

The Information Layering Approach: A Technique for Formally Notating Multiple Communications in a Single Information Display Presentation

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The amount of information that is presented to all of us is increasing rapidly. However, humans don't have unlimited information processing capabilities, and thus can only process a limited amount of that information, which necessarily means that some of the information to which one is exposed to will be lost. However, if that information is important and requires the attention of a user, how can the presentation of that information be presented in such a way that it is not lost? This paper introduces a concept termed "Information Layering" which describes a common but as yet unexamined method of communicating multiple pieces of information through one transmission channel. This paper also presents the "Information Layering Model" which illustrates graphically the concepts behind this model. Finally, a method for notating the specific information layers present on a display is presented, along with thoughts about implementation, application, and future areas of research.

1.0 Introduction

The amount of information being created is increasing exponentially. According to a study conducted at UC Berkeley, 250 megabytes of information are created for every person on earth per year (Varian 2000). This can be attributed to the remarkable technological advances made in recent years, and those advances, as well as those yet to come, facilitate not just the creation of new information but the ability of people to be exposed to that information as well. This would be considered by many to be a positive outcome, however humans are limited in their ability to process this information. According to the well-known study conducted by Miller, human beings can only process and retain approximately seven unique pieces of information (*Miller 1956*) in short term memory. This is especially significant today, as we drown in a never-ending flood of information, continuously trying to sort out what is relevant from that which does not require immediate attention. The combination of limited cognitive space and the ever-increasing amount of information can lead to information overload, which is defined by Sheridan and Ferrell as information received so quickly that the human is unable to interpret and act on that information (Sheridan & Ferrell, 1974) and by Losee as "the economic loss associated with the examination of non- or less-relevant messages" (Robert M. Losee, 1989). Sowell adds to this, stating that when too much information presents itself to an individual too quickly, *information saturation* occurs. In this case, rather than simply ceasing to process the information as happens with information overload, the individual simply attends to all of them equally at a very low level of detail

and comprehension, rather than focusing on those stimuli which possess immediate relevance (Sowell, 1980).

Considering all this, the question then becomes one of being able to present large amounts of information to an individual without overloading their cognitive processes. Domain specific studies and attempts have been made in many environments including aviation (Bart J. Brickman, 2000), education, (Chandler & Sweller, 1991), Web searching (Berghel, Berleant, Foy, & McGuire, 1999), (Rockland, 2000), human resource management (Nordstrom, 1996), and even listening to the radio (Potter, 2000). These are just a small sample; the need to present large amounts of information without decreasing the cognitive abilities of the human is present in almost all domains.

One method by which this is done, and has been done for quite some time, is through a very common technique, which this paper will refer to as *information layering*. This simply refers to the process of communicating multiple messages with a single information display presentation. A very simple example of this type of communication would be the phrase "CURRENT TEMPERATURE STATUS" in red on a screen. On inspection, it becomes apparent that this communication is actually indicating two separate things. Its primary function is to communicate that it is representing the status of the current temperature. Its secondary function is to communicate that the status is 'red.' Red has not been defined here; it may have an inherent meaning such as 'danger,' or it may indicate some other characteristic such as a specific range of temperatures. For the purposes of this example we will assign it a meaning of 'danger,' in line with the traditional western traffic-light definition of green meaning safe or yellow meaning caution. Referring back to Miller's paper, this has now consolidated what could have been two separate communications into one 'chunk' and the user has been given two pieces of information in one transmission. The user's cognitive load is reduced, the attentional load is reduced, and the area on which an individual needs to focus is reduced, all while the overall cognitive and communication bandwidth is expanded. These factors result in decreased response time and increased decision-making abilities (Ricciardelli, Bonfiglioli, Nicoletti, & Umiltà, 2001). Information layering also reduces the issue of *split-attention*, which is defined by Sweller and Chandler in an educational context as the presence of a primary attentional task along with associated secondary, but integral information, which requires the attention of the user to be divided between the two attentional tasks (Sweller & Chandler, 1994). In addition, the authors state that without an interaction between the primary task and the secondary information, the individual must find a relationship between the elements and this can impose a heavy cognitive load. By layering information into one communication, the various layers and their meanings can be attended to simultaneously, ultimately reducing the cognitive load of the user, and increasing response times.

The concept of information layering is not limited to two communications. Stop signs, for example, communicate three messages: The primary communication (stop), and two secondary communications; the color red (danger), and the shape of the sign (octagon), which indicates what class of street sign it belongs.

