# DEVELOPING SAFER SYSTEMS IN A NPP ENVIRONMENT USING THE OPERATOR'S COMFORT PARAMETERS AND VIRTUAL REALITY

S. Alenka Brown-VanHoozer, Ph.D.

Argonne National Laboratory
P.O. Box 2528, MS 6000
Idaho Falls, ID 83403



Submitted for Publication at the

Symposium on Human Factor Management and Organization of Outages in NPPs: Impact on Safety

Agence DE L'OCDE Pour L'Energie Nucleaire
OCED Nuclear Energy Agency
Stockholm, Sweden



June 19-21, 1995

## DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

# DEVELOPING SAFER SYSTEMS IN A NPP ENVIRONMENT USING THE OPERATOR'S COMFORT PARAMETERS AND VIRTUAL REALITY

**DR. Alenka Brown-VanHoozer**

Argonne National Laboratory
P.O. Box 2528, MS 6000
Idaho Falls, ID 83403

## ABSTRACT

*The contents of this paper is based on two studies involving the design of visual displays from the operator's point of view, and the utilization of virtual reality for operations, training and maintenance repairs. The studies involve a methodology known as Neuro-Linguistic Programming (NLP), and its use in strengthening design choices from the user's perspective model of the environment. The contents of this paper focuses on the results which may be implemented in nuclear power plants for the purpose of providing systems which are less inherently error prone.*

## INTRODUCTION

*"The decisions made to model systems into image displays have a disadvantage because of the cognitive phenomena that decisions are unobservable internally to the mind, so there is no completely empirical way to describe and measure decision processes. However, we can use several other types of methods, one of them being mental representations of how people make decisions based not on the actual data available to them, but on how they represent or perceive the data presented to them,"* (Helander 1991, 999).

Users can always adapt to their systems through sheer need or "brute" force, based on prior experience or intelligence. Intelligence or experience, however, is not the point of this paper. Instead, this paper focuses on the importance of how users access and process information and its significance. By ignoring the importance of the integration of the user interface at the information process level, the result can lead to inherently error prone systems regardless of the skill level of the operator/user.

Therefore, to minimize or eliminate these errors in human-interactive systems, it is essential that designers understand how each user's processing characteristics affects how the user gathers and communicates relevant information to the designer and other users. Such a tool at the designer's disposal is a methodology known as Neuro Linguistic Programming (NLP).

## NEURO LINGUISTIC PROGRAMMING

*"...the basic premise of NLP is that there is a redundancy between the observable macroscopic patterns of human behavior (e.g., eye movements, hand gestures, voice tonality) and patterns of human of the underlying neural activity governing this behavior,"* (Dilts 1983, 3).

In other words, individual behavioral indicators are indicative of their neurological indicators. By observing the two, the designer can establish the user's "favored representational system" and cultivate a rapport with which to attain explicit information about a system or situation from a **willing** operator/user.

*"When NLP was first used to study subjective experience, the structure of meaning was found to occur in the specific sequence of the representational systems a person used to process information. These representational system sequences are called **strategies**"* (Bandler and MacDonald 1988).

*Work Supported by U.S. Dept. of Energy, Nuclear Energy Programs, under Contract W-31-109-ENG-38.

*Synesthesia*

*Synesthesia "is the crossover connections between representational system complexes, such that the activity in one representational system initiates activity in another system"*

*Hearing* a the sound of a particular voice causes your stomach muscles to *tense* is an auditory-kinesthetic synesthesia.

These synesthesia patterns constitute a large portion of how the human processes the information while communicating with others. The correlations between representational system activities are at the root of such complex processes as **knowledge, choice** and **communication.** By replacing missing information (given by the user) in its most concise possible form, specific details (that are required for diminished "error free" systems) are gathered and incorporated into the system's model.

*Seven Categories of An Experience*

The seven categories of an experience is a framework which from the designer can elicit detailed description of ongoing experiences in order that sufficient, high quality, reproducible data, *insofar as that is possible when dealing with human subjects,* is obtained for the calibration process.

