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Understanding the cognitive aspects of human error will increase the usability of user interfaces.

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By

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Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Information Technology

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Hypothesis

Understanding the cognitive aspects of human error will increase the usability of user interfaces.

Abstract

Understanding the cognitive aspects of human error will increase the usability of user interfaces. It is important to study the cognitive aspects of human error because many disasters have been attributed to operator errors. Creating usable interfaces that reduce the likelihood of error will save industries a great deal of money and may even save human lives. A greater understanding of human errors can be obtained by examining the psychological basis of errors, the methods used to study errors, some of the problems associated with studying errors and different types of errors. Next, the current research findings can then be applied to user interfaces to reduce the probability of user errors. Then, a web survey system, phpESP, will be analyzed based on the guidelines for reducing human error in user interfaces. The analysis of the survey system can server as a guide to help designers reduce potential user errors.

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Introduction

Understanding the cognitive aspects of human error will increase the usability of user interfaces. It is important to study the cognitive aspects of human error because many disasters have been attributed to operator errors. Creating usable interfaces that reduce the likelihood of error will save industries a great deal of money and may even save human lives. A greater understanding of human errors can be obtained by examining the psychological basis of errors, the methods used to study errors, some of the problems associated with studying errors and different types of errors. Next, the current research findings can then be applied to user interfaces to reduce the probability of user errors. Finally, a web survey system will be analyzed based on the guidelines for reducing human error in user interfaces.

Many different viewpoints exist regarding how error should be defined. Some critics argue that errors involve planning sequences whereas others believe that errors are merely a subset of human behavior. Reason (1990) defines an error as, " a generic term to encompass all those occasions in which a planned sequence of mental or physical activities fails to achieve its intended outcome, and when these failures can not be attributed to the intervention of some outside agency" (p. 9). An important element of Reason's definition is that an error only occurs if an outside force does not disrupt the individual's plan. How many times have your plans failed because of someone/something? In contrast, Senders and Moray's definition of an error is built on

the underlying principle that the optimum method of studying errors is to investigate human behavior. They state, "Behavior still consists of perception, attention, memory, action, etc., all functioning as they usually do. It is only as we classify the result that defines an error" (Senders & Moray, 1991, p. 19).

Critical systems such as nuclear power plants could have detrimental effects when errors occur. Errors in critical systems often result in the lost of human lives and irreversible environmental hazards. The failure of critical systems played a role in the Challenger, Three Mile Island, and Chernobyl incidents. Exploring the Chernobyl tragedy will demonstrate the common phenomenon, groupthink, which is present in the failure of many critical systems.

An explosion at a Ukrainian, nuclear power plant, killed many people and released cancer-causing chemicals into the atmosphere. Reason (1987) explains, " At 01 24 on Saturday 26 April 1986, two explosions blew off the 1000-tonne concrete cap sealing the Chernobyl-4 reactor, releasing molten core fragments into the immediate vicinity and fission products into the air." Many Americans were shocked to discover the negative impacts of a nuclear explosion. Most Americans blamed the explosion on incompetent operators or the lack of regulations in place for nuclear power plants in the Ukraine. However, the cause of the explosion was based on a physiological factor that is applicable to all humans. A greater understanding of groupthink can help reduce errors and the lost of human lives.

Groupthink was the major psychological factor involved in the explosion. The incident began with a group of engineers that wanted to see if they could keep the core cooling system in operation at all times. Normally, the core cooling system would shut

off for two to three minutes during a power failure. The engineers tried to alter the cooling system so that it stayed on at all times. The engineers believed that they could alter the system because they were deeply entrenched in groupthink. Reason (1987) describes groupthink, "The term 'groupthink' was used to describe the deterioration of mental efficiency, reality testing, and moral judgment that results from belonging to a relatively small, highly cohesive and often elite planning group". Clearly, the engineers were engaged in groupthink because they thought that a disaster was unlikely and they continued to tweak the system.

Creating usable systems that accommodate for errors can be used to reduce costs that are associated with the system. Implementing usable systems provides many general benefits as well as more specific monetary benefits. Usability advocates can encourage others to adopt usable systems by backing up the general benefits with monetary figures. Mayhew (1992) states that the general benefits of usable systems are, "decreased cost of providing training, decreased customer support cost, decreased maintenance costs, decreased training time, and decreased user turnover" (cited in Gorden, Liu, and Wic kens, 1998, p. 42).

Monetary figures confirm the powerful impact of a usable system. Managers often use figures and projections to drive decisions. Therefore, the ability to calculate the monetary advantages of usability plays a critical role in creating usable systems. Mayer has created a simple method that can easily be used to calculate the cost benefits of usability. Mayer (1992) explains,

> One might calculate the average time to perform certain tasks using a particular product and/or the average number of errors and the associated time lost. The

same values are estimated for a performance if a human factors effort is conducted. The difference is then calculated. These numbers are multiplied by the number of times the tasks are performed (cited in Gorden, Liu, and Wickens, 1998, p. 44).

Table 1 illustrates how Mayer's formula could be used to compute the estimated the monetary benefit of a three second reduction in screen use.

Table 1
Hypothetical Estimated Benefit for a 3-Second Reduction in Screen Use

	250 users
X	60 screens per day
X	230 days per year
X	Processing time reduced by 3 seconds per screen
X	Hourly rate of $15
=	$43,125 savings PER YEAR

Source: D.J. Mayhew (1992).

Designers that take human errors into account during the development and implementation phases will create more usable interfaces. First, designers should understand the psychological principles involved in human error so that they can design prototypes that minimize the likelihood of human error.

Psychological basis of errors

Goals/Intentions/Action Theory

Exploring the link between goals, intentions, and action theory will help explain some common types of errors. Action theory provides a framework for explaining human behavior through intentions and actions. Goals can be defined as broad ideas about something a person wishes to accomplish. After a person has formulated a goal he/she forms specific statements that will allow him/her to achieve their goals called intentions. Next, the person translates his/her intentions into actions that will enable him/her to reach

their goal. Frese, Ulrich and Dzida (1987) illustrate, "Acts are motivated and regulated by intentions, or higher order goals, and are realized through actions" (p. 207). The two most common types of errors are slips and mistakes. The main difference between a slip and a mistake is the person's intention.

The notion of intention can be used to explain the difference between a slip and a mistake. Reason (1990) defines a slip as, "errors which result from some failure in execution and/or storage of an action sequence" (p. 9). In other words, a slip occurs when a person formulates the correct sequence of actions but encounters a problem while carrying out the actions. A common slip that people often make is pouring salt into their coffee instead of sugar because they are distracted. The person intended to pour sugar into his/her coffee but he/she performed an incorrect action by pouring salt into their coffee. In contrast, a mistake occurs when an incorrect intention guides a person's action. Reason (1990) describes a mistake as, "deficiencies or failures in the judgmental and/or inferential processes involved in the selection of an objective" (p. 9). An example of a mistake is a user believing that a web form is submitted merely by filling it out. However, he/she does not realize that the information also has to be submitted via the submit button. Therefore, the user does not submit the web form correctly because of his/her flawed plan.

Memory

The inherent properties of short-term and long-term memory greatly influence human error. Short-term memory allows people to quickly recall information. However, the drawbacks of short-term memory are that it has a limited capacity and is prone to errors during interruptions. Norman (1988) describes short-term memory as, "the

memory of the just present. Information is retained in it automatically and retrieved without effort" (p. 66). Research has shown that the average capacity of short-term memory is five to seven items. In contrast, long-term memory has a much larger capacity. "One informed scientist estimates the capacity as a billion (10^9) bits or about 100 million (10^8) items" (Norman, 1988, p. 66). What are the weaknesses of long-term memory? Long-term memory takes a considerable amount of time and effort to store and retrieve information.

Utilizing knowledge in the head and knowledge in the world is one way to reduce errors by capitalizing on the advantages and disadvantages of short-term and long-term memory. Knowledge in the head is the information that is stored in long-term memory. Whereas, knowledge in the world is when the knowledge to complete a task is within our environment. Reminders can help reduce user errors because they combine knowledge in the head with knowledge in the world. Reminders use something in the environment to trigger information that is stored in long-term memory. Are their any guidelines for creating a reminder? Norman and Draper (1986) believe, that an ideal reminder should, "Help resumption of an activity by retrieving the exact previous state of the activity and making it available to the user" (p. 276). An example of a reminder would be a save button in a web survey that stored the user's responses. The save button would also allow the users to continue the survey where he/she left off.

Reminders also help reduce human error because they help people remember where they left off when they are interrupted. Norman and Draper (1986) explain, "Because of a person's limited processing and memory capacity, one suspends work on current activity at the risk of losing track of current activity by failing to resume the work

where it was interrupted" (p. 268). So, when should reminders occur so that they don't interrupt the user? After all, a reminder will also disrupt the user's current activity. Reminders should occur when the user's memory load is low. The seven stages of action can also be used to guide when reminders should take place. According to Norman and Draper (1986), "Interruptions should be most disruptive while in the planning and evaluation stages: i.e., during the interpretation and evaluation of the outcome" (p. 278).

Schema

A part of memory called the schema uses past experiences to guide human behavior. People often use their past experiences to guide their behavior in new situations that are similar. The activation-trigger-system (ATS) is used to explain how schemata are triggered. Bovair and Byrne (1997) illustrate, "In such a system, various schemata (organized memory units) for action exist at varying levels of activation. Each schema has a series of triggering conditions associated with it" (p. 33). For instance, a user that encounters a web survey for the first time may activate the schema for a survey. Therefore, a web survey system should contain a section that explains the process of completing a web survey.

