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Users navigated through a mock e-commerce site where each page that loads has a 50% chance of implementing Ajax technology, from functions of the shopping cart to expanding categories of products. Users were observed through eye tracking and measuring their pulse and respiratory effort. Questionnaires were administered before and after these tasks to assess their thoughts about the study.

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THE EFFECTS OF AJAX WEB TECHNOLOGIES ON USER EXPECTATIONS: A WORKFLOW APPROACH

by
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1 Introduction

This paper aims to more accurately define users' information expectations as web technologies continue to improve in loading time and uninterrupted interface interactivity. Specifically, it reports on an exploration of Ajax, a web technology that allows developers to load pages, scripts, images, or even plaintext in an already loaded page without loading another one. It combines XHTML/CSS, DOM, and CGI technologies with JavaScript at its core. Do web technologies like Ajax – or, more abstractly, a quicker fulfilling of user needs – change these needs, or do they merely fulfill preexisting expectations?

The study involved users navigating through a mock e-commerce site where each page that loads has a 50% chance of implementing Ajax technology, from shopping cart functions to expanding categories of products. Data was collected from users as they navigated across the site to perform specific tasks. Users were observed through eye tracking and measuring their pulse and respiratory effort. Questionnaires were administered before and after these tasks to assess their thoughts about the study.

Qualitative observation found that users almost unanimously favored the Ajax functions over the non-Ajax. Eye tracking studies showed a decrease in pupil size over the course of the study, possibly as users became more frustrated with the variance in interface. Facilitating certain functions, such as the act of adding products to one's shopping cart, were drastically altered as a result of changing the interface to an Ajax function. Users emphasized the usability concerns of switching to Ajax, especially regarding feedback.

2 The experiment: preliminaries

2.1 Background

"Ajax" (Asynchronous JavaScript and XML) is a combination of web technologies that allows web designers and information architects to deliver interactive content such that server responses can be loaded inside a page; i.e. a new page does not have to be loaded after each interactive step.

Current formal research into Ajax – especially the cognitive consequences therein – is threadbare. Many studies have already been performed regarding cognition and workflow interruptions; I hope to connect this existing literature to new developments on the web that are quickly gaining traction among all levels of users, from large businesses to laypersons of varying expertise.

2.2 Hypothesis

The progression of web technologies in the past five years strongly favors reducing load times over other features. This is fairly unsurprising; users want faster machines and faster Internet connections so they can increase their productivity, and to that end the technological developments in computing (most notably Moore's Law, which states that every 18 months the average processor speed of a new computer doubles) have closely correlated with international developments in broadband deployment and consumer network speed.

As a result, I believe that users will strongly favor Ajax over the course of the study. As they navigate through the sample web site, they will develop increasing favor for the Ajax functions and increasing distaste for the non-Ajax. I believe that the majority will favor Ajax technology as a means of communicating on the Web to the functionally similar, but technologically different, alternative.

3 Literature review

3.1 Psychology: intelligence and cognition

Many papers exist in information science, computer science, and psychology about cognitive interruptions and workflow distractions, both related and unrelated to the web. In order to understand the research question, I will spend some time discussing the cognitive tenets of workflow and interruption, and what that could possibly mean for the study's parameters and at-large human-computer interaction (HCI) research.

In 1998, Robert Sternberg and Jaems Kaufman published a review that examined the state of intelligence and human ability in cognitive, biological, psychometric, and traditional approaches (Sternberg 479). This is implicitly pertinent because it frames the time constraints being analyzed. No matter how fast a page is delivered, a user still has to read that page. The speed of user cognition allowed me to understand how long, on average, it may take for them to understand prompts (Ajax-based ones especially), showing the delay I have to account for in my analysis of biometric response. Additionally, I am analyzing site response times that vary between fractions of a second (Ajax) and only two or three seconds (non-Ajax); the intervals studied in previous literature (see section 3.4) involve up to 30 seconds, an interval where it is much easier to discern specific points of user response and which is less prone to measurement error.

Sternberg and Kaufman also outlined the varied definitions of intelligence in the past twenty years, highlighting the differences between Eastern and Western approaches. In most Western cultures, definitions of intelligence vary mostly in how much cognitive ability (both reasoning and memory, but mostly the former) was emphasized over social skills. Also notable is the Western emphasis on what Sternberg and Kaufman call "technological intelligence" intrinsic in machine reasoning.

For the sake of my study, cognitive ability probably matters much more than social skills – or at least social skills only matter to the extent that one knows how to use a web browser, and has at least some experience in using the Internet.

The various approaches here can be broadly categorized as either biological (analyzing brain activity and development, reflexes, and motor skills) or psychometric [measurement in terms of psychosocial abilities "such as strength of hand grip or visual acuity" (Sternberg 6)].

Used by some theorists today, one biological notion of intelligence was proposed by Hebb in 1949 that refers to "Intelligence A" as "innate potential" and "Intelligence B" as "the functioning of the brain as a result of … actual development" (Sternberg 4, Hebb). Luria stated that towards this end, the brain comprises three primary functions: "(a) a unit of arousal … (b) a sensory-input unit … and (c) an organization and planning unit" (Sternberg 4, Luria). More modern theories deal specifically with the functions of particular brain areas, but this is less important because I am measuring the results thereof and not planning any direct measurement of brain activity.

Psychometric approaches to intelligence largely involve more traditional assessments like IQ tests or the SAT. Theoretical assessments of the concept include Carroll's proposal of stratified abilities where narrow abilities like spelling ability and reasoning speed exist separately from group-factor abilities (flexibility and adaptation) and a broad "general intelligence" on the final stratum. Most interesting to Sternberg and Kaufman – and also most interesting for this study – is the middle stratum, for it seems to involve the ability to both view things in novel ways (useful for the Ajax-based interfaces that differ so strongly from previous interaction paradigms) and accumulated knowledge (allowing them to have some grounding in basic web behaviors and instincts).

Sara Sparrow provides a good set of starting points in determining cognitive faculties towards this end. She states that "most neuropsychological assessment models require the independent evaluation of (1) attention; (2) auditory, visual, and tactile perceptual functions; (3) verbal and language functions; (4) spatial/constructional processing abilities; (5) memory and learning; and (6) executive functions (conceptual reasoning, problem solving, flexibility in cognitive strategies, and implementing cognitive plans)" (Sparrow 118). Considering these domains, memory is important in understanding the difference between the two sets of tasks that I am presenting users; problem solving and cognitive plans help in establishing workflows and providing high-level solutions to the web-based problems users face; attention can be easily diverted from sites that take too long to load, in extreme cases, or attention may waver slightly with short load times; and the visual cues that Ajax provides may shape the former two issues.

Within this exists the effect of interruptions on workflow and task execution. McDaniel et al. assert that interruption can affect a user's workflow at different points, with different ways to overcome potential events. It was shown that interruption length did not affect performance as much as the existence of an interruption at all, which may have affected the subjects' morale. Moreover, it was shown that memory failures exacerbated the interruptions' detrimental effects, suggesting that external cues may function admirably as reminders (McDaniel 533).

Addressing this, Gregory Trafton wrote an interesting paper about the resumption of a task after being interrupted, proposing an "interruption lag" (Trafton 583) during which users subconsciously prepare to resume the task being interrupted (i.e. between being notified that you have new email, and reading and responding to that email). This is an interesting way to frame the study because users will initially have no idea that they are being deliberately lagged, and will possibly adapt to that as they continue to navigate through the site. As they reach a certain threshold of time that's longer than Ajax but shorter than non-Ajax, will they start to mentally prepare for the delay? Trafton states that subjects "resumed faster with practice" (Trafton 583); to this end, this may be pertinent, even if his chronology of task completion involves the insertion of a full "secondary task" inside of the primary, and our study will involve more linear navigation where opening separate windows to do other things is unspecified and hence implicitly discouraged (Trafton 585).

Henk Aarts reinforced Trafton's points with a study that new goals interrupting "mundane behavior" could be "enriched … with implementation intentions" (Aarts 971). In leaving the instructions fairly transparent in the study – simply buy these products, by whatever means – the pre-task planning is left to the user. Habits that they may have formed can be easily determined by leaving them do what they want.

A year later and in the same journal, Sander Koole revealed the flip side: that not furnishing these details could lead to a lack of subject optimism in completing the study (Koole 873). As a result, I tell subjects extensively about the content on the site and how it is structured, *but not how it operates* (i.e. that there is Ajax on half the pages). This will reinforce users' memories of previous web use while guiding them and establishing proper context to make the experimental setup as transparent as possible. Gabriel Cook corroborates this with the tested assertion that users associating responses "with a future context" improved "time-based responding" (Cook 345).

Finally, in 1974 Amos Tversky wrote an influential paper about biases held during judgment under uncertainty (Tversky 1124). He discussed the beliefs and possible misconceptions that researchers may harbor as they enter a study: they could be insensitive to their sample size, the predictability (or lack thereof) of results, or the effectiveness of search criteria. In order to curb these effects in the study design, a pre-study questionnaire will be issued to gain a brief history of each user's browsing habits: one who used (or currently uses) dialup connections, for example, may be more patient for long load times than one who has used megabit broadband for ten years.

3.2 Cognition and interruptions as they apply to HCI: possible solutions

Extending these psychological premises to a workflow context is particularly important. One establishes both short- and long-term goals as they browse, often while multitasking with many browsers; and the realization of those goals is both directly measurable (at least by whatever metric the user establishes for themselves) and highly dependent on load time.