It is believed that this model was inspired by Miller's theory of plus or minus seven bits of information possible to be processed by humans. This technique is designed to evoke responses to supply specific answers describing: (1) what the person is doing; (2) how that information is stored by sensory based; (3) what impact the experience has internally; (4) the precise situation in which the person is involved, which includes, but is not limited to: location, time, persons other than subject with whom engaged, etc.; (5) how important the experience is in personal terms for the subject - a rank ordering; (6) what, exactly, *makes* the experience occur, and (7) what it all *means*, to the subject.

Derived from these efforts is the expectation of developing general or specific models that can be applied to the design of visual displays for safe reactor operations that would reduce human error. The focus of both studies was to establish a way to determine how a person accessed and processed information, and how this would relate to the development of more accurate visual displays or system models for safe reactor operations.

## Research Study I: Visual Displays (on CRTs)

This was a general research experiment conducted for the purpose of determining whether there was a correlation between a user's FRS and visual display attributes. The result was the beginning of establishing the users' comfort parameters of the for visual displays.

*Study*

The study consisted of 38 subjects whose FRS were established as well as their likes and dislikes on graphic displays. The FRS were resolved through a video-taped interview and calibrated against both a written instrument and visual examination of the tapes. The focus of the examination was the establishment of individual-specific eye accessing patterns associated with other non-verbal cues and linguistic usage patterns (predicates). A survey was used to provide a crude profile of the person and a basis for speculation from the information that was obtained.

The subjects were asked to complete a survey, answer questions that were used to establish individual strategies based on eye accessing cues, and evaluate six different visual displays from which their comments were correlated with their FRS. The results revealed areas that overlapped between the three modalities and areas that were divided.

*Findings*

Of the 38 subjects tested the FRSs established were as follows: 22 were kinesthetic, nine were visual and seven were auditory. Of the 18 reactor operators that were tested out of the 38 subjects; 11 were kinesthetic, four were visual and three auditory. The mechanical and maintenance personnel tested tended towards being kinesthetically oriented first.

The study showed that the representational systems overlapped in areas of color contrast, standard color and iconic coding, consistency in and between displays regarding color, symbols and text sizes and fonts, and displays in which the information could be quickly accessed, scanned and interpreted.

It was also found that all three representational systems preferred illustrative (iconic or symbolic) visual displays over text or document style displays, though the visually oriented group reported they were comfortable using both. The visual affect of pictorial displays allows for a larger amount information to be processed more quickly with less error. This is supported by the fact,

"*...that icons are faster to "read" compared to text...are easier to learn than text; they are easier to remember and to recognize once we know which one is advantageous (to the process), since recognition is easier than recall,*" (Rasmussen et al 1994, 286).

Also, colors that were "easy-on-the-eyes (less fatiguing)" seemed to be an issue more for the auditory and kinesthetic groups than for the visual group. For example, gray lettering on a black background was difficult to see and caused eye strain and fatigue.

Visually Oriented Individuals

Individuals that were visually oriented did not favor any specific realm of colors. They especially disfavored gray text or lines on black background or fluorescent/extreme colors. These combinations were difficult to see causing eye strain and fatigue, and the concern was with the acuity and resolution (brightness) of the colors. They preferred colors that were "easy-to-see" (no fussiness around geometric figures and text) close up or at a distance. This group considered seven to nine colors comfortable to work with.

Visually oriented people found it comfortable to work with "busy" displays that were not "complex." These users defined "complex" displays as having to consciously construct or create additional geometric pictures in their minds to complete what was being depicted on the display.

These individuals memorizes by pictures, remember what has been seen, and have trouble remembering verbal instructions. They would rather see a picture of text or symbols or read a set of instructions or procedures. These individuals are very observant and cautious until mentally clear about the task to be performed. (Grinder 1991).

Auditorily Oriented Individuals

Individuals that were auditorily oriented favored "pure" earth-tone colors of yellows, greens, blues, reds, orange, etc. and disapproved of colors that were "muddy" (lower levels of saturation), e.g., yellow-greens, green-browns, blue-greens, and so forth. Colors had to be clear (distinct) and of good contrast within the spectrum of "pure" earth-tone colors (again no gray on black). They were comfortable working with no more than four or five different colors per display.

This group preferred a single system be shown per display and relevant information be expressed in an illustrative format. Labeling techniques needed to be used in ways that would explicitly describe the system. Fluorescent colors were a consideration of this group in the color scheme design of visual displays. Sound was a strong factor in the generation of any visual display.

