OPTIMIZATION BASED TOUCHSCREEN GRAPHICAL USER INTERFACE DESIGN

A Thesis

presented to

the Faculty of California Polytechnic State University,

San Luis Obispo

In Partial Fulfillment

of the Requirements for the Degree

Master of Science in Industrial Engineering

by

Christian D. Royer

April 2014

COMMITTEE MEMBERSHIP

TITLE:	Optimization Based Touchscreen Graphical User Interface Design
AUTHOR:	Christian D. Royer
DATE SUBMITTED:	April 2014
COMMITTEE CHAIR:	Dr. Tali Freed Professor of Industrial Engineering
COMMITTEE MEMBER:	Dr. Lizabeth Schlemer Professor of Industrial Engineering
COMMITTEE MEMBER:	Dr. Reza Pouraghabagher Professor of Industrial Engineering

ABSTRACT

Optimization Based Touchscreen Graphical User Interface Design

Christian D. Royer

Tablets have been increasing in popularity throughout the past couple years and developers are designing their graphical user interfaces (GUIs) with this trend in mind. This thesis attempts to examine how a process can be designed to automatically create a GUI layout for a menu driven interface based on predetermined criteria. The effectiveness of the system along with a qualitative analysis of GUIs was examined through the use of human subjects testing ATM designs on a tablet. A three-way ANOVA was designed to see if Gender, the type of Form, or if the order they did their testing was a significant factor in how fast a subject was able to complete certain tasks and what they thought of each of these forms. While these results were not able to prove which form could be completed the fastest because of an interaction between blocking and forms, the subject's ratings were able to demonstrate their high preference towards a system that was more simplified. They felt that a simpler designed interface is more aesthetic and usable. The subjects also had a higher sense of satisfaction while using a simple form. This thesis provides background for future research in designing a process that can automatically determine the layout of a menu driven system.

Keywords: Human Computer Interaction, Graphical User Interface Design, Operations Research, Tablets, Touchscreens

ACKNOWLEDGMENTS

I want to thank Dr. Tali Freed for providing me with feedback and guidance throughout the course of this thesis. She was extremely helpful in assisting with the design of the operations research system and getting the project completed. In addition, I want to thank Dr. Schlemer and Dr. Pouraghabagher for providing advice and help throughout my college career and helping me become the engineer that I am today.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER1: INTRODUCTION

When operating a computer many individuals take for granted all the work that goes into creating the design of an interface. Ever since Xerox introduced the Star in the 1980s, engineers and designers have been trying to make our interaction with computers and programs a more enjoyable experience. People have moved on from traditional personal computers to tablets and smartphones as time progressed. As our usage in these electronic devices change so must our research in how to make these experiences effective.

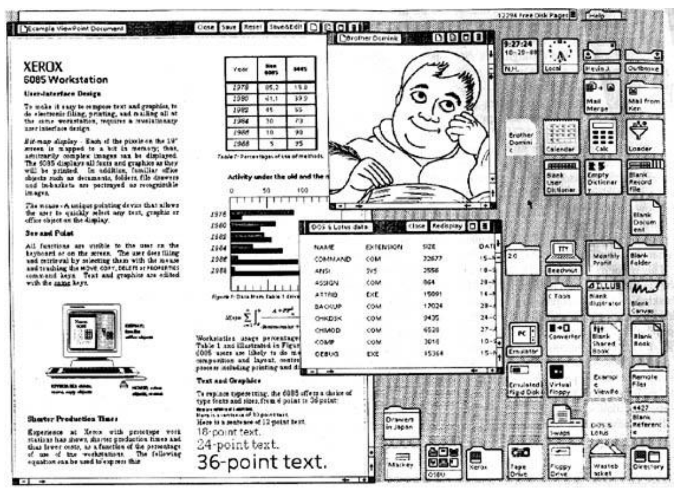


Figure 1 - Xerox Star GUI Example [20]

Tablets are not new inventions, but their popularity has been increasing rapidly since the introduction of the Apple iPad. In 2001, Bill Gates spoke to CNN about their usefulness and said “It’s a PC that is virtually without limits – and within five years I predict it will be the most popular form of PC sold in America” [23]. While it took a bit longer than the five years he predicted, tablets have been rapidly replacing laptops and ultrabooks. Within the 14 months of being on the market, the iPad sold 25 million tablets, and by the end of 2011 it sold over 55 million worldwide [6]. Moreover, their use in the business world has been increasing as well. Gartner predicts that the purchase of tablets will more than triple in volume from 13 million in 2012 to 43 million by 2016 [4]. The Yankee Group also predicted that about 30% of employees would be using a tablet while at their job [4]. Lastly, Canalys, a market research industry analyst, predicts that in the year 2014 Tablets will take over 50% of the personal computer market by selling over 285 million units and continuing to increase rapidly with 396 million units by 2017 [24]. Because of their rise in popularity Microsoft designed their latest operating system, Windows 8, to be a more touch friendly UI and tried to improve their use among casual users [2] [10].

Figure 2- Example of Windows 8 GUI [10]

For these reasons companies need to pay attention to the popularity of tablets when designing their GUIs or “Graphical User Interfaces”. Especially since tablets typically have smaller screens compared to a laptops. Ultimately, the designer cannot fit as many items on a screen as they could before. There are many aspects to look at when designing an effective GUI. The aesthetics, function, and useful are some of the important aspects to look at while designing a GUI and tablets can showcase them in new ways.

CHAPTER 2: LITERATURE REVIEW

This section will feature some background information on the GUIs (Graphical User Interfaces). This information is to explain the different type of design aspects that go into creating and utilizing a GUIs. It also highlights some important features to consider like aesthetics and symmetry.

2.1 History of Graphical User Interfaces

2.1.1 History of Traditional Graphical User Interfaces

The history of GUIs goes back to the 1950s when researchers at Massachusetts Institute of Technology would use a cathode ray tube and a light pen to control actions being performed on the screen. Later in the late 1970s, Xerox began to experiment more with GUI with personal computers and introduced the Xerox Star in 1981 [8].While they created the first application with a GUI it was slow and not a commercial success. It wasn't until Steve Jobs introduced the Apple Macintosh that the design began to take off. The Macintosh featured a mouse, menu, and icons. It marked the beginning of the modern day GUI since the computer could be used with a mouse to select items on a display and having a menu system prevented the user from selecting unrelated tasks to be performed. Typically, a good GUI will not stand in the way of a user trying to complete a task [9].

2.1.2 History of Touchscreen Computer Interfaces

Touchscreen interfaces have been developed since the 1970s alongside with the mouse and they were mostly used for medical device, industrial, and point of sale machines [13]. Most touchscreens in the past have been single touch along with nonmoving applications like an ATM that featured a touchscreen. These type of actions typically only require the user to touch the screen with their finger and do not need much finesse. While multi-touch has been increasing in popularity with the rise of smart phones and tablets [13], this project will focus on static images that do not require multi-touch displays.

2.2 Design Aspects of Graphical User Interfaces

Designing a graphical user interface involves utilizing many different factors. There is not a set guideline for how to create one, but there are many opinions backed by research about how a designer should create one.

2.2.1 Aesthetics

Aesthetics in GUIs is related to the beauty of the design. The aesthetics are an important role in designing a good GUI, but it needs to be a balancing act. The design needs to be something that looks good to the user, but doesn't distract or prevent tasks from being completed [27].

2.2.2 Usability

A computer system that is usable has been defined as a computer system that has learnability, efficiency, memorability, errors (or free from them), and satisfaction [27]. In short, usability refers to how easy a user is able to perform tasks without making errors. Having a usable design is important because for many companies (and people) time is money. If a person is spends time searching through a GUI for the correct input it wastes times and it can even harm their health. There have been studies that show bad GUI design can even effect a users' health because of all the extra motion that needs to be done [12].

2.2.3 Simplicity

Even though flashing color and lights may be interesting or get people's attention, they do not always make a good GUI. Many people prefer things that are simple and easy to understand. Some researches argue that people need to stop thinking that graphics need to be energetic or "alive" [26]. Most users just want to know the bare minimum of how to get things done. So while it is possible to put a lot of options on one screen it does not mean a designer should. [7]

2.2.4 Color

An important aspect to consider is the color of the not only the background, but the icons as well. Different color schemes can allow the operator to focus or not focus on areas of the screen. For example, the color red is usually associated with danger or stop. This color could be used to log off or stop an application [22].

2.2.5 Information Limits

George Miller's study on our capacity for information processing has been used in many fields and GUI design is no exception. With "Miller's Law" it is frequently said that human mind processes items in a one-dimensional batch of seven, plus or minus two. [15] This also applies to GUI design because the human mind will process menu items and icons in this same type of setting and overloading the user with more icons can cause the user to get frustrated and make mistakes. [9].

2.2.6 Symmetry

Symmetrical designs have been thought of as ideal and aesthetic ever since the time of the Greeks [18]. They had an idea that there was beauty and perfection in things that were in nature or man-made that were symmetrical. This idea of symmetry as beauty has been carried out to modern times and there has been numerous studies on the symmetry of people's faces in relation to beauty [19]. In a GUI, symmetry can allow the user to see the options in a simple manner that doesn't confuse.

2.2.7 Information Sequencing and Standardization

When creating a layout the order of actions should be put on a screen in way that makes logistical sense for the end user. When something is standard or used often users will expect these actions to take place on similar GUIs. Hence important features that people use should be featured at the top of the screen because that is what users are familiar with or they should be placed in similar locations every time [9].

2.2.8 Button Size and Importance

Things of importance should be in a location that is easily distinguishable for users. If there are many options that are possible, the most frequently used ones should be at the top of the list [9]. Button size should also be taken into account for users because of eye strain [7]. It can also be used to engage the user into performing certain tasks.

2.3 Operations Research

Operations research (OR) as defined by INFORMS (Institute of Operations Research and the Management Sciences) is the field of study that involves the use of advanced analytical methods to make decisions that are optimal or near-optimal. It typically overlaps with disciplines like industrial engineering and it is often used to find a maximum or minimum of criteria like profit, performance, or risk [28]. Operations research typically includes many different problem solving techniques such as decision analysis, mathematical optimization, data analysis, and viewing of different economical methods.

Operations research can be used in many different fields to find solutions to problems that come up. Things like scheduling airlines, managing water flows, establishing locations of warehousing, and even identifying company strategies are areas that operations research has been used [28]. Operations research has also been used as a research tool to look into the following [14]:

- Creating or improving models of various systems
- Creating or improving algorithms to solve models
- Creating or improving methodologies
- Creating or improving software tools
- Increasing the understanding

2.4 Previous Studies on the Subject

2.4.1 What is Beautiful is Usable [26]

In a study titled, *What is Beautiful is Usable,* Tractinsky and Ikar looked at the relationship between a usable GUIs and an aesthetically pleasing one. In this study an ATM system was utilized to see the relationship between how a user's thoughts on different GUIs and how quickly they could complete the experiment. In this experiment it was seen that users had a high correlation between what they thought was aesthetic and what they thought was usable; however, their actual results did not show an improvement on their completion times. This shows that people view an aesthetic GUI as “working better” even if that isn’t the actual case. The study of aesthetics was also shown in a study in Japan showing that this may be a worldwide phenomenon [25]. This can be important because users will leave a system feeling happy and possibly want to work on it again.

2.4.2 Research on GUIs that Automatically Adjust in Size

There has been research on designing systems that automatically adjust in sized based on the user’s criteria. It was difficult to find papers on using operations research on GUI, but there has been a few papers that are similar in nature. These studies have involved utilizing a traditional desktop and mouse setup [30]. In one study with fuzzy agents, two engineers created a program of small blocks that required users to stack a smaller box into a larger one through a mouse. While this is not the same as operations research, they did use an analytical mathematic model of fuzzy agents to change the clickable area based on the task the user was performing [1].

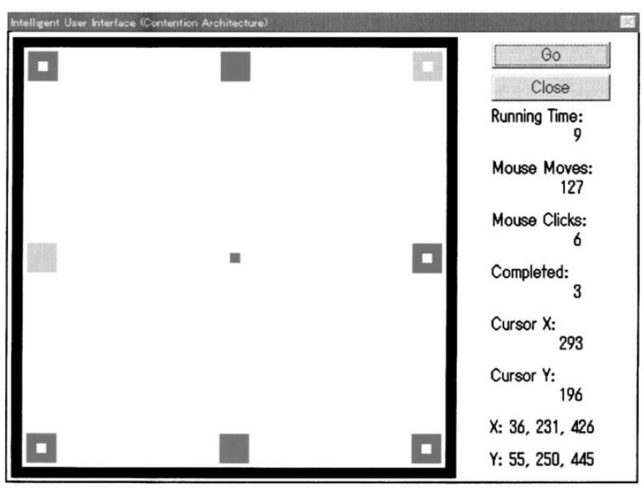


Figure 3- Fuzzy Agent GUI [1]

They were able to demonstrate a faster completion time for the six subjects they used in the experiment by changing the clickable area around each task making it easier for people to use. While their completion times were increased, they did not test the user's satisfaction or opinions on the GUIs they used. There are also patents pending on GUI designs that change automatically based on predetermined criteria set by the user [3] [21]. However these patents do not display their effectiveness nor measure how users react to changing GUIs.

Research Question:

Does the use of optimization design increase the usability, aesthetics, and performance of a menu driven touchscreen GUI design and is there an interaction with gender or blocking.

CHAPTER 3: METHODS

In order to examine if an optimization model for GUI design is possible a task needed to be created so that the effectiveness could be tested. Developing an ATM model was chosen because of the prior research on GUI design used on ATMs [26]. Moreover, tasks involving an ATM are easy to understand for non-tech users and they are familiar for most people. There were many steps that were taken in order to build a usable ATM model. This goes over the reasons and justifications for this.

3.1 Preparation for Building an ATM

3.1.1.1 Examining an ATM

Multiple ATMs on campus were first examined to see what the main components on the front screen were. One specific Major US Bank was chosen in order to test the optimization model against. Some of these components were:

- Statement Print
- Payments
- Additional Services
- Fast Cash
- Withdrawal
- Account Balances
- Deposit

3.1.1.2 Statement Print

This button would allow the user to print the following transactions on their receipt at the end of the transaction.

- Last 5 Card Transactions
- Last 5 Checks
- Last 5 Deposits
- Last 10 Transactions

3.1.1.3 Payments

This button was not able to display anything useful for the user unless the person with the account already has payments going through.

3.1.1.4 Additional Services

This served as a miscellaneous option that allows the user to change their preferences about what appears when they use their debit card on the ATM.

3.1.1.5 Fast Cash

On this screen the user can select to withdrawal money, but only in intervals that was present on the display screen.

- $20
- $40
- $60
- $80
- $100
- $200
- $300
- $400

3.1.1.6 Withdrawal

This screen allows the user to withdraw money in multiple ways. One option would be to type in the number the user wants to withdraw (in intervals of $20) using the number pad. The second option allows the user to select predesigned cash amounts of the same as Fast Cash.

3.1.1.7 Account Balances

This button allows the user to print their Account Balances on the receipt.

3.1.1.8 Deposit

This option allows the user to either Deposit Cash or Deposit Checks.

3.1.2.1 Building a Survey

In order to create the criteria for the optimization design the most common uses of an ATM needed to be found. To do this a survey was created to see how the average student at California Polytechnic State University used an ATM. A Google Form was created that would allow for an easy survey of Cal Poly Students. It was assumed that people would be focused on their most requested tasks and that special attention should be paid when creating an ATM GUI to these tasks.

3.1.2.2 Survey Location

The participants in the survey were verbally asked in the University Union and their answers were recorded electronically on a Microsoft Surface Pro using the Google Form. Fifty-Two Cal Poly students were asked for their input.

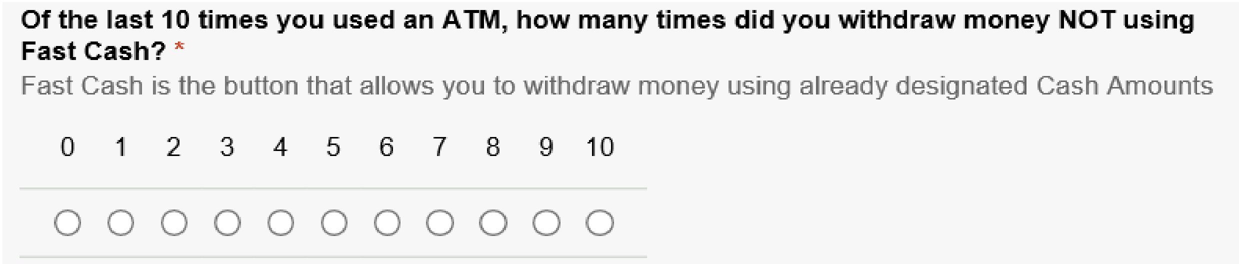
3.1.2.3 Survey Script

Thank you for taking the time to do this survey. I am doing a study on ATMs. I wanted to ask you questions about your last 10 times you were at an ATM. If you have not used an ATM more than 10 times then I cannot ask for your survey results. If you did multiple things during an ATM transaction please count each task.

3.1.2.4 Survey Questions and Form

The following questions were asked for the survey and the participant would then select from 0 to 10 how many times this happened during an ATM transaction:

1. Of the last 10 times you used an ATM, how many times did you withdraw money NOT using Fast Cash?
2. Of the last 10 times you used an ATM, how many times did you withdraw money USING Fast Cash?
3. Of the last 10 times you used an ATM, how many times did you deposit a check using an ATM?
4. Of the last 10 times you used an ATM, how many times did you deposit cash using an ATM?
5. Of the last 10 times you used an ATM, how many times did you transfer money using an ATM?
6. Of the last 10 times you used an ATM, how many times did you print out your LAST FIVE transactions during A SINGLE transaction?



Of the last 10 times you used an ATM, how many times did you withdraw money NOT using Fast Cash? *

Fast Cash is the button that allows you to withdraw money using already designated Cash Amounts

0	1	2	3	4	5	6	7	8	9	10
○	○	○	○	○	○	○	○	○	○	○

Figure 4 – Example of Questions from Survey

3.1.2.5 Results from Survey

All the responses were summed up and the following are the results from the survey. 32% of the time people were withdrawing money not using the Fast Cash button and 28% were withdrawing money using the Fast Cash button on their ATM. The next highest numbers were Depositing Check and Depositing Cash at 17% and 13% respectively.

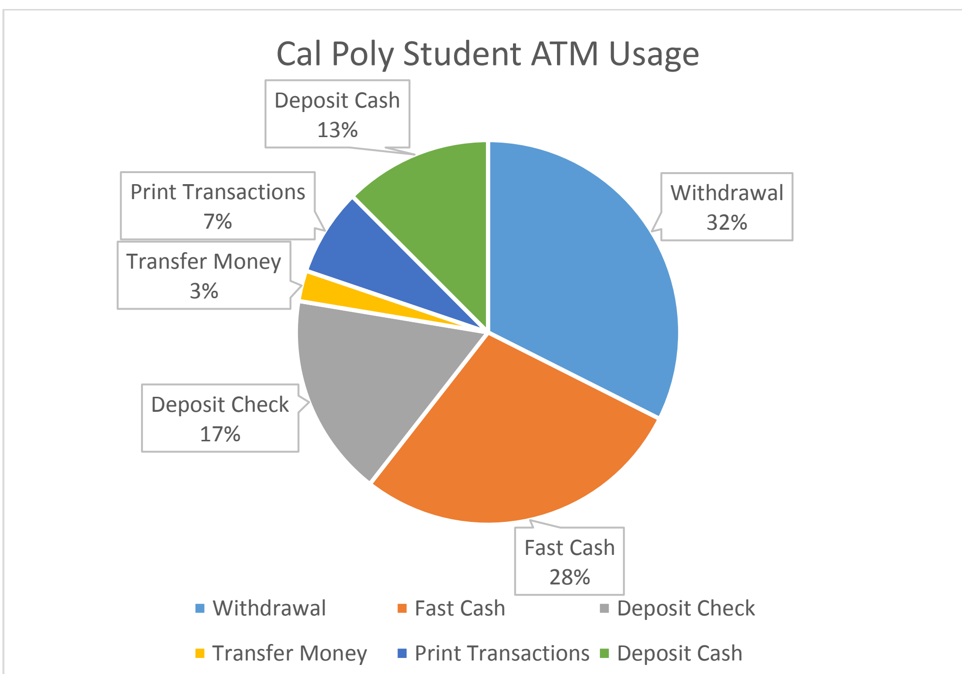


Figure 5 - Cal Poly Student ATM Usage

This survey shows that majority of the time (over 50%) people want to withdraw money at the ATM. And around 30% of the time people want to deposit cash or checks into the ATM. This is important because it shows what the most common uses of an ATM are and this popularity will be built into the optimization model.

3.2 Building Optimization Model

Building the Optimization model required creating constraints based on the design criteria stated in the literature review. This includes symmetry, button size, and button location. The survey results from the students about ATM usage was also used to create button sizes and the layout order.

3.2.1 Location of Buttons

Nodes were created in order to keep symmetry and simplicity to show where buttons could and could not go. The assumption is that a simple and symmetric design would be good for a user according to the research stated in the literature review [18] [19] [27]. Since the experiment is being tested on a Tablet with a 10 inch screen there was a limit on the amount of buttons that could be fit. It was decided that four rows of three columns would maximize space while not overloading the user with buttons as seen below in Figure 6 - Location of Nodes.

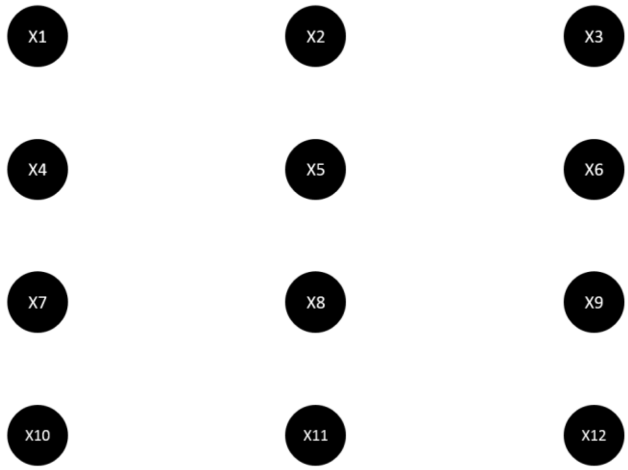


Figure 6 - Location of Nodes

3.2.2 Size of Buttons

To keep the model simple there were two size buttons decided for the Optimization model, a large size and a small size. A large size button would take the spot of its own node as well as the button below itself. For example, if a large button was placed in node X1 it would also take the spot of node X4. It was decided that a large button would be used if a task is done more than 25% of the time for all tasks. A small size button would only take the spot of a single node. Withdrawals and Deposits were chosen as the larger buttons since they represented he majority of the user's tasks.

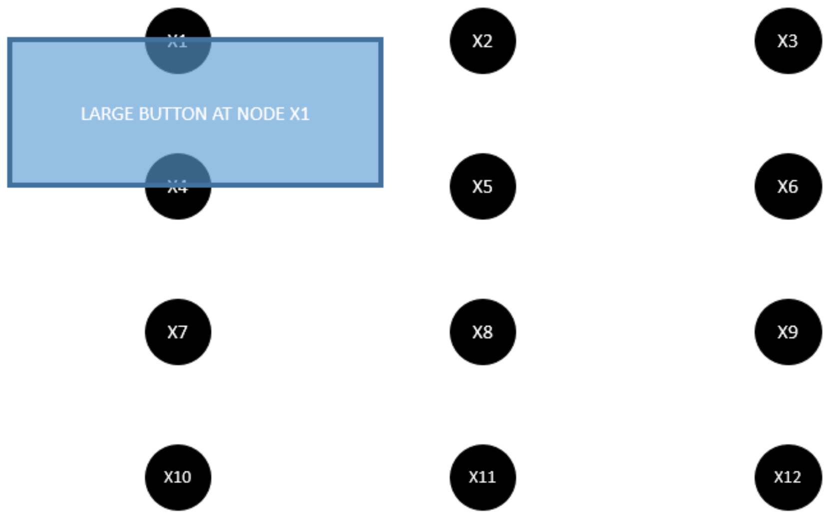


Figure 7 - Large Button at Node X1

3.2.3 Symmetry of Buttons

To keep aesthetics high with the Optimization model it was decided that the design needed to have symmetry. The following guidelines were developed to account for symmetry:

- Each row can only have buttons of the same size
- If an odd amount of the same size buttons is needed than one of the same size buttons needs to be in the middle
- If an even amount of the same size buttons is needed than the same size buttons must be placed on the sides

3.2.4 Number of Buttons

The number of buttons is limited by the size of the screen and the amount of nodes. A large button takes the space of two nodes and there can only be two nodes per row. Therefore, there can be a maximum of 4 large buttons or a maximum of 8 smaller buttons.

3.3 Developing the Optimization Model

Using the constraints above a binary programming model was created using Microsoft Excel 2013 and the Solver Add On.

3.3.1 Defining the Variables in Optimization Model

In the Optimization model each button at each location is represented by the following binary variable:

$$X_{ij} = 1\ if\ \ location\ i\ has\ a\ button\ size\ j, and\ 0\ otherwise$$

$$Where\ i = 1,2\ \ldots,12; and\ j = s\ (small\ buton) or\ L\ (large\ button)$$

The locations of each node is shown in Figure 6 - Location of Nodes.

3.3.2 Developing Objective Function

While not everyone reads lists the same way the majority read lists from top to bottom [5]. The top row has the highest value for large buttons and the value gets decreasingly big as you go down each row. Having a higher value at the top row for the large button makes sure that if a large button is chosen it has a preference towards being at the top. This way their eyes are not conflicted from looking at two different locations (a big button on the bottom and stating naturally at the top). The numbers 2, 1.5, and 1 were chosen because it was an easy way to logically see the order of importance of each row. The sides of the small button were chosen to have more importance because than the middle because if there are less rows on the GUI it will appear more simple for the end user. If the middle had the same weight as the sides there exists the chance of having multiple rows of just one button causing the form to appear longer. The goal of the objective function is to maximize the score so that the GUI would have the highest aesthetics. Thus the objective function is shown in Figure 8 - Objective Function.

$$Max\ Z: 2X_{1L} + 2X_{2L} + 2X_{3L} + 1.5X_{4L} + 1.5X_{5L} + 1.5X_{6L} + X_{7L} + X_{8L} + X_{9L} + X_{1s} + X_{2s} + X_{3s} + X_{4s} + X_{5s} + X_{6s} + 1.1X_{7s} + X_{8s} + 1.1X_{9s} + 1.1X_{10s} + X_{11s} + 1.1X_{12s}$$

Figure 8 - Objective Function

3.4 Constraints

3.4.1 Number of Buttons

The first constraint guarantees there are not more buttons than allowed based on the requirements of the user. This was based off of the results of the ATM survey and what tasks are required to do on the ATM. It was determined that there were two main tasks that would be given a large button, Deposit and Withdrawal. The four remaining tasks, Transfer Account Balances, Statement Print, Additional Services, and Log Off, were chosen to have smaller buttons. This can be seen in Figure 9 - Number of Buttons.

$$X_{1L} + X_{2L} + X_{3L} \ldots + X_{9L} \leq 2$$

$$X_{1S} + X_{2S} + X_{3S} \ldots + X_{12S} \leq 4$$

Figure 9 - Number of Buttons

3.4.2 Symmetry

The second set of constraints makes sure a button is symmetrical about the middle by not allowing only one button on the left or right side. Either both are chosen to be a button or neither is chosen.

$$X_{1L} - X_{3L} = 0$$

$$X_{4L} - X_{6L} = 0$$

$$X_{7L} - X_{9L} = 0$$

$$X_{1S} - X_{3S} = 0$$

$$X_{4S} - X_{6S} = 0$$

$$X_{7S} - X_{9S} = 0$$

$$X_{10S} - X_{12S} = 0$$

Figure 10 - Symmetry Constraints

3.4.3 Large Button Interference

A large box or small box cannot exist in the same column in the following row of an existing large box. This constraint can be seen in Figure 11 - Large Button Interference.

$$X_{1L} + X_{4L} + X_{1S} + X_{4S} \leq 1$$

$$X_{2L} + X_{5L} + X_{2S} + X_{5S} \leq 1$$

$$X_{3L} + X_{6L} + X_{3S} + X_{6S} \leq 1$$

$$X_{4L} + X_{7L} + X_{4S} + X_{7S} \leq 1$$

$$X_{5L} + X_{8L} + X_{5S} + X_{8S} \leq 1$$

$$X_{6L} + X_{9L} + X_{6S} + X_{9S} \leq 1$$

Figure 11 - Large Button Interference

3.4.4 Adjacent Buttons

Symmetry is kept in the design by preventing adjacent buttons.

$$X_{iL} - X_{(i+1)L} \leq 1 \; for \; i = 1,2 \ldots 8$$

$$X_{is} - X_{(i+1)s} \leq 1 \; for \; i = 1,2 \ldots 11$$

Figure 12 - Adjacent Buttons

3.4.5 Mixing Boxes

A small box cannot be between two large boxes

$$X_{1L} + X_{3L} + X_{2s} \leq 2$$

$$X_{4L} + X_{6L} + X_{5s} \leq 2$$

$$X_{7L} + X_{9L} + X_{8s} \leq 2$$

Figure 13 - Mixing Boxes

3.4.6 Results from Optimization Model

The results from the Optimization model gave the following result:

- Large Boxes Located at X1 and X3
- Small Box Located at X7, X9, X10, and X12
- "Score" from Objective Function is 8.4

3.5 ATM System Design

The ATM System design was creating using Microsoft Access 2013 on a Microsoft Surface Pro featuring Windows 8.1. Microsoft Access was used because of the familiarity of the coding language VBA, and because it could store time completion data and export it easily to Excel. There were 3 ATM systems created. One featured every button on the main menu screen, another featuring a traditional ATM GUI, and lastly an ATM GUI utilizing the Optimization design.

3.5.1 All ATM Models

In order to reduce the type of variations in the different GUI models some aspects were kept the same in each model. Each model had a red-orange log off button that would call the users attention to exit the program when the user was completed. Each button and background in the models had the same color to prevent color from being a factor that needed to be tested. Each GUI was also capable of performing the same actions, the only difference was the way the layouts were designed and if a user needed to go into sub menus to perform tasks.

3.5.2 All Button ATM GUI

In this ATM setting the ATM features a button for every single action on the front screen. This will be to see if a "crowded" GUI will effect performance or aesthetics compared to the Optimization or Traditional form. It will also see if a user finds a form more useful if every option is available for the subject. When a user wants to withdraw cash they must enter a different screen in order to punch in the numbers.

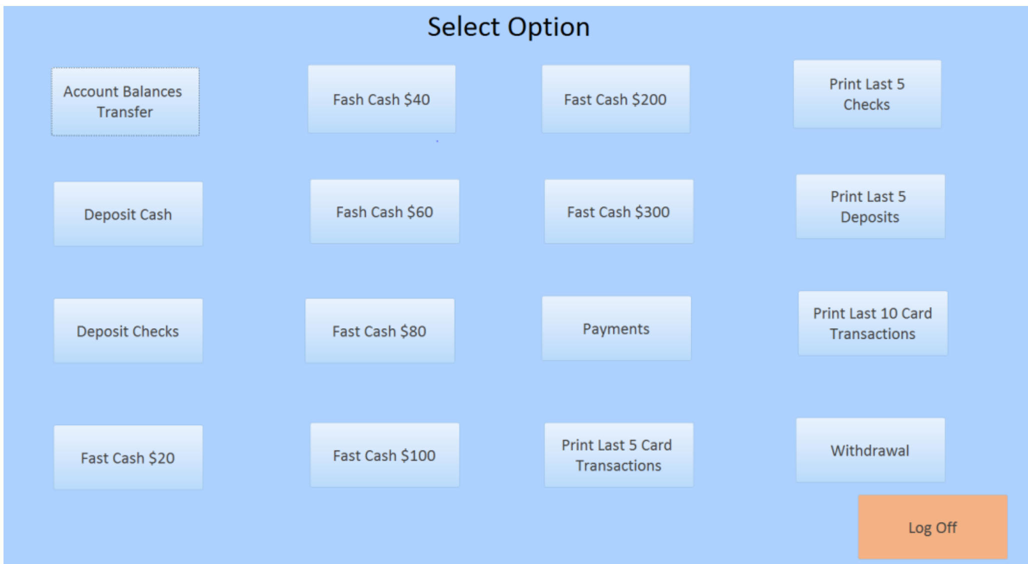


Figure 14 - Example of the Main Screen

In this setting the buttons are arranged in alphabetical order from up and down since previous GUI said that having a set order makes a good graphical design [9]. When an option is selected on this screen a message box will open up letting the user know the task has gone through.

For example, when a user clicks the button that says "Print Last 5 Checks" a menu box opens and alerts the user that the transaction has gone through as seen in Figure 15 - All Buttons Menu Box Message Box.

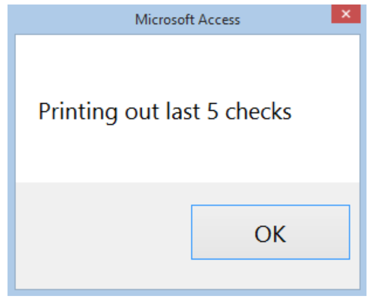


Figure 15 - All Buttons Menu Box Message Box

3.5.3 Traditional ATM GUI

This GUI features a traditional ATM layout of a major US Bank on California Polytechnic State University's campus. The options are symmetric from all sides and all the buttons are the same size. In this form users will need to select an option before completing a task. This is the opposite of the All Button form where every action is on the front of the screen.

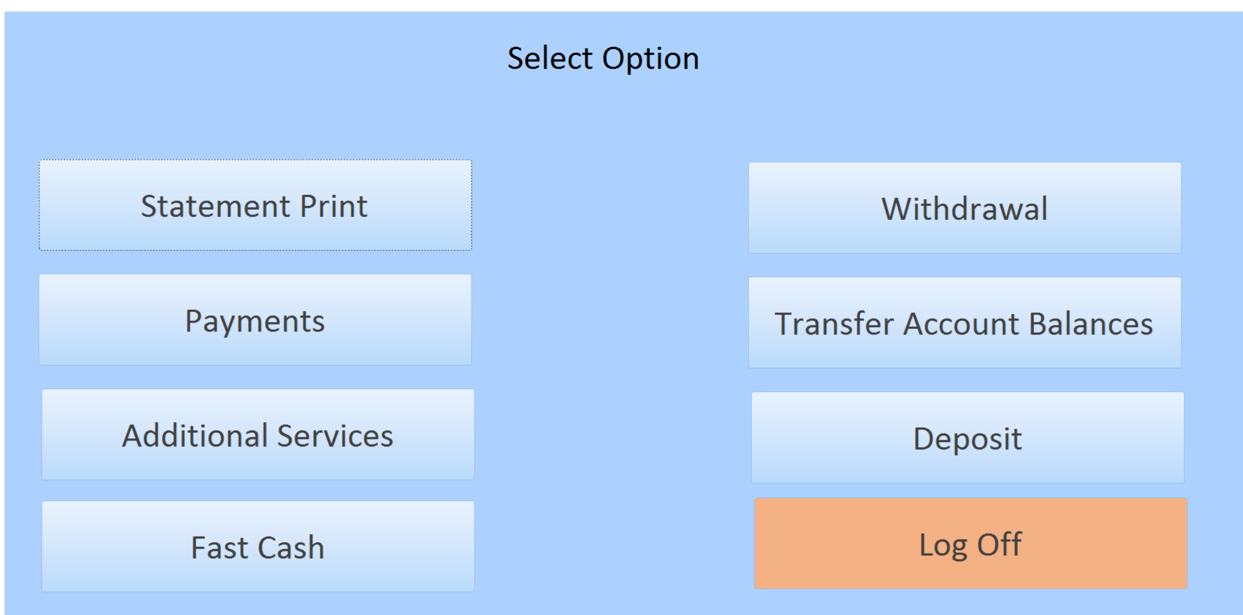


Figure 16 - Traditional ATM GUI

When a user clicks on one of the buttons the next menu opens up. For example, when a person clicks on “Statement Print” a list of available actions is shown as seen in Figure 17- Statement Print Form GUI.

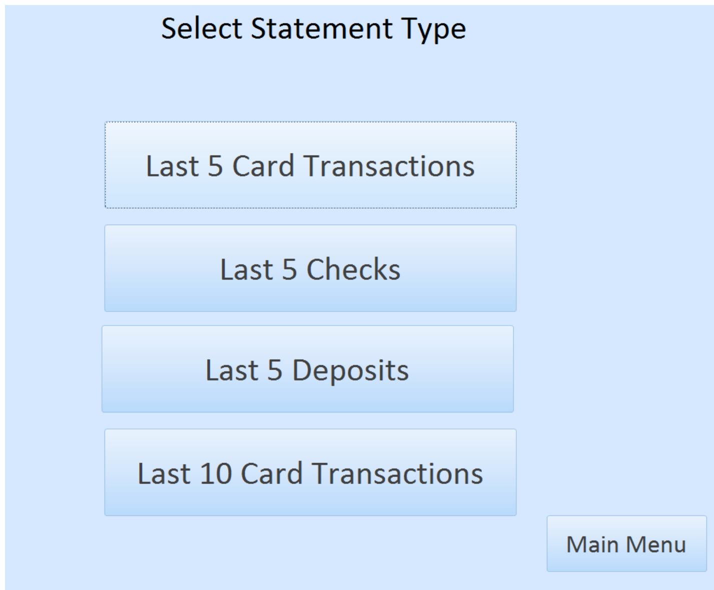


Figure 17- Statement Print Form GUI

From this menu the user would be able to print statements to show up on the receipt and a message box would appear as shown in Figure 18 - Printing Out Last Debit Cards Message Box.

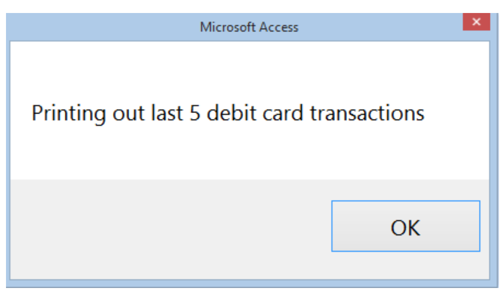


Figure 18 - Printing Out Last Debit Cards Message Box

3.5.4 Optimization Model ATM GUI

This model is based off of the Optimization Model that was created. There are two large buttons located at X1 and X3. There are small buttons located at X7, X9, X10 and X12. The Withdrawal and Deposit are chosen because of the poll results that were decided earlier that these were the most popular transactions. There needed to be at least 4 other buttons to perform all the other tasks. So Statement Print, Additional Services, Transfer Account Balances, and Log Off were chosen as the final option for the smaller buttons.