Human memory attempts to control interruptions actively and passively as the priorities of the task present themselves with varying granularity (broad issues versus subtasks, for instance) (Oulasvirta 2005 1124). Memory can reorganize itself to varying degrees after different interruptions occur in different contexts across a workflow (Oulasvirta 2005 1125). Interfaces have been developed that attempt to measure this mental load (Chen 1513-14) using electroencephalogram (EEG) and Heart Rate Variability (HRV), the latter of which is calculated in our study.

Going a step further, interface design principles have been developed to a minor extent in light of interruptions (Oulasvirta 2004 1155), which not only recognizes the crucial importance of interruptions in the workplace but also that they have palpable costs on productivity. Oulasvirta shows that an interface must be "invisible" (not perceivable by the user as something that must be understood on any level beyond instinct), progressively negotiating (continuous with its prompting, establishing an active and maintained relationship with the user), and pre-attentively processing (computing tasks not directly related to the interaction while the user is not actively prompting the system) (Oulasvirta 2004 1156).

On the web, cache prefetching has been proposed as a possible adaptive, dynamic solution, where frequently used pages, images, or stylesheets are downloaded mid-navigation (Segura-Devillechaise 110). On the operating system level, "awareness displays" have been proposed that show the workload of the to-be-interrupted worker on his/her office's exterior, possibly motivating the interrupter to consider prompting the worker at another time (Dabbish 182).

About thirteen years before these possible solutions, though, George Huber discussed a theory of "advanced information technologies" as they apply to decision making in the workplace. In this, he attempted to ascertain the effects of advanced information technologies in comparison to traditional ones. How will new technologies affect decision-making? What will be its effect on the size or uniformity of decision makers? Will more efficient meetings result? Will it effect change in organizational hierarchies? Will communicative impediments be broken down as technology is adopted in a more widespread capacity? This paper was published in 1990, but its relevance is clear in adopting a frame of reference towards understanding just how technology has affected users since the wide distribution of personal computers and the Internet, and their dual entrenchment in office culture.

He addresses these questions optimistically, by proposing that a larger number and variety of employees participate in organizational decision-making as a result of technological advancement; and that this leads to a more uniform probability that a given organizational level will make a given decision (Huber 53). As a corollary, using these technologies leads to more centralization in organizations, and it reduces the amount of organizational levels involved in processing messages.

Most importantly, though, these technologies reduce the amount of time needed to make a decision. The trends predicted by Huber imply that technology makes us more efficient, and as a result we tend to expect greater efficiency when using improved technology. As technological developments continue, we expect ourselves to become more efficient, and we expect *new* technology to make us *more* efficient.

3.3 Workflow issues and their direct and indirect application to the web

It is possible to break workflows into cognitive tasks and subtasks, at which boundaries exist such that interruptions can be easily classified in importance – and their quantitative effects on mental workload – based on when they occur (Iqbal 311-312). It was shown in a 2005 study that "workload decreases at subtask boundaries" and that measurement must be coupled with a salient task model in order to fully understand the nature and effect of each interruption (Iqbal 311). Eric Horvitz assessed the cost of this interruption in an attempt to qualify the interruptions effected by various external devices, but not the actual page within the site (Horvitz 20); however, in determining a metric for interruption and attention – measurable in real time (Horvitz 22) – an interesting basis is formed for his study that could imply a means of instantaneous correction. He presents an "Interruption Workbench", a set of tools for capturing and modeling workplace events such that problems can be isolated and possibly remedied. This was not directly implemented in my study design, but it helped inform the premises behind the data analysis methods that I employed.

The past decade of Cheri Speier's research has been geared towards understanding how interruptions affect short- and long-term decision-making. A 1997 paper discusses the "need to examine how the design and delivery of information systems can help to mitigate the potentially deleterious effects of interruptions on decision-maker performance" (Speier 1997 21). She presented some interesting third-party definitions of interruptions: "fragmented activities that occur at an unrelenting pace" (Kurke); "a stream of disjointed activities" (Carlson). In her experiment, she tested 238 subjects for two factors: the influence of work environments on workflow, and the characteristics of various interruptions. It was concluded that interruptions may change the relationship between a user and the information they must process for complicated tasks, and that "this result is interesting because it suggests that interruptions change the way information is perceived, used, and processed" (Speier 1997 32).

She elaborated on this in a much more comprehensive paper in 2003, concluding that interruptions aid in completing simple tasks quickly, whereas they inhibit performance on more complicated problem-solving. My study involves simple tasks, which users are largely already familiar with (the first two tasks users must complete are, moreover, intended to get them up to speed on the system's workings); no major creative prowess or high-level thinking is involved in executing them.

The interruptions, however, come frequently enough that a user could be frustrated; moreover, according to Speier, accuracy may end up existing at the expense of time. It was proven that for simple symbolic tasks (determining the meaning of symbols), decision time is faster but accuracy is *lower* when interrupted; and for simple spatial tasks (establishing relationships among a group of symbols), time is faster and accuracy is *higher* (Speier 2003 776).

Both symbolic and spatial tasks exist in this study. Prompts are symbolic; determining what the prompts mean in the global site context is spatial. As a result, the potential divergence of this data set in light of the user's attitude towards the site could drastically affect the data's conclusiveness.

Piotr Adamczyk predicted some "best points for interruption" which "consistently produced less annoyance, frustration, and time pressure; required less mental effort; and were deemed by the user more respectful of their primary task" (Adamczyk 271). Given the nature of his study, it is reasonable to assume that perceptible load times do not fall under such a category. He proposes that such timed interruptions serve as a sort of "attention manager system" (Adamczyk 277) such that users can be diverted when they are at their least attentive to the actual task. Web prompts, however, are arguably when the user is *most* attentive: they want to figure out what feedback will occur (be it in a long load time or the resultant page or prompt itself), and wish to continue to the next step of their task.

Brid O'Conaill discusses the implications of productivity interruptions, saying that while many surveyed employees received benefit from being interrupted – they were probably able to return to their problem with a new perspective, or a clearer head – in over 40% of the incidents they did not resume the task they were working on (O'Conaill 262). Future research could determine what kinds of interruptions effect this, and if they can be classified according to their effects on the worker. Gloria Mark examined this among three dimensions, including the kind of interruption, and concluded that workers tend to spend very little time on any given task and are often interrupted *as catalyst to another task.* My study will not involve any alternate tasks besides the one they are assigned to work on: as a result, interruptions will possibly cause frustration on the premise that they will not be able to move to other matters (or perhaps even that the interruption does not actively cause them to move to other matters).

Most of these implications are summarized nicely in a 2003 article in *Communications of the ACM*, stating that user interfaces should be more "attentive" to user needs (McCrickard 67). One telling quote: "The success of a notification system hinges on accurately supporting attention allocation between tasks, while simultaneously enabling utility through access to additional information" (McCrickard 68). Both of these points are fulfilled to a greater extent through the careful, well-reasoned deployment of Ajax.

3.4 The web

Though the beginnings of the Internet lie in the late Sixties, the web was not created until the early 1990s when Tim Berners-Lee began developing text-based browsers (W3C History). Within the web, technological development remained somewhat insular from the surrounding world of computers, which was largely shaped by gains in processor speed and other hardware developments. Languages and standards such as CSS (Cascading Style Sheets), HTML, XHTML, XML (Extended Markup Language), and JavaScript/DOM (Document Object Model) came into widespread use largely because of the efforts put forth by the World Wide Web Consortium (W3C, at http://www.w3.org), but the content of these standards – as well as third-party programming languages like Ruby on Rails, PHP, and Perl – were dictated by the web's organizational methodology, the necessity of interacting with dynamic SQL-based databases, the basic functional infrastructures of web servers like Apache and Microsoft Internet Information Server (IIS), the constraints and liberations of de facto standard web browsers, Windows and UNIX file system layouts, and the speed and stability limitations of commodity user connections.

The number of variables in creating and deploying a web application that will work on as broad an array of platforms and contexts as possible has remained famously difficult – if not outright impossible for those lacking entire teams devoted to the task full-time – since about 1998, when Microsoft and Netscape competed for market share with their respective browser platforms. Many versions on several major Windows- and Mac-based platforms, across at least three operating systems each, provided a formidable set of permutations that required – and still require – testing on as many as six different individual computers or dual-booted systems (to account for different operating system versions, and the fact that it is very difficult to install two separate versions of Internet Explorer on the same system) for the paranoid or legitimately concerned, and helpful cross-platform testing tools (in addition to blind faith) for the budget- or time-strapped. Yahoo!, for example, currently employs a set of stringent regulations for testing its applications on various browsers, platforms, and operating system versions, showing which are of critical importance and which are of incrementally lower priority (Koechley). This list is up to date as of this paper's writing, but it will have to be revised when new browsers are released, new beta versions come out, new operating systems are released, new sub-versions of operating systems come out (Microsoft's service packs, or Apple's sub-versions), old browsers are formally deprecated by their parent companies, old operating systems lose formal support from their parent companies, large corporations adopt new technologies company-wide, or new web standards are approved by the W3C.