The inaccurate nature of a schema can result in the user making errors. The benefit of schemas is that they allow people to process information quickly. However, the disadvantage is they often contain recreated information that leaves out various details. Reason (1990) explains, "These knowledge structures are capable of simplifying the problem configuration by filling in the gaps left by missing or incomprehensible data on the basis of 'default values'" (p.66). Clinging to previous default values can make it difficult for a user to master a new system that contains different features. Think about

the different shortcuts that a user can use to cut and paste on a Macintosh based system and on a Windows based system. A user that is accustomed to using a Macintosh based system may try to use the cut and paste shortcut when they are using a Windows based system.

Feeling of knowing phenomenon

People are less likely to make errors if they feel that they know an answer. Have you ever felt like you knew the answer to a question but you just couldn't remember it? Studies have demonstrated that people that think they know an answer often do. Klatzky (1984) "has termed epistemic awareness: the feeling of knowing (FOK) about what one knows" (cited in Reason, 1990, p. 113). A person that experiences FOK scans their memory for a pointer to the desired knowledge. The scanning method enables the individual to quickly sort through the vast amount of information in memory.

A groundbreaking study conducted by J.T. Hart demonstrates the powerful effects of the FOK phenomenon. Specifically, Hart wanted to know if the FOK was accurate. The study administered tests of recall and recognition to twenty-two undergraduate students. First, the students were given tests of recall. Then, they were asked to identify the questions that they could not answer but felt that they knew the answer to. The identified questions were then placed on a multiple-choice test. Next, the answers to the questions that the students felt that they knew the answers to were compared on both tests. The evidence confirmed that the respondents were more likely to correctly answer the question that they thought that they knew the answer to on the multiple-choice test. Hart (1965) concluded that, "The important finding of the investigation reported is that the FOK experiences are relatively accurate indicators of memory storage" (p. 215).

Attention

If the proper amount of attention is not given to a task than an error can easily occur. Attention is a limited commodity that must be used wisely. People have to make a conscious effort to focus their attention. William James defined attention as:

> ...taking possession of the mind in clear an vivid form, of one of what seems several simultaneously possible objects or trains of thought. Focalization, or concentrations of consciousness are of its essence. It implies withdrawal from some things in order to deal more effectively with others (cited in Reason, 1982, p. 220).

The cause of most errors is the fact that attention is predisposed to wander off. Learning about common errors that are related to lack of attention will enable designers to regain the user's attention by alerting them when he/she makes an error.

Mistakes are often the result of inadequate attention. When people are distracted they tend to commit mistakes of bounded rationality. Have you ever been so distracted that you simply choose the easiest way to accomplish a task? Then you have made the mistake of bounded rationality. So, why do errors of bounded rationality occur? Duncan, Leplat and Rasmussen explain the cause of mistakes of bounded rationality as, "Attempts at 'thinking through' the consequences of the planned actions will be partial rather than complete, since this activity is extremely demanding of attentional effort and is further restricted by memory considerations" (1987, p. 16).

Slips also occur because people become distracted. The following situation illustrates a slip. Imagine that while going into the kitchen to prepare dinner you hear an ambulance. You decide to rush outside to see what all of the commotion is about. Upon

returning to your house you forget that you went into the kitchen to prepare dinner. The slip occurred because the ambulance captured your attention. Reason (1990) concurs that, "Slips arose because knowledge related to these changes was not accessed at the appropriate time, due almost invariably to attentional 'capture'" (p. 61).

Errors messages that effectively utilize attention can be used to alert users of their errors. Alerts that use colors and that are placed in a prominent area of the interface will be successful. A study that examined modalities and attention also showed that alerts that combine modalities would be valuable. The experiment compared the participants' ability to concurrently process auditory and visual stimuli. Specifically, the participants had to divide their attention between lists of auditory and visual stimuli. According to Treisman (1969), the results were that, "The Ss did appreciably better when dividing their attention between a visual and an auditory list" (p. 288). The term Ss in the prior statement stands for subjects. Therefore, alerts that contain an auditory and a visual component should be used to alert users. For example, a warning message and a beeping noise could be used to signify an error.

Theory of least effort

Humans strive to maximize benefits and minimize costs even if it causes them to use less than perfect knowledge. The theory of least effort explains why people are willing to sacrifice quality for speed. Dr. Tsai describes the theory of least effort as, "Among several alternatives of behavior leading to equivalent satisfaction of some potent organic need, the animal, within the limits of its discriminative ability, tends finally to select that which involves the least expenditure of energy" (cited in Zipf, 1965, p. 14). Humans choose to focus their attention on certain stimuli so that they do not overextend

the cognitive load on their brains. People also often estimate the amount of effort they must expend before they complete a task. Therefore, an individual's estimation about the amount of effort required to complete a task is often inaccurate because it is based on foresight.

Research has linked the theory of least effort with errors that are made while programming a vcr. The study demonstrated that people are often willing to use incomplete knowledge-in-the-head if it requires less effort than perfect knowledge-in-the-world. Gray and Fu (2001) describe the role that effort played in the experiment, "Internal effort includes the effort of storing an item in memory as well as the effort of subsequently retrieving that item from memory. External effort includes the effort of searching the environment to locate an item" (p. 112) The study included a group that learned how to program a vcr in advance and a group that did not. When asked to program a vcr both groups had access to knowledge in-the-world that contained instructions on how to program a vcr. When asked to program the vcr, the group that had to learned to program the vcr in advance made less errors. The study is interesting because it shows that people that have knowledge in-the-head for a given task are more likely to use the information in their head because it requires the least effort.

Cognitive underspecification

Cognitive underspecification is an intriguing phenomenon that has been linked with errors. Everyone forms certain habits that are difficult to break. Habits are especially hard to overcome when people are not functioning at their highest level of capacity. Habits are just one occurrence of cognitive underspecification. Reason (1990) describes cognitive underspecification as, "When cognitive operations are underspecified, they tend

to default to contextually appropriate, high-frequency responses" (p. 97). The advantage of the phenomenon is that it helps humans adapt to a highly routine environment. The drawback of the phenomenon is that people often make errors in novel situations because they do not have any responses stored for that situation. So, when is cognitive underspecification likely to occur? Cognitive underspecification often occurs when there is a lack of information or resources such as memory or attention. Some researchers believe that cognitive underspecification is an automatic process that is caused by activating a highly utilized schema during novel situations.

Various speech studies demonstrate the connection between cognitive underspecification and errors. Have you ever misread an old quote? Maybe, you left out a portion of the quote or added to it. You might have even reworded the quote so that it contained more commonly used words. The term banalization can be used to describe the process of replacing common words with words that occur less often. Timpanaro (1976) concurs that, "if a mistake occurs in the remembering of a word or phrase, in the vast majority of the cases it is due to banalization or to the attraction exerted by its context" (p. 99).

The fragment theory also illustrates that speech errors are associated with cognitive underspecification. The theory is based on the idea that people will select common words to fill in the gaps of a sentence rather than words that are less common. People tend to choose common words to fill in the sentence because they occur more frequently. However, the tendency to choose common words instead of rare words can lead to errors. Neisser (1967) agrees that, "of the misperceived stimulus is actually a common word, erroneous guesses about it include relatively fewer of the correct letters

when the stimulus is rare" (p. 117). Based on the speech related research, we could reduce human error by providing people with information about how to handle novel situations.

Culture

Culture has a tremendous impact on errors. Each culture is unique and is intricately linked to how people think and behave. "Elisa del Galdo [1] defines culture as a multitude of elements and their integration that includes the customary beliefs, social forms, and material traits of racial, religious, or social group" (cited in Baldacchini & Mrazek, 1997, p. 22). Users are more likely to make errors when the interface does not conform to their cultural values. Unfortunately, most of the attempts at creating cross-cultural interfaces merely involve translating the text into another language. In contrast, designers need to take into consideration the morals and values of a given culture when they design cross cultural interfaces.

A recent study tested the usability of various interfaces based on the Chinese culture. The Chinese culture tends to focus on relationships. Choong, Rau and Salvendy (2004) illustrate, "The Chinese people tend to display a cognitive style of seeing things in wholes rather than parts" (p. 120). Therefore, the experiment included two interfaces, a thematic based interface and a functional based interface. The functional based interface organized the items according to their function. For instance, the functional based interface organized all the cleaning items under the heading cleaning. In contrast, the thematic based interface arranged items based on their contextual relationships. For example, the thematic based interface placed on the kitchen items under the heading kitchen.

The layout of the interfaces influenced the number of errors that the users made. The Chinese participants made fewer errors when they used the thematic interface. Specifically, the average number of errors that the participants made using the thematic based interface was 34.5 percent compared to the 54 percent error rate associated with the functional interface.

The methodologies used to study errors

Subjective verses objective

Objective and subjective methods are two -techniques used to study errors. Objective data is based on fact and figures. Corbett & Kirakowski (1991) define objective data as, "The sort of activity we normally associate with objective records is that of counting events, and then of computing event destiny (ie, number of events per unit time)" (p. 31). For instance, an objective way of measuring errors would be to count the number of errors made during a given time period.

