too ill to be taken to functions outside a family home
Home & Hobbies	Life at home, hobbies, intellectual interests well maintained	Life at home, hobbies, intellectual interests slightly impaired	Mild but definite impairment of function at home; more complicated hobbies abandoned	Only simple chores preserved; very restricted interests, poorly maintained	No significant function in home
Personal Care	Fully capable of self care	Fully capable of self care	Needs prompting	Requires assistance in hygiene, keeping of personal effects	Requires much help with personal care

Considerable research scrutiny has been applied to the first of these. Navigation Structures have been classified into linear, grid, hierarchical and pure web structures [Powell et al. 1998]. Hierarchical and tabular structures have been found to be most widely used in website interface design [Nielsen 2000]. Mixed web structures (hierarchical with cross-referential links) have been shown to result in better user performance than that with hierarchical or non-linear structures [McDonald and Stevenson 1998]. From a different perspective, Navigation Structures have also been classified, based on subject matter, into usage-oriented, subject-oriented, and combined hierarchies [Fang and Holsapple 2002].

Knowledge Acquisition Tasks have been classified into simple and complex [Fang and Holsapple 2003]. The former is one for which the knowledge required for the completion of a task exists in a single web page; the latter is one that requires the user to visit multiple pages. Empirical studies have found that, for both simple and complex tasks, the quality of knowledge acquisition via usage-oriented hierarchies and combined hierarchies (i.e., networks) is superior to use of subjected-oriented hierarchies; and for complex knowledge acquisition tasks, users perform significantly faster with a usage-oriented hierarchy than a networked structure [Fang and Holsapple 2000; 2002; 2003]. Finally, a few studies have examined the role played by the third element, Content Compatibility of the interface, in fostering positive user perceptions of the system [Chau and Hu 2002; Chen et al. 2002].

It also seems plausible that the two viewpoints – the 'technocrats' and the 'behaviorists' -- are not mutually exclusive or at odds with one another. For instance, it would appear that Usability is a function of Navigation Structure and that Functionality and Knowledge Acquisition Task are related concepts. One may regard the technocrats' concerns of Usability, Visualization, and Functionality as being more "general purpose" and intended to facilitate website usage by a wide group of (implicitly, healthy young adult) users. The behaviorists' attention to Navigation Structure, Knowledge Acquisition Task and Content Compatibility, on the other hand, may be regarded as a more micro-level focus, involving individual users of a site, as the attributes Knowledge Acquisition Task and Content Compatibility are highly user dependent. Here again, however, focus to date has been on healthy young adults. Both perspectives seek to improve website accessibility by their target users.

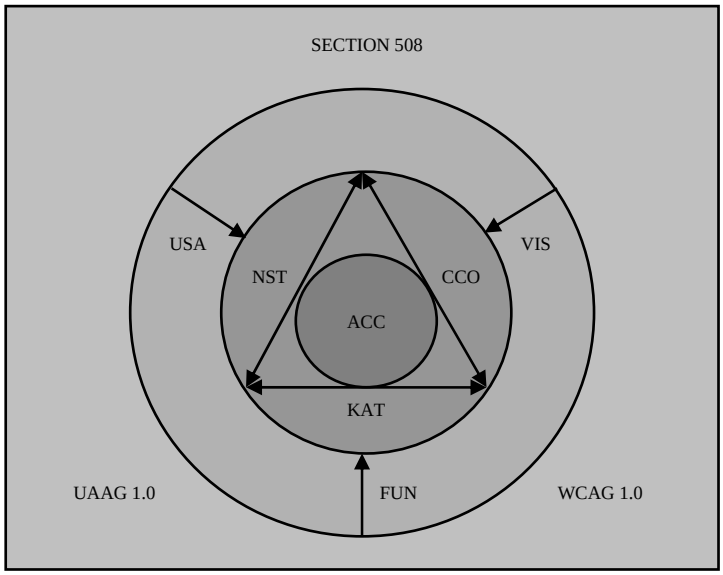
4. The Website Accessibility Framework

In this paper, we seek to develop a framework to help examine what benefit the UAAG 1.0 / WCAG 1.0 and Section 508 guidelines (see Appendix 1 for a description of the guidelines) potentially offer a website user with AD, in terms of increased levels of accessibility over a traditional website interface. In other words, in what way or ways do these guidelines, if implemented, result in enhanced user perceptions about an interface and/or performance with that interface given particular settings for the Knowledge Acquisition Task, Navigation Structure, and Content Compatibility elements? The assumption here is that evidence of improvement in perceptions and/or performance is evidence of improved accessibility. In broad terms, accessibility is defined as the practice of giving people with disabilities equal access to websites and online content [World Wide Web Consortium 1999c]. Appendix 2 presents two practical examples provided by the World Wide Web Consortium of how the implementation of these guidelines could enhance accessibility.

