Usability Testing Using Physiological Analysis

GRADUATE PROJECT TECHNICAL REPORT

Submitted to the Faculty of
the Department of Computing Sciences
Texas A&M University-Corpus Christi
Corpus Christi, Texas

in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Computer Science

by

Rita A. Sperry
Spring 2007

Committee Members

Dr. John Fernandez
Committee Chairperson

Dr. David Thomas
Committee Member

Dr. Michael Scherger
Committee Member
ABSTRACT

Because traditional measures employed in usability testing are inherently subjective, it is necessary to develop an objective method for evaluating the usability of a system. This project uses physiological analysis to quantify the ease of use of a Web site, specifically concentrating on the effect of color combinations on the user’s bodily processes. Testing of the system reveals that there is a definite correlation between the results of physiological analysis and subjective user satisfaction surveys. Thus, physiological analysis results can be used in the place of contrived values to assess the usability of a system.
# TABLE OF CONTENTS

Abstract ................................................................................................................................................... ii

Table of Contents ............................................................................................................................... iii

List of Figures ...................................................................................................................................... vi

List of Tables ...................................................................................................................................... viii

1. Introduction and Background .......................................................................................................... 1

   1.1 Background .................................................................................................................................. 1

       1.1.1 Physiological Responses ..................................................................................................... 2

       1.1.2 Web Design Color Theory .................................................................................................. 3

       1.1.3 Previous Work .................................................................................................................... 4

   1.2 Motivations .................................................................................................................................. 6

       1.2.1 Traditional Usability Testing ............................................................................................ 6

       1.2.2 Web Site Design Guidelines .............................................................................................. 7

   1.3 Technical Report Contents .......................................................................................................... 8

2. Usability Testing Using Physiological Analysis ................................................................................. 9

   2.1 NFL PickEm 2006 Web Site ........................................................................................................... 9

       2.1.1 Home Page .......................................................................................................................... 10

       2.1.2 Teams Page ....................................................................................................................... 11

       2.1.3 Weeks Page ....................................................................................................................... 13

       2.1.4 Picks Page ........................................................................................................................ 14

       2.1.5 Standings Page .................................................................................................................. 17

       2.1.6 Admin Page ...................................................................................................................... 18
4.2 Physiological Data Analysis .................................................................50
  4.2.1 Heart Rate .....................................................................................51
  4.2.2 Skin Conductivity .........................................................................56
4.3 Comparisons and Discussion ...............................................................62
  4.3.1 Text Readability ...........................................................................62
  4.3.2 Color Preference ..........................................................................64
  4.3.3 Animated Backgrounds ..................................................................66
5. Future Work ............................................................................................67
6. Conclusion ..................................................................................................68
Acknowledgements .........................................................................................70
Bibliography and References .............................................................................71
Appendix A. NFL PickEm 2006 Data Dictionary ..............................................74
Appendix B. User Performance Tasks .............................................................75
Appendix C. Paper Usability Survey ..............................................................77
LIST OF FIGURES

Figure 2.1. **NFL PickEm 2006** Home Page .........................................................10
Figure 2.2. **NFL PickEm 2006** Teams Page.........................................................11
Figure 2.3. **NFL PickEm 2006** Team Page............................................................12
Figure 2.4. **NFL PickEm 2006** Weeks Page..........................................................13
Figure 2.5. **NFL PickEm 2006** Picks Page.............................................................14
Figure 2.6. **NFL PickEm 2006** Email Picks Page.................................................15
Figure 2.7. **NFL PickEm 2006** Review Picks Page...............................................16
Figure 2.8. **NFL PickEm 2006** Week Picks Page....................................................17
Figure 2.9. **NFL PickEm 2006** Standings Page......................................................18
Figure 2.10. **NFL PickEm 2006** Admin Sign In Page...........................................19
Figure 2.11. **NFL PickEm 2006** Admin Functions Page........................................19
Figure 2.12. **NFL PickEm 2006** Show Players Page.............................................20
Figure 2.13. **NFL PickEm 2006** Add New Player Page........................................21
Figure 2.14. **NFL PickEm 2006** Display Player Information Page........................22
Figure 2.15. **NFL PickEm 2006** Display Update Player Picks Page......................23
Figure 2.16. **NFL PickEm 2006** Display Update Scores Page..............................24
Figure 2.17. **NFL PickEm 2006** Add Tiebreaker Page..........................................25
Figure 2.18. BioTrace+ Performance Task Screen..................................................26
Figure 2.19. BioTrace+ Performance Task Screen..................................................27
Figure 2.20. BioTrace+ Session Overview Screen..................................................28
Figure 3.1. footballDB Entity-Relationship Diagram.............................................32
<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.2</td>
<td>BioTrace+ Screen Template</td>
<td>36</td>
</tr>
<tr>
<td>3.3</td>
<td>BioTrace+ Button Action Screen</td>
<td>37</td>
</tr>
<tr>
<td>3.4</td>
<td>BioTrace+ Select Channel Screen</td>
<td>38</td>
</tr>
<tr>
<td>3.5</td>
<td>BioTrace+ Compute Statistics Screen</td>
<td>39</td>
</tr>
<tr>
<td>3.6</td>
<td>Example of BioTrace+ Statistics</td>
<td>39</td>
</tr>
<tr>
<td>3.7</td>
<td>Equipment Set Up</td>
<td>41</td>
</tr>
<tr>
<td>3.8</td>
<td>Heart Rate and Skin Conductivity Sensors</td>
<td>42</td>
</tr>
<tr>
<td>3.9</td>
<td>Baseline Test</td>
<td>43</td>
</tr>
<tr>
<td>4.1</td>
<td>Hardest to Read Color Combination Responses</td>
<td>47</td>
</tr>
<tr>
<td>4.2</td>
<td>Easiest to Read Color Combination Responses</td>
<td>48</td>
</tr>
<tr>
<td>4.3</td>
<td>Most Preferred Color Combination Responses</td>
<td>49</td>
</tr>
<tr>
<td>4.4</td>
<td>Least Preferred Color Combination Responses</td>
<td>49</td>
</tr>
<tr>
<td>4.5</td>
<td>Effect of Animated Backgrounds Responses</td>
<td>50</td>
</tr>
<tr>
<td>4.6</td>
<td>Aggregate Average Heart Rate Per Task</td>
<td>52</td>
</tr>
<tr>
<td>4.7</td>
<td>Aggregate Average Heart Rate Per Color Combination</td>
<td>53</td>
</tr>
<tr>
<td>4.8</td>
<td>Aggregate Difference From Baseline Average HR</td>
<td>55</td>
</tr>
<tr>
<td>4.9</td>
<td>Aggregate Average Skin Conductance By Task</td>
<td>57</td>
</tr>
<tr>
<td>4.10</td>
<td>Aggregate Average Skin Conductance Per Color Combination</td>
<td>59</td>
</tr>
<tr>
<td>4.11</td>
<td>Aggregate Difference From Baseline Average SC</td>
<td>60</td>
</tr>
</tbody>
</table>
LIST OF TABLES

Table 4.1.  Average Heart Rate Per Task For Each Subject...........................................51
Table 4.2.  Average Heart Rate Per Color Combination For Each Subject....................53
Table 4.3.  Difference From Baseline Average HR By Subject.................................54
Table 4.4.  t-test Comparison Between Color Combinations (HR).................................55
Table 4.5.  t-test Comparison Between Baseline and Each Color Combination (HR) ...56
Table 4.6.  Average Skin Conductance Per Task For Each Subject...............................57
Table 4.7.  Average Skin Conductance Per Color Combination For Each Subject........58
Table 4.8.  Difference From Baseline Average SC By Subject......................................60
Table 4.9.  t-test Comparison Between Color Combinations (SC).................................61
Table 4.10. t-test Comparison Between Baseline and Each Color Combination (SC)....61
Table 4.11. Comparison Between Paper Survey and Biofeedback Data, 1.................62
Table 4.12. Comparison Between Paper Survey and Biofeedback Data, 2.................64
Table 4.13. Comparison Between Paper Survey and Biofeedback Data, 3.................65
Table 4.14. t-test Comparison Between Non-Animated and Animated Backgrounds ....66
1. Introduction and Background

In today’s Web-based world, one of the most frustrating phenomena that a user can encounter is a poorly designed Web site. Usability tests have been promoted by proponents of Human-Computer Interaction, or HCI, as a vital phase in the overall design process to ease the frustrations of end-users. In response to the growing population of Web applications, a host of guidelines for quality design have been made available to even the most inexperienced Web designer.

This initial goal of this research project was to test the reality of utilizing biofeedback data to objectively measure a user’s response to a test Web site. More specifically, this experiment was interested in the response prompted by the text and background colors selected for a mock Web site. Ultimately, the success of this project could have significant implications for traditional usability testing techniques, as well as Web design guidelines.

Before attempting to use physiological data to analyze its effectiveness in usability testing, however, it was first necessary to explore the two specific biofeedback responses that were the focus of this study: heart rate and skin conductivity. In addition, aspects of color theory were researched in order to help design the color scheme for a mock Web site. Finally, it was important to look at previous work done with physiological studies.

1.1 Background
The research phase of this project took a considerable amount of time because it involved various aspects of computer science, as well as other fields such as biology and art science. Most importantly, it was vital to research the current beliefs about the meanings that can be applied to biofeedback data. A secondary concern was to explore color theory for specific guidelines for Web page color selection. Finally, as is common in the commencement of any type of exploratory research, it was necessary to investigate current and related work in the field of interest.

1.1.1 Physiological Responses

Both heart rate and skin conductivity were used in this study, if not solely because the equipment necessary to record both types of biofeedback was available, then because both have been used extensively in the medical field to assess stress levels in patients. Both heart rate and skin conductance have been used to study human biological responses to everything from the listening to stuttered speech [Guntupalli 2006] to public speaking anxiety [Croft 2004].

Heart Rate

Heart rate, defined as “a measure of cardiac activity usually expressed as number of beats per minute” [HR 2002], has consistently been linked to stress. Heart rate has been shown to increase during mental stress in patients and healthy subjects alike [Insulander 2003]. One report showed that the difference between baseline and mentally stressed heart rates is somewhere between .1 and .2 Hz [Vuksanović 2007]. Multiplying by 60, this range translates to an increase of 6-12 heartbeats per minute.

Skin Conductivity
Caused by the sympathetic nervous system, skin conductance is “one of the most robust and well studied physiological responses and has been shown to be linked to measures of emotion, arousal, and attention” [Dawson 1990]. The unit for measurement of skin conductivity is seimens, which is “equal to one ampere per volt” [SI 2002]. Skin conductance has been shown to provide “an objective method for evaluating a person’s state of arousal” [Storm 2000]. In a study based on physiological reactions to music, skin conductance appeared to be linked to stimulating emotions such as fear and happiness [Khalfa 2002].

1.1.2 Web Design Color Theory

It might seem more than obvious, but one of the most common design flaws made by amateur Web designers is the selection of combinations for text and background colors that make the page hard to read. Even worse is the faux pas of using animated backgrounds to “spice up” the Web page, with the inevitable side effect of making it nearly impossible to discern the text [Williams 2005].

The selection of colors in Web design has been the subject of many research projects, including that of Richard Hall and Patrick Hanna [Hall 2004], who found that text and background color combinations with “greater contrast ratio generally lead to greater readability.” In addition, it was noted that preferred colors also play a part in the viewer’s satisfaction with a Web page. Stemming from their research, this project sought to look at both text readability and user preference for particular color combinations.

Some interesting phenomena occur with particular color schemes. For example, some color combinations will cause the text to appear to “vibrate” on the screen [Clarke 2002]. Called “chromostereopsis,” this effect is best exemplified by the colors blue and
red, which are “perceived at different depths” due to an aberration in the human eye [Wiegand 2003]. It is believed that these color combinations cause stress to the viewer and are therefore cautioned against [Johansson 2002].

Finally, the World Wide Web Consortium, or W3C, has derived an algorithm to ensure that text and background color combinations provide enough contrast to allow for discernment of the text. The two equations listed below (as Eq. (1.1) and Eq. (1.2), respectfully) take the RGB values of the foreground and background colors as input and output range values that represent the brightness and color differences. If the brightness difference is above 125 and the color difference is above 500, then the two colors theoretically provide “good color visibility” [Ridpath 2000].

\[
\begin{align*}
\text{B} & \Delta = (((R_1 \times 299) + (G_1 \times 587) + (B_1 \times 114)) / 1000) - \\
& \quad (((R_2 \times 299) + (G_2 \times 587) + (B_2 \times 114)) / 1000) \\
\text{C} & \Delta = (\max(R_1, R_2) - \min(R_1, R_2)) + \\
& \quad (\max(G_1, G_2) - \min(G_1, G_2)) + \\
& \quad (\max(B_1, B_2) - \min(B_1, B_2)) 
\end{align*}
\]

1.1.3 Previous Work

Physiological analysis, for all intents and purposes, can be understood as the use of bodily reactions – skin conductivity, blood pressure, heart rate – to determine the impact of a system’s design on the user. These phenomena are impacted and produced “by the body’s ‘fight or flight’ response to perceived threat, brought about by impulses from the hypothalamus to the sympathetic nervous system” [Ward 2000]. Although these reactions have been linked to outside causes for many decades [Selye 1956], the
application of these techniques to usability testing appears to be a recent idea, proposed first by Ward and Marsden at the University of Huddersfield [Ward 2000].