Subjective is far more variable and is based on the subject's thoughts or experiences. Wickens (1980) states, "Subjective measures are those that rely on human experience, judgment, perception, or cognition" (p. 32). Examples of subjective measures are interviews, verbal protocols, and videotaping. Many researchers prefer to use subjective methods because they are easier to analyze. Wickens (1980) illustrates, "collections of vast amounts of objective data will result in large amounts of coding and data reduction before the performance measures can be analyzed" (p. 35). Other critics argue that subjective methods are superior to objective methods because they provide the researcher with a window into the user's thought processes.

Case Studies

Case studies provide in depth coverage of a given event. Case studies in human error research are often based on catastrophic disasters of the past. Some common case studies are Chernobyl, Bhopal, and the Challenger. Researchers believe that by analyzing the chains of events in past disasters that they can prevent further ones. Reason (1990) concurs, "we are able to study the interaction of various causal factors over an extended time scale in a way that would be difficult to achieve by other means" (p. 16). Case studies often incorporate numerous sources of data. "Yin (1994) lists six sources of evidence for data collection in the case study protocol: documentation, archival records, interviews, direct observation, participant observation, and physical artifacts" (cited in Tellis, 1997, para 33).

Some critics argue that case studies should be used with caution. One drawback of a case study is that it only represents a single occurrence of an event. Soy (1996) makes an excellent point that, "a small number of cases can offer no grounds for establishing reliability or generality of findings" (para 2). Analyzing events after they occur is also highly susceptible to the hindsight bias. The hindsight bias takes place when a person believes that they knew why an event occurred after it has taken place. Reason (1990) describes it as the 'knew it all along' effect. Hindsight bias took place in the Chernobyl disaster. The operators at the nuclear plant thought that they knew why the explosion occurred but failed to recognize that groupthink played a role.

Verbal protocol

Verbal protocols are highly utilized in human computer interaction and psychological research. Researchers employ a verbal protocol technique by asking users

to explain their thought processes during a given task. For example, participants in a study maybe asked to say their thought processes aloud while they complete a web survey. The verbal protocol enables researchers to gain a deeper understanding of the participants' thought patterns. Clemmensen, Nielsen and Yssing (2002) explain the purpose of the verbal protocol is, "to get users' inferences, intuitions, and mental models...reasons...decisions...while doing the task" (p. 102). The verbal protocol obtains information about the participants thought patterns by tapping into their short-term memory. (Clemmensen et al., 2002) state, "The assumption is that everything we know has, at some point, gone through our short-term memory (STM) and we have been conscious of it. We can verbalize what we are perceiving while in the process of perceiving, and we can verbalize what we are conscious of" (p. 105).

Researchers have found that participants that implement the verbal protocol are more likely to detect errors. A study that trained participants to use a database contained sessions that utilized the verbal protocol and sessions that did not. The results of the study revealed that the participants that used the verbal protocol detected more errors. Reason (1990) reveals the miraculous results of implementing the verbal protocol, "Overall, the subjects made 924 errors and detected 780 of them" (p. 160). Some critics believe that participants are more likely to detect their errors if they use the verbal protocol because it makes them more aware of their own thought processes.

How are verbal protocols analyzed? First, the data is transferred from a verbal format and transcribed into a written format. Next, the written data is encoded and segmented into categories. So, how is segmentation done? "Segmentation may be done on the basis of content, e.g. ideas or time" (Clemmensen et al., 2002, p. 105).

Video

Videotaping provides researchers with a wealth of information. The major benefit of videotaping is that it creates a permanent record of the participant's actions and body language. Multiple cameras can also be positioned at various angles so that a multitude of data can be obtained. For instance, one camera could focus on the computer screen and another could concentrate on the user. The stated camera configuration will record the user's error(s) and the user's reaction when he/she detects or corrects the error(s). Video tapes are also used to compare how various people complete a given task. Wickens (1980) states, "Task performance is videotaped to allow for adequate analysis at a later point. It is important to identify different methods for accomplishing a goal, rather than only identifying the one typically used be a person" (p. 60).

Analyzing video data is a time consuming endeavor. Video data can be analyzed based on the task or performance. The task based analysis strategy tries to decipher how a user accomplishes a given task. Whereas, analyzing a user's performance is based on more objective measures such as frequency and time. Benton, Carey, Holland, Simon, Preece, Rogers, Yvonne and Sharp (1994) illustrate that analyzing a user's performance involves, "frequency of user errors and the time taken up by various cognitive activities, such as pausing within and between commands" (p. 620). A videotape must be played back numerous times so that it can be thoroughly analyzed. Benton et al. (1994) state, "If a more detailed understanding of user actions or task performance is required, the evaluators either have to collect and analyze user protocols or select relevant performance measures and play through any videotape or system log several times" (p. 620). So, how long does it take to analyze a videotape? "One hour of videotape could take five hours or even a day or more to analyze" (Benton et al., 1994, p. 620).

Problems associated with studying errors

Attribution theory / feeling of blame

It is often difficult to study errors because people are not willing to admit their errors. Compounding the problem is the fact that we live in a society that likes to blame someone or something when an error occurs. People also tend to believe that they are not at fault when an error happens. They rarely attribute their errors to other factors such as bad design. Norman (1988) illustrates, "if we believe that others are able to use a device and if we believe that it is not very complex, then we conclude that any difficulties must be our own fault" (p. 40).

The attribution theory also explains why people hesitate to report their error(s). Reason (1990) defines the attribution theory as, "People's readiness to overattribute the behavior of others to dispositional causes, thus ignoring the influence of situational factors such as role or context" (p. 41). Therefore, people are also reluctant to report their error(s) because they believe that it represents a lack of competence on their part. Unfortunately, it is difficult to study errors because a vast majority of them are not reported. One researcher recognizes the disastrous effects of combining error and blame. Denning (1990) explains, "a search for blame...distracts us from learning from our mistakes, from seeing the limitations of current engineering methodology, and from improving our discourse of design" (p. 6).

Types of errors

Slips

Slips are common types of errors that occur frequently. Moray and Senders (1991) define a slip as, "an unintended error of execution of a correctly intended action" (p. 27).

In other words, a slip occurs when a person forms a suitable plan but does not carry out the correct action(s). When do slips occur? Slips often occur because behavior is highly automatic. Highly automatic behavior is prone to error because people often repeat or omit steps. Attention also plays a role in the likelihood of a slip. When an individual's attention is diverted from a given task than a slip is probable. Reason (1990) illustrates, "Unless it is periodically refreshed by attentional checks in the interim, this intention will probably become overlaid by other demands upon the workspace" (p. 71)

Mistakes

In contrast to slips mistakes involve an inadequate intention. Most researchers generally categorize errors as either mistakes or slips. However, many other categories of errors exist and they are discussed later in the paper. Moray and Senders (1991) describe mistakes as, "planning failures: errors of judgment, inference or the like, when actions go as planned-but the plan is bad" (p. 27). Mistakes are difficult to detect because people are often unaware that their plan or intention is incorrect. Reason (1990) states, "mistakes can passed unnoticed for lengthy periods" (p. 9). For instance, a person taking a web survey may not know that radio buttons only allow them to select one answer. Therefore, the user selects multiple answers to a question that utilizes radio buttons. Then, he/she is surprised that multiple answers are unacceptable for the question. The user's intention was to answer the question with multiple responses. He/She made a mistake because his/her plan could not be fulfilled because multiple answers were unacceptable. How do people select a plan? People select plans that will allow them to achieve their objectives with the least amount of effort.

Post completion errors

Post completion errors are errors that occur after a goal has been accomplished. Have you ever made a forgotten to retrieve the original document after you made a photocopy? If so, then you have experienced the post completion error. Bovair and Byrne (1997) define the post completion error as; "This type of error seems to occur when people have an extra step to perform in a procedure after the main goal has been satisfied" (p. 31). The reason that you might have forgotten the original document in the photocopier is because your goal of making copies has been fulfilled. Figure 1 illustrates the task structure for the photocopier task. The ovals represent goals and the rectangles represent subgoals.

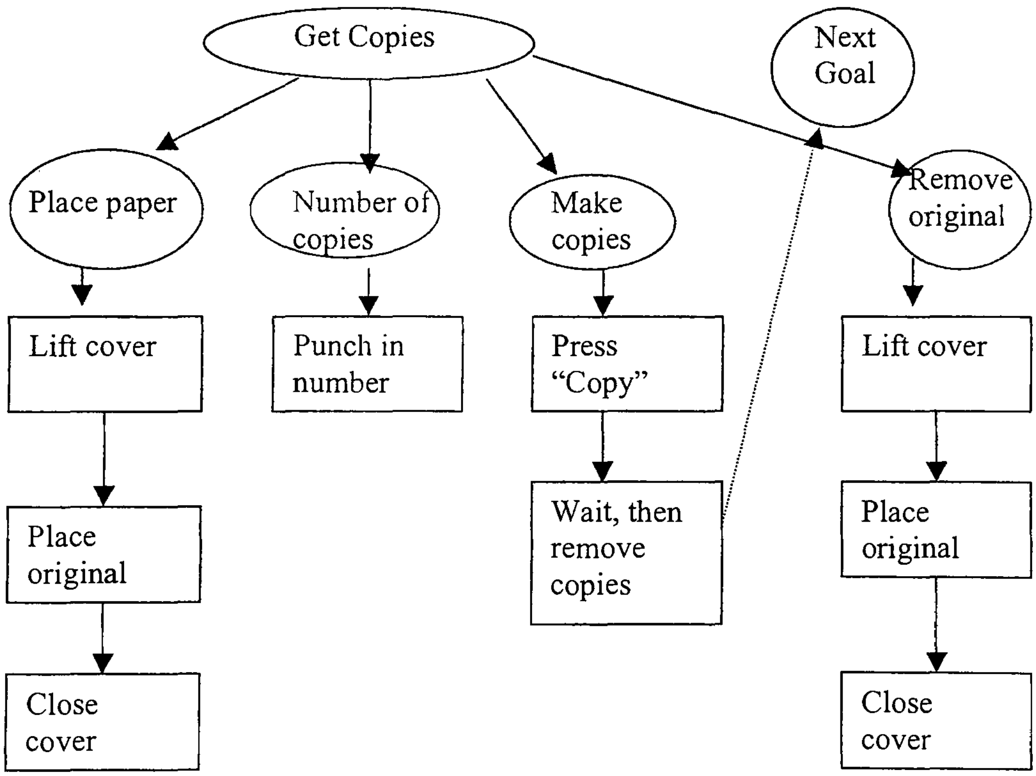


Figure 1. Task structure for the photocopier task.
Source: Bovair & Byrne (1997).