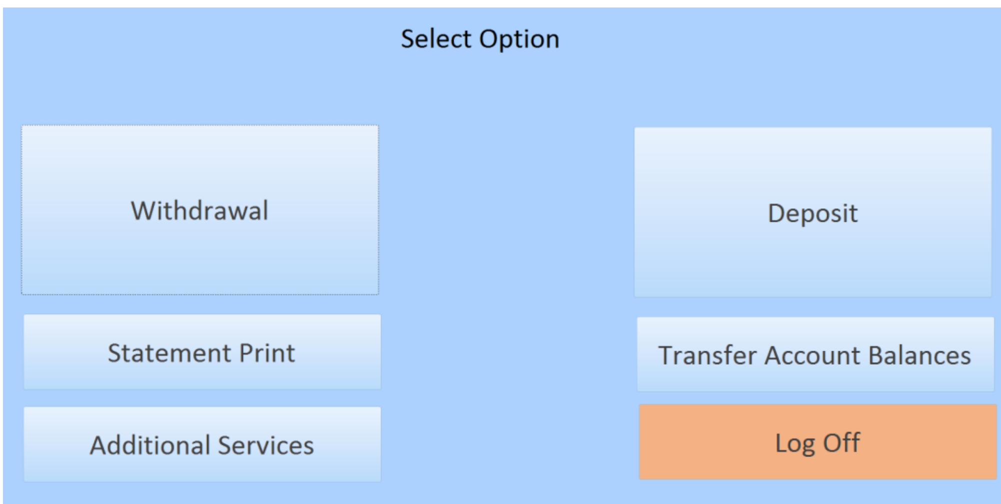


Figure 19 - Optimization Model GUI

When a user clicks on one of these buttons another form will open up allowing the user to select the final action. For example, when clicking on Deposit another menu screen pops up as seen in Figure 20 - Deposit Options GUI

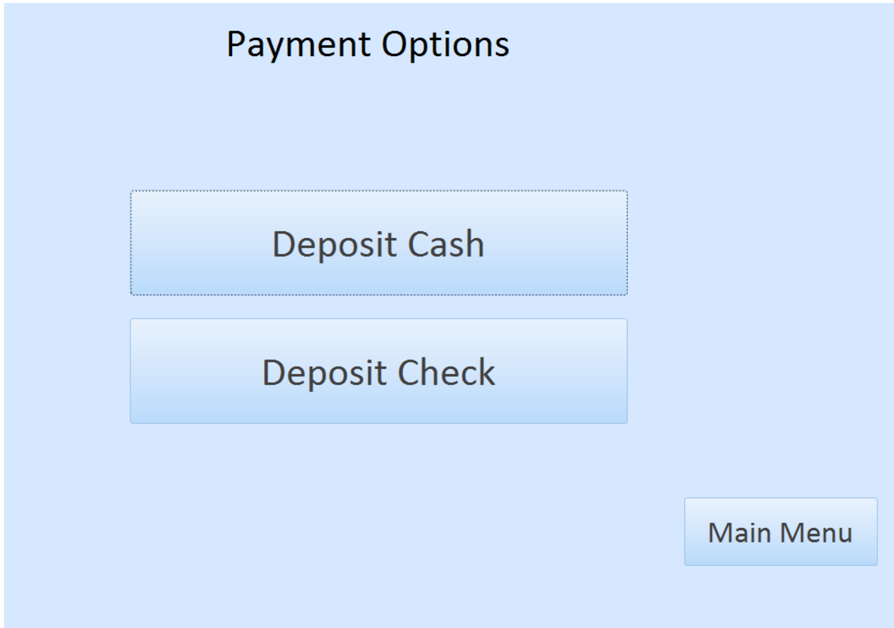


Figure 20 - Deposit Options GUI

From here the user can select the Deposit Cash or Check and a message box appears as seen in Figure 21 - Depositing Cash Message Box.

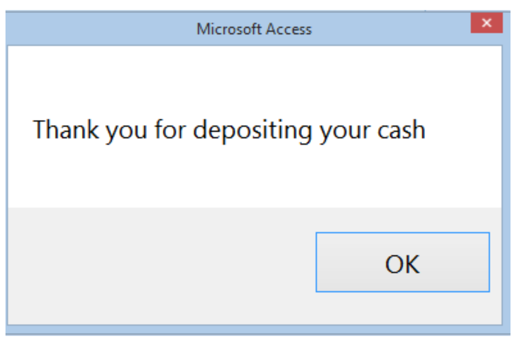


Figure 21 - Depositing Cash Message Box

3.5.5 Post Experiment Survey

After the participant is finished with the experiment he or she will be asked to fill out what they thought about the aesthetics, usability, and satisfaction about the design of each of the GUIs. This data will be stored in a Microsoft Excel database.

A Likert scale was chosen to rate the forms so that the users feedback could be analyzed statistically. A scale from 1 to 7 was chosen and was kept constant throughout the entire experiment to reduce biases from the subjects. Even though some people may have different opinion on a GUI, this scale can effectively take a holistic approach at all users feedback. [11] [17].

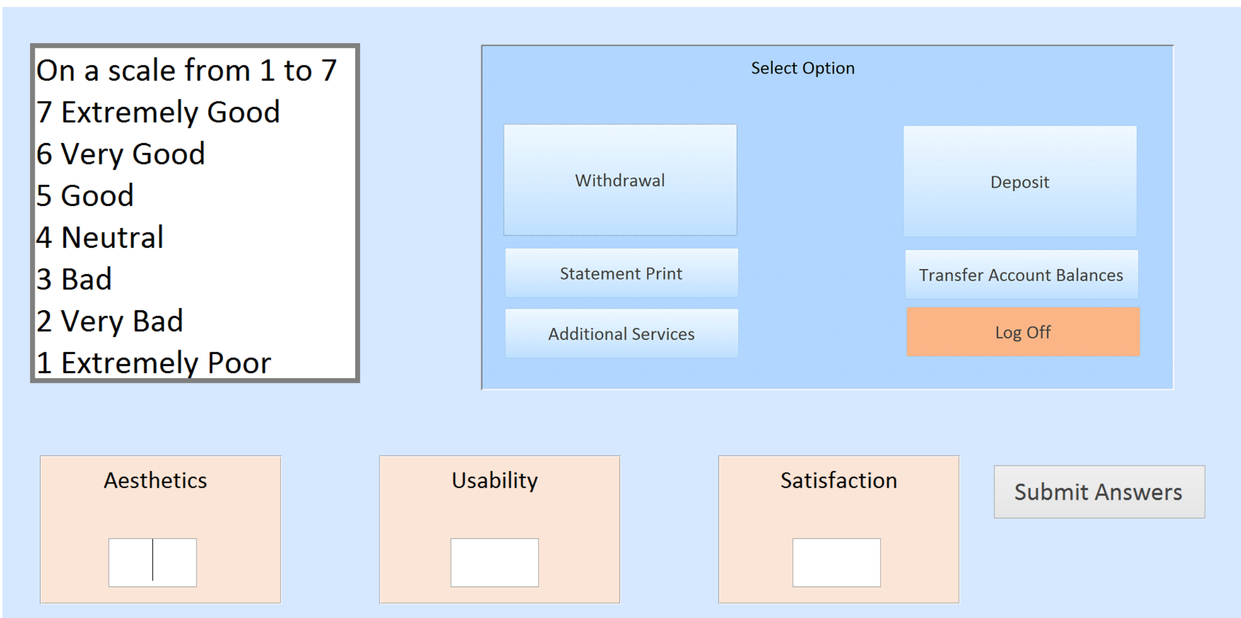


Figure 22 - Rating form of Optimization Model

CHAPTER 4: METHODOLOGY

4.1 Design

The design of the experiment is a three-way ANOVA with three fixed variables: Form, Gender, and Block. The factors and experiment design are detailed in Table 1 and Table 2.

Table 1 - All Factors and Levels

Factors	**Levels**	**Type of Variables**
Form	3	Fixed
Gender	2	Fixed
Block	6	Fixed

Table 2- Experimental Design

	All Buttons	**Optimization**	**Traditional**
Male			
Female			

In order to reduce the effects of learning the experiment was counterbalanced as seen in Table 3 - Combination of Runs. Every male and female subject in the experiment performed all three tests; however, the order was changed per participant. The number 1 under each run corresponds to the All Button form, 2 is the Optimization form, and 3 is the Traditional form. First Run, Second Run, and Third run refer to how many times the order has been repeated. For example, Subject 16 would be the third male to do complete the experiment in Optimization, Traditional, and All Button form order.

Table 3 - Combination of Runs

	Subject	First Run			Subject	Second Run			Subject	Third Run		
Male	**1**	1	2	3	**7**	1	2	3	**13**	1	2	3
	2	1	3	2	**8**	1	3	2	**14**	1	3	2
	3	2	1	3	**9**	2	1	3	**15**	2	1	3
	4	2	3	1	**10**	2	3	1	**16**	2	3	1
	5	3	1	2	**11**	3	1	2	**17**	3	1	2
	6	3	2	1	**12**	3	2	1	**18**	3	2	1
Female	**Subject**	**First Run**			**Subject**	**Second Run**			**Subject**	**Third Run**		
	19	1	2	3	**25**	1	2	3	**31**	1	2	3
	20	1	3	2	**26**	1	3	2	**32**	1	3	2
	21	2	1	3	**27**	2	1	3	**33**	2	1	3
	22	2	3	1	**28**	2	3	1	**34**	2	3	1
	23	3	1	2	**29**	3	1	2	**35**	3	1	2
	24	3	2	1	**30**	3	2	1	**36**	3	2	1

4.2 Hypotheses

There are seven hypothesis in this experiment. This purpose of the experiment is to see if the type of form (All Button, Optimization, or Traditional) or gender (Male vs Female) has an effect on the speed of completing tasks using a tablet or their ratings of the aesthetics, usability, or satisfaction. The blocking (A, B, C, D, E, or F) is also looked at to see if the way they complete the experiment has an effect on their results. The hypotheses are listed below in Table 4- Hypotheses.

Table 4- Hypotheses

Null Hypothesis	Type
The population means for Forms are equal	Main effect
The population means for Gender are equal	Main effect
The population means for Blocks are equal	Main effect
There is no interaction between Forms and Gender	First-Order Interaction
There is no interaction between Forms and Blocks	First-Order Interaction
There is no interaction between Gender and Blocks	First-Order Interaction
There is no interaction between Forms, Gender, and Blocks	Second-Order Interaction

4.3 Participants

The subjects for this experiment were recruited on campus and needed to fit the following criteria.

- Cal Poly Students between the ages of 18 and 26
- All majors except Computer Science and Software Engineers
- A student needed to have normal vision. If a student uses contacts or glasses they must wear them during the experiment.

Thirty-Six subjects were recruited in this experiment, eighteen men and eighteen women. Each subject was offered a slice of pizza or a candy bar for participating in the experiment.

4.4 Variables

4.4.1 Controlled Variables

The following are the variables that were held constant throughout the experiment for all participants:

- Location: Ergonomics Laboratory, Building 192 Room 237
- Set up: The same table, seats, and cubicle was used for all participants
- Lighting and Sound: The participants were all kept in the same lighting and atmospheric conditions
- Tablet Placement: The tablet was situated nine inches away from the edge of the desk. The tablet was held up by a built in kickstand that held the tablet at a 22 degree angle.
- The notecard with instructions that were flipped over were put into the same spot, directly in front of the tablet.
    - If the subject was right handed the experimenter sat on the left side of the subject and vice versa if the subject was left handed. This was to prevent interference with the subject using the tablet
- The subjects were offered the same pizza or candy reward for completing the experiment
- Script, instructions, procedures, and consent form remained constant.

4.4.2 Independent Variables

There are three independent variables, Form, Gender, and Blocking. Gender has two levels male and female. GUI has three levels: All Buttons, Optimization, and

Traditional form. Blocking has 6 levels that corresponds to the order the experiment is completed: A, B, C, D, E, & F.

4.4.3 Dependent Variables

The dependent variable is the speed in how fast they complete the tasks per form in seconds. Moreover, they were asked to rate the Aesthetics, Usability, and Satisfaction of each form on a scale that went from 1 to 7.

4.5 Experiment

First the participant will be asked to read and sign the Informed Consent Form. [See Appendix D] Afterwards the subject will be asked to perform the practice run (See Figure 23 - Example of Practice Form) so that they can become familiar with the experiment. [Attachment F] will be given to them. They will be asked to perform the following tasks on the practice form through index cards:

- Touch Button 1
- Touch Button 5
- Touch Button 6

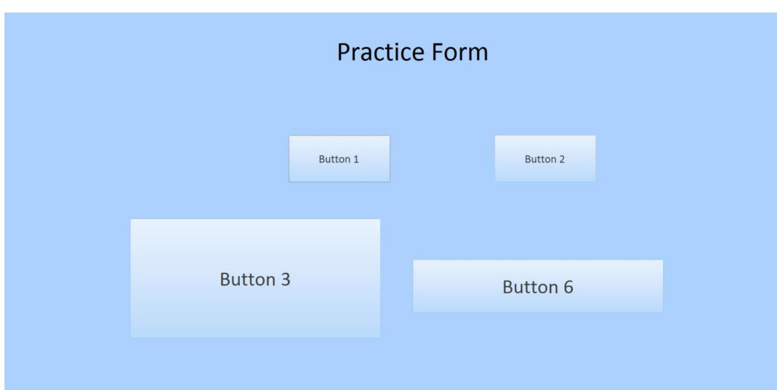


Figure 23 - Example of Practice Form

Each task will be shown one at a time and the next task will not be shown until they complete the preceding task. This shows the subjects three major things about the program: How a button reacts to being touched on the system, how a message box appears, and how a subject may need to push a button in order to access the next button. This way they are not learning this when they are experimenting on the actual experiment GUI.

After the practice run is completed the subject will be handed the instructions [See Appendix E] while the experimenter reads them out loud. The participant will be randomly assigned an order to complete the three forms as shown in Table 3 - Combination of Runs. The timing would begin as soon as the subject touched “Begin the Experiment” and would stop when they touched “Log Off”. The subject would start the experiment doing the following transactions on the ATM in the same order for all the forms.

- Deposit Cash
- Withdraw $100
- Deposit Check
- Print Last 5 Deposits
- Withdraw $120
- Print Last 5 Checks
- Withdraw $180
- Deposit Check
- Print Last 5 Card Transactions
- Log Off

Each task would be on a notecard and would be revealed to the subject in between themselves and the tablet only after they completed the preceding task. The subject was not told that the order would be the same for all three forms.

4.6 Post Experiment

The subject would then be asked to read over the survey form when they completed the experiment. (See Appendix F) They would be asked to rate the forms in the same order that they completed the experiment on the Aesthetics, Usability, and their Satisfaction of the forms.

CHAPTER 5: RESULTS

5.1 Overview of Data

The completion times and the user's ratings based on Aesthetics, Usability, and Satisfaction of each form was analyzed to determine if Gender, Form, or Blocking were significant interactions in the experiment. First, descriptive statistics were made for each of the completion times and rating criteria. Next, the normality of the data was analyzed for each criteria. Finally, a three-way ANOVA as performed to see if the factors or their interactions had any significant effect on the results.

5.1.1 Overview of ANOVA Tests

The ANOVA model is a three factor ANOVA test. The levels and factors are shown below. The same ANOVA model is used for Time, Aesthetics, Usability, and Satisfaction Scores.

Table 5 ANOVA Factors and Levels

Factor	Gender
Level 1	Male
Level 2	Female

Factor	Form
Level 1	All Button
Level 2	Optimization
Level 3	Traditional

Factor	Block	Order
Level 1	A	1,2,3
Level 2	B	1,3,2
Level 3	C	2,1,3
Level 4	D	2,3,1
Level 5	E	3,1,2
Level 6	F	3,2,1

5.2 Completion Time Score Data

5.2.1 Descriptive Statistics of Completion Times

Table 6 - Descriptive Statistics for Completion Times

Descriptive Statistics: Completion Times	
N	108
Mean*	58.54
Standard Deviation*	10.83
Minimum*	36
Q1*	49.50
Median*	57.50
Q3*	65.75
Maximum*	86
Skewness	0.46
Kurtosis	-0.40

*Units in seconds

The average time to complete the forms is 58.54 seconds. The fastest completed time is 36 seconds and the slowest time is 86 seconds. The histogram of the completion times is shown in Figure 24- Histogram of Score. The Skewness is 0.47 positive skew and it is moderately skewed to the left. A negative Kurtotis 0.48 shows that the data is marginally flatter than normal data.

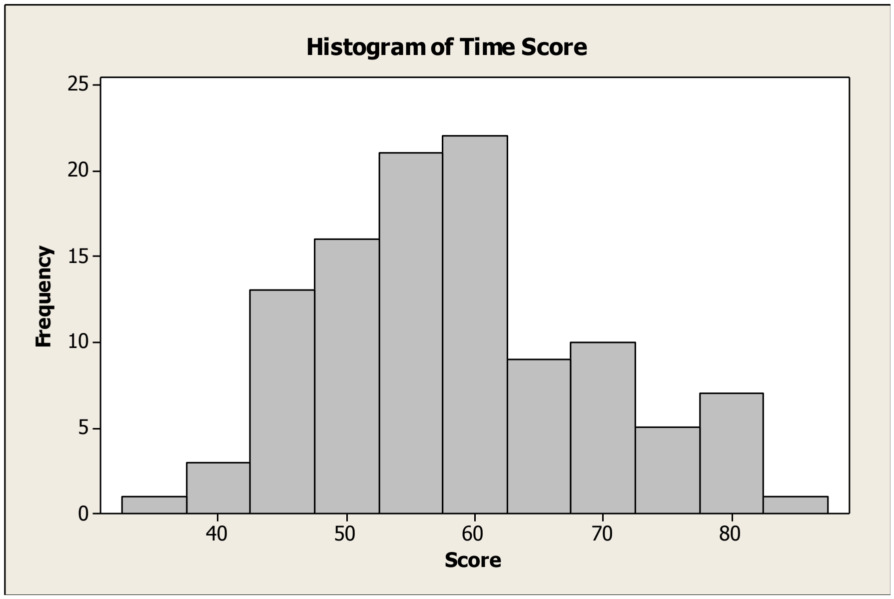


Figure 24- Histogram of Score

5.2.2 Test of Normality of Time Score

The residuals was tested for normality to verify that ANOVA tests could be done. Ryan-Joiner test of normality was chosen because it avoids rejecting normality due to rounding. The residuals were tested for normality and has a P-Value of >0.100 shows that the data is normal.

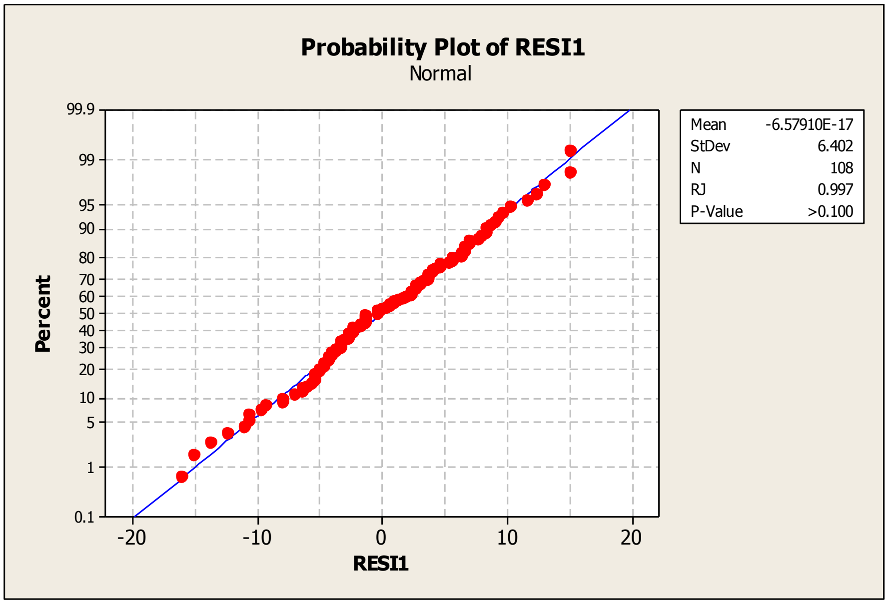


Figure 25 - Residual Normality of Time Score

5.2.3 Time ANOVA Table

Table 7 - Time ANOVA Table

Source	DF	F Value	P Value
Gender	1	0.22	0.641
Form	2	28.53	0.000
Block	5	2.2	0.063
Gender*Form	2	0.14	0.871
Gender*Block	5	1.78	0.128
Form*Block	10	4.83	0.000
Gender*Form*Block	10	0.82	0.613

There are two significant factors in the experiment for the time score as seen in Table 7 - Time ANOVA Table. The interaction between Form and Block and the Form in the experiment with P-Values of 0.000. Blocking proved to be a notable effect with a P-Value of 0.063; however, it was above the P-Value of 0.05 so it is not significant.

Another notable factor was the interaction between Gender and Blocking with a P-Value of 0.128. Gender, Gender & Form Interaction, and Gender & Form & Block interactions were not significant with P-Values of 0.641, 0.871, and 0.613 respectively.

5.2.4 Interaction Plots of Score Time

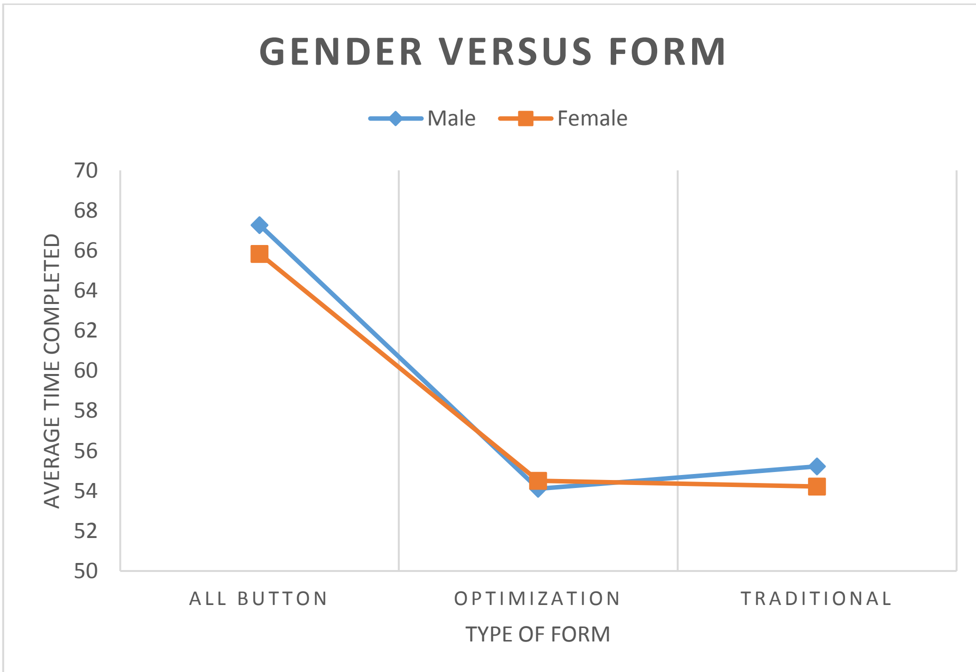


Figure 26 – Gender Versus Form Time Score Interaction

The interaction plot for Gender and Form shown in Figure 26 – Gender Versus Form Time Score Interaction similar average completion times for both men and women among all three forms and it is not significant with a P-Value of 0.871. The scores follow the same parallel and have slower times for the All Button form and decrease to similar times for Optimization and Traditional forms.

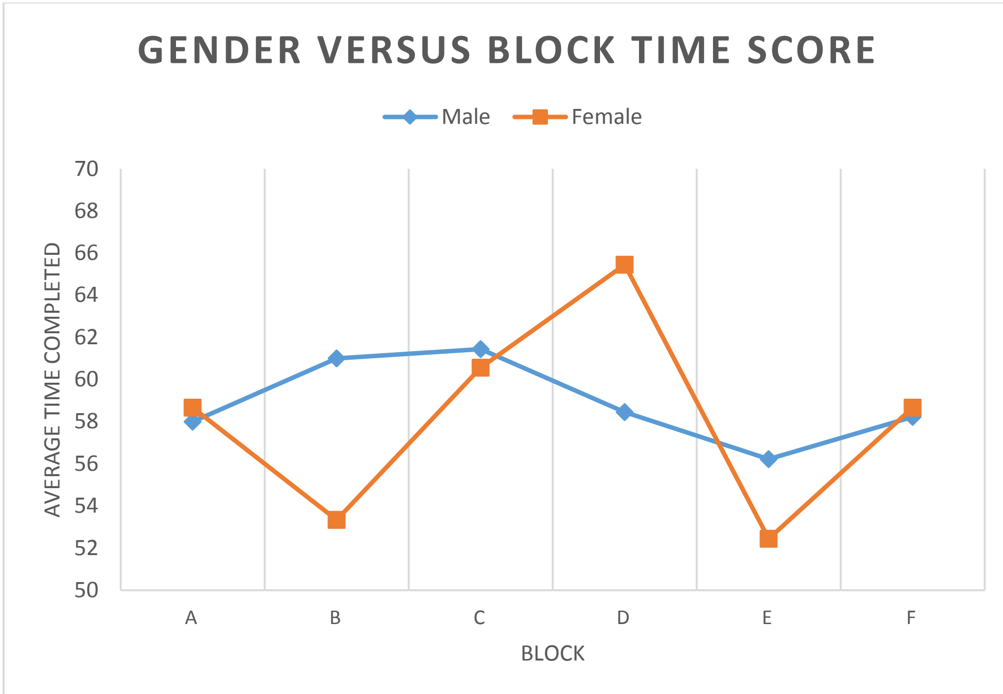


Figure 27 - Gender Versus Block Time Score Interaction

The interaction between Gender and Block (Figure 27 - Gender Versus Block Time Score Interaction) has a larger variability of average completion times for Females compared to Males; however, there is not a significant interaction according to the ANOVA tests with a P-Value of 0.128. For women, the fastest average completion times occur when the Optimization form was completed last, Blocks B & D. For men, the Optimization form have the fastest average completion time in Block E when the Optimization form was last, but unlike women, was slower in Block B. For women, the slowest completion times are when the Optimization for was completed first in Blocks C & D. For men, the slowest completion times are in Blocks B & C. Men and Women have similar completion times in Block A and F which have the same order but reversed.

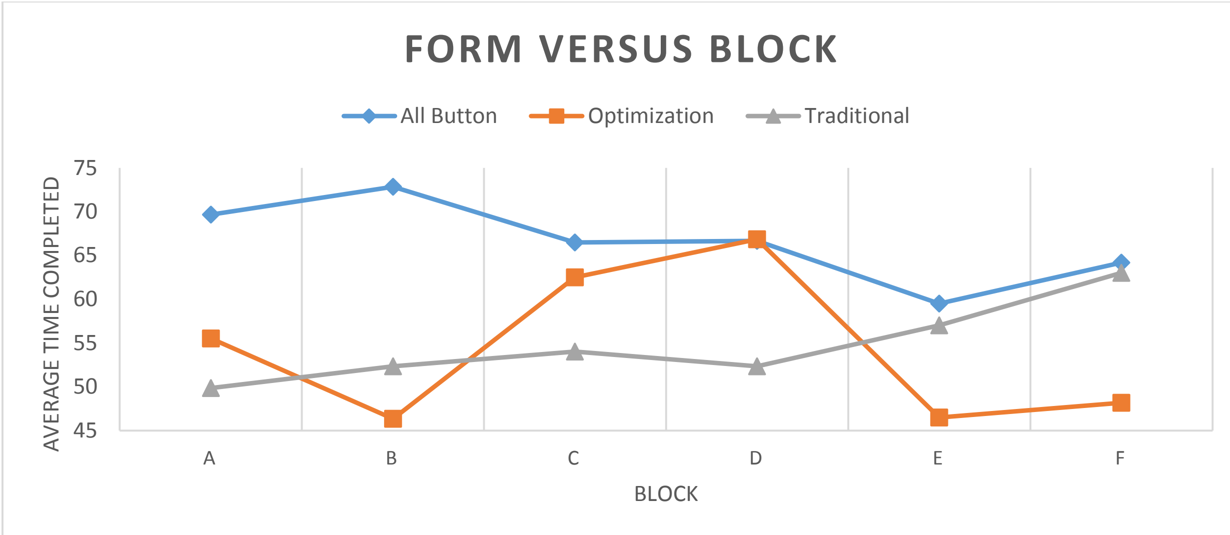


Figure 28- Form Versus Block Time Score Interaction

The Form and Block has a significant interaction (Figure 28- Form Versus Block Time Score Interaction) effect on the average completion times with a P-Value of 0.000. The All Button Form consistently has the slowest times over the course of the experiment. In the Blocks where the All Button Form was completed first, Blocks A & B, the average completion time is the slowest.

The Optimization Form has the slowest completion times in Blocks C & D and that was when the Optimization form was completed first for the subjects. Block B is completed in a faster average time than Block A for the Optimization form. In Block B, the Optimization form was completed last and in Block A it was completed second. The completed times for Block B, E, and F are similar in completion time.

When the Traditional Form was completed first, Blocks E & F, the average completion time is slowest. The average completion times is similar for Blocks A, B, C, & D. The completion times for the Traditional Form is slower than the Optimization Form in Blocks B, E, & F.

5.2.5 Comparison for Order

The slowest average time for every form occurred when the form went first for the subject. In order to see how this effect played out throughout the experiment a different Three-Way ANOVA model was analyzed. The normality of the residuals was tested which has a P-Value of 0.080 as seen in Figure 29 - Probability Plot of Form and Order showing that the data is normal.

Table 8 - Order ANOVA Design

Factor	Gender
Level 1	Male
Level 2	Female

Factor	Form
Level 1	All Button
Level 2	Optimization
Level 3	Traditional

Factor	Order
Level 1	Completed 1st
Level 2	Completed 2nd
Level 3	Completed 3rd

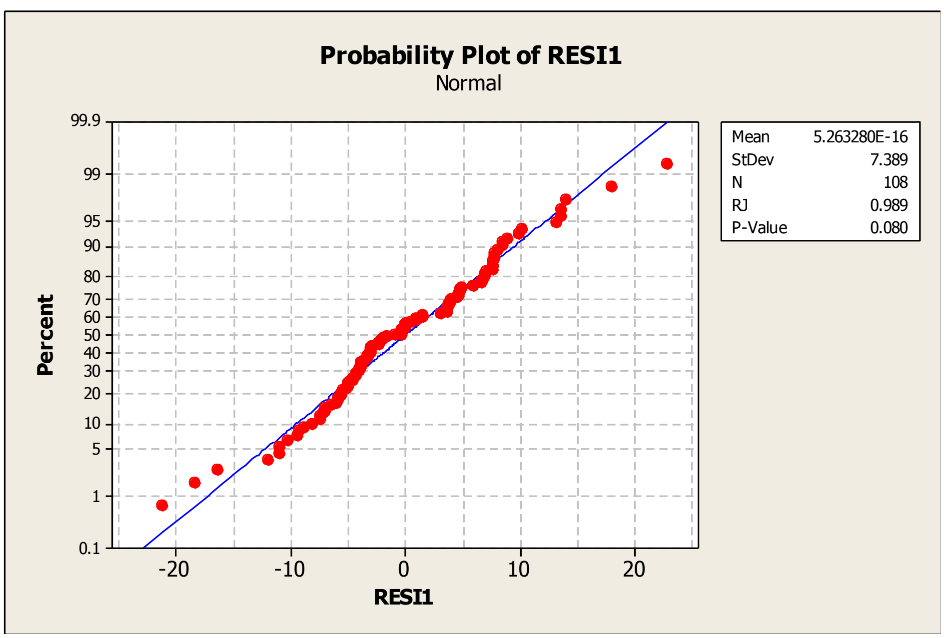


Figure 29 - Probability Plot of Form and Order

5.2.6 Order ANOVA Table

Table 9 - Order ANOVA Table

Source	DF	F Value	P Value
Gender	1	0.21	0.651
Form	2	26.77	0.000
Order	2	19.23	0.000
Gender*Form	2	0.13	0.879
Gender*Order	2	0.12	0.885
Form*Order	4	2.08	0.090
Gender*Form*Order	4	0.54	0.704

The Form and the Order both have a significant effect on the average completion times with P-Values of both 0.000. The interaction between the two, while notable, is not significant with a P-Value of 0.090. Gender, Gender*Form, Gender*Order, and Gender*Form*order do not have a significant effects on the average completion times with high P-Values of 0.651, 0.879, 0885, and 0.704 respectively.

5.2.7 Interaction Plots of Order Interaction

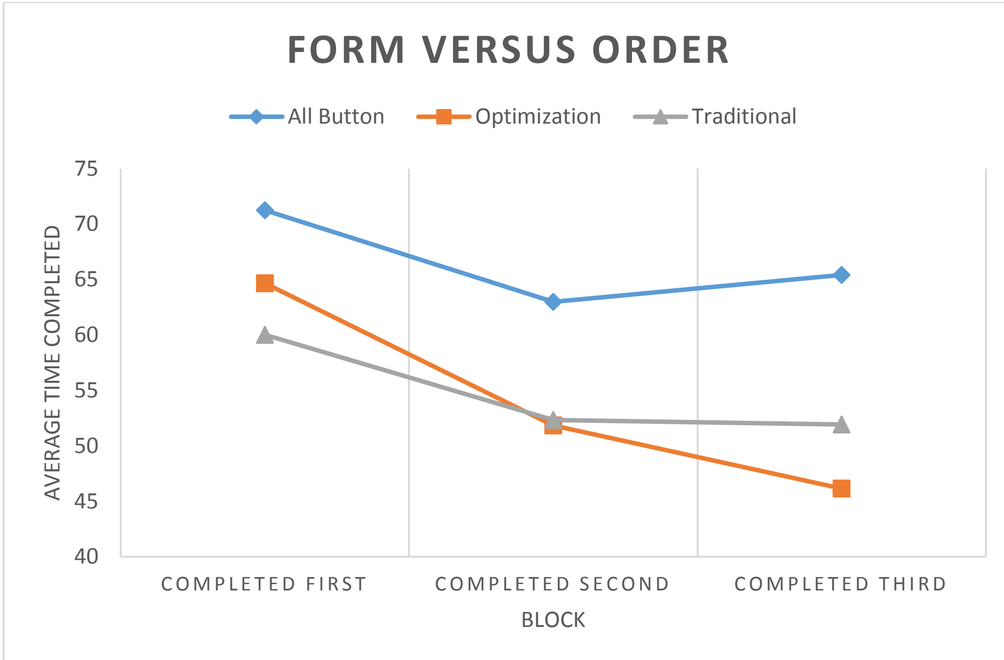


Figure 30 – Form Versus Order Time Score Interaction

As seen in the interaction plot Figure 30 – Form Versus Order Time Score Interaction the forms follow a parallel with a high completed first average and then drop for the second and third completed times. The Optimization form average completion time is reduced by a larger margin than the other two forms; however, the P-Value was 0.090 showing the interaction was not significant.

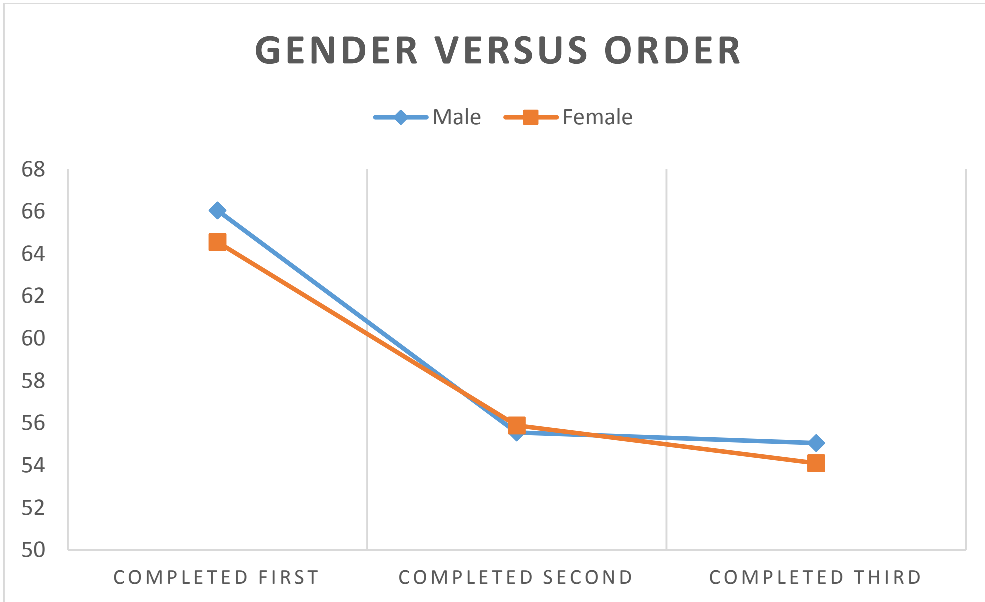


Figure 31 - Gender Versus Order Time Score Interaction

5.2.8 Tukey Tests

Table 10 - Tukey Test of Order

Form	N	Mean	Grouping
All Button	36	66.56	A
Traditional	36	54.75	B
Optimization	36	54.31	B

Order	N	Mean	Grouping
Completed 1st	36	65.31	A
Competed 2^{nd}	36	55.72	B
Completed 3^{rd}	36	54.58	B

Subjects did significantly worse on the first form they completed compared to their second and third form as evidenced in Table 10 - Tukey Test of Order. The second and third forms completed have similar completion times with averages of 55.72 and 54.58 respectively. The All Button form also completed significantly slower on average compared to the other two forms with an average that is 12 seconds slower.

5.3 Aesthetics Score Data

5.3.1 Descriptive Statistics of Aesthetics Scores

Table 11 - Descriptive Statistics for Aesthetics Scores

Descriptive Statistics: Completion Times	
N	108
Mean*	4.750
Standard Deviation*	1.686
Minimum*	1.000
Q1*	4.000
Median*	5.000
Q3*	6.000
Maximum*	7.000
Skewness	-0.71
Kurtosis	-0.33

*Units in seconds

The average score for the form is 4.750. The lowest rating that was given is 1 and the highest rating given is 7. The histogram of the scores given is in shown in Figure 32- Histogram of Aesthetics Scores. The Skewness is 0.71 negative skew and it is moderately skewed to the right. A negative Kurtotis 0.33 shows that the data is marginally flatter than normal data.

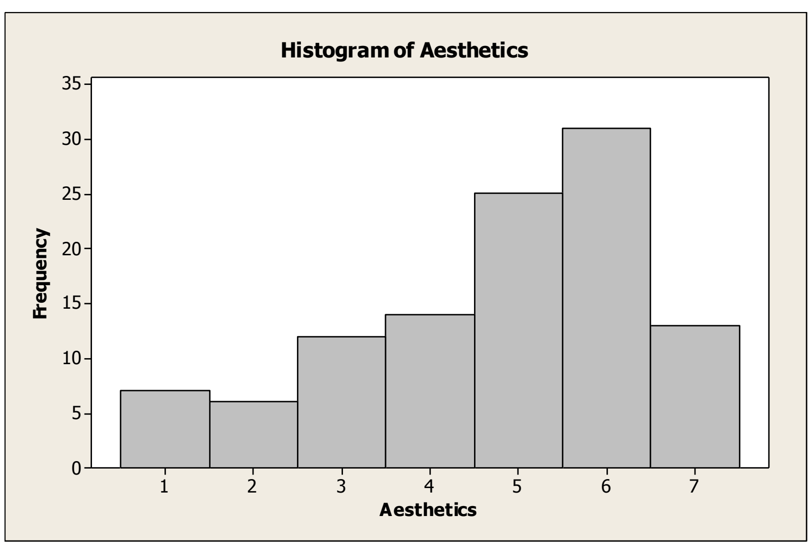


Figure 32- Histogram of Aesthetics Scores

5.3.2 Test of Normality for Aesthetics

The residuals was tested for normality to verify that ANOVA tests could be done. Ryan-Joiner test of normality was chosen because it avoids rejecting normality due to rounding. The residuals were tested for normality and has a P-Value of 0.077 shows that the data is normal.