The inspiration behind physiological analysis is that a user’s dissatisfaction with a system’s design can be determined by examining his bodily reactions. This can be further explained by one of two concepts. The first suggestion is that the mental processing required to navigate through a system causes noticeable changes in the physiology of the user. The second theory is that the actual emotion experienced by the user – namely, frustration or enjoyment – causes changes in bodily measures. Either way, it would seem that physiological reactions have the potential of providing a perfectly objective measurement of usability [Ward 2000].

A 2002 study at the University of Huddersfield required participants to use either a “well designed” or “poorly designed” variation of the same Web site, differentiated by the use or disuse of good Web design principles. Both skin conductivity and blood volume pulse data were measured while the subjects traversed through the Web site attempting to find solutions to provided questions. The summary data showed that “measures of skin conductivity, blood volume and pulse rate….are able to distinguish differences in arousal levels in different computer-based situations” [Ward 2002].

Results of this study demonstrate that “psychophysiology can be informative about software usability,” but that interpretation of the results is “problematic” because they can be attributed to a multitude of factors [Ward 2002]. Therefore, the challenge with physiological analysis is not the testing process, but the interpretation of the data. The practitioner must be able to discern whether or not the changes in bodily processes
were a direct result of the design of the system or a reaction to some other outside stimulus.

1.2 Motivations

Although both usability tests and design guidelines intend to improve the quality of systems, they are rarely based on objective approaches [Potosnak 1988]. Physiological analysis offers the objectivity required to give the designer impartial feedback during usability testing. In addition, the results of physiological analysis can provide practitioners with a clearer indication of what it takes to make a quality Web site.

1.2.1 Traditional Usability Testing

Usability tests have been practiced for several years in an attempt to alleviate potential functional and aesthetic problems. The traditional approach has been to collect subjective data in order to analyze the overall usability of the system. Some methods that have been used to counter bad design concerns include the use of paper prototypes [Grady 2000], interviews, surveys, focus groups, and performance tests [Dieli 1988].

Inherent problems may exist, however, when designers put all their eggs in the proverbial basket and rely only on the results of subjective testing. Not only do most of the conventional testing techniques provide a poor imitation of real-world situations, but they also can be costly and time-consuming [Ward 2000]. In addition, subjective interviews and surveys may be able to provide designers with personal opinions, but they
do little to specify the exact faults of the overall system and the effect they have on the user [Wenger 1989].

An objective approach to usability testing can be used in conjunction with subjective test results to more accurately determine the specific characteristics of the design that impact the usability of a system. Although physiological testing equipment is far from inexpensive, it is easy to use and implement in traditional work settings [SC 2006]. In time, physiological testing may be seen as the best and most cost-effective manner for the usability testing of new systems.

1.2.2 Web Site Design Guidelines

Numerous guidelines have been created to guide the design of quality Web sites. The International Academy of Digital Arts and Sciences, for example, evaluates the following six characteristics of a Web site when determining the winner of the prestigious Webby award: “content, structure and navigation, visual design, functionality, interactivity, and overall experience” [White 2005]. The World Wide Web Consortium, or W3C, on the other hand, provides designers with specific documentation that “explain[s] how to make Web content accessible to people with disabilities” [Chisholm 1999].

These examples show that the degree of detail in the guidelines available to Web site designers varies greatly. Exceptionally vague guidelines obviously do not tell the whole story and are subject to personal interpretation. However thorough a set of guidelines may be, they can still be incomplete. In addition, unanticipated differences between users can cause problems when a design adheres strictly to a given set of
guidelines [Ward 2000]. For example, it has been demonstrated that an understanding of color theory may be required to make simple color decisions [Cooper 2005].

Studies have been conducted to provide a basis for Web design guidelines using empirical research [Barrick 2004]. Physiological analysis, on the other hand, can provide another source for the creation of a complete set of guidelines for good Web design practices. These guidelines, based on objective measurement techniques, may help future designers create quality Web sites in a more timely and cost-effective manner.

1.3 Technical Report Contents

The following sections of this document outline and define the specific steps that were taken to realize the successful completion of this research project. Sections 2 and 3 identify the external and internal view of the completed experiment, including the mock Web site that played a crucial role in the research process. The results of the experiment described in those sections can be found in Section 4, while Section 5 discusses the possible next steps. Finally, Section 6 provides a complete summary of the results of the research undertaken by identifying its key components.
2. Usability Testing Using Physiological Analysis

The design of this project required the creation of a functional Web site, as well as the formation of a user-specified testing protocol under the BioTrace+ software system, each of which would run on a separate platform. Thus, the scope of knowledge required to conduct the usability testing extended beyond the field of human-computer interaction. This section will describe the external aspects of the two components that each played a key role in the completion of the project.

2.1 NFL PickEm 2006 Web Site

In order to accurately depict the users’ biological responses to Web site text and background color combinations, a mock Web site was created. Since the content of the Web site was unimportant in regards to the ultimate intended use of the site, the topic of football was quickly determined as its theme. Aptly entitled NFL PickEm 2006, this Web site allows groups of fellow football fans to compete against one another in determining which teams will win in each of the 17 weeks of the National Football League (commonly referred to as a Pick ‘Em league).
The following sections provide a detailed description of the user interface of the NFL PickEm 2006 Web site. The internal design, however, will not be explored until Section 3. Nonetheless, understanding the external aspects of the Web site will become important in Section 3.3 of this document, which will describe the user tasks that were conducted by each subject.

2.1.1 Home Page

The Home Page of the NFL PickEm 2006 Web site is relatively plain (as seen in Figure 2.1). The major significance of this page, however, is that it introduces the layout of the entire Web site. Throughout the site, the title “NFL PickEm 2006” always displays at the top, with a menu on the left and a large main section.
The menu on the left also remains constant throughout the **NFL PickEm 2006** Web site. There are six links: Home, Teams, Weeks, Picks, Standings, and Admin. Below the links are five numbered buttons, which represent the five text and background color combinations available: (1) blue text on red background, (2) light gray text on dark gray background, (3) white text on animated green background, (4) green text on animated plaid background, and (5) green text on purple background.

Whenever a user selects one of the five numbered buttons, the Web site changes from its default text and background colors (red text on white background) to the color combination selected. The text and background colors will remain the same for any subsequent visited page on the Web site. The colors will not change again until another button is selected.

**2.1.2 Teams Page**

The Teams Page lists all thirty-two teams in the National Football league by conference and division (see Figure 2.2). There are two conferences – the AFC and the NFC – and each of these conferences has four divisions: North, South, East, and West. The teams are listed in alphabetical order by location (city, state, or region) in order to allow for easy searching.
Team Page

Each team name in this list is actually a link to a page not listed in the menu on the left – the Team Page (see Figure 2.3). The Team Page contains information on a single team in the National Football League. The current win-loss record of the specific team is listed below the team name.

The Team Page contains a list of all of the games in which the specific team is scheduled to play during the season, either away or at home. In addition, the scores for any games already played are included, and the word “Win” or “Loss” is displayed. The number of appearances of “Win” and “Loss” correspond with the win-loss record previously mentioned. Finally, the numbers listed in the “Week” column on the Team Page are links to the Weeks page, which are discussed in the next subsection.
2.1.3 Weeks Page

The Weeks Page provides users with a listing of all of the games – or matchups – for each of the 17 weeks in the NFL regular season (see Figure 2.4). By default, the link from the menu to the Weeks Page displays the matchups for Week 1. However, the user can navigate to any of the 17 weeks by selecting the desired week number at the top of the screen.
The Weeks Page displays the away team and home team for all of the games scheduled for the given week. Each team name – whether away or home – is a link to the Team Page for that team. If the game has already been played, the final score will be listed in the third column. The format for the score is to list the score of the away team followed by the score of the home team.

2.1.4 Picks Page

“Picks” is the colloquial term for a hypothesized list of winning teams. Thus, the Picks Page provides players with the opportunity to email their picks for the current week to the league manager (see Figure 2.5). Another purpose of the Picks Page is to allow players to view the picks of all of the players for a given week in tabular form.
Email Picks

Once a player clicks on the link to email his or her picks for the current week, the Web site navigates to an input page (see Figure 2.6). Using the drop boxes, the player can select either the away team or the home team to win each of the games in the current week. The score of the Monday Night Football game is used as the tiebreaker in the case that two or more players choose the same number of winning teams. Therefore, the player will also enter his or her guess at the final score for the tiebreaker game. When he or she is content with the picks, the player will press **Submit Picks**.

**Figure 2.5 NFL PickEm 2006 Picks Page**
The second part of the email submission process is a review of the picks made by the player (see Figure 2.7). The Web site displays each game for the current week, with the player’s pick from the previous screen in bold letters. The final score for the tiebreaker game is provided at the bottom. The player is then given the option to revise his or her picks or email the picks to the league manager. In order to complete the process, the player must enter his or her name and a previously-provided code.
Figure 2.7 NFL PickEm 2006 Review Picks Page

View Picks

Players in the league can review the picks of all players for every week up until the current week. Once a week is selected, a new window will pop up with a tabular listing of all the picks for each game in that week. Players can print out the contents of this page to keep up with their progress as the games progress.

The amount of information displayed on the week picks page can be quite daunting (as seen in Figure 2.8). The column headings are the games scheduled for the given week – at any point in the season, there are either 13, 14, or 16 games. The next column contains the players’ estimations of the final score. The last column contains the number of games that each player guessed correctly. Each player’s names and picks are listed on a separate row, while correct guesses are highlighted in green and incorrect
guesses are highlighted in red. The number of green cells corresponds with the number in the “Wins” column.

![Figure 2.8 NFL PickEm 2006 Week Picks Page](image)

### 2.1.5 Standings Page

Some players may be interested in knowing which player has the most wins – or correct picks – over the entire 17-week season. The Standings Page provides this functionality (see Figure 2.9). Whether a player has played once or every week, his or her name will appear in the standings chart, along with the number of correct picks for each week. The final column on the Standings Page contains the total for all weeks played. Thus, it is relatively easy to determine which player in the alphabetically-sorted list leads the league in correct picks.
2.1.6 Admin Page

There are many administrative functions required to support this type of league. Thus, the Admin Page provides the functionality for several functions, including listing the current players, adding a new player, displaying player information, updating a player’s picks, entering final scores, and specifying the tiebreaker game for a given week. First and foremost, however, the league manager must log in.

Sign In Page

The Sign In Page follows the traditional method of requiring both a login name and a password (see Figure 2.10). The only login name used for this project was “login,” while the password was “pass.” Once the login is complete, the system displays the available administrative functions (see Figure 2.11).
Figure 2.10 NFL PickEm 2006 Admin Sign In Page

Figure 2.11 NFL PickEm 2006 Admin Functions Page
Show Players Page

The administrator can view a list of all the current players in the league by clicking on the Show Players button on the Admin Functions Page. This page, entitled the Show Players Page, lists all of the players in the league alphabetically by last name (see Figure 2.12). The names are hypertext links to unique Display Player Information pages, which are described below. At the bottom of the page is an Add Player button.

Add Player Page

To add a new player, the administrator must first navigate to the Show Players Page and click on the Add Player button. The administrator must then enter the first and last names of the new player on the Add Player Page (see Figure 2.13). An error message
will be displayed if another player with the same first and last name is already in the league. Otherwise, the Web site presents the Display Player Information Page for the new player. This system does not include the functionality to update or delete a player.

![NFL PickEm 2006 Add New Player Page](image)

**Figure 2.13 NFL PickEm 2006 Add New Player Page**

**Display Player Information Page**

The Display Player Information Page lists the number of correct picks a single player made for each week in the football season, as well as a total number of correct picks for the entire season (see Figure 2.14). Each week is a link to the Update Player Picks Page for the same player. This page can be reached via selecting a player from the Show Players Page or from the successful addition of a new player to the league. The
administrator can return to the Show Players Page by clicking on the **Show Players** button at the bottom of the page.

![NFL PickEm 2006 Display Player Information Page](image)

**Figure 2.14 NFL PickEm 2006 Display Player Information Page**

**Update Player Picks Page**

If the administrator clicks on a link specifying one of the weeks in the NFL regular season from the Display Player Information Page, he or she will be redirected to the Update Player Picks Page for the corresponding week and player (see Figure 2.15). This page will allow the administrator – and the administrator only – to update the picks for a particular week.

At the top of the screen, the administrator can choose to navigate to a different week in the football season by clicking on a numbered hyperlink. All of the games for the
given week are displayed in tabular form. The administrator can choose either the away team or the home team as the player’s pick for each game, as well as the final score for the tiebreaker game. If the game has already taken place, the final score will be displayed on the Update Player Picks Page, along with a message indicating whether or not this player chose the correct winner.