Up until now, there has been no formal methodology for documenting or even conceptualizing these layers of information, so this paper presents what it terms the Information Layering Model, which allows an analyst, system designer, or interface designer a means for notating all information presentations delivered to a user, even when

those communications are taking place through a single communication channel. Additionally, these are not limited to visual displays, but will also work in the case of auditory communications.

2.0 The Information Layering Model (ILM)

The following diagram illustrates the concepts underlying the Information Layering Model as well as the formal notation used, and a discussion of the model follows its presentation. For this example, we are using a medical environment as the context in which the diagram is applied:

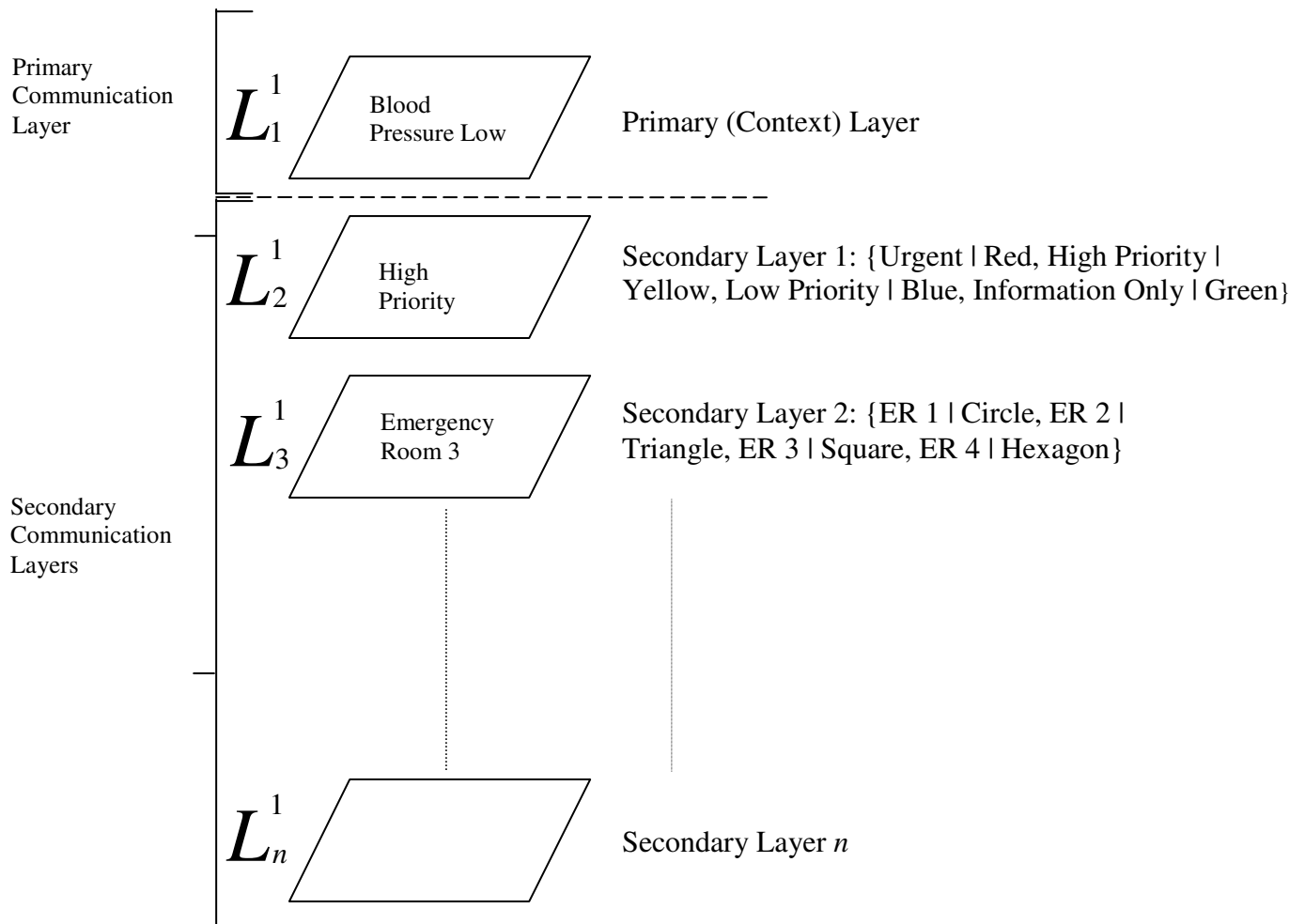


Figure 1: The Information Layering Method

2.1 Layer notation

As can be seen in the above diagram, the Information Layering Model is comprised of 2 main sections. The first section contains a single information layer, termed the Primary Layer and indicated by the notation " L^1 ", the superscript of which

