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UI Use Across Differences In Experience with Computer Games Convention

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Abstract

As software becomes more and more demanding of our time and cognitive faculties, how this software is designed is becoming more and more important. This study aims to explore the origin of game design convention by examining how users interact with game UI depending upon their level of experience with a type of software; specifically StarCraft 2 (SC2). Participants were interviewed and sorted into three different groups: those with Below Average game experience (at or less than 5 hours/week playing video games), those with Above Average game experience (more than 5 hours/week playing video games), and those with SC2-specific experience. They were then asked to play the game for up to an hour as practice before their eye movements were recorded during a game against the AI and the percentage of total time spent upon different elements of the SC2 UI was analyzed using a one-way ANOVA. They were also surveyed on their impressions of the UI and those results were analyzed in another one-way ANOVA. Analysis found statistically significant results in four of the nine areas of interest, as well as in two of the five subjects on the questionnaire, mostly in relation to how the Below Average group compares to the other two groups. However, despite the significance of these results, several limitations on the study lead to the conclusion that the current study was largely inconclusive.

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Background

In an age of increasing reliance on computer tools, the user experience for those at different levels of experience with systems is important to study. Someone new to a system or just learning will have a different way of thinking about their use of a system than those who have mastered it (Fix, Weidenbeck & Scholtz, 1993). For example, someone who has not looked at Photoshop before, or who has only used it to crop a photo, may not care about using calculations to make a complex selection, yet the software still has to cater to both users. Studying these concepts lets us understand how we can apply the diverse needs of different users to the development of new systems and technology.

To combat confusion for new users, developers use design conventions present in other, similar programs. The idea is that users that are familiar with a type of program will be able to quickly learn another program with similar goals as long as there are recognizable similarities. This coding of products allows designers to quickly impart meaning to the user without having to write out a description of each individual aspect of the program. Moreover, a common pattern of cross-program conventions can facilitate incidental learning (Grossman, Dragicevic & Balakrishnan, 2007) as well as benefit experiential learning through similar experiences and goals that can capitalize on the previously formed schema (Kiili, 2005). For example, many programs grey out options in a menu, showing the user that these options aren't available for whatever reason, usually while they have a certain aspect selected that is incompatible with the command they are trying to give. This is a practice so universal that it is used across all modern computers' user interface (UI). In fact, if you are reading this online and right-click on your mouse with nothing selected right now, the menu option "Copy" will likely appear in this state.

An obvious use of such coding is in computer and console games. A common example is using stimulating colors (Joosten, Lankveld, & Spronck, 2010), such as the color red to signify enemies and green to signify allies. In a first-person shooter game (FPS) such as Call of Duty, the targeting reticule in the middle of the screen will often flash red if you shoot an enemy, and green if you shoot an ally. Similarly, in strategy games, health bars are usually red for enemies and green for allies. Alternately, the same health bars might be green at full health, yellow at half health, and red at very low health. However, colors are just one aspect of shared coding between games, even between different genres. Controls and keys bindings are another aspect that is often similarly coded. For example, many players of computer games will default to placing their hands on the W, A, S, and D keys, and the pause/game menu button is usually bound to the ESC key.

While Grossman (2007) showed that cross-software conventions applied to non-competitive and non-game systems, are the results applicable to games? Unlike the database software Grossman used to test learning methodologies, computer games are quite varied in their experiential purpose. An FPS game like Call of Duty will have very little to do with a real time strategy (RTS) game like Age of Empires, but both still use game conventions such as color theory and default hand placement as well as a historical setting that uses the player's knowledge of real world events to contextualize gameplay decisions, all while having vastly different victory conditions and play experiences. Moreover, just like the historical framing device, the same conventions of color and user hand position can be viewed as merely extensions of real-world experiences, such as red being used in “stop” or “do not enter” road signs, or a user having practiced typing and habitually positioning their hands on the keyboard the same way regardless of program intent. In other words, are the cross-program conventions games rely upon merely a series of game-specific design shorthand or are they extensions of our real world experiences, leveraged for personal enjoyment and competition?

To examine this topic more closely, it first must be determined if there are differences in behavior between those with game experience and those without game experience, with those who are more proficient at any game used in the study as a control. If such differences exist, where the differences lie could shed some light on the source of shared cross-program conventions.

Methods

In order to best study how different groups of people play a game we need to find a way to study the user experience of the participants. Many studies in UX research and systems are qualitative studies that focus on asking participants to use a system, product, or piece of software and recording their responses as well as any problems they encounter (Rohrer, 2014). However, in order to study a user’s natural state of gameplay, participants should not feel as thought they are being scrutinized or having someone look over their shoulder, nor should they comment about their actions while playing; another form of self-report that would take them out of the experience of playing the game. It would be far more helpful when examining differences in play patterns to use a minimally invasive method that will provide quantitative data in the form of hard numbers about in-game behavior.

An option that satisfies all these requirements is using a wearable eye tracker. Using eye-trackers to analyze elements of game UI via gaze fixation has already proved to be a popular analytical method for computer games (Corcoran, Nanu, Petrescu & Bigioi, 2012). In addition, by applying analytical tools such as gaze fixation and visual span analysis, eye tracking has been shown to display different results for those of different experience levels in both professional (Law, Atkins, Kirkpatrick & Lomax, 2004) and recreational tasks (Reingold, Charness, Pomplun & Stampe, 2001). This system can capture unconscious actions such as eye movements while still being minimally intrusive to the participant, allowing them to play naturally without the need of someone looking over their shoulder or potentially diminishing their investment in the game by constantly self-reporting.

When looking at quantitative rather than qualitative UX research, eye tracking is frequently used in advertising, measuring where, when, and for how long you fixate when looking at a display or an online ad. Eye trackers have also been used to map areas of interest and fixation in much more dynamic environments such as driving (Palinko, Kun, Shyrokov & Heeman, n.d.) or when shopping (Dalton, Collins & Marshall, 2015), and have been used to show clear differences between the gaze behavior of novices and experts at specific tasks (Gegenfurtner, Lehtinen & Säljö, 2011). It is my goal that by using eye tracking to measure a user's eye movement and gaze fixations on important areas of the screen while playing a game, we can attain insight into how differing levels of experience influences a player's approach to that game. As the most obvious way that games deliver information is through the interface, we can see what information is prioritized across groups based upon how much of their time is spent fixating on which UI elements, and how that differs between groups, if such differences exist at all.