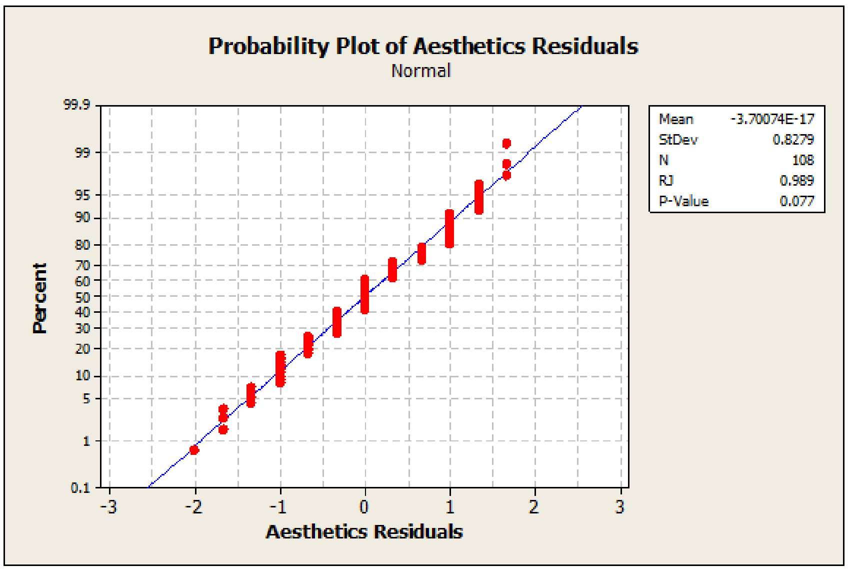


Figure 33 - Residual Normality of Aesthetics Score

5.3.3 ANOVA Table for Aesthetics Score

Table 12- ANOVA of Aesthetics Score

Source	DF	F Value	P Value
Gender	1	0.01	0.924
Form	2	98.51	0.000
Block	5	0.19	0.965
Gender*Form	2	2.22	0.116
Gender*Block	5	0.95	0.456

Form*Block	10	1.22	0.292
Gender*Form*Block	10	0.73	0.690

There is only one significant factor (Table 12- ANOVA of Aesthetics Score) based on an alpha of 0.05 and that is the type of Form used with a P-Value of 0.000. Gender is not a significant effect and neither is the Block with P-Values of 0.924 and 0.965 respectively. The interaction between Gender and Form is notable, but it is not a significant effect with a P-Value of 0.116. The other interactions (Gender*Block & Form*Block) are not significant with P-Values of 0.456 and 0.292. Lastly, the second-order interaction is not significant either with a P-Value of 0.690.

5.3.4 Interaction Plots of Aesthetics Score

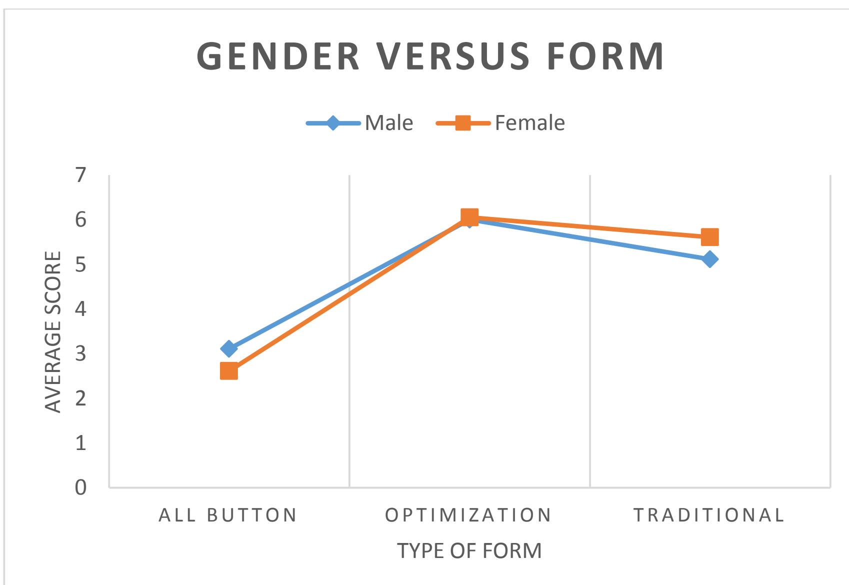


Figure 34- Gender Versus Form Aesthetics Score Interaction

The Gender and Form interaction plot (Figure 34- Gender Versus Form Aesthetics Score Interaction) has similar average scores for each data point by form. This shows there is not an interaction as evidenced by the P-Value of 0.116. It is notable that

Men's average scores were further away from the extreme values (1 or 7) than Women's average scores. The average score for the All Button form had a lower average compared to the Optimization Form and the Traditional Form.

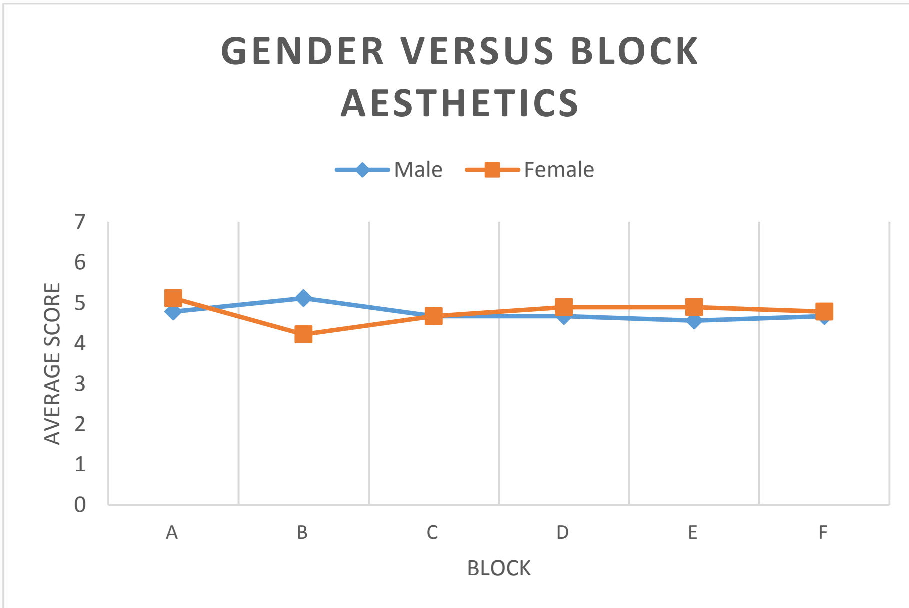


Figure 35 - Gender Versus Block Aesthetics Score Interaction

The Gender and Block interaction plot (Figure 35 - Gender Versus Block Aesthetics Score Interaction) has similar average scores for each data point by form. This shows there is not an interaction as evidenced by the P-Value of 0.456. It is notable that in Block B the average Male score increased and the average Female score decreased.

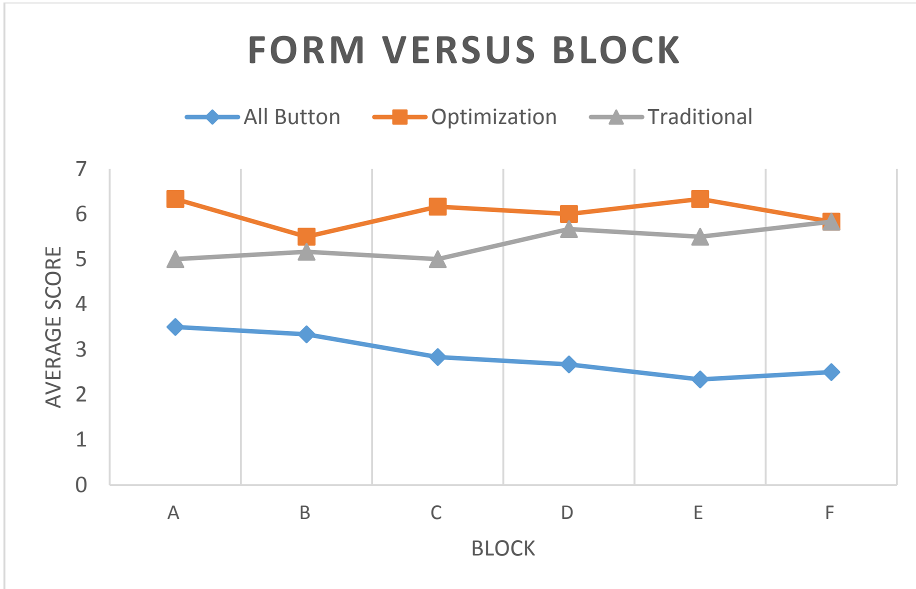


Figure 36 - Form Versus Block Aesthetics Score Interaction

The interaction between Form and Block is not significant in this experiment with a P-Value of 0.292. The average score for Aesthetics remained the highest in all blocks for the Optimization Model, followed by the Traditional form and then the All Button form. In Blocks where the Optimization and Traditional Buttons were done back to back (Block A, B, D, and F) the scores were closer in Blocks B, D, and F. The average score for the All Button form is the highest when it was the first form completed (Blocks A & B).

5.3.5 Tukey Results of Aesthetics Score

The type of Form used was the only significant effect discovered in the experiment. A Tukey Test was performed on the Aesthetics scores to see the differences in results. The results from the Tukey test showed that each of the forms are significantly different as seen below in Table 13 - Aesthetics Tukey Results. The form with the highest aesthetics average score was the Optimization Form with an average of 6.0278. Next was the Traditional Form with an average of 5.3611, about 0.7 lower than the Optimization Form. The All Button form had the lowest average about 2.8.

Table 13 - Aesthetics Tukey Results

Form	N	Mean	Grouping
Optimization	36	6.0278	A
Traditional	36	5.3611	B
All Button	36	2.8611	C

5.4 Usability Score Data

5.4.1 Descriptive Statistics of Usability Scores

Table 14 - Descriptive Statistics for Completion Times

Descriptive Statistics: Completion Times	
N	108
Mean*	4.944
Standard Deviation*	1.645
Minimum*	1
Q1*	4
Median*	5
Q3*	6
Maximum*	7
Skewness	-0.73
Kurtosis	0

*Units in seconds

The average score for Usability score is 4.944 (Table 14 - Descriptive Statistics for Completion Times), which is 0.3 points higher than the average for Aesthetics. The lowest and highest scores are 1 and 7, the min and max allowable score. The Skewness is negative 0.73 showing that the data is negatively skewed to right. The Kurtosis is 0 following a normal distribution.

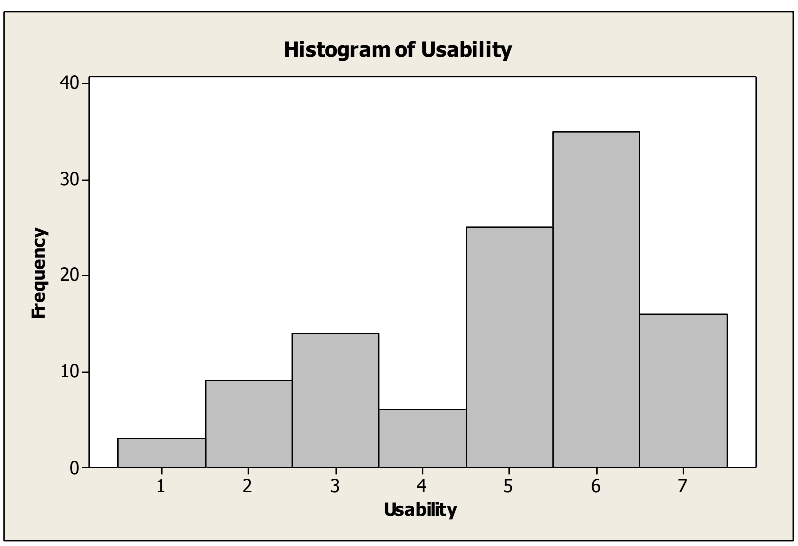


Figure 37- Histogram of Usability Scores

5.4.2 Test of Normality

The residuals was tested for normality to verify that ANOVA tests could be done. Ryan-Joiner test of normality was chosen because it avoids rejecting normality due to rounding. The residuals were tested for normality and have a P-Value of 0.040 which is under a P-Value of 0.05; however, there has been arguments against restricting ANOVA tests for Likert scales on normality results [17]. Thus, the ANOVA testing was done in order to keep similar comparisons to the Aesthetics and Satisfaction instead of using a non-parametric test, but there is an acknowledgement on the P-Value being 0.04.

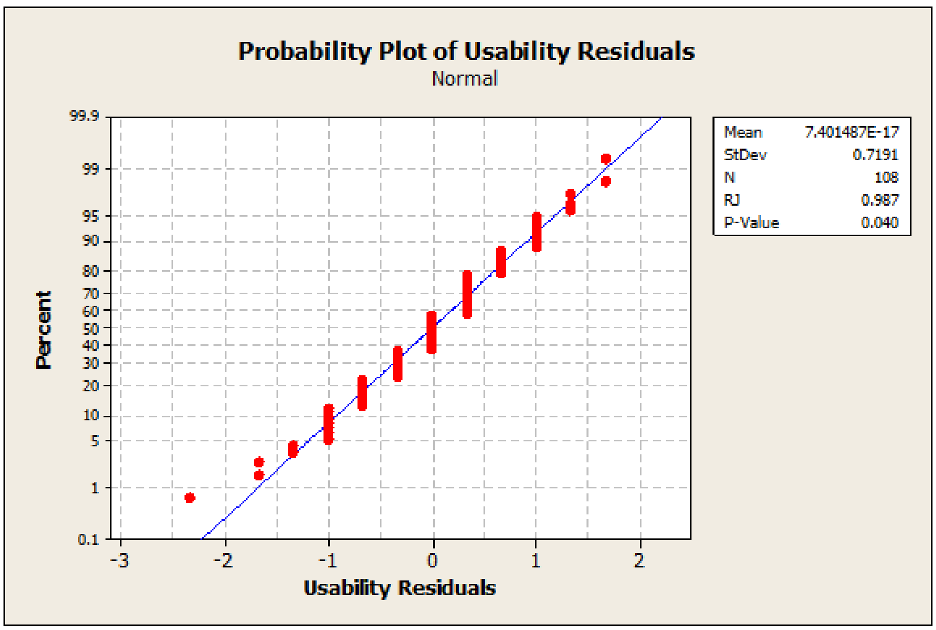


Figure 38 - Residual Normality of Usability Score

5.4.3 ANOVA Table for Usability Score

Table 15- ANOVA of Usability Score

Source	DF	F Value	P Value
Gender	1	2.36	0.129
Form	2	134.71	0.000
Block	5	0.46	0.803
Gender*Form	2	0.52	0.598
Gender*Block	5	1.12	0.359
Form*Block	10	1.50	0.159
Gender*Form*Block	10	0.92	0.517

There is only one significant factor based on an alpha of 0.05 and that is the type of Form used with a P-Value of 0.000 as seen in Table 15- ANOVA of Usability Score. Gender, while notable, is not a significant effect with a P-Value of 0.129. The Blocking is not significant with a high P-Values of 0.803. The interaction between Gender and Form is not significant effect with a P-Value of 0.598. The interaction between Form*Block is notable but is not significant with a P-Value of 0.159. Lastly, the second-order interaction is not significant either with a P-Value of 0.517.

5.4.4 Interaction Plots of Usability Score

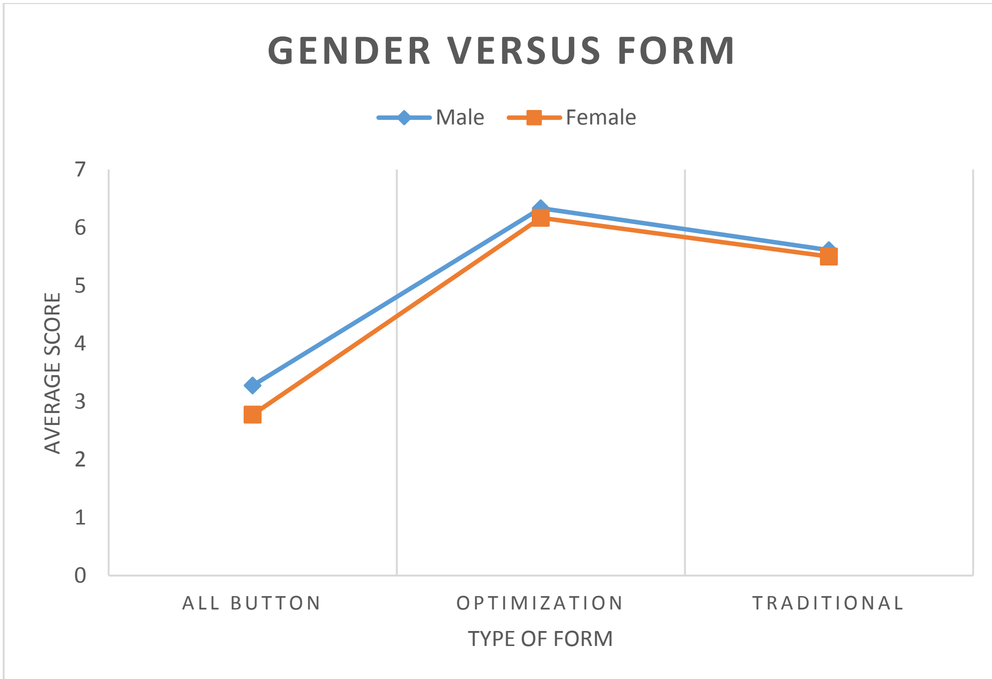


Figure 39 - Gender Versus Form Usability Score Interaction

The Gender and Form interaction plot (Figure 39 - Gender Versus Form Usability Score Interaction) has similar average scores for each data point by form. This shows there is not an interaction as evidenced by the P-Value of 0.598. Men and women followed the same parallel by increasing to the highest for the Optimization form and slightly lower for the Traditional form. It is notable that Men's average scores were further away from the extreme values (1 or 7) than Women's average scores similar to the Aesthetics Score.

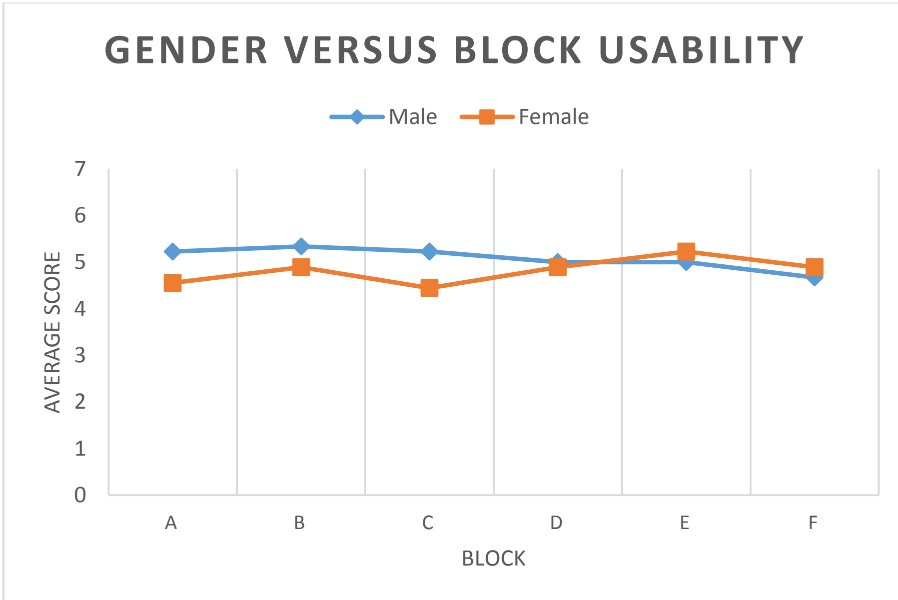


Figure 40 - Gender Versus Block Usability Score Interaction

The Gender and Block interaction plot (Figure 40 - Gender Versus Block Usability Score Interaction) has similar average scores for each data point by form. This shows there is not an interaction as evidenced by the P-Value of 0.359. It is notable that in Blocks where the Traditional Form was used first (Blocks E & F), women gave marginally higher average scores than men compared to the other blocks when female's scores were lower.

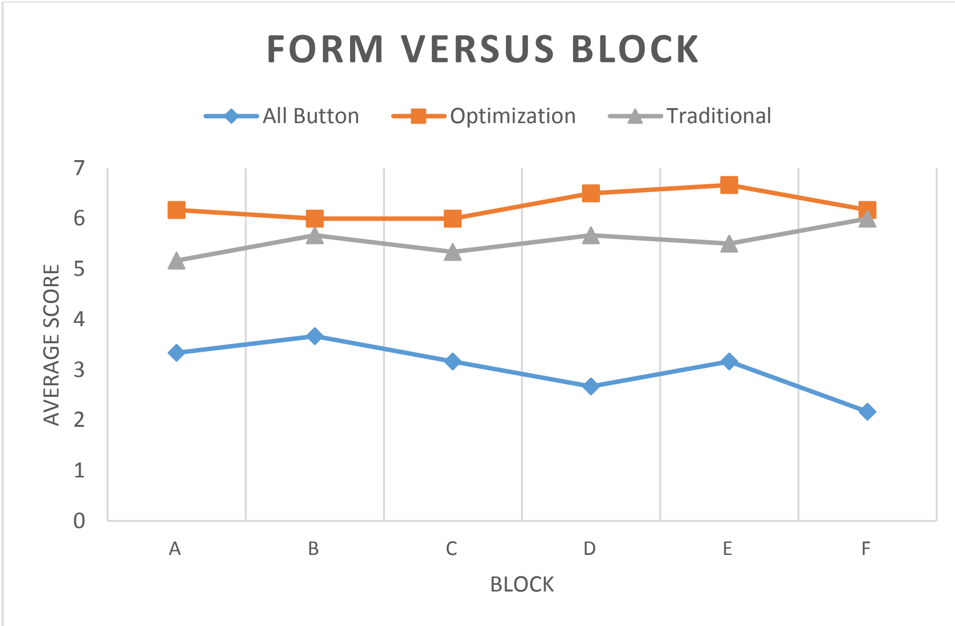


Figure 41 - Form Versus Block Usability Score Interaction

The interaction between Form and Block (Figure 41 - Form Versus Block Usability Score Interaction) is not significant in this experiment with a P-Value of 0.159, but it is notable. The average score for Usability remained the highest in all blocks for the Optimization Model, followed by the Traditional form and then the All Button form. In Blocks where the Optimization and Traditional Buttons were done back to back (Block A, B, D, and F) the scores are closer in Blocks B and F, but not Blocks A and D. In Blocks where the All Button form went last (Blocks D and F) the average score is lower compared to going second (Blocks C and E). This same phenomena exists for the Traditional model, but not the Optimization model.

5.4.5 Tukey Results of Usability Score

The type of Form used was the only significant effect discovered for the usability score. The results from the Tukey test showed that each of the forms are significantly different as seen below in Table 16 - Usability Tukey Results. The form with the highest usability average score was the Optimization Form with an average of 6.25. Next was the Traditional Form with an average of 5.556, about 0.7 lower than the Optimization Form. The All Button form had the lowest average about 3. The scores for each form were about 0.2 higher than the Aesthetic scores.

Table 16 - Usability Tukey Results

Form	N	Mean	Grouping
Optimization	36	6.25	A
Traditional	36	5.556	B
All Button	36	3.0278	C

5.5 Satisfaction Score Data

5.5.1 Descriptive Statistics of Satisfaction Times

Table 17 - Descriptive Statistics for Completion Times

Descriptive Statistics: Completion Times	
N	108
Mean*	4.852
Standard Deviation*	1.828
Minimum*	1.000
Q1*	3.250
Median*	5.000
Q3*	6.000
Maximum*	7.000
Skewness	-0.68
Kurtosis	-0.61

*Units in seconds

The average score is 4.852 for the subjects' satisfaction of the forms (Table 17 - Descriptive Statistics for Completion Times). The highest and lowest scores given also correspond to the highest and lowest possible scores to give on the survey. The average score is also higher than the Aesthetics average, but lower than the Usability average. The

Skewness is negative 0.68 showing the data is negatively skewed to the right. The kurtosis is -0.61 showing that the data is flatter as evidence in the histogram (Figure 42 - Histogram of Satisfaction Scores).

Figure 42 - Histogram of Satisfaction Scores

5.5.2 Test of Normality

The residuals was tested for normality to verify that ANOVA tests could be done. Ryan-Joiner test of normality was chosen because it avoids rejecting normality due to rounding. The residuals were tested for normality and has a P-Value of 0.082 shows that the data is normal.

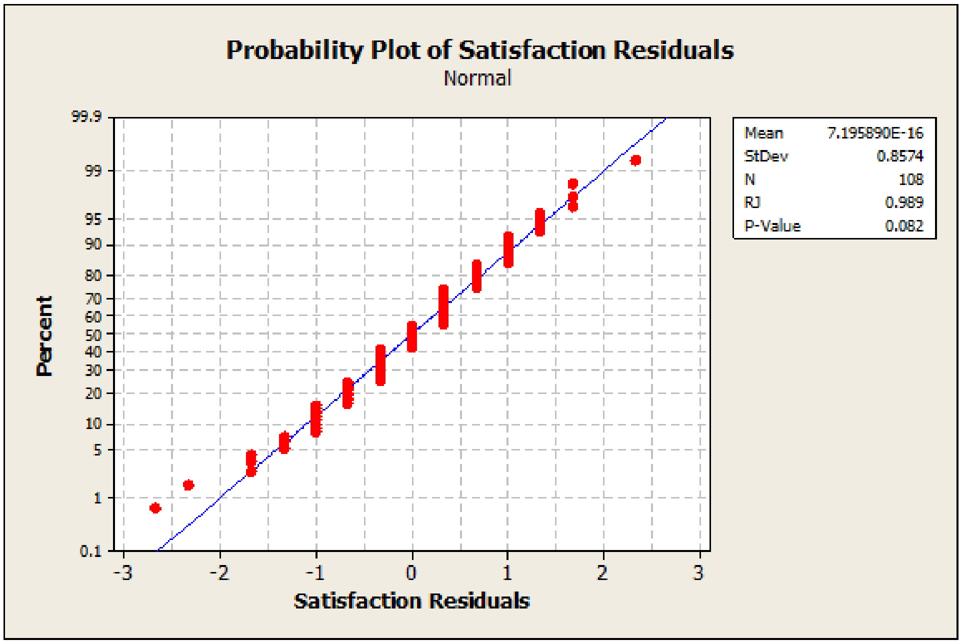


Figure 43 - Residual Normality of Satisfaction Score

5.5.3 ANOVA Table for Satisfaction Score

Table 18- ANOVA of Usability Score

Source	DF	F Value	P Value
Gender	1	0.03	0.854
Form	2	113.14	0.000
Block	5	0.60	0.697
Gender*Form	2	0.26	0.770
Gender*Block	5	1.03	0.406
Form*Block	10	1.53	0.145
Gender*Form*Block	10	0.50	0.887

There is only one significant factor based on an alpha of 0.05 and that is the type of Form used with a P-Value of 0.000. Gender, is not a significant effect with a P-Value of 0.854. The Blocking is not significant with a high P-Values of 0.697. The interaction is not significant for Gender*Form nor Gender*Block with P-values of 0.770 and 0.406 respectively. The interaction, between Form*Block is notable, but is not significant with a P-Value of 0.145. Lastly, the second-order interaction is not significant either with a P-Value of 0.887.

5.5.4 Interaction Plots of Satisfaction Score

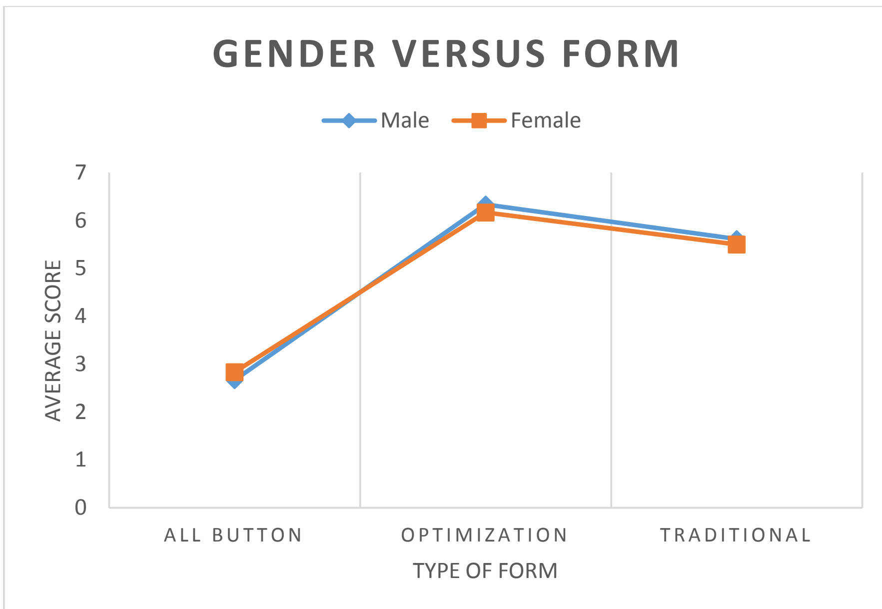


Figure 44 - Gender Versus Form Satisfaction Score Interaction

The Gender and Form interaction plot (Figure 44 - Gender Versus Form Satisfaction Score Interaction) has similar average scores for each data point by form. This shows there is not an interaction as evidenced by the P-Value of 0.770. The scores follow the same parallel for both me and women. The scores increase in satisfaction for the Optimization form and decrease slightly for the Traditional form. Women and Men both have the lowest satisfaction score for the All Button form.

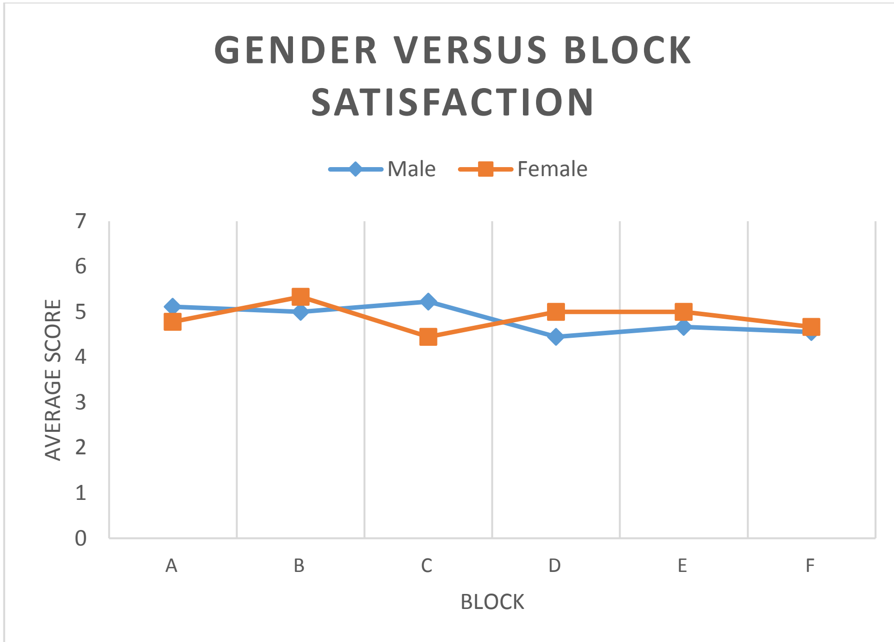


Figure 45 - Gender Versus Block Satisfaction Score Interaction

The Gender and Block interaction plot (Figure 45 - Gender Versus Block Satisfaction Score Interaction) has similar average scores for each data point by form. This shows there is not an interaction as evidenced by the P-Value of 0.406. Male and Female are scores slightly different throughout the experiment, but the largest gap was during Block C. In Block C, the Optimization form was first and women's' average scores went down, while men had their highest scores.

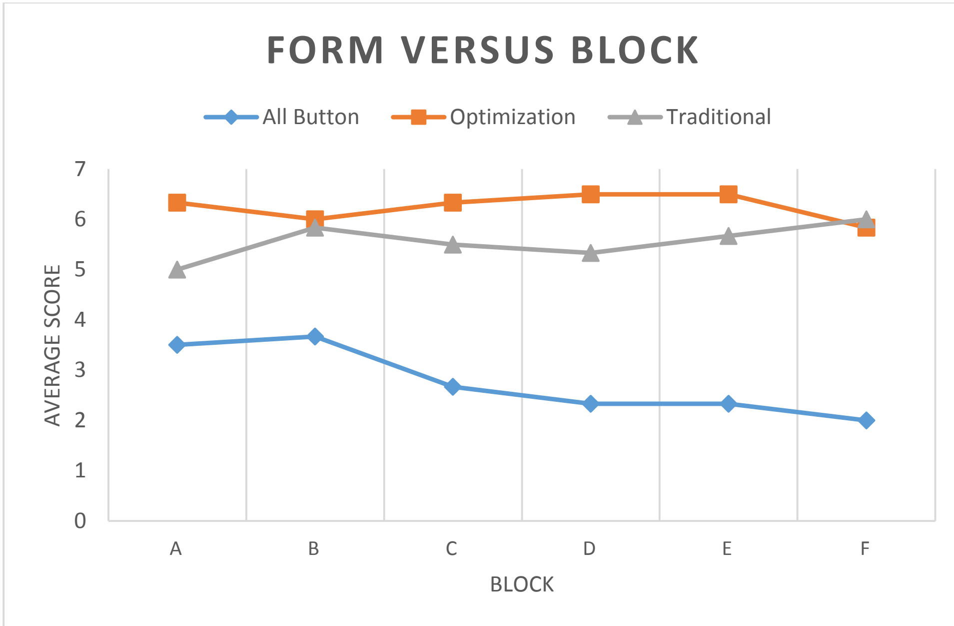


Figure 46 - Form Versus Block Satisfaction Score Interaction

The interaction between Form and Block (Figure 46 - Form Versus Block Satisfaction Score Interaction) is not significant in this experiment with a P-Value of 0.145. The average score for satisfaction remained the highest in all blocks for the Optimization Model except in Block F where Traditional scored marginally higher. The average satisfaction score for the All Button form is higher on Blocks that it was first (Blocks A and B). The Optimization form had lower average scores when it went last (Block B and F).

5.5.5 Tukey Results of Aesthetics Score

The type of form used was the only significant effect discovered for the satisfaction score. The results from the Tukey test showed that each of the forms are significantly different as seen below in Table 19 - Satisfaction Tukey Results. The form with the highest satisfaction average score is the Optimization Form with an average of 6.25. Next, is the Traditional form with an average of 5.556, about 0.7 lower than the

Optimization Research form. The All Button form has the lowest average about 3. The scores are the same as the usability averages; however, the All Button form has a lower average.

Table 19 - Satisfaction Tukey Results

Form	N	Mean	Grouping
Optimization	36	6.25	A
Traditional	36	5.556	B
All Button	36	2.750	C

CHAPTER 6: DISCUSSION

6.1 Time Score Discussion

In order to cut back on the learning effect in this experiment a practice form was created in order to teach the subjects how to use the interface on a tablet. The subjects were also given every possible block combination so that the bias of the results would be reduced. Even with these safe guards in place the interaction between blocking and form has a significant effect on the experiment with a P-Value of 0.000. Every form in the experiment performs the slowest in blocks where the form is set to appear first; however, every form does not have the fastest average time when completed last (See Figure 28- Form Versus Block Time Score Interaction). This is further shown in the second ANOVA model that was created that looked at the order instead of the block of the forms. The Tukey test is not able to demonstrate a significant difference in time when a form was completed second or third, but only when a form was completed first. This same Tukey test also demonstrates that the Optimization and the Traditional form had a significantly faster average time than the All Button form (See Table 10 - Tukey Test of Order).

Despite having a slower average time for the All Button form, the user had to click on the screen less times compared to the other forms. In order to complete the required tasks the All Button form required only 26 clicks, while the other two forms required 33 clicks (26% increase in clicks.) Since the All Button form required less clicks the reasons for the slower times had to be from other criteria. The All Button form has 17 buttons, the Traditional form has 8 buttons, and the Optimization form has 6 buttons on the home screen. Many users verbally expressed their discomfort on the All Button form by making comments that there were so many buttons on the screen and that it was too confusing. This could play into the prior research about Miller's Law and information limits. The Optimization and Traditional form fall within the seven plus or minus two limit while the All Button form is well outside this limit. Many subjects spent a large amount of time scanning the interface screen in order to complete the tasks. Since there was a large amount of buttons on the All Button screen it is possible that they were not able to focus as well as the other forms since they were not able to store all the buttons in their short term memory. Having the larger buttons on the Optimization form on the top did not give a significant time difference compared to the Traditional form as evidence by the Tukey tests.

Gender did not play a significant role on the average completion time with a P-Value of 0.641. The interactions of Gender with Form or Block did not have a significant effect on the completion times either. Lastly, the second order interaction did not have a significant effect on completion times either.

Ultimately, because there is an interaction with blocking and form a definitive conclusion cannot be drawn about which form allows users to complete tasks fastest. If only the order of the form is taken into account, then the All Button form performed slower on average than the other two forms which could be due to the memory limit on people's short terms memory.

6.2 Aesthetic Discussion

The only factor that had an impact on the Aesthetics score according to the ANOVA test was the type of form used with a P-Value of 0.000. Gender and Block did not have a significant effect on the aesthetic scores P-Values of 0.924 and 0.965

respectively. The interactions do not have an effect on the ratings either. According to the Tukey tests each form was statistically different effect on the Aesthetic score. The Optimization form has the highest average score, 6.028 which corresponds to “Very Good” according to the Likert Scale chosen for the experiment. The Traditional form has an average score of 5.361 which corresponds to “Good” on the Likert Scale. Lastly, the All Button form had an average of 2.861, which rounds up to “Bad”.

The Optimization form was made to create symmetry and balance for the user so that the user can easily process the buttons on the screen; however, there is less symmetry than the Traditional form. The Optimization form had two large buttons on the top of the form, though symmetrical vertically, it was not symmetrical horizontally like the Traditional form. This may show that having 100% symmetry is not the only important feature of an aesthetic menu driven interface, but can just be one factor. The Optimization form had large easy to access buttons for components that people mostly used an ATM form. They could have subconsciously chosen this form as the most aesthetic because it was easy for them to focus on when doing a transaction involving withdrawing cash or depositing money. Most users verbally responded that they liked the visual look of the Optimization form because it was easy to read.

6.3 Usability Discussion

Same as the aesthetics, the type of form is the only factor that has a statistically significant impact on the rating score with a P-Value of 0.000. Gender and Block did not have a statistically significant effect on the usability score with P-Values of 0.129 and 0.803 respectively. The interactions and the second-level interaction also had no effect on the ratings score. The Tukey test performed shows that each form is statistically different for the usability score. The Optimization form scored the highest with a score of 6.250, which was “Very Good”. The Traditional Form has an average of 5.556 which is in between “Good” and “Very Good”. Lastly, the All Button form is 3.028 which scored a “Bad”.

According to the ratings given, people consider a form that is easier to understand as a very usable form. This is in contrast to a form that has all the options in front of the user so that the user does not need to go through deeper menus to accomplish tasks. This is an important distinction for people designing a touchscreen driven menu interface. Users will want to work on a form that is easy to digest, rather than have complete control at the start of the screen.

6.4 Satisfaction Discussion

The type of form used was the only factor that has a significant impact on the rating score of satisfaction with a P-Value of 0.000. The Gender and Block do not have a significant impact on the satisfaction score with P-Value 0.854 and 0.697 respectively. The interactions and second order interaction did not have an effect either. According to the Tukey test every form has a statistically different satisfaction score. The Optimization form has the highest average satisfaction score of 6.250, which is “Very Good”. The Traditional form has an average of 5.556 which is in between “Good” and “Very Good”. Lastly, the All Button form has an average of 2.750 which corresponds to “Bad”.