From Table 1, the Memory/Orientation, Judgment/Problem Solving and, Community Affairs/Hobbies dimensions (i.e., rows) are the predominant factors that characterize an AD patient's medical condition. From the perspective of our research, a patient's Memory and Orientation CDR dimension ratings determine how facile a particular Navigation Structure proves to be for him/her. His/her Judgment & Problem Solving CDR dimension ratings make a particular Knowledge Acquisition Task either harder or easier for him/her. Finally, a patient's ratings in the Community Affairs and Home & Hobbies CDR dimensions determine the extent of Content Compatibility of a website. Presumably, the UAAG 1.0 / WCAG 1.0 and Section 508 guidelines seek to mitigate, to one extent or another, cognitive impairments an AD-patient has in any of these elements.

The three elements, Navigation Structure, Knowledge Acquisition Task and Content Compatibility, and their interplay, form the foundations of the Website Accessibility Framework (WAF), shown in Figure 1. The figure depicts their influence, both in isolation and together, on the fourth element, Accessibility (ACC). The rationale behind our focus on Navigation Structure, Knowledge Acquisition Task, Content Compatibility and Accessibility in the context of people with AD, are as stated in the preceding paragraph. The figure also shows the influence of the general-purpose, technocrat-proposed elements of Functionality, Visualization, and Usability on the more individualized Navigation Structure, Knowledge Acquisition Task and Content Compatibility elements postulated by the behaviorists.

As our Website Accessibility Framework is grounded on the CDR scale that outlines the definitive cognitive characteristics of AD, it forms a sound experimental base for researchers to structure experiments that seek to examine whether the UAAG 1.0 / WCAG 1.0 and Section 508 guidelines are indeed beneficial in enhancing accessibility among AD patients, and in isolating detrimental impacts, if any, on particular user groups such as healthy adult users. It enables researchers to identify potential interaction effects of the guidelines with the three elements of Navigation Structure, Knowledge Acquisition Task, and Content Compatibility, which as we have seen are critical factors for AD patients while browsing through a website. In the following sub-sections, we examine details of these interactions and influences.



ACC – Accessibility, NST – Navigation Structure, KAT – Knowledge Acquisition Task

Figure 1. The Website Accessibility Framework (WAF)

4.1 Navigation Structure (NST) and Accessibility

Let us consider the interplay between Navigation Structure and Accessibility in the context of users with AD. We focus on two of the many possible website interface navigational structures, the Hierarchical (HR) and the Networked (NW). A Hierarchical structure is a linear structure wherein each link on the index (home) page leads to a set of logically-grouped sub-level pages. The hierarchy could involve more than two levels. Although sub-level pages within a set are logically grouped, the sets themselves are mutually independent as are pages within a set. As such, there are no cross-referential links between sub-level pages within a set or across different sets. Consequently, to access another sub-level page from a given sub-level page, a user must traverse far enough up the hierarchy to an appropriate page from which to traverse down the hierarchy, again, to an appropriate sub-level page. A Network structure relaxes this restriction by permitting cross-referential links from any given sub-level page to any other sub-level page regardless of set. The two structures defined are extreme cases where one is a pure hierarchy and the other is a pure (fully-connected) network or mesh. In practice, other structures are possible; indeed, less extreme versions of Hierarchical and Network are more prevalent, as pure networks and hierarchies could prove impractical in realistic settings.

The Mental Model Theory of thinking and reasoning [Craik 1943] could be applied to develop suitable performance-related hypothesis with regard to the two navigation structures. Mental models are primarily representations of reality constructed in one's mind from perception, imagination, or reading. They are generally grounded in visual images. Mental models are commonly used to address issues that require reasoning and inference. When a user navigates a website, a mental model of the navigation structure is created in his or her mind and can be used to navigate efficiently and quickly from one web page to another making use of a minimum number of links.

