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The Effect Overall Density Plays On Performance and Preference in a Windowed Environment

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THE EFFECT OVERALL DENSITY PLAYS ON PERFORMANCE AND
PREFERENCE IN A WINDOWED ENVIRONMENT

by

Lucas M. Downard

A thesis submitted to the
School of Computing
in partial fulfillment of the requirements for the degree of

Master of Science in Computer and Information Sciences

UNIVERSITY OF NORTH FLORIDA
SCHOOL OF COMPUTING

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ABSTRACT

This thesis consists of fundamental research into the effect that a display's overall density has on a user's performance and preference while performing simple tasks using a window-styled computer application specifically developed for this study. This study sought to reevaluate previous findings by exploring their application in the more current, present-day environment. In this research, overall density was considered to be a measure of a screen's complexity and was examined at three different levels. Users performed a series of tasks using only one of three available screens with different density levels. The same tasks were performed by all users to determine if different density levels exhibit any effect on the user's performance (as measured by completion time and accuracy) or preference. The outcome of these trials demonstrates that overall density and complexity play an important role in a user's performance and acceptance of a screen.

Chapter 1

INTRODUCTION

Computer systems have found their way today into nearly every home and office workspace in the industrialized world. Computer development has continually evolved and throughout what has been an explosion in computing processing power, the human interface has not been forgotten. People must be able to interact with the machine, and the machine-to-human interface must be capable of delivering that information efficiently. When considering this interface, several aspects, or features, of the display device play a deciding role in its adoption or rejection. Guidelines have been developed that seek to assist the designer in a display's creation (e.g., the guidelines developed by Smith [Smith86]). An increased understanding of these aspects will most likely result in improvements being made in interface designs and user desirability.

A display's complexity is one aspect of user interface design that requires further study in order to better assess its impact to both hardware (display construction) and software (graphics applications) development. One would then expect a better understanding of display complexity to ultimately translate into more usable and productive products.

Along these lines, it would be beneficial if a professionally accepted complexity metric and measurement method were available. However, the research conducted in preparation for this study found no established, universal method for measuring display complexity (as there are many contributing factors and varying procedures employed).

Neither is there a complete understanding of complexity's effect on a user's performance and preference.

While not necessarily a tangible metric, user preference is still important to study as it contributes to a display's adoption or rejection. For example, a screen may allow a proficient user to perform a task very efficiently or quickly but be designed in a manner that causes it to be rejected by the user community as a whole. This can translate into additional expenses if a commercial entity is forced to redesign a screen because of a lack of user acceptance. On the other hand, a screen needs to be designed with efficiency in mind as well, or users may spend more time than necessary performing desired tasks.

Considering both user performance and preference in the study of display complexity will provide a multifaceted view of any metric used to measure or define display complexity.

1.1 Related Work

Various studies have been conducted concerning human preference for an object or display in relation to the complexity of the object or display in question. Some have considered how the complexity of an object or display, in addition to preference, may also affect human performance.

In a study conducted by Vitz [Vitz66], eight line drawings (stimuli) of increasing complexity (created by adding lines, or “steps”, to the previous image) were used to test the premise that humans have an ideal level of complexity at which they are best able to process and store information. Users evaluated and preferentially ranked each drawing. The results supported the assertion that humans do have preferred amounts of, and limits to, complexity.

Maddi [Maddi61] sought to develop a thorough explanation of the role novelty plays in human behavior. He reviewed previous research and examined the effect that novelty and deviations from learned expectations have on user’s desire to approach or avoid an object or situation. As described in Maddi’s work, the Discrepancy Hypothesis stated that small deviations between what the user expected and what actually occurred bring about positive effect leading to approach behavior, while large deviations bring about negative effect leading to avoidance behavior. Maddi made two propositions for a “Modified Discrepancy Hypothesis”. The first proposition stated that as unexpectedness increases from a minimum, the resultant effect starts negative, then climbs to peak in the positive, and finally descends to negative again. The second proposition to the Discrepancy Hypothesis stated that the more positively a person feels about a particular thing, the more likely he or she is to approach it. These propositions support the premise that users prefer more complexity in an interface or computer display until it reaches a level that becomes unappealing or uncomfortable. At this point, their preference for the interface or display decreases.

Tullis [Tullis83] presented a survey of display research dealing with alphanumeric displays. He noted that improved screen design can have a significant positive effect on a user's ability to interpret the information presented and can result in practical productivity gains. He provided descriptions and definitions of four display characteristics: overall density, local density, grouping, and layout complexity.

Tullis defined overall density as the number of characters used divided by the total number of character spaces present. He also notes that, "The total amount of information displayed on a single frame should be kept to a minimum" [Tullis83, page 662].

Tullis defined local density similarly to overall density but further related it to how densely packed the items are in relation to each other. Two screens can have the same overall density but different local densities. Line spacing and blank spaces adjacent to characters can be used to decrease local density. Considering this, local density is defined as, "the number of filled character spaces near each character" [Tullis83, page 662].

It's important to note the difference between overall and local density as it pertains to this study involving windowed computer screens. For example, if a screen contains a single window which occupies a percentage of the visible area of the display, this percentage would equate to the overall density of that display. Changes inside that single window (e.g., adding or removing text, buttons, or images) would affect the local complexity related to that window but would have no effect on the overall density of the

display as a whole. Overall density, therefore, is computed from everything occupying space on the display, while local density relates to the windows on the display and their contents. The figures below provide two examples of screens (everything within the box) with the same overall density but different local densities. Figure 1 has a lower local density than Figure 2.