Third-party protocols confound the formula further. Flash, developed by Macromedia (now Adobe), has to develop plug-ins for each separate browser and operating system; fortunately, these have a wide adoption rate by the Internet's user base, often seeing more than 80% but usually over 90% across browsers. Java, developed by Sun, used "applets" to develop flash-like programs that loaded inline in a page, which were used in a largely non-commercial context between 1996 and 1999. ActiveX, announced in 1996, is a Microsoft invention for Windows-based Internet Explorer browsers that allows a "Windows-like" interactivity within various web applications. IE users can enjoy animation, 3-dimensional rendering, and dynamic scripting; but apart from Microsoft's web applications, this has been used much less frequently, largely because ActiveX has proven itself open to many security holes.

Frustrations related to load times on the web have been extensively covered, but mostly in the context of broadband versus dialup connections, which involves a remarkably large gap: to load a 100 kilobyte web page would take approximately three seconds on a consumer 384/384 ADSL line but thirty seconds on a normal 56K dialup. Fiona Fui-Hoon Nah discussed this very well, even explaining delays in the short intervals that this study covers: it was shown that the approximate tolerable waiting time before frustration sets in is two seconds, but this could be with users who are less accustomed to dialup connections (Fui-Hoon Nah 153). Jakob Nielsen stated that if a system responds within 0.1 seconds, the user believes it is acting "instantaneously", after 1.0 seconds the user begins to feel "interrupted", and after ten seconds the user's attention diverts considerably enough that site response becomes an issue of critical importance (Nielsen).

Hawkey and Inkpen covered how variant contexts could interrupt workflow on the web (Hawkey 1443). It was shown that changes in user behavior across a site's interaction are often not accounted for in web-based interface design, leading to sites that come across as sterile and unforgiving. Web design firm 37signals, creators of Ruby on Rails, once posited that web sites provide contingencies for when things go wrong too infrequently, leaving users in the lurch and resulting in errors that can often be prevented with a few lines of code (Fried). Disabling the "submit" button when purchasing items; providing comprehensive information on 404 pages; giving users a "breadcrumb trail" to trace their movements backwards in a site; implementing effective search; and engaging in effective, clear, unambiguous, gracefully degrading information display are a handful of the myriad common sense ideas that remain incredibly uncommon in the current state of the web – and 37signals' book on the subject was written two years ago, a lengthy time in the fast-paced development of web practice.

Gerard Ryan and Mireia Valverde proposed thirteen new "types of [Internet-based] waiting situations" that show the many variant and largely unknowable contexts users wait in. Initially, they discuss the previously described ways of waiting on the internet as "download time, download delay, internet latency, waiting time, world wide wait, and feedback delay" (Ryan 222), but then they discredit these approaches as being synonymous. They instead presented a new definition: *"waiting on the Internet is devoting more time than perceived necessary in order to complete a task on the Internet"* (Ryan 228). In concrete terms, these included download delay, dealing with online advertising, poor usability, waiting for an ordered product to be delivered, waiting for a reply to enquiry, dealing with junk mail (spam), pre-process problems (waiting before the task even begins), in-process problems (non-responding web sites, Internet connection dies, etc), time spent searching, registering for access, recuperating passwords, dealing with offline tasks before beginning the online process, waiting for confirmation, or installing software to continue (Ryan 230-232). Some of these can be grouped together (recuperating a password and initial registration, for instance, stem from the same abstract principle: having to register in the first place), but they cover a comprehensive array of issues that can often be tested and at least accounted for if not eliminated entirely. There are even entire books published that allow users to kill time while waiting for their slow connection to trudge through a huge page (Bowman); in partial light of this, the cultural importance of load times should not be underestimated.

To consider the variant scenarios a user could encounter, I established narratives that would help guide feature development and refinement of functionality – something that was nicely elaborated on by Nancy Broden in a 2004 article, which stated that establishing the various stages of interaction in sequence provides a more comprehensive outlook than "widgetifying" the creative process (Broden 1-3).

3.5 Ajax

The history of Ajax runs mostly independent from third-party web inventions, instead focusing on W3C-spawned aspects. It does not depend on third-party implementation, instead relying on what standards should be implemented on browsers to begin with. Importantly, this provides a browser- and platform-agnostic method of deploying rich web applications (as opposed to ActiveX, for instance, which is just for Windows; or XUL (XML User Interface Language), which is currently only supported in Mozilla and Firefox).

The clearest beginning of Ajax's precursors is 1997, when versions 4.0 of Internet Explorer and Netscape were released and DHTML (Dynamic HTML) subsequently entered wide use. Like with Ajax, DHTML combines static HTML, a client-side scripting language (almost always JavaScript), and a presentation medium (usually CSS/DOM) to create an interactive web site. Assembler.org, now defunct but archived, was perhaps the most visually striking example of early DHTML, malleably animating a series of 3-dimensional blocks in colorful and mathematical ways (Assembler).

DHTML, however, failed to gain traction beyond those who saw it as a flashy lark, and it gained almost no support on corporate sites. As a result, it lay dormant until web frameworks, DHTML, and user interface design converged several years later; Richard Monson-Haefel of technology consulting firm Burton Group stated that, ironically, "DHTML has faded in use as a term [but] it is being employed more frequently than ever before" (Monson-Haefel 2).

In February 2005, Jesse James Garrett of web consulting firm Adaptive Path coined the term "Ajax" as a DHTML-based combination of various web technologies with the critical building block "XmlHttpRequest", a JavaScript function that allows developers to request files of any kind from a web server without reloading the page they have presently navigated to (Garrett). These files can be anything from images to CGI scripts to images to entire HTML documents. Ajax can be called in a document an unlimited amount of times.

Because of its flexibility, Ajax has been used to widely varying application in the years since its inception. At the time of this writing, perhaps the most famous of these examples is Google Maps (http://maps.google.com), an international mapping tool that allows you to view satellite images, automatically pan and zoom through calling various map "tiles" with Ajax. Recent Yahoo! acquisition Flickr (http://www.flickr.com), an image sharing and archiving site, allows users to annotate images in-line with "notes" on the image itself or captions, both of which are deployed using Ajax.

Even the e-commerce shopping cart, one of the web's oldest and least-changed applications, is reinventing itself: software company Panic (http://www.panic.com) sells t-shirts on its site by providing a small frame as a "drop box" where users actively drag t-shirt thumbnails to it, updating the shopping cart accordingly and providing active feedback. For expanding its potential in the future, many integrated development environments (IDEs) and application platforms now contain robust Ajax connectivity, including Microsoft Atlas and Ruby on Rails.

Despite all this, though, Ajax remains somewhat infertile and undeveloped. As is the case with many demanding web functions, Ajax remains problematic to implement across platforms. Microsoft provides a separate set of calls for Ajax-related JavaScript/DOM functions than other browsers, forcing most developers to employ browser detection and two sets of scripts that do the same thing.

Ajax has comparatively poor online documentation, a small user base when compared with giant widespread technologies like PHP, and is primarily accessible only to developers with a firm grounding in its constituent technologies (XHTML, CSS, JavaScript, DOM, and scripting), with a very high learning curve for those less experienced. As a consultant, Monson-Haefel recommended that Ajax is "still too immature for more conservative organizations" as of January 2006, and that "it's fairly easy to add Ajax to an existing web site, but actually implementing it in a way that offers more value and does not diminish the user experience is more difficult" (Monson-Haefel 1).

Still, Ajax performs many important interface functions with relative speed over its possible alternatives. Donald A. Norman asserts that active feedback response and natural mapping are two functions grossly lacking in most modern interfaces (Norman). In the case of Panic's shopping cart, the side frame and nearly instant updating provide an intriguing (and never before seen) analogy with shopping in a conventional store and placing items in your (real) shopping cart. After adding a note to an image, Flickr shows a "please wait" message that provides more comfort to the user than the simple Windows hourglass (or Macintosh beach ball, etc), indicating that it has received the data and is acting accordingly.

The importance of this rapid, lightweight reassurance should not be understated, and although the user does not need to be led by their hand through every step of a web site, this could be vitally helpful to those who possess unreliable connections, distrust new technology, or both. First impressions of web pages have recently shown to be made in the first fifty milliseconds after prompting, possibly risking a user's trust in the site's functionality and (perhaps more importantly) giving new significance to the term "load time" (Lindgaard 115). A good first impression could possibly cause a user to consider future problems, snags, or outright bugs in a more positive light; conversely, a negative first impression could cause those same snags to drive the user away.

In scholarly publications, literature on Ajax in specific is practically nonexistent, possibly due to its young age and the constant changing of web technology. Searching for “Ajax,” “Web 2.0,” “XmlHttpRequest,” and even “in-page loading” and all reasonable related synonyms turned up a grand total of two documents across LISA, ACM Portal, and Wiley InterScience. Blackwell Synergy, and Academic Search Elite.

That said, Ajax is covered extensively – in description and in application – on countless news sites and weblogs (some good examples: Paulson, 14-17, Asaravala 23-28, Mangalindan, Matlis). And not only is Ajax described, but its benefits are clearly outlined and the drawbacks of implementing it are precisely documented, both concisely (Rasmus) and with near-absurd verbosity (Crane), with the intermediate thrown in (Traversa). Hopefully, this sort of coverage will eventually catalyze closer analysis in academia.

4 Research question

Do web technologies like Ajax – or, more abstractly, a quicker fulfilling of user needs – change these needs, or do they merely fulfill preexisting expectations?

In this study, the research question asks whether Ajax *in specific* bifurcates web design technologies such that users will be more comfortable with one or the other paradigm (and, more likely, will favor Ajax). There are many papers that address the notion of workflows, web or no; and there are many that discuss the effect of new technology on market demands; but few have addressed the specific ramifications of new developments on the web, much less Ajax, partly because this form of technological development simply has not existed before. I hope to address this while recognizing the need for considering a new methodology of progress on the web.