indicates that this is referring to message one. The primary layer of message 2 would therefore be indicated as " L^2 " which allows a way of notating a distinction between all messages communicated in a particular system or interface. The subscript merely refers to which layer is being represented, in this case layer one, or the primary layer. The second section contains multiple informational layers, termed Secondary Layers, indicated by the Primary Layer notation as well a subscript indicating " L_2, L_3, \dots, L_n ." For the purposes of illustration and clarity, this paper will limit this to two secondary layers. While this notation may seem unnecessarily confusing at first, it is important in the case of multiple messages with multiple layers within an individual design. Thus, the third secondary layer of message 2 would be indicated by the notation L_3^2 , making it clear by glancing at the notation that this referenced the third informational layer of message 2. Along with the layer notation, each possible communication that the secondary layers can communicate is notated, along with its associated communication method such as "Urgent | Red." This is referred to as the 'what | how' structure. This is significant in the secondary layers, as these layers can only communicate information culled from a discrete set of lexical terms such as "urgent, high priority, low priority, information only." This is necessary because the information being communicated via the secondary layers is not done so through the use of words but discrete, easily identifiable stimuli, such as colors, shapes, icons, or even sounds. Because there are no words used for communication in these layers, the determination of 'what' additional message is being communicated and 'how' it is being communicated are very important. Currently, the assumption is made that should the discrete set of terms exceed four items, the cognitive overload will become too much for the user especially when there are multiple secondary layers, however this is an issue for further study, and will be discussed at the end of this paper. In addition, the primary layer contains no what | how structure, as its 'what' is always communicated through text.

2.2 Layer Descriptions

The primary layer of the Information Layering Model contains the actual textual communication, the lexical meaning, of the message being communicated. This layer is the most important, as it serves as the context for all other communications from the secondary layers. Referencing Figure 1, the primary layer communication is "Blood Pressure Low." This communication can be any word or series of words in the user's familiar language. This is not the case with the secondary layers, as their meanings can only be culled from discrete sets of lexical terms. Additionally, it has not yet been determined how many secondary layers can be combined before the onset of cognitive overload. In that vein, one of the characteristics of the secondary layers that make them efficient communicators for the purpose of reducing cognitive load while presenting additional information is their reliance on non-textual methods of information communication. These types of presentation methods include such constructs as shapes, colors, and sounds, the variations in which can be assigned to one of the terms included in the set of terms assigned to that particular layer. Clearly, to present a separate word for every message being communicated would be more akin to the user reading a paragraph than it would the user interpreting single discrete terms.

Keeping the above in mind, consider a message communicating the information that your car is low on gas, it is a high-priority concern, and needs to be attended to in the

next 24-48 hours. The first layer, that is, the Primary layer, would contain the lexical communication of the message, that being "low fuel." However there are other bits of information that need to be communicated along with that primary message. Thus, according to the example, secondary layer 1 needs to communicate the additional information that the message is a high priority message. This could be done with a light that is color coded according to a pre-determined scale. For example, a yellow light could indicate high priority, while a red light may indicate urgent. The next bit of information that needs to be communicated is that the condition needs to be attended to in the next 24-48 hours. This could be communicated with a shape. Hypothetically, a circle may indicate 24-48 hours, while a triangle could indicate 12-23 hours. Considering the hypothetical example and the codings discussed, the message would contain a Primary communication layer containing the words "low fuel" with the information referencing the priority of that message communicated through secondary layer 1 via the words illuminated in yellow. Secondary layer 2 would communicate the time frame in which the problem needs to be addressed by presenting the words inside a circle. This would provide three simultaneous channels of information communication though the presentation of only one word. In effect, "layering" information such that it can be presented all at once without overwhelming the user cognitively. The notating of these communications according to the method presented in this paper would then be as follows: L_1^1 : Low Fuel, L_2^1 : high priority | yellow, L_3^1 : 24-48 hours | circle. This illustrates that message one, indicated by the superscript, communicates three individual messages, as indicated by the subscripts. Each notation is followed by a colon, and the layer's what | how structure.