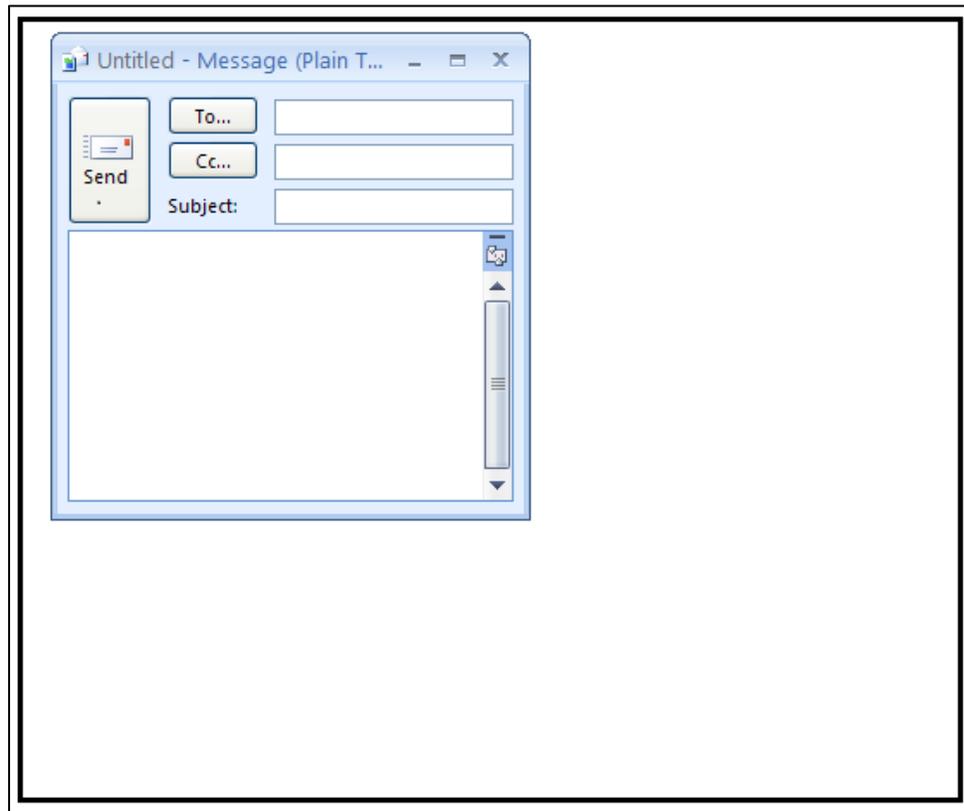


Figure 1: Overall and Local Complexity Example Screen 1

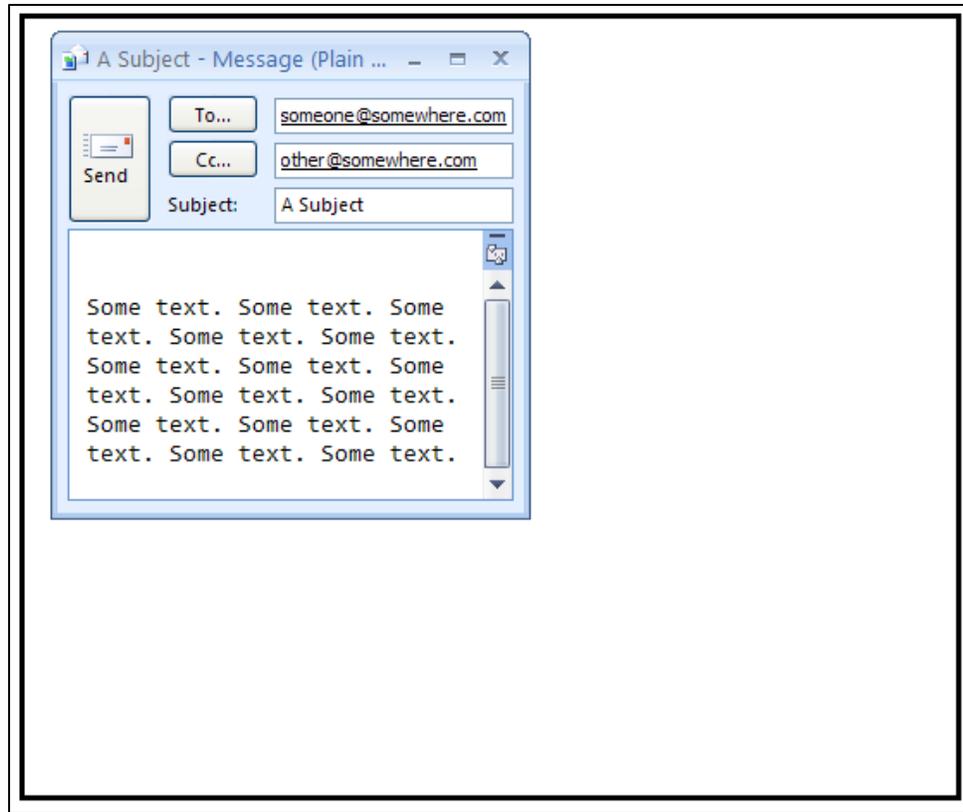


Figure 2: Overall and Local Complexity Example Screen 2

Grouping is related to local density since spacing is what is often used to create and distinguish groups. The data studied by Tullis provided support for the concept that grouping has a positive effect on performance; although he goes on to discuss the possibility that the number and size of groups may also have an effect (positive or negative). He provided a simple definition of grouping as, “the extent to which items form well-defined perceptual groups” [Tullis83, page 662].

Layout complexity was the last of the characteristics Tullis mentioned and was defined as, “the extent to which the arrangement of items on the frame follows a predictable visual scheme” [Tullis83, page 662]. That is, items on the screen should be organized

and displayed in a format that increases the user's ability to anticipate where other items will be located.

Finally, Tullis noted that the data he had collected may support a relationship between the first three characteristics mentioned (overall density, local density, and grouping) and user performance. He also noted that, "a study that manipulates these characteristics in a controlled fashion needs to be conducted" [Tullis83, page 680]. A previous study [Tullis81] had not done this. By studying the characteristics together, it was unknown if differences in performance were due to some of the characteristics, all of the characteristics, or other characteristics not even documented.

Other research using layout complexity has been performed which seeks to determine its usefulness in evaluating screen designs. Comber's [Comber96] research is noteworthy as it focused on one of Tullis' characteristics, was applied to Graphical User Interface (GUI) screens, and supported the idea that a medium level of complexity was more preferable and less prone to errors. In his research, Comber set out to study if a metric might exist that could be used to evaluate a screen layout and provide feedback to its designer. A program was developed to analyze a layout and calculate a complexity score. The program was used to score four different layouts created for this purpose. Users were asked to perform a simple task using each screen and then provide their preference. Their accuracy and completion time was also tracked by the application. Overall, the middle screens (mid-level complexity) received better ratings, completion times, and error scores.

Coll [Coll90] created screens of differing density levels (24%, 37%, and 64%) using alphanumeric displays. He used Tullis' [Tullis83] definition of overall density to compute the screen density levels and this became the basis of his definition of complexity for the study. Users performed a series of tasks using an assigned screen density level (condition) and provided feedback on their preference. The same tasks were performed for each screen condition using a two-level screen. For the low complexity screen condition (24%), the first screen contained the initial selection (task type) and the second allowed the user to enter information based on their initial selection. The higher complexity screen conditions (37% and 64%) presented an initial language selection screen and then incorporated all the required selections (as performed in the low complexity condition) into one additional screen (maintaining the two-levels). They were also set up to contain additional related, but unnecessary, information to reach their designated density levels. User performance, measured by task completion time, was also considered in this study. Coll's results supported his proposition that screens that are too simple or too complex will affect a user's performance as well as how comfortable a user feels while using the screen.

Weller [Weller04] studied the effects density (overall and local) and pseudo-graphics have on web page design. Pseudo-graphics are elements in a display that do not inherently transmit information but provide separation or intentional distraction. A total of 240 displays were created, and users evaluated each display searching for a target word. The results revealed, "a significant main effect for overall density" [Weller04,

page 39]. The high-density screens in the study had greater search times. This significant main effect was not found for local density.

These studies support, some explicitly, the concept that user performance and preference regarding complexity (as defined in each study) generally follows an inverted U-shaped curve. This curve indicates that a user's preference for an object or display increases to a certain point, or complexity level, before starting to decrease. The performance data follows the same pattern with the medium level of complexity in the study generally receiving fewer errors and quicker completion times.

1.2 Current Study

The aforementioned researchers studied the effects variations in display characteristics (including overall density) have on a user's performance and preference in various human interaction and display situations. However, there was no work found that focused solely on the effects of overall density on these human factors in a windowed, non-web (non-browser), environment.

This study assessed the screen as a whole to research the role overall density plays on user performance and preference. The core application was not changed for the different screen levels studied. Overall density and Tullis' other characteristics were not affected by the functionality offered by the application. This allowed for a controlled assessment of the characteristic overall density. Overall density was the only characteristic

purposely manipulated and measured in order that this single aspect could be focused on more easily. Relating to Tullis' statement that, "studies have repeatedly shown that human performance deteriorates with increasing display density" [Tullis83, page 663] it was believed that studying this characteristic independently would be applicable to any interaction between a user and a computer display. Finally, this study sought to determine if the findings would prove beneficial in determining if the overall density of a display would, "affect the user's ability to process the information" [Tullis83, page 657] and help determine the utility of this characteristic as a complexity indicator for developing efficient window-style screens.

Chapter 2

METHODOLOGY

This study consisted of fundamental research examining the effect a screen's overall density has on a user's performance and preference. The users interacted with and performed tasks using a stand-alone windows-based application displaying screens of varying overall densities.

Tullis' [Tullis83] definition of overall density was used and considered an indicator of the screen's complexity. This screen characteristic was the only one used and directly manipulated in this study, as Coll noted [Coll90, page 257] that the other characteristics described by Tullis tend to co-vary (vary together) with overall density.

