HF700: Foundations in Human Factors

Assignment Two: Pre-attentive Processing

Analysis of Selected Software Components: Mass Chromatogram Deconvolution (MCD) System

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Introduction

The Mass Chromatogram Deconvolution (MCD) system is a proprietary application developed for use by lab scientists at a major pharmaceutical company. These scientists work with compositions consisting of pure compounds and some degree of substance impurity, which is usually produced as a byproduct of the chemical reaction. The scientist's job is to determine why the unknown substances exist, and to ascertain their impact on the overall effectiveness of the drug. To extract the data and represent it in a fashion that humans can comprehend, the scientists process the material using a mass spectrometer. This instrument shakes the material and measures the frequencies at which compounds resonate. When the resulting values are plotted on a graph, the compounds exhibit definitive signatures. The MCD system was developed to help scientists visualize such signatures and to automate the process of identifying known components, thereby isolating areas of uncertainty. Using various screens throughout the MCD system as examples, this paper will examine the pre-attentive processing factors that are critical to its successful use in a laboratory environment.

About Pre-attentive Processing

Pre-attentive processing refers to the tendency of the human mind to automatically and selectively organize information captured by our visual sensory system. This is helpful primarily because of the overwhelming amount of visual signals that continuously and simultaneously are perceived with our eyes on a biological level. Pre-attentive processing allows us to discriminate and attend to the "important" aspects of an image, without the need for focused attention (Pre-attentive Processing in Visualization Page; Walters, 112). The Gestalt laws provide the basis for empirical research into the various aspects of pre-attentive processing. Together, these timeless principles and the experiments that follow them allow human factors specialists to reduce the user's level of cognitive effort and create *truly* intuitive interface designs.

Critical Pre-attentive Factors

This section identifies the pre-attentive factors that are critical to the usability of the MCD system. It also provides research-based explanations of why these factors are present in the sensory perceptual systems of human beings, with a focus on how these areas might be used to increase the overall intuitiveness of the design.

Figure/Ground

All interfaces require their users to identify and discriminate among objects to perform a task. In the case of the MCD system, this task is to manipulate the data and use it to identify known substances. As Figure 1 illustrates, the figure/ground relationships present in both the tool icons and the graph that make up the 3D Chart Viewer are critical to the use of the application. The inability to distinguish figure from ground would violate the "fundamental perceptual act of identifying objects" (Ware, 212) and result in a design that would seriously obstruct the prime goal of the MCD system, which is some action on the part of the scientist (Weisstein and Wong, 31).