To do this, the computer game in question must be sufficiently engaging, so that anyone wearing an eye tracker will spend most of his or her time looking at the software itself, rather than at a researcher. StarCraft 2 (SC2), an RTS game with a plethora of previous research (Huang, Yan, Cheung, Nagappan & Zimmermann, 2017) (Churchill & Buro, 2011) (Vinyals et al., 2017), fits this goal well. This game has many factors that make it a good metric for this study in particular. To start with, playing the game well requires constant attention and demands both knowledge of complex systems and quick inputs. Its UI is simple without menus moving or information obscuring the field of play, making it easy for the current eye-tracking software to analyze. It has a simple and unchanging core goal that even new players can easily understand; namely, gather resources and make an army to destroy your enemy's base while protecting your own. Lastly, it also has an interactive tutorial for learning the basics, meaning that anyone completely new to the game will be able to learn it in a more effective way than just reading a guide or watching a video (Allcoat & von Mühlenen, 2018).

As SC2 employs a comprehensive UI for all aspects of play, examining how much time is spent on different aspects of the UI for each of three levels: below average games experience, above average games experience, and experience with SC2 specifically, would be an effective measure of how these different g levels experience the game. However, the variable length of a game of SC2 means that simply analyzing total number of fixations or total fixation duration, like previous eye-tracking studies, would lead to wildly different results. Therefore, rather than study duration of gaze fixations, studying the percentage of total time spent fixated upon a specific UI element across total game time compared between groups would be far more effective. With that in mind, and based upon previous research, it is my hypothesis that those with previous experience playing SC2 will spend a lower percentage of their game time looking at the UI in comparison to those with below average game experience, with those with above average game experience falling in between the two.

Procedure

Participants consisted of 23 people, mostly students, (20 men and 3 women) between the ages of 21 and 32 gathered from online message boards, school newsletters, and word of mouth. Participants were screened to make sure that those who need glasses to play computer games were excluded, as the eye tracker was incompatible with glasses.

Measurements of eye movement using a gaze sampling frequency of 50hz were taken using Tobii Pro 2 wearable eye tracking glasses. Games were played on a tower PC with a corded mouse and a mechanical keyboard. All games were played on the same map (Catalyst LE) and had a maximum playtime of 30 minutes with default handicap. Participants were free to chose their race (Terran, Zerg, or Protoss) as well as the level of AI they would play against. This self-regulation was to ensure a more uniform level of comfort than one AI against all groups. No mods were installed on the game and all other lobby settings were at their default. After testing was complete, all outside lobby settings, such as camera controls, were returned to their default.

A small white paper border was applied to the monitor to help facilitate eye-tracking analysis. The lab space consisted of a desk with the computer, a chair designed for computer use, and a small stool positioned beside the desk so that researchers were not directly looking over participants' shoulders.

All participants were briefed on what the details of the experiment. After giving written consent, each participant was interviewed about their history playing games as well as their demographic information (Questions in appendix A). They were asked if they had played StarCraft 2 before this study, and if so, how much they play/played as well as if they have any custom settings. Notes on custom settings, if any, were taken. Lastly, they were asked how many hours per week they played electronic/computer games in general, and if they did, what games or genre of games they play.

Questions were open-ended and answers were used to sort them into one of three groups, with no one participant in more than one group. These were administered in a light and friendly tone to limit both undue stress and performance anxiety caused by the nature of the experiment, as well as to promote a relaxed atmosphere so that participants can play how they naturally would.

The three exclusive groups divided participants up by their past gaming experiences and the number of hours they reported playing games during the week. A study by Loan (2011) found that students in university reportedly spent an average of five hours playing video games each week, with some outliers. With this in mind, those that reported spending less than five hours per week of playing games recreationally were sorted into the Below Average (BA) group. The Above Average (AA) group was made up of those that reported spending five hours or more than five hours a week playing games. Lastly, participants that reported previous experience playing StarCraft 2 were sorted into the SC2 Specific (SCS) category.

After the interviews, all participants were given one hour to play StarCraft 2 while wearing the eye tracking glasses turned off, so as to acclimate to playing while wearing them. Those without prior experience were encouraged to play the beginner tutorial built into the game. This was to provide a base knowledge of the game without the effort of unstructured exploration (Tuovinen & Sweller, 1999). After they were finished with the tutorial, or if they elected to ignore it, participants were shown the lobby where the data will be collected and were encouraged to play a game and practice against the AI on the map the data collection game would be played on. They were given the freedom to choose which of the three “races” to play as, Terran, Zerg, or Protoss. During this time, the researcher would inform the participant that if they felt lost, or had any questions or concerns about the mechanics of the game, the researcher would endeavor to answer them to the best of their abilities.

After the hour was up, or if the participant felt ready and wanted to move on before the hour had elapsed, the participant was asked to end what they were doing. The eye tracking glasses were then turned on and calibrated. In cases where calibration was difficult, a small secondary exercise was run to make sure that all peripheral eye movement was being successfully tracked by the glasses. Then the player was placed into a custom lobby and asked to choose an opposing AI level they felt would be neither too easy nor too difficult. Participants were also asked to silence their cellphones and remove any headphones if they were wearing any to prevent unintended interference with the glasses. Once the participant started the game, the researcher was to be as quiet as possible and not interrupt unless otherwise necessary until the game was over, regardless of outcome.

After the game ended, participants were asked to fill out a ten-question survey about the UI and their experience with it (Appendix B) to determine how the three groups perceived the UI itself. This survey was created using questionnaire items developed by Laugwitz, Held, & Schrepp that were designed to measure the user experience of a user interface across 5 factors: Perspicuity, Efficiency, Dependability, Stimulation, and Novelty (Laugwitz, Held & Schrepp, 2008). For the purposes of this study, of the 20 different questionnaire items they evaluated, one appropriate item was used from one each of the five categories to make up the 10 questions. These asked the user to report how much thy agreed that the UI was Conventional, Supportive, Exciting, Organized, and Easy to Learn, as well as their respective reverse-coded alternatives. Participants were then asked to rate their agreement with the statements made on a seven-point Likert scale where 1 = “Completely Disagree” and 7 = “Completely Agree.”

Afterwards, all participants were thanked and debriefed as to the nature of the experiment, which in no way differs from the initial informed consent form.

Data Analysis

The eye tracking data was analyzed using TobiiPro eye tracking analysis software. Locations on the screen that contain UI elements were mapped and labeled as areas of interest (or AOIs). Nine distinct AOIs were plotted on the screen (fig 1).