In the case of Alzheimer's patients, we suggest that as a patient advances along the CDR scale, prior mental models will deteriorate at a faster rate, new mental models will likely be harder to completely and accurately form, and whatever models are formed, will likely deteriorate faster with increasing CDR stage. Overall, we would expect deteriorations in mental model construction, retention, and use capabilities with increasing CDR stage. Under such circumstances, for a given CDR stage, the non-linear navigability possible with the Network structure should result in better accessibility than that possible with the linear Hierarchical structure, particularly as the number of pages to be traversed increases. In addition, for both Network and Hierarchical structures accessibility should decrease with increasing levels of the disease. These suggested trends are visually depicted in Figure 2.

In the figure, notice that at an earlier CDR stage (i.e., with healthier individuals), we expect the difference in accessibility between the two Navigation Structure choices to be narrower than at later stages. With the progression of the disease, we hypothesize that Network structure would be increasingly preferable to the Hierarchical structure, all else being constant. Further, there is no particular reason to suppose that, at very early stages (e.g., CDR-0.5) or

with healthy individuals (CDR-0), the Network structure is necessarily better than the Hierarchical structure. Finally, the relationships between CDR stage and Accessibility in both cases may well be non-linear.

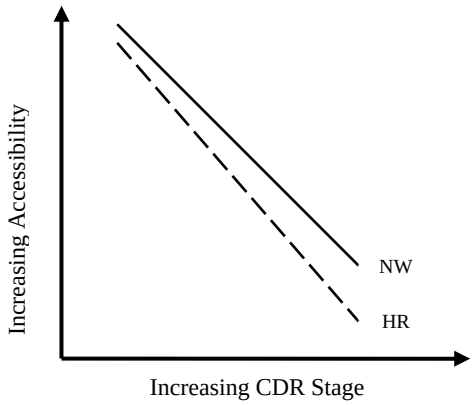


Figure 2. Navigation Structure and Accessibility

4.2 Knowledge Acquisition Task (KAT) and Accessibility

The process of acquiring knowledge from a website has been studied in the context of a simple task (single page visit) and a complex task (multiple page visits required) [Fang and Holsapple 2003]. We further refine this concept of complexity by drawing on Anderson's ACT theory [Anderson 1990], which classifies knowledge as being "declarative" and "procedural." Declarative Knowledge refers to factual knowledge (or "knowing what"). For example, knowing the capital city of the state of Kentucky or yesterday's temperature in the Bluegrass would constitute instances of an individual's declarative knowledge base. Procedural Knowledge, on the other hand, refers to knowledge concerning the execution of a particular process (i.e., is "knowing how"). For instance, knowledge of cooking a particular dish or performing mathematical operations like subtraction or addition would fall into this category.

We extend Anderson's definitions of knowledge types to tasks that we term as Declarative Tasks (DT) and Procedural Tasks (PT). A Declarative Task is one that involves the acquisition of a piece of Declarative Knowledge. A Procedural Task involves both the acquisition and the "use" of Procedural Knowledge to create new pieces of Descriptive Knowledge. This use may involve arithmetic operations, logical comparisons, or both. Both task types are knowledge-acquisition oriented, but a Procedural Task, in general, is more complex than a Declarative Task.

Obtaining the price of a particular car from a website that lists factual information, including prices, arranged in some fashion (e.g., tabular with entries arranged by manufacturer), constitutes the performance of a Declarative Task. The listing itself may occupy a single page or span multiple pages. Thus, the particular navigation structure employed (Hierarchical or Network) comes into play. Consider, next, a scenario where an individual must access the prices of two different cars (say, a Ford sedan and a comparable Toyota) and compute the difference in their prices or comment on which is more expensive. The inclusion of such arithmetic and logic operations renders this a Procedural Task.

It may well be the case that the afore-described activities are relatively straightforward and simple for healthy individuals. However, such an assertion cannot be as confidently made in the case of those with AD, given their impaired memory/recall capabilities and diminished abilities to judge/solve problems. Such considerations lead us to postulate that with increasing severity of the disease, a user with AD would be relatively increasingly better at performing declarative tasks rather than procedural tasks. This is depicted in Figure 3.

As with Navigation Structure, here again, the widening gap between the two plots in the figure is intended to convey our suggestion that those with AD should find procedural tasks increasingly, relatively harder with increasing disease progress, all else being constant. Once again, the linear patterns shown are purely for expository convenience.