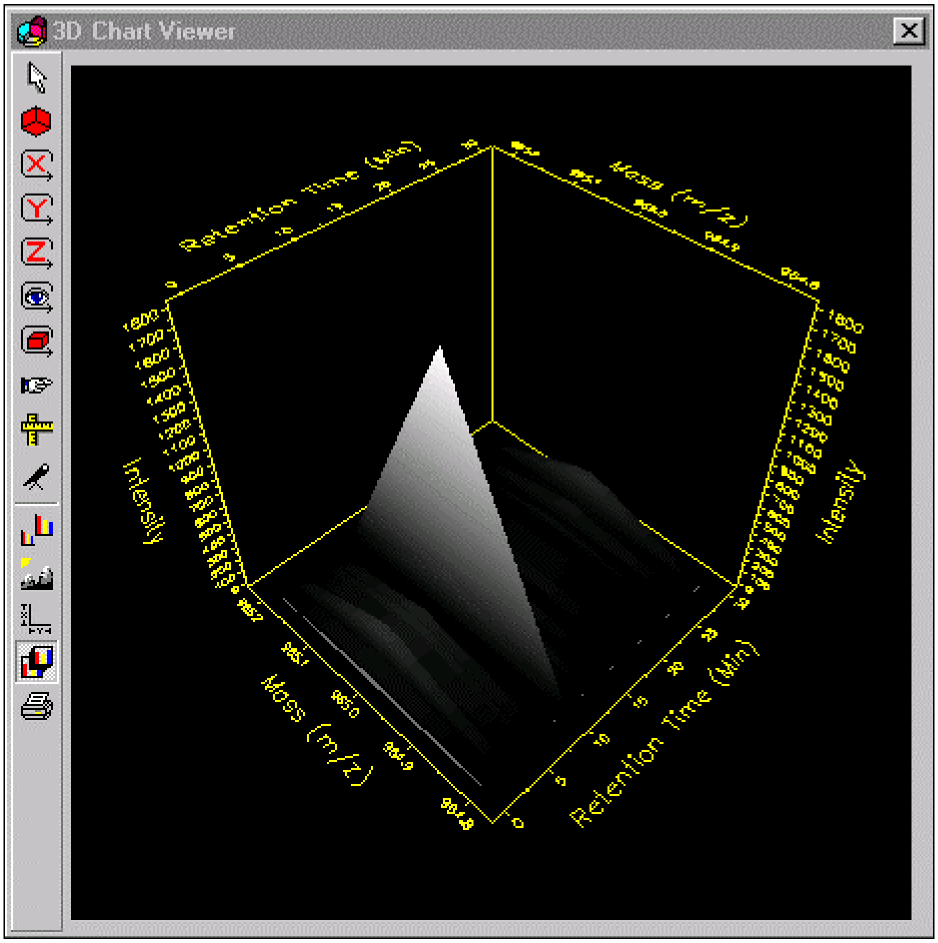

Figure 1 -- 3D Chart Viewer Window

Many of the original Gestalt theories have either been experimentally proven or have given rise to new ideas about perception and figure/ground organization. The icons along the left-hand side of the 3D Chart Viewer support the concept that a figure is a defined structure with characteristics that differ from its associated ground, which is often perceived as a “formless region”. In this case, the gray background provides the formless region while the different shapes and colors of the icons placed upon it create structures that can be differentiated. Furthermore, the smaller area used for the icons (as opposed to the area taken up by the gray column) lends to the user’s tendency to view the icons as figures. The graph portion of the 3D Chart Viewer also demonstrates that “small, surrounded areas [are] more readily seen as figures” (termed the “principle of surroundedness”) and that the color black is one not typically associated with “figure”. Finally, the fact that scientists can use the tools represented by the icons to move and rotate the graph through the space provides another cue (motion) that allows users to associate the graph as figure as opposed to ground (Weisstein and Wong, 31-34).

Grouping/Organization

Grouping and organizing objects is a pre-attentive factor that helps the mind sort through the numerous signals present in our world. Although our attention is not yet focused on a particular aspect of a display, humans can successfully perform many image analysis tasks in less that 250-msec., including target detection (Pre-attentive Processing in Visualization). Many cues received by the sensory perceptual system (categorized by the Gestalt psychologists) provide us with the ability to structure information in this way, including proximity, alignment and similarity.

Proximity and Alignment

Like figure/ground, the concepts of proximity and alignment are critical to almost any system design. Because the scientists often work in a busy lab environment, they may require more design cues to facilitate quick and accurate selection of the appropriate tool. For this application, mistakes in navigation may not only result in one-step backtracking (as in typical Web interfaces), but may also force scientists to abort and restart the process because of carefully defined procedures.

The principles of proximity and alignment can help MCD users by facilitating the grouping of elements, thus reducing the total number of items that require further scrutiny (and effort on the part of the user) (Pomerantz, 7). Figure 2 (shown below) provides a good example of proximity and alignment. First, the X, Y, and Z Axis labels, the Minimum label, and the corresponding text fields (with Auto checkboxes) are located close together (spatial proximity). For the Maximum column, these elements (though not always close in proximity, as in the case of the X, Y, and Z Axis labels) lie along common vertical and horizontal lines. Lastly, the buttons shown at the bottom of the dialog box are spaced far from the other form fields, but close to each other; they are also aligned both vertically and horizontally.

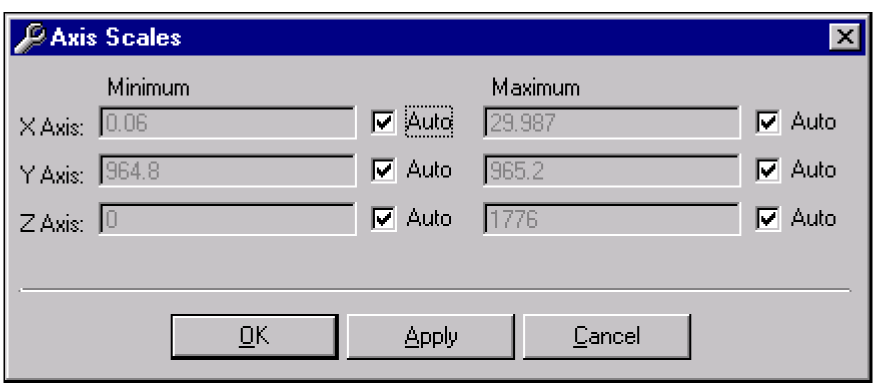

Figure 2 – Axis Scales Dialog Box

According to the Gestalt theories, close spatial proximity increases the likelihood that perceived elements are grouped together. So too, does the fact that the elements exhibit smooth linear continuation (Ware, 203 & 206; Lowe, 22). If this is true, the scientists will pre-attentively group the elements above the horizontal line as one group, and the buttons beneath the horizontal line as another (proximity). Within the top portion of the dialog box, it is also possible that the users will see two subgroups, created by the vertical alignment of the text fields (alignment). This occurs because the text fields are the largest elements within that portion of the dialog box, and humans perceive the simplest forms (that is, the ones that "require the least information to specify") most readily in the pre-attentive arena (Lowe, 22-25). Why this perception may be problematic to users of the MCD system is discussed in *Suggestions for Improvement*.