1. Resources (the requirements to build an army).
2. Unit/Build Popups (Information about any building, unit, or skill that can be constructed)
3. Unit Skills (the window in which units and buildings are given orders beyond movement and attacking)
4. Unit Portrait (an only cosmetic animated image of the currently selected unit or building)
5. Minimap/Clock (a moving map of the battlefield showing your units and buildings as well as any enemies that you can see and a small clock just above it)
6. Idle Groups (notification location for any units not currently being used)

7. Control Groups (players can see here where they have assigned groups of units to particular keys)
8. Army Details (displays the current number and type of unit or units selected)
9. Overworld Orders (the part of the screen where the majority of the game is played. Here players give movement, combat, and build location orders. Not an element of the game's UI.)

The percentage of time spent looking at each of these nine elements was compared per element across the three groups using One-Way ANOVAs and subsequent post-hoc analyses, dependent on normality of the variables, using SPSS (with $\alpha = 0.05$). Reponses to the questionnaire were also compared across groups and tested for significance.

(Figure 1. AOIs in colored boxes clearly labeled.)

Results

A total of 20 men and 3 women between the ages of 21 and 32 took part over the course of three months. For groups, 6 fit the requirements for the Below Average (BA) group, 7 fit the requirements for the Above Average (AA) Group, and 10 were reported having previous experience with the game, resulting in their inclusion into the SC2 Specific group (SCS). Of the three playable factions within the game, 8 chose Terran, 7 Zerg, and another 8 Protoss.

A one-way between subjects ANOVA was run to determine total percentage of the game time spent looking at each of the nine UI elements across all three groups. There were found to be a significant effect the level of experience had on the percentages of time spent looking at the AOIs of Overworld Orders [$F(2, 20) = 7.69$, $p= .003$], Unit Skills [$F(2,20) = 4.87$, $p= .019$], Unit/Build Popups [$F(2,19) = 9.74$, $p= .001$], and Idle Groups [$F(2,20) = 11.28$, $p= .001$].

Post Hoc comparisons using the Tukey HSD test (Appendix C) showed that the BA Group spent significantly less time fixating on the Overworld orders compared to the SCS group (64.2 ± 6.2% *vs*. 81.3 ± 6.8%, $p= 0.003$). It was also found that the BA group spent significantly more time fixating on the Unit Skills window compared to the SCS group (13.69% ± 6.4% *vs*. 5.23% ± 5.25%, $p= 0.02$). Further examination showed that the SCS group ($M= 2.51\%$, $SD= 1.7\%$) spent significantly less time fixating on the Unit/Build Popups than both the AA group (2.51% ± 1.7% *vs*. 11.37% ± 6.96%, $p= 0.001$) and the BA group (2.51% ± 1.7% *vs*. 9.27% ± 2.15%, $p= 0.017$), although no significant difference was found between the AA and BA groups. Lastly, it was found that the BA group spent significantly more of their game time fixating upon the Idle Groups AOI than by both the AA group (0.95% ± 0.59% *vs*. 0.11% ± 0.1%, p= 0.001) and the SCS group (0.95% ± 0.59% *vs*. 0.15% ± 0.3%, p= 0.011), although no significance was found between the AA and SCS groups.

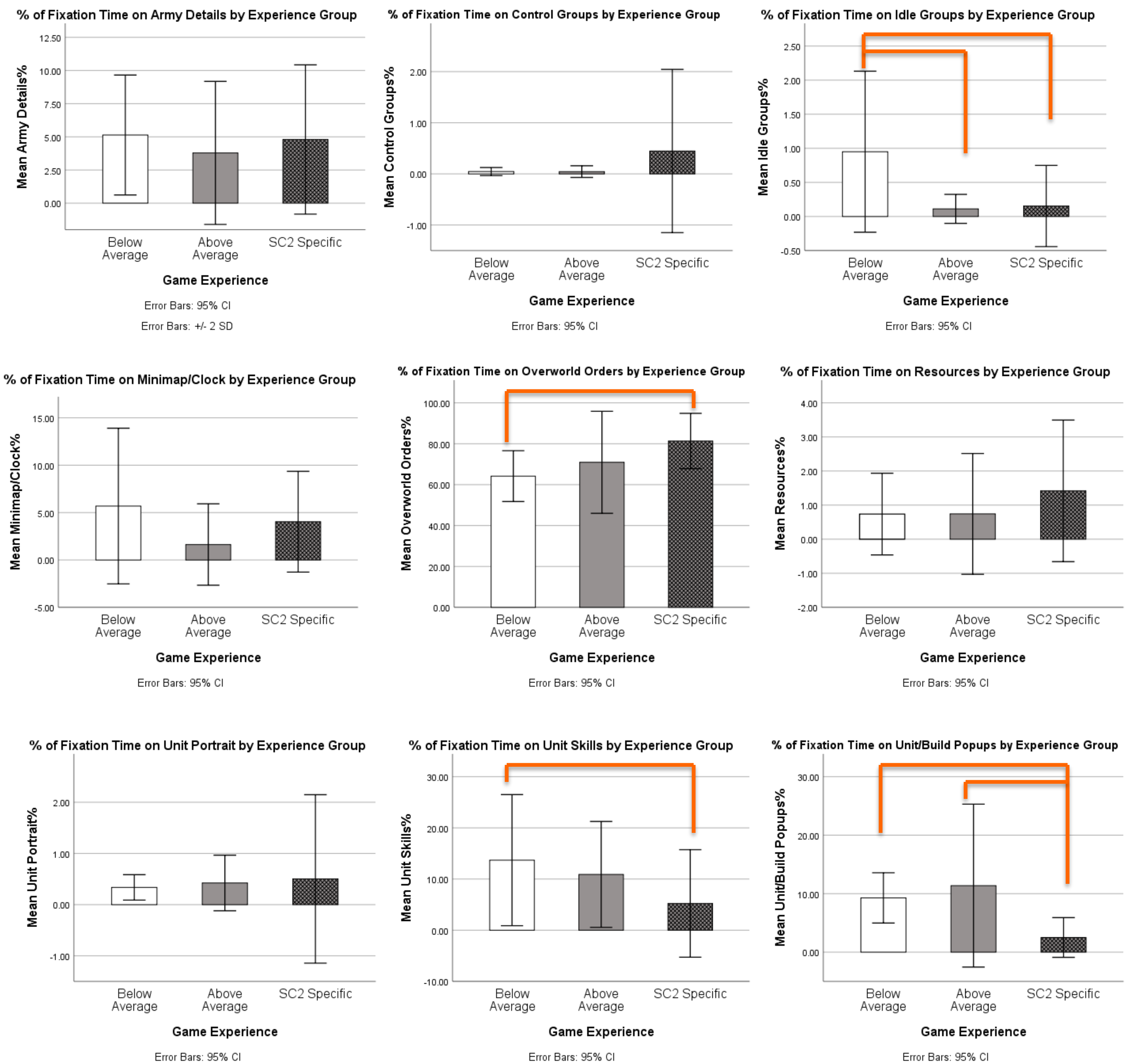
A second one-way between subjects ANOVA was run to determine score of participants' surveyed opinions on the UI elements across all three groups. There were found to be a significant effect the level of experience had on the opinion of the UI as Conventional [F(2, 20) = 4.86, p= .019] and upon the opinion of the UI as Supportive [F(2,20) = 5.02, p= .017]. Post Hoc comparisons using the Tukey HSD test (Appendix D) showed that the BA group reported finding the UI less Conventional than the AA group (3.91 ± 0.66 *vs*. 5.14 ± 0.94, p= 0.015). It was also found that the BA group reported finding the UI less Supportive than the SCS group (3.75 ± 1.6 *vs*. 5.55 ± 0.8, p= 0.017).