At the bottom of the page, the administrator can select to update the current picks, return to the Show Players Page, or navigate back to the Admin Functions Page. If the administrator makes changes to the picks on the Update Player Picks Page, but navigates away from the page without clicking on the **Update Picks** button to save the current picks, then they will not be saved.
**Update Scores Page**

On the Admin Functions Page (Figure 2.11), the administrator has the option to select any particular week in the football season. Once the administrator presses the **Go!** button, the Update Scores page is displayed for the desired week (see Figure 2.16). The administrator can then enter the final scores for any games that have already been played and save them by pressing the Update Scores button. Additionally, the user can add a tiebreaker game to the current week or choose to return to the Admin Functions Page.

![NFL PickEm 2006 Display Update Scores Page](image)

**Figure 2.16 NFL PickEm 2006 Display Update Scores Page**

**Add Tiebreaker Page**

Finally, the Add Tiebreaker Page simply allows the administrator to select one of the games during the specified week to be the tiebreaker game (see Figure 2.17). This
page can only be accessed via the **Add Tie Break** button on the Update Scores Page. The administrator selects a game from the drop-down menu and presses the **Add Game** button to save it as the tiebreaker for the given week.

![NFL PickEm 2006 Add Tiebreaker Page](image)

**Figure 2.17 NFL PickEm 2006 Add Tiebreaker Page**

### 2.2 BioTrace+ Software

The collection of accurate physiological data was vital to the completion of this project. Fortunately, the BioTrace+ software package – normally intended for clinical purposes to provide graphical interaction with the Nexus-10 hardware and described in more detail in Section 3.2 – provided all of the capabilities necessary in its screen-based system. Whether user-defined or built-in, the following screens were used in the testing phase to facilitate the data gathering process.
2.2.1 Baseline Screen

This user-defined screen occurs at the beginning of the testing phase, once the recording session has begun. It displays for exactly thirty seconds and is outfitted with a countdown graphical display (see Figure 2.18). After thirty seconds, the program links to the next page in the user-defined protocol – the screen for Task 1.

![Baseline Screen](Image)

Figure 2.18 BioTrace+ Performance Task Screen

2.2.2 Performance Task Screen

For each of the ten user performance tasks defined in Section 3.3, there is a corresponding user-defined screen saved in the BioTrace+ program (see Figure 2.19).
These screens simply display the current task number, along with a button to go on to the screen for the next task (or, in the case of Task 10, to end the session). In case of error, each of these screens contains a Restart button in the bottom left-hand corner. Pressing this button will result in the session restarting with Task 1.

![Figure 2.19 BioTrace+ Performance Task Screen](image)

**Figure 2.19 BioTrace+ Performance Task Screen**

#### 2.2.3 Session Overview Screen

At the end of each data recording session, the system can display a session overview screen which is invoked by simply pressing the Tab button (see Figure 2.20). This overview presents the data collected from all of the sensors attached to the Nexus-10
hardware in graphical form. This built-in feature served multiple purposes for this project, in that it is customizable and presents the data in such a way that can be stored for later use.

Figure 2.20 BioTrace+ Session Overview Screen
3. Research

The ultimate completion of this research project included three fundamental components. The first necessary implementation was a mock Web site with database support. The external aspects of the NFL PickEm 2006 Web site, described in Section 2.1 of this report, required a significant amount of time and effort to design and create. This section will detail the internal view of the sample Web site used for this project.

Secondly, the BioTrace+ software package was necessary for data collection. This software package, which collects biological feedback data via the Nexus-10 equipment, had to be learned and adapted for use as part of a physiological study. Though not difficult, it took quite some time to mold this software package to the particular needs of this project.

Finally, as in any research experiment, a well-defined research methodology was needed to guide the entire process. Careful planning – including everything from the placement of the equipment to the selection of research subjects – was required before the experiment could even take place. Furthermore, a detailed set of user tasks were defined to model common situations a player or league manager might encounter on the mock football Web site.

3.1 Web Site

The NFL PickEm 2006 Web site was constructed entirely from scratch and therefore took a significant amount of time to create. In addition, the fact that a database was also needed to provide sample data and to allow for the complex functionalities described in Section 2.1 further complicated the process. Finally, the colors that were
selected for the text and background color combinations were significant in the creation of this Web site and therefore necessitate an explanation. The following sections detail the design and implementation of the mock Web site used in the testing phase of this project.

### 3.1.1 Languages

The **NFL PickEm 2006** Website was written in PHP, a “widely-used general-purpose scripting language that…can be embedded into HTML” [PHP 2007]. This language was chosen because it allows for dynamic pages to be generated, thus allowing for more flexibility with less coding. In addition, PHP is designed to work well with the database server used in this project, MySQL.

Cascading Style Sheets – or CSS – was used to define the layout and color scheme of the Web site. The buttons numbered from 1 to 5 on the menu on the left of every page on the **NFL PickEm 2006** Web site were dynamically linked to five different CSS files. These files contained identical layout information, but differed when it came to background and text color specifications. The current background was passed from page to page via PHP variables.

### 3.1.2 Database

As previously mentioned, the database service used for this project was MySQL. Only four tables were required to implement the footballDB database for the **NFL PickEm 2006** Web site: Team, Game, Player, and Pick. While the data dictionary for the footballDB database can be found in Appendix A, the following sections provide a brief description of each of the tables. Finally, the database description for this project will end with the entity-relationship diagram for the footballDB database.
Team

The Team table holds all of the 32 teams in the National Football League. The entries for this table had to be inputted manually, simply because the 32 teams do not change. Yet, the Team table is updated each time the scores are input on the Update Scores page to add a win to the winning team and a loss to the losing team. Nonetheless, the NFL PickEm 2006 Web site usually interacts with this table through the SELECT database function.

Game

The Game table must also be input manually via the MySQL interface. This is because the games for all 17 weeks in the football season are scheduled before the season even begins. However, the Game_TieBreaker field is updated whenever the league manager adds a new tiebreaker game to a desired week, as described in Section 2.1.6. In addition, the Game table is updated each time the scores are input on the Update Scores page to keep track of the points scored by both the home team and away team for the game. Other than that, the majority of the interaction with the NFL PickEm 2006 Web site is through the SELECT function.

Player

The Player table holds all of the current players in the league, indexed by the composite of first and last names. This table is altered whenever the league manager adds a new member. This table is subsequently updated every time the NFL PickEm 2006 Web site refreshes either the Picks Page or the Update Player Picks Page. As it exists, there is currently no way to DELETE a player from this table besides manually doing so in the MySQL interface.
Pick

The Pick table holds the pick for a single game and player. Thus, each week, every player in the league adds anywhere from 12 to 15 entries to the Pick table, depending on the number of games being played that week. This table is updated whenever the league administrator enters a player’s picks for a given week on the Update Player Picks page. This table can also be updated via the same page. Again, there is no way to completely delete a pick from the Pick table.

Entity-Relationship Diagram

Figure 3.1 is the entity-relationship diagram for the footballDB database. Note that all but one of the tables is indexed by a composite key. The footballDB is in third-normal form (3NF), except for the Player table. This table was left unnormalized because each time it is called from the NFL PickEm 2006 Web site, all 17 weekly totals are needed.

![Diagram of footballDB Entity-Relationship Diagram]

Figure 3.1 footballDB Entity-Relationship Diagram
3.1.3 The Colors

The color combinations for text and background colors on the NFL PickEm 2006 Web site were carefully selected for a variety of reasons, although their order of appearance on the Web site was determined randomly. The following sections provide short insights as to the reasons behind the selection of the five color combinations used on the mock Web site: (1) blue text on red background, (2) light gray text on dark gray background, (3) white text on animated green background, (4) green text on plaid background, and (5) green text on purple background.

Blue Text on Red Background

As previously mentioned in Section 1.1.2, this color combination, due to chromostereopsis, naturally causes a vibrating effect on the screen. This effect, in turn, reduces readability. Also, it can be simply unattractive. According to Eq. (1.1), the brightness difference between red and blue is 47.175 and the color difference is 510 according to Eq. (1.2). Thus, this color combination is considered to be difficult to read.

Light Gray Text on Dark Gray Background

Although the brightness difference between light and dark gray is merely 24 and the color difference is 72, light and dark gray is a popular Web site color combination in the form of a monotone achromatic color scheme [Johansson 2002]. The light gray text, with an index of 136, might perhaps be bright “enough” to allow for readability. In addition, the fact that the color difference is so small may possibly cause less stress to user.
White Text on Animated Green Background

This color combination is meant to test the effect that animated backgrounds have on the usability of a Web site. The green background consists of two main shades of green: a dark green with a RGB value of (18, 178, 26) and a light green with a RGB value of (4, 238, 55). The majority of the screen is the lighter shade of green, which has a brightness difference of 107.828 and color difference of 468 when compared to the white text. However, both the brightness difference (142.168) and the color difference (543) are above the “good” range when the dark green background color is behind the white text. Subsequently and in theory, if the screen was not animated to switch between four similar background images per second, then it would be comparatively easy to read.

Green Text on Plaid Background

This color combination switches between two background images. The first image displays on the screen for one second and is composed of the overlay of pink and yellow lines, with green points of intersection. The second image lasts for approximately half a second and contains pink and blue lines of varying thicknesses, with darker pink intersections. Both of the background images contain a plethora of whitespace.

All of the permutations of brightness and color differences were tabulated for the green text and plaid background colors. Not surprisingly, the greatest brightness difference index was between the green text and white background (105.315). The least brightness difference (41.616) was found between the green text and the darker pink intersections of the second background image. The greatest color difference, 576, occurs between the green text and the intersection of the pink and blue lines, while the least color difference exists between the green text and the green intersections of the first
image. It is important to note that almost all of the color combinations provide a color difference index in the “good” range.

Thus, it would seem like this color combination would provide for a similar reading experience as the green animated background with white text listed above. However, the fact that the animation of the plaid background is significantly slower (an average of 1.33 frames per second as compared to 4) might result in significant differences in overall experience and usability.

*Green Text on Purple Background*

Based on appearance, it would seem that chromostereopsis also takes place between the green text and purple background colors chosen for the fifth color scheme. If not, this color combination has at least been cautioned against in Web design guidelines [WFU 2007]. The brightness difference between these two colors is 26.622, which is one of the smallest differences found throughout the five color combinations, second only to the light on dark gray scheme. The color difference, however, is 459, very nearly in the “good” range.

### 3.2 BioTrace+ Software

A critical characteristic of the BioTrace+ software platform is that it permits the construction of user-defined protocols [SC 2006]. For this study, a customized protocol was created to correspond with the research method. The system therefore contained separate screens for the baseline measurement and each of the tasks that were performed by the subject in the test session. These simple screens, described previously in Section 2.2, contained buttons that were pressed at the beginning of each new task. The button
presses set up markers, or segments, in the Session Overview Screen, which allowed for easy determination of the start and end times of each task performed by a subject.

### 3.2.1 Screen Creation

The process to create a custom BioTrace+ screen protocol was far from swift. Each screen had to be created individually from a blank template and saved as a separate file (see Figure 3.2). Thus, even though the screens for each performance task were nearly identical in structure, each one had to be constructed from scratch. Additional setbacks occurred when the testing of a button caused the system to navigate to another screen before the new screen was saved. When this occurred – unfortunately several times throughout the course of this project – the new screen was lost.

![Figure 3.2 BioTrace+ Screen Template](image-url)
A GUI interface of sorts was used to add text or a button to the page. Once a text box or button was in place, its attributes could be specified by right-clicking on the widget itself. Besides the button text, the software provided many options regarding the actions invoked by a button press (see Figure 3.3). For this protocol, each button linked to another screen. In addition, each button press created a new segment – which represents the start of a new user performance task – in the Session Overview Screen.

![Figure 3.3 BioTrace+ Button Action Screen](image)

### 3.2.2 Session Overview Screen

At the end of each test under the custom protocol, the BioTrace+ software provides a Session Overview screen under default settings. However, custom settings can
be specified to user needs. Thus, for this project, the Session Overview Screen was altered to only display desired information – specifically, the heart rate, blood volume pressure, and skin conductivity data recorded for the previous session (see Figure 3.4).

Figure 3.4 BioTrace+ Select Channel Screen

In order to save the session overview data, the statistics for each segment had to be computed. Luckily, doing just that only required a right-click of the mouse anywhere on the Session Overview Screen. Clicking on the “On All Segments” option of the “Compute Statistics” submenu produced a complete listing of all the desired data for each
segment (see Figures 3.5 and 3.6). This segment data could then be copied into an Excel spreadsheet for later analysis.

Figure 3.5 BioTrace+ Compute Statistics Screen

Figure 3.6 Example of BioTrace+ Statistics
3.3 Research Methodology

The research method for this project closely modeled that of a traditional usability test, with added equipment and software to monitor physiological factors. Subjects in this study each underwent the same structured testing procedure, which was composed of three key components: the baseline test, the performance tasks, and the paper survey. At the end of this progression, the physiological data was stored for later scrutiny. Careful actions were taken to ensure that the physiological data was not affected by outside sources while the testing was conducted.