5 The experiment: procedure and results

5.1 Limitations of the procedure

Beyond simply understanding the underlying premises, the issue of user acclimation to the sites in the study could also confound data; users could perceive their workflow in a different light if they have less experience with using the interface, and across the course of the study will become more accustomed to it. The idea of goal planning comes into play here: as users are able to understand the interface more, they will devote more attention to the actual study tasks.

The data from my biometric devices requires some interpretation. In specific, pupil size is often regarded as a metric for determining a user's attention state. Studies have revealed that pupil size can increase when people view stimuli that they regard as interesting, and unpleasant or boring things catalyze pupil constriction. Increases in pupil size are also correlated with increased mental activity in solving problems, which could account for the parts of the study where users take time to acclimate to the interface (Hess). Additionally, as users become adjusted to the relatively low light levels in the room, their pupils could decrease in size. This was partly dealt with by shining a bright light at the wall behind the computer, but this could still be an issue.

There are many possible other sources of error: users becoming accustomed to the site; users having unforeseen expectations and perceptions about the web; the difference in cognition that users may encounter from framing the study such that Ajax-powered tasks are interspersed or segregated from the "Web 1.0" ones; and the "digital divide" in experience and technological anxiety that may bifurcate my data set.

Users were tested in a room in the center of an old building with poor ventilation; the heat generated by people and computers has been an eternal issue. As a result, the problem of auditory distraction from several lab-installed high-power fans could have been an issue, as I wanted the user to focus as much on the interface as possible (Beaman).

Auditory distractions could be as problematic as visual ones here, so I turned the fans and any unused computers off during the course of the actual study (but not the two questionnaires: see 5.2).

5.2 Procedure

The experiment compared two nearly identical web interfaces, one that used Ajax and one that did not. The user interfaces and layouts of each site were as identical as possible, barring minor differences in the placement of user notifications due to the way the two technologies tend to prompt users.

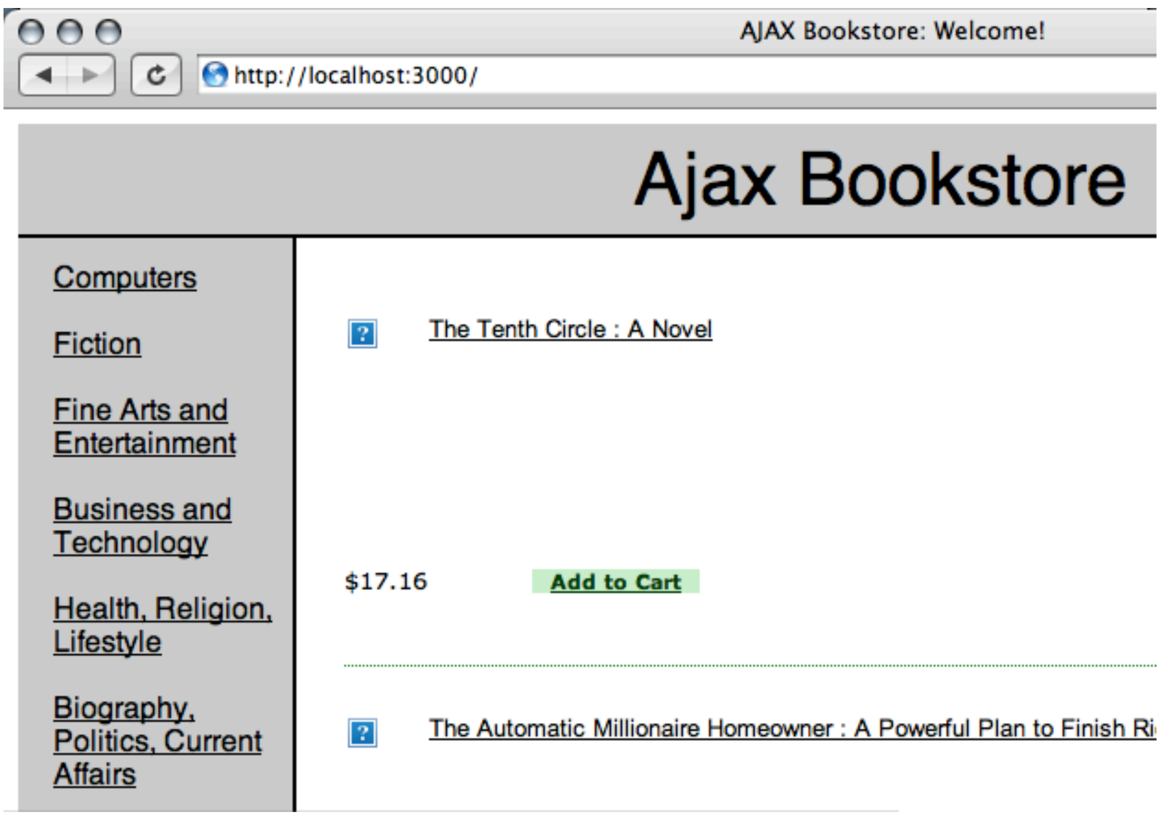


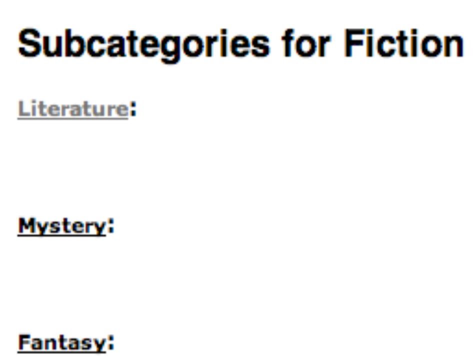
Figure 1. Ajax Bookstore's first screen.

Users were directed through a web site and asked to complete various tasks that may or may not be Ajax-enabled, distributed randomly throughout the interaction (and recorded as they go); see Figure 1 (The preview images are not included for this figure, but in the study they were approximately 100 by 150 pixels). The site was a mock-up "bookstore", not unlike Amazon, where users "purchased" various books and checked out. Books were distributed in two levels of hierarchy – subcategories contained on a one-to-many basis within categories, and products on a one-to-many basis within a given subcategory (i.e. a category has multiple subcategories and a subcategory has only one governing category; and a subcategory has multiple products, and a product has only one governing subcategory).

I chose an e-commerce site for the study because it involves many discrete steps of varying interface functionality that users must go through, and a great deal of data is exchanged between client and server: searching for a product, placing a product in one's shopping cart, editing one's shopping cart, the decision to "check out," submitting one's information, confirming different parts of information, possible credit card verification, the order confirmation, and the order confirmed page all come into play here.

Every individual page they loaded on the site had a 50% chance of containing Ajax. Potential Ajax-based functions included:

1. Clicking on a category opens the subcategory list on a separate page (figure 2) instead of navigating to a separate page that contains the subcategories (figure 3).



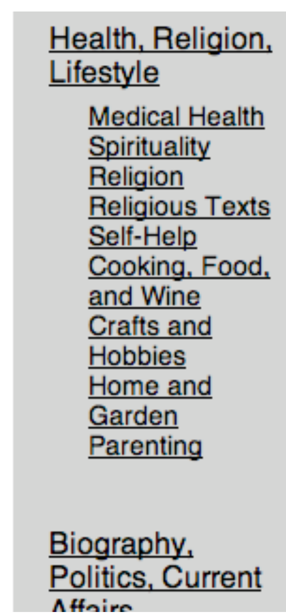


Figure 2 (left). Body text for Fiction's separate subcategory page.
Figure 3 (right). Left sidebar for Health, Religion, Lifestyle subcategory.

2. Adding a product to cart pops up a prompt that says "added item to cart" instead of navigating to the updated shopping cart. On the plus side, users have to wait less time; but one also doesn't know what is exactly in their cart (figure 4).
3. Users who navigated to a list of subcategories (likely the result of receiving a non-Ajax interface in the side navigation) can possibly receive a list of products when given Ajax, with corresponding links to their sub-pages, which in turn contain thumbnails. If not, they are sent to a separate page that contains a similar listing without other subcategories in context (figure 5).

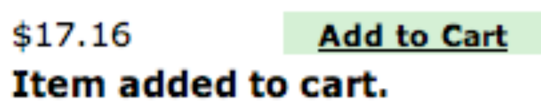


Figure 4. Sample"Item added to cart" Ajax prompt. This occurs immediately below any "Add to Cart" button.

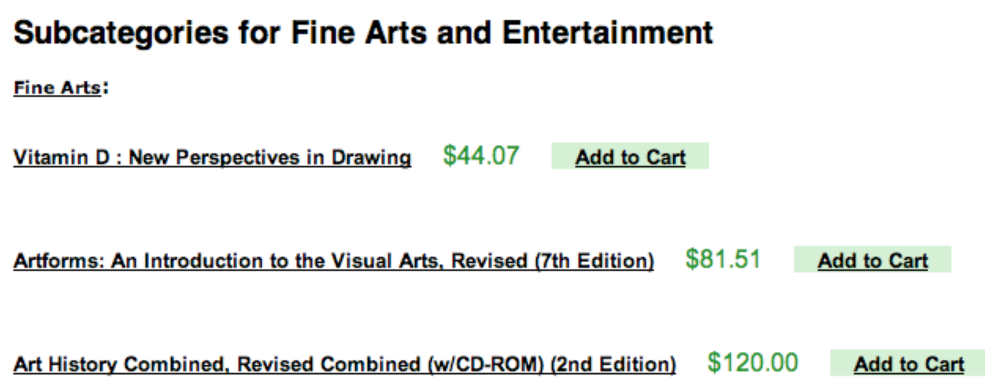


Figure 5. Sample Ajax prompt for displaying the products associated with a specific subcategory.