Heatmaps of the gaze data were also examined for outliers or technical errors in data collection, and used to adjust AOIs in extreme cases (Fig 2).

Fig 2. Heatmap created from a member of the SCS group showing the places with the longest gaze duration.

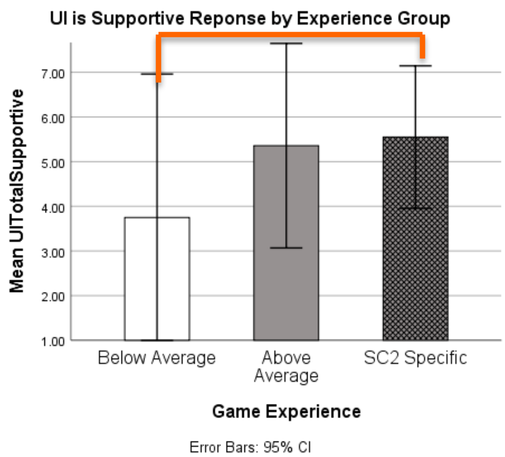
Eye-Tracking Fixation Duration %

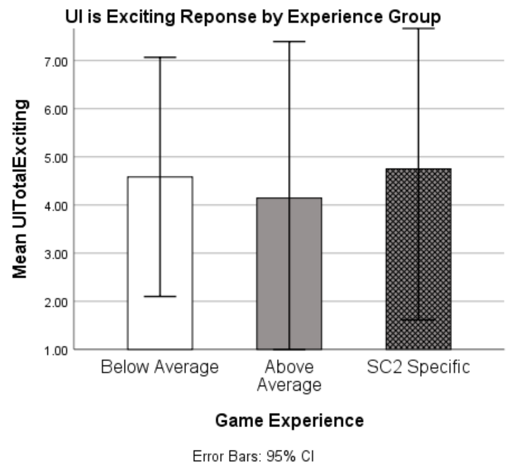
(Statistical Significance shown by orange lines)

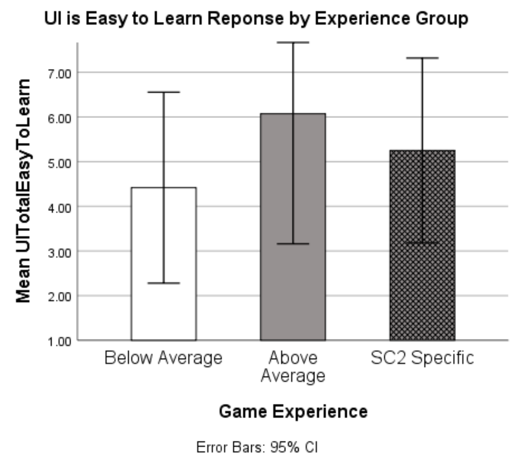


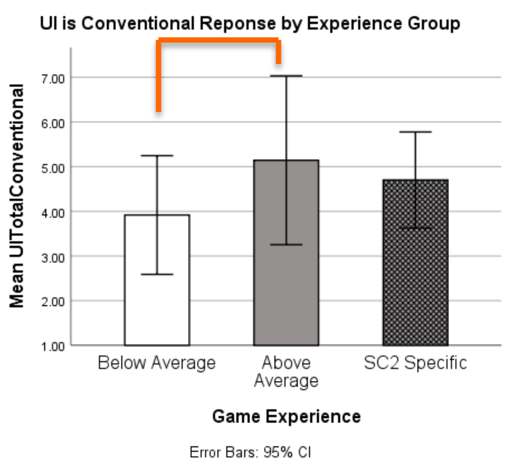
UI Survey Responses

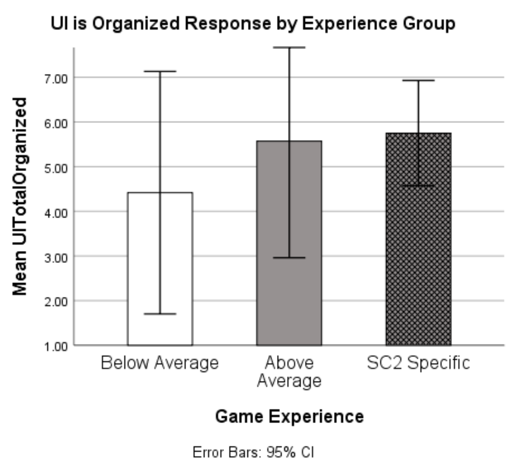
(Statistical Significance shown by orange lines)











Discussion

Results indicate that the hypothesis was partially supported, with a significant difference found between the mean percentages of fixation duration on the UI vs. the overworld of the game between the BA and the SCS groups. However, there were no significant differences found between the AA group and the other two groups, leading to the second half of the hypothesis remaining unsupported. This significance is easily explained when the data is examined alongside past research, which has shown that there is a clear differentiator between novice and expert performance and knowledge (Larkin, McDermott, Simon & Simon, 1980) (Judkins, Oleynikov & Stergiou, 2008). In other words, the BA group that is interacting with unfamiliar software will undoubtedly rely upon the information found in the UI more than someone with game-specific knowledge. Indeed during testing those in the Below Average group asked most of the questions. Topics of the questions were concerned mainly with controls, but sometimes there were inquiries about where something was, or what to do next. Questions often came back even after being shown more in-game knowledge. In three of the cases, confusion persisted even into data collection time.