These individuals memorizes by steps, procedures or series and remember what has been discussed; therefore, they have no trouble remembering verbal instructions. These individuals are easily distracted and try alternatives verbally first through internal and external dialogues. (Grinder, 1991).

Kinesthetically Oriented Individuals

Individuals of kinesthetic orientation also leaned towards colors that were earth-tone base and made them *feel bright* (happy, soothing, relaxing, and pleasant), e.g., greens, yellows, yellow-greens, light blues and so forth. Most seem to disapprove of black backgrounds, because of the "negative" feelings that were generated. Acceptable number of colors on a display ranged from five to six, and they preferred displays that illustrated the information of a system in a **dynamic flow pattern**. This group specifically liked tactile feedback responses, i.e., touch screens.

These individuals memorizes and learn by doing. They are physically oriented, and remember an overall impression of what was or is experienced. (Grinder, 1991) They are weak on visual details, however, they are very good at describing process flow.

*The Surveys*

It may be worthwhile to mention the two part survey that was given. Part two of the survey seemed the closest in correlating to the FRS results of the video-taped interviews. What was surmised (but requires more extensive research) is that people access and process written information differently from that of their physical environment. It is this difference that can be seen in when designers give out surveys regarding a product or system and find later that was written by the user did or does not match what was or is being discussed or said by the user.

*Conclusion*

Whether developing visual displays, system models, safety procedures, or process controls for safe engineering controls of NPPs, the designer needs to be aware of the different impacts the three representational systems have on how individuals process information. It would be to the designer's advantage to incorporate the users' comfort parameters that overlap from each of the representation systems: *visual, auditory and kinesthetic*. How this is accomplished will depend on how the designer utilizes the operator's feedback.

Moreover, it is important to realize several issues; (a) that by using the users' comfort parameters, the designer is establishing positive outcomes, (b) he will attain shorter learning curves from the operator/user, (c) will provide a less frustrating work environment, (d) reduce the amount of resistance by the operator/user in accessing and utilizing visual displays, (e) realize the elimination of (or less emphasis on) ***force adaptability*** from the operator/user, and (f) the designer should obtain more reliable and precise information from the operator/user at the conceptual stage of the design model.

## Research Study II: Virtual Reality Models

The focus of this informal study was to use the NLP techniques of meta-model, synesthesia and the seven categories of an experience to develop a virtual environment that closely resembled the operator's mental perspective of the fuel handling system of Argonne National Laboratory's Experimental Breeder Reactor - II. An informal study was conducted using NLP as the behavioral model in a virtual reality (VR) setting.

*Background*

An AutoCAD model of EBR-II was used as the test model for determining whether a VR environment would be feasible in the area of fuel handling for operation and training. This model was designed by Linda Hansen and Charles Weigand of ANL-W.

Operation of the fuel handling system at EBR-II is based primarily on tactile feedback during fuel handling operations, and conceptual visualization as seen in photographs, blueprints, training and operational manuals and through verbal communications. Lack of direct visualization is due to the configuration of the reactor. So, in an attempt to provide the operators with a visual perspective of the system and process that was dynamic and "life-like" a VR model was constructed in a CAVE environment. The research began at the University of Illinois-Chicago (UIC), and was completed and evaluated at Argonne National Laboratory-East in Chicago.

The word CAVE is not an acronym, but refers to the time when man-made fires would project images on the cave walls. The CAVEs at UIC and Argonne are projection-based VR systems that surround the viewer with three screens for walls, and a down-projection screen for the floor. A head tracking device is attached to the viewer so that the computer can calculate for each wall the correct perspective and stereo projections as the viewer moves freely around the CAVE. The walls consist of five screens (three walls, a ceiling and a floor). A sensory based wand is held by the viewer which provides interaction with the virtual environments, (CAVE User's Guide, 1994). The implementation of the CAVE interface requires computation of viewer-centered perspective projections (viewer's orientation within the CAVE), tracking equipment, synchronization of displays and understanding of the projector and tracking limitation. (Cruz-Nelra 1992) The outcome is an experience of immersion (a degree of visual simulation a virtual reality interface provides for the viewer (Cruz-Nelra 1992)) within the model being projected. The EBR-II CAVE model covered three of the four aspects of VR, static segments (the reactor), dynamic segments (fuel handling process), and low-level human-interactive behavioral control (menu selection for operation). The artificial intelligence aspect was not incorporated.