4.3 Content Compatibility (CCO) and Accessibility

Prior research with healthy individuals has indicated that when the content material of an interface matches the values, beliefs, and experiences of a user, it results in positive user perceptions about the interface and the system [Chau and Hu 2002; Chen et al. 2002]. Alzheimer's patients, whilst oftentimes appearing disconnected with the present, have been observed as experiencing heightened enjoyment and total immersion in activities associated with prior experiences [President and Fellows of Harvard College 2002]. Thus, the Content Compatibility of an interface

should affect accessibility by people with AD. We classify Content Compatibility into two categories, Compatible (CO) and Incompatible (IC).

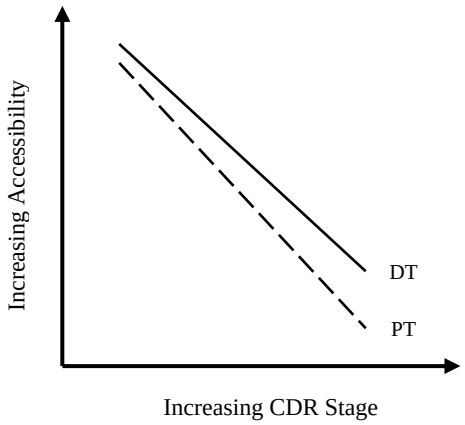


Figure 3. Knowledge Acquisition Task and Accessibility

A Compatible website interface is one that refers to content material that has relevance and meaning to the subject, in light of his/her past experiences. An Incompatible interface lacks such relevance and meaning. For example, one could expect a website dealing with basketball or football, to be a compatible website for many in the US while one on the game of cricket would lack compatibility for many. At any given CDR stage, we expect enhanced accessibility with a Compatible interface over an Incompatible interface. Compatibility becomes an increasingly critical element with increasing CDR stage. These suggested trends are depicted in Figure 4 (using simplified straight-line trends).

Observe that a particular Knowledge Acquisition Task is either facilitated or impeded by the particular Navigation Structure and Content Compatibility settings. For instance, if the Ford sedan's price is on a given page but the Toyota sedan's price appears on a different page, the user must initially retrieve one of the two pieces of information, store it, navigate to the other page, retrieve the second piece of information, recall stored information, and then perform the necessary arithmetic and/or logical comparison operations. Such operations may involve more than two pieces of information, further complicating the procedural task. Finally, an automobile-oriented site may or may not be compatible with a particular user. Thus, the Web Accessibility Framework holds that the net accessibility level for a website is a function of the combined impacts of the three basic elements of Knowledge Acquisition Task, Navigation Structure, and Content Compatibility. We next characterize potential interactions among these three elements.

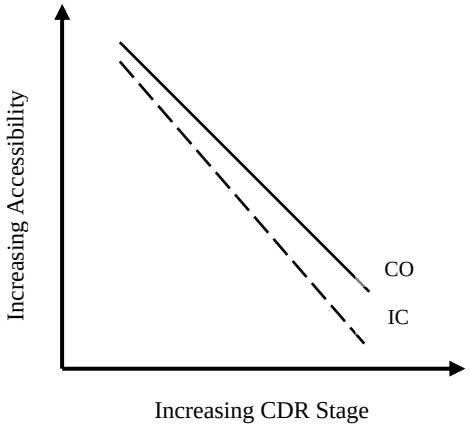


Figure 4. Content Compatibility and Accessibility

4.4 Interactions among the Web Accessibility Framework Elements

To comprehend the potential conjunctive impact of all three basic elements, let us first consider two of these – namely, Knowledge Acquisition Tasks and Navigation Structures -- and examine their interplay. Given that we expect accessibility for a Declarative Task to be higher than that for a Procedural Task, and accessibility in an Network environment to be higher than that in an Hierarchical environment, it follows that, for a given CDR Stage and Content Compatibility setting, accessibility will be highest for a Declarative Task (DT) in an Network (NW) environment and weakest for a Procedural Task (PT) within an Hierarchical (HR) environment. This is depicted in Figure 5.

In addition, for any given combination of Knowledge Acquisition Task and Navigation Structure, there will be a decline in performance with increasing CDR stage, for a given Content Compatibility setting. What is the expected impact of varying Content Compatibility? Drawing on our prior arguments relating to the three aspects of task, navigation structure, and content, we expect that at a given CDR Stage, accessibility will be maximum for a Declarative Task within a Compatible-Network environment and minimum for a Procedural Task within an Incompatible-Hierarchical environment.