The Optimization form satisfaction mirrors the results for the aesthetics and usability scores. This could be because people are more likely to give the same scores for each factors when they are rating a form. If a user feels that a form is aesthetic and usable they are more likely to be satisfied with the forms that they used.

Another argument could be made that All Button form has the lowest satisfaction scores because the subjects completed this form the slowest on average. They may not be satisfied with a form that confuses them and takes them a long time to complete.

CHAPTER 7: CONCLUSION & FUTURE WORK

7.1 Conclusion

As tablets continue to grow in popularity there will be an importance in designing interfaces that are simple for users to use, but allows them to complete all the tasks that are needed. There are different ways to design interfaces based on many different types of criteria. An optimization approach to designing a menu based system on tablets can be a useful tool for companies and developers to use so that a good human computer interaction can be achieved.

There is an interaction between blocking and the form used for how long it takes to complete a form in this experiment. Because of this a definitive conclusion cannot be drawn from the data achieved in this experiment on how fast a task can be completed; however, the three ratings criteria proved to have significant effects. The Optimization form scored the highest for aesthetics, usability, and satisfaction. This shows that by designing an interface where the most used options with a larger "weight" and button size users may appreciate and want to use something like this.

The experiment also showed that putting every option on a menu based system at the front of a tablet screen can confuse users and make them more frustrated while using a program. This can serve as a tool for programmers that they need to make sure that having all the options directly in front of a user does not make work more efficient since they need to scan and glance at all the buttons.

7.2 Future Work

In order to determine what type of form allows users to complete tasks the fastest another experiment could be done in order to reduce the effect of blocking. A way to do this would be to allow users to complete each form twice and only use the times from the final run. This way they will have a chance to learn how to use the programs and there will be less of a learning effect as there was in this experiment

There are also other criteria in GUI design that can be analyzed that was not looked at in this experiment. Some of these factors include color, sound, and order of the buttons on a GUI layout. This can help narrow down the scope of what creates a good GUI and all these things can be included in an optimization model. For example, there has been studies shown that people read websites in an “F” shape [16]. This means that people read from top-left to top-right and then move slightly downward and read from left to right and then continue straight down from the left side. This can be important to give preference towards buttons being placed on these parts of the “F” and different areas of the F can be served by different values. More factors to examine are the subjects themselves. This experiment only looked at students who were not computer science majors and were between the ages of 18-26. The results may be different from people who are outside this age range.

More things to consider are different fields of work to do this testing, like on a factory floor and workers using it. This way it can be seen if memory limits are impacted when users are dedicated to tasks that require multitasking. Other experiments could include ordering food from a menu based tablet system since that has been on the rising in the past years and research has shown that people are willing to spend more money on an easier to use interface [29].

Lastly, while this paper did not account for every factor in GUI design on tablets, it can give a stepping stone in developing optimization systems to design menu based systems in the fast growing field of tablets.

References

1. Agah, A. , & Tanie, K. (2000). Intelligent graphical user interface design utilizing multiple fuzzy agents. *Interacting with Computers*, *12*(5), 529-542.

2. Chacos, Brad. "Windows UI designer explains why forcing Metro on all is great for power users." *PCWorld*. N.p., 18 Feb. 2014. Web. 28 Feb. 2014.

3. Cypress, Semiconductor, Corporation. (2013). U.S Patent Office Patent 6971004. San Jose, CA. Retrieved from Google Patents.

4. Do tablets have a future in business?. (2013). *Information Management Journal*, *47*(4), 6

5. Duffy, B. (2003). Response order effects - how do people read?. *International Journal of Market Research*, *45*(4), 457-466

6. Griffey, J. (2012). The rise of the tablet. *Library Technology Reports*, *48*(3), 7-13.

7. Frank, A. , Saverino, V. , Glowacki, J. , & Virrilli, J. (2007). Gui guidance. *Residential Systems*, *8*(4), 30.

8. Feature: Graphical user interfaces. (1993). *Computing Canada*, 19(6), 29.

9. Jansen, B. (1998). The graphical user interface. *ACM SIGCHI Bulletin*, *30*(2), 22-26.

10. Jared, Newman. "Ex-Microsoft Employee Launches 'Fixing Windows 8' Campaign." *PCWorld*. N.p., 14 Mar. 2012. Web. 28 Feb. 2014.

11. Hartley, J. (2014). Some thoughts on likert-type scales. *International Journal of Clinical and Health Psychology*, *14*(1), 83-86.

12. Kostaras, N. , & Xenos, M. (2011). A study on how usability flaws in gui design increase mouse movements and consequently may affect users' health. *Behaviour & Information Technology, 30*(3), 425-436.

13. Lamont, L., & Crawford, C. (2012). Touchscreen computer interfaces: Electronics. *Handbook of Visual Display Technology*, 997-1008.

14. Manson, N J. "Is Operations Research Really Research?." *ORiON*, 22.2 (2006): 155.

15. Miller, G. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81-97.

16. Nielsen, Jakob . "Nielsen Norman Group." *F-Shaped Pattern For Reading Web Content.* N.p., 17 Apr. 2006. Web. 22 Apr. 2014.

17. Norman, G. (2010). Likert scales, levels of measurement and thse "laws" of statistics. *Advances in Health Sciences Education : Theory and Practice*, *15*(5), 625-632.

18. Osborne, H. (1986). Symmetry as an aesthetic factor. *Computers and Mathematics with Applications*, *12*(1), 77-82.

19. Rhodes, G. , Proffitt, F. , Grady, J. , & Sumich, A. (1998). Facial symmetry and the perception of beauty. *Psychonomic Bulletin & Review*, *5*(4), 659-669.

20. Raymond, Eric, and Rob Landley. "The first GUIs." *The first GUIs*. N.p., n.d. Web. 28 Feb. 2014.

21. Research in Motion Limited. (2013). U.S Patent and Trademark Office U.S Patent Application No. 20130093764, Unpublished (filing date Oct. 12, 2012) Waterloo, CA. Retrieved from Google Patents

22. Schneider, T. (1994). Tips for designing graphical interfaces. *Manufacturing Systems*, *12*(4), 21.

23. Sieberg, Daniel. "Comdex: Gates foresees 'digital decade'." *CNN*. Cable News Network, 12 Nov 2001. Web. 17 Feb. 2014.

24. "Tablets to make up 50% of PC market in 2014." Canalys. N.p., 26 Nov. 2013. Web. 4 Apr. 2014.

25. Tractinsky, N. (1997). Aesthetics and apparent usability: Empirically assessing cultural and methodological issues. *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems*, 115-122.

26. Tractinsky, N. , Katz, A. , & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers*, *13*(2), 127-145.

27. Tufte, E. , & Schmieg, G. (1985). The visual display of quantitative information. *American Journal of Physics*, *53*(11), 1117.

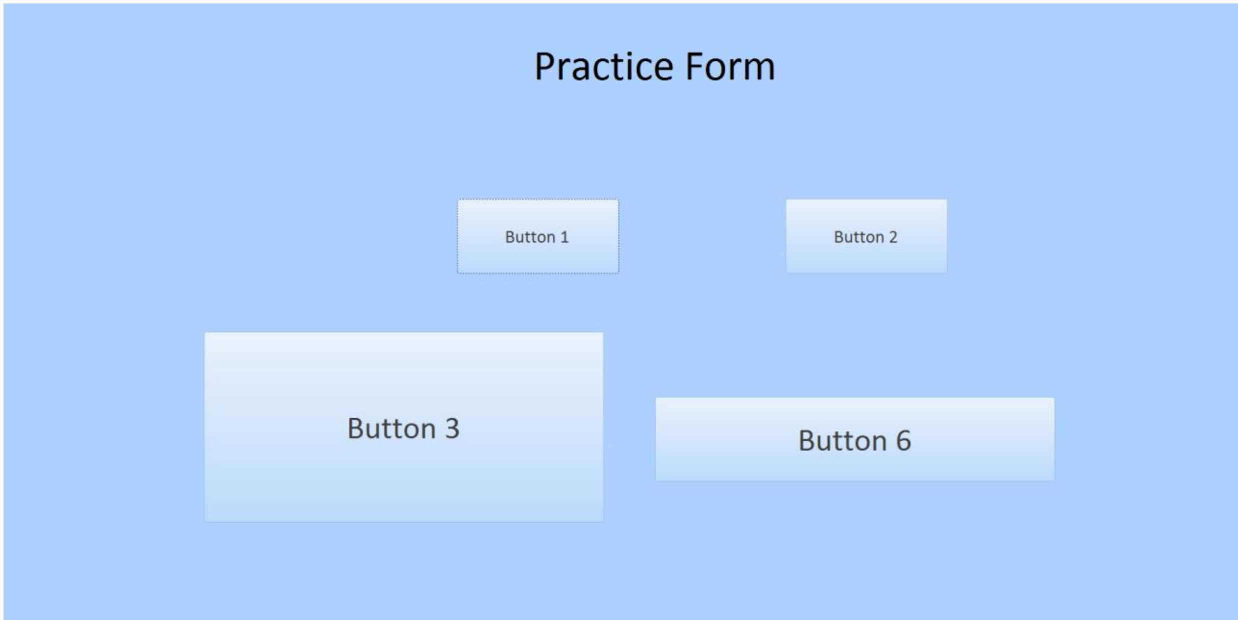
28. "What is Operations Research?." *INFORMS*. N.p., n.d. Web. 11 Apr. 2014.

29. Wong, Venessa. "That Tablet on the Restaurant Table Will Make You Spend More." *Bloomberg Business Week*. Bloomberg, 17 Sept. 2013. Web. 3 Apr. 2014.

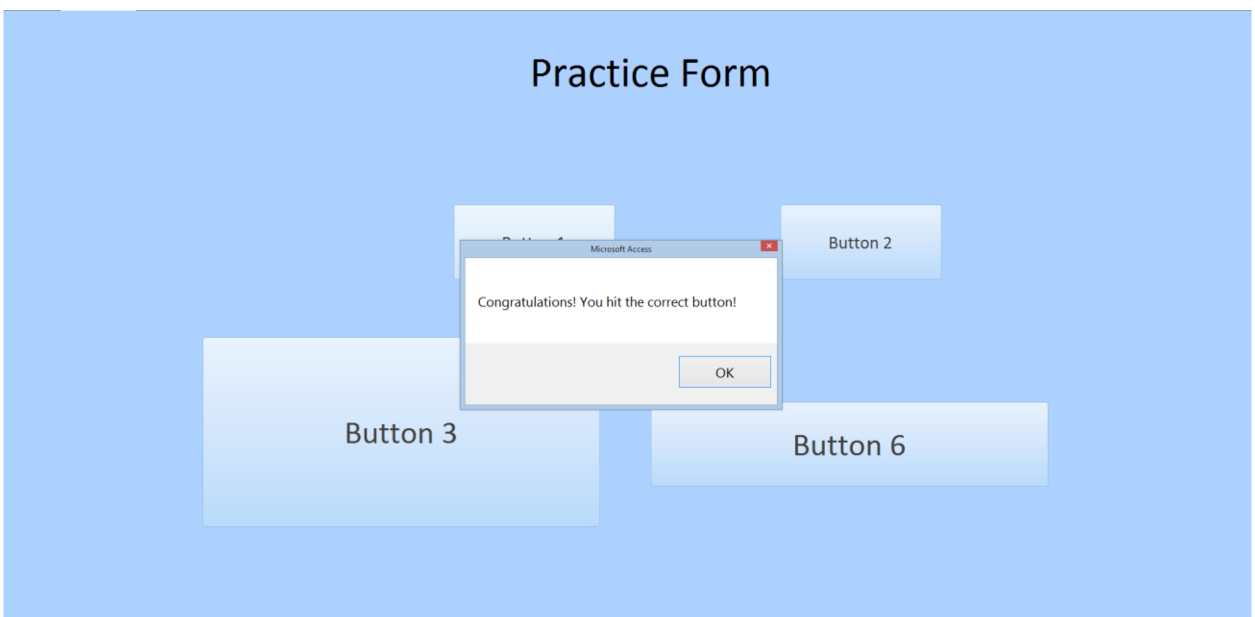
30. Yang, Y. , & Klemmer, S. (2009). Aesthetics matter: Leveraging design heuristics to synthesize visually satisfying handheld interfaces. *CHI '09 Extended Abstracts on Human Factors in Computing Systems*, 4183-4188.