3.3.1 Equipment and Set Up

This study required the use of two laptop computers. In addition, the aforementioned BioTrace+ software package was used to collect the physiological data through communication with the Nexus-10 equipment. The placement of these various components remained consistent throughout the testing process in an attempt to ensure similar physical environment experiences for all subjects.

Equipment

A Dell Latitude D610 laptop owned by the Computing Sciences department was placed near the subject. This laptop ran the BioTrace+ software and was connected to the Nexus-10 through BlueTooth technology. All measurement data was maintained on the department laptop, which was stored henceforth in a locked location on campus.

A personal Dell Inspiron 6000 laptop computer was also used in the study. This laptop was connected to the Internet through its internal wireless card. It displayed the NFL PickEm 2006 Web site and was situated directly in front of the subject. A standard mouse was attached to the laptop to allow for traditional Web browsing practices.
Set Up

Before a subject began the test session, several duties were performed. The chair was placed directly in front of the personal laptop that was used to look at the Web site, although it initially only displayed the desktop image. The department laptop was placed to its left and displayed the first screen in the customized protocol. The Nexus-10 system was placed nearby, ready to record the session (see Figure 3.7).

![Figure 3.7 Equipment Set Up](image)

Once the subject was seated at a comfortable distance from the personal laptop, the sensors were placed on his left hand fingers (see Figure 3.8). Specifically, a blood volume pulse sensor that “monitors the relative blood flow…with near infrared light” was painlessly fastened on the middle finger via a padded clamp, while skin conductivity sensors that monitor electrical currents were Velcro-strapped to the subject’s pointer and ring fingers [SC 2006].
Figure 3.8 Heart Rate and Skin Conductivity Sensors

Special care was taken to ensure that the sensors did not cause any unintended discomfort. Fortunately, both the blood volume pressure and the skin conductivity sensors were easily adjustable. After each use, the sensors were sanitized to avoid any germ contamination.

3.3.2 The Subjects

The 23 subjects in this study were gathered through advertisement in first-year Computer Science courses. These students were selected because, as first-semester students, they were unfamiliar with the process of software usability testing, but had approximately the same level of Web knowledge. No incentive was used initially, other than the exposure of first-year students to computer science research on campus. However, students that participated were ultimately granted $5 coupons to the University Center Commons.

Upon beginning the test session, each subject was assigned a number that the BioTrace+ software used to relate to the data. The subject also used this number to identify the subsequent paper survey. No names were used in the system to ensure
confidentiality. As previously mentioned, the data was only stored on a department laptop that was locked in a secure room on campus.

3.3.3 The Method

Since this is a usability study, the research followed traditional techniques. The test session for each subject included three distinct phases: the baseline test, the performance tasks, and the paper survey. The following sections will explain each of these phases in detail.

**Baseline Test**

In order to determine fluctuations from the average for both physiological measurements being examined, it was necessary to establish a baseline for comparison purposes. Consequently, each subject first experienced a 30-second baseline test. During this time, the system simply recorded biofeedback data while the subject looked at an image displayed on the desktop of the personal laptop (see Figure 3.9).

![Figure 3.9 Baseline Test Image](image-url)
Performance Tasks

Each subject was asked to perform ten tasks on the NFL PickEm 2006 Web site. Five of these tasks required typing while the other five did not. The subject performed one typing and one non-typing task for each of the five different text and background color combinations offered on the Web site. The subject was instructed when to select a specific button to change the background and text colors.

The following list, which can be found in more detail in Appendix B, contains the ordering of the color combinations encountered and a brief description of each of the tasks that were performed by each user:

1. Blue text on red background – Find number of wins for a given team
2. Light gray text on dark gray background – Add player to league
3. White text on animated green background - Find win total for a given player
4. Green text on animated plaid background - Email the picks for the current week
5. Green text on purple background - Find a given player’s pick for a given game
6. Blue text on red background - Enter a score for a given game
7. Light gray text on dark gray background - Find the final score of a given game
8. White text on animated green background - Add a tiebreaker game for a week
9. Green text on animated plaid background - Find player with most correct picks
10. Green text on purple background - Update a player’s picks for a given week

Throughout the process, the project practitioner stood near the department computer, but did not assist the subject in the completion of the tasks unless absolutely necessary. The subject informed the practitioner when each task was completed. At the
beginning of each new task, the practitioner clicked on the corresponding button in the BioTrace+ system to set the time marker.

Paper Survey

At the end of the session, the subject was asked to complete a short paper survey. The same number used to identify each subject in the BioTrace+ database was assigned to the survey answers. This survey included five subjective questions – listed in Appendix C of this document – that asked for the users’ opinions on which color combinations were the hardest and easiest to read, which color combinations were the most and least appealing, and how much of a difference animated backgrounds make on the ability to use a Web site.
4. Evaluation and Results

This study was founded upon the belief that physiological analysis has the potential to provide an objective means of determining usability. Testing was conducted on 23 volunteer subjects, resulting in the collection of a significant amount of data. Subsequently, many levels of comparison and evaluation were necessary to uphold the claim that biofeedback data can be used as a method to derive the level of usability of a Web site.

First and foremost, the results of the subjective usability survey had to be computed and represented in graphical form. Secondly, the biofeedback data recorded by the Nexus-10 equipment, funneled through the BioTrace+ software, and saved in a Microsoft Excel spreadsheet also had to be analyzed. A comparison between the two was the final step in the search for conclusions.

4.1 User Survey Results

The user survey, taken at the end of the testing situation, contained five basic questions that were characteristic of typical paper surveys. The first four questions asked the subject to select one of the five color combinations to fit each description: most difficult to read, easiest to read, most appealing colors, and least appealing colors. Thus, all that was required was a simple tabulation of the color scheme that appeared most often for each particular description.

The final question, however, asked the subject to state whether or not he agreed that animated backgrounds affect the ability to use a Web site using a standard Likert
Scale, and therefore required different calculations [Likert 1932]. The following sections contain the results for each of the five questions on the paper usability survey.

4.1.1 Most Difficult to Read Color Combination

The results for this survey question were overwhelmingly in favor of the third color combination – white text on green animated background (see Figure 4.1). Out of the 23 subjects tested, 21 subjects selected the third color combination as the most difficult to read. The remaining subjects selected the green text on plaid background as the least readable.

![Hardest to Read Color Combination Responses](image)

**Figure 4.1 Hardest to Read Color Combination Responses**

4.1.2 Easiest to Read Color Combination

The results for the second survey question were much more dispersed than that of the first. However, a majority of the subjects (13 out of 23) selected the second color combination as the easiest to read, as evidenced in Figure 4.2. The rest of the responses were spread between the first, fourth, and fifth color combinations. In agreement with the
results of the first question, none of the subjects selected the third color combination as the easiest to read.

![Easiest to Read Color Combination Responses](image)

**Figure 4.2 Easiest to Read Color Combination Responses**

### 4.1.3 Most Preferred Color Combination

Since one aspect of this project was concerned with whether text readability or color preference correlates more with biofeedback responses, the third question asked subjects to select the color combination they liked the most. Obviously subjective, it was not surprising that the results to this question were varied (see Figure 4.3). The second color combination again was the preferred choice for 13 out of the 23 subjects tested. In fact, 10 out of the 23 participants chose the second color combination as the easiest to read and most preferred. The remaining responses were divided amongst the first, third, and fourth combinations.
4.1.4 Least Preferred Color Combination

This survey question prompted the most diverse responses (see Figure 4.4). Each of the five color combinations appeared at least once. Both the first and fourth color combinations tied with 7 responses as the least preferred. There does seem to be some agreement between the third and fourth survey questions in that the second color combination – which gained the most responses as most preferred – gained the fewest responses as least preferred.
4.1.5 Effect of Animated Backgrounds

The final survey question asked the subjects to reflect on the effect that the animated backgrounds had on the ability to use the mock Web site. The results were in favor of the idea that animated backgrounds do have an effect on the way observers use a Web site (see Figure 4.5). In fact, 21 out of 23 respondents disagreed or strongly disagreed with the notion that animated backgrounds have no effect. The most common response was to disagree with this notion, while the least common – a neutral opinion – did not even make an appearance as a response.

![Effect of Animated Backgrounds Responses](image)

Figure 4.5 Effect of Animated Backgrounds Responses

4.2 Physiological Data Analysis

While the user survey results could be compiled through simple tallying of responses, the analysis of physiological data proved to be much more time-intensive. Choices had to be made as to how to aggregate the data to find the overall trends, if any existed. The results of the data collected by the heart rate and skin conductivity sensors
are presented in the following sections, first by user performance task and then by color combination. In addition, a student t-test was conducted on various data sets to determine whether or not their differences were significant.

4.2.1 Heart Rate

The heart rate data was collected through a clamped sensor on the middle finger of the left hand. The BioTrace+ software then segmented the heart rate for the entire session based on the user-defined testing protocol. Thus, it was possible to determine the average baseline heart rate, as well as the average rate for each performance task, for each individual subject (see Table 4.1). It was also possible to determine aggregate average heart rates for each performance task (see Figure 4.6).

<table>
<thead>
<tr>
<th>Base</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>120.58</td>
<td>125.13</td>
<td>128.88</td>
<td>125.68</td>
<td>120.45</td>
<td>117.31</td>
<td>128.91</td>
<td>112.98</td>
<td>115.13</td>
<td>109.52</td>
</tr>
<tr>
<td>2</td>
<td>94.28</td>
<td>93.37</td>
<td>97.12</td>
<td>94.04</td>
<td>96.24</td>
<td>94.67</td>
<td>97.57</td>
<td>97.3</td>
<td>94.78</td>
<td>98.24</td>
</tr>
<tr>
<td>3</td>
<td>57.52</td>
<td>62.66</td>
<td>64.83</td>
<td>65.64</td>
<td>63.25</td>
<td>59.54</td>
<td>62.43</td>
<td>69.86</td>
<td>63.89</td>
<td>67.4</td>
</tr>
<tr>
<td>4</td>
<td>109.28</td>
<td>100.02</td>
<td>96.18</td>
<td>94.56</td>
<td>94.76</td>
<td>91.77</td>
<td>91.71</td>
<td>94.59</td>
<td>89.65</td>
<td>89.21</td>
</tr>
<tr>
<td>5</td>
<td>98.98</td>
<td>101.76</td>
<td>101.67</td>
<td>99.64</td>
<td>101.22</td>
<td>101.11</td>
<td>97.88</td>
<td>101.33</td>
<td>101.21</td>
<td>102.47</td>
</tr>
<tr>
<td>6</td>
<td>104.34</td>
<td>101.99</td>
<td>106.54</td>
<td>101.36</td>
<td>102.85</td>
<td>102.27</td>
<td>101.38</td>
<td>99.51</td>
<td>100.88</td>
<td>99.81</td>
</tr>
<tr>
<td>7</td>
<td>97.91</td>
<td>104.14</td>
<td>104.73</td>
<td>98.45</td>
<td>99.33</td>
<td>89.8</td>
<td>95.02</td>
<td>95.94</td>
<td>93.96</td>
<td>91.04</td>
</tr>
<tr>
<td>8</td>
<td>92.68</td>
<td>97.65</td>
<td>94.95</td>
<td>92.62</td>
<td>103.72</td>
<td>91.56</td>
<td>97.3</td>
<td>96.27</td>
<td>91.94</td>
<td>96.39</td>
</tr>
<tr>
<td>9</td>
<td>96.59</td>
<td>96.9</td>
<td>99.02</td>
<td>98.99</td>
<td>99.8</td>
<td>94.27</td>
<td>96.52</td>
<td>98.53</td>
<td>100.47</td>
<td>100.44</td>
</tr>
<tr>
<td>10</td>
<td>96.84</td>
<td>95.54</td>
<td>99.84</td>
<td>97.96</td>
<td>101.72</td>
<td>95.16</td>
<td>98.24</td>
<td>98.2</td>
<td>97.78</td>
<td>98.8</td>
</tr>
<tr>
<td>11</td>
<td>97.3</td>
<td>94.31</td>
<td>100.1</td>
<td>104.45</td>
<td>103.21</td>
<td>100.4</td>
<td>108.79</td>
<td>103.21</td>
<td>102.53</td>
<td>105.95</td>
</tr>
<tr>
<td>12</td>
<td>82.91</td>
<td>81.54</td>
<td>82.11</td>
<td>85.48</td>
<td>90.81</td>
<td>93.2</td>
<td>91.2</td>
<td>92.4</td>
<td>94.66</td>
<td>96.47</td>
</tr>
<tr>
<td>13</td>
<td>82</td>
<td>84.76</td>
<td>84.87</td>
<td>81.48</td>
<td>88.22</td>
<td>83.45</td>
<td>82.74</td>
<td>85.98</td>
<td>83.19</td>
<td>85.6</td>
</tr>
<tr>
<td>14</td>
<td>81.4</td>
<td>77.08</td>
<td>76.31</td>
<td>79.38</td>
<td>79.22</td>
<td>76.87</td>
<td>78.16</td>
<td>78.49</td>
<td>79.14</td>
<td>79.04</td>
</tr>
<tr>
<td>15</td>
<td>86.11</td>
<td>128.01</td>
<td>52.09</td>
<td>48.69</td>
<td>55.12</td>
<td>53.28</td>
<td>50.27</td>
<td>50.08</td>
<td>50.8</td>
<td>45.6</td>
</tr>
<tr>
<td>16</td>
<td>71.02</td>
<td>69.04</td>
<td>69.25</td>
<td>68.27</td>
<td>70.29</td>
<td>68.81</td>
<td>70.82</td>
<td>70.77</td>
<td>68.94</td>
<td>68.61</td>
</tr>
<tr>
<td>17</td>
<td>78.53</td>
<td>83.57</td>
<td>83.75</td>
<td>83.68</td>
<td>85.74</td>
<td>86.37</td>
<td>85.76</td>
<td>86.49</td>
<td>85.64</td>
<td>86.45</td>
</tr>
<tr>
<td>18</td>
<td>127.34</td>
<td>124.8</td>
<td>127.21</td>
<td>120.81</td>
<td>124.12</td>
<td>122.71</td>
<td>125.16</td>
<td>123.61</td>
<td>127.05</td>
<td>128.74</td>
</tr>
<tr>
<td>19</td>
<td>97.6</td>
<td>98.16</td>
<td>98.3</td>
<td>96.33</td>
<td>95.72</td>
<td>95.2</td>
<td>93.2</td>
<td>95.81</td>
<td>96.16</td>
<td>95.88</td>
</tr>
<tr>
<td>20</td>
<td>87.59</td>
<td>84.88</td>
<td>84.2</td>
<td>83.31</td>
<td>84.5</td>
<td>86.52</td>
<td>82.92</td>
<td>84.48</td>
<td>84.45</td>
<td>89.35</td>
</tr>
<tr>
<td>21</td>
<td>62.44</td>
<td>63.47</td>
<td>66.78</td>
<td>61.94</td>
<td>62.95</td>
<td>60</td>
<td>60.47</td>
<td>62.44</td>
<td>61.44</td>
<td>59.53</td>
</tr>
<tr>
<td>22</td>
<td>90.56</td>
<td>87.09</td>
<td>90.01</td>
<td>88.42</td>
<td>89.44</td>
<td>87.48</td>
<td>90.44</td>
<td>87.96</td>
<td>89.2</td>
<td>87.91</td>
</tr>
<tr>
<td>23</td>
<td>66.74</td>
<td>65.64</td>
<td>67.48</td>
<td>68.77</td>
<td>71.33</td>
<td>68.23</td>
<td>69.97</td>
<td>82.58</td>
<td>66.49</td>
<td>68.01</td>
</tr>
</tbody>
</table>
Each color combination was encountered twice throughout the ten performance tasks. Specifically, the color combinations were divided into the following five groupings: 1 and 6 with the blue text on red background, 2 and 7 with the light gray text on dark gray background, 3 and 8 with the white text on animated green background, 4 and 9 with the green text on animated plaid background, 5 and 10 with the green text on purple background. Therefore, heart rates averages could be computed for each color combination for each subject (Table 4.2). Again, an aggregate average for each color combination was also determined (Figure 4.7).
Table 4.2 Average Heart Rate Per Color Combination For Each Subject