In addition, for any given combination of Knowledge Acquisition Task, Navigation Structure and Content Compatibility, we could expect a decline in accessibility of an interface (and therefore, perceptions about and performance with that interface), with increasing CDR Stage index, all else being held constant. Other such combinations of the Knowledge Acquisition Task, Navigation Structure and Content Compatibility elements are possible (there are eight in all). For each such combination, one may estimate the impact on accessibility, perceptions, and performance using our framework.

4.5 Other Considerations

Given that we are dealing with AD patients at various disease stages, choosing task difficulty level (for both Declarative Task and Procedural Task) requires careful attention. A single difficulty level, chosen arbitrarily or intuitively, may well prove inappropriate as being either too simple or too challenging for subjects at a particular stage. It would be preferable to create multiple levels of task difficulty and expose subjects to tasks in increasing order of difficulty, at each CDR stage. An added benefit of introducing levels of task complexity, and exposing subjects to a given task in increasing order of complexity level, is that one could also study learning effects in subjects, an issue that is of special interest given their medical condition.

In the case of a Declarative Task, complexity may be varied by locating required information in a page other than the home page, in more than one page, varying the location of information on a page, varying its font and point-size, and/or varying display color, intensity, the presence/absence of reverse video effects, and such. The challenges posed by such choices are further compounded in the case of a Procedural Task particularly when a subject must retain information from one or more prior pages in memory whilst retrieving further required information from the current page. If memory fails, the subject must revisit prior pages to re-gather forgotten information.

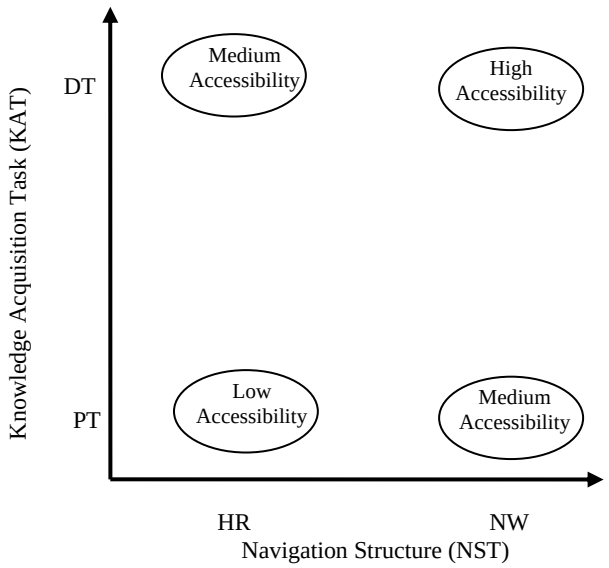


Figure 5. Navigation Structure, Knowledge Acquisition Task, and Accessibility

Prior behavioral studies focus heavily on user perceptions. Given that we are dealing with the cognitively impaired, it would be imprudent to rely solely on their perceptions about site ease of use, site usefulness, and such, as their perceptions are likely quite unreliable. We recommend that such subjective, perceptual measurements be supplemented with non-perceptual measurements pertaining to actual performance with each interface. Such measurements could include monitoring actual levels of task accomplishment, time efficiency of task accomplishment, and navigation path efficiency of task accomplishment, among others.

5. The UAAG 1.0 / WCAG1.0 / Section 508 Guidelines and Accessibility

Prior research has examined the influence of one or, in a few cases, two of the three elements of Knowledge Acquisition Task, Navigation Structure, and Content Compatibility. Given that these elements would tend to have compound influences (interactive effects), and given our operationalization of each as a two-valued categorical variable, our framework in the context of people with AD incorporates all three elements simultaneously in a combinatorial design. Following our discussions in Section 4, we expect an interface with an <Network, Declarative Task, Compatible> orientation, for example, to be more accessible than one with a <Hierarchical, Declarative Task, Compatible> or a <Hierarchical, Procedural Task, Incompatible> orientation.

If the UAAG 1.0 / WCAG1.0 / Section 508 recommendations were indeed beneficial, then we would expect accessibility to improve in any of these orientations. The World Wide Web Consortium has divided its recommendations into three priority levels, P1, P2, and P3 with the following interpretations. If an interface design does not satisfy a P1 guideline, one or more groups of users with disabilities will find it impossible to access the Web. If a design does not satisfy a P2 guideline, one or more groups of users with disabilities will find it difficult to access the Web. If a design satisfies a P3 guideline, one or more groups of users with disabilities will find it easier to access the Web. Also, a site that is P2 compliant is automatically P1 compliant as well, and one that is P3 compliant is (P1 and) P2 complaint. Thus, as the level of UAAG compliance of a website interface progresses from P1 to P2 to P3, the accessibility level should potentially increase. Thus, one could expect the plots in each of figures 2, 3, 4, and 5 to shift in the direction of increasing accessibility with increasing levels of incorporation of these guidelines.