Appendix A: Images of ATM System

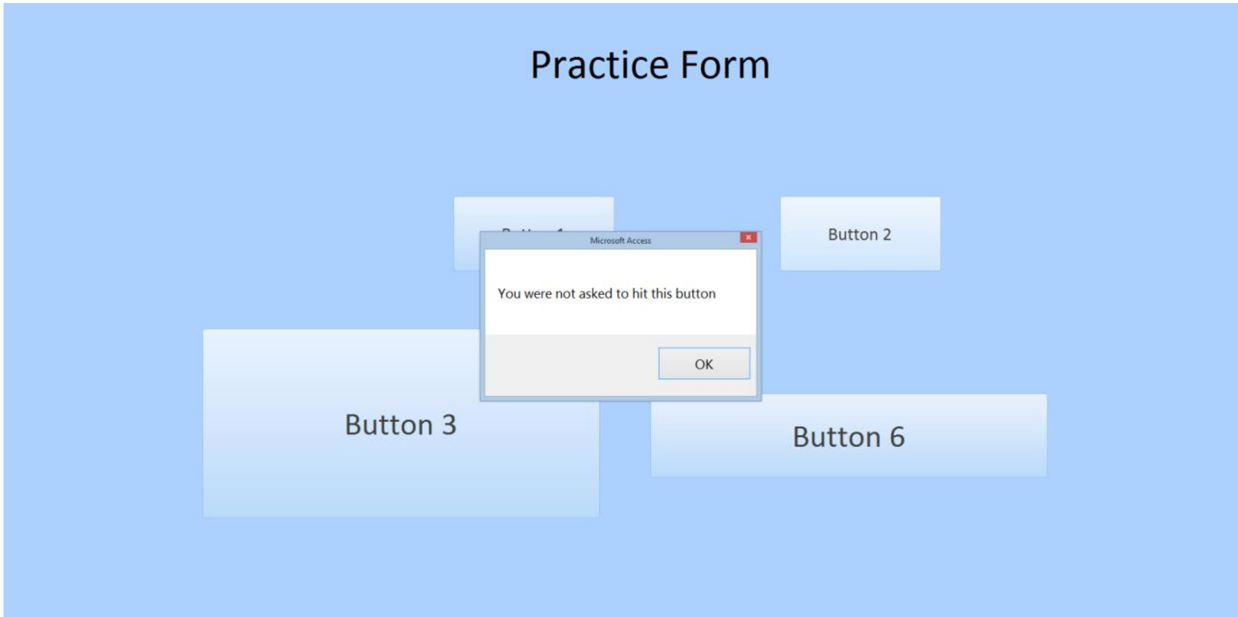
Practice Form



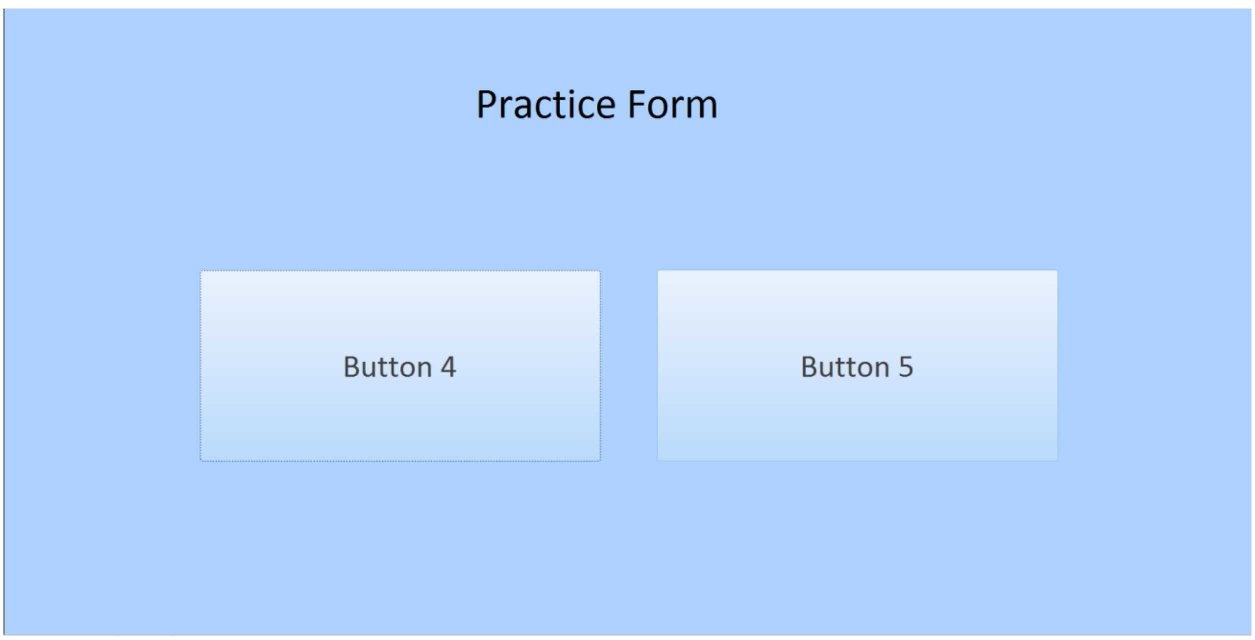
First Practice Form Page



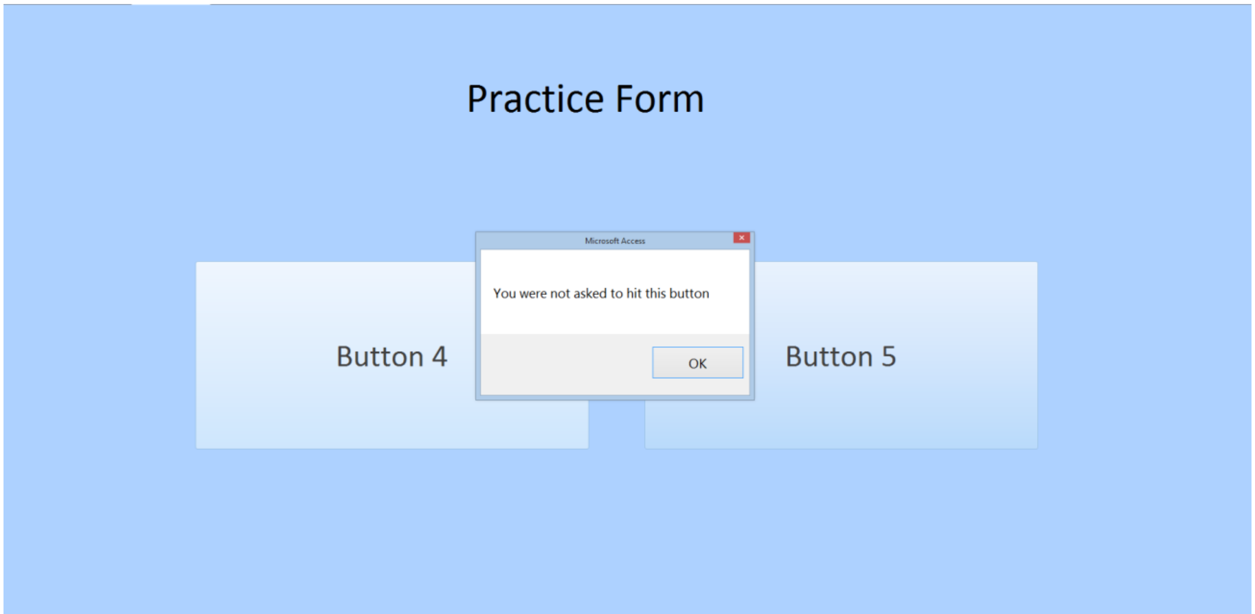
Clicking Button 1



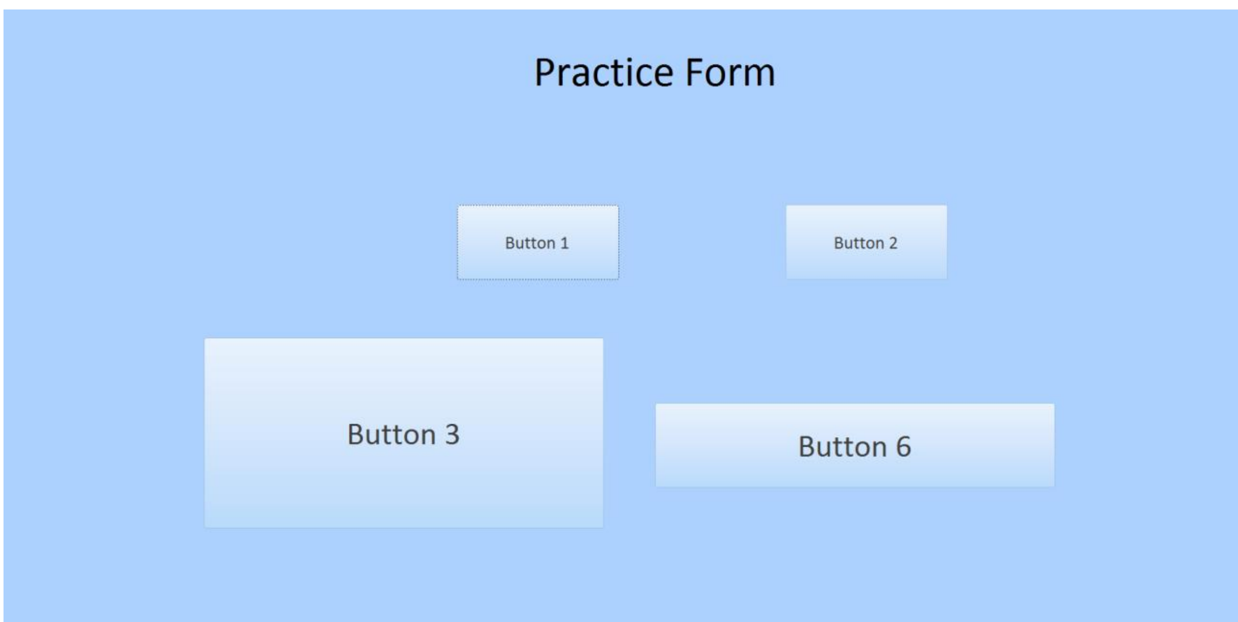
Clicking Button 2



After Clicking Button 3

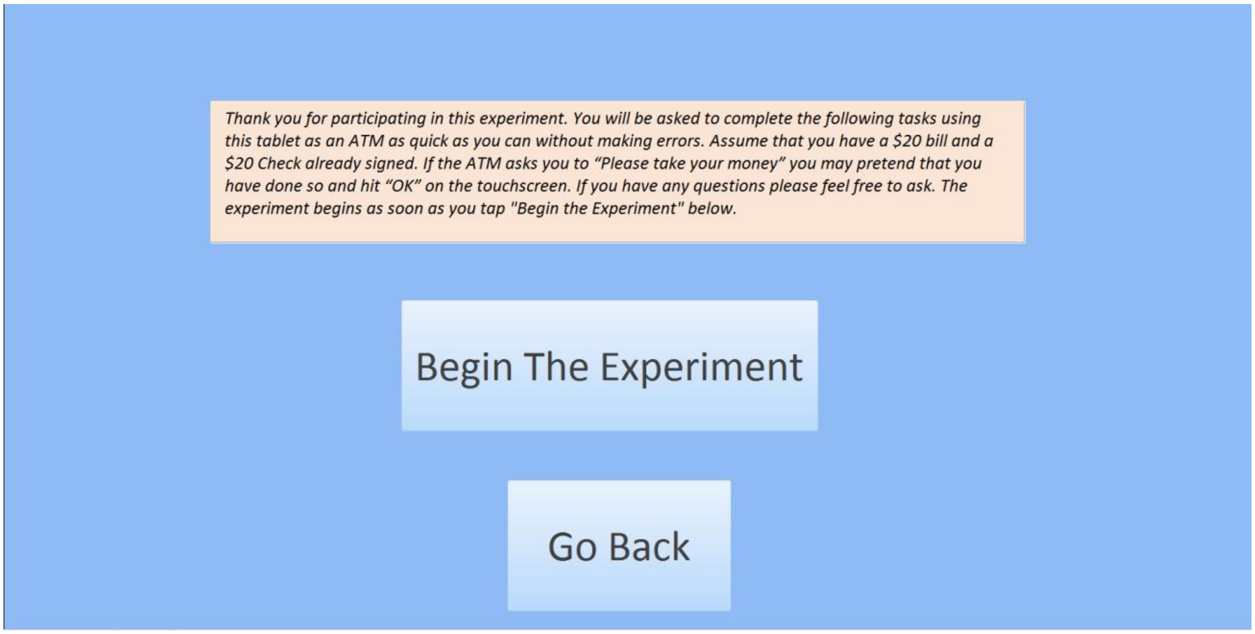


After Clicking Button 4



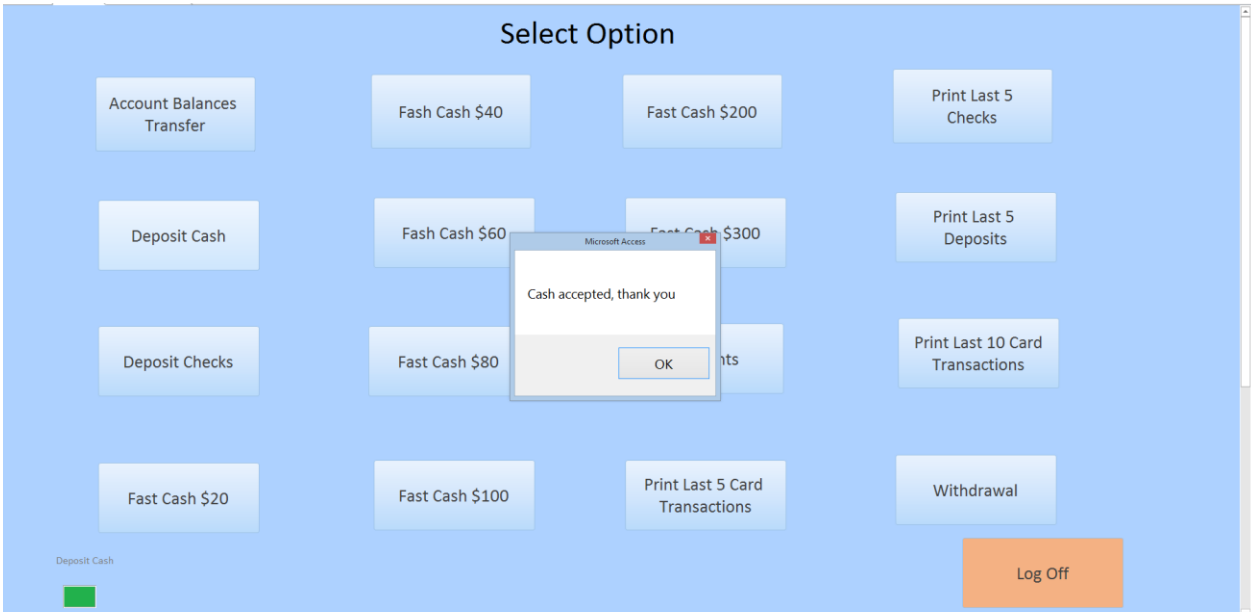
After Clicking Button 5

All Button Form

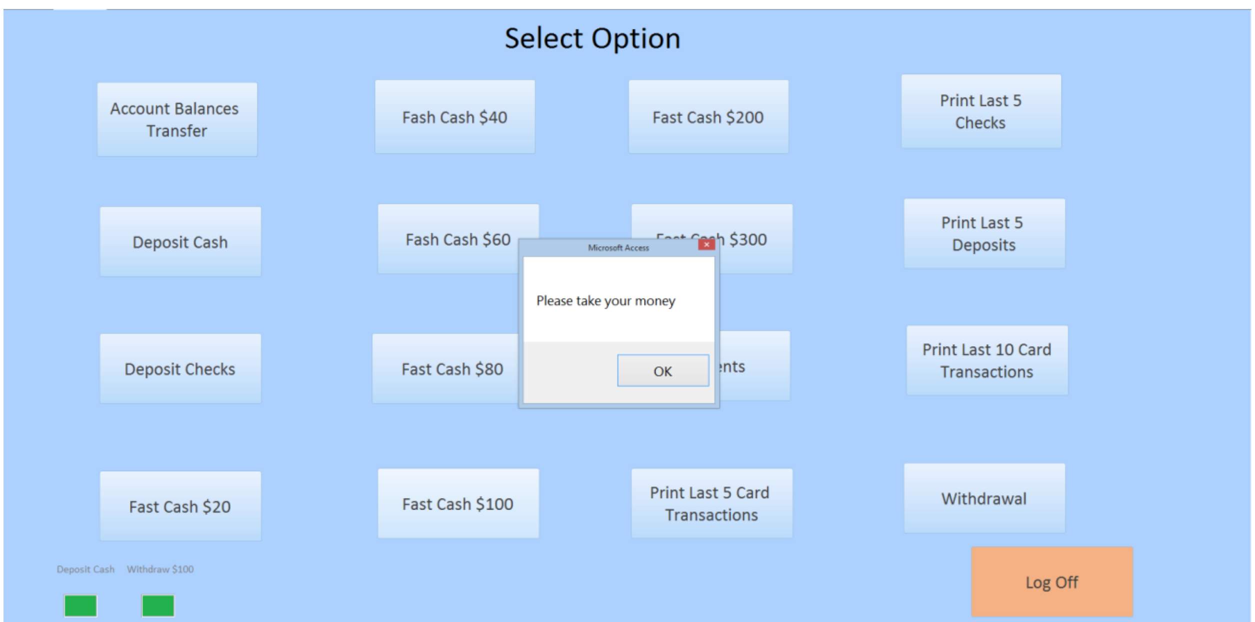


Instructions Before All Buttons Form

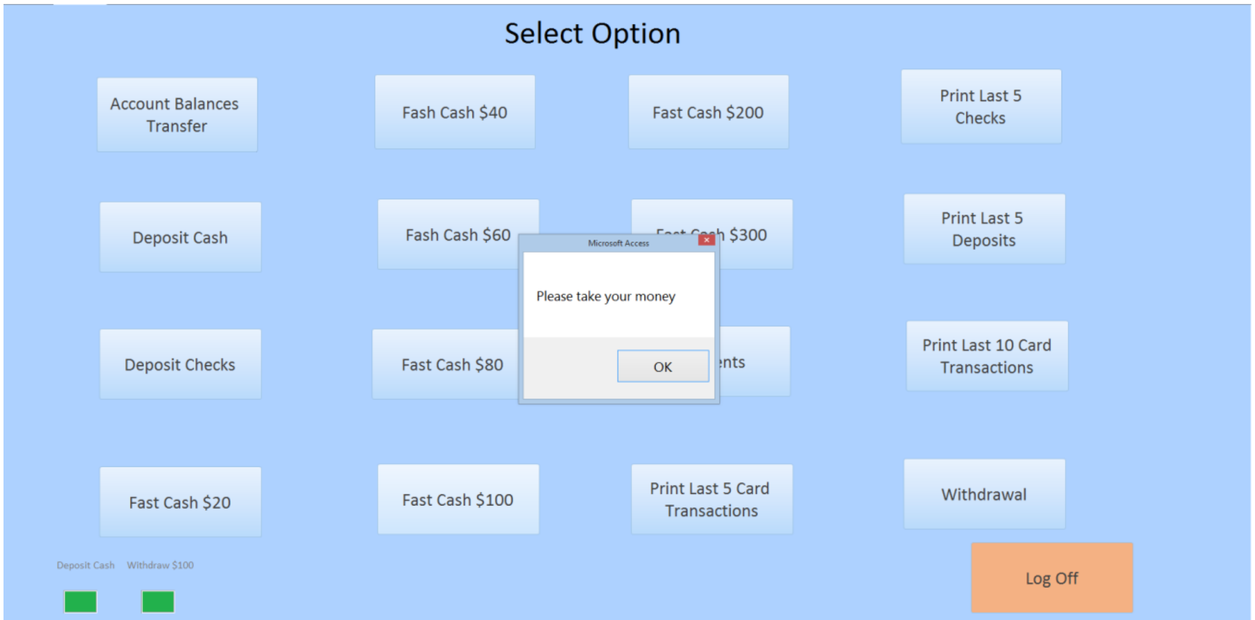
Front of All Buttons Form



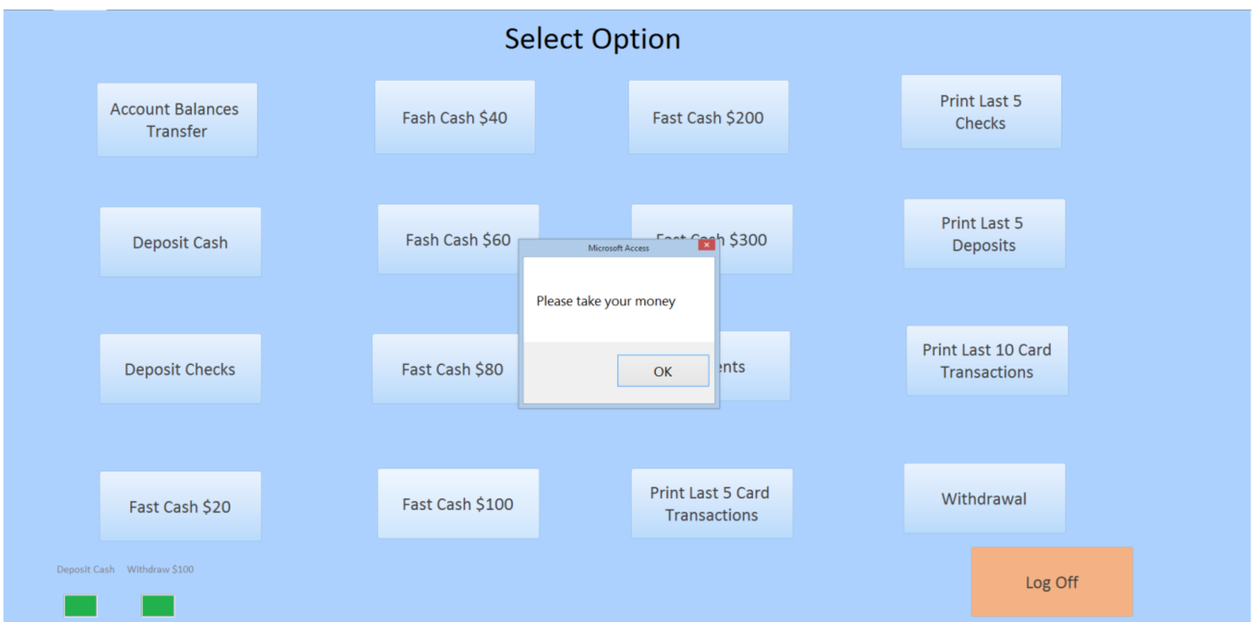
Deposit Cash Button



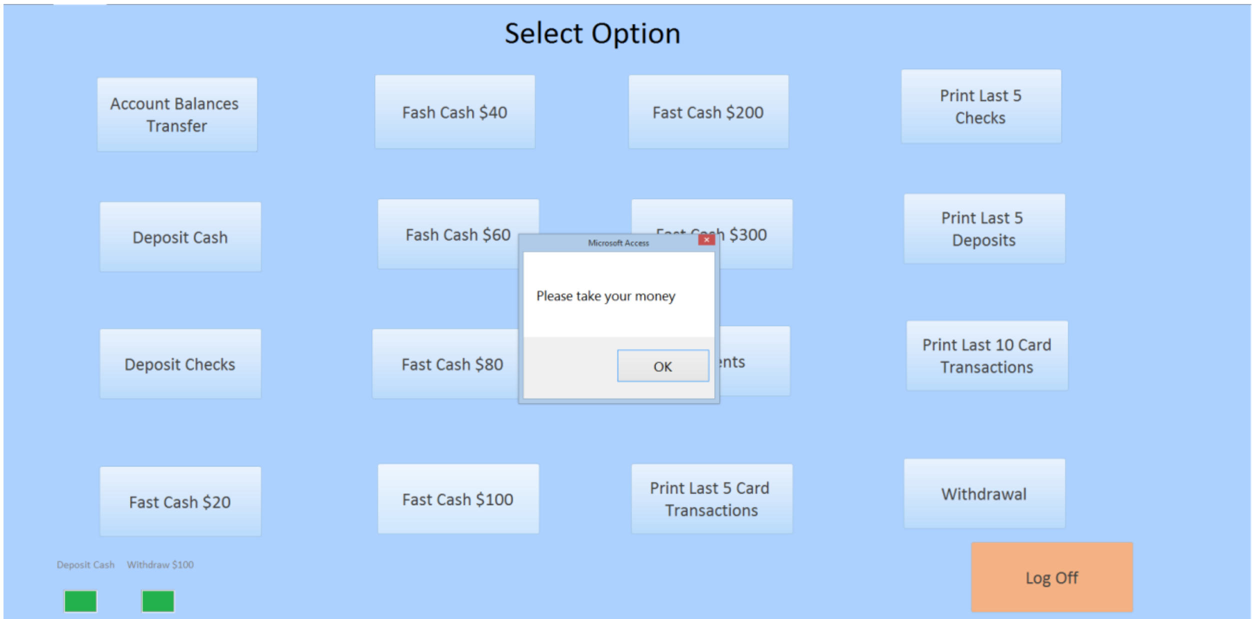
Fast Cash $20 Button



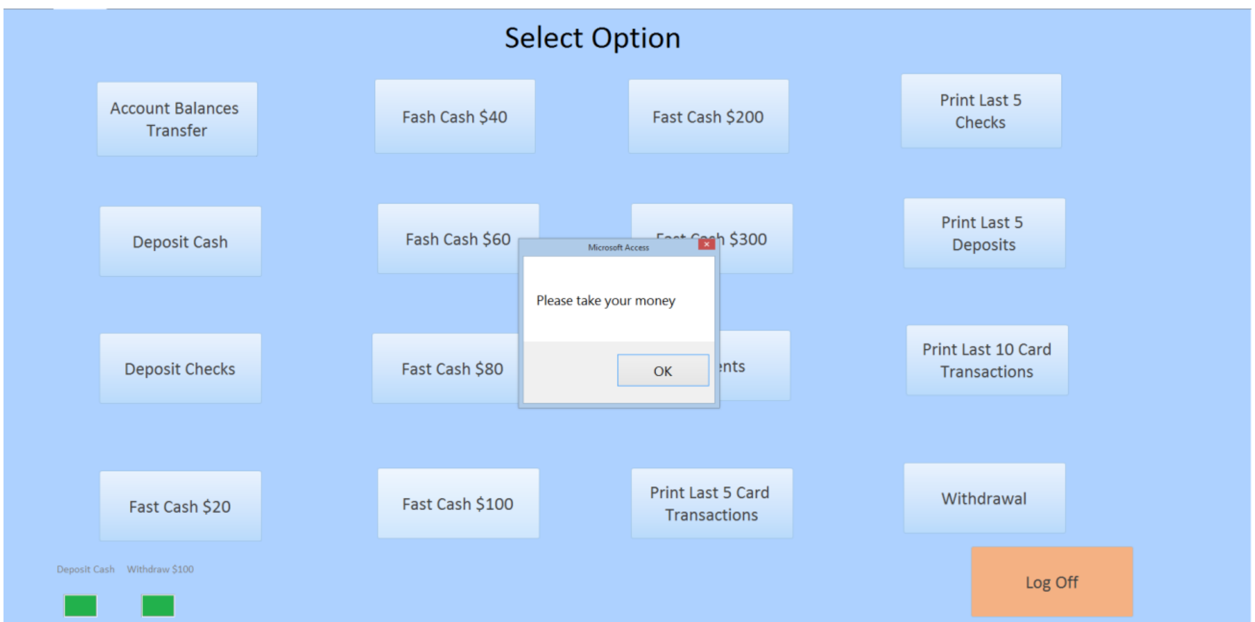
Fast Cash $40 Button



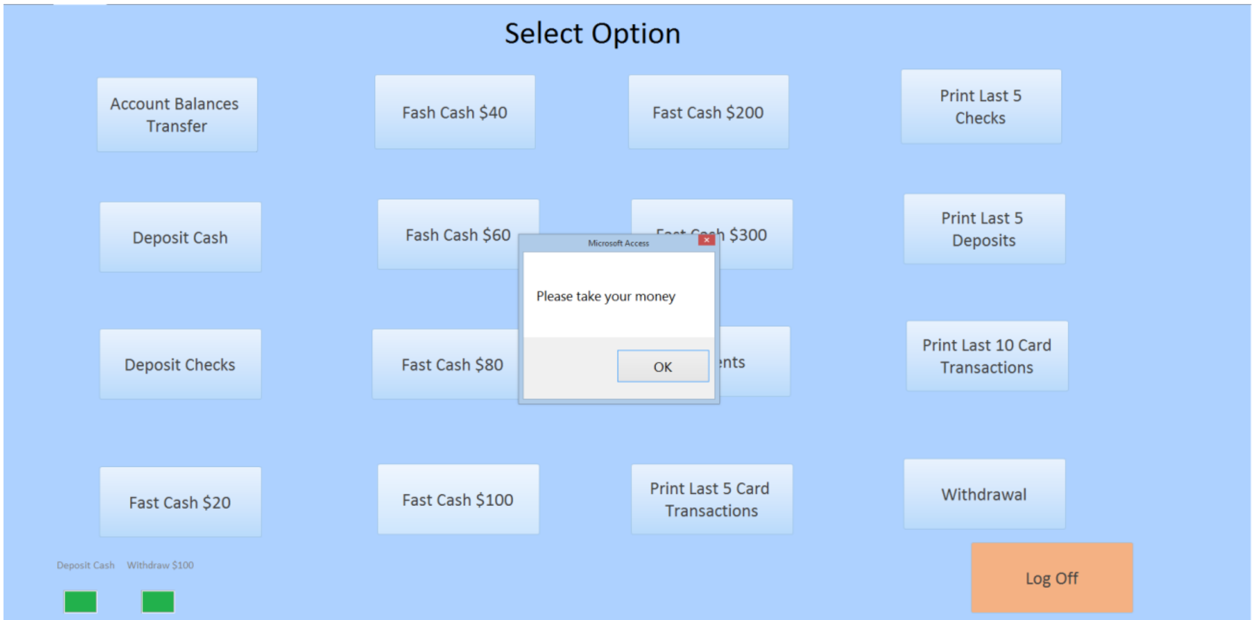
Fast Cash $60 Button



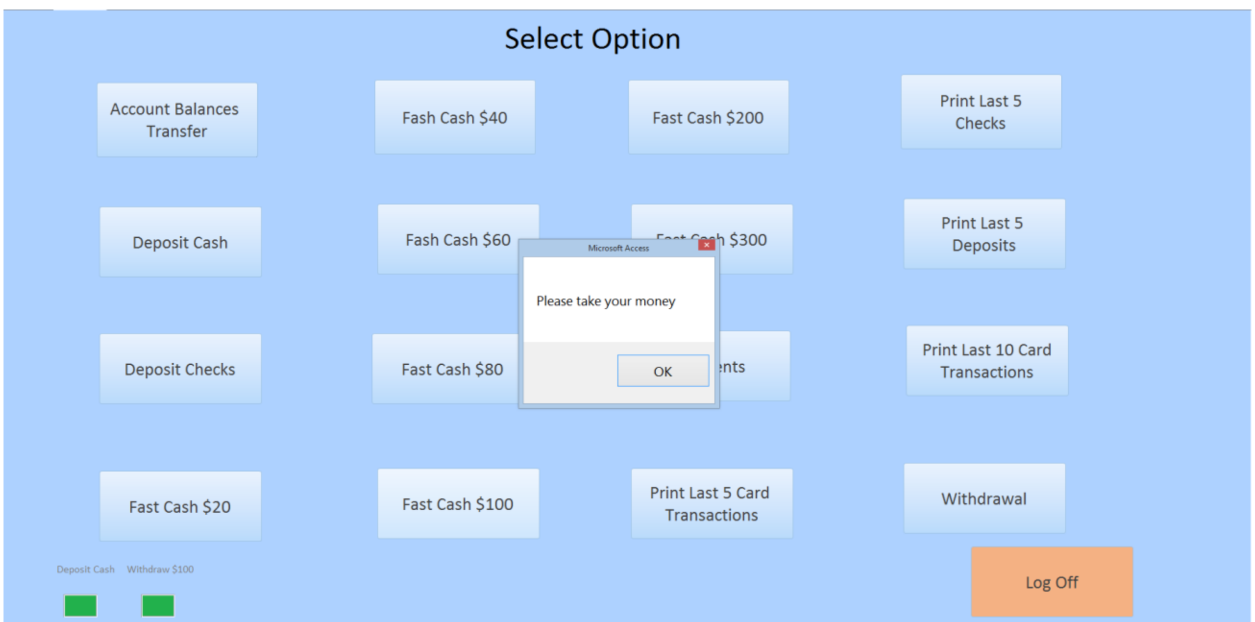
Fast Cash $80 Button



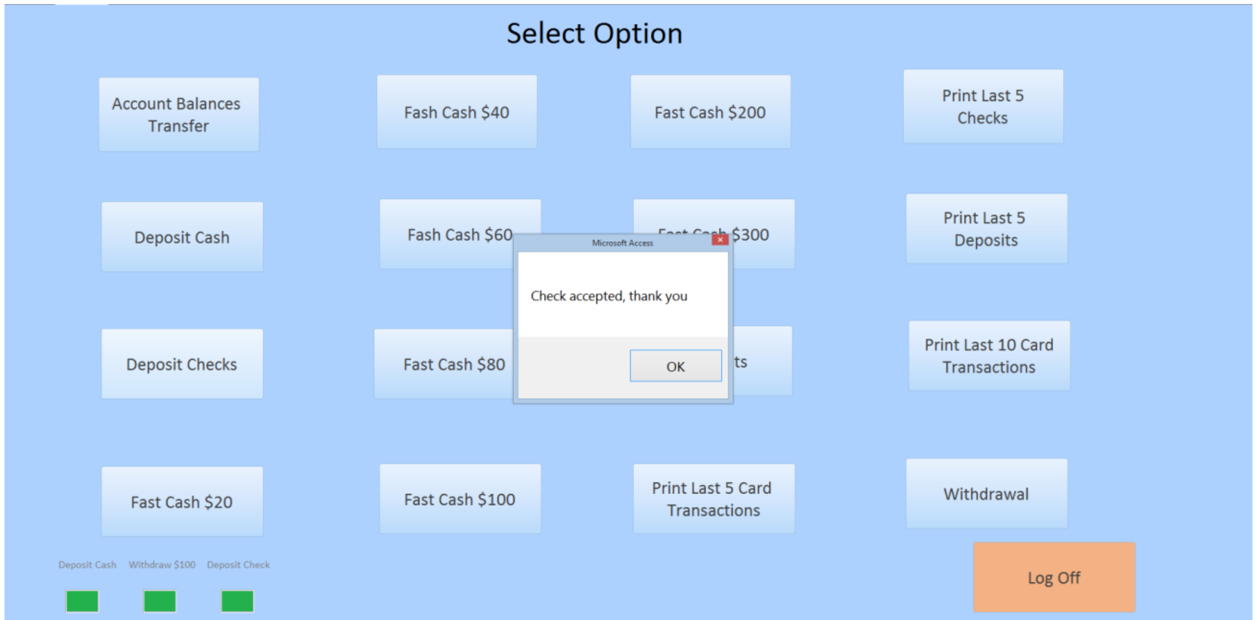
Fast Cash $100 Button



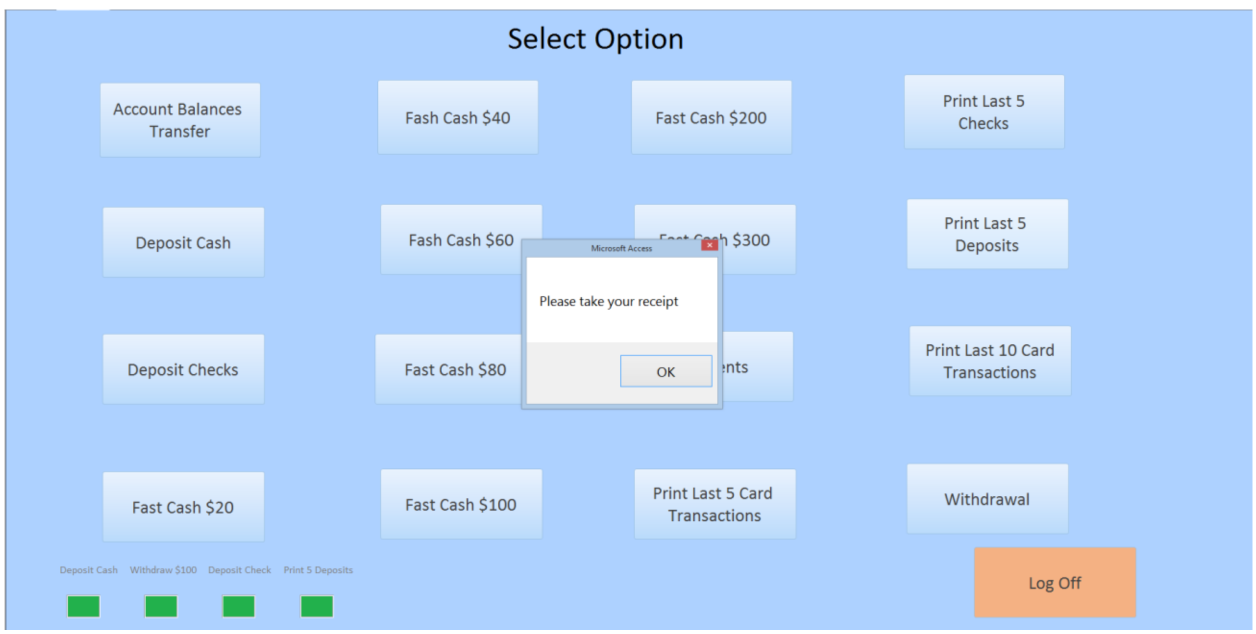
Fast Cash $200 Button



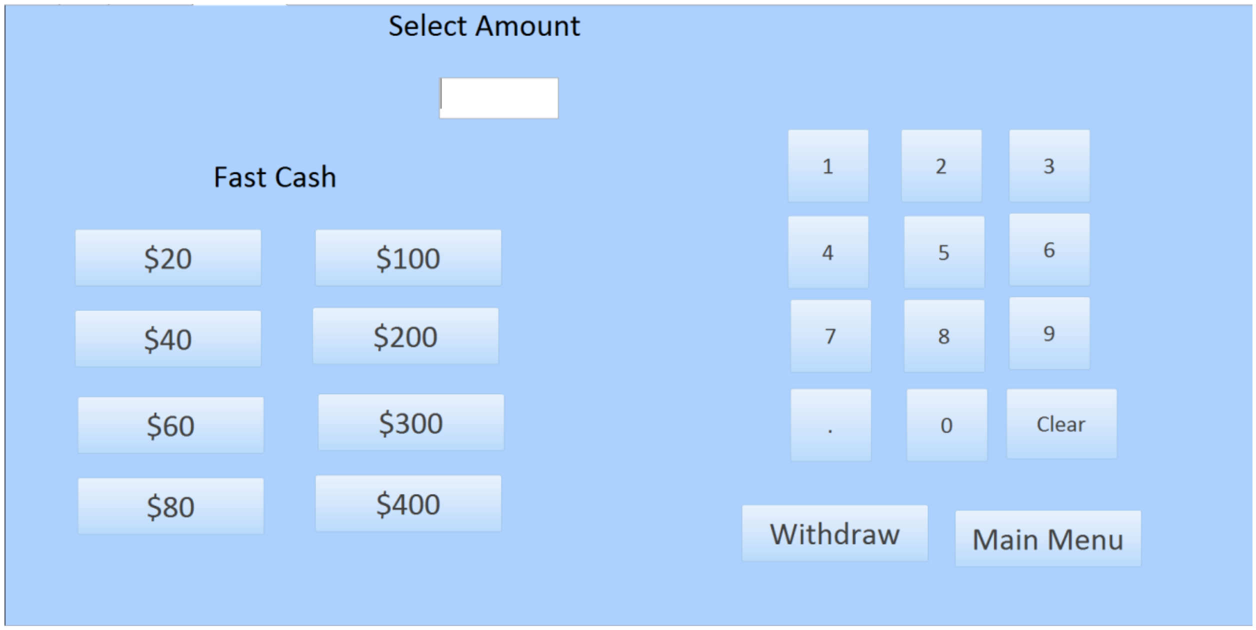
Fast Cash $300 Button



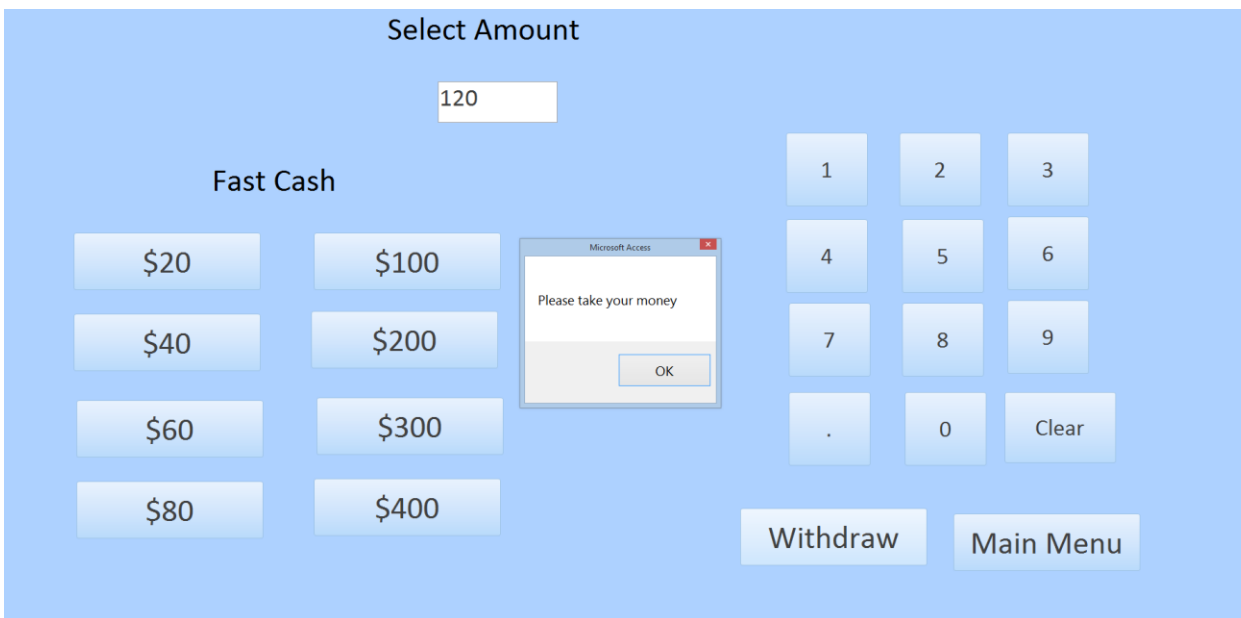
Deposit Check Button



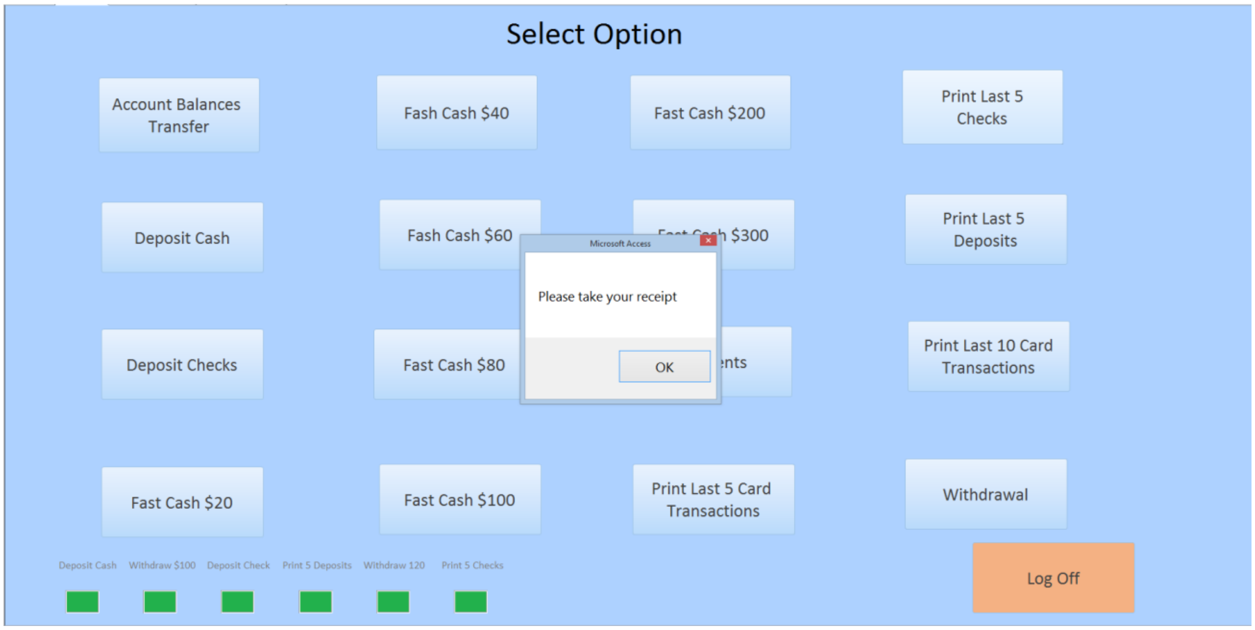
Print Last 5 Deposits Button



Withdraw Button



After Punching $120 into ATM



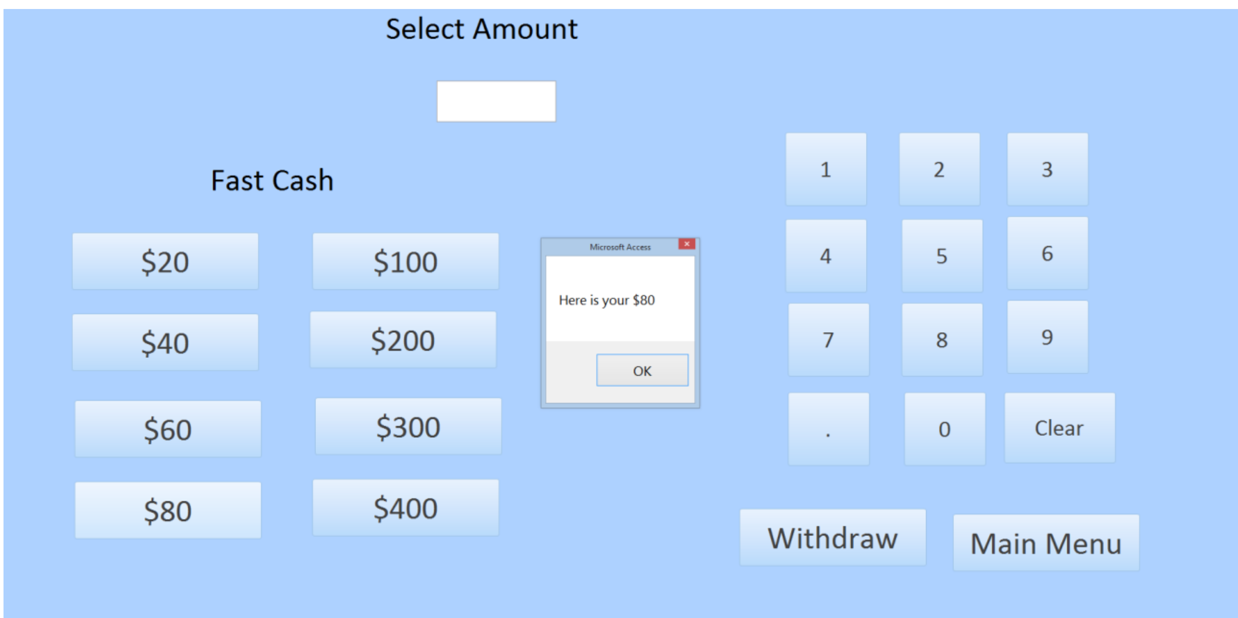
Print Last 5 Checks

After Punching $180 into ATM

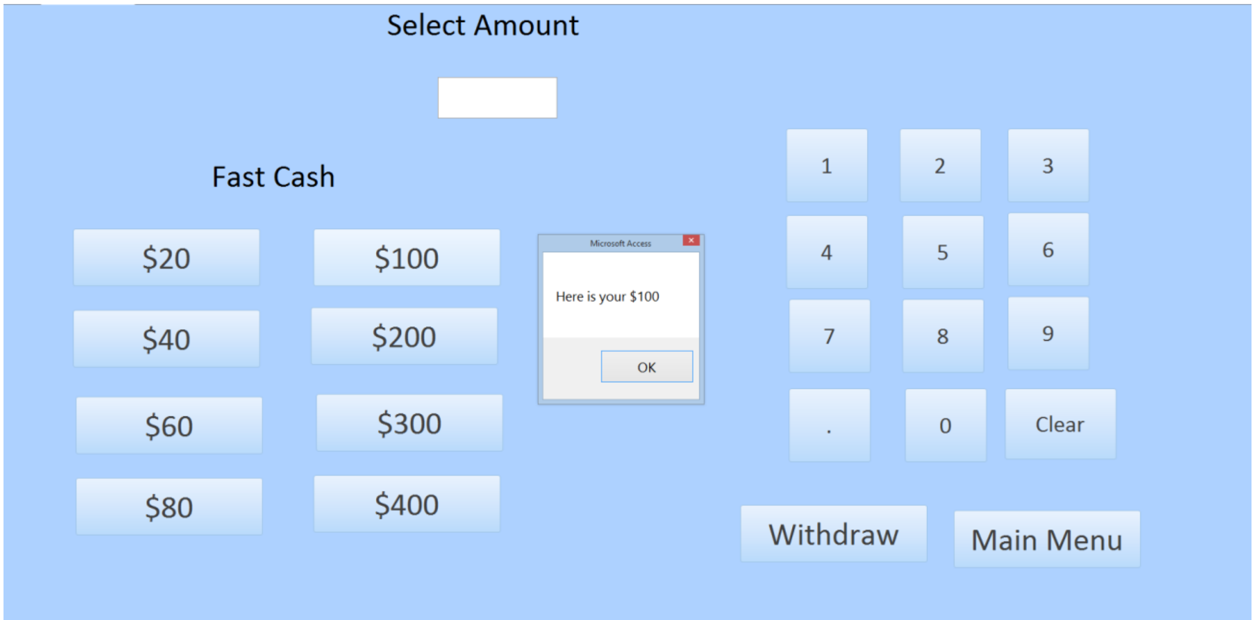
Fast Cash $20 Button

Fast Cash $40 Button

Fast Cash $60 Button

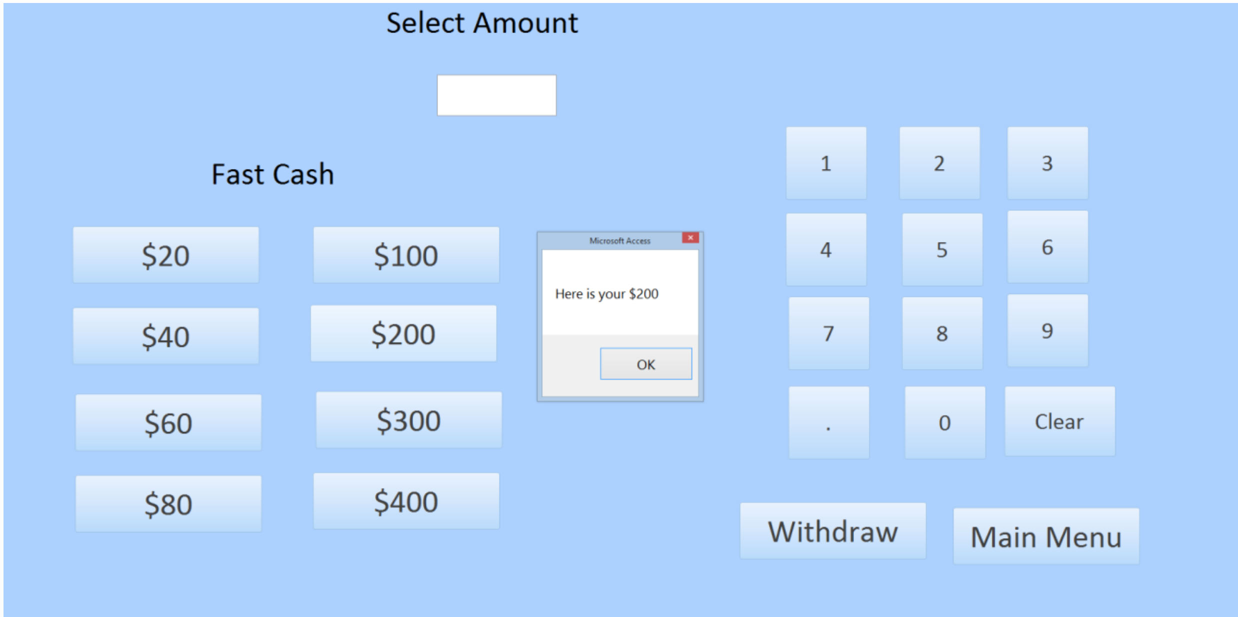


Fast Cash $80 Button

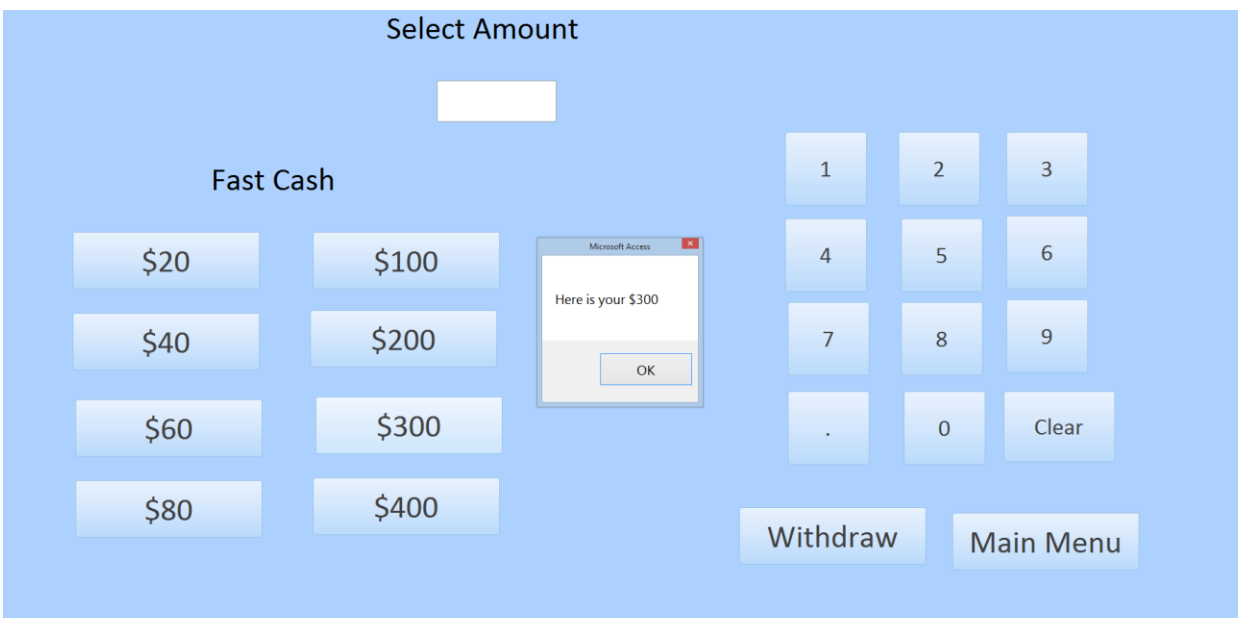


Fast Cash $100 Button

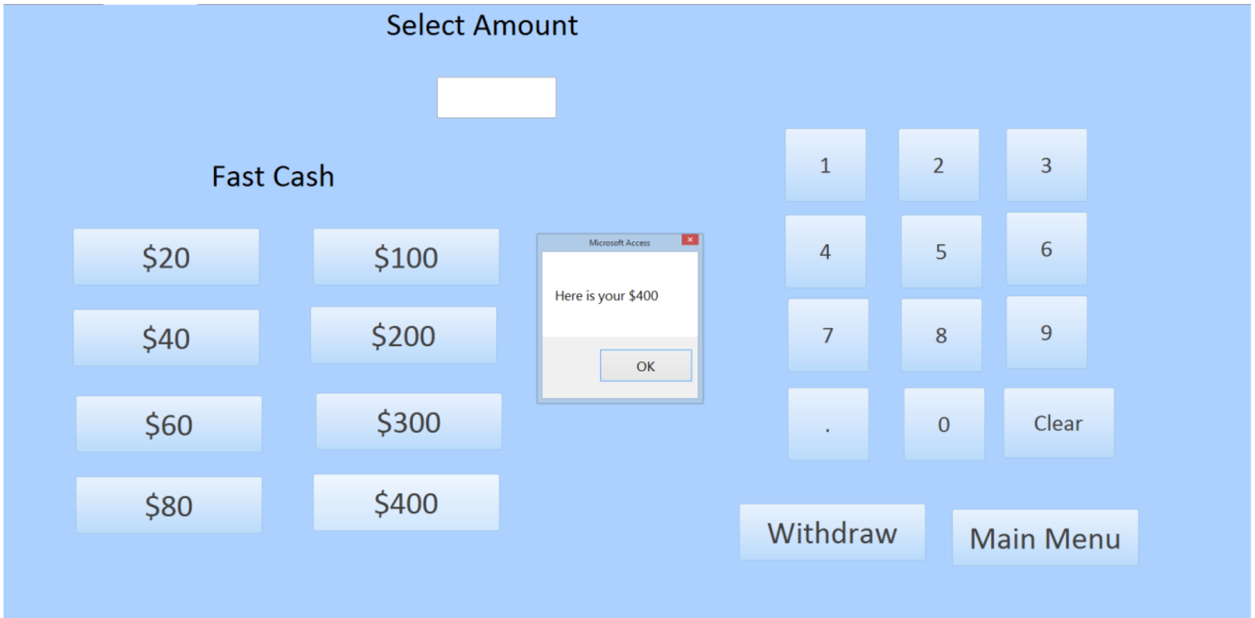
After Punching $100 into ATM



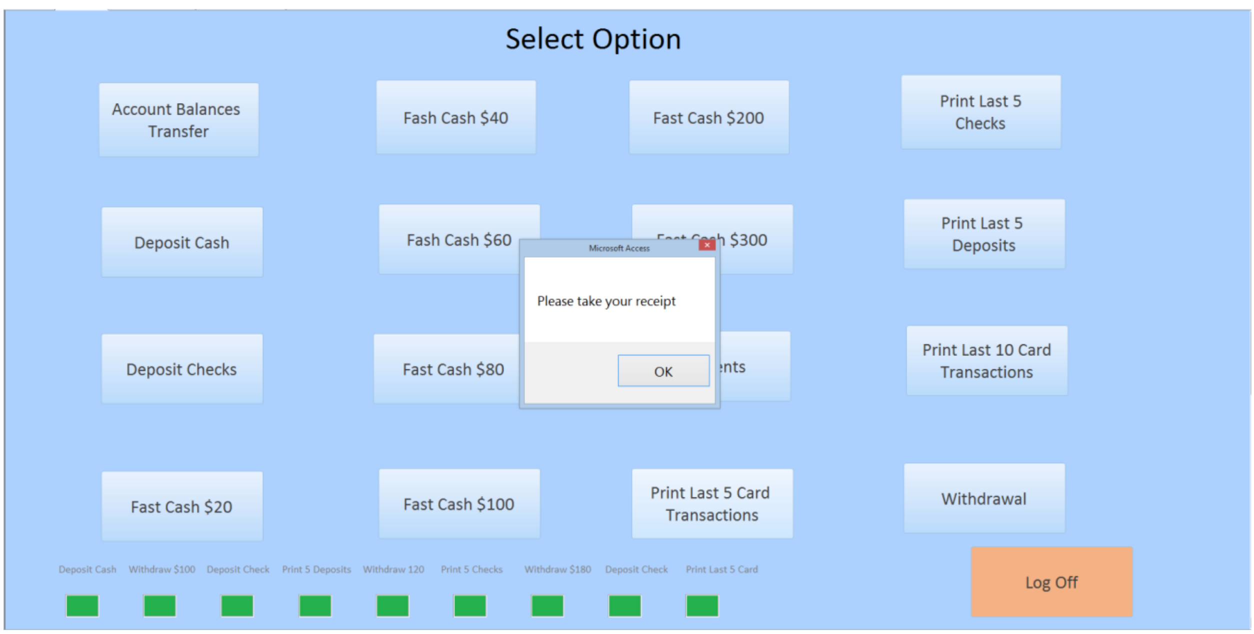
Fast Cash $200 Button



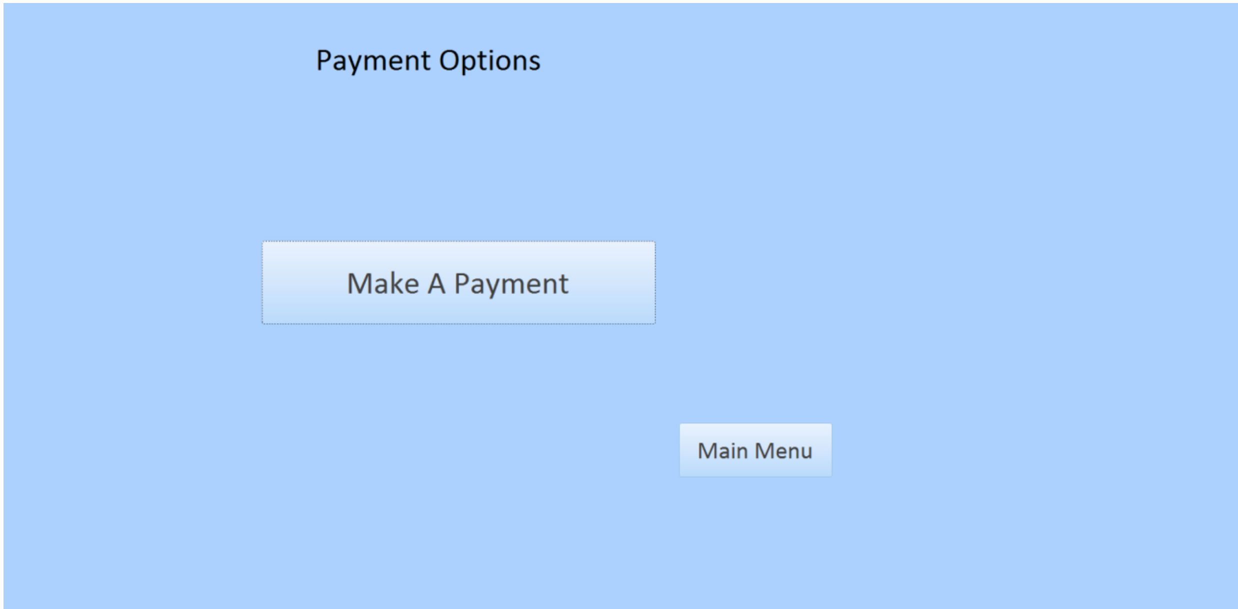
Fast Cash $300 Button



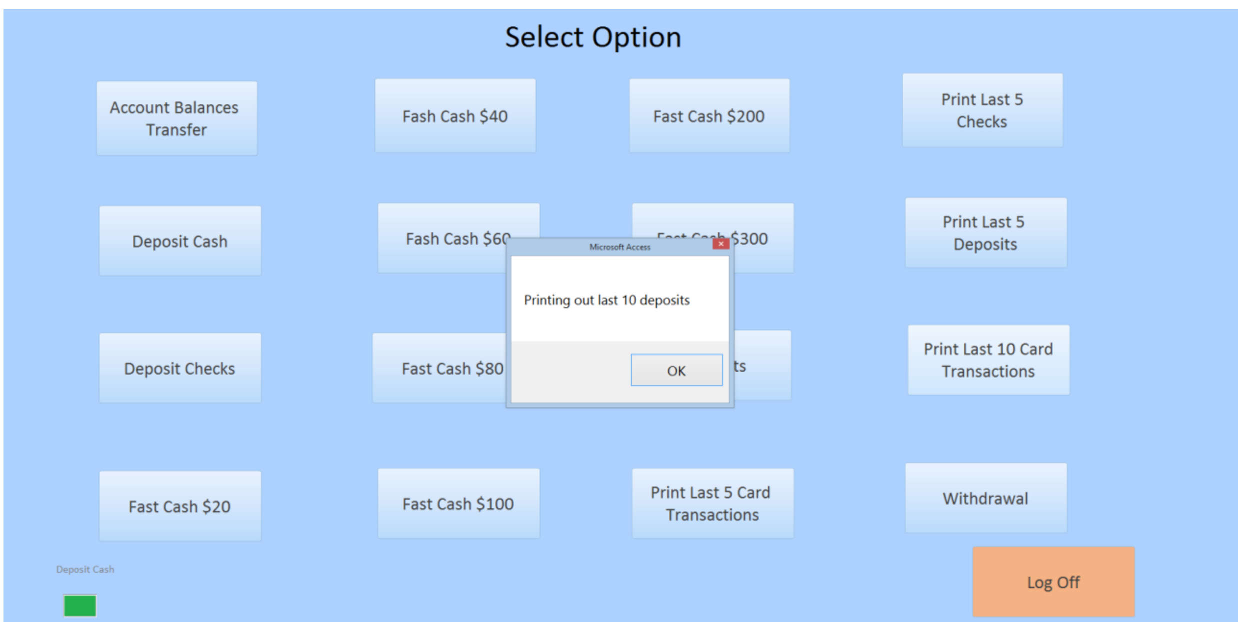
Fast Cash $400 Button



Print Last 5 Card Transactions

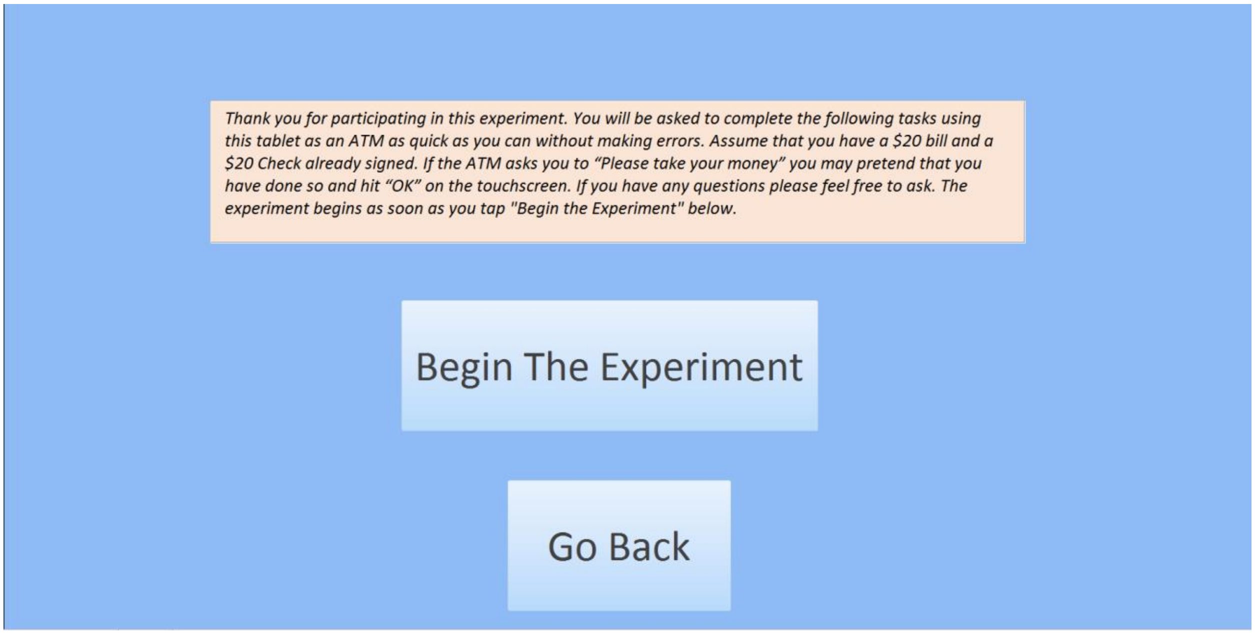


Payments Button

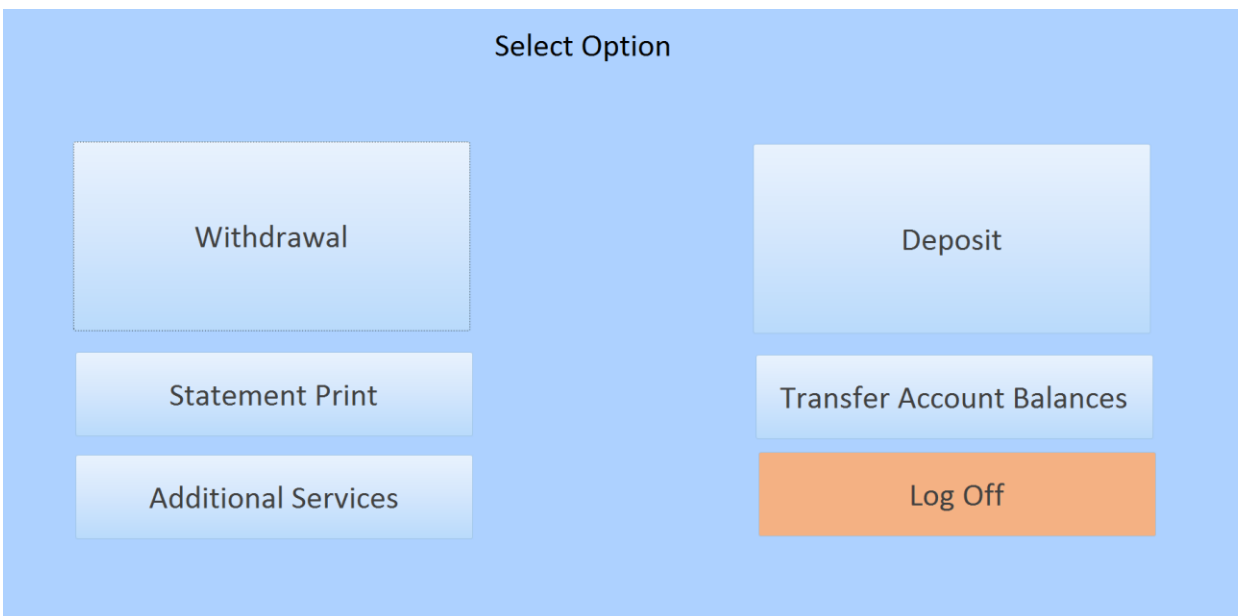


Print Last 10 Card Transactions

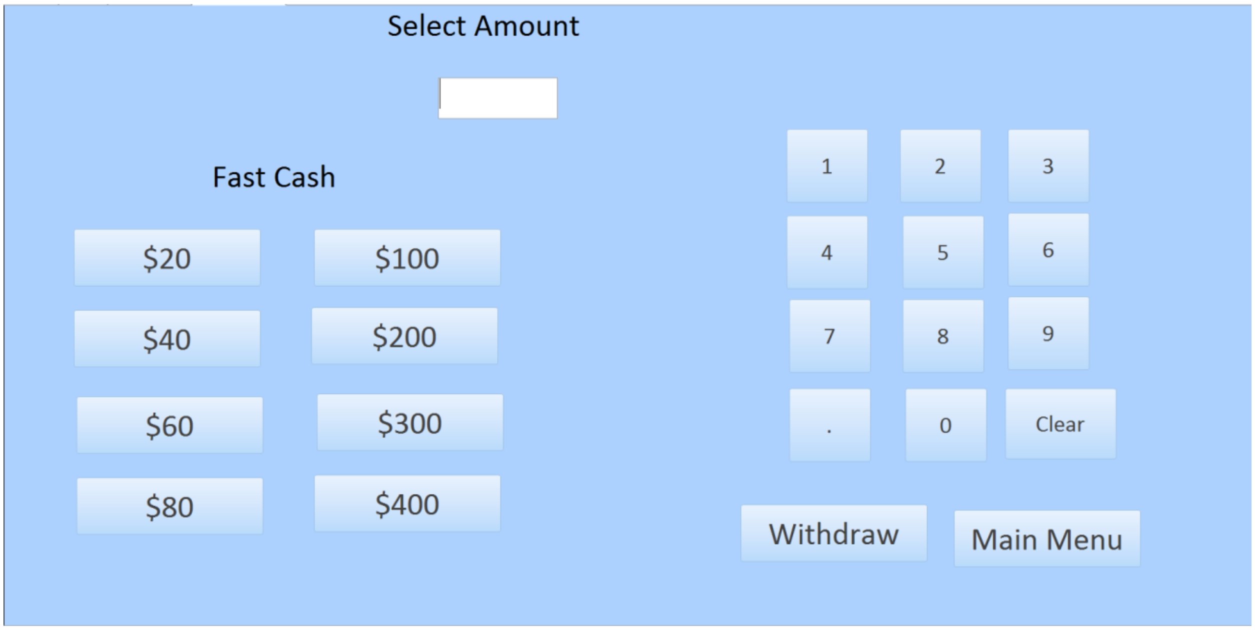
Optimization Form



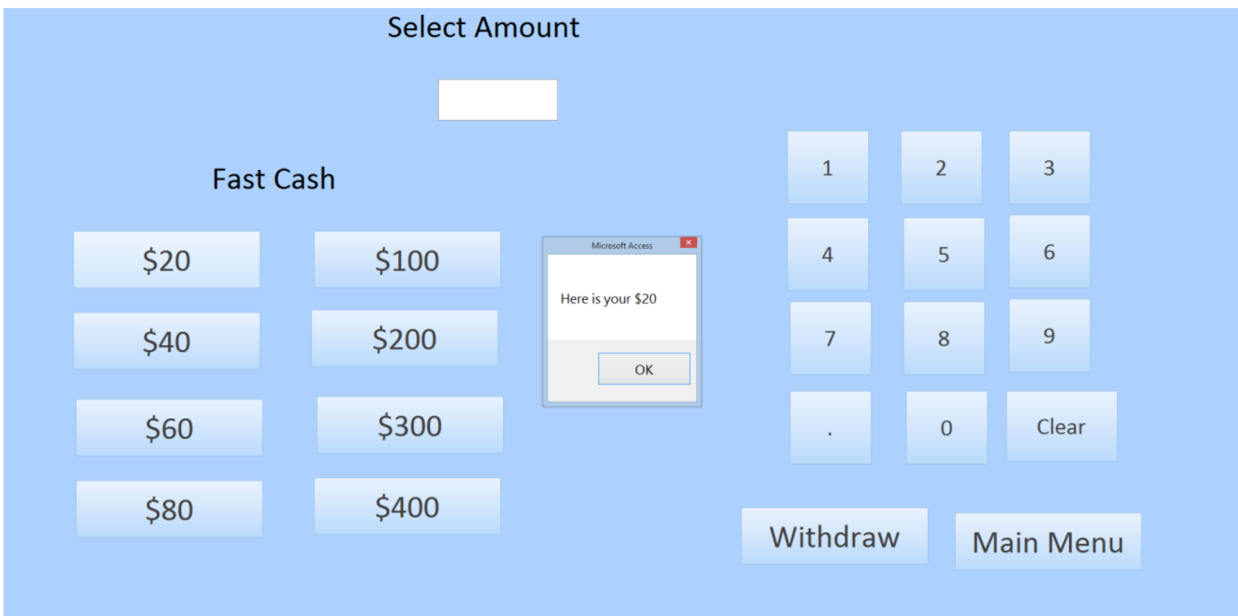
Instructions Before All Buttons Form



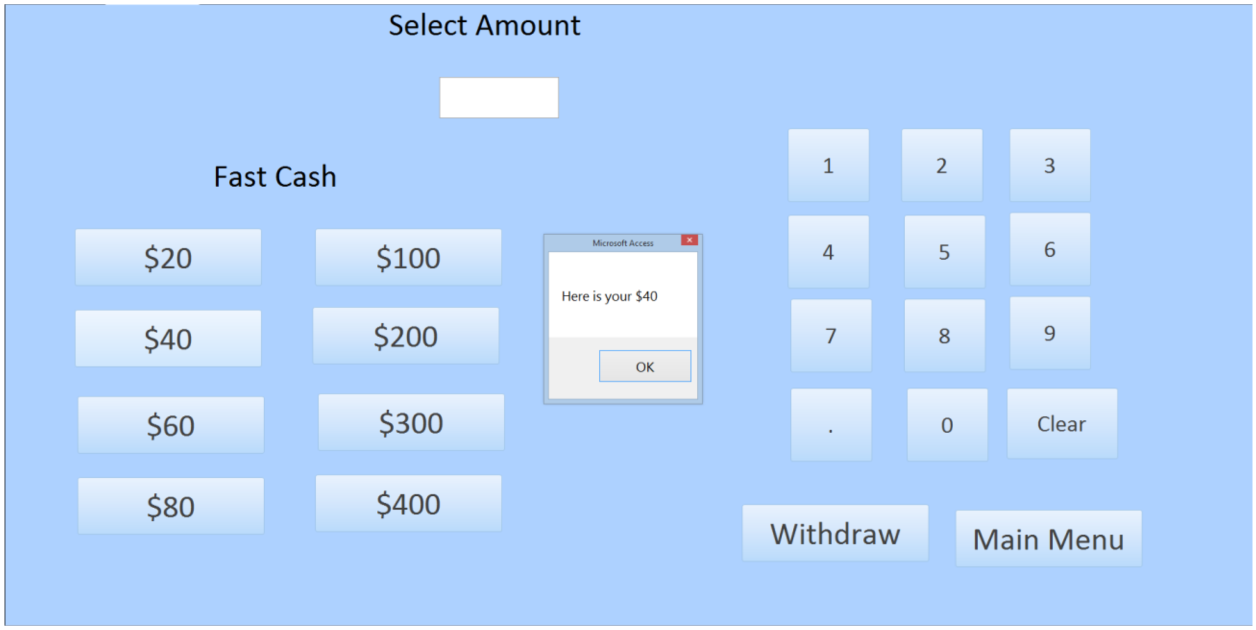
Front of Optimization Form



Withdrawal Button

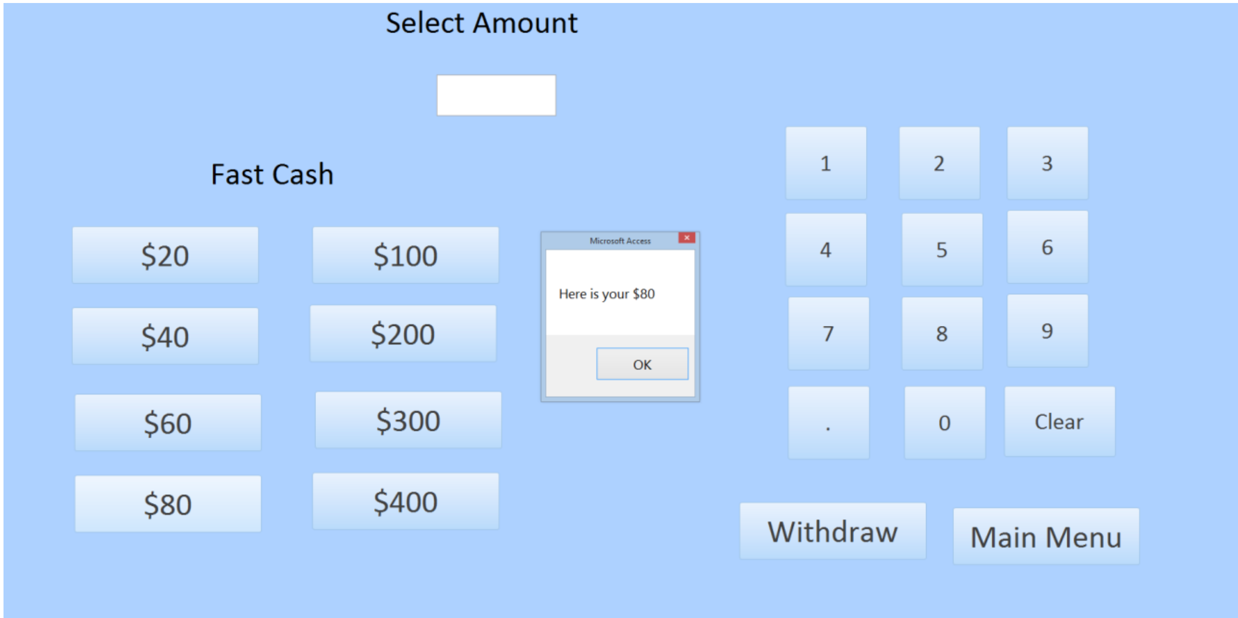


Fast Cash $20 Button

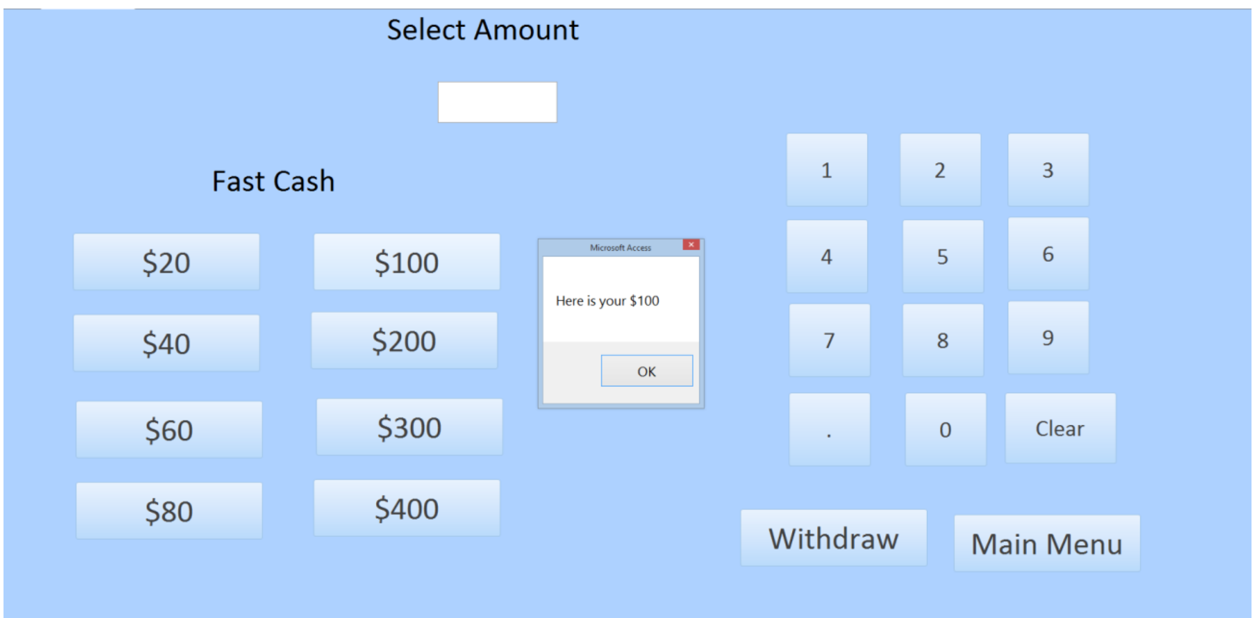


Fast Cash $40 Button

Fast Cash $60 Button

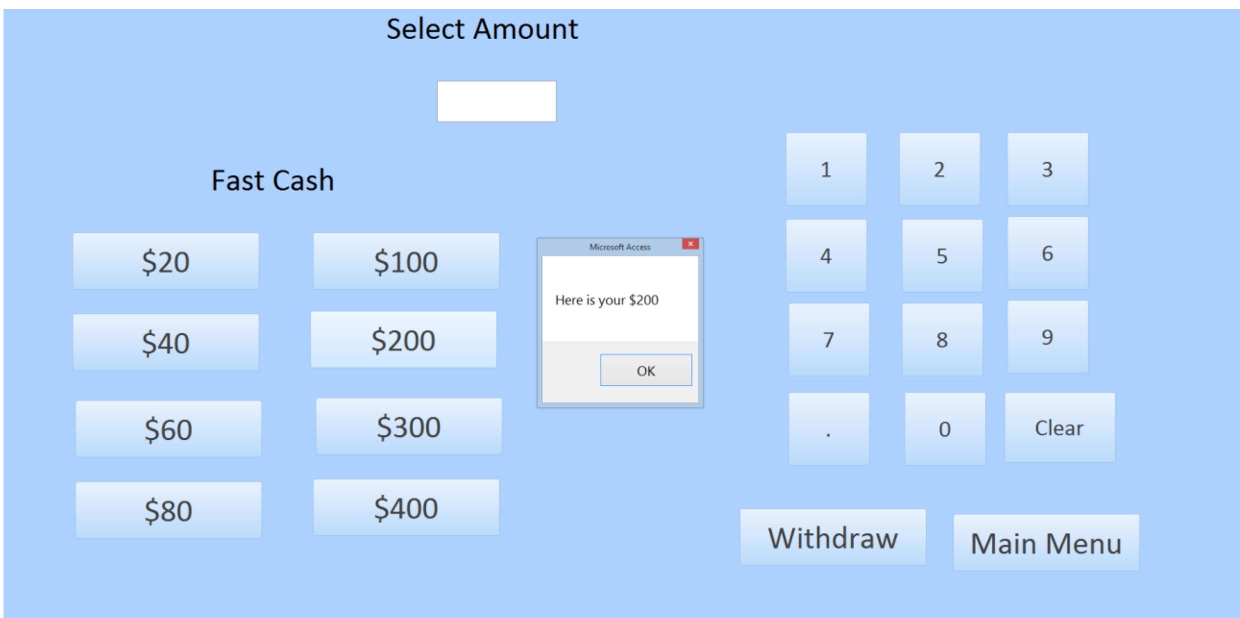


Fast Cash $80 Button

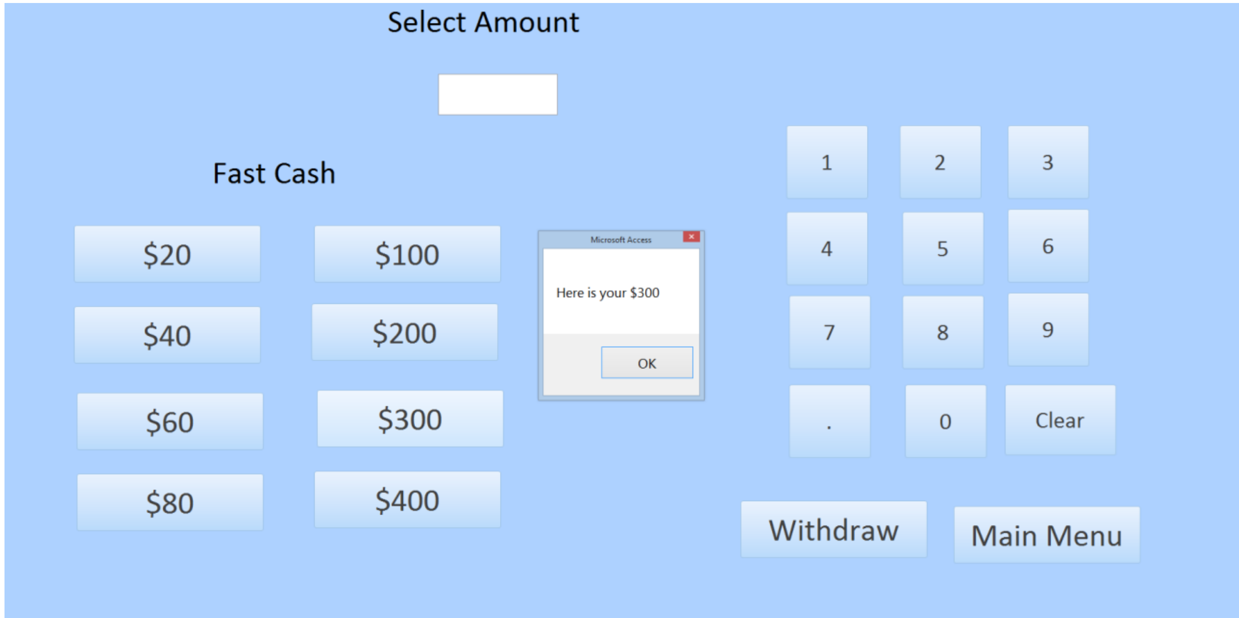


Fast Cash $100 Button

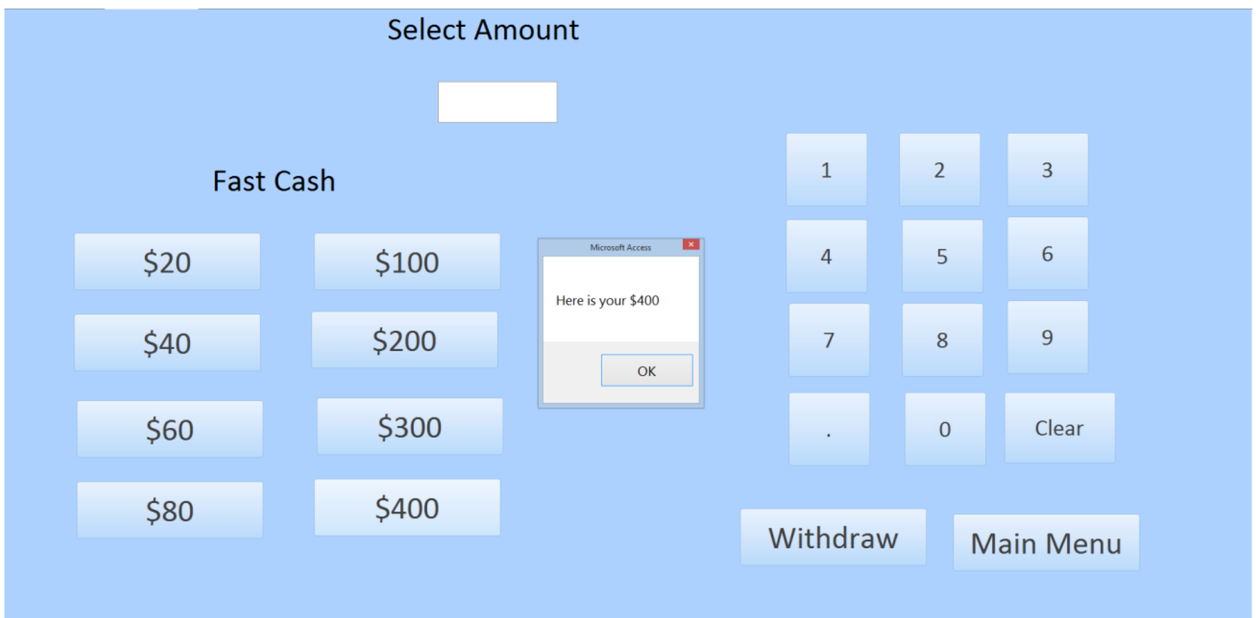
After Punching $100 into ATM



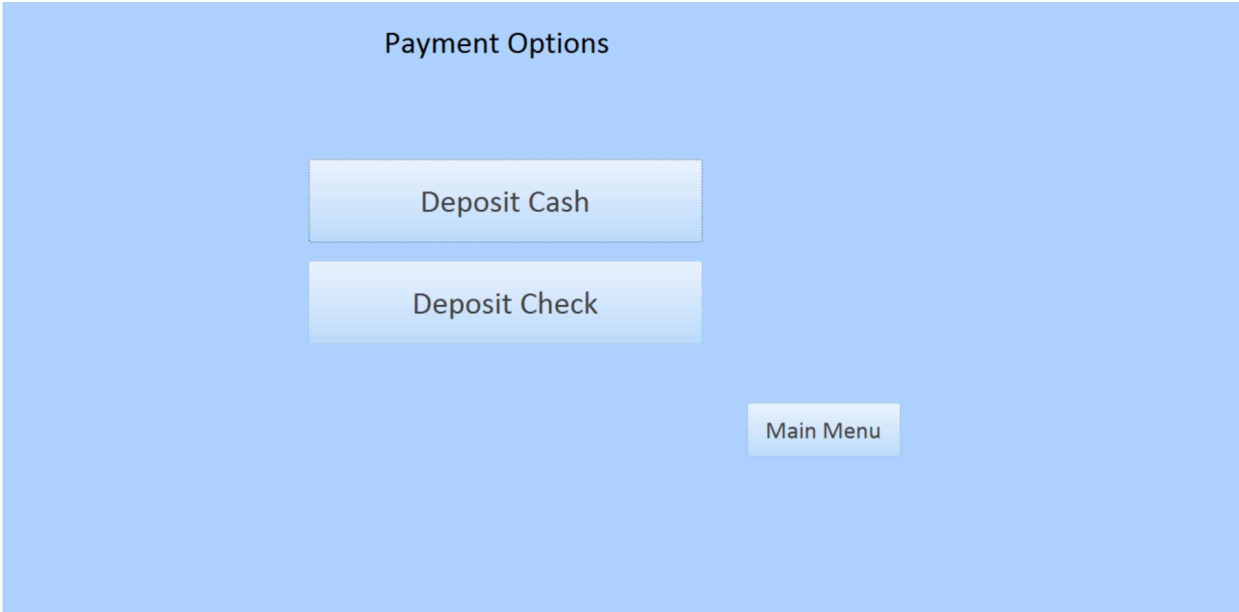
Fast Cash $200 Button



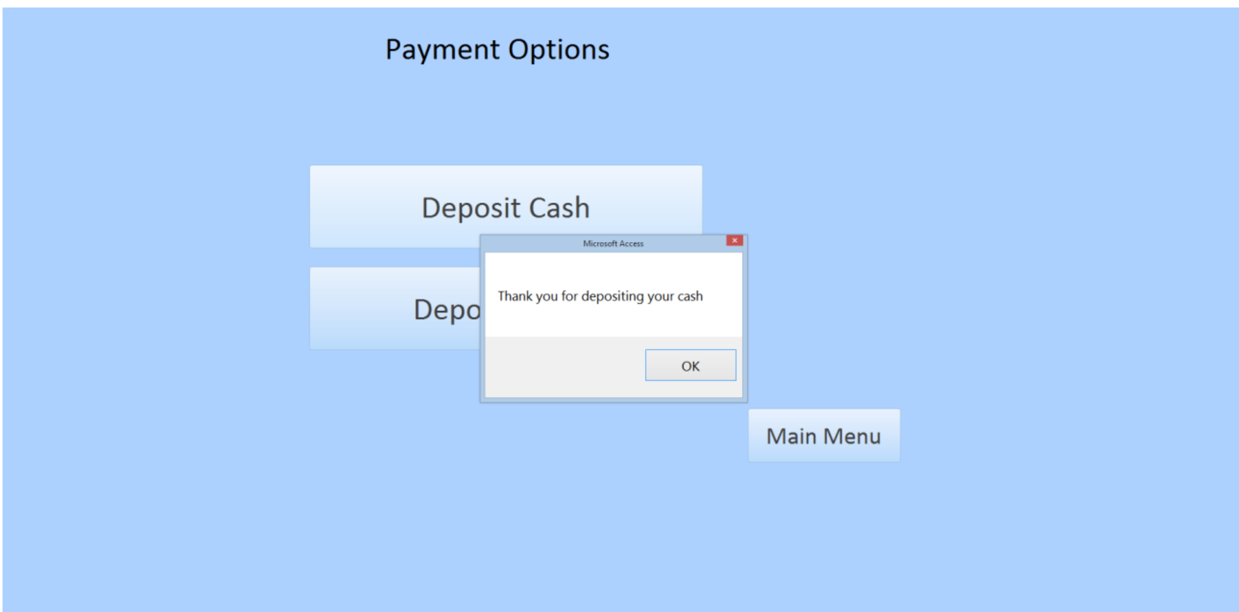
Fast Cash $300 Button



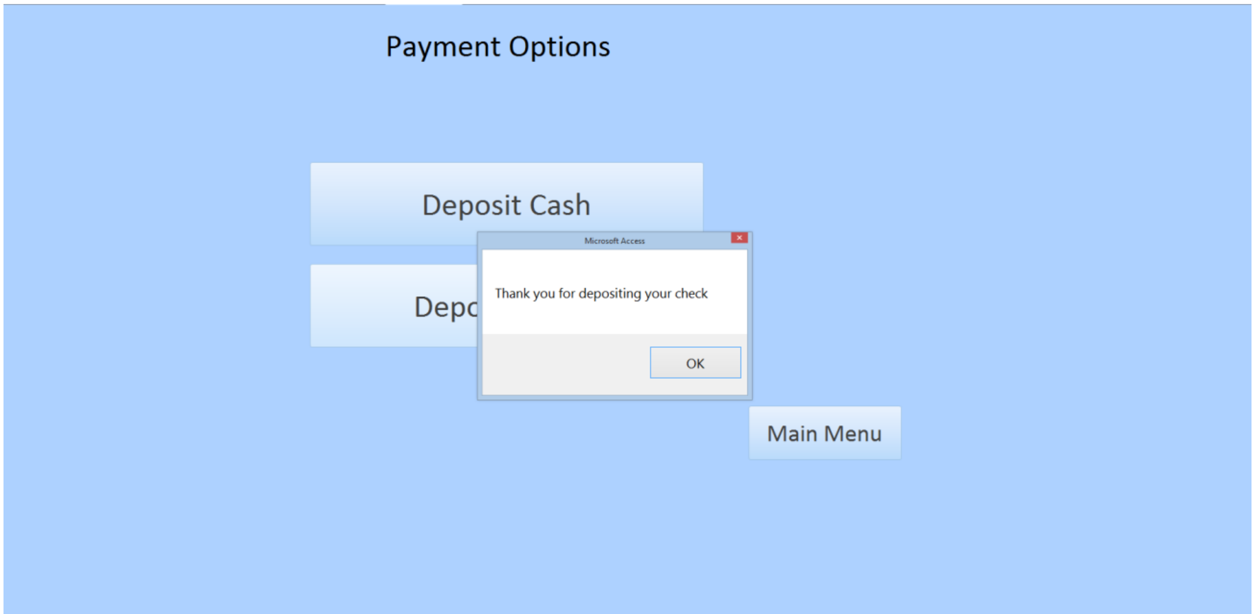
Fast Cash $400 Button



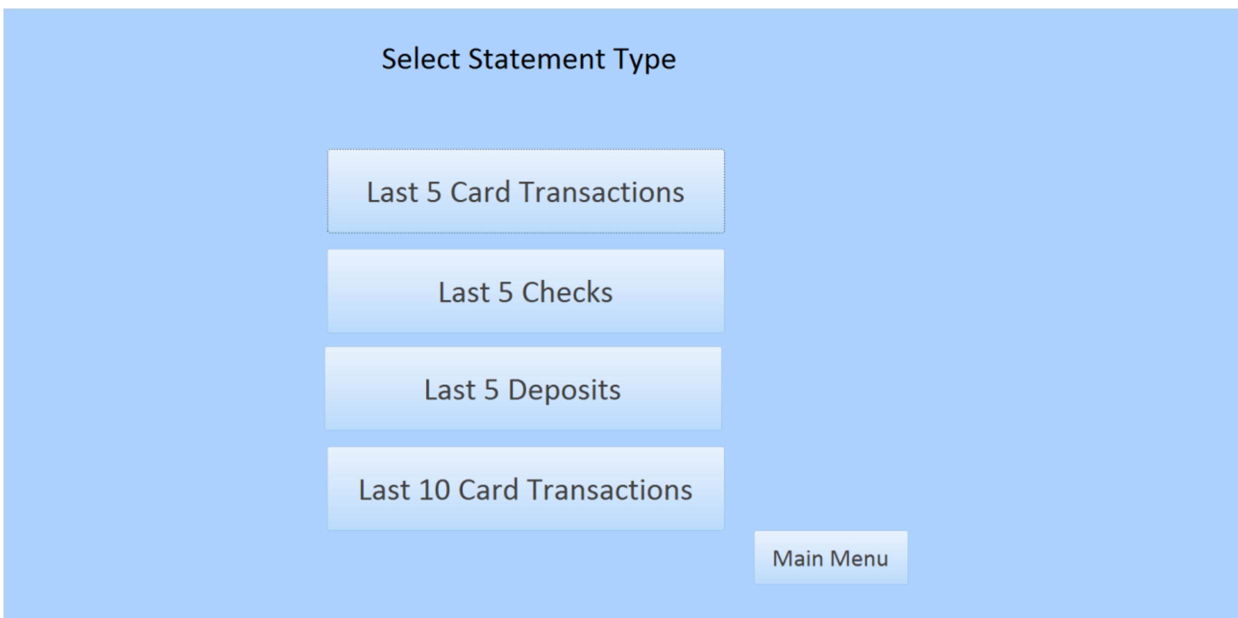
Deposit Button



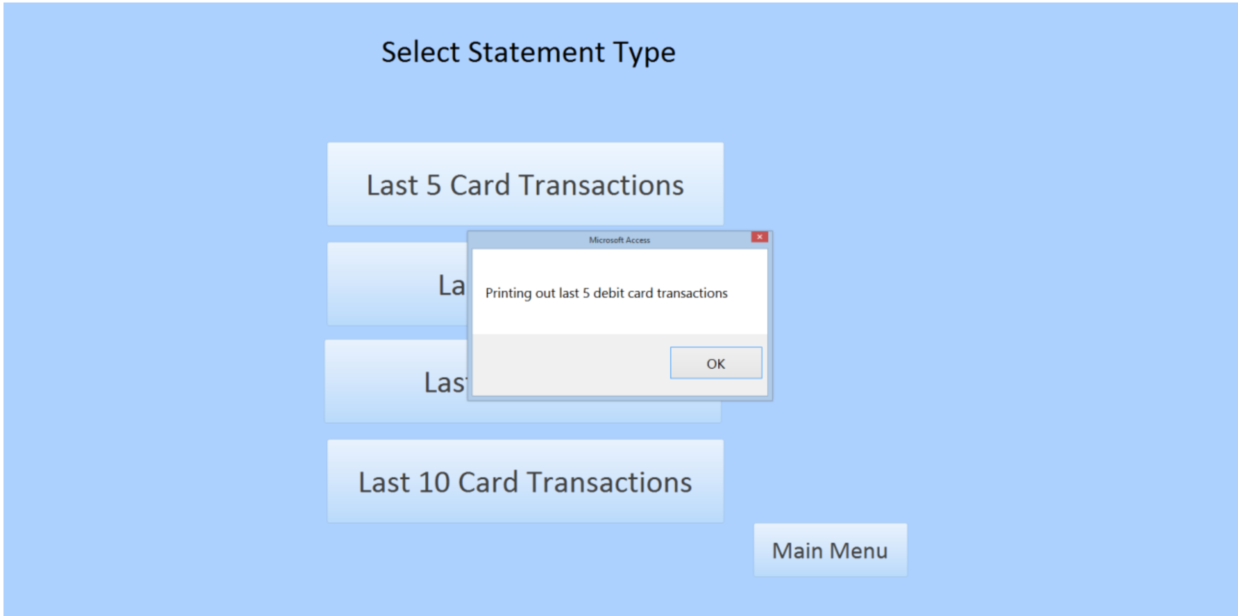
Deposit Cash Button



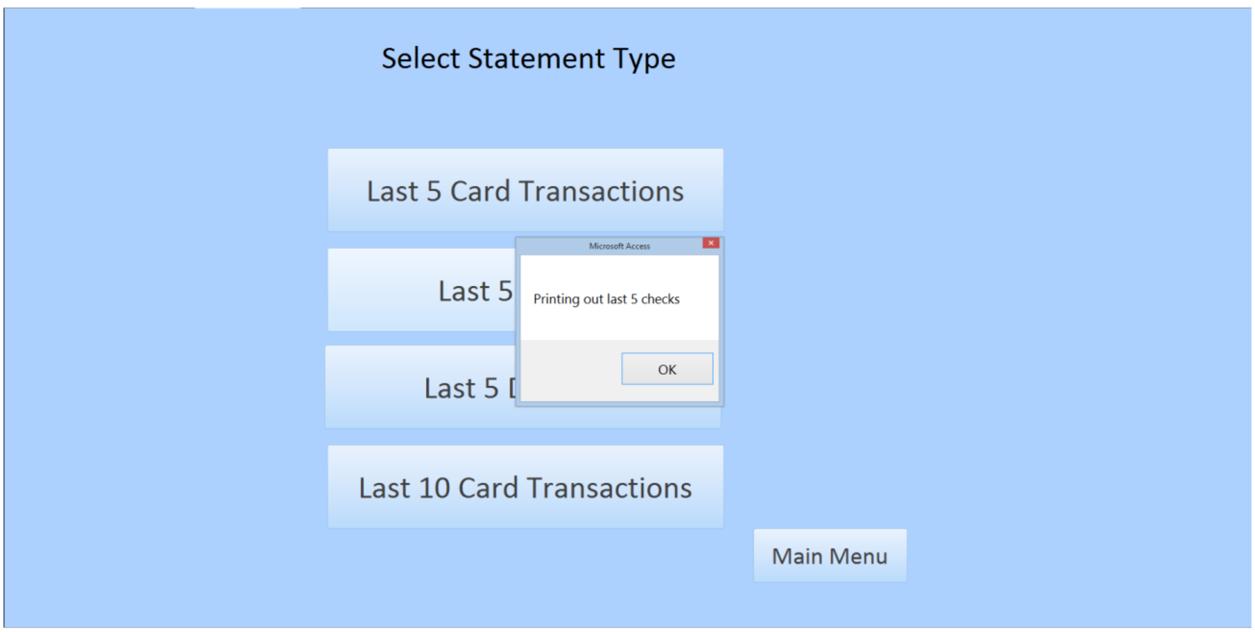
Deposit Check Button



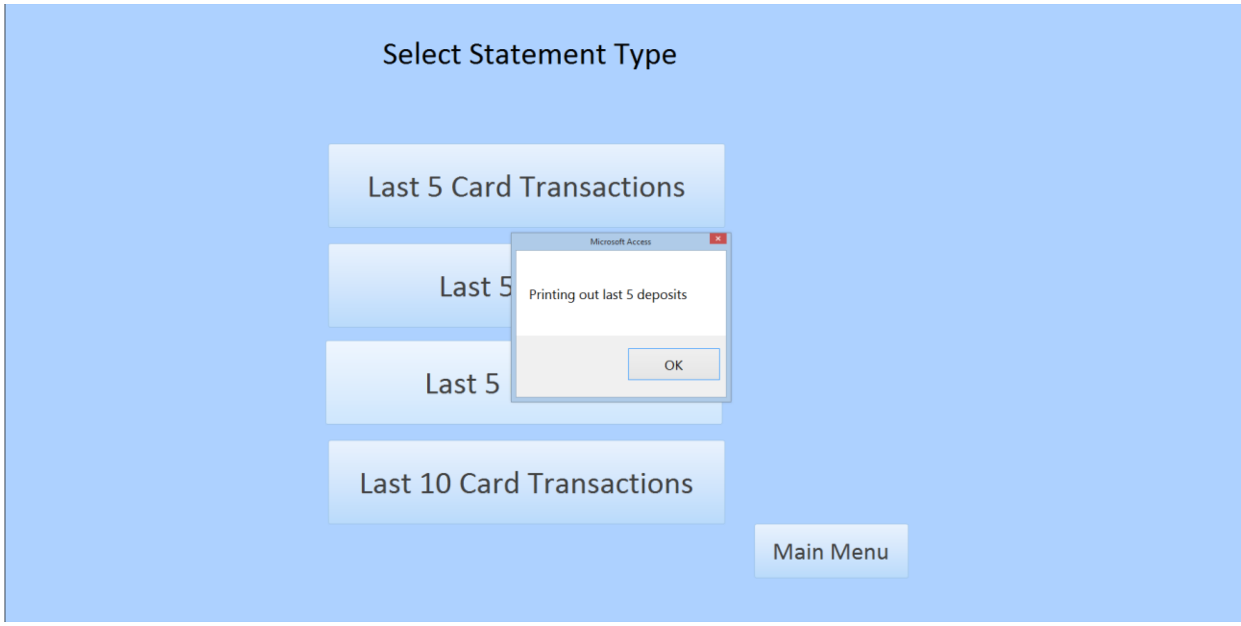
Statement Print Button