Why do post completion errors occur? Memory load and the activation of goals and subgoals are major components of post completion errors. Specifically, post completion errors are probable when memory load is high. Bovair and Byrne (1997) state that, "The error is made when the load on working memory is high ... but will not be made when the load is low" (p. 31). Working memory contains goals that are arranged in stacks. When one goal is fulfilled the next goal or subgoal moves to the top of the stack. The goals in memory are activated according to the load. A high memory load results in activating only some of the goals. In contrast, a low memory load enables all of the goals to be activated. Bovair and Byrne (1997) illustrate, "When working memory load is high, the lost of support from a parent goal may lead to the loss of still unsatisfied subgoals" (p. 38). Lets apply our knowledge of memory and goals to the post completion error that commonly occurs in a photocopying task. A person that is preoccupied when making a copy will likely leave the original in the photocopier because the remove original subgoal will not be activated.

Latent / active errors

Latent errors are far more complex than active errors. Active errors occur frequently and are easy to detect. In contrast, latent errors are much more difficult to detect. Reason (1990) defines latent errors as, "errors whose adverse consequences may lie dormant within the system for a long time, only becoming evident when they combine with other factors to breach the system's defences" (p. 171). For instance, a system designer creates a latent error when an error is made during the design process. Only later when a problem arises will the designer's latent error be discovered.

Latent errors are more probable in highly automated systems. Systems have become more complex with the increased level of automation in current systems. These highly complex systems have become opaque to users. Reason (1990) explains, "This opacity has two aspects: not knowing what is happening and not understanding what the system can do" (p. 179). How can users correct an error if they are unaware of it or don't understand how to fix it? Clearly, automated systems make it harder to track down problems. Many system designers also contribute to the problem because they try to design out the human components so that errors are less likely to occur. However, designers cannot figure out how to automate every aspect so humans are involved.

A major role that users play is taking manual control of the system during a failure. Unfortunately, many users do not receive adequate training about how to control the system if a failure occurs. The users also often have a difficult time responding to a system failure because they are not accustomed to it. Reason (1990) concurs, "One of the consequences of automation, therefore, is that operators become de-skilled in precisely those activities that justify their marginalized existence" (p. 180). It has been suggested that one way to improve operator's responses to system failures is by exposing them to a variety of system failures before they occur.

Error detection and correction

Confirmation bias

Confirmation bias greatly inhibits people from detecting errors and subsequently correcting them. Once human beings have an idea they tend to mold available information to fit it. Reason (1990) explains, "in the face of ambiguity, it rapidly favors one available interpretation and is then loath to part with it" (p. 89). The confirmation

bias makes it extremely difficult for an individual to detect errors if the given data contradicts an existing idea that he/she holds.

An error committed by a pilot illustrates the confirmation bias. Ladkin (1997) states, "the pilot of one of the USSR interceptor aircraft . . . had been directed, by his ground command and control units, to shoot down an aircraft which they assumed to be a U.S. RC-135" (p. 160). The pilot's error also demonstrates that peer pressure can increase the probability of the confirmation bias. To reduce the occurrence of the confirmation bias occurring while users interact with the interface automated assistants could be implemented. The automated assistants could pop up at various intervals and suggest alternative ways of accomplishing a given task.

Self monitoring

Self-monitoring is a process that helps people to correct and detect errors. Specifically, people monitor how closely their actions bring them to their desired goal. Hanley, Proctor, Strybel and Vu (2000) illustrate, "successful performance will depend on things such as correct identification of the problem and the desired goal, assessment of whether an initial plan or problem representation is likely to lead an accomplishment of the goal" (p. 44). Many studies have also demonstrated that people that quickly detect an error are more likely to correct it. Certain types of errors are more likely to be detected and corrected. An experiment that implemented a visual search task, using letters, found that participants easily detect and correct errors of omission. Errors of omission involve leaving a step out of a process. Exploring further studies will provide valuable insights regarding the self-monitoring process.

A researcher used a verbal protocol to examine the problem solving process that participants utilized while using a database. She found that when participants detected an error that they began to work backwards to correct it. Chen (2000) states, "The key to working backward is to start with the goal and try to change it into the givens" (p. 10). The participants also employed a subgoal analysis technique that involves breaking down goals into smaller subgoals. The research concludes that it is highly important for people to be aware of how they detect errors so that it will be easier for them to correct errors.

A study that examined solving math problems identified three ways to detect errors. The various ways to detect errors were discovered by analyzing verbal protocols. Have you ever checked over the answers on a test before you handed it in? If so, then you have utilized the standard check mechanism for error detection. Reason (1990) describes the standard check as when, "the subject simply decides to carry out a general check" (p. 159). Another common situation is when a person suddenly remembers that they filled out the wrong answer on a test so they go back and change their answer. The person's need to go back and change their answer is linked to the direct error-hypothese formation. Reason (1990) states the cause of the direct error-hypothese formation as, "These episodes are triggered by an abrupt detection of a presumed error" (p. 159). Finally, people experience an error suspicion when they believe that they have committed an error but they are not sure what it is.

Forcing functions

Forcing functions are a drastic way to prompt users to detect and correct errors. Norman (1988) defines a forcing function as, "a form of physical constraint: situations in which the actions are constrained so that failure at one stage prevents the next step from

happening" (p. 132). A common forcing function is the electronic seatbelt. Forcing functions should inform the user about what the problem is and how to correct it. Having error messages that accompanies forcing functions is one way to provide the user with information. Bagnara, Marchigiani, Parlangelo and Rizzo (1996) state, "When a forcing function (Norman, 1983) is supported by a message this should provide information on what objects are involved and what values are improper for each object" (p. 116). For instance, if a user enters an invalid filename then he/she would not be allowed to proceed. Next, he/she would receive an error message that explains invalid filenames.

Automation

Some believe that increasing the levels of automation in systems will decrease human errors. However, some critics warn that humans should not be designed out of systems because humans and machines each have their own strengths and weaknesses. Fitts (1951) states that humans excel at the ability to detect small amounts of visual or acoustic energy, the ability to perceive patterns of light or sound, the ability to improvise and use flexible procedures, the ability to store very large amounts of information for long periods and to recall relevant facts at the appropriate time, the ability to reason inductively, and the ability to exercise judgment (p. 10). In contrast, machines outperform humans in their ability to perform repetitive and routine tasks, the ability to store information briefly and then erase it completely and the ability to reason deductively including computational ability (Fitts, 1951, p.10).

Capitalizing on the strengths of humans and machines can reduce human errors. The greatest strengths of humans are their ability to flexibly, adapt to a variety of situations. Machines greatest asset is their ability to perform repetitive tasks. Therefore,

humans should monitor systems that perform repetitive tasks so that they can step in if an error occurs. "It is coping with contingencies that man is irreplaceable by machines" (Jordan, 1963, p. 63). With systems becoming more and more opaque it is crucial to train operators of critical systems how to recognize errors and fix them.

Ways to reduce errors in user interfaces

Feedback

Providing the user with feedback is a very effective way of dealing with errors. Users' primary concern when interacting with the interface is obtaining their goal(s). Feedback enables users to identify their progress towards fulfilling their goal(s). Feedback comes in a variety of forms such as visual and auditory. Visual feedback involves altering the appearance of the interface based on the user's action(s). Visual feedback is implemented in many hypertext links because they change colors when the user mouses over them. Sounds can also help users measure the progress towards their goals(s). Sounds are often used to alert the user of an error because they gain the user's attention. Norman (1988) explains, "One of the virtues of sounds is that it can be detected even when attention is applied elsewhere" (p. 102).

There are some crucial points at which feedback should be given. Research has shown that there are common forms of error such as mistakes and slips. Keeping a log of when the error forms occur can help identify when the errors will most likely take place. Providing the users with feedback at crucial points where errors are likely to occur can help prevent errors. Norman (1983) illustrates, "A major issue here is simply to know the critical place at which errors occur so that remedial action can be built into the system at a critical point" (p. 256). Feedback should also be given directly after an error takes place

so that the user is aware of when the error occurred. The National Aeronautics and Space Administration's 1997 design guide states, "Feedback should be provided as close in time as possible to the completion of the user entry/action" (p. 18). If the feedback was given to far after the error occurred then the user might become confused and make more errors.