The guidelines themselves are not limited to those pertaining to cognitive disabilities alone. As such, some pre-processing and justification is needed to segregate the recommendations to aid those with cognitive disabilities from the remainder of the guidelines.

6. Concluding Remarks

This paper contributes to the literature on IT accessibility by establishing the foundation for a stream of research aimed at enhancing the accessibility of websites by people with AD. This foundation is comprised of the theory-grounded Website Accessibility Framework and the outline of a research agenda using this framework. Our work extends prior research on website design in the following important respects:

(a) Prior research focuses on examining settings incorporating either one, or sometimes two, of the three elements of Knowledge Acquisition Task, Navigation Structure and Content Compatibility. We incorporate all three in our research framework.

(b) Whereas prior work focuses on healthy, young adults, our interest extends to the cognitively impaired, in particular, those with Alzheimer's disease. While historically the disease has been diagnosed in older adults, today, we know that it also affects people in their thirties and can be genetically transmitted.

(c) Previous studies, unlike ours, are unconcerned with guidelines for enhancing website access by the cognitively impaired. Our framework enables one to systematically assess prescriptive guidelines put forth by the US Government, the World Wide Web consortium, or any other body for that matter.

Based on our framework, one may develop testable propositions to verify the veracity of the framework and, therefore, any set of website re-design guidelines. Of particular relevance is an examination of the interaction among the three elements underlying our framework, as well identification of new elements that could play a pivotal role in influencing accessibility.

The concepts presented in this paper and our findings could be best applied to those websites that are being designed specifically for people with AD or the cognitively impaired. These could be websites maintained by medical institutions and other service organizations that aim to provide disease, treatment, care giving, and support-related information to those with AD. While it seems plausible to assume that any and all such enhancements should also be beneficial to the general populace as a whole, this may not be true. For example, a purely Network structure that may prove appealing to people with AD, might evoke negative reactions in a cognitively healthy user. As mentioned earlier, many practical websites tend to incorporate some amalgam of the Hierarchical and Network navigation structures. Finally, the concepts presented in this framework could be extended to other domains where cognitive impairments could impede access. These include both the aged and the very young; both groups generally

exhibit diminished cognitive abilities not because of any disease but because of their chronological life stage. Although this study focuses on website design, future research could also examine the roles of web browser design and specialized user training towards helping AD patients interact with websites.

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APPENDIX 1

Objective of the WCAG Guidelines [http://www.w3.org/TR/WCAG10/]

These guidelines explain how to make Web content accessible to people with disabilities. The guidelines are intended for all Web content developers (page authors and site designers) and for developers of authoring tools. The primary goal of these guidelines is to promote accessibility. However, following them will also make Web content more available to all users, whatever user agent they are using (e.g., desktop browser, voice browser, mobile phone, automobile-based personal computer, etc.). Following these guidelines will also help people find information on the Web more quickly.

Sample WCAG Guidelines [http://www.w3.org/TR/WCAG10/]

Provide context and orientation information

Provide context and orientation information to help users understand complex pages or elements. Grouping elements and providing contextual information about the relationships between elements can be useful for all users. Complex relationships between parts of a page may be difficult for people with cognitive disabilities and people with visual disabilities to interpret.

Ensure user control of time-sensitive content changes

Ensure that moving, blinking, scrolling, or auto-updating objects or pages may be paused or stopped. Some people with cognitive or visual disabilities are unable to read moving text quickly enough or at all. Movement can also cause such a distraction that the rest of the page becomes unreadable for people with cognitive disabilities.

Sample UAAG Guidelines [http://www.w3.org/TR/WAI-USERAGENT]

Allow configuration not to render some content that may reduce accessibility

Ensure that the user may turn off rendering of content (e.g., audio, video, scripts) that may reduce accessibility by obscuring other content or disorienting the user. Some content or behavior specified by the author may make the user agent unusable or may obscure information. For instance, flashing content may trigger seizures in people with photosensitive epilepsy, or may make a Web page too distracting to be usable by someone with a cognitive disability. Distracting background images, colors, or sounds may make it impossible for users to see or hear other content. Dynamically changing Web content may cause problems for some assistive technologies. Scripts that cause unanticipated changes (e.g., viewports that open without notice or automatic content retrieval) may disorient some users with cognitive disabilities.