Similarity in Size, Shape, Color

The principle of similarity is important in the MCD system because scientists can perform a wide variety of activities using the data. While it is obvious that the scientists should understand the difference between these activities, it is also helpful if they can pre-attentively determine a group of tools that perform similar functions. As previously described, this ability reduces the amount of focused attention that needs to be allocated, allowing busy scientists to further scrutinize only a subset of choices for the desired action (Pomerantz, 7).

As an example, there are a number of icons/tools presented in the 3D Chart Viewer (see Figure 1) that allow scientists to perform rotation functions on the graph. The icons shown as , , and  allow scientists to drag the mouse (and thus the graph) about the x, y, or z-axis, respectively. The  (cube) icon is a tool that will rotate the graph freely in any direction, while the  (eye) icon will rotate the graph about a predefined center/view point. All five of these icons are similar in size. The X, Y, and Z icons all use letters of the alphabet and have a circling arrow around them (indicating rotation); they also have the same color and basic shape. The cube icon loses some of the similarity in shape (line forms replaced by a solid cube), but retains the similarity in color. The eye icon not only loses some of its shape similarity, but also gives up the similarity in color.

Both hue and form are pre-attentive visual features. When used separately, these features cause viewers to "rapidly and accurately" determine targets within a sea of distractors. However, when numerous features are modified – as in the case of the eye icon – it is doubtful that users will pre-attentively "see" it as a member of the rotation tools group (Pre-attentive Processing in Visualization). Additionally, the difference in hue (blue as opposed to red) makes it appear as though the eye icon recedes, while the red icons appear to move forward. Since it is important for scientists to view these tools as a group, some modification should be made (see *Suggestions for Improvement*).

Normalizing

Figure 3 shows a dialog box that allows a select group of MCD users (administrators) to assign other scientists to specific profiles. Depending on the user's profile, they will have certain permissions into the system (such as approving or just submitting drugs, test procedures, or compounds). At first glance, the interface appears to utilize a fairly standard design and seems easy enough for the scientists to use. In fact, it is doubtful that anyone has noticed the misspelling of "Members" next to the drop-down menu.

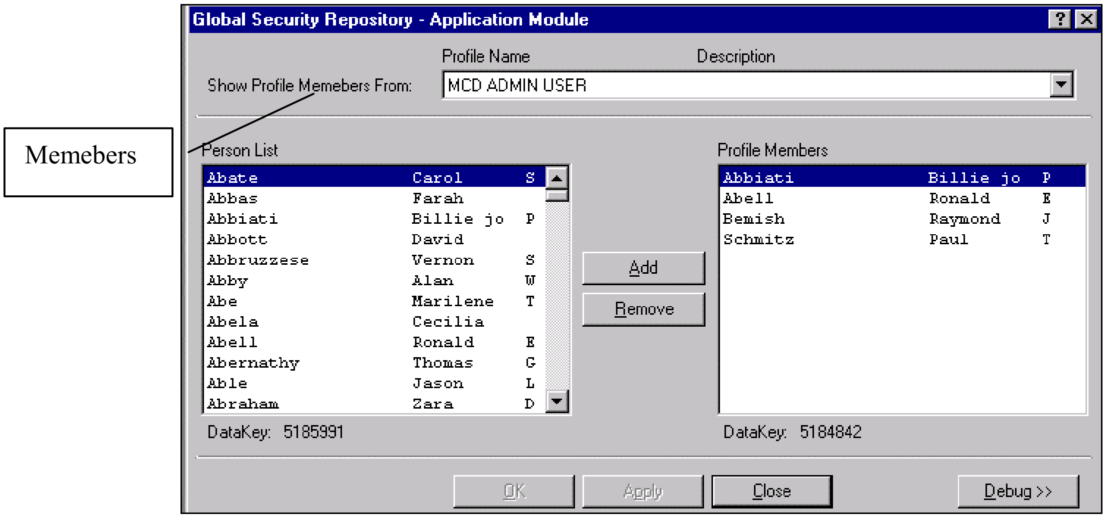

Figure 3 – Global Security Repository – Application Module Dialog Box

Such self-correcting behaviors directly result from the pre-attentive nature of the human visual processing system. As Velmans describes, words presented in contexts that are familiar require as little as 200-msec. for identification. This short timeframe allows for only the first two phonemes of a word to be analyzed. The familiar context then, is what causes humans to automatically complete the word or sentence in question (sometimes inaccurately). But doesn't context require "conscious" or cognitive resources? Surprisingly, no! Research has shown that "consciousness of a given stimulus does not arise until at least 200-msec. **after** the stimulus arrives at the cortical projection areas, i.e. after the identification of a word (in context) has been achieved" (Is Human Information Processing Conscious Page).