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Blue/Red</th>
<th>Gray/Gray</th>
<th>White/Green (A)</th>
<th>Green/Plaid (A)</th>
<th>Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>120.58</td>
<td>127.02</td>
<td>120.93</td>
<td>120.405</td>
<td>114.985</td>
<td>117.88</td>
</tr>
<tr>
<td>2</td>
<td>94.28</td>
<td>95.47</td>
<td>97.21</td>
<td>94.41</td>
<td>97.24</td>
<td>95.215</td>
</tr>
<tr>
<td>3</td>
<td>57.52</td>
<td>62.545</td>
<td>67.345</td>
<td>64.765</td>
<td>65.325</td>
<td>60.19</td>
</tr>
<tr>
<td>4</td>
<td>109.28</td>
<td>95.865</td>
<td>95.385</td>
<td>92.105</td>
<td>91.985</td>
<td>93.835</td>
</tr>
<tr>
<td>5</td>
<td>98.98</td>
<td>99.82</td>
<td>101.5</td>
<td>100.425</td>
<td>101.845</td>
<td>102.08</td>
</tr>
<tr>
<td>6</td>
<td>104.34</td>
<td>101.685</td>
<td>103.025</td>
<td>101.12</td>
<td>101.33</td>
<td>101.595</td>
</tr>
<tr>
<td>7</td>
<td>97.91</td>
<td>99.58</td>
<td>100.335</td>
<td>96.205</td>
<td>95.185</td>
<td>92.425</td>
</tr>
<tr>
<td>8</td>
<td>92.68</td>
<td>97.475</td>
<td>95.61</td>
<td>92.28</td>
<td>100.055</td>
<td>96.29</td>
</tr>
<tr>
<td>9</td>
<td>96.59</td>
<td>96.71</td>
<td>98.775</td>
<td>99.73</td>
<td>100.12</td>
<td>96.07</td>
</tr>
<tr>
<td>10</td>
<td>96.84</td>
<td>96.89</td>
<td>99.02</td>
<td>97.87</td>
<td>100.26</td>
<td>96.58</td>
</tr>
<tr>
<td>11</td>
<td>97.3</td>
<td>101.55</td>
<td>101.655</td>
<td>103.49</td>
<td>104.58</td>
<td>100.815</td>
</tr>
<tr>
<td>12</td>
<td>82.91</td>
<td>86.37</td>
<td>87.255</td>
<td>90.07</td>
<td>93.64</td>
<td>95.125</td>
</tr>
<tr>
<td>13</td>
<td>82</td>
<td>83.75</td>
<td>85.425</td>
<td>82.335</td>
<td>86.91</td>
<td>81.98</td>
</tr>
<tr>
<td>14</td>
<td>81.4</td>
<td>77.62</td>
<td>77.4</td>
<td>79.26</td>
<td>79.13</td>
<td>78.58</td>
</tr>
<tr>
<td>15</td>
<td>86.11</td>
<td>89.14</td>
<td>51.085</td>
<td>49.745</td>
<td>50.36</td>
<td>50.9</td>
</tr>
<tr>
<td>16</td>
<td>71.02</td>
<td>69.93</td>
<td>70.01</td>
<td>68.605</td>
<td>69.45</td>
<td>69.585</td>
</tr>
<tr>
<td>17</td>
<td>78.53</td>
<td>84.665</td>
<td>85.12</td>
<td>84.66</td>
<td>86.095</td>
<td>86.05</td>
</tr>
<tr>
<td>18</td>
<td>127.34</td>
<td>124.98</td>
<td>125.41</td>
<td>123.93</td>
<td>126.43</td>
<td>124.515</td>
</tr>
<tr>
<td>19</td>
<td>97.6</td>
<td>95.68</td>
<td>97.055</td>
<td>96.245</td>
<td>95.8</td>
<td>96.05</td>
</tr>
<tr>
<td>20</td>
<td>87.59</td>
<td>85.7</td>
<td>83.56</td>
<td>83.895</td>
<td>84.475</td>
<td>86.895</td>
</tr>
<tr>
<td>21</td>
<td>62.44</td>
<td>61.97</td>
<td>64.61</td>
<td>61.69</td>
<td>61.24</td>
<td>60</td>
</tr>
<tr>
<td>22</td>
<td>90.56</td>
<td>88.765</td>
<td>88.985</td>
<td>88.81</td>
<td>88.675</td>
<td>87.74</td>
</tr>
<tr>
<td>23</td>
<td>66.74</td>
<td>67.805</td>
<td>75.03</td>
<td>67.63</td>
<td>69.67</td>
<td>68.17</td>
</tr>
</tbody>
</table>

![Aggregate Average HR Per Color Combination](image)

Figure 4.7 Aggregate Average Heart Rate Per Color Combination
The next step in the data representation was to compare how the average heart rate differed on each color combination from the baseline average heart rate. This calculation was made by subject (Table 4.3) and as an aggregate whole (Figure 4.8).

**Table 4.3 Difference From Baseline Average HR By Subject**

<table>
<thead>
<tr>
<th></th>
<th>Blue/Red</th>
<th>Gray/Gray</th>
<th>White/ Green (A)</th>
<th>Green/ Plaid (A)</th>
<th>Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6.44</td>
<td>0.35</td>
<td>-0.175</td>
<td>-5.595</td>
<td>-2.7</td>
</tr>
<tr>
<td>2</td>
<td>1.19</td>
<td>2.93</td>
<td>0.13</td>
<td>2.96</td>
<td>0.935</td>
</tr>
<tr>
<td>3</td>
<td>5.025</td>
<td>9.825</td>
<td>7.245</td>
<td>7.805</td>
<td>2.67</td>
</tr>
<tr>
<td>5</td>
<td>0.84</td>
<td>2.52</td>
<td>1.445</td>
<td>2.865</td>
<td>3.1</td>
</tr>
<tr>
<td>6</td>
<td>-2.655</td>
<td>-1.315</td>
<td>-3.22</td>
<td>-3.01</td>
<td>-2.745</td>
</tr>
<tr>
<td>7</td>
<td>1.67</td>
<td>2.425</td>
<td>-1.705</td>
<td>-2.725</td>
<td>-5.485</td>
</tr>
<tr>
<td>8</td>
<td>4.795</td>
<td>2.93</td>
<td>-0.4</td>
<td>7.375</td>
<td>3.61</td>
</tr>
<tr>
<td>9</td>
<td>0.12</td>
<td>2.185</td>
<td>3.14</td>
<td>3.53</td>
<td>-0.52</td>
</tr>
<tr>
<td>10</td>
<td>0.05</td>
<td>2.18</td>
<td>1.03</td>
<td>3.42</td>
<td>-0.26</td>
</tr>
<tr>
<td>11</td>
<td>4.25</td>
<td>4.355</td>
<td>6.19</td>
<td>7.28</td>
<td>3.515</td>
</tr>
<tr>
<td>12</td>
<td>3.46</td>
<td>4.345</td>
<td>7.16</td>
<td>10.73</td>
<td>12.215</td>
</tr>
<tr>
<td>13</td>
<td>1.75</td>
<td>3.425</td>
<td>0.335</td>
<td>4.91</td>
<td>-0.02</td>
</tr>
<tr>
<td>14</td>
<td>-3.78</td>
<td>-4</td>
<td>-2.14</td>
<td>-2.27</td>
<td>-2.82</td>
</tr>
<tr>
<td>15</td>
<td>3.03</td>
<td>-35.025</td>
<td>-36.365</td>
<td>-35.75</td>
<td>-35.21</td>
</tr>
<tr>
<td>16</td>
<td>-1.09</td>
<td>-1.01</td>
<td>-2.415</td>
<td>-1.57</td>
<td>-1.435</td>
</tr>
<tr>
<td>17</td>
<td>6.135</td>
<td>6.59</td>
<td>6.13</td>
<td>7.565</td>
<td>7.52</td>
</tr>
<tr>
<td>18</td>
<td>-2.36</td>
<td>-1.93</td>
<td>-3.41</td>
<td>-0.91</td>
<td>-2.825</td>
</tr>
<tr>
<td>19</td>
<td>-1.92</td>
<td>-0.545</td>
<td>-1.355</td>
<td>-1.8</td>
<td>-1.55</td>
</tr>
<tr>
<td>20</td>
<td>-1.89</td>
<td>-4.03</td>
<td>-3.695</td>
<td>-3.115</td>
<td>-0.695</td>
</tr>
<tr>
<td>21</td>
<td>-0.47</td>
<td>2.17</td>
<td>-0.75</td>
<td>-1.2</td>
<td>-2.44</td>
</tr>
<tr>
<td>22</td>
<td>-1.795</td>
<td>-1.575</td>
<td>-1.75</td>
<td>-1.885</td>
<td>-2.82</td>
</tr>
<tr>
<td>23</td>
<td>1.065</td>
<td>8.29</td>
<td>0.89</td>
<td>2.93</td>
<td>1.43</td>
</tr>
</tbody>
</table>
Finally, a t-test was performed between each of the results above to determine if the differences that existed amongst each of the five color combinations were significant. Thus, the null hypothesis for each permutation of the color combinations listed in Table 4.4 below was that the differences between the results were simply due to chance. Although none of the null hypotheses could be rejected, the difference that was most likely due to chance (P = .493) was that between color combinations 3 and 5. Of other note, the difference least likely due to chance (P = .136) was that between combinations 1 and 5.

Table 4.4 t-test Comparison Between Color Combinations (HR)

<table>
<thead>
<tr>
<th></th>
<th>(1) Blue/Red</th>
<th>(2) Gray/Gray</th>
<th>(3) White/Green (A)</th>
<th>(4) Green/Plaid (A)</th>
<th>(5) Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Blue/Red</td>
<td>-</td>
<td>-</td>
<td>0.406</td>
<td>1.074</td>
<td>0.518</td>
</tr>
<tr>
<td>(2) Gray/Gray</td>
<td>-</td>
<td>-</td>
<td>0.526</td>
<td>0.110</td>
<td>0.549</td>
</tr>
<tr>
<td>(3) White/Green</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.396</td>
<td>0.018</td>
</tr>
<tr>
<td>(4) Green/Plaid</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.417</td>
</tr>
</tbody>
</table>

Figure 4.8 Aggregate Difference From Baseline Average HR
Table 4.5 contains a t-test comparison between the baseline and each of the color combinations. Again, the null hypothesis was that any differences between the average heart rate values were simply due to chance. Although it was not possible to reject the null hypothesis in any of the cases, it was more probable that the differences between the baseline and color combinations 1, 2, and 4 were due simply to chance than that of color combinations 3 and 5.