Ensure user control of rendering

Ensure that the user can select preferred styles (e.g., colors, size of rendered text, and synthesized speech characteristics) from choices offered by the user agent. Allow the user to override author-specified styles and user agent default styles.

For dynamic presentations such as synchronized multimedia presentations, users with cognitive, hearing, visual, and physical disabilities may not be able to interact with a presentation within the time frame assumed by the author. To make the presentation accessible to these users, user agents rendering multimedia content (audio, video, and other animations), have to allow the user to control the playback rate of this content, and also to stop, start, pause, and navigate it quickly. User agents rendering audio have to allow the user to control the audio volume globally and to allow the user to control distinguishable audio tracks.

Section 508 Guidelines [http://usability.gov/accessibility/508.html]

The criteria for web-based technology and information are based on access guidelines developed by the Web Accessibility Initiative of the World Wide Web Consortium. The standards apply to Federal web sites but not to private sector web sites (unless a site is provided under contract to a Federal agency, in which case only that web site or portion covered by the contract would have to comply). Accessible sites offer significant advantages that go

beyond access. For example, those with "text-only" options provide a faster downloading alternative and can facilitate transmission of web-based data to cell phones and personal digital assistants.

Sample Section 508 Guidelines

A text-only page, with equivalent information or functionality, shall be provided to make a web site comply with the provisions of this part, when compliance cannot be accomplished in any other way. The content of the text-only page shall be updated whenever the primary page changes.

When a timed response is required, the user shall be alerted and given sufficient time to indicate more time is required.

APPENDIX 2

Examples of how the implementation of UAAG 1.0 / WCAG 1.0 guidelines could enhance accessibility [http://www.w3.org/WAI/EO/Drafts/PWD-Use-Web]

Supermarket assistant with cognitive disability

Mr. Sands has put groceries in bags for customers for the past year at a supermarket. He has Down syndrome, and has difficulty with abstract concepts, reading, and doing mathematical calculations. He usually buys his own groceries at this supermarket, but sometimes finds that there are so many product choices that he becomes confused, and he finds it difficult to keep track of how much he is spending. He has difficulty re-learning where his favorite products are each time the supermarket changes the layout of its products.

Recently, he visited an online grocery service from his computer at home. He explored the site the first few times with a friend. He found that he could use the Web site without much difficulty -- it had a lot of pictures, which were helpful in navigating around the site, and in recognizing his favorite brands. His friend showed him different search options that were available on the site, making it easier for him to find items. He can search by brand name or by pictures, but he mostly uses the option that lets him select from a list of products that he has ordered in the past. Once he decides what he wants to buy, he selects the item and puts it into his virtual shopping basket. The Web site gives him an updated total each time he adds an item, helping him make sure that he does not overspend his budget.

The marketing department of the online grocery wanted their Web site to have a high degree of usability in order to be competitive with other online stores. They used consistent design and consistent navigation options so that their customers could learn and remember their way around the Web site. They also used the clearest and simplest language appropriate for the site's content so that their customers could quickly understand the material.

While these features made the site more usable for all of the online-grocery's customers, they made it possible for Mr. Sands to use the site. Mr. Sands now shops on the online grocery site a few times a month, and just buys a few fresh items each day at the supermarket where he works.

Retiree with several aging-related conditions, managing personal finances

Mr. Yunus uses the Web to manage some of his household services and finances. He has some central-field vision loss, hand tremor, and a little short-term memory loss.

He uses a screen magnifier to help with his vision and his hand tremor; when the icons and links on Web pages are bigger, it is easier for him to select them, and so he finds it easier to use pages with style sheets. When he first started using some of the financial pages, he found the scrolling stock tickers distracting, and they moved too fast for him to read. In addition, sometimes the pages would update before he had finished reading them. Therefore, he tends to use Web sites that do not have a lot of movement in the text, and that do not auto-refresh. He also tended to "get stuck" on some pages, finding that he could not back up, on some sites where new browser windows would pop open without notifying him. Mr. Yunus has gradually found some sites that work well for him, and developed a customized profile at some banking, grocery, and clothing sites.