The human factor study (proposed of the VR model) was to interview at least six to nine operators with different levels of training and learning experiences of the reactor and fuel handling system and process. The operators were to describe their experiences and understanding of how and what the primary tank, the reactor vessel and fuel handling system "*looked, felt and sounded like to them.*" By using the NLP techniques a detailed description of the reactor was revealed from each participant, which was then to be applied to the VR model. The final objective was to create a model that included both the users' comfort parameters and their mental image or perspective of the reactor system and fuel handling process.

*Findings*

Six of the nine operators to be selected have been tested. Their experience with the EBR-II reactor ranges from 4-35 years. Based on their FRS and experience, the operators described the system in very "detail" or "general" visual terms of the components and process, or by component functionality and process flow. The following is a brief description of what reactor operator's described.

Participant One

This participant was one of the original operators who had worked inside the primary tank and reactor vessel before the sodium fill in the early 1960's. The FRS of the individual was established to be "*detail*" visual. This where the subject communicates experiences in very explicit visual details. The system described by the individual was portrayed in different shades of color, shapes, sizes, component locations, spatial relationships, and the *feel* of the environment with respect to how the environment was *seen*. Colors ran from stainless steel of dull grays to blue-grays. Recall included how pitch black the internals of the reactor was without lighting, detail description of color and shape of fittings for scaffolds, the size, color and location of each nozzle, the intricate detail of the neutron shield and catch basin, and so forth. Even the color and texture of the scaffold was remembered.

Texture was described with respect to the physical recall of touch of the components and equipment such as; the pipes were shiny or glossy looking and smooth to rough in touch. An example of size was illustrated by the extension of the subject's arms around the storage basket as he saw himself extend his arms around the basket. The fuel handling equipment and process was recounted in just as great visual detail. Haptic remembrance was occasionally referenced for description of the system, but never sound.

Participant Two

This participant has operated the reactor over the last fifteen years, and was not present before the primary tank was filled with sodium. The FRS of this individual was established to be more "*general*" visual. This is where the individual communicates experiences thoroughly, but not in explicit or precise detail. The overall system was described from the photographs, design blueprints and the verbal training received over the years. However, the individual concentrated more in describing the fuel handling system and primary tank based general visual details and component or process functionality rather than in terms of explicit physical characteristics or layout of the reactor components and equipment.

Colors of the equipment or components were defined as different shades of grays of the stainless steel, and other colors equated or was relative to temperature. The individual related the subassemblies to be blue-grays in color, except for the top portions of some subassemblies which were red, blue, and yellow corresponding to the heat generated by the fuel pins.

Distance between components related to what had been seen in the design prints, i.e., the basket was as wide as *probably* his two arms extended.

The individual felt that lighting would be visible inside the primary tank and reactor vessel if the covers to both sections were retracted. The participant thought he mentally could hear an audible sound generated when the transfer arm and subassembly made contact. This, the subject explained, was due to the vibration induced by the two components. The first participant stated that the only sound that may exist in the primary tank was the pumping of the sodium coolant.

Participant Three

This participant has operated the reactor over the last 31 years. The subject was employed before the fill of the primary tank, but never say the inside of the reactor. The FRS of this individual was established to be more *kinesthetic.* The overall system was described from past long experience of verbal communications supported by photographs, blueprints, training manuals, and system design manuals that had been reviewed over the years.

This participant described the reactor and the fuel handling system by their functionality and process flow or operation of the system. When asked to describe the hardware of a component, e.g., the primary pump, the response was in the form of functionality, and the only colors were "stainless steel." Whereas, the first participant described the physical hardware structure of each component and focused less on functionality process. This reactor operator could feel have everything worked and correlated this feeling to how he imaged the process worked and looked like.