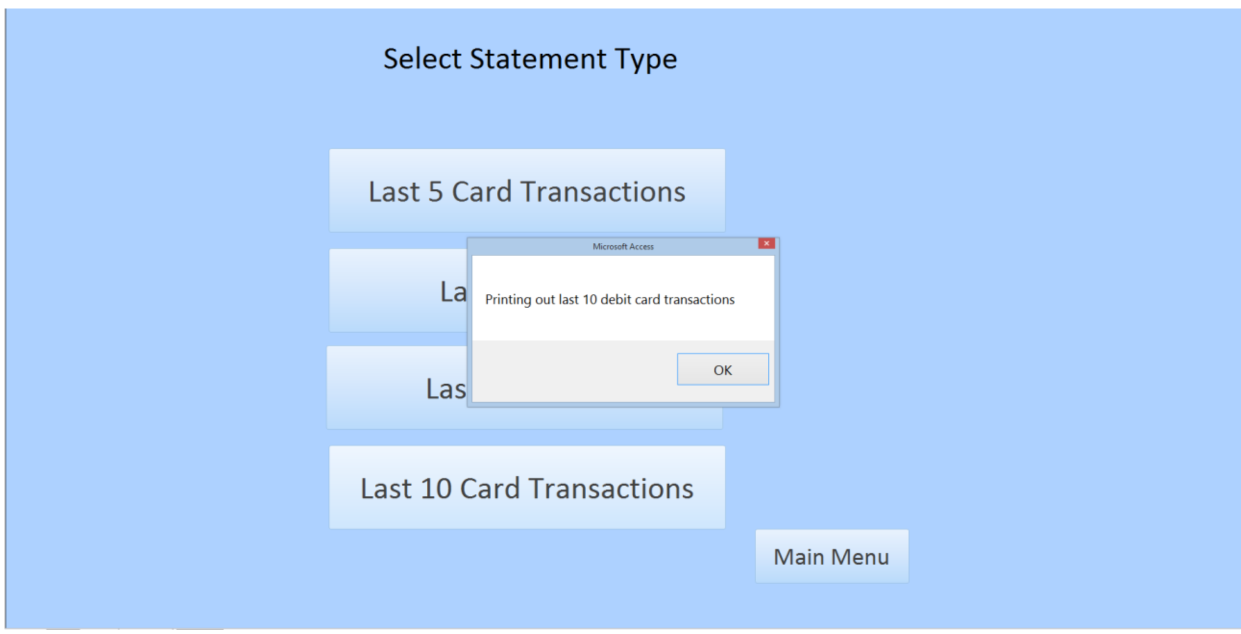
Last 5 Card Transactions



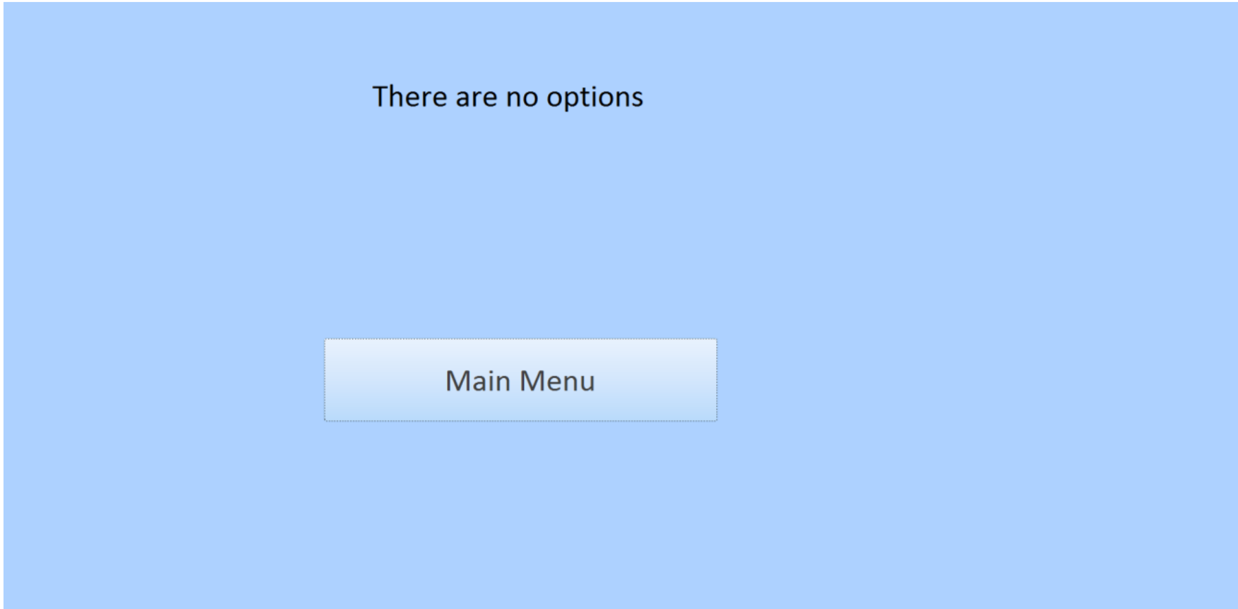
Last 5 Checks



Last 5 Deposits

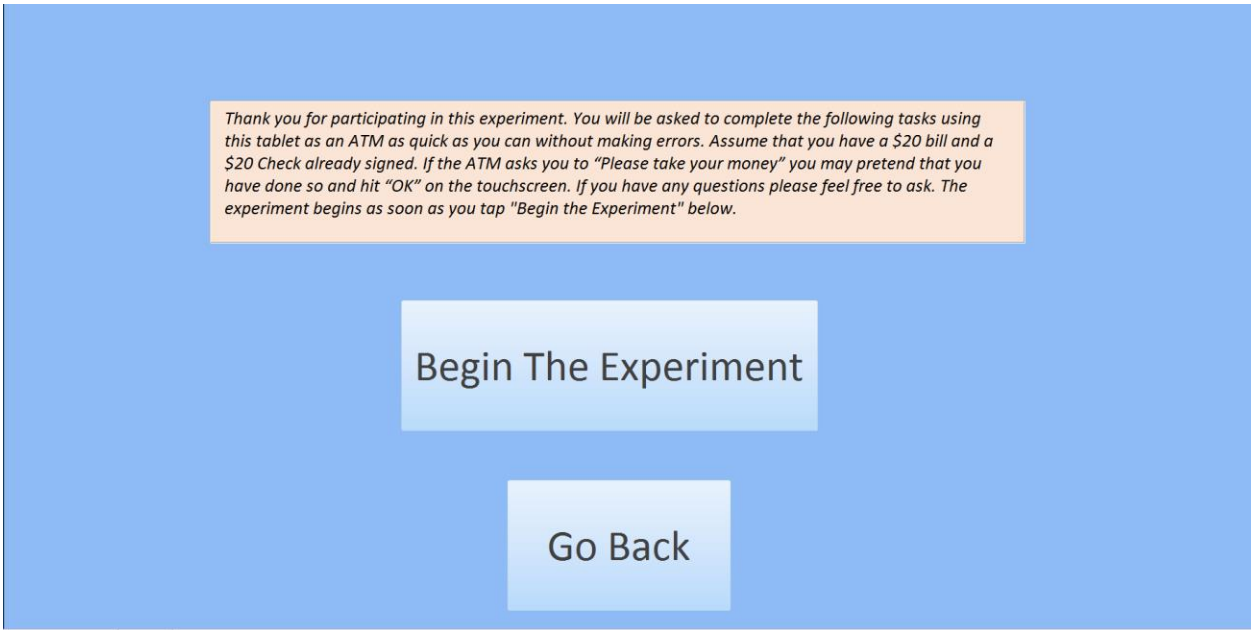


Last 10 Card Transactions

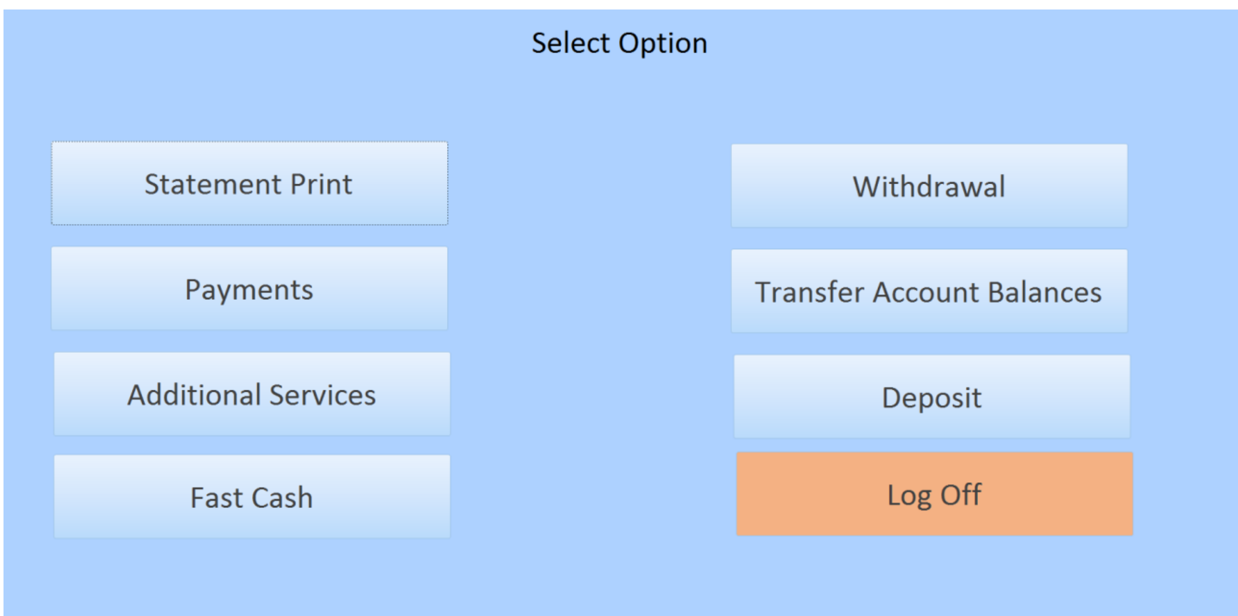


Additional Services

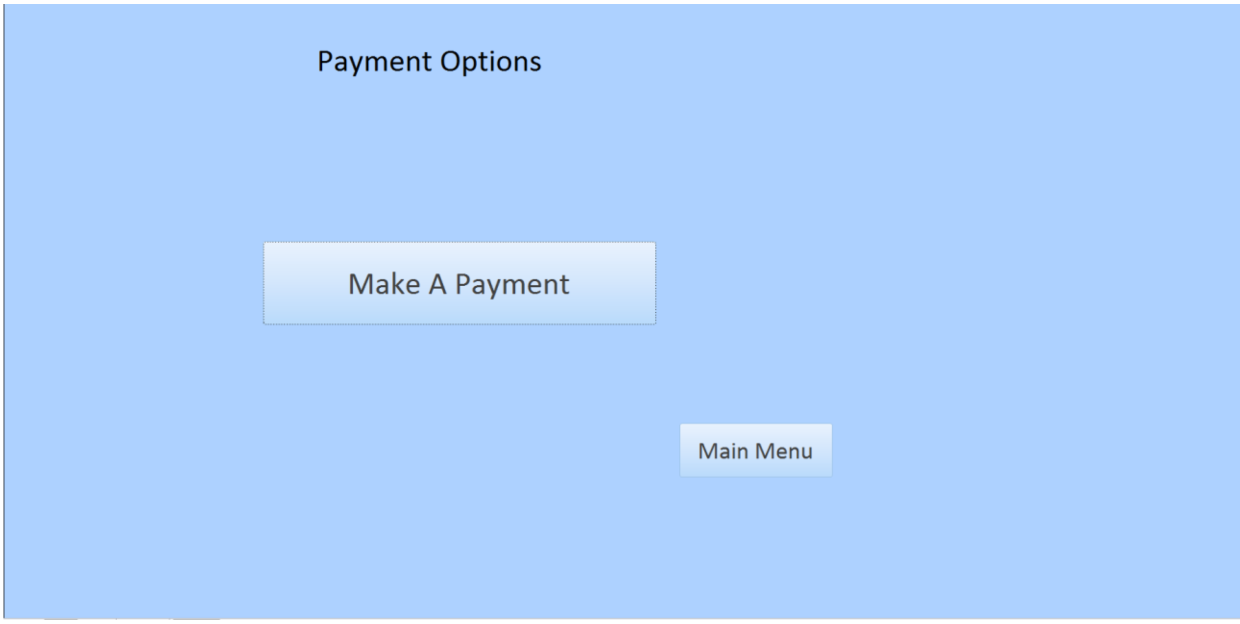
Traditional Form



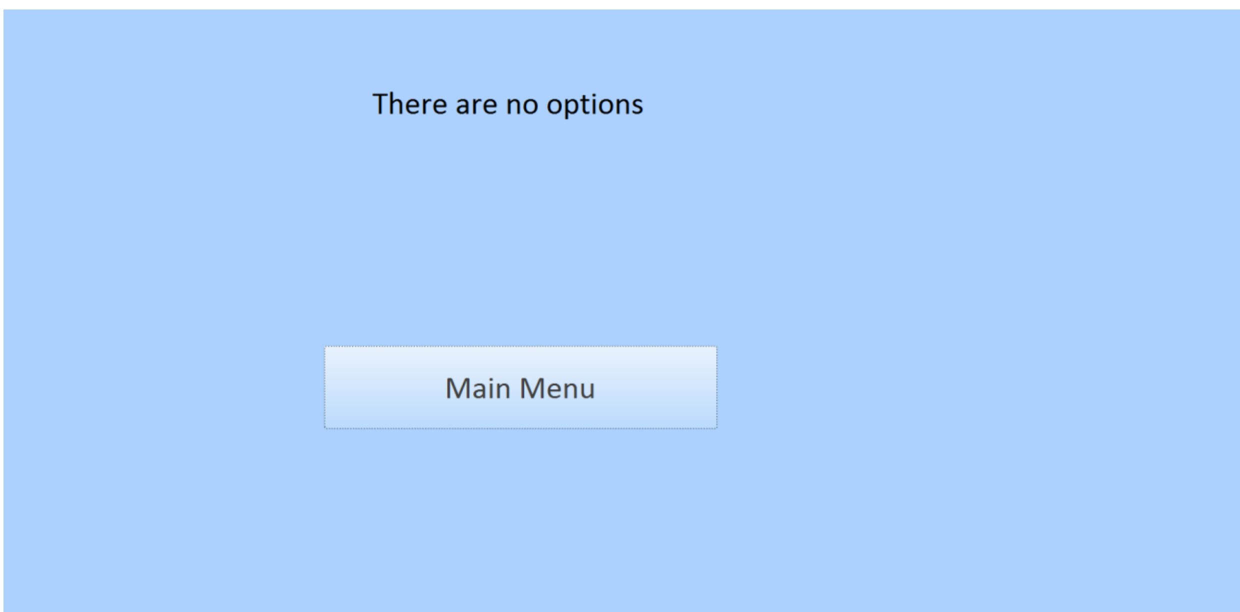
Instructions Before All Buttons Form



Front of Traditional Form



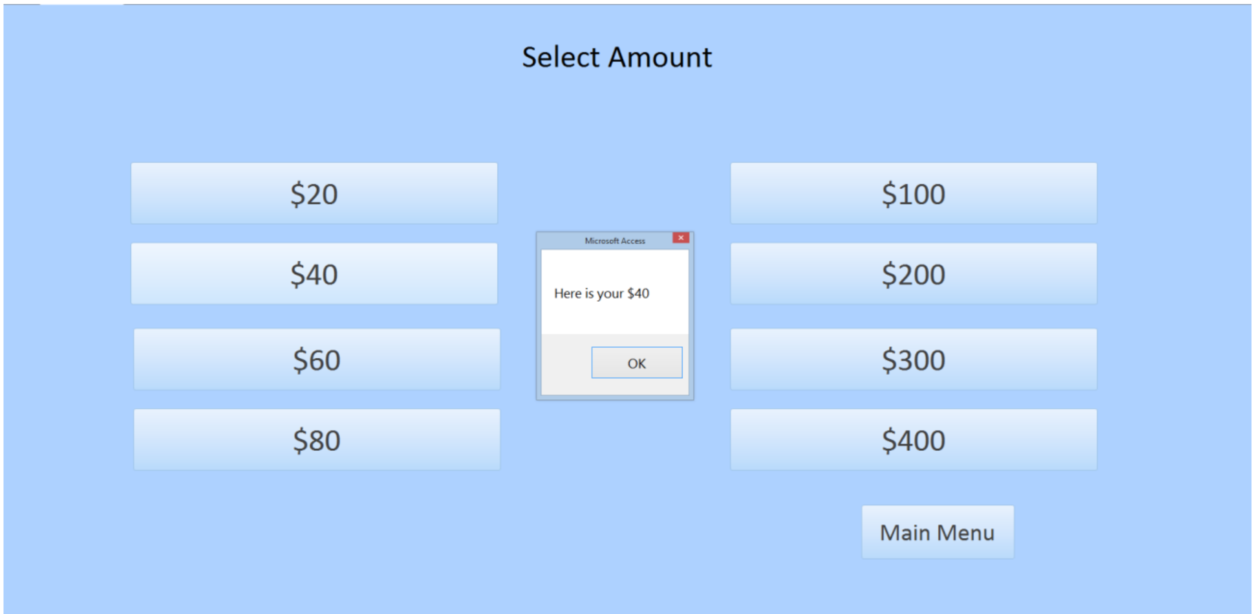
Payments Button



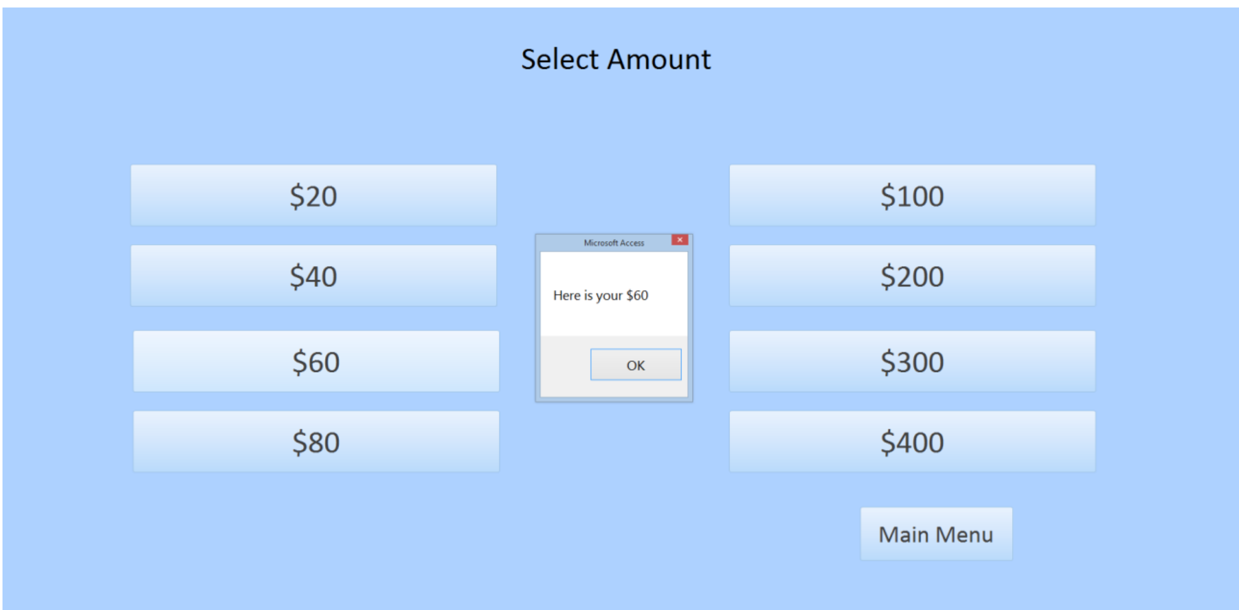
Additional Services

Fast Cash Button

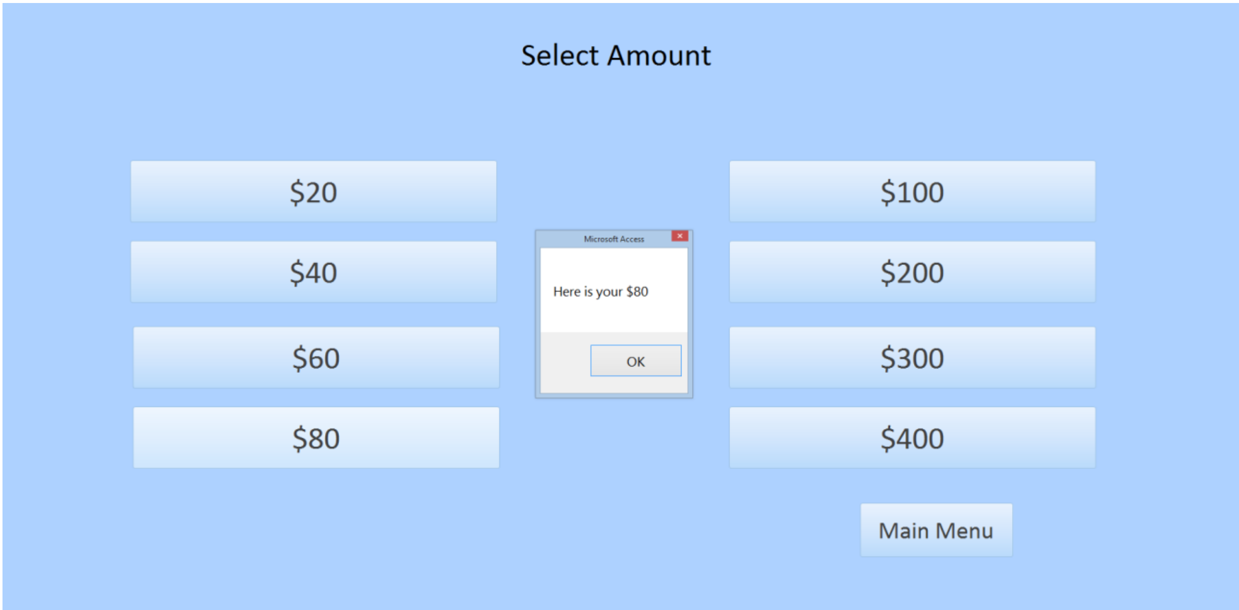
Fast Cash $20 Button



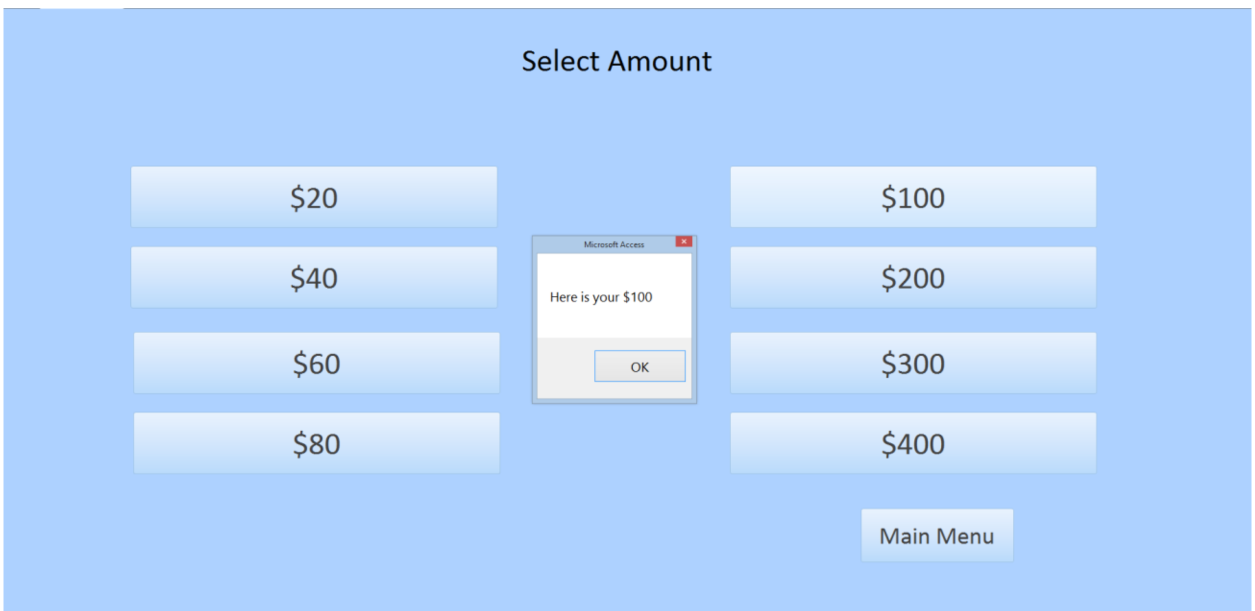
Fast Cash $40 Button



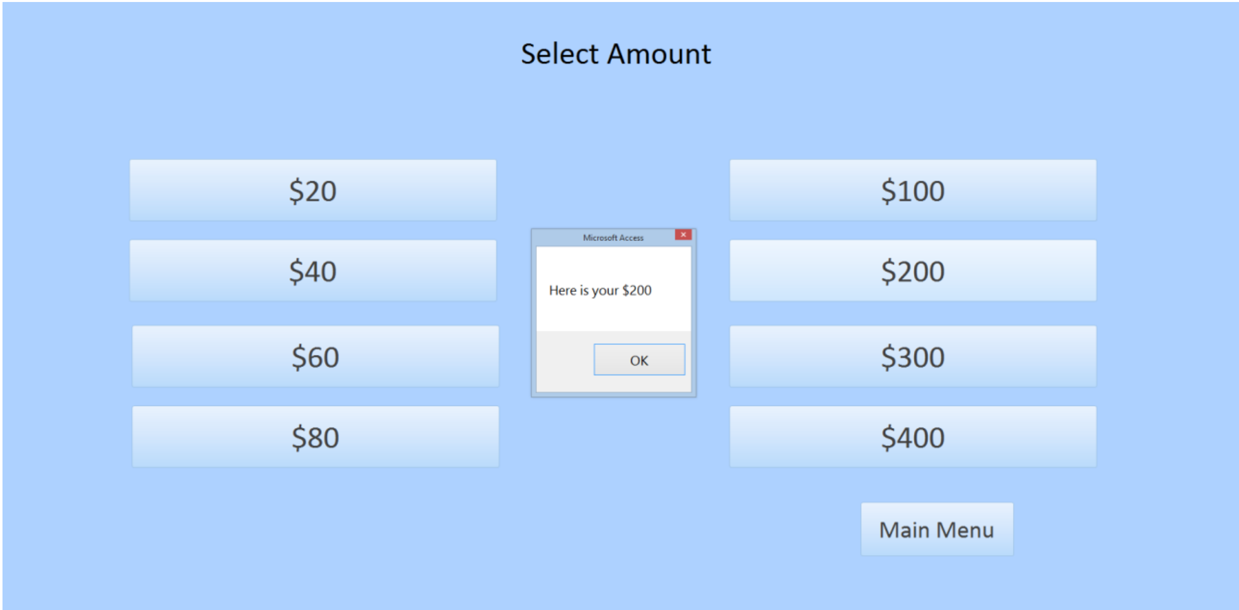
Fast Cash $60 Button



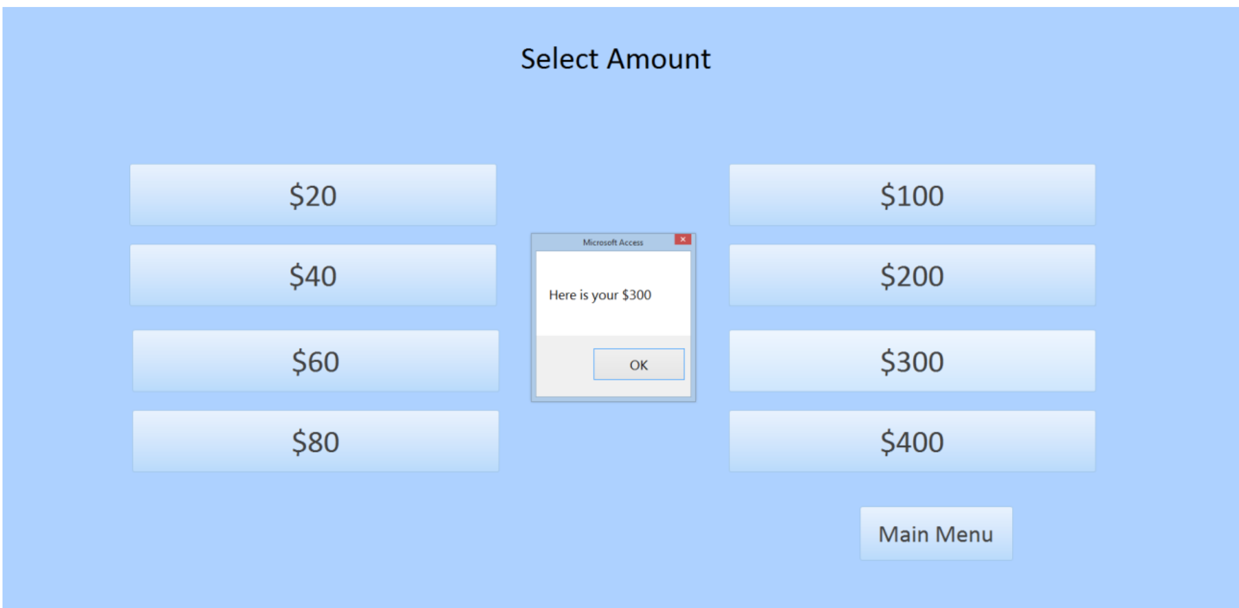
Fast Cash $80 Button



Fast Cash $100 Button

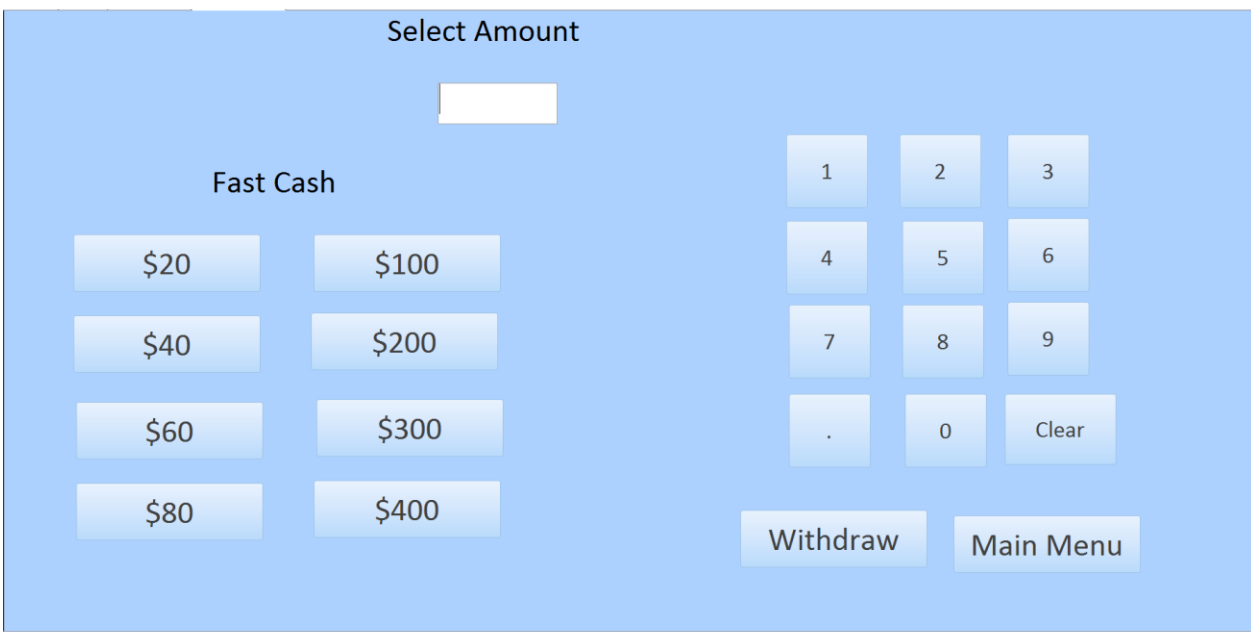


Fast Cash $200 Button



Fast Cash $300 Button

Fast Cash $400 Button

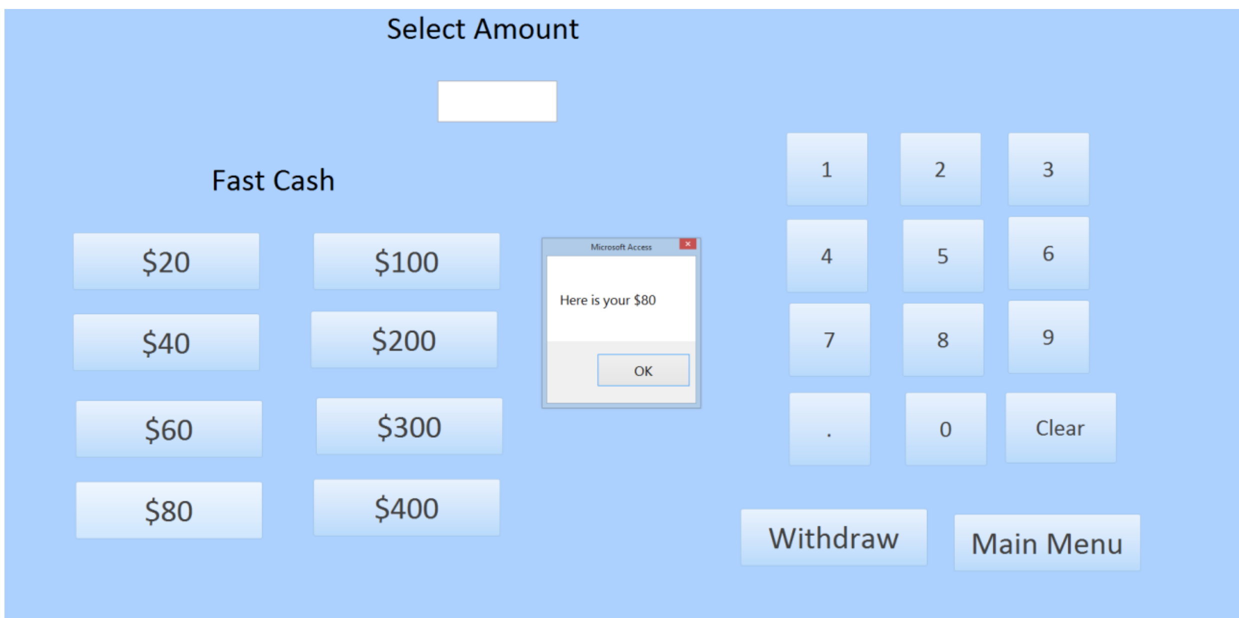


Withdrawal Button

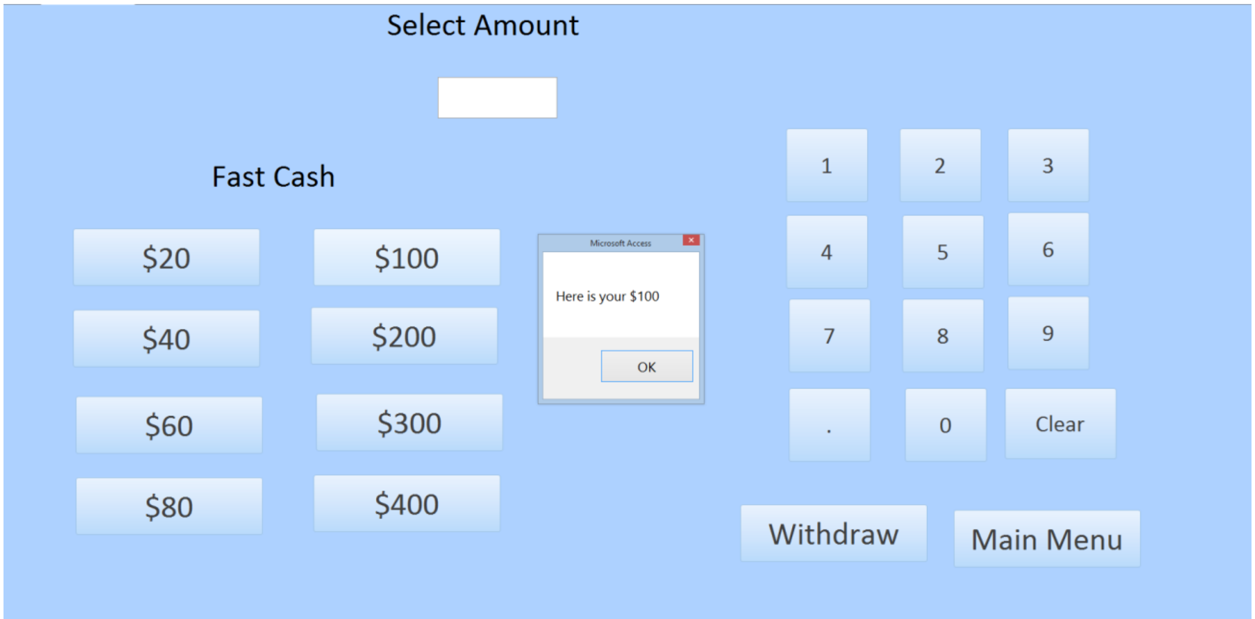
Fast Cash $20 Button

Fast Cash $40 Button

Fast Cash $60 Button

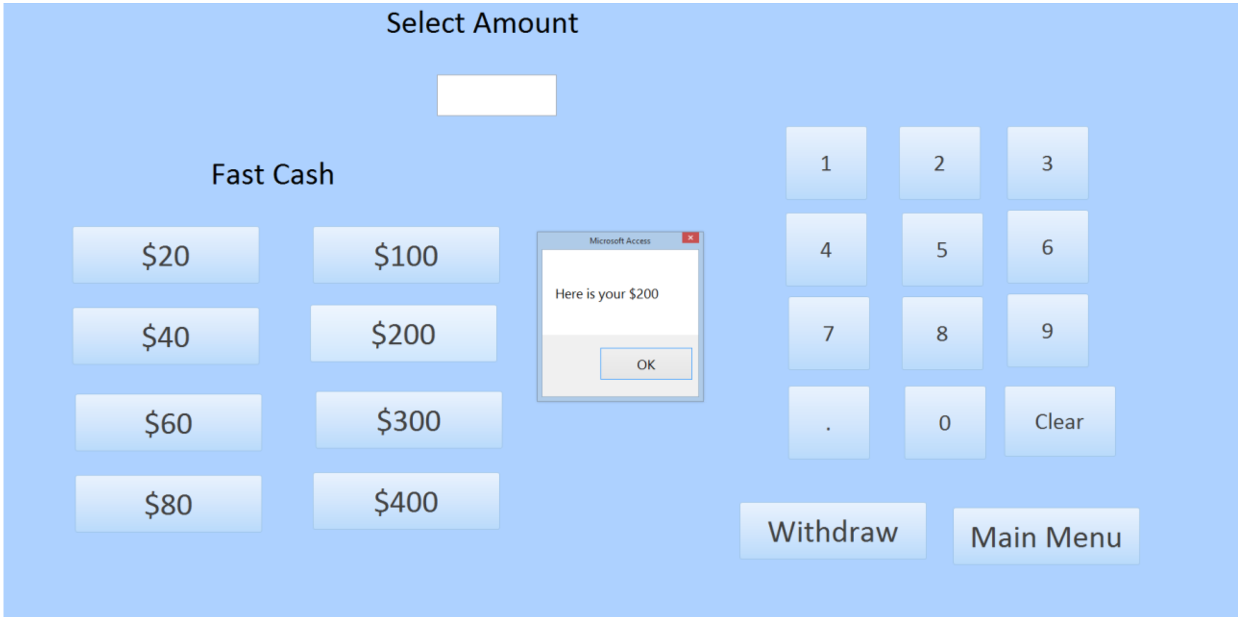


Fast Cash $80 Button

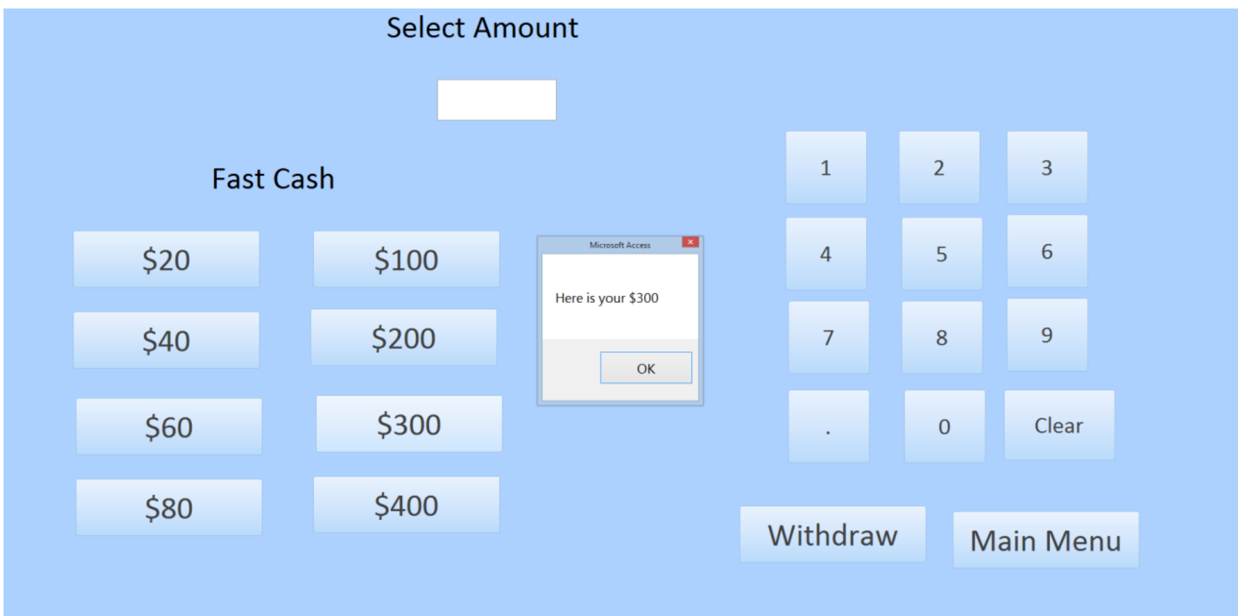


Fast Cash $100 Button

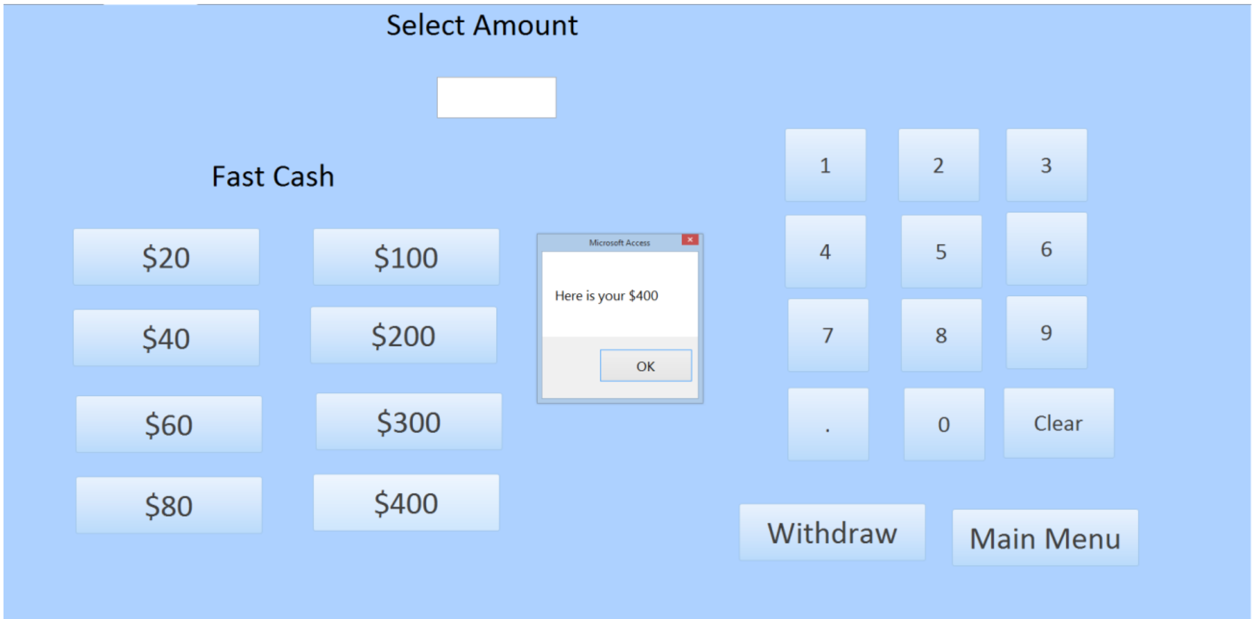
After Punching $100 into ATM



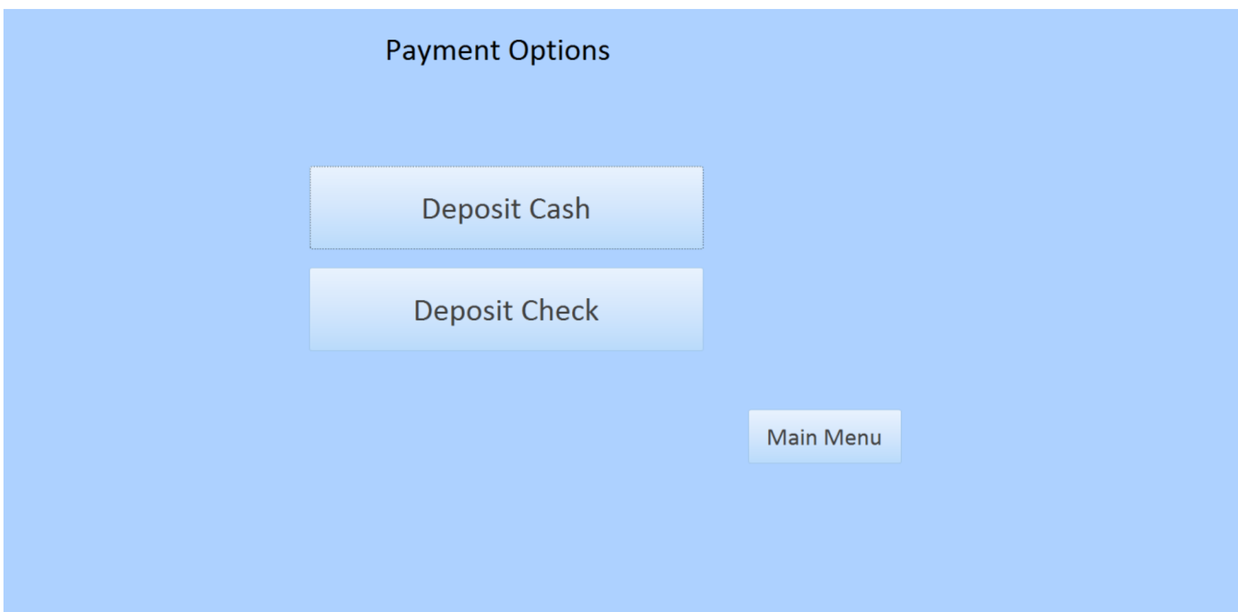
Fast Cash $200 Button



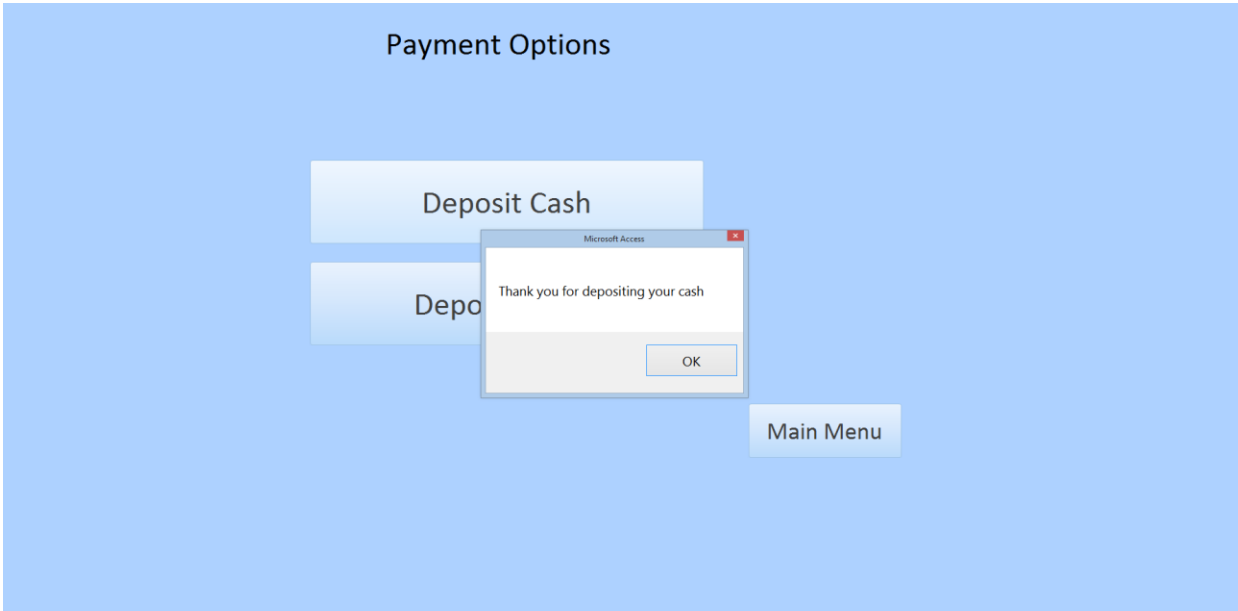
Fast Cash $300 Button



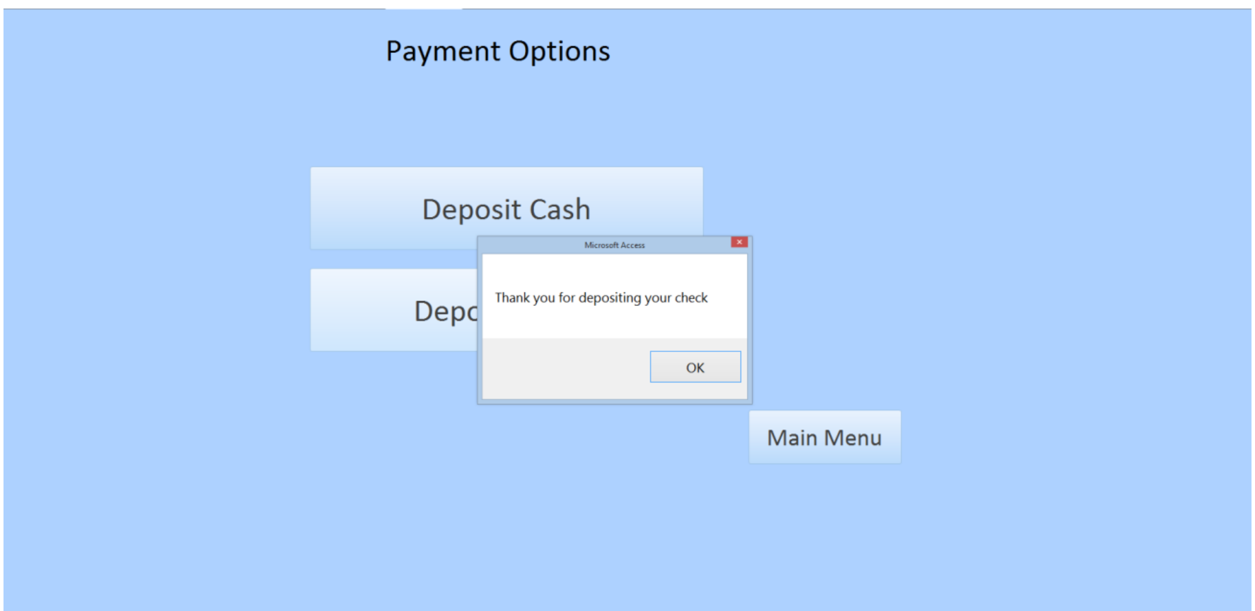
Fast Cash $400 Button



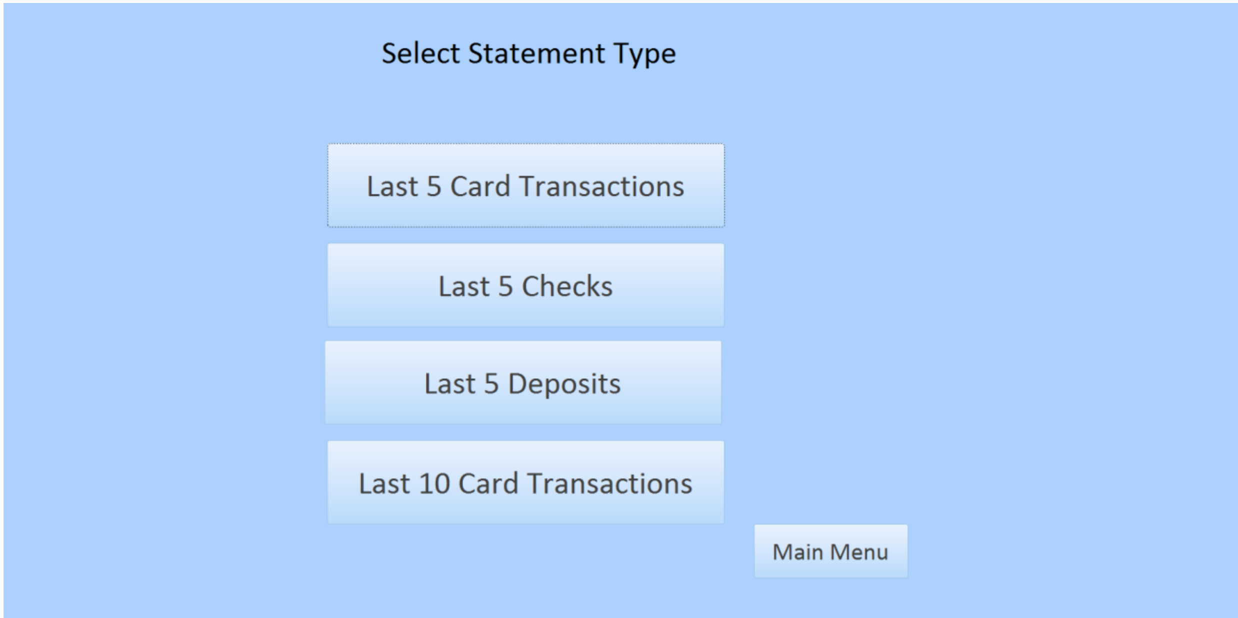
Deposit Button



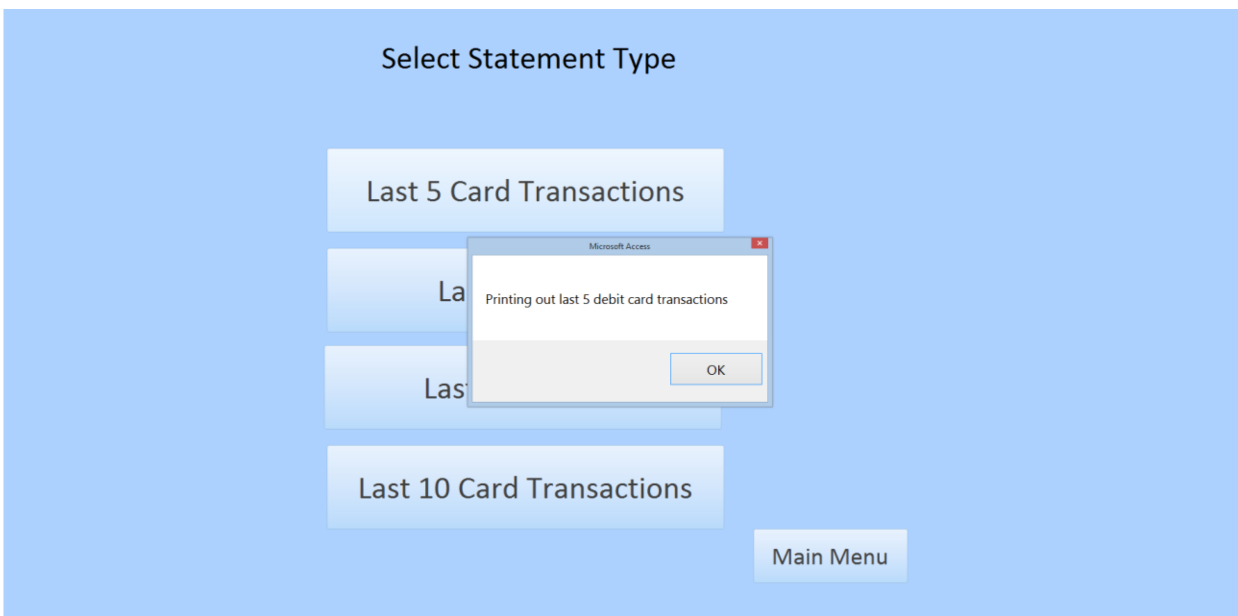
Deposit Cash Button



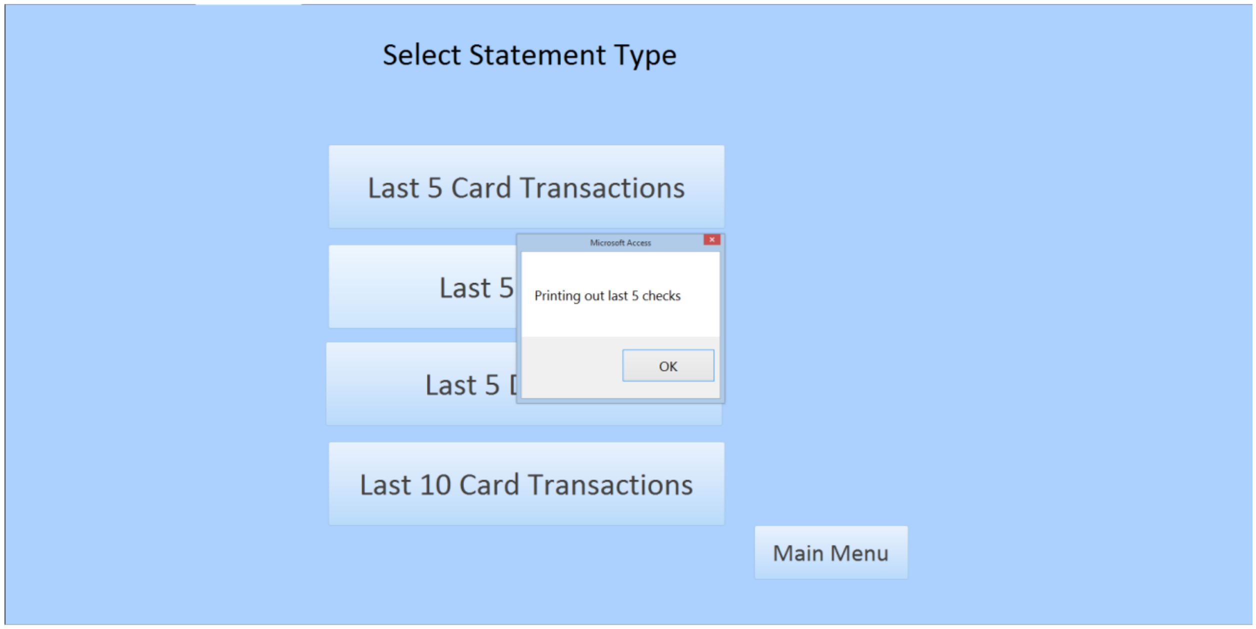
Deposit Check Button



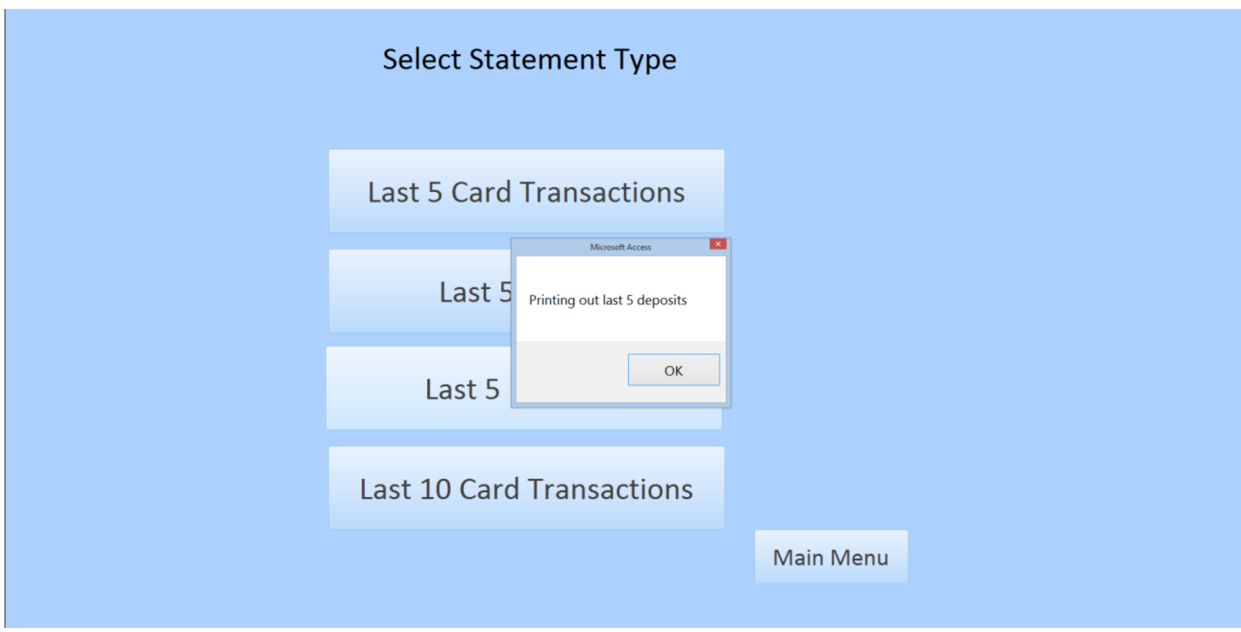
Statement Print Button



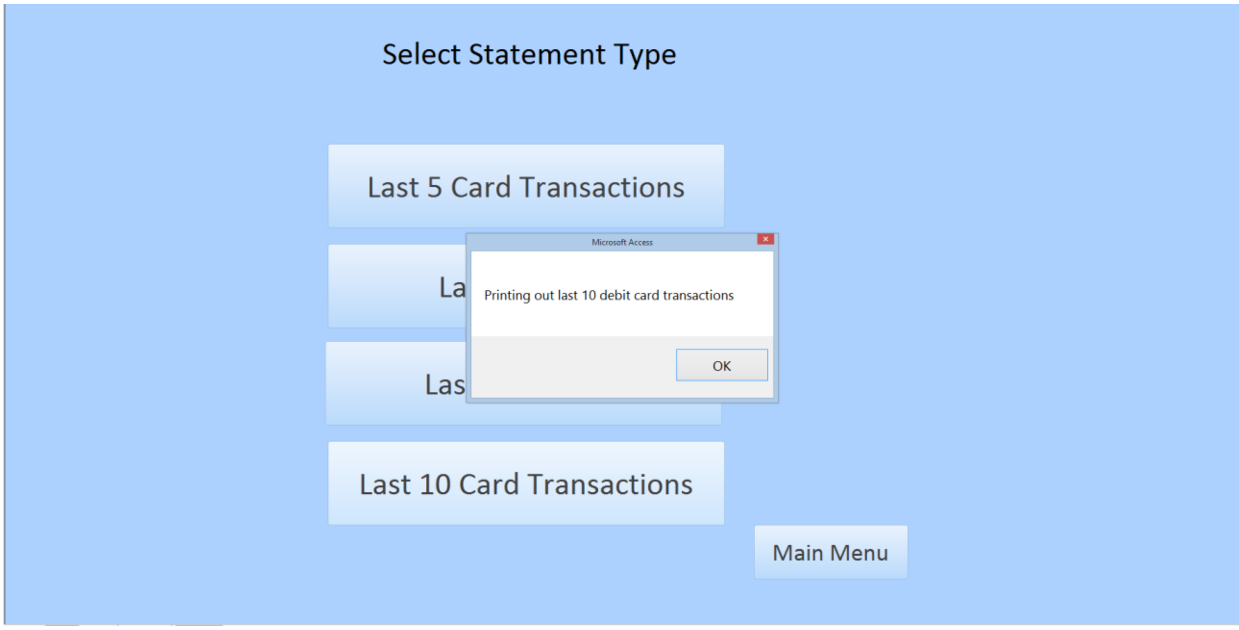
Last 5 Card Transactions



Last 5 Checks



Last 5 Deposits

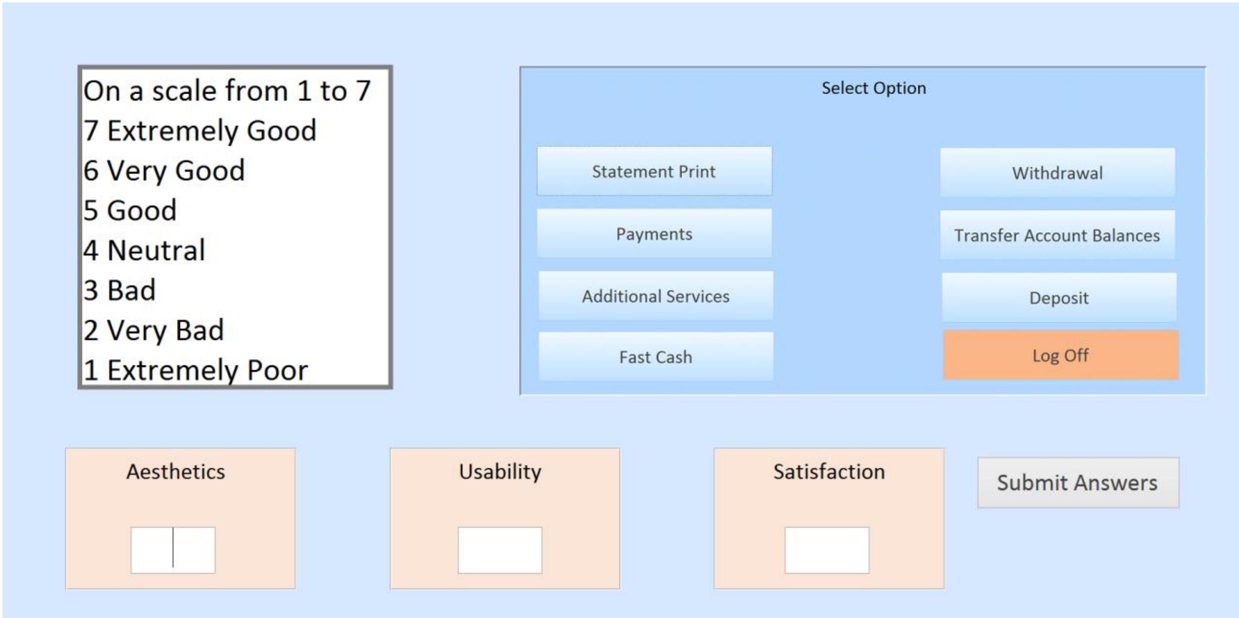


Last 10 Card Transactions

Rating Forms

Rating Form for All Button Form

Rating Form for Optimization Button



Rating Form for Traditional Form

Appendix B: Images of Solver

1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	0	1			
X1L	X2L	X3L	X4L	X5L	X6L	X7L	X8L	X9L	X1S	X2S	X3S	X4S	X5S	X6S	X7S	X8S	X9S	X10S	X11S	X12S			
2	2	2	1.5	1.5	1.5	1	1	1	1	1	1	1	1	1.1	1	1.1	1	1.1	1	1.1	8.2		
1	1	1	1	1	1	1	1	1													2	≤	2
									1	1	1	1	1	1	1	1	1	1	1	1	4	≤	4
1		-1																			0	=	0
			1		-1																0	=	0
						1		-1													0	=	0
									1		-1										0	=	0
												1		-1							0	=	0
															1		-1				0	=	0
																		1		-1	0	=	0
1			1						1			1									1	≤	1
	1			1						1			1								0	≤	1
		1			1						1			1							1	≤	1
			1			1						1			1						1	≤	1
				1			1						1			1					0	≤	1
					1			1						1			1				1	≤	1
1	1																				1	≤	1
	1	1																			1	≤	1
			1	1																	0	≤	1
				1	1																0	≤	1
						1	1														0	≤	1
							1	1													0	≤	1
									1	1											0	≤	1
										1	1										0	≤	1
												1	1								0	≤	1
													1	1							0	≤	1