Error messages are also a form of feedback. How many times have you encountered an error message that made absolutely no sense? The best error messages are clear and easy to understand. More importantly the message should inform the user about where he/she went wrong in achieving his/her goal(s). Johnson, Johnson and Zhang give an example of a cryptic message, "The following message appeared in a dialog box after the user performed an action; 'Form-load ERROR [3251] Operation is not supported for this type of object' " (2000, para 17). The error message indicates an error code that would help debug a program and provides no value to the average user. Clearly, a more effective message would help the user. Following a few guidelines can produce effective error messages. Johnson et al. state, "The following guidelines should be used to construct satisfactory error messages: positive tone, natural language, clarity, understandable format, and consistent terminology and placement" (2000, para 16).

Standardization

Using standardized elements in an interface makes it easier for users to learn. Interfaces that are easy to learn result in users making less errors. So, what makes an interface easy to learn? Srinivas (1997) states, "Building consistency, rules, and patterns into the interface will increase learnability and thus reduce errors" (para 10). Think about the last time that you tried to use a new interface. Did the interface's standardized

features and appearance make the interface easier to learn? According to Jakob's Law of the Web User Experience, interfaces that conform to common standards are easier to use. Nielson (1999) illustrates, "Remember Jakob's Law of the Web User Experience: users spend most of their time on the other sites, so that's where they form their expectations for how the web works" (para 4).

Consistent interfaces will also encourage users to rapidly learn the interface. Stylesheets are just one of the ways to make the appearance of an interface consistent. Also, functions that are used frequently should be located in similar locations throughout the interface so users can easily find them. A variety of strategies suggested by Nichols (1995, para 13) can also be used to prompt interface consistency.

- "Use regular geometric forms, simplified contours, and muted colors wherever possible."
- "If multiple similar forms are required make them identical, if possible, in size, shape, color, texture, lineweight, orientation, alignment, or spacing."
- "Limit variation in typography to a few sizes from one or two families."
- "To reap the benefits of regularity, make sure critical elements intended to stand out in the display are *not* regularized."

Undo Function

Undo functions reduce errors because they make people feel more comfortable using the interface. Many users are afraid to try new things because they are scared that they will make an error that they cannot recover from. Draper and Norman (1986) tout the benefits of the undo function. They state, "It allows users to experiment more freely,

it reduces anxiety and tension, and it permits ready recovery of many simple errors" (p. 430). Clearly, users with a greater level of confidence are less likely to make errors.

There are a variety of ways to implement the undo function in an interface. How far back should the user be able to undo their actions? Is the user only allowed to undo actions in a certain sequence? The most common flavor of the undo function is the single step undo which enables the user to erase the previous action. Two other forms of the undo function also exist. Sun (2003) explains, "the chronological 1 undo that allows a user to undo a sequence of operations in the reverse order of their executions, and the selective undo that allows a user to undo operations in any order" (p. 8).

Properly utilizing knowledge in the head and knowledge in the world

Knowledge in the world can be used to decrease the cognitive load, which reduces the likelihood of errors. Human memory can only handle so much information. On average, short tem memory holds only five to seven items. Chunking items into groups of five to seven items can help users process information in short term memory. Designers can implement chunking in an interface by grouping related items together. Researchers also believe that people are better at recognizing information than recalling it. Hinum (2004) illustrates, "The human brain is better in recognizing something than recalling the same information from memory without help". Designers can capitalize on the brain's ability to recognize information by providing the user with a set of options when they answer a question. For example, dropdown boxes are one way to provide the user with a set of answers that he/she can choose from.

Interfaces should only contain essential information. Albers (2003) explains, "Too much information causes cognitive overload which results in the information being

ignored. Too much information can result when the design strives for completeness over clarity" (p. 1). Other researchers believe that users are more likely to make errors when too much information is provided because it captures their attention. Drommi, Shoemaker and Ulferts illustrate, "The split attention affect occurs when people are required to divide their attention and mentally integrate multiple sources of information resulting in less effective acquisition of information". Clearly, interface designers should carefully evaluate the value of each item included in the interface.

User analysis

Analyzing the potential users of an interface during the design and testing phases will help detect future errors. The users of an interface often have a variety of backgrounds. Some users may have extensive computer experience while others do not. A through understanding of the users is a crucial component of designing a successful interface. Will the users be old, young, educated, or handicapped? These are just a few of the potential users. So, how is a user analysis conducted? The author's of User-Centered Product Creation in Interactive Electronic Publishing (2003) explain, "Informal methods such as observation, interview, document analysis, focus group analysis, checklists or questionnaires can be used" (para14).

An easy way to analyze users is based on their experience. Novice and expert users organize information differently and interfaces should accommodate these differences. Expert users already have a more sophisticated understanding of the interface, which enables them to think of the interface in terms of chunks. Wu (2000) illustrates, "Experts do more chunking than novices. This means that they are able to take large amounts of information and see it as connected in units" (p. 2). Therefore,

interfaces that cater to expert users should contain more advanced features. In contrast, novice users are more concerned about the interface being easy to learn and guessable. Wu (2000) states, "They would like the interface to be guessable which means that users who do not have previous experience of the system can use the interface" (p.2).

Designers have the responsibility of creating an interface that meets the needs of novice users and expert users. Designers have to satisfy both levels of users because the level of expertise that user has can change over time. For instance, a novice user that interacts regularly with the system may become an expert. Likewise, an expert user that infrequently uses the system may revert to being a novice. One way that designers can create interfaces that accommodate both novice and expert users is to make common functions easy to use and find. Also, the more advanced features in the interface should be accessible but they should less prominent then the frequently used functions. Making the more advanced features less prominent helps to ensure that novice users will easily find frequently used functions without becoming confused by encountering the more advanced features. Finally, the expert users will also be satisfied because the advanced features will enable them to engage in more complex activities.

Application

Applying current research findings about human error to interfaces can help reduce the likelihood of user errors. Specifically, version 1.6 of the web survey system phpESP will be analyzed based on the cognitive aspects of human error and the specified criteria for reducing errors in interfaces. However, the demo version lacked some of the features that are available in the full version. Therefore, an independent programmer implemented a signup page and a login page to recreate the full functionality of the system. The survey system contains two major components they are the management interface and the respondent interface. Both the interfaces will be analyzed based on the following categories: memory load, feedback, the theory of least effort and attention. Positive observations about the interface and recommendations for various sections will be discussed

Positive Observations

Feedback

The interface offers users that are creating a survey or taking a survey an enormous amount of feedback. Research has noted that feedback often occurs in the form of error messages. Error messages are used in the interface to inform users that he/she has entered incorrect data or has attempted to upload a file that does not exist. Error messages are also used to implement forcing functions when the user is creating a survey. For instance, users cannot create an additional section of a survey if they have not completed the required fields in a prior section.

Memory Load

PhpESP does an excellent job using chunking to reduce the user's memory load. The management portion of the user interface uses tabs to chunk information during the survey creation process. The tabs break the survey creation process into the following five steps: general, questions, order, preview, and finish. A unique feature of phpESP is that it allows survey makers to chunk questions together on separate or individual pages in the survey.

Theory of Least Effort

The interface will appeal to the human tendency to exhibit the least amount of effort to accomplish a given task. Dropdown boxes are used through out the interface so that users simply have to select an answer choice instead of typing it. The theory of least effort has also been implemented in the section of the interface that enables the user to edit the survey. Specifically, when the user edits a survey the preexisting values area already filled in. The user may not want to edit the survey if he/she had to retype the values.

Attention

The interface primarily uses colors and horizontal rules to gain the user's attention. The color red is used in various screens to alert users that he/she has made an error and to make them aware of required fields. Horizontal rules are another method that is used to grab the attention of users. Horizontal rules are utilized in the survey creation portion of the interface to make users aware of the different parts of each section

.

Recommendations: The Management Interface

Section Name: Create a New Survey / Finish Tab

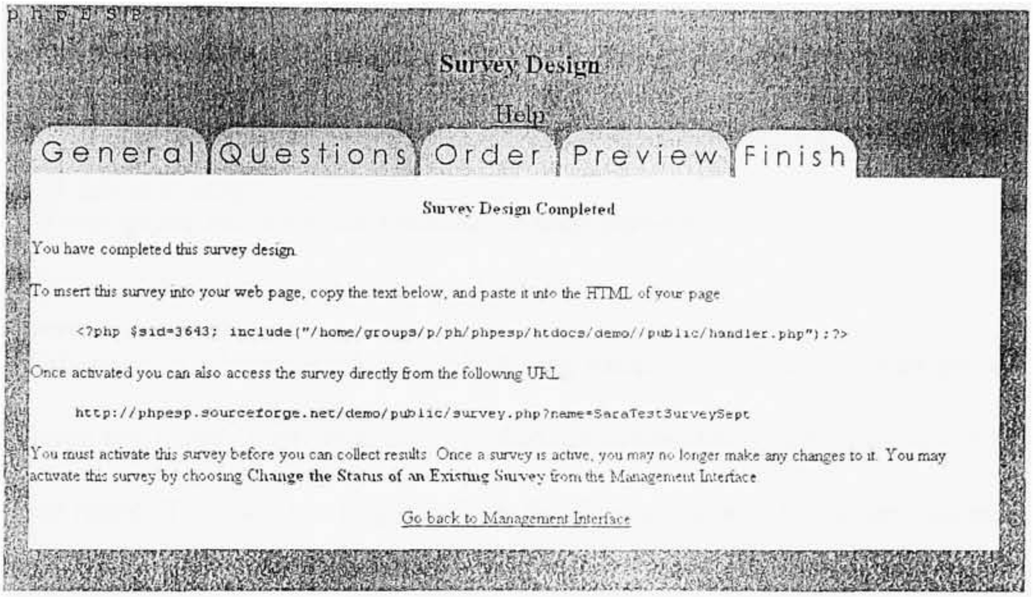


Figure 2. New Survey / Finish Tab
Source: http://phpesp.sourceforge.net/demo/admin/manage.php

Recommendations:

- The address of the survey can only be found on the finish section of the management interface. The user has to remember the address of the survey when it is activated because it is not stated on any other portion of the interface. This can lead the user to make errors because he/she could easily forget the address of the survey.