Coll's work [Coll90] was foundational and served as the basis for this research. The study he performed used alphanumeric displays and relied on Tullis' definition of overall density. Coll used this characteristic as the measure of complexity. The methodology of this study, as described in this chapter, is adapted from Coll [Coll90].

Primarily, the results from the trials discussed below were analyzed to determine what effect, positive or negative, overall density has on performance and preference.

Secondly, the results were assessed to determine if an inverted U-shaped preference and/or performance curve would be found as was the case in previous research.

2.1 Research Design

This study used a factorial design analyzing the difference overall density made across the three distinct screen series. Overall density was the study's independent variable and is described in the Procedure section below. Dependent variables were trial accuracy and completion time and are described in the Measurement section below. This design is illustrated in Table 1.

Low Density	Medium Density	High Density
Trial Accuracy Completion Time	Trial Accuracy Completion Time	Trial Accuracy Completion Time

Table 1: Research Design

2.2 Equipment

The trial application was written in the C# programming language using Microsoft's Visual Studio.

A Microsoft Windows personal computer with a monitor capable of displaying a resolution of 1280 X 1024 pixels was used for the trials. A keyboard, mouse, desk, and chair were also utilized by the subject in performing the trial.

2.3 Testing Environment

The trials were conducted over the Spring 2012 semester, one subject at a time, in a general-purpose room at the University of North Florida. Each subject was seated at a desk facing the personal computer screen. The desk was positioned in an office cubical arrangement with no view of the outside (i.e., no windows). The subject was able to adjust the screen, keyboard, mouse, and chair. The trial moderator was in a non-visible position behind the subject while the subject faced the personal computer screen. There were no visible icons on the screen and the Windows Task Bar was hidden.

2.4 Participants

The trial consisted of 31 subjects with varying computer skills and recruited from courses at the University of North Florida. Participants were recruited after obtaining Institutional Review Board (IRB) approval. This study was approved by the IRB as Exempt, Category 2 (IRB# 11-105, see Appendix F). There were 21 male participants and 10 female participants. Participants ranged in age from 18 to 48. Users had experience using a mouse and keyboard and possessed normal or corrected-to-normal eyesight. No direct compensation or incentive was offered for participation though some university professors voluntarily offered their students extra credit for taking part in the research.

2.5 Procedure

Three separate screens of varying density levels, or series, were utilized. The measurements were based on a screen resolution of 1280 X 1024 pixels. This equates to roughly 1,310,720 available pixels. The first screen series (low density) exhibited a density measurement of approximately 24% (roughly 314,573 pixels used). The second screen series (medium density) measured approximately 37% (roughly 484,966 pixels used). The final screen series (high density) measured approximately 64% (roughly 838,861 pixels used). Screen sizes for all displayed windows were set programmatically to ensure their accuracy and were within 1% of the figures provided above. These established measurement percentages match those in Coll [Coll90].

The low-density screen consisted solely of the core application the user was to use (described below). The medium-density screen consisted of the core application with the addition of another small window containing non-essential information. The high-density screen extended the medium screen content by introducing an additional window containing other non-essential information. The purpose of the additional windows for the medium and high-density screens was to present supporting data related to, but not necessary for, the trial. The data presented in these windows were the image of a vehicle, a text document with information about the automotive industry, and a spreadsheet containing a simple financial report. These additional windows were sized, taking into account the core application (which remained unchanged between screen series), to reach the required density level of the screen series where they were included.

The locations of all windows were set programmatically to ensure they appeared in the same location on the screen and were consistent between all users across all trials. The users were also instructed not to close or alter the placement of any windows or displays. See Appendix B for images of the additional windows.

The core application was an automotive management system that allowed the user to perform query (simple data look up), insert, and modify functions on “Financial”, “Inventory”, and “Order” data. Each screen, with the exception of the “Welcome” and “Main Menu” screens, contained a “Back” and “Main Menu” button. The “Welcome” screen contained a “Begin” button and the “Main Menu” screen contained an “Exit” button. The user was required to navigate a menu structure to reach any required queries, insertions, or modifications. Screen size and local complexity for the core application were held constant across all trials. See Appendix A for images of the system screens.

2.6 User Trial

Users were divided equally among the three screen series and received the same instructions and trial conditions. Each user was trained on their assigned screen series. Training consisted of a trial run through the system. The user was presented with each screen, and its purpose and functionality were demonstrated through a set of nine total tasks (i.e., three tasks - a query, insertion, and modification - per system capability: “Financial”, “Inventory”, and “Order” management). The user was given the opportunity to ask questions and obtain any clarification required. Once training was complete, the

user began the trial using a sheet with 30 tasks divided among the “Financial”, “Inventory”, and “Order” system capabilities. The tasks (training and trial) are listed in Appendix E. The users were asked to complete all the tasks on the sheet and when finished, return to the main menu and click the “Exit” button to end the trial.

2.7 Data Collection

When the system initialized (which occurred for each user), three data files were read to preload values for financial, order, and inventory information. This information was stored in memory and was the basis for the accuracy information. Additionally, on initialization, the current time was stored in memory. As a user performed the trial – updating and changing values for financial, order, and/or inventory data – new values were stored in memory causing the preloaded values to be updated. When a user selected to exit the system, these values were written to a file in a comma-delimited format. Using the initialization time previously stored, the system computed the elapsed time of the trial, from initialization to exit, and included that value as part of the file name.

Demographic information was collected before the trial began by utilizing a user-completed questionnaire (see Appendix C). Also, user preference information was collected after the trial using a similar questionnaire (see Appendix D). No personally-identifiable information was collected.

2.8 Measurement

Overall density, based on the description in Tullis [Tullis83], was defined as the number of used pixels divided by the total number of pixels available on the screen. Trial accuracy information collected consisted of the values of the fields in the system and any values entered into the physical task sheet. Answers to any questions in the trial where the user was asked to look up information were entered in the appropriate space of the physical task sheet. All user-entered values were checked against the expected values. Any values that were changed incorrectly, or any values that were not changed but should have been, were considered a mistake. Completion time was calculated from the point the user clicked to commence the trial to the point the user returned to the main menu and clicked the “Exit” button to exit the application. Exiting the application also caused the values in the system to be stored for analysis.

The demographic information collected consisted of age, gender, and computer experience (see Appendix C).

After the user completed the trial, he or she was presented with a questionnaire that was used to determine their preference regarding their assigned screen series. They were asked to select a score on a numeric scale based on six criteria (see Appendix D).

2.9 Analysis

Post-trial assessments included executing a set of descriptive analyses on trial completion time and accuracy data as well as on the demographic data. A frequency count was also performed on the user preference data.

A full cross-correlation matrix was compiled using the Pearson Product-Moment Correlation. Input data consisted of the dependent variables completion time and accuracy, the demographic information collected, and the preference scales used to determine if any correlation existed between these variables. The correlation values were determined to be significant if the correlation coefficient value (r) was greater than the absolute value of 0.3 and the significance value (p) was less than 0.05.

A one-way Analysis Of Variance (ANOVA) was used on the data from the trials. The independent variable was overall density. The dependent variables were completion time, accuracy, and each of the user preference variables: usability, efficiency, desirability, complexity, helpfulness, and satisfaction. An ANOVA was performed to determine if a significant effect existed between completion times for the different screen series. An ANOVA was also performed to determine if a significant effect existed between the response accuracies for the different screen series. Additionally, an ANOVA was performed to determine if a significant effect existed between the preference data (usability, efficiency, desirability, complexity, helpfulness, and satisfaction) for each of the different screen series. The result of the ANOVA was

determined to be significant if the p value was less than 0.05. If significant effect was found, a Post Hoc test was performed to determine which group or groups (screen series) contained the difference.

