# COGNITIVE BLINDNESS—LOOKING FOR SOURCES OF HUMAN ERRORS WITH PRODUCT INTERACTIONS & INTERFACES

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**ABSTRACT**

While it's easy to determine the physical characteristics of users (at least in a face-to-face situation), the cognitive characteristics are elusive. Most individuals don't even know if they have less than average working memory capacity or if their personality undermines their ability to notice detailed information. As product designers, we tend to design for ourselves first—if we can't use it, chances are it won't work for others as well. But if the product's interface serves its designer well, it's no guarantee that it will serve its audience with equal success. Cognitive blindness is a term used here to recognize the difficulty we all face when it comes to knowing how others think and how these cognitive processes are different from our own. For a simple example, consider the ability to remember a photographic image. Are you better then most at this task? How can we compare and judge the quality of visual memory? Did a person focus on details or the overall effect? Was the composition or color scheme more memorable? Did everyone see the same color? But while judging the quality of memory is difficult, finding errors is easier—did the person remember the color of the butterfly spots or not? This paper analyzes some common sources of human errors and provides a few suggestions for design compensations. The main theme is to design with human errors in mind: every product will fail, but designers can minimize and mitigate the most common errors and those with the worse outcomes.

**KEYWORDS**

Interaction design, interface design, human errors, cognitive blindness.

## 1. INTRODUCTION

Cognitive blindness refers to the recognition of the difficulties designers face when they try to imagine cognitive differences between themselves and their users. The result is that educational designers focus on designing products that are intuitive to them, but not necessarily so to their student users. Users make mistakes, experience frustration, and develop negative attitudes towards products. One solution to cognitive blindness is a design process that focuses on common roots of user errors. This article explores memory, attention controls, perception, language, background knowledge, cultural differences, and others cognitive characteristics as sources of product interaction failures.

## 2. MEMORY ERRORS

When it comes to product's interaction and interface failures, most users complain of inability to "find that button" or not remembering how to use the something. In analyzing user errors, we're starting with memory failures. It’s important to remember that students using technology to farther their education have to learn and become comfortable with the technological platform delivering educational content as well as the learning materials themselves.

**Cold Recall vs. Recognition.** Cold recall and recognition deal with long term memory access (Woolfolk, 1998). As with any good library of information, the quality of the index system is key to success. Long term memory filing and retrieval differs in efficiency from person to person and from subject area to subject area. Expertise in a particular domain implies a high-quality index to long term memory data. Many memory errors can be traced to a person's inability to pull up the right bit of information at the right time (Jonassen & Grabowski, 1993).

It's easier to choose from a list of options rather than pull information from memory. Cold recall requires a great degree of familiarity with content, with subject matter knowledge. But even an expert can find himself struggling to remember a term or a formula that is not part of his everyday discourse. Icons, illustrations, drop-down lists are all methods to elicit recognition in the user and to limit the search space for the correct choice (Mandel, 1997). They effectively place the needed information into the environment.

**Working Memory Overload.** Working memory is where all the thinking takes place. It's where we manipulate ideas that we pull from long term memory, store interim solutions, and examine observations coming in from our senses. But working memory is very limited. The common proverb, "he's able to walk and chew gum at the same time," is the commentary on the limitations of working memory. It's very difficult to do multiple tasks simultaneously— working memory gets easily overloaded and we lose track of important information (e.g.: the next sequence in a complex routine, the first digits of the telephone number, car keys).

In a continuous effort to present more and more information at the same time, interaction designers can easily create working memory overload in their users. While designing interfaces that rely on recognition, product creators have to keep in mind the limitations—most individuals can only hold in mind and compare a few items at the same time (Shneiderman, 1998). Thus the recognition search space has to be reasonably small to support the users and limit the errors. In situations where the consequences of a wrong action have catastrophic results, working memory limits needs to be given top consideration.