Table 4.5 t-test Comparison Between Baseline and Each Color Combination (HR)

<table>
<thead>
<tr>
<th></th>
<th>(1) Blue/Red</th>
<th>(2) Gray/Gray</th>
<th>(3) White/ Green (A)</th>
<th>(4) Green/ Plaid (A)</th>
<th>(5) Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base (t-test)</td>
<td>-0.092</td>
<td>0.076</td>
<td>0.347</td>
<td>0.134</td>
<td>0.356</td>
</tr>
<tr>
<td>Base (P)</td>
<td>0.464</td>
<td>0.470</td>
<td>0.365</td>
<td>0.447</td>
<td>0.362</td>
</tr>
</tbody>
</table>

4.2.2 Skin Conductivity

The skin conductance data was collected through Velcro-strapped censors on the index and ring fingers of the left hand. The figures were represented in micro siemens when reported by the BioTrace+ system. Again, the user-defined protocol allowed for segmentation of the data, meaning that an average skin conductance level could be computed for each individual task. These figures could be represented by subject (Table 4.6) or in an aggregate form (Figure 4.9).
Table 4.6 Average Skin Conductance Per Task For Each Subject

<table>
<thead>
<tr>
<th>Base</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.95</td>
<td>2.35</td>
<td>2.36</td>
<td>2.36</td>
<td>2.55</td>
<td>2.65</td>
<td>2.94</td>
<td>3.01</td>
<td>3.01</td>
<td>2.84</td>
</tr>
<tr>
<td>2</td>
<td>7.46</td>
<td>6.71</td>
<td>8.05</td>
<td>7.77</td>
<td>7.57</td>
<td>8.51</td>
<td>7.58</td>
<td>7.33</td>
<td>8.73</td>
<td>7.95</td>
</tr>
<tr>
<td>3</td>
<td>3.81</td>
<td>4.18</td>
<td>4.4</td>
<td>4.56</td>
<td>4.53</td>
<td>4.55</td>
<td>4.71</td>
<td>4.82</td>
<td>4.87</td>
<td>4.89</td>
</tr>
<tr>
<td>4</td>
<td>9.25</td>
<td>10.41</td>
<td>9.6</td>
<td>10.05</td>
<td>10.07</td>
<td>11.22</td>
<td>11.13</td>
<td>11.47</td>
<td>11.61</td>
<td>11.59</td>
</tr>
<tr>
<td>5</td>
<td>9.22</td>
<td>11</td>
<td>10.62</td>
<td>10.91</td>
<td>10.4</td>
<td>10.39</td>
<td>10.68</td>
<td>11.5</td>
<td>11.32</td>
<td>10.33</td>
</tr>
<tr>
<td>6</td>
<td>16.06</td>
<td>16.37</td>
<td>16.28</td>
<td>15.94</td>
<td>15.31</td>
<td>15.58</td>
<td>15.91</td>
<td>15.53</td>
<td>15.51</td>
<td>15.6</td>
</tr>
<tr>
<td>7</td>
<td>4.95</td>
<td>6.49</td>
<td>7.05</td>
<td>6.97</td>
<td>7.15</td>
<td>7.26</td>
<td>7.35</td>
<td>7.65</td>
<td>7.34</td>
<td>6.87</td>
</tr>
<tr>
<td>8</td>
<td>6.71</td>
<td>8.03</td>
<td>8</td>
<td>7.7</td>
<td>8.41</td>
<td>7.62</td>
<td>8.18</td>
<td>9.01</td>
<td>8.14</td>
<td>7.66</td>
</tr>
<tr>
<td>10</td>
<td>6.26</td>
<td>5.9</td>
<td>6.29</td>
<td>6.9</td>
<td>7.48</td>
<td>6.85</td>
<td>6.42</td>
<td>6.29</td>
<td>6.6</td>
<td>6.32</td>
</tr>
<tr>
<td>11</td>
<td>3.55</td>
<td>4.23</td>
<td>4.6</td>
<td>4.77</td>
<td>4.81</td>
<td>4.48</td>
<td>4.83</td>
<td>4.83</td>
<td>4.89</td>
<td>5.17</td>
</tr>
<tr>
<td>12</td>
<td>1.71</td>
<td>1.88</td>
<td>1.84</td>
<td>1.84</td>
<td>1.65</td>
<td>1.71</td>
<td>1.7</td>
<td>1.67</td>
<td>1.71</td>
<td>1.77</td>
</tr>
<tr>
<td>13</td>
<td>3.4</td>
<td>4.36</td>
<td>4.06</td>
<td>4.67</td>
<td>4.49</td>
<td>4.94</td>
<td>5.71</td>
<td>4.88</td>
<td>5.14</td>
<td>5.73</td>
</tr>
<tr>
<td>14</td>
<td>5.87</td>
<td>6.57</td>
<td>6.34</td>
<td>6.89</td>
<td>6.85</td>
<td>7.12</td>
<td>7.03</td>
<td>7.14</td>
<td>7.31</td>
<td>7.21</td>
</tr>
<tr>
<td>15</td>
<td>4.64</td>
<td>4.65</td>
<td>4.55</td>
<td>4.31</td>
<td>4.62</td>
<td>5.16</td>
<td>5.04</td>
<td>5.09</td>
<td>4.92</td>
<td>4.82</td>
</tr>
<tr>
<td>16</td>
<td>2.76</td>
<td>3.07</td>
<td>2.99</td>
<td>3.26</td>
<td>3.3</td>
<td>2.96</td>
<td>3.03</td>
<td>2.98</td>
<td>2.76</td>
<td>2.57</td>
</tr>
<tr>
<td>17</td>
<td>4.83</td>
<td>4.34</td>
<td>4.55</td>
<td>5.11</td>
<td>6.15</td>
<td>6.44</td>
<td>6.11</td>
<td>5.65</td>
<td>6.09</td>
<td>5.72</td>
</tr>
<tr>
<td>18</td>
<td>3.76</td>
<td>4.37</td>
<td>4.98</td>
<td>5.18</td>
<td>5.75</td>
<td>5.57</td>
<td>5.36</td>
<td>6.47</td>
<td>7.4</td>
<td>6.16</td>
</tr>
<tr>
<td>19</td>
<td>4.97</td>
<td>5.45</td>
<td>5.62</td>
<td>5.88</td>
<td>5.82</td>
<td>5.75</td>
<td>5.86</td>
<td>5.79</td>
<td>5.86</td>
<td>5.79</td>
</tr>
<tr>
<td>21</td>
<td>18.22</td>
<td>20.4</td>
<td>19.27</td>
<td>23.74</td>
<td>22.24</td>
<td>20.87</td>
<td>20.13</td>
<td>22.56</td>
<td>21.72</td>
<td>20.52</td>
</tr>
<tr>
<td>22</td>
<td>3.98</td>
<td>3.92</td>
<td>3.63</td>
<td>3.85</td>
<td>3.89</td>
<td>4.03</td>
<td>3.2</td>
<td>2.92</td>
<td>2.72</td>
<td>2.47</td>
</tr>
<tr>
<td>23</td>
<td>3.22</td>
<td>2.86</td>
<td>2.72</td>
<td>2.41</td>
<td>3.17</td>
<td>3.34</td>
<td>3.4</td>
<td>3.25</td>
<td>3.78</td>
<td>3.16</td>
</tr>
</tbody>
</table>

Figure 4.9 Aggregate Average Skin Conductance By Task
The next step in the analysis of the skin conductivity data was to merge the tasks that encountered the same color combinations: 1 and 6, 2 and 7, 3 and 8, 4 and 9, and 5 and 10. The results of this phase were first tabulated per subject (Table 4.7). It was then possible to compute aggregate average skin conductance data for each color combination (Figure 4.10).

**Table 4.7 Average Skin Conductance Per Color Combination For Each Subject**

<table>
<thead>
<tr>
<th></th>
<th>Base</th>
<th>Blue/Red</th>
<th>Gray/Gray</th>
<th>White/Green (A)</th>
<th>Green/Plaid (A)</th>
<th>Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.95</td>
<td>2.645</td>
<td>2.685</td>
<td>2.685</td>
<td>2.695</td>
<td>2.91</td>
</tr>
<tr>
<td>2</td>
<td>7.46</td>
<td>7.145</td>
<td>7.69</td>
<td>8.25</td>
<td>7.76</td>
<td>8.33</td>
</tr>
<tr>
<td>3</td>
<td>3.81</td>
<td>4.445</td>
<td>4.61</td>
<td>4.715</td>
<td>4.71</td>
<td>4.88</td>
</tr>
<tr>
<td>4</td>
<td>9.25</td>
<td>10.77</td>
<td>10.535</td>
<td>10.83</td>
<td>10.83</td>
<td>11.455</td>
</tr>
<tr>
<td>5</td>
<td>9.22</td>
<td>10.84</td>
<td>11.06</td>
<td>11.115</td>
<td>10.365</td>
<td>10.395</td>
</tr>
<tr>
<td>6</td>
<td>16.06</td>
<td>16.14</td>
<td>15.905</td>
<td>15.725</td>
<td>15.455</td>
<td>15.845</td>
</tr>
<tr>
<td>7</td>
<td>4.95</td>
<td>6.92</td>
<td>7.35</td>
<td>7.155</td>
<td>7.01</td>
<td>7.17</td>
</tr>
<tr>
<td>8</td>
<td>6.71</td>
<td>8.105</td>
<td>8.505</td>
<td>7.92</td>
<td>8.035</td>
<td>8.095</td>
</tr>
<tr>
<td>10</td>
<td>6.26</td>
<td>6.16</td>
<td>6.29</td>
<td>6.75</td>
<td>6.9</td>
<td>6.535</td>
</tr>
<tr>
<td>12</td>
<td>1.71</td>
<td>1.79</td>
<td>1.755</td>
<td>1.775</td>
<td>1.71</td>
<td>1.76</td>
</tr>
<tr>
<td>13</td>
<td>3.4</td>
<td>5.035</td>
<td>4.47</td>
<td>4.905</td>
<td>5.11</td>
<td>5.385</td>
</tr>
<tr>
<td>14</td>
<td>5.87</td>
<td>6.8</td>
<td>6.74</td>
<td>7.1</td>
<td>7.03</td>
<td>7.19</td>
</tr>
<tr>
<td>15</td>
<td>4.64</td>
<td>4.845</td>
<td>4.82</td>
<td>4.615</td>
<td>4.72</td>
<td>4.86</td>
</tr>
<tr>
<td>16</td>
<td>2.76</td>
<td>3.05</td>
<td>2.985</td>
<td>3.01</td>
<td>2.935</td>
<td>2.985</td>
</tr>
<tr>
<td>17</td>
<td>4.83</td>
<td>5.225</td>
<td>5.1</td>
<td>5.6</td>
<td>5.935</td>
<td>6.115</td>
</tr>
<tr>
<td>18</td>
<td>3.76</td>
<td>4.865</td>
<td>5.725</td>
<td>6.29</td>
<td>5.955</td>
<td>4.945</td>
</tr>
<tr>
<td>19</td>
<td>4.97</td>
<td>5.655</td>
<td>5.705</td>
<td>5.87</td>
<td>5.805</td>
<td>5.85</td>
</tr>
<tr>
<td>20</td>
<td>4.36</td>
<td>5.82</td>
<td>6.075</td>
<td>6.36</td>
<td>6.335</td>
<td>6.39</td>
</tr>
<tr>
<td>21</td>
<td>18.22</td>
<td>20.265</td>
<td>20.915</td>
<td>22.73</td>
<td>21.38</td>
<td>22.065</td>
</tr>
<tr>
<td>22</td>
<td>3.98</td>
<td>3.56</td>
<td>3.275</td>
<td>3.285</td>
<td>3.18</td>
<td>3.52</td>
</tr>
<tr>
<td>23</td>
<td>3.22</td>
<td>3.13</td>
<td>2.985</td>
<td>3.095</td>
<td>3.165</td>
<td>3.155</td>
</tr>
</tbody>
</table>
Figure 4.10 Aggregate Average Skin Conductance Per Color Combination

The third level of data analysis examined the difference between the average for each color combination and the baseline average. At the risk of being redundant, it is necessary to report that this data can be represented by subject (Table 4.8) or aggregate average difference from the baseline average (Figure 4.11).
### Table 4.8 Difference From Baseline Average SC By Subject