Section Name: Edit an Existing Survey

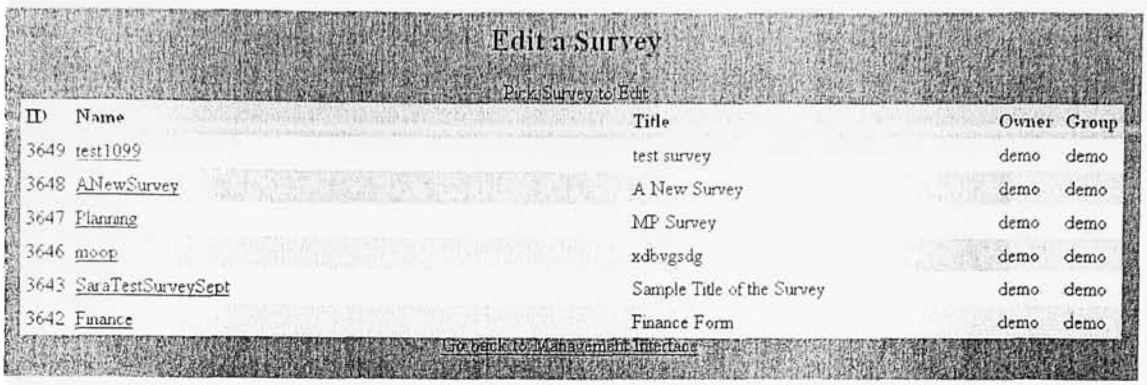
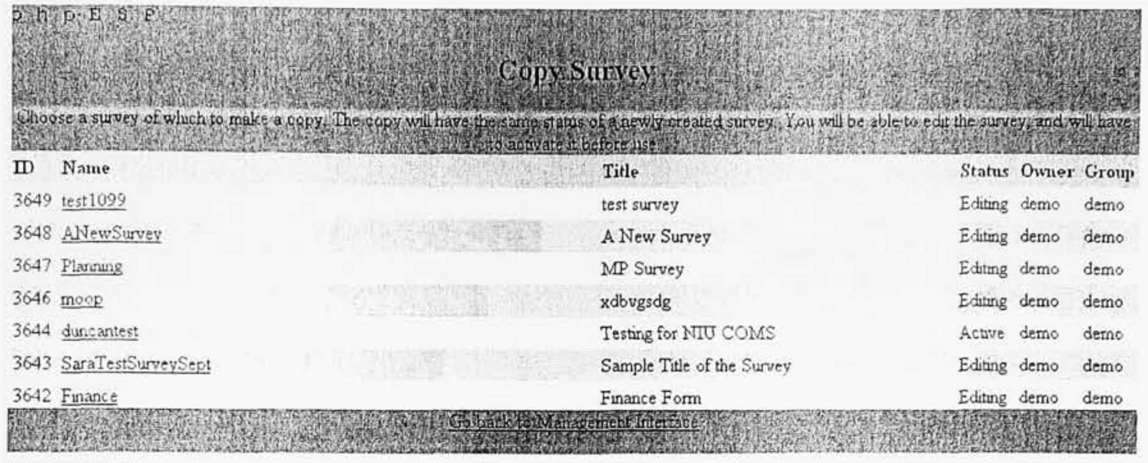


Figure 3. Edit an Existing Survey
Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=edit

Recommendations:

- This section of the interface is confusing because only surveys that are in editing mode are listed. Therefore, surveys that are active, being tested, or are archived are not listed. The user has to go back to the Change Survey Status section and put the survey they want to edit into edit mode. Unfortunately, the Edit an Existing Survey section does not inform the user that he/she has to change the mode of the survey to the editing mode before the survey can be edited. The user is likely to make an error while attempting to edit a survey because a cue is not provided to inform him/her about how to edit existing surveys that are not listed. Also, this section of the interface does not contain a help link. A help link that explains how to edit a survey would greatly help the user. Placing a brief explanation, about how to edit a survey, on the top of the page would also decrease the likelihood of errors.

Section Name: Copy an Existing Survey


p h p E S P

Copy Survey

Choose a survey of which to make a copy. The copy will have the same status of a newly created survey. You will be able to edit the survey, and will have to activate it before use.

ID	Name	Title	Status	Owner	Group
3649	test1099	test survey	Editing	demo	demo
3648	ANewSurvey	A New Survey	Editing	demo	demo
3647	Planning	MP Survey	Editing	demo	demo
3646	moop	xdbvgsdg	Editing	demo	demo
3644	duncantest	Testing for NIU COMS	Active	demo	demo
3643	SaraTestSurveySept	Sample Title of the Survey	Editing	demo	demo
3642	Finance	Finance Form	Editing	demo	demo

Go back to Management Interface

Figure 4. Copy an Existing Survey
Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=copy

Recommendations:

- The user is currently taken back to the management interface when he/she makes a copy of an existing survey. This section of the interface could be improved by providing the user with better feedback. The user should not be taken back to the management interface when he/she makes a copy of a survey. Instead, he/she should be taken back to the make a copy section and the new copy of the survey should be displayed. The user is more likely to make an error because an extra step is involved.

Section Name: Change the Status of a Survey

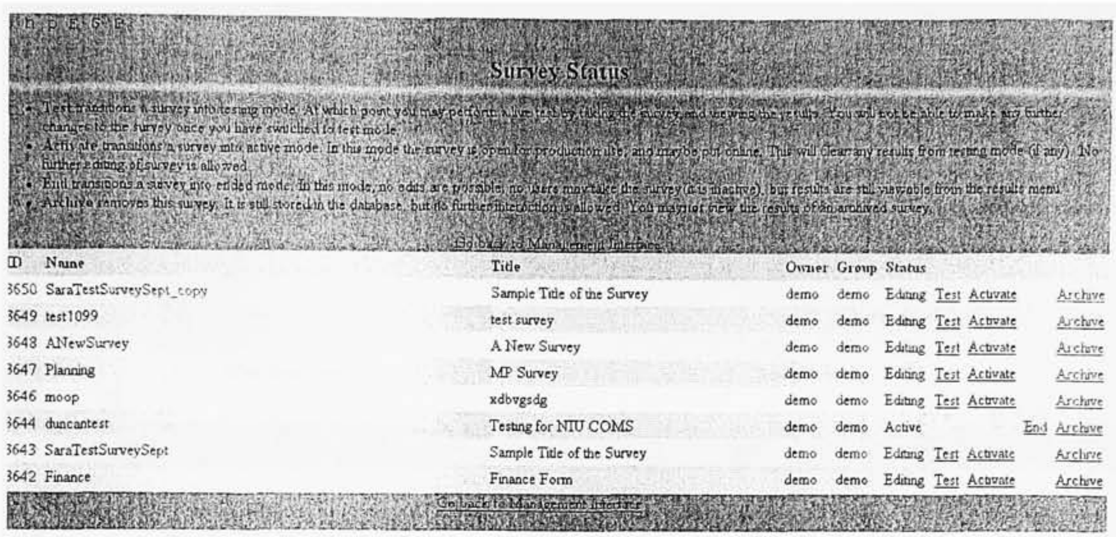


Figure 5. Change the Status of a Survey

Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=status

Recommendations:

- This section of the interface can be improved by explaining the functionality of edit mode. All of the other modes are explained besides edit mode. This might lead to confusion and result in the user making errors. The section should also contain a help section.