All other measures of percentage of fixation duration on the UI that were found can also be explained by experience, but the question still remains if the differences come from experience with computer game convention as a whole, or from experience with SC2 specifically. To explain this, if the significant difference only lies between the BA and the other two groups, and neither of them have statistical significance, then we can conclude that the most likely factor distinguishing their results is their inexperience with games as a whole. Conversely, if the SCS group shows significance in relation to the other two groups, but those groups do not have significance between them, then we can conclude that the results are from experience with StarCraft 2 rather than with games as a whole. However, the Overworld Orders AOI results found no significance in the AA group's relation to either of the other groups. While this might lead one to believe that neither claim about the conventions of design was supported, another explanation for this could be that some in the AA group were not just familiar with games, but familiar with games of a similar genre. Indeed, many participants reported familiarity with other RTS games like Age of Empires, Age of Mythology, etc., often naming them specifically, after which they seemed much more comfortable. While the results still remain inconclusive as to the origin of game convention, it does hint that future studies examining a similar AA group divided by game genre preference may yield far more concrete results.

With that in mind the significance found in the mean viewing percentages of the Idle Groups UI element between the Below Average group (0.95%) and both the Above Average (0.11%) and SC2 Specific (0.14%) groups can likely be explained by a less experience with games. The Idle Groups UI element is meant to tell the player if they have units sitting around that haven't been given orders, and more helpfully, this includes worker units. However, it also shows a Hotkey shortcut to automatically select an idle worker. So someone with more experience using a computer for games could be more used to using hotkeys than someone who was less familiar. I think that familiarity with hotkeys and keyboard shortcuts goes a long way to explaining this difference, as pressing the hotkey for an idle unit when no units are idle does nothing. Anyone familiar with this idea can simply press and check without looking at the element itself, while those unfamiliar would have to visually check. This may also explain why this element made up only about 0.95% of average duration, even in the highest duration group, as after a few visual checks, players will start using the hotkey, negating the need for visually checking the element. The only difference would be in how quickly they picked up that idea, a difference based upon game experience.

Familiarity with Hotkeys as a concept might partially explain the significant difference found between the percentage of time the BA group (13.69%) and SCS group (5.23%) spent viewing the Unit Skills UI element, despite there being no significance being found in relation to the AA Group. While the Idle Groups element has only one hotkey, the Unit Skills element displays dozens that represent the orders that you can issue to any specific army unit, building, or worker. This one panel can display multiple nested menus, all with hotkey shortcuts, not to mention that while some orders, such as patrol, are shared across units, many units are unit-specific. In other words, each time you click something new, unit or building, this panel changes meaning that familiarity varies between units. The hotkeys for workers are used every game, so players are much more familiar with their specific hotkeys, but might not be as sure about the hotkeys for the skills of units they aren't used to building, and so would have to look at them to double-check unless they play regularly and/or are ranked incredibly highly, even if they are familiar with hotkey use as a whole. In fact, one grandmaster-ranked participant did not look at this section even once during his game. When asked about it he replied by laughing and commenting that he forgot that part existed and that it was all muscle memory to him. In other words, if there were access to sufficient numbers of high-level SC2 players to form their own participant group, this part of the UI might not be looked at by anyone. However, among the other 22 participants, each person fixated there at least once, which is unsurprising considering the complexity of the element.

When it came to elements not listing hotkeys, only one UI element showed any significant differences in fixation duration percentages between groups: Unit/Build Popups. It was found that SCS group spent a significantly lower percentage of game time (2.51%) when compared to both the AA (11.37%) and BA (9.27%) groups. This is hardly surprising as the popups for units and buildings display detailed information about the skills of units and what buildings can produce, as well as how much it will cost of each of your resources. Information that is this specific would only be known to those who have invested, or currently invest, a lot of time into the game. Ergo it makes sense that the only significant difference found would be for those with SC2 specific knowledge.

When looking at survey specific results, there are only two areas where any statistical significance was found in how participants reported their opinion of the UI: how conventional it was and how supportive they found it. All questions were asked on a 1-7 Likert Scale with 1 being Strongly Disagree and 7 being Strongly Agree. In terms of how conventional participants found the UI, the BA group offered a significantly lower mean score of 3.9, or just under a neutral 4 between agreeing and disagreeing, in comparison to the a 5.1 reported by the AA group. As was already discussed, many AA group members identified familiarity with other RTS games, so their average rating of closer to “Completely Agree” makes sense. Unfortunately, there were also several comments over the course of testing from all groups about being confused by the question. Those in the AA and SCS groups expressed confusion about how the UI could be any other way, hinting at a possible reliance upon game genre convention. Indeed, according to industry professionals, computer game UI is tested and retested internally at the earliest stages of development by people already familiar with the game, and it can then undergo frequent changes as the game itself changes (Candland, 2016). In other words, game UI is a direct result of game design convention, so their confusion about SC2's UI possibly being outside convention makes sense. Conversely, those in the BA group seemed lost on how to answer the question, which makes sense, as they wouldn't be aware of any game UI conventions in the first place. Despite this significance, the numbers don't tell us much, except perhaps that our groups think differently about game UI, and that game UI may be far more reliant upon convention than UI displayed in other software.

Thankfully, the response to how supportive participants found the UI is a little more telling. The significance involves the BA group reporting a lower mean score of 3.7, just below the 4.0 neutral score, than the SCS group who reported a mean difference of 5.5, much closer to agreeing that the UI is supportive. This could be due to a few different factors. It could be simply that the SCS group have a better idea of what they need to do in game, and thus find the UI far more supportive towards that goal, while the BA group might not be as clear on what needs to be done minute to minute that the UI facilitates, even if they understand the broader goal of "win with your army". It could also be that the BA group interpreted this question as relating to how supportive the UI was towards learning the game. However, I am less inclined to believe this, as there was no significance found in the any of the "Easy to Learn" question responses.

Speaking of confusion, there were some other confounds, both in technical limitations and human factors, which I believe should be addressed in any future studies. For starters, while the survey has proven to be effective when assessing the responses to non-game UI, I do not believe that it was fully as effective here as it could be. Many participants, despite all speaking English, expressed confusion over the terms “obstructive” and “conventional.” I believe the core confusion was in how UI is used in games compared to in other, non-entertainment software. Any popups that are considered obstructive are either part of the game (such as zooming in on cards in something like Hearthstone or Magic the Gathering: Arena) or out of the way, as is the case in SC2, unless the popup is actually a separate menu used to pause the game or adjust the settings. I would assume this was an issue with many of the participants not being native English speakers, however the original version of the questionnaire was created in Germany and its English translations were assessed for validity and found no issue. Either a specific group with a unanimous goal, such as new players stress-testing the UI or professional players evaluating it for potential improvements, or a new evaluation questionnaire aimed at game UI in particular could potentially yield more significant survey results.

