

Using Visualization to Enable Decision-Makers

This paper briefly introduces some of the many cognitive tasks that are involved in the decision-making process, and describes some issues surrounding these tasks. Next, it describes how visualizations like decision diagrams (or decision trees, as they are often called) can assist decision makers by reducing their cognitive load and taking advantage of humans' advanced visual processing capabilities. This paper closes by analyzing a real-world decision-making problem related to the author's current work, and provides an example of a decision diagram that may help make the process easier.

Cognitive Underpinnings of the Decision-Making Task

A seemingly infinite number of cognitive tasks are involved in decision-making. However, these tasks can be organized into the following categories:

- Acquiring Relevant Information
- Manipulating Information
- Managing Environmental Constraints and Individual Factors

Note: Although organized into neat, linear categories for the purposes of this discussion, the cognitive tasks involved in decision-making are actually part of a complex, iterative process. Decision-makers frequently switch between cognitive tasks with little conscious thought (Albers 1999, pp. 156).

Acquiring Relevant Information

A broad category of cognitive task inherent in any decision-making situation is the acquisition of relevant information. Acquiring relevant information first requires the decision-maker to limit the complexity of the problem space by defining it, understanding it, and then decomposing it into smaller, more manageable components (Albers 1999, pp. 154, 156). Defining a problem in an appropriate way requires the decision-maker to ask the right questions and consider all of the problem's dimensions (Albers 1996, pp. 59). It requires decision-makers to keep the context of the problem

in mind (also described as “maintaining situation awareness”), which helps to ensure that the problem is being framed in a fashion that allows relevant data to be gathered (Albers 1999, pp. 154, 156). Thus, the decision-maker is immediately thrust into a complex situation that requires much mental exertion and whose outcome (of many smaller decisions) greatly affects any further decision-making efforts.

If the decision-maker believes the problem to be adequately scoped, the next step involves actually locating information that is relevant to the decision-making task (Albers 1999, pp. 155). There is an extraordinary amount of information available to any decision-maker from the external environment. Therefore, the next cognitively challenging task for the decision-maker is to filter out irrelevant data without overlooking information that is truly relevant (Albers 1996, pp. 61; Tegarden, pp. 8). The constant and wide variety of signals in our environment all demand our attention and use of our limited perceptual resources, making this filtering difficult. Nonetheless, “we have to choose what to recognize and process” (Decision Making Process Page). Although the strategies used to filter information differ by decision-maker, they are typically influenced by environmental constraints and individual factors. (See “Managing Environmental Constraints and Individual Factors” on page 3.) Not surprisingly, the scoping of the problem space and the success of information filtering strategies are also tightly intertwined. It has been shown that the complexity of a problem space inversely affects the quality of a person’s decision-making strategies. In other words, the more complex the problem seems, the more simplistic (and thus more error-prone) a person’s heuristics for making a decision become (Albers 1996, pp. 61-62). In complex problem spaces, therefore, a decision-maker’s information filtering strategies are more likely to be impaired.

Manipulating Information

Even if the decision-maker gathers relevant information, he or she must also work at understanding or comprehending that information (Albers 1996, pp. 63). This cognitive task involves “encoding,” or transforming data into propositions that will be incorporated into the decision-maker’s mental model of the problem situation (Cognitive Technologies Page). Of course, a complete mental picture of the gathered information can not be established if the decision-maker has not also identified relationships among that information. Decision-makers establish these relationships by “relating it to their real-world situations,” drawing inferences, and comparing the information to that which resides in their existing mental model (Albers 1999, pp. 154-156). Perceiving relationships among information may also require the decision-maker to evaluate trade offs (Sauter, pp. 114), confirm intermediate choices, and estimate the consequences of their actions far into the future (Albers 1999, pp. 154).

When a decision-maker allows a new piece of relevant information to enter their field of attention, that information must also be integrated into the existing mental model by adjusting the model appropriately (Albers 1999, pp. 154). Studies have shown that the order people receive information and the presentation of the information affects how it is evaluated, so these factors may influence how a decision-maker organizes the new data into their existing mental framework (Albers 1996, pp. 62-63). Albers states:

“The user constructs meaning from the information; the quality of the resulting construction depends on the effectiveness of the presentation. The amount of perceived cognitive effort seems to be the driver in how different presentations affect assessment strategies” (1999, pp. 62).

Not surprisingly, leaving the decision-maker unsupported in the task of integrating information has also been shown to have a negative impact on decision-making abilities (Albers 1999, pp. 155). For example, if a decision-maker is unsure about their understanding of information, they are likely to make assumptions that may not be accurate (Albers 1996, pp. 63). Therefore, it is also a cognitive requirement that the decision-maker continuously examine the quality of the assumptions underlying information (Sauter, pp. 114).

The cognitive tasks described here may affect the decision-maker’s definition of the problem space as well as the type of information that may be relevant to the decision-making task. Therefore, as decision-makers move between acquiring and manipulating information, they are also responsible for determining when they have collected a sufficient amount of information that will allow them to make a good choice (Albers 1999, pp. 154). In other words, decision-makers are also responsible for deciding when there have been enough iterations between information acquisition and manipulation.