Chapter 3

RESULTS OF DATA ANALYSIS

The data analysis was performed using the statistics package SPSS. The notable and significant findings are reported in the sections below. Section 3.1 covers the relationship between overall density and the performance data elements of completion time and accuracy (measure of incorrect responses). Section 3.2 deals with the data related to overall density and user preference. Finally, section 3.3 highlights a number of significant correlations.

Generally, results of analysis were considered significant if the significance value (p) was less than 0.05. Additionally, correlations were considered significant if the significance value (p) was less than 0.05, and the coefficient value (r) was greater than the absolute value of 0.3.

A Power Analysis for a one-way ANOVA with three cells was computed to determine the optimum number of subjects per cell for any extensions to this pilot work. With a significance level of .05 and a medium effect of 1.0, the optimum number of subjects per cell for future research is 10 subjects.

3.1 Screen Performance Findings

There was not a significant main effect found for the ANOVA performed for completion time. For all screen series, the average time to complete the trial was 725.2026 seconds, with a minimum time of 554.77 seconds and a maximum time of 951.10 seconds. See Table 2 for the results from the completion time ANOVA.

Sum of Squares	df	Mean Square	F	P
3342.268	2	1671.134	0.143	0.867

Table 2: ANOVA: Completion Time

There was not a significant main effect found for the ANOVA performed for accuracy. For all screen series, the average number of incorrect answers a user scored was 7.61, with a minimum of 0 and a maximum of 16. See Table 3 for the results from the accuracy ANOVA.

Sum of Squares	df	Mean Square	F	P
112.718	2	3.283	3.103	0.061

Table 3: ANOVA: Accuracy

3.2 Screen Preference Findings

A significant main effect was found for an ANOVA performed using the user's rating of screen desirability for the different screen series. The results of this ANOVA are in Table 4.

Sum of Squares	df	Mean Square	F	P
11.538	2	5.769	6.401	0.005

Table 4: ANOVA: Desirability

The descriptive analysis for this ANOVA is presented in Table 5.

Density Level	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean	
					Lower Bound	Upper Bound
24	10	3.00	1.054	0.333	2.25	3.75
37	10	1.809	0.632	0.200	1.35	2.25
64	11	3.18	1.079	0.325	2.46	3.91
Total	31	2.68	1.107	0.199	2.27	3.08

Table 5: Descriptive Analysis: Desirability

A Student-Newman-Keuls post hoc test was performed (see Table 6) and indicated the difference between the medium density screen and the low and high-density screens was significant. There was no significant difference found between the low and high-density screens. The mean rating of the medium density screen was 1.80, while the mean rating for the low-density screen was 3.00. The mean rating for the high-density screen was 3.18.

Complexity Level	N	Subset for alpha = 0.5	
		1	2
37	10	1.80	
24	10		3.00
64	11		3.18
Significance		1.000	0.667

Table 6: Post Hoc Test: Desirability

3.3 Correlations with Significance

Table 7 summarizes the significant correlations found in the data analysis.

Characteristics Correlated	Pearson Correlation	p (2-tailed)	Description
Desirability Efficiency	-0.374	0.038	Indicates that a user who found a screen to be more efficient also found the screen to be more desirable.
Complexity Total Incorrect	-0.365	0.044	Indicates that the more complex the user found the screen to be, the more incorrect answers they received.
Helpfulness Efficiency	-0.557	0.001	Indicates that a user who thought a screen was more efficient also thought it was more helpful.
Satisfaction Usability	-0.474	0.007	Indicates that users who found a screen more usable also found the screen more satisfying.
Satisfaction Efficiency	0.467	0.008	Indicates that users found more efficient screens to be more satisfying.
Desirability Helpfulness	0.595	0.000	Indicates that a user who found a screen to be more helpful also found the screen to be more desirable.
Desirability Satisfaction	-0.516	0.003	Indicates that a user who found a screen to be more satisfying also found the screen to be more desirable.
Helpfulness Satisfaction	-0.420	0.019	Indicates that a user who found a screen to be more satisfying also found the screen to be more helpful.

Table 7: Significant Correlations

Chapter 4

DISCUSSION

Screen design and development has progressed greatly from small, monochrome, simple text-based displays to the large (sometimes wall-sized), full-color GUI displays of today. While previous research demonstrated performance and preference differences between screens of different complexities, there are several reasons to perform new research in this area. First, much of the cited research is dated, some having been performed before GUIs were common (e.g., [Tullis83], [Coll90]). Second, related to the first, much of the research was not done in a modern setting utilizing today's technology, such as higher resolution displays, multiple windows, etc. (e.g., [Tullis83], [Coll90]). Third, the other more modern research, while dealing with display complexity, was not focused on overall density as the complexity measurement (e.g., [Comber96], [Weller04]). Displays have become more advanced and the average user has become more accustomed to displays of various kinds as computers (and screens in general) have become more ubiquitous. Understanding if these previous findings are still applicable to modern screens and modern users will help to either reinforce current assumptions or may lead to revisions in the current understanding of what users expect and/or need.

4.1 User Performance

This study found no significant results for the ANOVAs performed regarding the performance metrics (completion time and accuracy) and screen density. This was not the expected result and, as such, does not provide support to the previous research that found that density has an effect on a user's performance or that, by extension, designing to certain fixed levels of density (complexity) will affect performance. One possibility for this could be that users in general are much more familiar with screens and displays of various kinds than in the past. There is a considerable difference in the exposure an average person has to screens and displays today than even just a few years ago. This may provide some limited advantage to the user in this situation. However, it is difficult to speculate on the cause of this divergence without further research to narrow the possibilities and to provide additional insight.

4.2 User Preference

Relating to preference data, the results from the desirability ANOVA and subsequent Post Hoc test illustrate that the medium-density screen was significantly different than the low or high-density screen levels. It received a mean score of 1.80 versus means of 3.00 and 3.18 for the 24% density (low) and 64% density (high) screens, respectively. This indicates the medium-density screen was more desirable than the other screens.

The users were not exposed to the other screen levels during the actual trial. Thus, there was no opportunity for comparison between screens before the post-trial questionnaire (where this desirability rating was recorded) was completed. Among the user-provided preference ratings, it would seem reasonable to deduce that the desirability score would be the single value most closely related to and synonymous with the user's preference for their assigned screen. Considering this, the desirability finding supports previous research that demonstrated that a screen exhibiting a medium level of complexity was preferred over a screen where complexity was judged to be too low or too high (e.g., [Coll90], [Maddi61], [Vitz66]). This result also supports the inverted U-shaped preference curve described previously.

Considering overall density when designing a screen could provide a quick "first impression" to a developer on the reception of the screen by the users. These density levels could be studied further to determine an optimal range, which could then be incorporated into a tool the developer would run against their screen. This feedback would be beneficial as it could occur before any user trials or reviews. This has the potential to save valuable resources, including time the user spends evaluating the screen or the time a developer would spend in redesign efforts.

4.3 Relationships Between Performance and Preference

While not as conclusive as more empirical data might be, there were a number of significant correlations found between the preference data ratings collected from the user

after they finished the trial. These provide additional evidence of the user's reaction to their screen and the impressions it left on them.

As mentioned previously, there were no significant findings for the performance data directly linking the overall density used with the user's performance metrics. But, this study did find evidence that complexity affected the user's performance. The correlation between the total number of incorrect answers and the user's rating of their screen's complexity indicates that the more complex the user perceived the screen to be, the greater number of incorrect answers they generated. Thus, a screen the user perceived to be complex had an influence on their performance irrespective of whether the screen met some "standard" of complexity. This signals that screen designers should not only consider and consult general established guidelines when designing screens, but also take into account the specific user population. It would seem that being aware of features, layouts, or functions that would appear complex to those users, and then taking actions to lower that perceived complexity, would lead to higher performance ratings.