However, the problems encountered with the technological aspects of the study are much harder to diagnose. While the Tobii Pro 2 eye tracker that was used had a few known limitations, such as an inability to accurately gather the data of those who needed glasses or wore eye makeup, it appeared to have trouble with gathering data along the peripheral of vision as well. Oftentimes these errors would indicate that participants spent time looking just off to the side of the monitor. Upon analysis, it was found that many participants showed errors in fixation location when viewing either the top right or bottom left corners (Fig 2). Some inaccuracies were also found with the bottom right corner, but these were much less common.

While this is a known issue when it comes to gathering eye-tracking data (Holmqvist et al., 2011), the issue is far more pronounced here as two important UI elements, those of resources and the minimap/clock, are located in the top right and bottom left of the screen respectively. To account for this error, AOIs had to be partially tailored for each individual from visualized heatmap data (Fig 2). Despite these issues, the choice to use a wearable eye tracker for data collection was found to be far more comfortable and easy to use for participants who did not voice any discomfort, although some found the glasses more noticeable than others.

Overall, despite significant results, I think that there was not enough data here to make a concrete generalization about the habits and action of three groups from only 23 participants. That said, I do not think that there is nothing that can be interpreted here. Comments, questions, and conversations were different enough across all groups that I am confident that further research with a wider collection of participants would find far more differences here than were found here. For a few SCS players familiar with the game at a more competitive level, there was the desire to customize their hotkeys and establish camera controls, indicating knowledge of informational requirements not already accounted for in the default setup of the game. One or two even brought their own keyboards. Ideally a future study would also include a fourth group, one for grandmaster rank and above SC2 players: those that play regularly for several hours a week and know the game inside and out. Possible research into the settings used could yield some interesting results about changing priorities as experience with SC2 increases.

Another possible direction for future studies is in preferred game genre. While this was touched upon earlier in regards to RTS games, the sheer diversity of games reported in the interview ranged from strategy games to shooters to old Nintendo 64 classics like Super Mario 64 and the Legend of Zelda titles, games with completely different control schemes, many on consoles. Another option is too examine when participants have more time to familiarize and play, possibly 2 hours of maximum time, or asking participants to play daily and using journaling to document their experiences when learning the game or the score at the score screen. To further examine the impact of UI elements, modifying a game and changing color, size, or frequency of popups across different groups could provide more detailed information on what aspects of UI are preferred, and could shed new light on past color-theory research.

Perhaps the most interesting direction to take future research is in the ways in which we learn games beyond shared convention. One of the more surprising incidents during participation was from someone in the AA group that reported playing a lot of strategy games. Upon finishing the tutorial, they pulled out their phone and looked up a strategy they had heard about elsewhere, and then they won against medium AI in about nine minutes. As this was a strategy in line with how they might play at home, and we had no rules against it, it was allowed, although it was unexpected. Do in-game aspects facilitate the transition from complete novice to a grandmaster player that can issue more than sixty precise commands in a minute (Vinyals et al., 2017) or is it all about researching a specific game? Players learn esports not through traditional social learning spaces, such as a classroom but through personal introspection about your own performance within the game (Kow, 2017) in addition to online resources, such as video content or articles, and engaging with other players via online forums sought out by self-directed learning (Loyens, Magda & Rikers, 2008), but these merely offer another context for a player's own introspection of their performance (Huang, Yan, Cheung, Nagappan & Zimmermann, 2017). Past research also shows that the more easily the information is imparted to the player, the clearer any mistakes become, thus improving the rate at which someone can learn (Felder & Brent, 2003). A study that can measure an aspect of that learning process, or disrupts it by removing or restricting outside source learning, could shed more light upon how we learn to play games.

It's fairly clear that there is a lot more research that can be done into games as a whole, and cross-program convention in particular, but were our results conclusive? Ultimately, while significance was found between groups on a variety of AOIs, results on the source of the differences were very much inconclusive, with only an examination on the use of informational popups yielding an easily understood result. It is highly recommended that more academic research into this topic be done, ideally with a larger sample size, before any concrete conclusions about the nature of game convention are drawn.

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APPENDIX: A. Pre-Test Interview Questions.

Age? ____________

Sex? ____________

Have you played Starcraft 2 before now? (yes/no)

If so, how many much? ____

Do you have a rank? If so, what is it? _______________________________

Do you use any specific settings, control options, UI arrangement or size, or keyboard shortcuts beyond control groups? _______________________________________

____

Do you play a lot of video games in general? _________________

About how many hours per week on average?

____

(If the participant plays games) What do you like to play?

____

APPENDIX: B. Post-Test UI Survey.

#________

Rate on the following 7-point scale how much you agree with the following statements, with 1 meaning "Completely Disagree," and 7 meaning "Completely Agree."

1.) The UI was conventional.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

2.) The UI was cluttered.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

3.) The UI was easy to learn.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

4.) The UI was organized.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

5.) The UI was boring.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

6.) The UI was inventive.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

7.) The UI was difficult to learn.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

8.) The UI was obstructive.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

9.) The UI was supportive.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

10.) The UI was exciting.

Completely Disagree	1	2	3	4	5	6	7	Completely Agree

APPENDIX: C. Output Tables for Eye Tracking. (Next page)