4. The shopping cart has an Ajax function for emptying the cart of items. Clicking on it replaces the shopping cart listing with an alert that "Your cart is now empty." It does not send you back to the front page, since that would affect load time.
5. Choosing to check out could, if Ajax is enabled, open the checkout form below the shopping cart listing without navigating away from the page (figure 6).

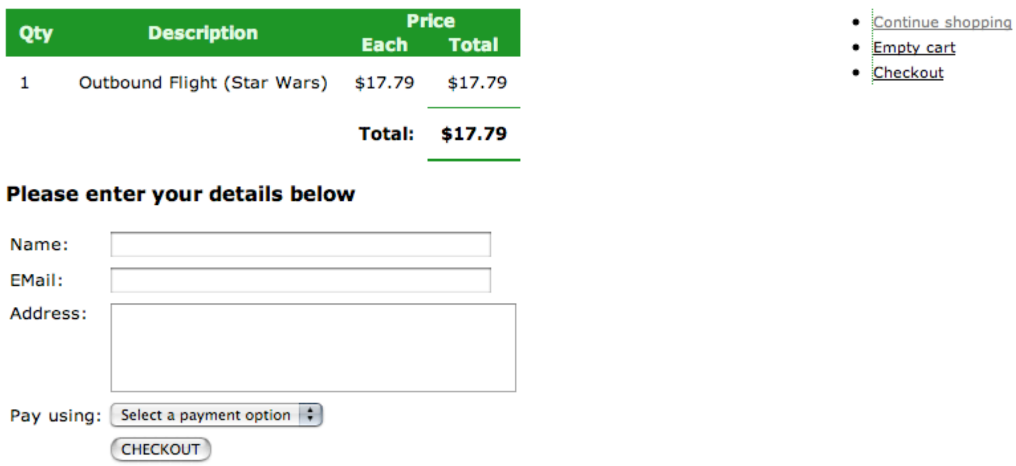


Figure 6. Ajax prompt for user details upon deciding to check out.

6. In the checkout form, actually checking out can either send you back to the front page with an alert that checkout was successful; or, if Ajax is enabled, checking out will display a similar prompt on the page itself (figure 7).

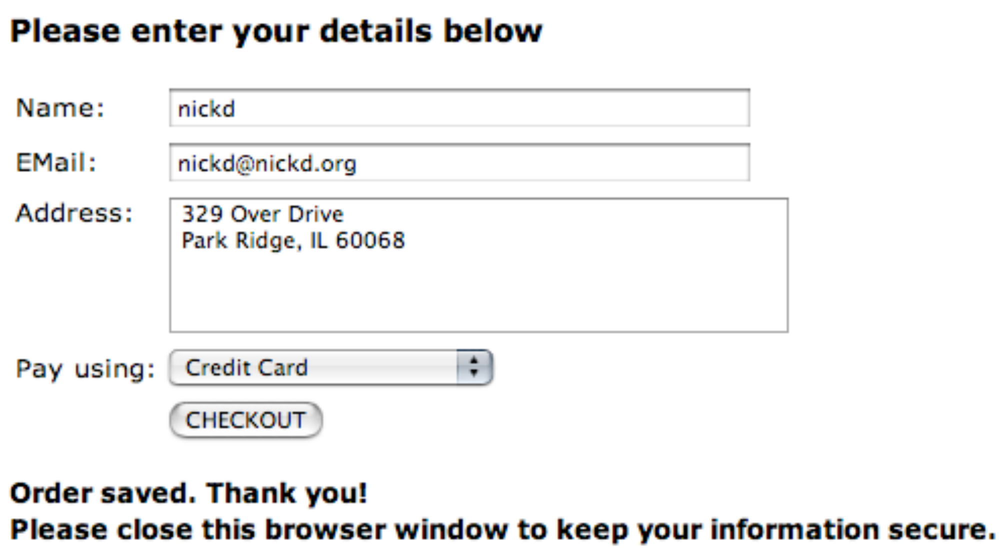


Figure 7. Ajax prompt for checkout finish.

It was possible to create a full – if comparatively featureless – site like this, with such specific requirements and what essentially amounted to two completely different sets of code (for Ajax and non), using a lightweight framework called Ruby on Rails (“Rails” or

"RoR" for short; see http://www.rubyonrails.org). This is pertinent to Ajax's development because the functionality to enable Ajax on a Rails site is considerably easier to implement than it presently is for any other framework. Rails contains a library of Ajax functions that are both easy to deploy on an existing Rails site and quickly intuitive to the user. One of the things stunting Ajax's widespread deployment is the requirement of two basic sets of JavaScript code, one for Internet Explorer and one for everybody else (though IE7's release next year may change this); to this end, using Rails helps make Ajax more accessible to the masses and simpler to quickly deploy.

For our study, a great deal of code was adapted from the sample e-commerce front created in the tutorial of the primary Rails book (Thomas). Having the basic structure in place while modifying it to fit the study's parameters helped greatly in concerning myself more with the experimental design than with fixing bugs, and it allowed me to save a considerable amount of time in setting up the experiment.

Users were asked to complete the following three tasks (see also Appendix B, section 9):

1. Buy four books in the same subcategory. Check out.
2. Navigate to two different subcategories within the same category. Buy four books. Check out.
3. Navigate across at least 2 categories, 5 subcategories, and 20 items. Buy at least eight books. Check out.

During this, their heart rate, respiration, and movements on the screen were captured through biometric devices and cameras; eye-tracking software was employed to determine what they are looking at on the screen at any given time, as an augmentation to the on-screen video.

Before the study took place, I presented subjects with a questionnaire regarding their past experience with load times on the Web. After the study completed, I presented another questionnaire focusing more specifically on the use of Ajax on the web and their thoughts about the study. Both of these questionnaires are attached (Appendix A, section 8).

The data I collected was a combination of quantitative and qualitative: quantitative from the biometrics I received (pulse and respiratory effort), the raw eye-tracking data, and some of the questionnaire responses that required a response from 1 to 5 or 1 to 10; and qualitative from the users' sentence-based questionnaire responses, recorded comments and observations during the study itself, and any potential unforeseen consequences.

I initially intended to recruit fifteen users for the study, in the hopes that at least ten would sign up; thirteen did, and all completed the study successfully, except for one user who had the Biopac system (pulse and respiratory sensors) crash midway through. This sample size should sufficiently account for any unforeseen errors in data collection, users who may not have become acclimated to the interface within the timeframe of the study (possibly because they have little experience with navigating such a site), or clear outliers in their opinions of the site's navigation – which tend to exist for any web-based usability study.

5.3 Tasks and site structure

The experimental setup forced me to inspect both contingencies for every interactive step, to ensure scientific integrity and quality data. In order to do this, I had to plot a small site map, along with a list of steps and possible motions a user could proceed as they purchase products on the site.

Many use cases were also contingent on whether or not Ajax was used for the preceding task. This forced me to carefully consider the parameters of the site's design, as to ensure that Ajax would not be used more or less prominently.

Site hierarchy

Figure 8 describes the various paths a user can take through a page. Arrows indicate the possible direction one can take; two-sided arrows indicate that the function it points to does not cause the user to navigate anywhere (in that it happens on the page, and does not involve a navigational step). Rounded rectangles are start or end points; the circle is a function that acts as end point. In the case of emptying the cart for non-Ajax, a page reload of the (then empty) cart is forced.

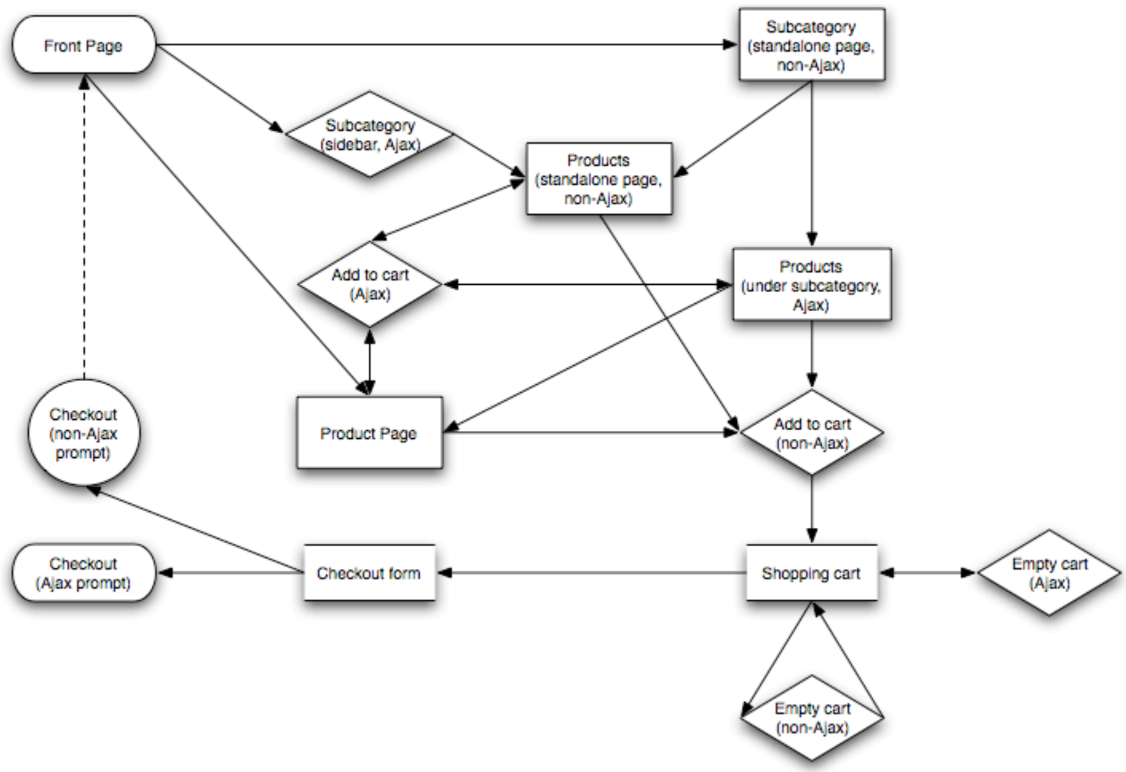


Figure 8. Site map and possible paths the user could take.