*Evaluation*

After describing their perspective experiences of EBR-II, the participants were asked to evaluate an EBR-II virtual reality model displayed in a virtual reality (VR) CAVE environment and on a VR Silicon Graphics Interface (SGI) monitor. The model consisted of three sections: the primary tank, the reactor vessel and the fuel handling components. Each of the sections were created as general models with minimal details. Surface lighting effects (produced through the computer) gave the illusion of different shades of metallic gray.

The first participant described the VR model as very recognizable, the shades of gray were close to what was remembered, certain components needed to be a little more shiny or glossy to reflect stainless steel, and there needed to be more detail to the storage basket and the neutron shield. The shades of gray were exactly what the first participant remembered and the second imaged the colors to be. The dynamic segments of the VR model required minor changes with respect to elevation of the gripper to the hold down mechanism, and the retrieval of the subassembly from the core.

The second participant described the model as "just what he had imagined the internals of EBR-II would look like if he could see it;" however, he felt that more color should be added to the fuel pin area of the subassembly. The dynamics of the model made the image in his mind more realistic and uniform. He felt that overall the model was what he had described, and that sound and touch would be a significant attribute to the model.

Both participants expressed that the model would be an excellent tool for training and operations. The experience of stepping through, atop and into the reactor was captivating for both participants. They remarked how important and less frustrating this type of model would be in helping them to explain to new operators, engineers and maintenance personnel how the reactor operated. They saw great potential in the use of VR as a tool for troubleshooting areas that were not accessable by humans or could not be seen through direct visualization. Their perception of the VR model on the monitor was one they felt could be utilized at the operational and on-site training levels.

*Conclusion*

The work for this study is complete, however the data analysis is on-going. What has been found from this research study is that the user can be asked to describe his/her model in detail in which all deletions, distortions and generalizations are replaced or explain using NLP.

The designer needs to understand that the users' mental models are very significant to the design and understanding of how the users interact with their systems. From their models, the designer can find the flaws and accuracies in the way the system is operated, as well as, the retrieval of each user's mental image of the system. Combined with that of the designer's blue print model, the outcome is a more "realistic" model closer in actuality to both that of users' and maybe the designers with reduced inherent errors.

The feasibility and usability of a virtual reality environment for training, operations (control and safety), research and development is a positive step in the direction of system modeling for understanding how a concept can be applied through seeing, hearing and feeling. All modalities are taken into account, thereby including all three representational systems.

## Summary

The key in the design of successful system models, visual displays, safety operations, etc., is to provide the designer with an effective means of communicating with the user that will allow the designer to "characterize" or "map the design territory" based on the user's model of the system. This will identify and minimize any problems or operator errors at the onset of the initial design, and thereby, remedy any deleterious design in a cost-effective manner. These are the principal thoughts in utilizing NLP methodology in the design of visual displays and systems. Therefore, implementing NLP techniques for design purposes is practical. The challenge comes in developing the model that is capable of matching each user's model of the world. Success will be based on how flexible the designer is with his/her assessment of the model to remain in harmony with that of the user's. By understanding the strategic cues given by the user, the designer has taken the first step in gathering the precise information required for the development of a successful system.

## Reference List


Bandler, R. and MacDonald, W., *"An Insider's Guide To Sub-Modalities,"* Cupertino, CA, Meta Publications, 1-3, (1988).

Bandler, R., Dilts, R., DeLozier, J., and Grinder, J., *"Neuro-Linguistic Programming:The Study of the Structure of Subjective Experience," Vol. I.*, Moab, Utah, Real People Press, 23-24, (1980).

Brown-VanHoozer , S. A. and VanHoozer, W. R., "Visual Displays and Neuro-Linguistic Programming," *Proceedings of the INEL Computer Symposium*, (1994).

*"CAVE User's Guide,"* February 1994. Accessed through the Internet.

Cruz-Neira, C., Sandin, D., DeFanti, T., Kenyon, R. , Hart, J., *"The CAVE: Audio Visual Experience Automatic Virtual Environment*, Publications of the ACM, Vol.35, No. 6. 67, 72 (June 1992).

Grinder, Michael, *"Righting the Educational Conveyor Belt,"* Portland, Oregon, Metamorphous Press, 20-21, (1991).

Lewis, B. A. and Pucelik F. R., *"Magic Demystified: An Introduction to NLP,"* Lake Oswego, Oregon, Metamorphous Press, 5-7, (1982).