<table>
<thead>
<tr>
<th></th>
<th>Blue/Red</th>
<th>Gray/Gray</th>
<th>White/Green (A)</th>
<th>Green/Plaid (A)</th>
<th>Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.695</td>
<td>0.735</td>
<td>0.735</td>
<td>0.745</td>
<td>0.96</td>
</tr>
<tr>
<td>2</td>
<td>-0.315</td>
<td>0.23</td>
<td>0.79</td>
<td>0.3</td>
<td>0.87</td>
</tr>
<tr>
<td>3</td>
<td>0.635</td>
<td>0.8</td>
<td>0.905</td>
<td>0.9</td>
<td>1.07</td>
</tr>
<tr>
<td>4</td>
<td>1.52</td>
<td>1.285</td>
<td>1.58</td>
<td>1.58</td>
<td>2.205</td>
</tr>
<tr>
<td>5</td>
<td>1.62</td>
<td>1.84</td>
<td>1.895</td>
<td>1.145</td>
<td>1.175</td>
</tr>
<tr>
<td>6</td>
<td>0.08</td>
<td>-0.155</td>
<td>-0.335</td>
<td>-0.605</td>
<td>-0.215</td>
</tr>
<tr>
<td>7</td>
<td>1.97</td>
<td>2.4</td>
<td>2.205</td>
<td>2.06</td>
<td>2.22</td>
</tr>
<tr>
<td>8</td>
<td>1.395</td>
<td>1.795</td>
<td>1.21</td>
<td>1.325</td>
<td>1.385</td>
</tr>
<tr>
<td>9</td>
<td>4.295</td>
<td>6.2</td>
<td>6.815</td>
<td>6.87</td>
<td>7.805</td>
</tr>
<tr>
<td>10</td>
<td>-0.1</td>
<td>0.03</td>
<td>0.49</td>
<td>0.64</td>
<td>0.275</td>
</tr>
<tr>
<td>11</td>
<td>0.98</td>
<td>1.165</td>
<td>1.28</td>
<td>1.44</td>
<td>1.37</td>
</tr>
<tr>
<td>12</td>
<td>0.08</td>
<td>0.045</td>
<td>0.065</td>
<td>0</td>
<td>0.05</td>
</tr>
<tr>
<td>13</td>
<td>1.635</td>
<td>1.07</td>
<td>1.505</td>
<td>1.71</td>
<td>1.985</td>
</tr>
<tr>
<td>14</td>
<td>0.93</td>
<td>0.87</td>
<td>1.23</td>
<td>1.16</td>
<td>1.32</td>
</tr>
<tr>
<td>15</td>
<td>0.205</td>
<td>0.18</td>
<td>-0.025</td>
<td>0.08</td>
<td>0.22</td>
</tr>
<tr>
<td>16</td>
<td>0.29</td>
<td>0.225</td>
<td>0.25</td>
<td>0.175</td>
<td>0.225</td>
</tr>
<tr>
<td>17</td>
<td>0.395</td>
<td>0.27</td>
<td>0.77</td>
<td>1.105</td>
<td>1.285</td>
</tr>
<tr>
<td>18</td>
<td>1.105</td>
<td>1.965</td>
<td>2.53</td>
<td>2.195</td>
<td>1.185</td>
</tr>
<tr>
<td>19</td>
<td>0.685</td>
<td>0.735</td>
<td>0.9</td>
<td>0.835</td>
<td>0.88</td>
</tr>
<tr>
<td>20</td>
<td>1.46</td>
<td>1.715</td>
<td>2</td>
<td>1.975</td>
<td>2.03</td>
</tr>
<tr>
<td>21</td>
<td>2.045</td>
<td>2.695</td>
<td>4.51</td>
<td>3.16</td>
<td>3.845</td>
</tr>
<tr>
<td>22</td>
<td>-0.42</td>
<td>-0.705</td>
<td>-0.695</td>
<td>-0.8</td>
<td>-0.46</td>
</tr>
<tr>
<td>23</td>
<td>-0.09</td>
<td>-0.235</td>
<td>-0.125</td>
<td>-0.055</td>
<td>-0.065</td>
</tr>
</tbody>
</table>

### Figure 4.11 Aggregate Difference From Baseline Average SC

![Aggregate Difference From Baseline Average SC](image-url)
As with the heart rate data, a t-test was performed between each of the results above. The null hypothesis for each of the color combinations listed in Table 4.9 was that the differences between the results were simply due to chance. While none of the null hypotheses could be rejected, the difference that was most likely due to chance \( (P = .460) \) was, yet again, the one that existed between the third and fifth color combinations. Additionally, the difference least likely due to chance \( (P = .139) \) was the one between the first and fifth color combinations.

### Table 4.9 t-test Comparison Between Color Combinations (SC)

<table>
<thead>
<tr>
<th></th>
<th>(1) Blue/Red</th>
<th>(2) Gray/Gray</th>
<th>(3) White/Green (A)</th>
<th>(4) Green/Plaid (A)</th>
<th>(5) Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Blue/Red</td>
<td>-</td>
<td>-0.479</td>
<td>-1.010</td>
<td>-0.764</td>
<td>-1.098</td>
</tr>
<tr>
<td>(2) Gray/Gray</td>
<td>-</td>
<td>-</td>
<td>-0.512</td>
<td>-0.276</td>
<td>-0.606</td>
</tr>
<tr>
<td>(3) White/Green</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.235</td>
<td>-0.100</td>
</tr>
<tr>
<td>(4) Green/Plaid</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-0.333</td>
</tr>
</tbody>
</table>

Finally, the data in Table 4.10 contains a t-test comparison between the baseline average skin conductance and each of the color combination aggregate averages. The null hypothesis was that any differences between the values were simply due to chance. Unfortunately, it was not possible to reject the null hypothesis in any of the cases. It may be significant, however, to note that the differences between third and fifth color combination averages had the highest probability of being due to chance.

### Table 4.10 t-test Comparison Between Baseline and Each Color Combination (SC)

<table>
<thead>
<tr>
<th></th>
<th>(1) Blue/Red</th>
<th>(2) Gray/Gray</th>
<th>(3) White/Green (A)</th>
<th>(4) Green/Plaid (A)</th>
<th>(5) Green/Purple</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base (t-test)</td>
<td>-0.729</td>
<td>-0.849</td>
<td>-0.999</td>
<td>-0.942</td>
<td>-1.040</td>
</tr>
<tr>
<td>Base (P)</td>
<td>0.235</td>
<td>0.200</td>
<td>0.1612</td>
<td>0.176</td>
<td>0.152</td>
</tr>
</tbody>
</table>
4.3 Comparisons and Discussion

The success of this project relied on the comparison between the subjective paper survey and the objective biofeedback data. Specifically, the evaluation was divided into the three categories outlined by the user reaction survey: text readability, color preference, and the use of animated backgrounds.

4.3.1 Text Readability

One aspect of this study was to determine whether the ease or difficulty of text readability was reflected in the physiological responses of the participants. As evidenced in Section 4.1, the color combination selected by the majority of the subjects as the easiest to read was the light gray text on the dark gray background, while the color combination deemed hardest to read was the white text on an animated green background. Table 4.11 below presents a comparison between the paper survey and biofeedback data results.

<table>
<thead>
<tr>
<th>Color Combinations in Subject-Rated Order of Readability</th>
<th>Average Difference from Baseline Heart Rate (Beats/Minute)</th>
<th>Average Difference from Baseline Skin Conductance (Siemens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray/Gray</td>
<td>-0.38283</td>
<td>1.093696</td>
</tr>
<tr>
<td>Green/Purple</td>
<td>-1.825</td>
<td>1.374783</td>
</tr>
<tr>
<td>Blue/Red</td>
<td>0.45413</td>
<td>0.917174</td>
</tr>
<tr>
<td>Green/Plaid (A)</td>
<td>-0.685</td>
<td>1.214783</td>
</tr>
<tr>
<td>White/Green (A)</td>
<td>-1.77652</td>
<td>1.325435</td>
</tr>
</tbody>
</table>

In the case of the heart rate, the light gray text on dark gray background average differs the least from the baseline. Thus, the heart rate that was deemed the easiest to read
caused the least deviation in the average heart rate of the subjects. In addition, excluding
the data for the green text on purple background combination, the average difference
from the baseline appears to increase as the text gets harder to read.

Two important inconsistencies stand out, however. The first is that, although all
the research presented in Section 1.1 seems to indicate that heart rate increases with
mental stress, the majority of the differences from the baseline are in the reverse
direction. In fact, the only color combination that had a positive difference from the
baseline average was the blue text on red background, which was the first combination
encountered in the subject tests. The decrease in heart rate for four out of five color
combinations seems indicate that something other than mental stress is at play when a
user views hard-to-read color combinations.

The second incongruity exists in the data collected for the green text on purple
background combination. Although this color combination was ranked second-easiest to
read by the subjects, the data shows the greatest average difference from the baseline
heart rate. One potential explanation for this discrepancy is that the green text on purple
background combination was the last color combination tested on each subject. Thus, the
simple fact that the experiment was nearing its end might have had an affect on the heart
rate difference.

The skin conductance comparison showed different results than that of the heart
rate data, especially in that all of the skin conductance figures increased from the baseline
average. In fact, as the readability decreases, the skin conductance follows an increasing
trend. Again, in agreement with the heart rate findings, the major inconsistency in the
skin conductance data is the green text on purple background combination. The second
color combination that appears to break the trend is the blue text on red background combination, which was the first color combination encountered by the subjects in the experiment.

This data appears to show a correlation between the biofeedback data and the paper survey results. Thus, it can be assumed that text readability does affect the physiology of a user when viewing a system, by decreasing the heart rate and increasing the skin conductance. The data that diverges from this conclusion could possibly be due to the order that the color combinations appeared to the subjects.

4.3.2 Color Preference

The third and fourth questions on the paper survey concerned user color preferences. It is possible that a subject’s partiality towards or distaste for a certain color combination might have had an impact on his or her biological responses to it. Again, the survey provided a most-preferred color combination and a least-preferred color combination. However, since the responses for the two survey questions did not agree, two arrangements of the color combinations must be used to compare to the physiological data (Tables 4.12 and 4.13).

Table 4.12 Comparison Between Paper Survey and Biofeedback Data, From Highest to Lowest Subject-Rated Color Preference, Based on Most Preferred Color Combination Survey Question

<table>
<thead>
<tr>
<th>Color Combinations in Subject-Rated Order of Preference</th>
<th>Average Difference from Baseline Heart Rate (Beats/Minute)</th>
<th>Average Difference from Baseline Skin Conductance (Siemens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray/Gray</td>
<td>-0.38283</td>
<td>1.093696</td>
</tr>
<tr>
<td>Blue/Red</td>
<td>0.45413</td>
<td>0.917174</td>
</tr>
<tr>
<td>Green/Plaid (A)</td>
<td>-0.685</td>
<td>1.214783</td>
</tr>
<tr>
<td>White/Green (A)</td>
<td>-1.77652</td>
<td>1.325435</td>
</tr>
<tr>
<td>Green/Purple</td>
<td>-1.825</td>
<td>1.374783</td>
</tr>
</tbody>
</table>
Table 4.13 Comparison Between Paper Survey and Biofeedback Data, From Highest to Lowest Subject-Rated Color Preference, Based on Least Preferred Color Combination Survey Question

<table>
<thead>
<tr>
<th>Color Combinations in Subject-Rated Order of Preference</th>
<th>Average Difference from Baseline Heart Rate (Beats/Minute)</th>
<th>Average Difference from Baseline Skin Conductance (Siemens)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gray/Gray</td>
<td>-0.38283</td>
<td>1.093696</td>
</tr>
<tr>
<td>Green/Purple</td>
<td>-1.825</td>
<td>1.374783</td>
</tr>
<tr>
<td>White/Green (A)</td>
<td>-1.77652</td>
<td>1.325435</td>
</tr>
<tr>
<td>Green/Plaid (A), Blue/Red</td>
<td>-0.685, 0.45413</td>
<td>1.214783, 0.917174</td>
</tr>
</tbody>
</table>

The figures above both seem to indicate a relationship between color preference and physiological responses. The first table, which is based on the question that asked subjects to select their most preferred of the five color combinations encountered, shows an overall trend of increasing distance from the baseline as the color combination decreases in preference. In addition, the skin conductance shows an increasing trend. In both cases, the only inconsistency lies with the blue text on red background color combination. Most importantly, however, is the fact that the green text on purple background color combination was the least preferred in this question, as well as deviating the most from the baseline for both the heart rate and skin conductivity, which was not the case when only text readability was taken into account.

The second table is based on the survey question that asked the subject to select which combination he least preferred. These results are quite different than any of the previous results, in that the differences from the baseline appear to be high at both ends, but relatively smaller in the middle of the color preference arrangement, forming a sort of parabola shape. This would indicate that both the most preferred and the least preferred
color combinations would cause the most drastic change in heart rate and skin conductance responses.

Regardless, this data seems to indicate that personal color preference also plays a role in a user’s physiological response to a system’s text and background color choices. In fact, because of the existence of fewer discrepancies in the data when arranged in preference order, it might even play a stronger role than text readability.