Possible tasks

- Displaying subcategory list
- Displaying product list for a subcategory
- Displaying product page
- Adding product to cart
- Displaying cart items
- Presenting checkout form
- Checking out
- Emptying cart (changing quantities was not a feature of this design, but it was impertinent to the tasks I presented to users)
- Navigating to main page

Uncommon paths witnessed

- Only one user emptied their cart. Only one user discussed changing quantities as an issue, but that was certainly a result of the study design, rather than a threadbare feature set.
- Some users clicked several times to add an item to their cart, either because they were confused by the Ajax prompt or because the non-Ajax page took too long to load. They were then surprised to find out they had more books in their cart than they had predicted.

6 Results and discussion

In total, thirteen subjects – five male and eight female, of average age 28 – were observed. All thirteen claimed to have experience in email, word processing, and web browsing; and of these, ten used their computer for web and database design. Most rated their experience with the web highly, stating that they use the Internet frequently and occasionally design sites.

Surprisingly, none used a dialup connection at the time of the study. On average, it had been approximately three years since subjects had last used a dialup connection at home or at work. This is good for keeping the study controlled, though, as it ensures their satisfaction with site performance is not a result of the connection's speed increase, but is rather because of attributes they are not presently used to. They rated their satisfaction with dialup about four times lower than with broadband, and in comments they unanimously favored broadband as substantially preferable to dialup; one user wrote "now when I've had to use dialup for any reason… the load times can be painful."

A few variables will tell us whether our hypothesis is true:

- **The variance in heart rate and respiration** in the first two tasks of the study, compared with the final task. If the heart rate and respiration have a greater variance in the final task, this likely means that the user was more frustrated when the non-Ajax prompts came up, and more satisfied when presented with Ajax.
- **The heart rate and respiration for Ajax functions versus non-Ajax.** I went through a video of the user's screen output and recorded what functions occurred at what points; this enabled me to randomly sample my other data sets to discover how user's heart rates changed with each function.
- **Average pupil size for all users versus *time,* compared to time-independent study-wide average.** If a user's pupil shrinks in size over the course of the study, that could possibly indicate greater frustration with the functionality of the page – especially when things go wrong.

- **The qualitative interaction paradigms observed in the video itself.** This is more difficult to provide a forceful argument for, but I hope to cite literature on web usability as a possible interpretation of these user experiences.
- **Anecdotal evidence from the post-study questionnaire.** Users were, thankfully, very passionate and verbose in their opinions of the site, possibly because they were more experienced than the norm in using the web.

The study's first two tasks were designed to get users more acclimated to the features of the interface and the broad site structure. It took an average of 16 minutes, 47 seconds for each user to complete all three tasks; it took an average of 7 minutes, 45 seconds for each user to complete the first two. The third task was intentionally longer, and its intentions were twofold: to compare resultant data with the first two tasks to determine if the user's stress levels went up, and to ensure that a user interacted with all the functions of the site multiple times, such that both Ajax and non-Ajax tasks were represented in equal amounts. Across all thirteen subjects, 345 Ajax and 331 non-Ajax tasks were performed.

On the video of each subject, I located the point where they began the third task. I then extrapolated that to the pulse and respiration data I received, calculating the rate of each in Biopac's software rather than using the raw data. This provided the cutoff point for determining the variance of the rate data. Using single-factor ANOVA, I then determined the variance of everything before this cutoff, and everything after this cutoff, for each individual. Additionally, the mean value was calculated for parts 1 and 2, and for part 3, for each user, and these totals were themselves averaged in the same way.

Twelve of the thirteen subjects were observed biometrically. Here are the results:

Variance of Pulse in Trials 1-2	45.38622708
Variance of Pulse in Trial 3	46.05386447
% Change in Variance of Pulse	0.18%
Variance of Respiratory Effort in Trials 1-2	271.9506767
Variance of Respiratory Effort in Trial 3	249.8608991
% Change in Variance of Respiratory Effort	-12.52%
Average of Pulse in Trials 1-2 (in BPM)	78.65239872
Average of Pulse in Trial 3	77.97948116
% Change in Average of Pulse	-0.95%
Average of Respiratory Effort in Trials 1-2 (breaths/min)	32.36266625
Average of Respiratory Effort in Trial 3	30.66060551
% Change in Average of Respiratory Effort	-3.93%

Figure 9. Biometric results.

There are a few potential explanations for these data. The unexpected downward trend may be due to users being thrust into a previously unknown environment, with three wires connected to them; the stress of being hooked up and having devices calibrated might have prefixed the study, and dissipated over the course of the interaction. As users figure out the workings of the interface itself, they might be less stressed.

There was also a non-negligible number of subjects who starkly contradicted the prevalent trend. In the respiratory average change, four of the twelve users for which data was taken presented an upward trend greater than 5%; in the case of the variance in pulse, six of the twelve showed an upward trend. This could indicate that these measurements are too fine to accurately make, due to the small difference in load time that was relatively imperceptible. Tellingly, in most post-study questionnaires the usability of the interface was weighted significantly over discussions of the site's load times.

Considering Ajax versus non-Ajax, I took a random sample of twenty pulse- and respiration-related data points for both Ajax and non-Ajax (for forty total) *during task 3 only* (so as to ensure that their frustrations were due to the interface, and not because they were getting used to it), and calculated their averages to determine if Ajax tasks had a higher or lower average pulse and respiration than non-Ajax. To ensure that an ideally broad user base was represented, I also took no more than four total data points (no more than two from each function set: Ajax and non-Ajax) from each user; and finally, to ensure a contiguous data set, I selected four consecutive data points that varied equally in Ajax or non (but the combinations differed, so I would have A, N, A, N for one user, and N, A, A, N for another, etc).

	Pulse (BPM)	Resp Effort (breaths/min)
Ajax	79.10208876	27.79563733
Non-Ajax	79.43738834	28.44499133
% Change	0.424%	2.336%

Figure 10. Biometric results: average rates.

Surprisingly, neither set of randomly sampled functions showed a conclusive change in pulse or respiratory effort. This could, however, be due to outliers in a relatively small population, so I plotted two histograms of averages by task (one for pulse, one for respiratory effort) (figures 11 and 12, respectively).

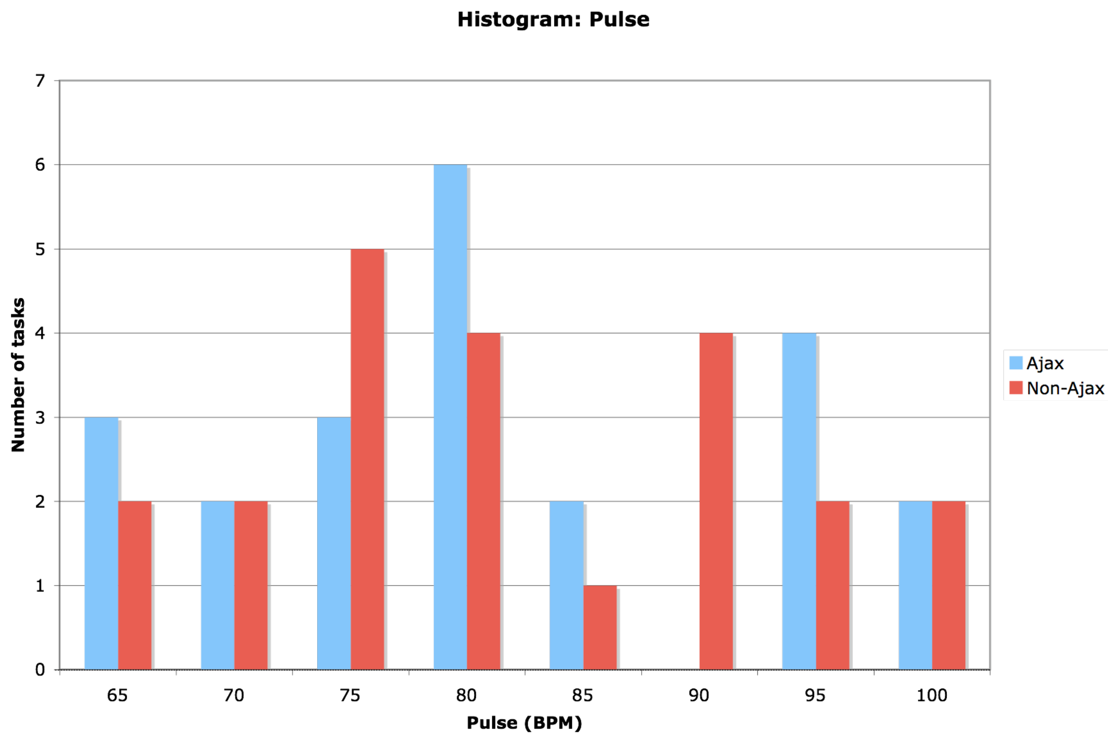


Figure 11. Pulse histogram.