3.0 A mathematic Representation of Attentive Decay based on Layers and Priority

Now that the concept and notation of layers has been established, a mathematic representation of the decay that takes place when attending to a specific communication based on the number of layers and their associated priority must be presented. Fortunately, the representative formula is relatively simple and straightforward, and is as follows:

$$D_{AL} = \frac{L}{P_{AL}} - 1$$

The above formula contains the following variables: D is the decay that takes place based on the number of levels and priority of the attended level, AL represents the layer to which a subject is currently attending, P represents the priority of the attended layer, and L represents the total number of layers. Priority assumes a value between 0 and 1 and can only be assigned by one familiar with the decision-making environment in which the communication takes place.

Below is a table presenting a very brief example of the application of this formula using varying degrees of priority and layers.

Priority	Layers	Decay
.85	7	7.24
.85	4	3.71
.85	1	0.18
.63	7	10.11
.63	4	5.35
.63	1	0.59
.25	7	27.00
.25	4	15.00
.25	1	3.00
1.00	7	6.00
1.00	4	3.00
1.00	1	0.00

The above table illustrates the formula provides the expected results. Considering the first row, if a specific layer has been assigned a priority value of .85, and that layer is part of a group of seven layers, that layer suffers an attentive decay of 7.24. However, if there are only four layers the decay is 3.71. The lower decay value is to be expected with fewer layers; there is less stimuli to distract a decision-maker.

If the priority of a layer is lowered to .63 among 7 layers the decay value rises to 10.11. This is also to be expected; as the priority of a layer lowers, the attentive decay rises since that layer is attended to less. Indeed, further lowering the priority to .25 results in a decay of 27. Moving in the opposite direction, one layer that requires full attention has an attentive decay of zero; there is nothing to interfere with the communication.

4.0 Summary

As technology increases, so does the ability to present ever-increasing amounts of information to people, and in the rush to do so it becomes possible to defeat the purpose of those presentations by exceeding an individuals ability to process that information. This paper presented a conceptual model of the process the author terms *information layering*, and presented a method for formally notating what messages are being communicated through a single information display presentation, and how those messages are communicated. This was accomplished through the use of the layer notation and it's accompanying what | how structure. In addition, a mathematical formula was presented to quantify how the number of levels and priority assigned to those levels affects the attention provided to them. It is the belief of the author that there are five areas in which this notation and its analysis will have impact: Consistency, redundancy, volume, comparison, and evaluation. Each of these areas is described in the following sections.

3.1 Consistency

Consistency is generally accepted as one of the most important of interface design. Schneiderman states that consistency is the first golden rule of interface design (Schneiderman, 1987), and consistency in design has been shown to contribute to a

decrease in error rates and task completion time, as well as an increase in user satisfaction (Park, Yoon, & Ryu, 2000, Ozok & Salvendy, 2000). However, it is also generally accepted that consistency has no formally agreed-upon definition (Nielsen, 1989, Grudin, 1989). For our purposes, consistency refers to consistency among messages in a single information display. That is, the method for communication of a specific secondary layer message is the same throughout the interface, as is the amount of information that each communication carries. Having said that, through the application of this notation, one can investigate the volume of messages being communicated at all primary layers, and then examine the amount of message being communicated at all secondary layers; either for one message, or compare the amount of secondary layers for one message to the others present in the same display. This will allow a designer or analyst to determine that one particular communication either carries too much information when compared to others in a display, or does not carry enough. This will allow the designer to address the issue by either splitting a heavily layered communication into multiple individual communications, or eliminating a message whose primary layer could be incorporated into another message's secondary layer.

Another aspect of consistency lies within the method for presenting information at the secondary layers. For example, if red is used to communicate danger in one message's secondary layer, then it must be used to communicate danger in *all* the secondary layers of all messages. To do otherwise would significantly increase the processing requirement of the user, which as has already been discussed reduces their ability to process information, and more importantly, act effectively on that information. By using information layering analysis, one would be able to determine how consistent secondary layer presentations are across an entire information display.