**Anxiety & Working Memory.** Anxiety is a working memory hog—the preciously limited resource of working memory is easily reduced even farther by the feelings of stress (Jonassen & Grabowski, 1993). In anxious people, most of the working memory is taken up by processing the feelings about the situation rather than analyzing the problem at hand. If a person is spending most of her working memory on worrying, then she has less working memory capacity to dedicate to the task itself. This is why some students are not good at taking tests—they might know the material, but the stress of the test situation diminishes their mental resources (Bransford et al., 2000). Anxious individuals don't deal well with uncertainty and require a lot of support. They also require a great deal of structure when they first encounter a new instructor, a new material, a new technology, or a new situation. Setting and meeting the expectations of anxious product users increases the probability of success and satisfaction with the product.

## 3. PERSONALITY-BASED DIFFERENCES IN ALLOCATION OF WORKING MEMORY

**Observers vs. Introspectives.** Some personality traits can be described in terms of dimensions that specify how individuals allocate their working memory and attention. One such dimension specifies whether an individual predominantly focuses on information coming from his senses—such individuals define the Observer end of the continuum—or on information streaming from internal dialogue—an Introspective end. We all do a bit of each, filling our working memory with thoughts, but some do more of one then the other. Thus observant people pay attention to the information that arrives through their physical senses, directly observing surrounding tangible reality and allocating most of their working memory to sensory input. Introspective individuals prefer to direct their attention inward, using their senses to gain impressions, which are then amplified by their imaginations. Introspective individuals tend to do a great deal of unconscious background synthesis; they pay attention to their thoughts or an internal dialogue. There are three times as many observant individuals than introspective ones in the American population (Keirsey, 1998).

**Schedules vs. Probers.** Another personality train continuum is the Schedulers to Probers dimension—a trait dealing with perception, processing, and comfort level with time management. Probers like to take risks and are comfortable with uncertainty. Schedulers are the exact opposites—they tend to be judicious, while probers are open to options. Schedulers make agendas, timetables, programs, lists, syllabi, calendars, outlines, registers, and so on, for themselves and others to follow. Probers keep their eyes open for chances to do things they want to and for opportunities and alternatives with which to avail themselves (Keirsey, 1998). Clearly, students who fall on the schedulers end of this continuum tend to do better at school and are able to cope well with independent study situations.

**Observers and Probers: When the Combination of Personality Traits Undermines Working Memory Performance .** Individuals with a personality that combines both observing and probing traits make up about 38% of the general population (Keirsey, 1998). For individuals with this personality type, it's all about the process; the end result is less interesting. And the process needs to be enjoyed—an individual with this personality will eventually (sooner rather than later) abandon an activity if he is not having a good time. If the activity is too repetitive or has little variation, it is not a good activity for this group. Thus drill and practice will not hold these people's attention for long (Gregorc & Butler, 1984). Lectures and presentations should be short, and so should reading assignments—this group works and learns in small-sized chunks (Werby, 2008A).

This is a group that jumps from one activity to the next and is impulsive. Thus the content has to grab a person and hold the users' interest in order for them to succeed. Games and simulations work really well. And these individuals thrive in problem-solving situations that challenge their skills. They are willing to take risks to succeed. They love hands-on activities and multimedia presentations. And they are very good at negotiating.

If bored, a person with an observing and probing personality is likely to act out, poking others, banging on furniture, and otherwise being disruptive. These individuals crave excitement and fun, even at work. They can be annoying to others around them, as they start far more projects than they ever complete.

From data, this group is the least represented in universities and colleges and has the lowest correlation between ability and school performance (Keirsey, 1998).

**Environment Induced Errors.** The amount of concentration one can bring to bear on a task depends, in part, on the number and quality of the distractions. Environment affects the working memory—anxiety and stress about a particular situation affects individual performance. A simple demonstration of the environmental effects on working memory is difference in performance of three digit multiplication problems while standing on a table in front of an audience as opposed to sitting at the desk (Werby, 2008A).