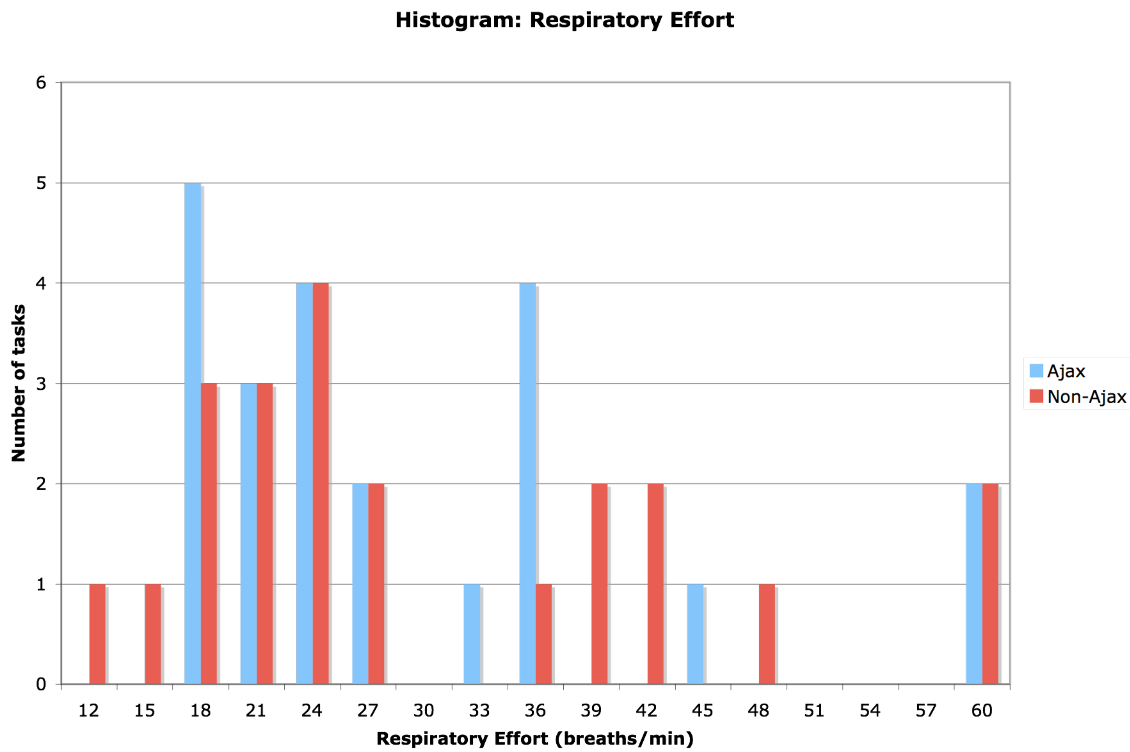


Figure 12. Respiratory effort histogram.

On the respiratory effort graph, the pair of outliers observed for each task set is probably inaccurate and hence skews the final calculation, as (I would hope) it is unlikely that my subjects were breathing 60 times per minute at any point in the study. More notably, both pairs of data points occur on the same two subjects, leading me to believe that the respiratory effort device was not calibrated properly or was otherwise giving poor data. Removing these points from my previous calculations yields the following corrected table (new calculations in italics):

	Pulse (BPM)	Resp Effort (breaths/min)
Ajax	79.10	*24.79*
Non-Ajax	79.44	*25.52*
% Change	0.424%	*2.942%*

Figure 13. Biometric functions: average rates, corrected.

This gives us a slightly more convincing figure for respiratory effort changing, but still not with enough of a difference that one can conclusively assert the hypothesis.

Viewing the pulse histogram, though, gives one an interesting portrait of the data distribution. First, the pulse distributions are not as clearly bimodal as with the respiratory effort; and second, the peak of pulse readings in the Ajax tasks is clearly higher than the non-Ajax in what could be interpreted as both peaks in the set.

I do not think this means we can conclusively support or reject the hypothesis, but I also do not think that this was any coincidence. During the study, many users took advantage of Ajax to perform many rapid tasks on a given page, during which their pulse would hypothetically increase due to excitement – or, at the very least, increased brain activity. I would not be at all surprised to find their pulse readings generally higher as a result of this behavior, but at the same time my random sampling did not account for lengthy strings of Ajax functions. Tellingly, about 15 more Ajax functions were globally performed (across all thirteen subjects) than non-Ajax; from watching the videos, this was easily explained by several users' sitting on one page and performing as many Ajax-powered tasks as possible, while they still had the chance to do so.

This interpretation was also highly prone to error because I had to synchronize two largely disparate data sets (the Biopac readings and the eye tracker) with each other, leading to a possible *consistent* skew of data for the *entire set*. This would effectively make my data worthless. I double-checked the start points for every individual data set, and attempted to curtail this by starting the Biopac and eye tracker at consistent times (using a stopwatch), but there still exists the possibility of failure despite this.

Even more potentially problematic was the method by which I determined when Ajax and non-Ajax tasks took place, and which one they were: I watched the videotape of every subject again at 1/5th speed, noting exactly when each task occurred and what kind of functionality it was. This could be off by a few seconds on each data reading, which could potentially add a few data points from one average calculation (and, subsequently, subtract a few points from another) that would additionally confound the data.

Finally, there was the issue of the Biopac unit's resolution in data aggregation. A few of these averages were determined with over fifty data points; many (over 60%) were determined with less than five; two were determined with two points; two more were determined with only one point. This happened for two reasons: users often executed tasks very quickly, to the point where there would be only a second or two's lapse until the next; or the Biopac did not determine an appreciable change in rate during the course of a user's task. While in most cases the Biopac worked extremely well – even giving me better data than the eye tracker – its post-data analysis was lacking in giving me enough data to prove or disprove my hypothesis.

The pupil size data from the eye tracker, on the other hand, showed a unanimously downward trend over the study's course. A sample chart of one user lies below. I plotted the pupil size (here, in tenths of millimeters) over time in seconds. Logarithmic and linear best-fit curves were plotted to show the clear downward trend.

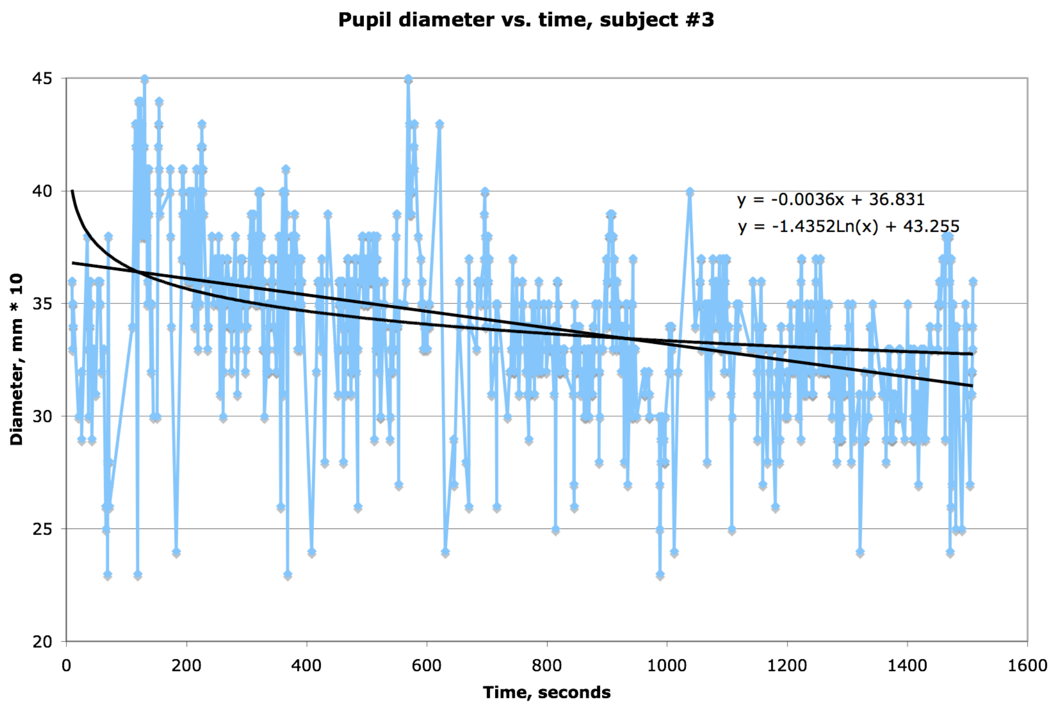


Figure 14. Sample user's pupil diameter vs. time graph.