3.2 Redundancy

By analyzing information layers, one can determine whether a single presentation is carrying more information than necessary. In effect, communicating two messages while presenting three layers. The third layer may contain no specific meaning while still being present, however it is more likely to present a redundancy in presentation. To give a very simple example, a presentation may contain a primary layer of 'Engine Overheating' with two secondary layers comprised of red text that is blinking. However, upon examining the layers, one may find that the red text indicates danger, and the blinking indicates danger. This is a redundancy in layers that becomes unnecessary and the presentation can be simplified easing the cognitive strain on the user. Keep in mind that no formal study of this aspect has been conducted, therefore it is quite possible that the redundancy is necessary, however this would be an application specific issue left up to the discretion of the system designer.

3.3 Volume

One of the main issues driving this report is the issue of cognitive overload. As was described earlier in this paper, this refers to the inability of a person to absorb and interpret information once the amount of information reaches a certain threshold. The notation presented here would allow for the analysis of an information display so determine the immediately apparent messages being communicated, that is, their primary layers, but it would also allow for an analysis of the volume of information being

communicated at all secondary layers as well. This type of analysis would illustrate very clearly exactly how much information is being communicated on an information display at any given time in a much more accurate manner than simply examining the display. This has additional importance as many of the secondary layers may be interpreted subconsciously, or the user may be altogether unaware of them and their meanings.

3.4 Comparison

Unlike the aspect of consistency, which allows for comparisons within a single information display, the Information Layering Method also allows for comparisons between multiple information displays used within the same context. Thus, once completing an evaluation of a display and the communications it contains, one could evaluate other displays used in similar environments, or simply compare their evaluation with others already completed. This would then be able to provide an individual with evidence that a specific message could be effectively redesigned with fewer layers to meet a specific need when compared to the implementation of that communication on another display.

3.5 Evaluation

When one combines the previously discussed four areas (consistency, redundancy, volume, comparison), the issue of evaluation emerges. By using this method to evaluate the consistency of the messages communicated in an information display, it can be determined how much of a cognitive requirement is being placed on a user. In addition, this method can be used to identify which secondary layers can be eliminated altogether, which can be combined with others, which hold to the conventions used in display design when compared to other designs in the same domain, and, perhaps most importantly, which messages need to be split into more than one communication due to their over-reliance on secondary layers.

4.0 Summary and Further Research

This paper presented an introduction to the concept of information layering, which refers to the multiple communications that take place through a single information display presentation. In addition, a method for formally notating the layers was presented which allows a system designer or analyst to evaluate how much information is actually being presented at any given time on a single display. Lastly, a formula was presented for quantifying the decay that takes place regarding a specific layer based on the number of layers and the assigned priority.

However, much is left to determine about this approach. In the diagram used in this paper, secondary layers were limited to two, and the discrete sets that could be used to describe those layers were limited to four terms. However, it is yet to be determined exactly how much is too much, both in terms of the number of secondary layers and the number of identifying terms for each of those layers. Additionally, the interaction between those two aspects will be an important detail to understand. Specifically, if there are x number of secondary layers, it must then be determined how many discrete terms

can be associated with each layer in order to minimize the cognitive load on the user while still maintaining the informational functionality of the display.

In addition, the effect of utilizing the information layering approach on each of the five aspects mentioned (consistency, redundancy, volume, comparison, evaluation) must be investigated. While each of these areas stands to benefit the design of information systems displays, each still needs to be investigated individually as well as what remedies present themselves for each dimension once a concern has been raised. It is intriguing as well to consider how altering an information display based on the findings relating to one of the five dimensions would affect the analysis or manifestation of the other four once that change has been implemented. In other words, investigating how altering the interface design based on one aspect affects, either favorably or negatively, the initial analysis of the other four upon re-evaluation after any change has been made.

The examples used in this paper are very simple one-line messages presented to a user. While they serve admirably as illustrations of the concept, the effect of information layering and how it is best notated must also be examined in much more complex environments. While the analysis of a message presented on an automobile dashboard serves as a reasonable example of the concept, it is still a simple one. The generalizability of the information layering approach to such domains as airline cockpits, air traffic control centers, power plant control rooms, and similar environments was beyond the scope of this report, however the ability of this approach as an analysis tool in those environments should be thoroughly investigated.

Finally, the formula needs to be studied through experimentation with subjects to validate its viability and effect.

These aspects require further study in order to make the information layering analysis approach fully utilizable, however it is the belief of the author that with that information, the ability to design and re-design interfaces that meet the specific needs of the user without overwhelming them while also addressing the needs of the application domain will be greatly improved.

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