## 4. GROUP DYNAMICS AND ERRORS CAUSED BY INTERPERSONAL MISCOMMUNICATION

The structure of a group project can support or undermine the success of the enterprise. People talk a lot about collaboration and cooperation without real understanding of the difference and its impact on the group dynamic. When a hundred Russian peasants dragged the barges up the river, they worked together, collaborating on every pull of the rope. But when a crew of sailors runs a ship, they each have a distinct job to do, even though their goal is the same. Do these sailors have the same degree of collaboration in their work as the peasants pulling the barge? Clearly, there's a difference. Collaboration and cooperation are not identical in meaning or in a group dynamic (Werby, 2007; Dillenbourg, 1999).

In a cooperative interaction, the overall goals are shared by all of the participants of a group, but the work load can be distributed in many different ways. Cooperative group members can make different contributions to the whole: some might take charge of the project's scheduling, some produce graphics and/or written materials, and others provide data. If group members work on different parts of the project, it's important to analyze the individual contributions and responsibilities to the whole. The relevant questions are: “Are all participants equally responsible for the overall project?” and “Are there disparities in work loads?” In a cooperative task, the work load does not have to be distributed equally among the group and usually is not.

Collaboration, on the other hand, specifies that group members work together on all aspects of the overall project: all contribute to writing, managing, data collecting, and so on. Making this distinction between collaboration and cooperation is helpful to set clear expectations of work load upon individual contributors to a group project. In collaborations, everyone knows each other and each other's capabilities, groups tend to be small, and projects limited in scope. In cooperations, some group members know each other and some don't. Cooperative groups can be large with members having limited knowledge of what others are doing, and group members can come and go during the project's tenure.

Individuals in both cooperative and collaborative projects share goals for the overall project and contribute their work towards achieving those goals. The relevant variables to consider during the initial group organization are (Werby, 2007):

• Duration—Is it a one-time thing or a continuous collaboration? Is it short-term or long-term working arrangement?
• Number of Participants—Are there a lot of individuals involved or few?
• Degree of Required Participation—Do all collaborators contribute the same amount to the job?
• Volition—Are the participants collaborating out of self-interest or out of necessity? Who generates the necessity?
• Constitution of the Group over Time—Are the same people collaborating for the duration of the project or are individuals free to come and go?
• Reward—Is the collaboration set up as a self-rewarding experience or is there an outside incentive?

## 5. PERCEPTUAL ERRORS

**Time & Space Perceptual Confusion Errors.** Sequential/temporal perceptual processing deals with the ability to observe and understand ordered chains of information—strings of data that have sequential patterns or a particular arrangement in time. The sequential processing system tends to be located on the left side of the brain, the spatial processing system on the right (Jonassen & Grabowski, 1993; Woolfolk, 1998).

People with poor sequential/temporal processing have trouble in making and keeping schedules. They are always late and have poor time management skills. These individuals might also have trouble understanding a sequence of instructions, have issues with recipes, and are poor at following directions.

Spatial perceptual processing deals with the ability to figure out visual patterns and to arrange information spatially. Geometry problems, mathematical graphs, chess board positions are all examples of spatially arranged information.

People with poor spatial processing tend to have closets that look like there has been an avalanche of socks. They have trouble managing and keeping track of their possessions. Their desks are messy. And they tend to have problems reading structured visual information—graphs are difficult, tables are hard, mathematical equations seem out of reach (Levine, 2002).

There are wide differences between individuals in their abilities to interpret, store, and communicate sequential/temporal and spatial information (Werby, 2008B). Clearly, if a person has poor sequential/ temporal and spatial perceptual processing skills, she will have trouble remembering such information and will experience stress when forced to deal with sequential/temporal or spatial data, further burdening her already overwhelmed working memory.