Section Name: Change Access to a Survey

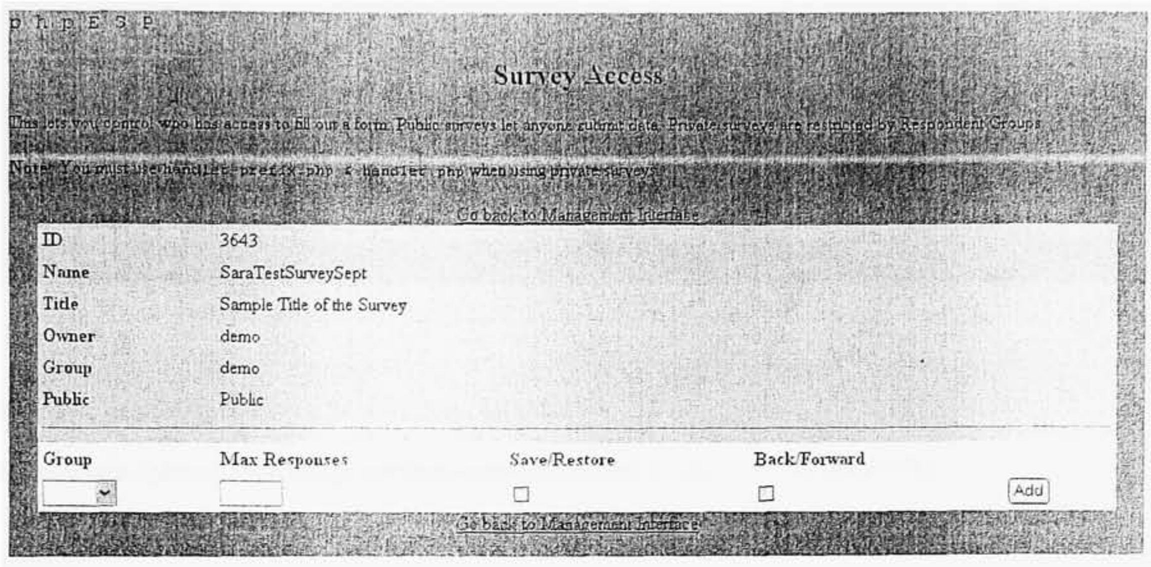


Figure 6. Change Access to a Survey

Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=access&sid=3643

Recommendations:

- The Group, MaxResponses, Save/Restore, and the Back/Forward functions are not explained anywhere in the system. Implementing unclear functions in the interface will lead to errors because the users will not understand how or when they should be used.

Section Name: View Results from a Survey / Error Message

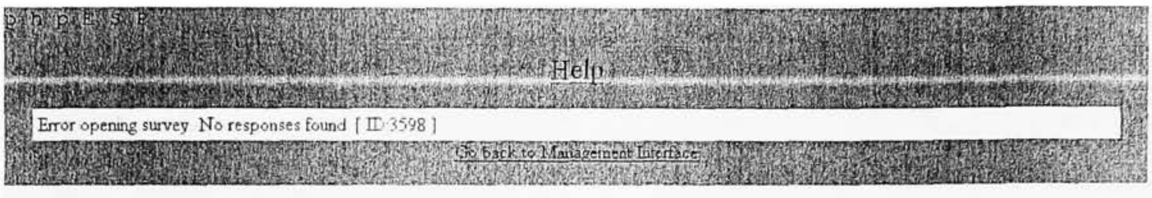


Figure 7. View Results from a Survey / Error Message

Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=results&sid=3598

Recommendations:

- The error message that notifies the user that he/she can not view the results of a survey because no responses have been submitted can be improved. The current error message says, "Error opening survey. No responses found. [ID:3348]". The error message should state the title of the current survey along with the ID. Stating the title of the survey in the error message would provide the user with an additional cue so that he/she could more easily identify the survey. Using multiple cues in the error message will result in fewer errors because multiple cues reduces memory load.

Section Name: View a Survey Report

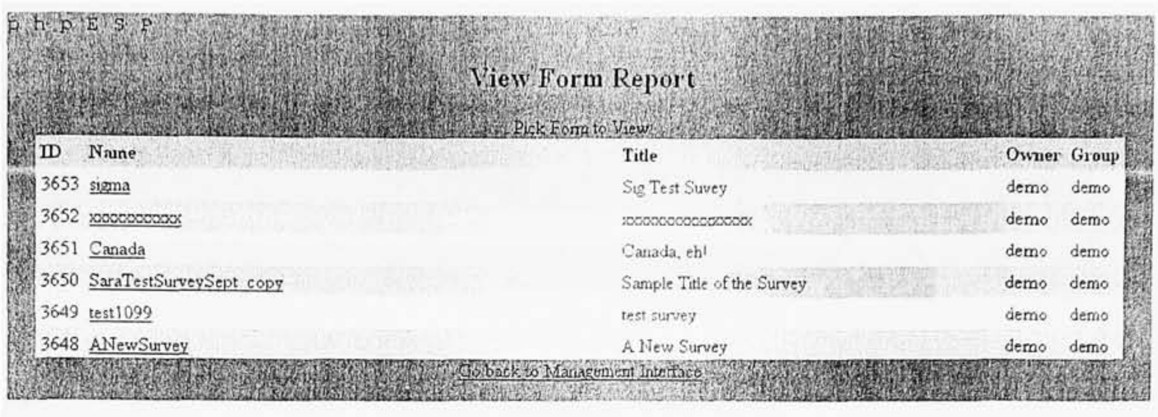


Figure 8. View a Survey Report

Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=report

Recommendations:

- Correct the title and the link labeled View Form Report so that the user does not have an increased memory load because the names are inconsistent.

Section Name: Export Data to CSV/ Error Message

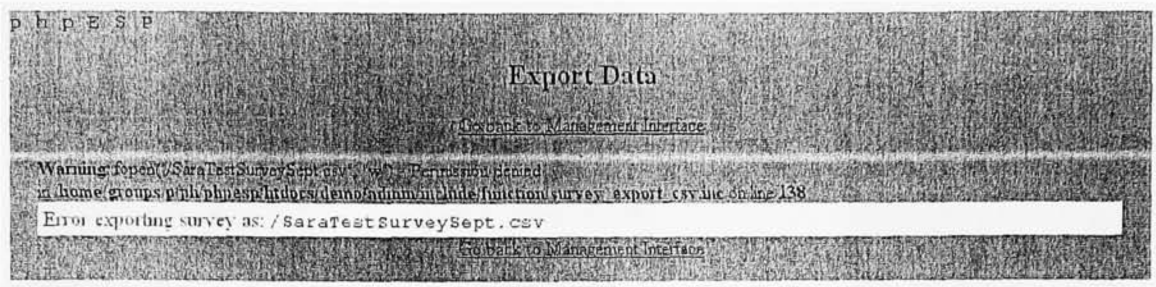


Figure 9. Export Data to CSV/ Error Message

Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=export

&type=csv&sid=3643

Recommendations:

- The error messages in this section should be altered. Currently, the user encounters the following error message when their is a problem exporting the survey as a CSV. The error message states:

  "Warning : fopen ("/GPP.csv", "w")- Permission denied in /home/groups/p/ph/phpesp/htdocs/demo/admin/include/function/survey_export_cvs.inc on line 138".

  The error message represents a problem opening up a file named GPP.csv . The file is being opened so that the survey information can be written to it. The error message can be improved by telling the user that a problem has occurred when the file, GPP.cvs, was being opened and therefore the survey information could not be written to the file. The error message should also clearly label the path to the file and tell the user to check the permissions on the file.

Section Name: Manage Designer Accounts

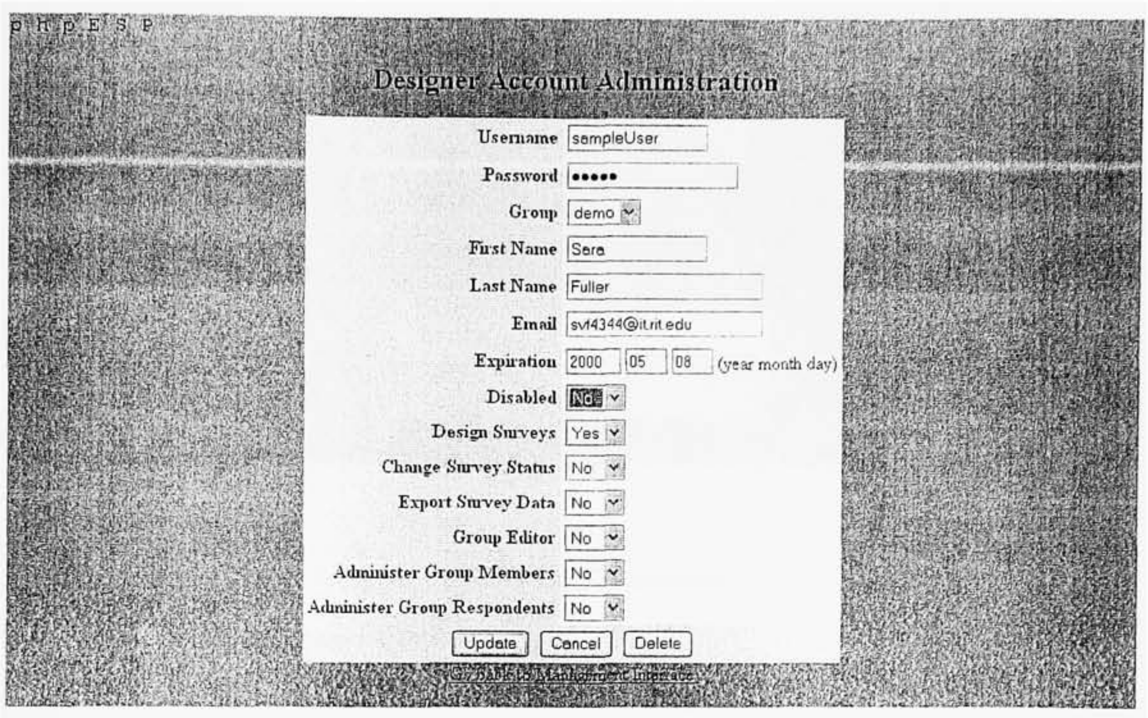


Figure 10. Manager Designer Accounts / Designer Account Administration

Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=admdesigner

Recommendations:

- Invalid data can be entered when the user is creating or updating a designer's account. Specifically, invalid email addresses and expiration dates can be entered. The user should be given an error message so that latent errors do not occur. For instance, latent errors could result in some designer's not being able to use the system because their account has expired.