Managing Environmental Constraints and Individual Factors

In any discussion of the decision-making process, one must not fail to consider the cognitive energy decision-makers expend to manage environmental constraints and any individual, internal factors that may have a bearing on how decision-makers arrive at their decisions. The external decision-making environment in most situations is characterized by uncertainty, unpredictability and change (Albers 1999, pp.154; Decision Making Process Page). Additionally, the information needed to make a good decision may be completely elusive to the decision-maker, and thus, judgement about just “how good” a decision must be must be derived from knowledge about the

expectations of others and other performance criteria (Albers 1996, pp. 58-63). The decision-maker's acceptable level of risk is also affected by these environmental factors (Albers 1996, pp. 62).

Furthermore, the urgency under which most decision-makers must choose can negatively affect their strategy for processing information, causing them to "focus on certain regions of the data...[that] can lead to erroneous decisions." Under [both uncertainty and] time constraints, the decision-maker's need for closure of the problem increases, as does their tendency to justify existing decisions and ignore conflicting data (Albers 1996, pp. 62-63; 1999, pp. 155-156). Interruptions and other distractions in the decision-maker's workplace have the same effect as time pressures: the trade off between cognitive effort and accuracy of the decision becomes a primary consideration (Speier, et. al., pp. 23).

Lastly, the ways in which an individual decision-maker approaches decisions can be influenced by past experience, values, ethics, morals, goals and plans (Albers 1996, pp. 63; 1999, pp. 156; Sauter, pp. 112). In sum, both external factors (related to the decision-making environment) and internal factors (related to the individual decision-maker's experience and social beliefs) may add to a decision-maker's already high cognitive load when they are faced with difficult choices.

About Decision Diagrams (Decision Trees)

Harris defines a decision diagram as "a graphic representation of alternative decisions or actions that might be taken, plus potential outcomes [that is, consequences] resulting from those decisions and actions" (pp. 130). Decision diagrams are comprised of several nodes connected by lines (paths) that indicate the relationships between them. Paths coming out of nodes may lead into decisions (represented by a square) or uncertain outcomes (represented by a circle) (Decision Tree Analysis Page). A pruned branch (a choice that people typically would not choose) may be indicated by double slashes through it or by graying it out. Typically, moving from left to right in a decision diagram indicates a forward movement through time (Decision Diagrams Page). Depending on the problem space, decision diagrams may be small trees or extremely large trees that all-too-clearly illustrate the complexity of the problem and thus, the decision to be made.

Like other cognitive enhancers, decision diagrams help overcome some limitations of the human mind by externalizing the information and thereby freeing up cognitive resources (Cognitive Technologies Page; Tegarden, pp. 13). Decision diagrams provide this assistance because they incorporate all the basic principals of a cognitive

enhancer: visualizing, chunking, labeling, contiguity, and contingency (Cognitive Technologies Page). Decision diagrams provide a “broad overview” of the information (Tegarden, pp. 15) and use humans’ innate visual processing capabilities to “increase the amount of data decision-makers can process without overload” (Tegarden, pp. 9). Decision diagrams can assist decision makers by helping them chunk information into functional (that is, memorable) groups (Tegarden, pp. 14) and by providing a structure that allows decision-makers to see relationships in the information (Tegarden, pp. 6). Additionally, decision diagrams are beneficial because they:

- Use spatial location to assist with searching tasks
- Aid the decision maker in making perceptual inferences (Tegarden, pp. 11)
- Encourage comparisons among options and allow all options to be challenged (Decision Tree Analysis Page; Tegarden, pp. 15)
- Focus analysis (Tegarden, pp. 6) while helping to identify areas requiring further exploration or consideration (Tegarden, pp. 6, 12)
- Illustrate the risks and rewards associated with choices (Decision Tree Analysis Page)

Because of environmental constraints and the sheer magnitude of the problem space, a decision-maker’s desire for problem closure is high and thus, so is their tendency toward cognitive narrowing. In almost all situations, therefore, decision diagrams provide the decision-maker with reminders about alternative information that may disprove their existing mental model (Albers 1999, pp.155-156).

Although all of the previously described benefits provide a solid case for using decision diagrams, when it comes down to it, decision diagrams can only “help us make the best decisions on the basis of existing information and best guesses” (Decision Tree Analysis Page).

Analysis of a Real-World Problem

Although indexing is a required component for releasing BEA documentation, it is a task that requires much cognitive effort on the part of the technical writer and is often done days (if not hours) before the documentation is generally available (GA). As such, writers must first decide how much effort to expend to create an index for GA, and by what methods that index will be created. Additionally, the high cognitive demand the actual indexing task places on the writer—coupled with extreme time constraints—can result in narrow decision-making strategies for selecting index entries that can negatively impact the quality of the index. Therefore, this analysis focuses on some of the decisions a writer should make when creating an index.

Note: See “Creating an Index Using Adobe FrameMaker + SGML 5.5 - Memory, Motivation, and Anxiety” (Hocko) for more information about the cognitive demands of indexing tasks.