Table #1: Eye-Tracking Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
Army Details%	Below Average	6	5.14%	2.26%	0.92%	2.76%	7.51%	1.16%	7.07%
	Above Average	7	3.79%	2.70%	1.02%	1.30%	6.28%	0.14%	7.78%
	SC2 Specific	10	4.80%	2.81%	0.89%	2.79%	6.81%	0.29%	8.27%
	Total	23	4.58%	2.59%	0.54%	3.46%	5.70%	0.14%	8.27%
Control Groups%	Below Average	6	0.05%	0.04%	0.02%	0.00%	0.09%	0.01%	0.12%
	Above Average	7	0.04%	0.06%	0.02%	-0.01%	0.10%	0.00%	0.16%
	SC2 Specific	10	0.45%	0.80%	0.25%	-0.12%	1.02%	0.00%	2.32%
	Total	23	0.22%	0.55%	0.11%	-0.02%	0.46%	0.00%	2.32%
Idle Groups%	Below Average	6	0.95%	0.59%	0.24%	0.33%	1.57%	0.23%	1.73%
	Above Average	7	0.11%	0.11%	0.04%	0.01%	0.21%	0.00%	0.30%
	SC2 Specific	10	0.15%	0.30%	0.09%	-0.06%	0.37%	0.00%	0.95%
	Total	23	0.35%	0.50%	0.10%	0.13%	0.57%	0.00%	1.73%
Minimap/Clock%	Below Average	6	5.69%	4.11%	1.68%	1.38%	10.00%	1.39%	13.09%
	Above Average	7	1.63%	2.15%	0.81%	-0.35%	3.61%	0.07%	6.30%
	SC2 Specific	10	4.04%	2.66%	0.84%	2.13%	5.94%	0.42%	7.51%
	Total	23	3.74%	3.24%	0.67%	2.34%	5.13%	0.07%	13.09%
Overworld Orders%	Below Average	6	64.17%	6.21%	2.54%	57.64%	70.69%	58.61%	74.68%
	Above Average	7	70.92%	12.47%	4.71%	59.39%	82.46%	54.38%	94.22%
	SC2 Specific	10	81.34%	6.76%	2.14%	76.50%	86.17%	71.65%	90.83%
	Total	23	73.69%	11.12%	2.32%	68.88%	78.50%	54.38%	94.22%
Resources%	Below Average	6	0.74%	0.60%	0.24%	0.11%	1.37%	0.23%	1.89%
	Above Average	7	0.74%	0.89%	0.34%	-0.08%	1.56%	0.04%	2.52%
	SC2 Specific	10	1.42%	1.04%	0.33%	0.68%	2.16%	0.33%	3.62%
	Total	23	1.03%	0.92%	0.19%	0.63%	1.43%	0.04%	3.62%
Unit Portrait%	Below Average	6	0.34%	0.12%	0.05%	0.21%	0.47%	0.16%	0.50%
	Above Average	7	0.42%	0.27%	0.10%	0.17%	0.67%	0.05%	0.76%
	SC2 Specific	10	0.50%	0.82%	0.26%	-0.09%	1.09%	0.00%	2.62%
	Total	23	0.43%	0.55%	0.12%	0.20%	0.67%	0.00%	2.62%
Unit Skills%	Below Average	6	13.69%	6.40%	2.61%	6.97%	20.41%	5.13%	23.23%
	Above Average	7	10.90%	5.17%	1.95%	6.12%	15.68%	1.16%	15.51%
	SC2 Specific	10	5.23%	5.25%	1.66%	1.48%	8.99%	0.09%	17.31%
	Total	23	9.16%	6.44%	1.34%	6.38%	11.95%	0.09%	23.23%
Unit/Build Popups%	Below Average	6	9.27%	2.15%	0.88%	7.02%	11.53%	5.57%	12.21%
	Above Average	7	11.37%	6.96%	2.63%	4.94%	17.81%	1.78%	20.62%
	SC2 Specific	9	2.51%	1.70%	0.57%	1.21%	3.82%	0.53%	5.35%
	Total	22	7.18%	5.70%	1.22%	4.65%	9.70%	0.53%	20.62%

Table #2: Eye-Tracking ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Army Details%	Between Groups	6.72	2	3.36	.48	.626
	Within Groups	140.30	20	7.02		
	Total	147.03	22			
Control Groups%	Between Groups	.92	2	.46	1.59	.229
	Within Groups	5.76	20	.29		
	Total	6.67	22			
Idle Groups%	Between Groups	2.94	2	1.47	11.28	.001
	Within Groups	2.61	20	.13		
	Total	5.55	22			
Minimap/Clock%	Between Groups	54.89	2	27.44	3.13	.066
	Within Groups	175.52	20	8.78		
	Total	230.41	22			
Overworld Orders%	Between Groups	1182.68	2	591.34	7.69	.003
	Within Groups	1537.77	20	76.89		
	Total	2720.45	22			
Resources%	Between Groups	2.60	2	1.30	1.61	.225
	Within Groups	16.21	20	.81		
	Total	18.81	22			
Unit Portrait%	Between Groups	.10	2	.05	.16	.856
	Within Groups	6.61	20	.33		
	Total	6.71	22			
Unit Skills%	Between Groups	298.53	2	149.27	4.87	.019
	Within Groups	613.56	20	30.68		
	Total	912.09	22			
Unit/Build Popups%	Between Groups	345.49	2	172.74	9.74	.001
	Within Groups	337.03	19	17.74		
	Total	682.52	21			

Table #3: Multiple Comparisons of Eye-Tracking Data.

Tukey HSD

Dependent Variable	(I) Revised Group	(J) Revised Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Army Details%	Below Average	Above Average	1.35%	1.47%	0.637%	-2.38%	5.08%
		SC2 Specific	0.34%	1.37%	0.967%	-3.12%	3.80%
	Above Average	Below Average	-1.35%	1.47%	0.637%	-5.08%	2.38%
		SC2 Specific	-1.01%	1.31%	0.723%	-4.31%	2.29%
	SC2 Specific	Below Average	-0.34%	1.37%	0.967%	-3.80%	3.12%
		Above Average	1.01%	1.31%	0.723%	-2.29%	4.31%
Control Groups%	Below Average	Above Average	0.00%	0.30%	1.000%	-0.75%	0.76%
		SC2 Specific	-0.40%	0.28%	0.335%	-1.10%	0.30%
	Above Average	Below Average	0.00%	0.30%	1.000%	-0.76%	0.75%
		SC2 Specific	-0.40%	0.26%	0.302%	-1.07%	0.27%
	SC2 Specific	Below Average	0.40%	0.28%	0.335%	-0.30%	1.10%
		Above Average	0.40%	0.26%	0.302%	-0.27%	1.07%
Idle Groups%	Below Average	Above Average	0.84%*	0.20%	0.001%	0.33%	1.35%
		SC2 Specific	0.80%*	0.19%	0.001%	0.32%	1.27%
	Above Average	Below Average	-0.84%*	0.20%	0.001%	-1.35%	-0.33%
		SC2 Specific	-0.04%	0.18%	0.969%	-0.49%	0.41%
	SC2 Specific	Below Average	-0.80%*	0.19%	0.001%	-1.27%	-0.32%
		Above Average	0.04%	0.18%	0.969%	-0.41%	0.49%
Minimap/Clock%	Below Average	Above Average	4.06%	1.65%	0.057%	-0.11%	8.23%
		SC2 Specific	1.66%	1.53%	0.535%	-2.21%	5.53%
	Above Average	Below Average	-4.06%	1.65%	0.057%	-8.23%	0.11%
		SC2 Specific	-2.41%	1.46%	0.250%	-6.10%	1.29%
	SC2 Specific	Below Average	-1.66%	1.53%	0.535%	-5.53%	2.21%
		Above Average	2.41%	1.46%	0.250%	-1.29%	6.10%
Overworld Orders%	Below Average	Above Average	-6.76%	4.88%	0.367%	-19.10%	5.59%
		SC2 Specific	-17.17%*	4.53%	0.003%	-28.63%	-5.72%
	Above Average	Below Average	6.76%	4.88%	0.367%	-5.59%	19.10%
		SC2 Specific	-10.42%	4.32%	0.064%	-21.35%	0.52%
	SC2 Specific	Below Average	17.17%*	4.53%	0.003%	5.72%	28.63%
		Above Average	10.42%	4.32%	0.064%	-0.52%	21.35%