This finding appears to be a characteristic of complexity in general and seems to be unrelated to the overall density of the screen. Considering this gives the impression that the overall density of the screen was not the factor influencing the user's perception of complexity. This is consistent with the lack of findings for the performance data and overall density mentioned previously.

The remaining significant correlations appear to yield no further evidence pertinent to this study. The relationships found are ones that might obviously be concluded or expected (e.g., it would be expected that a screen the user found to be more helpful would also be found more desirable). The additional correlations do provide direct value to this study in that they assist in validating the seriousness of the users and their responses (i.e., the users weren't simply marking random values).

4.4 Conclusion

Overall density plays an important role in a display's acceptance or rejection. This study found that designing a screen to utilize a medium level of density will generally translate into greater acceptance of that screen. While the current study was performed using a standalone application, it is suggested that these findings would apply regardless of the screen type. Developers (web, mobile, etc.) should then find it prudent to include the overall density of the screen as a design factor taking into account user preference for medium levels of screen density.

Evidence from this study also indicates that the user's perception of screen complexity (separate from overall density) has a direct effect on his or her performance. Users who had fewer incorrect answers (i.e., better performance) tended to rate their assigned screen as less complex than those who had a greater number of incorrect answers. This relationship existed regardless of the screen's density level. Given the absence of any association between density level and user performance, it seems that overall density

may not be reliable as a complexity metric. In short, there does not appear to be a performance benefit in using overall density as a factor in a screen's design.

4.5 Future Research

As previously suggested, further research might be conducted to isolate the reason(s) for the disparity in this study's performance findings with the findings of previous work. In particular, studies on the effect an increasingly technological and computer-literate test group has on research in this field might prove insightful.

Additionally, it may prove beneficial to study a variety of user populations to determine to what degree the data and findings between them vary. While the user base in this research was limited in some aspects in that all were students and all belonged to the same university, there were no experience, age, gender, or degree path limitations or groupings. Performing this study using more focused user groups may reveal performance trends as well as features or functions that particular user groups prefer.

Also, while the overall density of the screens in this study did not seem to have any bearing on user performance, test data collected indicated complexity, in general, was influential. Further study may reveal the specific aspect(s) of the program or environment which the user found to be complex.

Another area where research could be focused is in the narrowing and more precise identification of an optimum range of overall density values. This “density band” could serve as a uniform guideline for designers and developers when creating screens and displays (as was mentioned above when discussing the preference data findings).

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APPENDIX A

LM&Ds Automotive Management System Screens

Actual screens are approximately 560x560 pixels. Screen shots below have been reduced in size to better fit on the page.

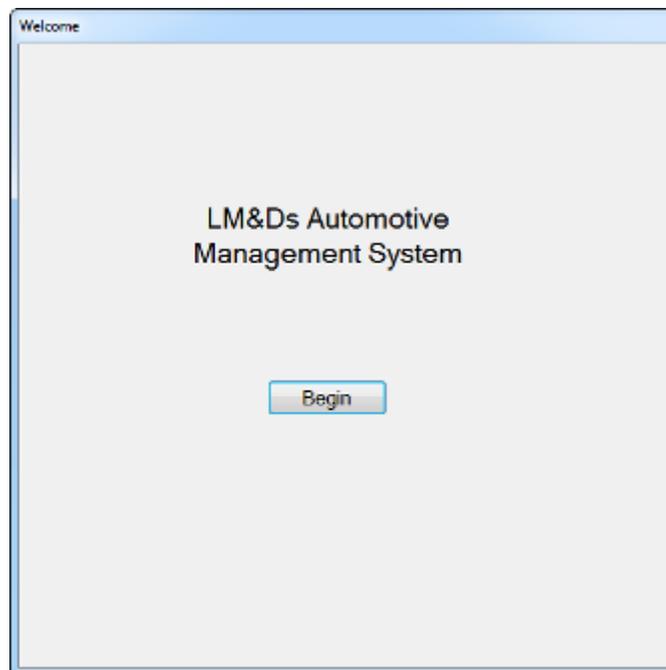


Figure 3: Welcome Screen

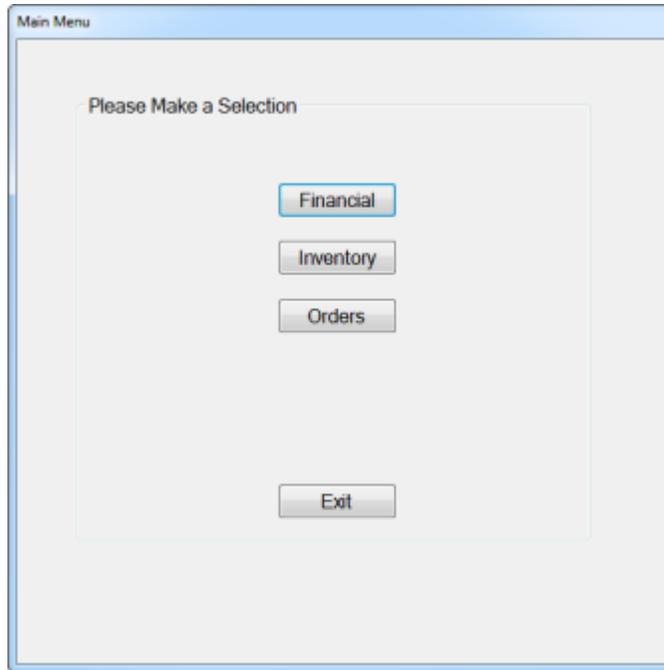


Figure 4: Main Menu – System Home Screen

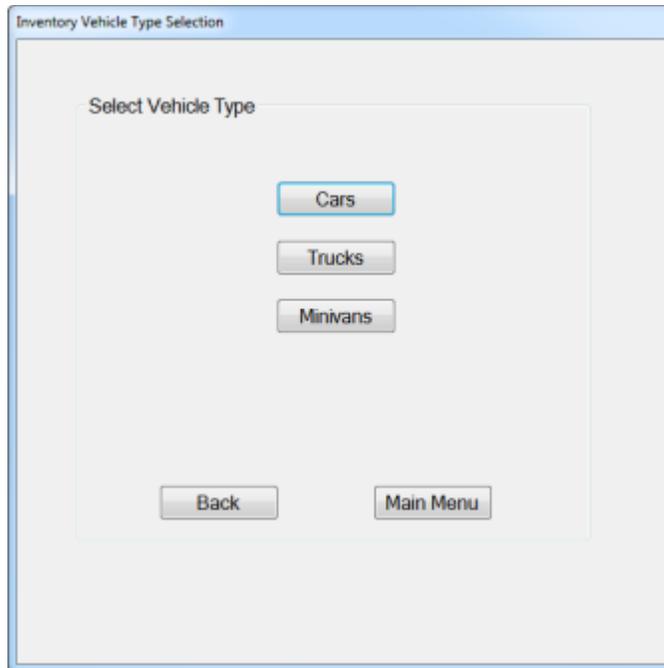


Figure 5: Inventory Main Screen

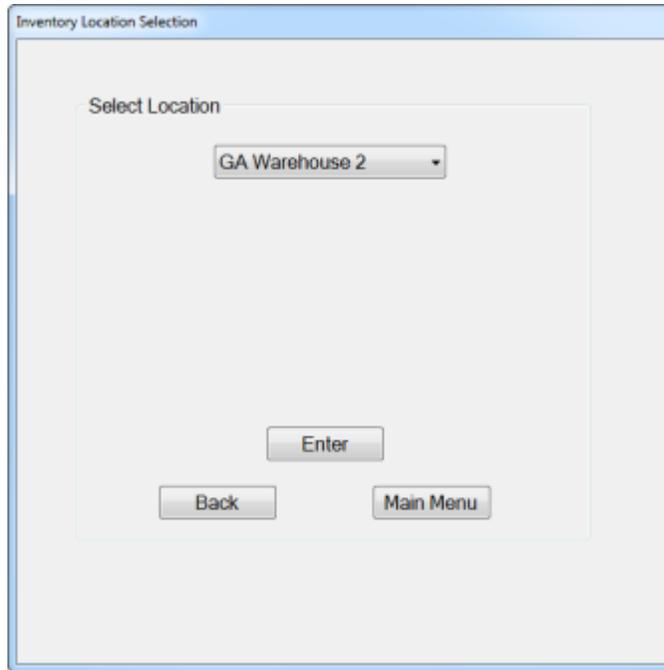


Figure 6: Inventory Location Screen (Post Vehicle Type Selection)