The interaction with sequential/temporal and spatial information can be broken down to (Werby, 2008B):

• Perceiving—an ability to figure out a pattern of sequentially or spatially arranged data;
• Remembering—the ability to remember a sequential or spatial pattern of information;
• Making—the ability to create, organize, or arrange information in a sequential or spatial pattern (this includes time and materials management); and
• Thinking—the ability to solve problems, to reason, and to think critically about sequential or spatial information.

An individual can be good at remembering sequential or spatial patterns of information, but be lousy at creating such patterns. Just as there are many more good readers than there are good writers, there are far fewer information architects than there are consumers of well organized information.

**Level of Detail.** If you've ever played a game requiring you to find hidden images inside a thematically unrelated illustration, then you know that some find these games easy while others struggle. The difference is how widely or narrowly one can focus the perceptual field. The ends of the continuum in the level of detail of perceptual processing dimension are Focusers and Scanners (Woolfolk, 1998; Jonassen & Grabowski, 1993). Scanners direct their attention actively and freely to all parts of the field. They miss a lot of detail and have a wide range focus of attention. Focusers have a narrow focus of attention and a restricted attention to fewer facets of their surroundings, but they notice more details from that limited field.

Focusers tend to miss the overall structure of interaction design, while scanners tend to misplace buttons, links, and directions. Certain professions require individuals to be closer to one spectrum then the other. Editors, for example, have to be able to narrow their focus or they'll miss too many mistakes. Impressionist painters are just the opposite. It's good to know the audience that is being targeted by the product so that interaction designers can create appropriate tools.

**Colorblindness.** About ten percent of the population is color blind to some degree, males being the overwhelming majority. The percentage can be higher among certain ethnic groups (e.g.: in a Jewish male population, colorblindness can reach into 20%). Red/green confusion is the most common form of colorblindness. A significant proportion is not even aware of their problem. Given such a high incidence of colorblindness among the population, it seems only prudent not to use red and green cues as a way of conveying differing information.

## 6. ATTENTION CONTROL ERRORS

Attention controls regulate how individuals manage their working memory (Levine, 2002; Werby, 2008A). Failures due to multitasking directly result from inadequate attention controls under taxing environmental conditions. Having a painting come into a visual filed, for example, is not the same as seeing the painting by directing the attention to perceiving and processing of visual information—focusing the cognitive resources on the painting. Many user errors result from poor attention controls or inability to pay attention to the right thing for just the right amount of time.

**Perceptual Blindness.** Perceptual Blindness is an attention control error—it occurs when individuals focus so intently on a task that the miss obvious information coming in through their senses. Selective attentional focus in combination with limited working memory resources can be the source of many user errors.

Daniel J. Simons of the University of Illinois and Christopher F. Charbris of Harvard University conducted an experiment designed to test our ability to process visual information (as opposed to our ability to see using our eyes). They asked a group of students to watch a video of a group of basketball players passing the ball to each other. The students were instructed to count how many passes were made during a certain period of time. After 35 seconds, a man in a gorilla suit ran into the field of players, beat his chest, and ran out of the room. When the researchers asked the students whether they saw a gorilla, 50% said no!

How could a group of visually healthy students miss the appearance of a man in a gorilla suit? They didn't expect a gorilla, and so it slipped past their perceptual processing, which was occupied with counting the basketball passes. In fact, when these students saw the video again, they accused the researchers of switching tapes! To read more about this experiment, visit http://viscog.beckman.uiuc.edu/djs_lab/

It's good to keep in mind just how much of an impact our expectations have on our ability to control our attention controls and to process information. This is particularly relevant in analyzing eyewitness testimony in criminal cases.

**Autopilot Errors.** Autopilot errors occur when we are very comfortable doing something—we are experts at performing the sequence of actions (Norman, 1998; Werby, 2008A). For example, we rarely end up at a store when we are driving around looking for a particular address. So anytime a person is asked to perform the same action over and over again with only an occasional variation, there is a strong chance that autopilot errors will arise. Such errors are the bane of factory assembly line workers and can lead to serious injuries.