4.3.3 Animated Backgrounds

Section 4.1.5 presented the results of the fifth survey question, which showed that 21 out of 23 subjects disagreed or strongly disagreed with the notion that animated backgrounds have no effect on the ability to use a system. Table 4.14 contains a t-test comparison of heart rate and skin conductance data for the non-animated and animated color combinations, with the null hypothesis that the differences are merely coincidental.

<table>
<thead>
<tr>
<th></th>
<th>Heart Rate Average Difference From Baseline</th>
<th>Skin Conductance Average Difference From Baseline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-Animated Backgrounds</td>
<td>-0.58439</td>
<td>1.128551</td>
</tr>
<tr>
<td>Animated Backgrounds</td>
<td>-1.23076</td>
<td>1.270109</td>
</tr>
<tr>
<td>t-test</td>
<td>0.679847</td>
<td>-0.80025</td>
</tr>
</tbody>
</table>

Unfortunately, the null hypothesis can not be rejected in either case. However, both the heart rate and skin conductance differences between non-animated and animated backgrounds still have relatively small probabilities of being due to chance (27.3% and 24.1%, respectively). Thus, it is still possible that this data shows that animated backgrounds such as the ones used in this experiment do affect the ability to use a system.
5. Future Work

The logical next step to the completion of this project would be to expand the study to include other facets of system design, such as layout and navigation. The goal of this future study would be to determine the feasibility of using physiological data in all aspects of usability testing. In essence, the study of text and background color combinations was just the tip of the iceberg when it comes to using biofeedback data in system design.

Another lesson learned was the fact that the order of appearance might play a part in the resulting physiological data. In this study, both the first and last color combinations encountered were the culprits when it came to data inconsistencies. Thus, it is recommended that future work in this research area should randomize the order of appearance of the different design characteristics under review.

Finally, it would be interesting to note the subsequent results when the subjects are allowed several minutes to fully relax before undergoing the testing scenario. As evidenced in the results section, the first color combination encountered caused discrepancies in the data that might have otherwise been avoided. In addition, adding a baseline test at both the beginning and the end of the testing session might reveal more obvious results.
6. Conclusion

This project was designed to evaluate the implementation of physiological analysis to conduct usability testing in order provide another means for determining users’ reactions to a system. The study concentrated on the text and background color combination choices for a mock Web site – NFL PickEm 2006 – and compared the results of a paper user reaction survey to biofeedback data that was collected by the BioTrace+ software package – specifically, heart rate and skin conductance. The results of the tests conducted on 23 subjects indicate that there appears to be a correlation between the user surveys and the biofeedback data.

A secondary goal of this project was to determine whether text readability or color preference plays a larger role in affecting biological responses to particular color combinations. Contrary to the researcher’s previous beliefs, it appears that personal color preference is more related to physiological responses than text readability. However, both text readability and color preference seem to have some correlation with heart rate and skin conductivity.

A third goal was to determine the effects of animated backgrounds on the ability to use a Web site. Although results were not conclusive, it does appear that the physiological data collected supports the notion that animated backgrounds hinder the ability to use a Web site. Nevertheless, this is one aspect of this project that could definitely be developed in the future.

The results of this study show that physiological analysis provides a relatively equivalent, if not superior, means of conducting usability tests. The fact that the survey results agreed to such a high degree with the biofeedback data indicates that
physiological analysis can be used in place of subjective usability tests. This may prove extremely important in situations that traditional usability testing methods are not possible.

Finally, this research shows that it is feasible that usability testing using physiological analysis could be used to improve current system design guidelines. The fact that text readability and user color preference affect biofeedback data indicates that both are important in the design of color schemes of systems. With these new guidelines in place, it may provide the first steps to freeing users from the burden of poorly designed Web sites.
ACKNOWLEDGEMENTS

First and foremost, I would like to thank my project chairperson, Dr. John D. Fernandez, for all of his assistance with this project and throughout my undergraduate and graduate careers at Texas A&M University – Corpus Christi. Without his assistance, I do not think I would have made it through these last six years with my sanity intact. I am grateful for his enthusiastic support in my academic, professional, and personal endeavors.

Next, I would be amiss to neglect the assistance of Drs. David Thomas and Michael Scherger. I realize that serving on a graduate committee takes considerable time and effort. More than anything, I appreciate the advice, insights, and tough questions posed by these honorable gentlemen.

I also must take this time to thank Professors Nancy Cameron and Charlotte Busch. For some reason, Nancy Cameron hired me as a mere first-year student to tutor and grade for a class I had never taken – a position that I held for over three years. This experience was invaluable because it fostered an even greater passion for teaching within me, in addition to funding my undergraduate pursuits. When I decided to return to Computer Science for graduate study – after a brief interlude in the Masters in Secondary Education program – Professor Charlotte Busch helped expedite the transition with overwhelming encouragement.

Finally, I have to thank my family for their never-ending love and support – especially my husband, Mark. I know that I was probably not the easiest person to be around the past year. I feel so blessed that Mark supported the completion of this project during our first year as a married couple. Frankly, it made everything a bit easier.
BIBLIOGRAPHY AND REFERENCES


APPENDIX A - NFL PICKEM 2006 DATA DICTIONARY

Table: Team

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Nullable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Team_City</td>
<td>VARCHAR(50)</td>
<td>NOT NULL</td>
<td>Location of team</td>
</tr>
<tr>
<td>Team_Name</td>
<td>VARCHAR(50)</td>
<td>NOT NULL</td>
<td>Name of team</td>
</tr>
<tr>
<td>Team_Conference</td>
<td>CHAR(3)</td>
<td>NOT NULL</td>
<td>AFC or NFC</td>
</tr>
<tr>
<td>Team_Division</td>
<td>VARCHAR(10)</td>
<td>NOT NULL</td>
<td>North, South, East, or West</td>
</tr>
<tr>
<td>Team_Wins</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of wins</td>
</tr>
<tr>
<td>Team_Losses</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of losses</td>
</tr>
</tbody>
</table>

Table: Game

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Nullable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game_Week</td>
<td>INT(2)</td>
<td>NOT NULL</td>
<td>Week 1-17</td>
</tr>
<tr>
<td>AwayTeam_Name</td>
<td>VARCHAR(50)</td>
<td>NOT NULL</td>
<td>Away team for game</td>
</tr>
<tr>
<td>HomeTeam_Name</td>
<td>VARCHAR(50)</td>
<td>NOT NULL</td>
<td>Home team for game</td>
</tr>
<tr>
<td>AwayTeam_Pts</td>
<td>INT(3)</td>
<td>NOT NULL</td>
<td>Away team points scored</td>
</tr>
<tr>
<td>HomeTeam_Pts</td>
<td>INT(3)</td>
<td>NOT NULL</td>
<td>Home team points scored</td>
</tr>
<tr>
<td>Game_TieBreaker</td>
<td>CHAR(1)</td>
<td>DEFAULT ‘N’</td>
<td>‘Y’ or ‘N’</td>
</tr>
</tbody>
</table>

Table: Player

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Nullable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Player_FName</td>
<td>VARCHAR(20)</td>
<td>NOT NULL</td>
<td>Player’s first name</td>
</tr>
<tr>
<td>Player_LName</td>
<td>VARCHAR(20)</td>
<td>NOT NULL</td>
<td>Player’s last name</td>
</tr>
<tr>
<td>Player_Wk1</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 1</td>
</tr>
<tr>
<td>Player_Wk2</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 2</td>
</tr>
<tr>
<td>Player_Wk3</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 3</td>
</tr>
<tr>
<td>Player_Wk4</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 4</td>
</tr>
<tr>
<td>Player_Wk5</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 5</td>
</tr>
<tr>
<td>Player_Wk6</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 6</td>
</tr>
<tr>
<td>Player_Wk7</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 7</td>
</tr>
<tr>
<td>Player_Wk8</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 8</td>
</tr>
<tr>
<td>Player_Wk9</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 9</td>
</tr>
<tr>
<td>Player_Wk10</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 10</td>
</tr>
<tr>
<td>Player_Wk11</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 11</td>
</tr>
<tr>
<td>Player_Wk12</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 12</td>
</tr>
<tr>
<td>Player_Wk13</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 13</td>
</tr>
<tr>
<td>Player_Wk14</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 14</td>
</tr>
<tr>
<td>Player_Wk15</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 15</td>
</tr>
<tr>
<td>Player_Wk16</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 16</td>
</tr>
<tr>
<td>Player_Wk17</td>
<td>INT(2)</td>
<td>DEFAULT 0</td>
<td>Number of correct picks for Week 17</td>
</tr>
</tbody>
</table>

Table: Pick

<table>
<thead>
<tr>
<th>Column</th>
<th>Type</th>
<th>Nullable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Game_Week</td>
<td>INT(2)</td>
<td>NOT NULL</td>
<td>Week for pick</td>
</tr>
<tr>
<td>Player_FName</td>
<td>VARCHAR(20)</td>
<td>NOT NULL</td>
<td>Player’s first name</td>
</tr>
<tr>
<td>Player_LName</td>
<td>VARCHAR(20)</td>
<td>NOT NULL</td>
<td>Player’s last name</td>
</tr>
<tr>
<td>HomeTeam_Name</td>
<td>VARCHAR(50)</td>
<td>NOT NULL</td>
<td>Game for pick</td>
</tr>
<tr>
<td>Winner_Name</td>
<td>VARCHAR(20)</td>
<td>NOT NULL</td>
<td>Name of team picked</td>
</tr>
<tr>
<td>Away_Pts</td>
<td>INT(3)</td>
<td>NOT NULL</td>
<td>Picked away points</td>
</tr>
<tr>
<td>Home_Pts</td>
<td>INT(3)</td>
<td>NOT NULL</td>
<td>Picked home points</td>
</tr>
</tbody>
</table>
APPENDIX B - USER PERFORMANCE TASKS

General Instructions for Usability Testing

NFL PickEm 2006 Web Site

In the next 10 minutes or so, you will be carrying out ten tasks on the NFL PickEm 2006 Web site. During this process, the text and background colors will change, but the layout of the screen and the menu options will remain constant. If you are confused at any point, please just make your best guess about how to proceed, using the information that you have been given. I will intervene if necessary to help you make progress.

The sensors on your left hand will be used to monitor your heart rate and skin conductivity throughout the testing process. Your name will not be used in this study, so there is no way to link you to the data that the sensors collect.

At the start of each task, please say out loud: “Beginning Task,” followed by the number of the task. When you are done, please say: “Task Completed.”

Specific Task Instructions

Background:

The NFL PickEm Web site is a tool for creating football leagues for fans of the game. Each player selects who they think will win for each game in the 17 week season. This system tracks the number of accurate guesses for each player, as well as the overall leader. In addition, the system maintains records for each of the 32 teams in the National Football League.

The tasks you will conduct model the actual use of the Web site by players and league managers.

Task 1

To begin the task, click on the button in the menu with the number 1 on it.
Find the number of games that the Cleveland Browns have won in the 2006 season.

Task 2

To begin the task, click on the button in the menu with the number 2 on it.
Click on Admin in the menu.
Login using the Login name login and the password pass.
Click on the Show Players button.
Add a new player with any first and last name of your choosing. (You will need to remember this name.)

Task 3

To begin the task, click on the button in the menu with the number 3 on it.
Find how many total wins that Mark S. has in the standings.

Task 4

To begin the task, click on the button in the menu with the number 4 on it.
Click on Picks in the menu.
Go through the process to email the picks for the current week.
  * Pick which teams you choose to win each game
  * In the tie breaker, write a score for each of the teams
  * Write anything you want in the Name and Code fields

**Task 5**

To begin the task, click on the button in the menu with the number 5 on it. Find out who **Joe P.** picked to win the Jaguars at Texans game in Week 7.

**Task 6**

To begin the task, click on the button in the menu with the number 1 on it. Click on Admin in the menu. Login using the Login name **login** and the password **pass**. Go to Week 12. Enter a score for the **Eagles at Colts** game and press Update Scores.

**Task 7**

To begin the task, click on the button in the menu with the number 2 on it. Find the final score of the **Chiefs and Broncos** game in Week 2.

**Task 8**

To begin the task, click on the button in the menu with the number 3 on it. Click on Admin in the menu. Login using the Login name **login** and the password **pass**. Go to Week 17. Go through the process to add a Tie Breaker game for Week 17.

**Task 9**

To begin the task, click on the button in the menu with the number 4 on it. Find the player who had the most correct picks in Week 10.

**Task 10**

To begin the task, click on the button in the menu with the number 5 on it. Click on Admin in the menu. Login using the Login name **login** and the password **pass**. Click on Show Players Click on the name of the player that you added in Task 1. Go through the process to update that players picks for Week 15.
APPENDIX C - PAPER USABILITY SURVEY

1. Which color combination was the hardest to read?
   1  2  3  4  5

2. Which color combination was the easiest to read?
   1  2  3  4  5

3. Which color combination contains colors that you like the most?
   1  2  3  4  5

4. Which color combination contains colors that you like the least?
   1  2  3  4  5

5. Animated backgrounds do not negatively affect the ability to use a Web site.
   Strongly Disagree  Disagree  Neutral  Agree  Strongly Agree