															1	1					1	≤	1
																1	1				1	≤	1
																		1	1		1	≤	1
																			1	1	1	≤	1
1		1								1											2	≤	2
			1		1								1								0	≤	2
						1		1								1					0	≤	2

Appendix C: Raw Data

Subject #	Gender	Form	Time	Block	Aesthetics	Usability	Satisfaction
1	M	1	72	A	3	5	3
2	M	1	78	B	4	5	4
3	M	1	57	C	4	5	5
4	M	1	63	D	3	3	2
5	M	1	73	E	1	3	1
6	M	1	72	F	4	2	3
7	M	1	82	A	5	3	3
8	M	1	82	B	5	4	4
9	M	1	58	C	4	4	4
10	M	1	56	D	5	5	4
11	M	1	59	E	3	3	3
12	M	1	61	F	3	3	3
13	M	1	53	A	3	4	4
14	M	1	78	B	3	3	3
15	M	1	71	C	1	2	1
16	M	1	78	D	2	2	1
17	M	1	59	E	2	2	2
18	M	1	59	F	1	1	1
1	M	2	65	A	7	6	7
2	M	2	45	B	6	7	7
3	M	2	59	C	6	6	7
4	M	2	61	D	6	6	7
5	M	2	54	E	7	7	7
6	M	2	49	F	5	6	5
7	M	2	59	A	7	7	7
8	M	2	55	B	6	5	4
9	M	2	58	C	6	7	6
10	M	2	52	D	5	7	6
11	M	2	45	E	6	7	6
12	M	2	47	F	6	6	6
13	M	2	46	A	5	6	6
14	M	2	45	B	6	7	6
15	M	2	81	C	6	6	6
16	M	2	67	D	5	5	5
17	M	2	44	E	7	7	7
18	M	2	42	F	6	6	6

Subject #	Gender	Form	Time	Block	Aesthetics	Usability	Satisfaction
1	M	3	60	A	3	5	4
2	M	3	51	B	5	6	6
3	M	3	52	C	6	6	7
4	M	3	48	D	5	6	6
5	M	3	61	E	6	6	6
6	M	3	75	F	6	6	6
7	M	3	49	A	6	6	7
8	M	3	61	B	5	5	5
9	M	3	60	C	5	6	6
10	M	3	48	D	5	6	5
11	M	3	56	E	4	5	5
12	M	3	54	F	5	5	5
13	M	3	36	A	4	5	5
14	M	3	54	B	6	6	6
15	M	3	57	C	4	5	5
16	M	3	53	D	6	5	4
17	M	3	55	E	5	5	5
18	M	3	65	F	6	7	6
19	F	1	72	A	3	2	3
20	F	1	72	B	4	5	6
21	F	1	71	C	4	3	3
22	F	1	76	D	2	1	2
23	F	1	53	E	3	3	3
24	F	1	71	F	1	2	1
25	F	1	64	A	3	3	4
26	F	1	66	B	3	4	4
27	F	1	56	C	2	3	2
28	F	1	73	D	1	2	2
29	F	1	58	E	4	3	3
30	F	1	55	F	4	3	3
31	F	1	75	A	4	3	4
32	F	1	61	B	1	1	1
33	F	1	86	C	2	2	1
34	F	1	54	D	3	3	3
35	F	1	55	E	1	5	2
36	F	1	67	F	2	2	1

Subject #	Gender	Form	Time	Block	Aesthetics	Usability	Satisfaction
19	F	2	59	A	7	6	6
20	F	2	48	B	5	5	6
21	F	2	63	C	6	6	6
22	F	2	70	D	7	7	7
23	F	2	42	E	6	6	6
24	F	2	60	F	7	7	7
25	F	2	52	A	6	6	6
26	F	2	41	B	6	6	7
27	F	2	48	C	7	5	7
28	F	2	80	D	7	7	7
29	F	2	49	E	5	6	6
30	F	2	46	F	5	6	5
31	F	2	52	A	6	6	6
32	F	2	44	B	4	6	6
33	F	2	66	C	6	6	6
34	F	2	71	D	6	7	7
35	F	2	45	E	7	7	7
36	F	2	45	F	6	6	6
19	F	3	60	A	5	4	3
20	F	3	57	B	5	5	6
21	F	3	53	C	6	5	6
22	F	3	57	D	5	4	4
23	F	3	52	E	6	6	6
24	F	3	68	F	6	7	7
25	F	3	46	A	5	5	5
26	F	3	48	B	5	6	7
27	F	3	46	C	5	5	5
28	F	3	59	D	7	6	6
29	F	3	59	E	5	5	5
30	F	3	56	F	6	6	6
31	F	3	48	A	7	6	6
32	F	3	43	B	5	6	5
33	F	3	56	C	4	5	4
34	F	3	49	D	6	7	7
35	F	3	59	E	7	6	7
36	F	3	60	F	6	5	6

Appendix D: Informed Consent Form

Informed Consent Form

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT, “Examining the Impact of Operations Research on Graphical User Interfaces on Touchscreens.”

A research project on human computer interaction is being conducted by Christian Royer in the Department of Industrial and Manufacturing Engineering at Cal Poly, San Luis Obispo, under the direction of Dr. Tali Freed. The purpose of the study is to compare the effects of different Graphical User Interfaces (GUIs) in completing tasks.

You are being asked to take part in this study by performing tasks on a tablet and giving feedback on the design of the GUI. Your participation will take approximately twenty minutes. Please be aware that you are not required to participate in this research and you may discontinue your participation at any time without a loss of benefits. You may also omit any questions you choose not to answer.