**Absentmindedness Errors.** Have you ever caught yourself putting your reading glasses in the refrigerator instead of the milk? Or throwing away the present instead of the wrapping paper? In both cases, you knew what you had to do—put the milk in the refrigerator or clean up the mess—but you just stopped paying attention to what you were trying to do. The result was that you performed the right action on the wrong object (Norman, 1998; Werby, 2008A). This is an example of an absentmindedness error.

There are individuals who excel at absentmindedness. If you talk to them, they know exactly what they need to do, but somehow it always turns out wrong. They put on pajamas when they should be getting dressed for work. They pack the wrong book into their bags, not because they don't know what to take, but rather because they stopped paying attention to what they were doing. They work on the wrong assignments or save papers in the wrong file. These peoples' actions are not intentional and thus are not remediable by punishment or even embarrassment. It's the job of an educational product designer to save these people from themselves!

**Interruptus Errors.** An interruptus error occurs when you forget what was being done in the middle of an action. You opened the refrigerator but then forget why you were there—it just slipped your mind. You were trying to make a point, but forgot what you were going to say—you lost your train of thought. In both cases, working memory got overloaded with other thoughts or outside resulting in an awkward moment. These are also examples of attention control errors—failure to keep the ideas in working memory by paying attention to them (Norman, 1998; Werby, 2008A).

A relative of interruptus error is completion error. Completion errors result when there is an interruption in mid multi-step action. The person is distracted and either skips steps or fails to finish the task all together. Completion errors occur in environments where multiple people or tasks vie for the attention of the individual, making it difficult to focus attention on a particular task. A perfect example is emergency rooms of a busy hospital. A doctor or a patient can easily get working memory overload and fail to complete a task or a procedure.

People who daydream a lot or who get easily preoccupied or distracted suffer interruptus errors all the time. The same is true for anxious individuals—most of their attention is taken up by worrying, leaving only a small sliver of working memory space to deal with current reality.

Interruptus errors can be particularly damaging for individuals who have a smaller than average working memory. These people already have a hard time managing the in and outflow of information. If, on top of this limitation, their attention easily wanders away from the task at hand, their performance suffers.

**Mode Errors.** Mode errors result when a device has multiple modes of operation, making an appropriate action in one mode give an erroneous result in another (Norman, 1998; Werby, 2008A; Carroll & Thomas, 1982). My microwave examples aside, this is the familiar remote control error—you press the play button for the DVD while the remote is in a TV mode and nothing works as expected. This is just another form of attention control error.

Unfortunately, as devices get smaller and smaller, designers rely on one button to do multiple actions, thus spawning numerous mode errors. And while they seem harmless (you can always just try switching modes), some people never get comfortable with the operation of some devices due to multiple functionality of controls. And in cases like car radio buttons, which tend to do double duty as CD controls, drivers can get into accidents while they fiddle with mode controls.

Note that these kinds of errors are different from the ones when a person just doesn't get how to use their remote—one is an attention error, the other in a background knowledge error. Understanding these types of errors makes it possible to try to design educational products that help student and teacher users avoid them.

## 7. CULTURAL AND SOCIAL ERRORS

Cultural errors focus on the differences between large groups, differentiated by political borders, language, and history. Social errors result from local variations and customs among people speaking the same language, living in the same country, and sharing the same history. (Werby, 2008A)

If we had to think through all of the implications of each social situation, we would get very little done. Fortunately, for most ordinary circumstances, we rely on scripts—a collection of expectations of dialogues and actions that fit specific interactions. We have restaurant scripts and doctor office visit scripts. And as long as everyone follows them, we feel comfortable to devote less then our total working memory capacity to each situation.

Cultural errors arise when our everyday scripts don’t match those of another culture with which we have to deal. Thus the errors are not only in language fluency, but also in the choice of culturally appropriate responses given a particular situation. For example, if after asking an individual “How are you?” the person launched in a lengthy discussion of personal vows, we would be shocked at the inappropriate response. For Americans, this question is not a question but a polite way of say hello.