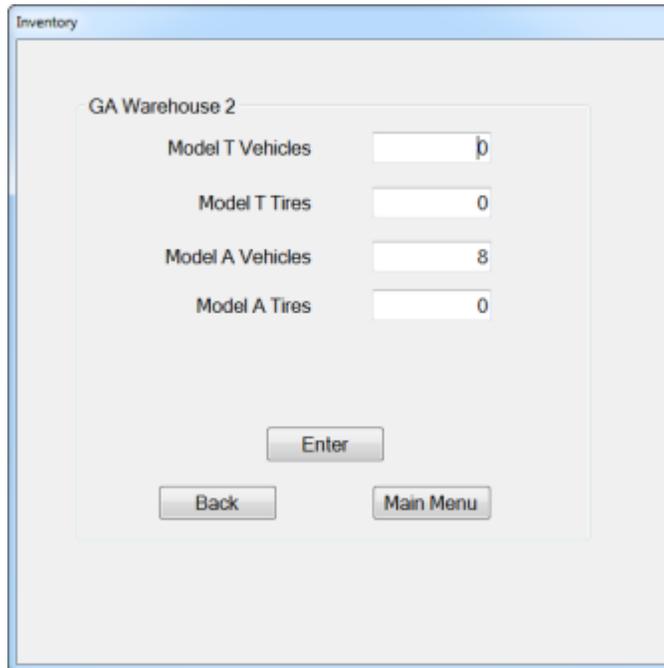


Figure 7: Inventory Type & Quantity Screens (After Selecting Location)

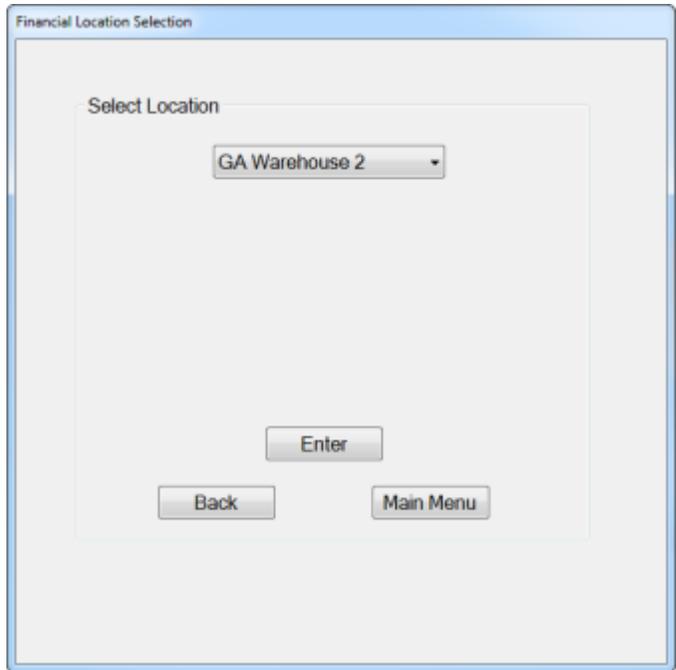


Figure 8: Financial Location Screen

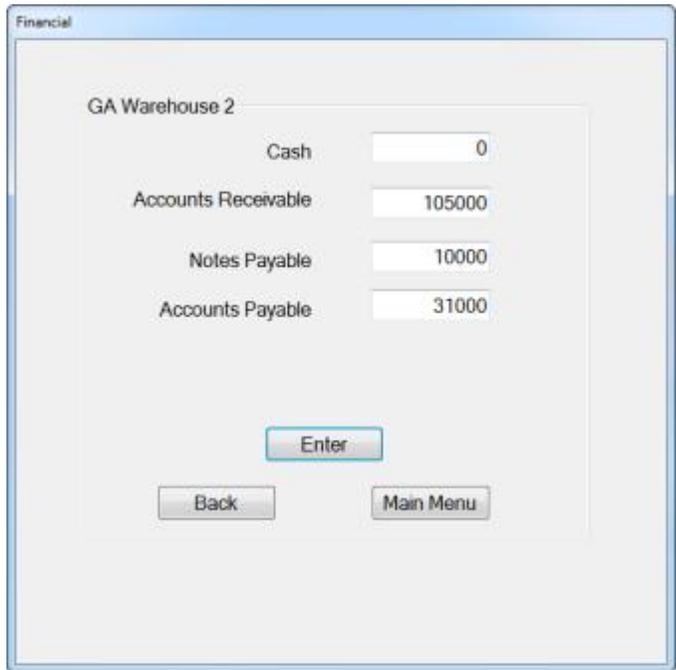


Figure 9: Financial Types Screen

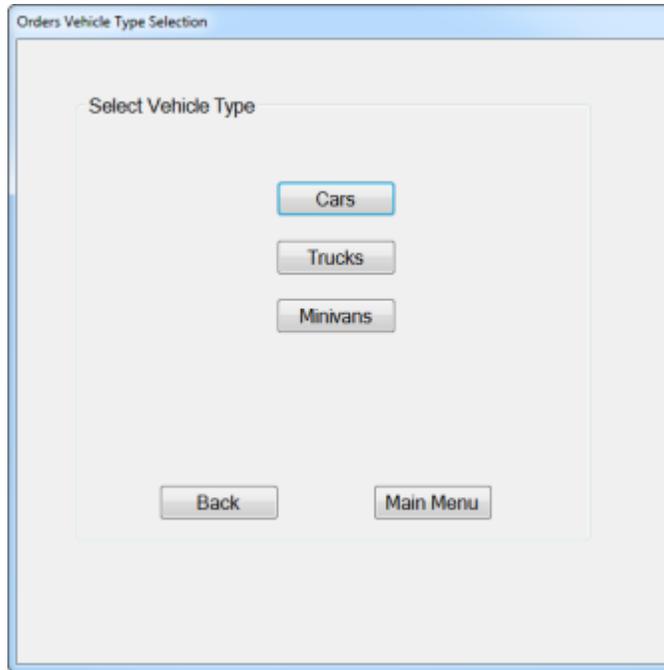


Figure 10: Orders Main Screen

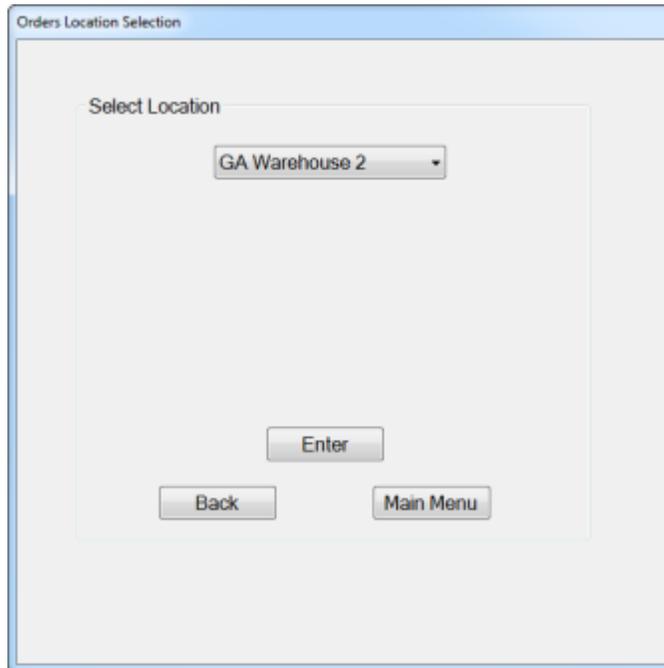


Figure 11: Orders Location Screen (Post Vehicle Type Selection)

The screenshot shows a software window titled "Orders" with a sub-header "GA Warehouse 2". Inside, there are four rows of input fields for quantities:

Item	Quantity
F-1 Vehicles	2
F-1 Tires	8
F-100 Vehicles	3
F-100 Tires	12

Below the input fields are three buttons: "Enter", "Back", and "Main Menu".