Although in this case the normalizing/self-correcting of the word "Members" should not cause any critical errors, it is possible that other, similar flaws exist throughout the MCD system. These flaws could result in errors that have drastic consequences, such as a mistake in substance identification.

A Brief Discussion of Depth

As shown in Figure 1, scientists using the MCD system have access to a 3-dimensional graph of the data, which they can manipulate using various tools. Depth is first created in the wire-frame axes using the "geometry of perceptive" (in this case, the concept that more distant objects appear as though they are smaller) (Ware 275-276). Then, the data set is represented graphically using the same technique, but also adding cast shadows and proximity luminance covariance. Because the image can be manually rotated, it is important that the application recalculate how these depth dues are represented. Although it is generally considered to be a stronger cue for use with motion, the use of proximity luminance covariance can cause the graph to blend too much into the background (as seen in the figure), reducing the amount of information one can see instead of enhancing it (Ware, 294-295).

The question of whether 3-D displays provide more information in recognition than their 2-D counterparts remains unanswered. In fact, it has been argued that such depth information is not necessary for recognition, and that it can potentially be misleading if not used properly. In particular, use of shading and gradients often assumes that regions have a "uniform reflectance", limiting the visualization to simple shape determination (Lowe, 10-12).

Suggestions for Improvement

Overall, the MCD system is designed in a manner that is fairly consistent with the research on pre-attentive processing. In the sub-factor of figure/ground (as shown in Figure 1), it is this reviewer's opinion that no changes need to be made. The icons and graph clearly stand out as figures against two different grounds. It is doubtful that any unnecessary burden is placed on users in this aspect of the design.

Where grouping and organization are concerned (as shown in Figures 2 and 3), this reviewer would suggest slight modifications. The proximity and alignment in Figure 2 is, overall, very good. However, it is important that scientists be able to quickly and accurately distinguish between the form fields for the Minimum and Maximum values of the x, y, and z-axes. This reviewer's recommendation would be to add more space between these two sections (specifically, between the first column of Auto checkboxes and the second column of text fields) so that three (not two) separate groups are pre-attentively distinguished in the dialog box. This will decrease the amount of time it takes users to locate the appropriate area, and allow them to dedicate their focus to determining which particular field requires modification.

With regard to the similarity principle, modification is needed to increase the likelihood that the five rotation elements are pre-attentively grouped together. Keeping the idea of "just noticeable difference" in mind, this reviewer is of the opinion that redundancy in color and shape can be added. Modification might include: 1) choosing a color other than red for all five icons [due to biological factors] 2) maintaining the circular arrow notation 3) using a more similar (wire-like but still different) image for all icons (that is, perhaps use a cube that is not filled in, or a not-so-detailed eye). The proximity of these five icons to others that perform a different set of tasks could also be modified; they should be spatially separated from the others.

Due to the critical nature of the MCD system, the entire application must undergo rigorous quality assurance to ensure that no errors that might be normalized are present. In the example presented, the error was in simple text. However, more investigation (by potential but un-exposed users) should be executed to identify other, potentially serious, oversights.

Although it is probably inconclusive as to whether the 3-D graph aids scientists in recognizing signatures more effectively than would a 2-dimensional representation, this reviewer would make no modifications to the application. The fact that the MCD system also includes a 2-D graph allows scientists to choose which method increases their ability to recognize patterns more easily, and provides a mechanism for confirming possible compound matches.

Conclusion

The consideration of pre-attentive processing in interface design is a useful tool for removing some cognitive burden from the user. Where the MCD system is concerned, scientists working in a non-typical application environment with data that is itself critical would greatly benefit from the design's ability to utilize some of the automatic signals that have been discussed. The density of the information displays within the application often requires conscious, focused effort on the part of the scientist. Granted, because of the seriousness of the task at hand this is often desired, but it should not be required for simple searching and locating tasks. The knowledge human factors specialists have in the areas of both biological and pre-attentive processing factors (among others) should be creatively incorporated into interface designs to guide the user's attention and require it only when it is absolutely necessary. Such careful use of these principles will no doubt make users more productive and less likely to make critical errors.

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