Social errors focus on unfamiliarity of interpersonal interactions of a small subgroup of individuals: employees of a particular company, members of a profession, students in a specific school. Creating a unique set of interaction scripts can identify group members and single out outsiders.

## 8. LINGUISTIC ERRORS

Many people talk about language barriers as the cause of user errors. Obviously it pays to be more specific—the more designers know and understand the source of user errors, the easier it is to design products that compensate for those failures. Like memory errors, communication failures come in many different flavors, requiring different design solutions. One of such communication breakdowns is discussed below.

Language provides access: access to information, access to community, access to social status, access to employment. Language is embedded in culture and inseparable from it. We talk about street language and scientific discourse—both might be based on the English language, but the vocabulary, the turn of phrase, and even the sound of the words are quite different. It's easy to speak the same language and still be unable to communicate. To join a community, to become a member of a social group, you have to learn its language.

Communication Barriers (Werby, 2008A):

• Lack of common language
• Colloquial variations
• Insufficient vocabulary
• Incomplete subject matter knowledge
• Cultural differences in tone, emotional style
• Divergent communication styles

Product interaction is a form of communication: it's a dialogue between the product designer and her audience. To be understood, product designers have to speak the language of their audience. They have to become part of that community of users, at least temporarily.

## 9. BACKGROUND KNOWLEDGE ERRORS

**Formal versus Informal Domain Knowledge Errors.** Background knowledge refers to individual’s expertise in a particular subject matter. It’s composed of formal background knowledge—information learned in formal educational settings like schools—and informal background knowledge—information that is picked from the environment through observation and other informal means. Informal background knowledge can be incorrect and still produce accurate predictive results to quarries (diSessa, 1993). For example, the sun orbiting around the earth results in similar predictions to the earth revolving around the sun. Knowledge acquired through formal means can also be inaccurate—it’s easy to misunderstand a concept taught in math or misremember a history date, for example.

Users base their decisions of the information they have access to, in particular to their personal background knowledge. Thus it’s important to know the level of expertise among the user population for which the product is designed.

**Inappropriate Mental Models.** A mental model is a mental representation of how something works (Norman, 1983 & 1988; Young, 1983; Carrol & Thomas, 1982; Kieras & Bovair, 1984; Halasz & Morgan, 1982). People have thousands of mental models of devices they use everyday: computers, calculators, cars, cameras, camcorders, cats, coffee makers, c-sections, coolers, spray canisters, rice cookers...

Mental models evolve based on observation. Unfortunately, people are not very good at making accurate observations. Individuals tend to pay attention to things they think are relevant and omit those that don't seem to be connected to the object of interest. Thus it's easily decide that two events form a pattern even when they have nothing in common other then spatial or temporal proximity.

Understanding the mental models that the users are likely to bring to the products is key for designers. Interaction designers can help users form more accurate mental models by creating diagrams or making action-sequence links more visible. Optimally, designers want to maneuver the user into taking a single action—the only obvious and right thing to do with the product.

Like mental models provide explanations and could be right or wrong and they might generate good predictions or bad. And mental models can be completely wrong and still have pretty good predictive powers.

Users have lots of mental models, but so do product designers. And designers are not immune to generating wonderfully outlandish ones. But the mental models don't end with product designers; they get released into the world through the products they create. Mental models don't only affect how users interact with products. They also change how designers approach them.

## 10. CONCLUSION

Designing of errors should be a common approach to solving interaction and interface design problems. It’s important to understand the origin of errors to be able to design appropriate solution and improve user experience. This paper touched briefly on a few frequently encountered errors and their origins. Most errors can be traced to attention controls, memory, perception, language, cultural differences, and circumstances under which the product is being used. Cognitive blindness describes the difficulties that product designers have visualizing the cognitive differences between themselves and their users.

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