Figure 12: Order Type & Quantity Screens (After Selecting Location)

APPENDIX B

Additional Images

Below are the images used in the trials to bring the overall density of the medium and high-density screen series to the required density levels.



Figure 13: Vehicle Image - 568x300 pixels [Weiss11]

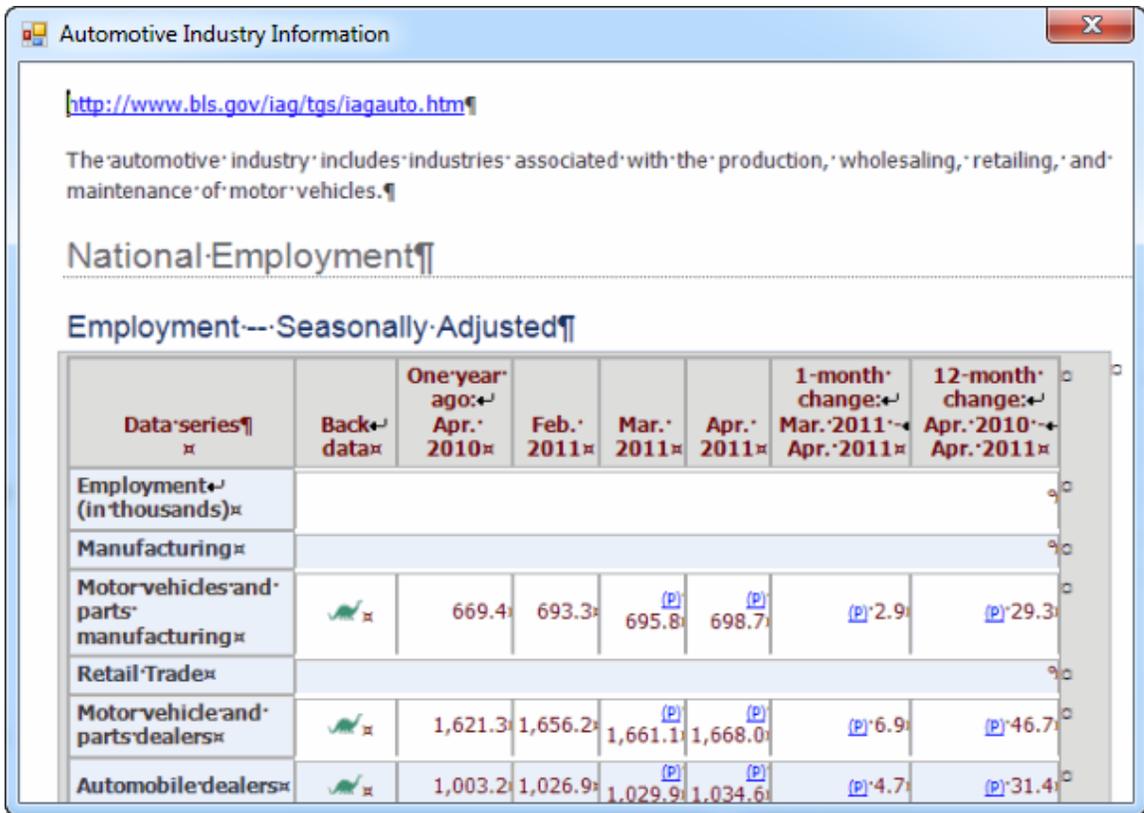


Figure 14: Automotive Industry Information - 606x430 pixels [Bls12]

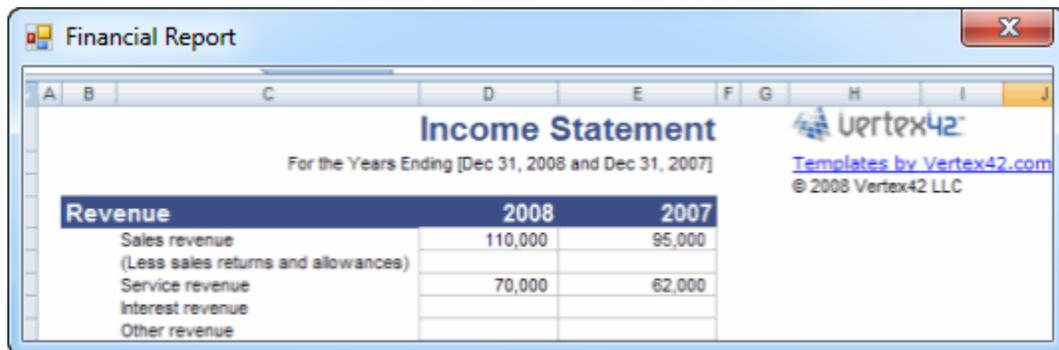


Figure 15: Simple Financial Report – 533x175 pixels [Vertex12]

APPENDIX C

Pre-Trial Questionnaire

Please enter your response in the space provided or circle your answer.

Age: _____

Gender: _____

Years using Microsoft Windows applications: 1-2 2-4 4-6 6-8 8 or more

Is your vision 20/20 or corrected to 20/20? Y N

Do you feel comfortable using a mouse and keyboard? Y N

APPENDIX E

User Tasks

Scenario

You will be working with a prototype of an inventory system for an automotive management company called LM&D Automotive. Management desires to move away from its current inventory management method of using spreadsheets and has hired a company to put together some prototypes for evaluation. Your job will be to report and update some of the information currently in one of the prototype systems as well as add new information as directed by the tasks below.

You will first work through some training tasks to familiarize yourself with the system before performing the actual trial.

Training Tasks

Instructions: Please complete the following tasks. You will not be timed for this section. Please use this time to become familiar with the system and ask any questions you may have concerning the tasks or instructions. Please do not close, move, minimize, or maximize any windows or displays. To begin, please select the “Begin” button from the Welcome screen. You will then be presented with the “Main Menu” screen. Each task will provide all the information required - there are no other resources needed.

If the task is financial in nature, click the “Financial” button. On the following screen, you will select which location’s finances you wish to query or update. Once the location is selected, click “Enter” and you will then be brought to a screen with the available financial data for the location you selected. When finished, you may click either the “Back” button to return and select another location, or the “Main Menu” button to return to the main menu.

If the task is concerning vehicle inventory, select “Inventory” from the main menu. From the next screen select a vehicle type (“Cars”, “Trucks”, or “Minivans”). The next screen will allow you to select a location for the inventory you wish to view. You may also click the “Back” button to return to the previous screen and select another vehicle type. Select the location and click “Enter”. You will then see a listing of the inventory for the vehicle type you selected at the location you selected. When finished, you may click either the “Back” button to return and select another location, or the “Main Menu” button to return to the main menu.

If the task is concerning vehicle orders, select “Orders” from the main menu. From the next screen select a vehicle type (“Cars”, “Trucks”, or “Minivans”). The next screen will allow you to select a location for the orders you wish to view. You may also click the “Back” button to return to the previous screen and select another vehicle type. Select the location and click “Enter”. You will then see a listing of the orders for the vehicle type you selected at the location you selected. When finished, you may click either the

“Back” button to return and select another location, or the “Main Menu” button to return to the main menu.