Section Name: Manage Designer Accounts / Upload Account Information

Figure 11. Manage Designer Accounts / Upload Account Information

http://phpesp.sourceforge.net/demo/admin/manage.php

Recommendations:

- The options add a new designer and the bulk upload feature should be links on the management interface page. Making the new designer and the bulk upload feature a link on the management interface will cause the user to pay more attention to the functions. Also, according to the theory of least effort users will be more likely to use the functions because they are located at the top level of the interface.

Section Name: ***Log Out***

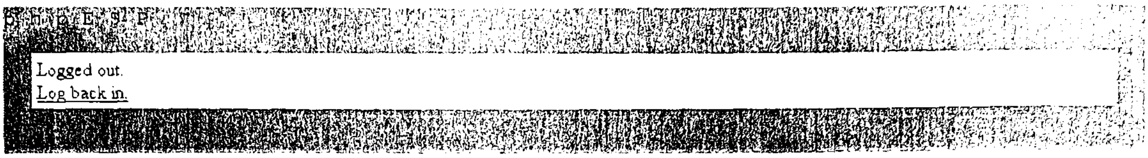


Figure 12. Log Out

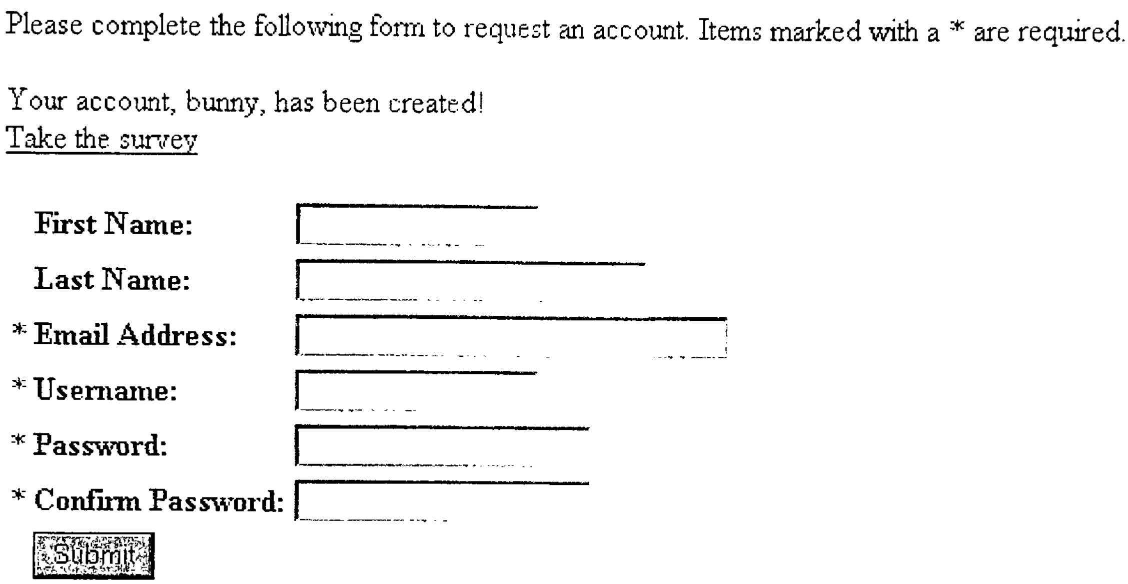
Source: http://phpesp.sourceforge.net/demo/admin/manage.php?where=logout

Recommendations:

- Currently, the demo version phpESP does not actually prompt the user to log in when they select the login link. The interface can be improved by implementing the login function. Overall, the screen is good because it does not contain any extra functions that would distract the user.

Recommendations: Respondent Interface

Section Name: Registration Page


Please complete the following form to request an account. Items marked with a * are required.

Your account, bunny, has been created!
Take the survey

First Name:
Last Name:
* Email Address:
* Username:
* Password:
* Confirm Password:
Submit

Figure 13. Registration Page
Source: http://polaris.it.rit.edu/~svf4344/mastersPro/public/signup.php

Recommendations:

- The registration page could be improved by applying the style sheet that is used when the user is taking the survey. Applying the style sheet would enable the user to more easily identify the survey during the registration process. Also, the link labeled take the survey should be changed to include the name of the survey. Applying the style sheet to the registration page will result in fewer errors because the page will be consistent with the other pages in the interface. Changing the link will also decrease the likelihood of errors because knowing the title of the survey will decrease the users' memory load.

Section Name: Login Page

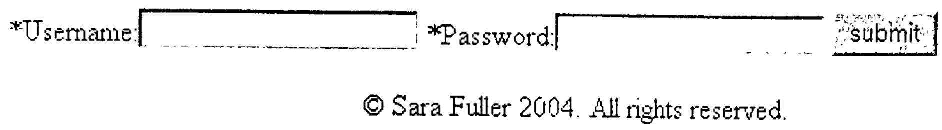


Figure 14. Login Page
Source: http://polaris.it.rit.edu/~svf4344/mastersPro/public/test3.php
?name=testSurveySaraFuller

Recommendations:

- First, a link should be added that allows the user to obtain their password via electronic mail. Second, a style sheet should be applied to the page so that the user is aware of the survey that he/she is logging into. Third, the required fields should use a star that is the color red like the other sections of the interface do. Enabling the user to retrieve their password via enable will reduce errors because it reduces the amount of effort that the user has to put forth to log in. Finally, users will be less likely to commit errors when an interface is consistent. Therefore, the color of the stars should be adjusted and a style sheet should be applied.

Section Name: Active Survey

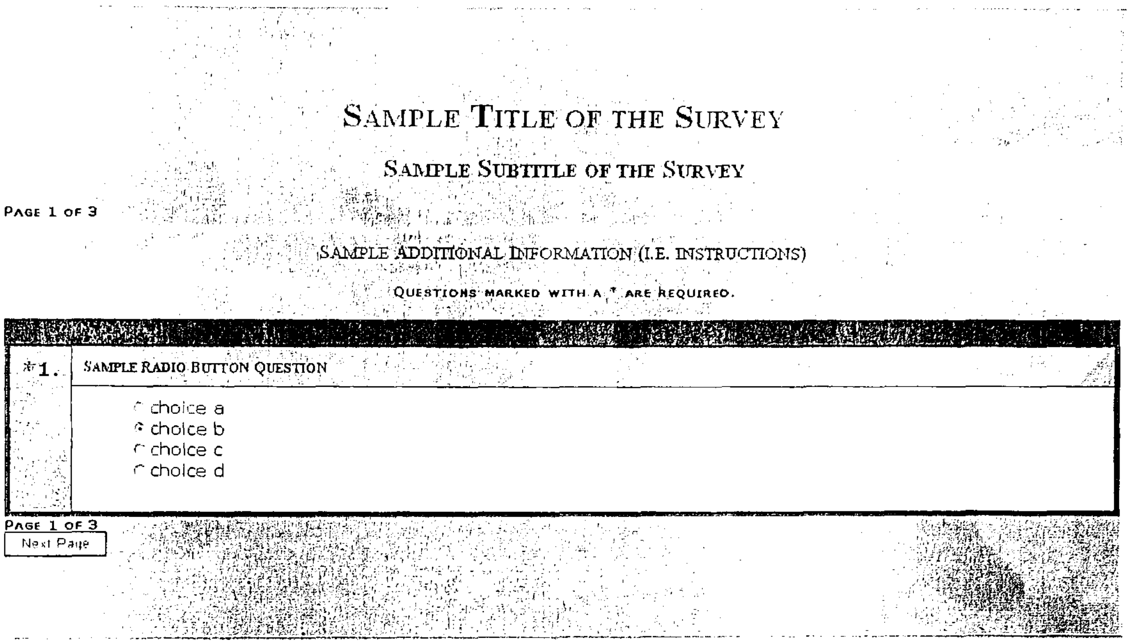


Figure 15. Active Survey

Source: http://phpesp.sourceforge.net/demo/public/survey.php
?name=SaraTestSurveySept

Recommendations:

- Implementing a few additional features would greatly enhance the survey section of the interface. One drawback of the interface is that the questions that do not require answers fail to give the user appropriate feedback. For example, a user may not answer a question because he/she forgot or was distracted. It is crucial to the user's self-monitoring process to receive a message that informs him/her that he/she did not provide an answer for the given question. Only when a user is made aware of a potential error can he/she detect or correct it. Users should also be given an opportunity to check their answers before they are submitted so that they can detect and correct any errors that they made. Allowing the user to log back into the survey and continuing where they left off can also enhance the interface.

Conclusions

Interfaces can be improved by applying research findings about human errors. In order, for interface designers to apply the research findings to user interfaces they must develop a method. First, the designer should establish guidelines that he/she can follow during the entire lifecycle of the interface. One way to create a guideline is to create a table that lists some of the theories and research findings associated with human error. Next, while the designer is critiquing the interface he/she can note the extent that each element in the table is utilized. Analyzing the web survey system phpESP demonstrated some of the common flaws in interface design that can be linked to human error research. Designers that know the causes of human error and how they are studied will create interfaces that will decrease the probability of user errors.

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