Other subjects showed more or less drastic magnitudes of change, but all of them showed a gradual reduction in pupil size. As a result, it is conclusive that subjects' pupils constricted across the course of the study. As stated in section 5.1, this could have been the result of no longer having to figure out the interface's tenets, but the continued trend towards the final half of the study (time-wise) leads me to believe that users might have become increasingly frustrated with the interface. Future studies should record higher resolution portraits of pupil size, with less data loss and more data points per second, to confirm this more convincingly.

Some qualitative results came from observing the tapes of the users interacting with the site. Many subjects had troubles with the Ajax prompts, probably because they were unused to that interaction paradigm, or did not expect it coming. On at least four instances, users clicked the “Add to cart” link several times wondering why they were not taken to a separate page indicating that it had been added, only to realize that the “Item added to cart” prompt was being displayed below the item. Two users went to the cart to check out, and clicked on the check out link expecting to be taken to a separate form, only to have the checkout form open below their cart. On average, this resulted in a full minute’s delay before the user realized what was going on. And when they were at the form itself, some were thrown off by the placement of the Ajax prompt confirming that their order had been received. Feedback systems are thus absolutely critical in ensuring the success of an Ajax system: simply writing prompt text in a separate file and expecting its being called in a div to suffice will result in poor site usability.

This was vocally – almost unanimously – echoed in the post-study questionnaires. When asked for their reaction to page requests presenting “an immediate response within that page,” 11 of 13 users reported positively (of those 11, 5 said they enjoyed it when they got used to the difference); when asked about requests that loaded a different page, 9 of 13 users reported negatively, using words like “disorienting,” “frustrating,” “puzzling,” “restlessness,” and “annoying”. One user even wrote “I was somewhat frustrated and often confused because I expected a response within the same page,” citing the “add to cart” function as example.

When users were asked what functions they liked on the site, five explicitly favored the same-page “add to cart” button and two favored the sidebar subcategory popup; four voiced their dislike for the non-Ajax add to cart function.

In a final free response question where users were asked to pose any suggestions to Web developers, five alluded to fewer page loads as a possible ideal; a notable response was that one should “perhaps decrease the number of ‘hoops’ one has to jump through to complete a task,” then reiterating the add to cart function as an ideal.

Interestingly, this seemed to be the critical point for users, and it was echoed in their interaction with the site. When asked to add multiple items from a subcategory to a site, a user would be able to click “add to cart” as they scrolled down a menu, effectively finishing the task in under five seconds each time; on the non-Ajax prompts, however, they would have to click add to cart, wait, view the cart, click the back button, and repeat the process for each product, usually quintupling the time involved and forcing cognitive breaks. This posed the clearest division between Ajax and non-Ajax, in terms of time required and cognitive load.

7 Conclusions and further directions

Do new technologies like Ajax change users' information expectations? Yes, but not in the sense that I had hypothesized. I had hypothesized that Ajax would change users' expectations regarding *rate of information acquisition*; it somewhat did, but to a far greater extent, usability concerns came to the fore and users demanded adequate feedback to account for the paradigmatic change in prompting.

The effect of Ajax in furthering Web development, then, is not only a reduction of load time, but also a change in how site interaction is handled. Further study should rigorously explore not only whether the cognitive interrupt is eliminated, but also whether various interaction setups cause it to be reduced even further. As seen with the "add to cart" situation, it is clear that interfaces can leverage Ajax such that the way tasks are performed is fundamentally altered to optimize efficiency and improve user concentration.

Further research can also employ eye-tracking studies with finer granularity to ascertain where users look on a screen when they do or do not expect Ajax.

The interaction setup I employed – using a random number generator to determine if Ajax will load on a page – may not have been the best course of action. My hypothesis could possibly be concluded in different ways (or more forcefully) if, for instance, Ajax was used for the entire second half of the study, or the middle third; the study design could be varied very simply in this situation, and one could discuss a significantly different set of implications.

A rigorous analysis of the variance in prompting, feedback, and site structure will also enable web developers to refine usability guidelines, as current rules are comparatively concerned more with application than theory; and as interaction paradigms change, usability methodology must adapt accordingly.

Using the Biopac device was helpful towards this end, and it provided promising data. This was the first Biopac-related study in our lab, so collection methodology can and will be refined in future studies. Biometrics allow usability studies to gain a clearer understanding of users' mental situations as they work; in employing them here, we have provided a frame of reference which future studies can use to collect data with finer resolution and more convincing results.

In the two weeks prior to this paper's completion, Amazon deployed a restructuring of their site that placed heavy emphasis on Ajax prompts. Hovering my wish lists tab in the navigation bar provided the prompt in figure 15; adding a product to my wish list gave me a large popup asking which wish list I wanted to add it to (or if I wanted to create another one); and hovering the product categories tab yielded the below dialog box, which in turn displayed all of the categories in a stylistically threadbare but interactively forward-thinking dialog box (Figure 16).

Figure 15. Ajax dialog box on Amazon.com to display all product categories.

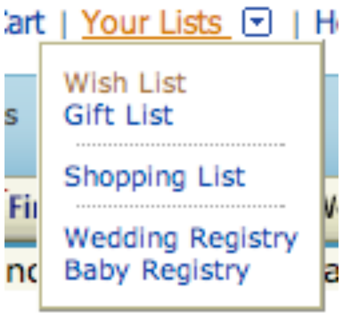


Figure 16. Ajax dialog box on Amazon.com to add a product to my wish list.

This represents the first significant use of Ajax in a major corporate e-commerce site, much less what is presently the largest e-commerce site on the Internet, and it uses a novel set of interaction models that result in a more usable page than what my subjects encountered at the Ajax Bookstore.

I believe that this shows the continuation of a trend in technological progression that has loosely paralleled equivalent developments in computer hardware, software, and network speeds. Further research must remain cognizant of these developments, adapting study designs to the contextual parameters of the technology being analyzed.

8 Appendix A. Questionnaires

AJAX Pre-study Questionnaire

1. Age ____ Gender M F

Do you wear glasses or contacts? Y N

What applications do you use? (Check all that apply)

Email	____
Word Processing	____
Web Browsing	____
Web Development/Design	____
Games	____
Databases	____
Programming	____

2. On a scale from 0 to 5 (5 being most expert), how would you rate your expertise with computers? 0 (never or rarely used) 1 2 3 4 5

3. How would you rate your expertise with the World Wide Web?
   a. Haven't ever used the Web
   b. Occasionally check email and surf on a dialup connection
   c. Occasionally check email and surf on a broadband (cable modem, DSL) connection
   d. Infrequently (1-2 times a week) use Internet on broadband, but understand its workings
   e. Frequently (5 days a week) use Internet at work
   f. Have designed Web sites and use the Internet frequently
   g. Expertly understand Internet architecture; have extensive programming and development experience (PHP, MySQL, Rails, Python, Perl, etc)

4. For how long have/did you used a dialup connection?
   a. Less than 1 year
   b. 1-3 years
   c. 4-6 years
   d. 7-10 years

5. Do you still use a dialup connection in your home or work? Yes No

6. **Only answer if you answered "No" to 5.** How long was it since you last used a dialup connection in your home or work?
    a. Less than 1 year
    b. 1-3 years
    c. 4-6 years
    d. 7-10 years

7. On a scale from 1 to 10 (10 being extremely satisfied), rate your satisfaction with Web response times on a dialup connection.

1 2 3 4 5 6 7 8 9 10 I've never used dialup

8. On a scale from 1 to 10, rate your satisfaction with Web response times on a broadband connection.

1 2 3 4 5 6 7 8 9 10 I've never used broadband

9. Any specific comments on your experiences with load times on dialup or broadband?

AJAX Post-study Questionnaire

1. When sending forms on a page presented an immediate response within that page, what was your reaction?

2. When sending forms on a page caused a delay in loading a different page, what was your reaction?

3. What site functions and responses did you enjoy, and why? What functions did you dislike, and why?

4. On a scale from 1 to 5, rate your experience with using MapQuest (www.mapquest.com), Yahoo! Maps (maps.yahoo.com), or other non-Google mapping engines.

1 2 3 4 5

5. On a scale from 1 to 5, rate your experience with using Google Maps (maps.google.com) or the recent update to Yahoo! Maps (maps.yahoo.com within the past two months).

1 2 3 4 5

6. **Only answer this question if you answered a 3 or greater to both 4 and 5.** Which service do you prefer, and why? Have you gone back to one service after using the other for a long time? What is your long-term experience with these mapping sites?

7. Is this your first experience with eye tracking in a study? If so, how do you feel about it?

8. What suggestions could you give us to improve the performance of the study?

9. What suggestions would you give Web developers to improve the responses (both in terms of content and in terms of load times) presented by any online applications?

9 Appendix B. Task List

Ajax Study – [url to site]

You will be performing tasks in a mock bookstore, not unlike Amazon, for this study. Like Amazon's primary hierarchy, the bookstore is divided into primary categories (computers, fiction, home repair) and secondary categories (programming languages, hardware; or fantasy, science fiction, romance). Each subcategory contains a representative sample of books you'd probably expect to find. "Checking out" doesn't involve sending any personal information, and what you do send doesn't get saved in our database; the form is just there to mimic an actual web environment.

If you have any questions, please feel totally free to ask the investigator. This study can be interrupted at any time.

Task 1. Buy four books in the same subcategory, and check out.

Task 2. Navigate to two different subcategories within the same category. Buy four books. Check out.

Task 3. Navigate across at least 2 categories, 5 subcategories, and 20 items. Buy at least eight books. Check out.

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