Indexing Preliminaries

- Is an index necessary? If readers can locate all the information they need from the table of contents, then the writer may omit the index. If not, an index must be created. (BEA templates require an index, but it may remain empty until post GA if there is not adequate time for indexing.)
- Is there adequate time to create the index? If not, the writer may have to settle for doing a short, simple index. Otherwise, may be able to do a longer, more thorough index if it is warranted.
- Is the writer skilled at creating indexes? If a novice, the writer can use the IXGen indexing tool. If an expert, the writer may prefer to do the index by hand. (The IXGen tool can remember a limited number of previous entries and therefore is good for simple, but not necessarily thorough indexes. It can also be frustrating for expert indexers.)
- Does the writer doing the indexing have a strong sense of how their audience will search for information? If yes, the index may be shorter and simpler because there is less uncertainty. If no, then index may be longer and more thorough to account for “mystery” audience needs. (BEA writers do not typically have a good sense of this.)

Adding Index Entries

Notes: Many of the considerations listed here are adapted from Merriam-Webster's Manual for Writers and Editors.

Indexing decisions made by BEA's indexing template are not addressed in the diagram because they are not decisions to be made by the individual writer. The diagram represents a limited view of the MANY indexing decisions writers must make, because to include them all would be out of scope for this assignment.

- Does the word or phrase appear in the preface or glossary chapters, or is it located in a chapter summary? If yes, do not add to the index. If no, proceed.
- Is the word or phrase defined in text or appear in the glossary? If yes, proceed. If no, is the word or phrase likely to be looked up by a reader? If yes, proceed. If no, do not add to the index.
- Is the item to be indexed a word or phrase? If a word, should it be singular or plural? If subentries are likely, the word should be plural. Otherwise, it depends.
- Should a subentry be created? If creating a subentry does not create more than three levels of index entries, proceed (BEA standard). Else, reword the entry. Is the main entry very long or contain many undifferentiated page numbers? If yes, create a subentry.
- If the phrase is a main entry, should it be arranged in natural or index order (rearranged to get keyword in the first position)? Is the phrase an adjective-plus-noun or noun-plus noun compound? If so, do not invert. Would the reader benefit from the natural order of a compound? If so, use natural order. Otherwise, invert.
- If the phrase is a subentry, should inverted or natural order be used? Should subentries begin with a preposition or conjunction or be rephrased so that the preposition/conjunction follows the keyword? Or should the preposition/conjunction be omitted entirely? (This may affect alphabetization, conciseness of index, reader understanding.)

The attached diagram represents the author's attempt to visualize these parts of the problem, and was drawn following the instructions provided on the Decision Diagrams Page and the Decision Tree Analysis Page.

References

- Albers, M.J. (1996). Decision Making: A Missing Facet of Effective Documentation. In Proceedings of the 14th Annual International Conference on Marshaling New Technological Forces: Building a Corporate, Academic, and User-oriented Triangle, pp. 57-65. New York, NY: ACM Press.
- Albers, M.J. (1999). Information Design Considerations for Improving Situation Awareness in Complex Problem-Solving. In Proceedings on the Seventeenth Annual International Conference on Computer Documentation, pp. 154-158. New York, NY: ACM Press.
- Cognition & Instructional Technologies Laboratory (CITL). (2000). Cognitive Technologies Page. <http://citl.tamu.edu/cognitive-tech.htm>. Accessed 28 February 2002.
- Harris, R. (1996). Information Graphics. Atlanta, Georgia: Management Graphics.
- Hocko, J. (2000). Creating an Index Using Adobe Framemaker + SQML—Memory, Anxiety, and Motivation. Unpublished assignment for Foundations in Human Factors Course at Bentley College.
- Institute for Strategic Clarity. (2001). The Decision Making Process Map Page. <http://www.instituteforstrategicclarity.org/dmp.htm>. Accessed 28 February 2002.
- Merriam-Webster. (1998). Manual for Writers and Editors. pp. 238-271. Springfield, MA: Merriam-Webster Incorporated.
- Mind Tools (2002). Decision Tree Analysis Page. <http://www.mindtools.com/dectree.html>. Accessed 28 February 2002.
- Sauter, V.L. (1999). Intuitive Decision-Making. In Communications of the ACM, 42 (6), pp. 109-115. New York, NY: ACM Press.
- Speier, C., Valacich, J.S., and Vessey, I. (1997) The Effects of Task Interruption and Information Presentation on Individual Decision Making. In Proceedings of the Eighteenth International Conference on Information Systems, pp. 21-36. Atlanta, GA: Association for Information Systems.
- Stibel, J.M. (1999). Decision Making, Consumer Choice, and the Internet. http://www.internettg.org/newsletter/mar99/decision_making.html. Accessed 28 February 2002.

Tegarden, D. P. (1999). Business Information Visualization. In Communications of the Association for Information Systems,(1) 4, pp. 1-37. Blacksburg, VA: Pamplin College of Business, Virginia Tech.

Vanguard Software Corporation (2000). Decision Diagrams Page.
<http://www.vanguardsw.com/dphelp/dph00100.htm>. Accessed 28 February 2002.