After each task is completed, click the “Main Menu” button to return to the main menu before starting the next task. Always start a new task from the main menu. Values will be entered into either this task sheet (into the spaces provided) for query tasks or into a text box in the application for insertions or modifications. To end the trial, return to the Main Menu and select the “Exit” button.

Training Exercises:

1. How much cash is available in “GA Warehouse 2”? Enter value here: _____
2. Enter \$10,000 in the field “Notes Payable” in “GA Warehouse 2”.
3. Update the “Accounts Payable” in “GA Warehouse 2” to the value \$36,000.
4. How many cars of type “Model T Vehicles” are in “GA Warehouse 2”? Enter value here: _____
5. Enter 12 for the inventory quantity of cars of type “Model T Vehicles” in “GA Warehouse 2”.
6. Update the inventory quantity of car tires of type “Model T Tires” in “GA Warehouse 2” to 64.
7. How many cars of type “Model A Vehicles” are on order in “GA Warehouse 2”? Enter value here: _____
8. Enter 16 for the quantity of car tires of type “Model T Tires” on order in “GA Warehouse 2”.
9. Update the quantity of cars of type “Model T Vehicles” on order for “GA Warehouse 2” to 7.
10. Return to the Main Menu and select “Exit” (Training Exercises are complete).

Trial Tasks

Instructions: Please complete the following tasks. You will be timed for this section.

Please work as quickly and accurately as possible. Please do not close, move, minimize, or maximize any windows or displays. To start the trial, please select the “Begin” button

from the Welcome screen. After each task, click the “Main Menu” button to return to the Main Menu before starting the next task. Values will be entered into either this task sheet (into the spaces provided) or into a text box in the application. To end the trial, return to the Main Menu and select the “Exit” button.

Trial Exercises:

1. Update the quantity of truck tires of type “F-1 Tires” on order for “GA Warehouse 2” to 56.
2. How much are "Notes Payable" in “GA Fabrication Plant”? Enter value here: _____
3. Update the quantity of trucks of type “F-1 Vehicles” on order for “FL Assembly Station” to 4.
4. How many minivan tires of type “Windstar Tires” are on order in “GA Warehouse 2”? Enter value here: _____
5. Update the inventory quantity of cars of type “Model T Vehicles” in “FL Assembly Station” to 13.
6. Enter 8 for the quantity of minivans of type “Aerostar Vehicles” on order in “GA Fabrication Plant”.
7. Enter 10 for the quantity of trucks of type “F-100 Vehicles” on order in “FL Assembly Station”.
8. Enter 5 for the inventory quantity of minivans of type “Aerostar Vehicles” in “FL Warehouse 1”.
9. Enter \$7,000 in the field “Cash” in “GA Warehouse 2”.
10. Enter 32 for the quantity of car tires of type “Model A Tires” on order in “FL Warehouse 1”.
11. How many trucks of type “F-100 Vehicles” are in “GA Fabrication Plant”? Enter value here: _____
12. How many trucks of type “F-1 Vehicles” are on order in “FL Assembly Station”? Enter value here: _____
13. How much are "Accounts Receivable" in “GA Warehouse 2”? Enter value here: _____
14. How many trucks of type “F-1 Vehicles” are in “FL Warehouse 1”? Enter value here: _____
15. Update the inventory quantity of truck tires of type “F-1 Tires” in “GA Fabrication Plant” to 64.
16. Update the “Accounts Payable” in “FL Warehouse 1” to the value \$6,000.
17. Update the "Notes Payable" in “FL Assembly Station” to the value \$3,000.
18. Enter 24 for the inventory quantity of car tires of type “Model A Tires” in “GA Warehouse 2”.

19. How much are "Accounts Receivable" in "FL Assembly Station"? Enter value here: _____
20. How much cash is available in "FL Warehouse 1"? Enter value here: _____
21. How many cars of type "Model A Vehicles" are in "GA Warehouse 2"? Enter value here: _____
22. Enter \$15,000 in the field "Accounts Receivable" in "GA Fabrication Plant".
23. How many minivans of type "Aerostar Vehicles" are on order in "FL Warehouse 1"? Enter value here: _____
24. How many truck tires of type "F-100 Tires" are on order in "GA Fabrication Plant"? Enter value here: _____
25. Update the "Cash" in "GA Fabrication Plant" to the value \$16,000.
26. Update the inventory quantity of minivans of type "Windstar Vehicles" in "GA Warehouse 2" to 26.
27. Enter 15 for the inventory quantity of trucks of type "F-100 Vehicles" in "FL Assembly Station".
28. Enter \$2,000 in the field "Notes Payable" in "FL Warehouse 1".
29. Update the quantity of minivans of type "Windstar Vehicles" on order for "GA Fabrication Plant" to 19.
30. How many minivan tires of type "Windstar Tires" are in "FL Assembly Station"? Enter value here: _____
31. Return to the Main Menu and select "Exit" (Trial Exercises are complete).

APPENDIX F

IRB Approval Document



Office of Research and Sponsored Programs
1 UNF Drive
Jacksonville, FL 32224-2665
904-620-2455 FAX 904-620-2457
Equal Opportunity/Equal Access/Affirmative Action Institution

UNF IRB Number: 11-105 Approval Date: 12-14-2011 Expiration Date: Exempt - None Processed on behalf of UNF's IRB <i>KLC</i>
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MEMORANDUM

DATE: December 14, 2011

TO: Mr. Lucas Downard

VIA: Dr. Layne Wallace
Computing

FROM: Dr. Katherine Kasten, Chairperson
On behalf of the UNF Institutional Review Board

RE: Review by the UNF Institutional Review Board IRB#11-105:
"THE EFFECT OVERALL DENSITY PLAYS ON PERFORMANCE AND PREFERENCE IN
A WINDOWED ENVIRONMENT"

This is to advise you that your project, "THE EFFECT OVERALL DENSITY PLAYS ON PERFORMANCE AND PREFERENCE IN A WINDOWED ENVIRONMENT" was reviewed on behalf of the UNF Institutional Review Board and has been declared Exempt, Category 2." Therefore, this project requires no further IRB oversight unless substantive changes are made.

This approval applies to your project in the form and content as submitted to the IRB for review. Any variations or modifications to the approved protocol and/or informed consent forms that might increase risk to human participants must be submitted to the IRB prior to implementing the changes. Please see the [UNF Standard Operating Procedures](#) for additional information about what types of changes might elevate risk to human participants. Any unanticipated problems involving risk and any occurrence of serious harm to subjects and others shall be reported promptly to the IRB within 3 business days.

As you may know, CITI Course Completion Reports are valid for 3 years. Your completion report is valid through 11/08/2013. If your completion report expires within the next 60 days or has expired, please take CITI's refresher course and contact us to let us know you have completed that training. If you have not yet completed your CITI training or if you need to complete the refresher course, please do so by following this link: <http://www.citiprogram.org/>. Based on your research interests we ask that you complete either the "Group 1 Biomedical Research Investigators and Key Personnel" CITI training or the "Group 2 Social Behavioral Researcher Investigators and Key Personnel" CITI training.

Should you have any questions regarding your project or any other IRB issues, please contact Kayla Champaigne at 904-620-2312, or K.Champaigne@unf.edu.

VITA

Lucas M. Downard graduated from the University of North Florida in December 2004 with a Bachelor of Science in Computing and Information Sciences. He anticipates receiving a Master of Science in Computing and Information Sciences from the University of North Florida in April 2013. Dr. Layne Wallace of the University of North Florida has served as Mr. Downard's thesis advisor and committee chairperson.

Mr. Downard lives in the Jacksonville, Florida area with his wife and two children. He has worked in the information technology industry for over 8 years and currently works as an Information Technology Specialist for the Fleet Readiness Center Southeast (FRCSE).