There are no risks anticipated with participation in this study. Please be aware that you may contact Christian Royer at (408) 439-6227 for assistance.

Your confidentiality will be protected; all personal information and your individual performance results will remain confidential. Potential benefits for yourself associated with the study include food for participating. Other benefits possible include better designed graphical user interfaces.

If you have questions regarding this study or would like to be informed of the results when the study is completed, please feel free to contact Christian Royer at (408) 439-6227. If you have concerns regarding the manner in which the study is conducted, you may contact Dr. Steve Davis, Chair of the Cal Poly Human Subjects Committee, at (805) 756-2754, sdavis@calpoly.edu, or Dr. Dean Wendt, Interim Dean of Research, at (805) 756-1508, dwendt@calpoly.edu.

If you agree to voluntarily participate in this research project as described, please indicate your agreement by signing below. Please keep one copy of this form for your reference, and thank you for your participation in this research.

___________________________________ _______________
Signature of Volunteer Date

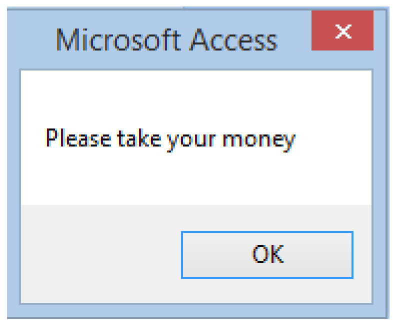
___________________________________ _______________
Signature of Researcher Date

Appendix E: Experiment Form

Experiment

Thank you for participating in this experiment. You will be asked to complete the following tasks using this tablet as an ATM as quickly as you can without making errors. Assume that you have a $20 Bill and a $20 Check already signed.

If the ATM asks you to "Please take your money" or to "Insert Cash or Check" you may pretend that you have done so and hit "OK" on the touchscreen, for example:



You will input commands based on the notecards that I flip over. If a task tells you to "Withdraw" a certain amount you must draw that exact amount. For example if you are asked to Withdraw $220, you must draw exactly that amount and not $200 and then $20. If you have any questions please feel free to ask. The experiment begins as soon as you touch "Begin the Experiment" on the screen.

Appendix F: Experiment Form

Practice

Thank you for participating in this experiment. You will be asked to complete tasks using this tablet as an ATM as quickly as you can without making errors.

In order to learn how to use the system you will perform a practice run so you can learn how the program works. You will input commands based on the notecards that I flip over. This section will not be timed. If you have any questions please ask. The practice run will begin as soon as you say "Ready."

Appendix G: Survey Form

Survey

Thank you for completing the experiment. Next you will be asked what you thought about Aesthetics, Usability, and your Satisfaction of the three ATMs. Please be honest with your feedback. If you have any questions about the definitions please ask.