Resources%	Below Average	Above Average	0.00%	0.50%	1.000%	-1.27%	1.26%
		SC2 Specific	-0.68%	0.46%	0.328%	-1.86%	0.49%
	Above Average	Below Average	0.00%	0.50%	1.000%	-1.26%	1.27%
		SC2 Specific	-0.68%	0.44%	0.301%	-1.80%	0.45%
	SC2 Specific	Below Average	0.68%	0.46%	0.328%	-0.49%	1.86%
		Above Average	0.68%	0.44%	0.301%	-0.45%	1.80%
Unit Portrait%	Below Average	Above Average	-0.09%	0.32%	0.961%	-0.90%	0.72%
		SC2 Specific	-0.17%	0.30%	0.844%	-0.92%	0.59%
	Above Average	Below Average	0.09%	0.32%	0.961%	-0.72%	0.90%
		SC2 Specific	-0.08%	0.28%	0.958%	-0.80%	0.64%
	SC2 Specific	Below Average	0.17%	0.30%	0.844%	-0.59%	0.92%
		Above Average	0.08%	0.28%	0.958%	-0.64%	0.80%
Unit Skills%	Below Average	Above Average	2.79%	3.08%	0.643%	-5.01%	10.59%
		SC2 Specific	8.46%*	2.86%	0.020%	1.22%	15.69%
	Above Average	Below Average	-2.79%	3.08%	0.643%	-10.59%	5.01%
		SC2 Specific	5.67%	2.73%	0.120%	-1.24%	12.57%
	SC2 Specific	Below Average	-8.46%*	2.86%	0.020%	-15.69%	-1.22%
		Above Average	-5.67%	2.73%	0.120%	-12.57%	1.24%
Unit/Build Popups%	Below Average	Above Average	-2.10%	2.34%	0.648%	-8.06%	3.85%
		SC2 Specific	6.76%*	2.22%	0.017%	1.12%	12.40%
	Above Average	Below Average	2.10%	2.34%	0.648%	-3.85%	8.06%
		SC2 Specific	8.86%*	2.12%	0.001%	3.47%	14.25%
	SC2 Specific	Below Average	-6.76%*	2.22%	0.017%	-12.40%	-1.12%
		Above Average	-8.86%*	2.12%	0.001%	-14.25%	-3.47%

*. The mean difference is significant at the 0.05 level.

APPENDIX: D. Output Tables for Survey Results. (next page)

Table #4: Survey Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
UITotalConventional	Below Average	6	3.92	.66	.27	3.22	4.61	3.00	5.00
	Above Average	7	5.14	.94	.36	4.27	6.02	4.00	7.00
	SC2 Specific	10	4.70	.54	.17	4.32	5.08	4.00	5.50
	Total	23	4.63	.83	.17	4.27	4.99	3.00	7.00
UITotalOrganized	Below Average	6	4.42	1.36	.55	2.99	5.84	3.00	6.50
	Above Average	7	5.57	1.30	.49	4.36	6.78	3.00	7.00
	SC2 Specific	10	5.75	.59	.19	5.33	6.17	5.00	7.00
	Total	23	5.35	1.16	.24	4.85	5.85	3.00	7.00
UITotalEasyToLearn	Below Average	6	4.42	1.07	.44	3.30	5.54	2.50	5.50
	Above Average	7	6.07	1.46	.55	4.73	7.42	3.00	7.00
	SC2 Specific	10	5.25	1.03	.33	4.51	5.99	3.00	6.50
	Total	23	5.28	1.30	.27	4.72	5.84	2.50	7.00
UITotalExciting	Below Average	6	4.58	1.24	.51	3.28	5.89	3.50	6.00
	Above Average	7	4.14	1.63	.61	2.64	5.65	1.50	7.00
	SC2 Specific	10	4.75	1.57	.50	3.63	5.87	2.50	7.00
	Total	23	4.52	1.47	.31	3.89	5.16	1.50	7.00
UITotalSupportive	Below Average	6	3.75	1.60	.66	2.07	5.43	1.50	5.50
	Above Average	7	5.36	1.14	.43	4.30	6.42	3.00	6.50
	SC2 Specific	10	5.55	.80	.25	4.98	6.12	4.50	7.00
	Total	23	5.02	1.34	.28	4.44	5.60	1.50	7.00

Table #5: Survey ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
UITotalConventional	Between Groups	4.94	2	2.47	4.86	.019
	Within Groups	10.17	20	.51		
	Total	15.11	22			
UITotalOrganized	Between Groups	7.17	2	3.58	3.18	.063
	Within Groups	22.55	20	1.13		
	Total	29.72	22			
UITotalEasyToLearn	Between Groups	8.87	2	4.43	3.16	.064
	Within Groups	28.05	20	1.40		
	Total	36.91	22			
UITotalExciting	Between Groups	1.55	2	.77	.34	.717
	Within Groups	45.69	20	2.28		
	Total	47.24	22			
UITotalSupportive	Between Groups	13.28	2	6.64	5.02	.017
	Within Groups	26.46	20	1.32		
	Total	39.74	22			

Table #6: Multiple Comparisons of Survey Data

Tukey HSD

Dependent Variable	(I) Revised Group	(J) Revised Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
UITotalConventional	Below Average	Above Average	-1.23*	.40	.015	-2.23	-.22
		SC2 Specific	-.78	.37	.109	-1.71	.15
	Above Average	Below Average	1.23*	.40	.015	.22	2.23
		SC2 Specific	.44	.35	.433	-.45	1.33
	SC2 Specific	Below Average	.78	.37	.109	-.15	1.71
		Above Average	-.44	.35	.433	-1.33	.45
UITotalOrganized	Below Average	Above Average	-1.15	.59	.150	-2.65	.34
		SC2 Specific	-1.33	.55	.061	-2.72	.05
	Above Average	Below Average	1.15	.59	.150	-.34	2.65
		SC2 Specific	-.18	.52	.938	-1.50	1.15
	SC2 Specific	Below Average	1.33	.55	.061	-.05	2.72
		Above Average	.18	.52	.938	-1.15	1.50
UITotalEasyToLearn	Below Average	Above Average	-1.65	.66	.052	-3.32	.01
		SC2 Specific	-.83	.61	.379	-2.38	.71
	Above Average	Below Average	1.65	.66	.052	-.01	3.32
		SC2 Specific	.82	.58	.356	-.66	2.30
	SC2 Specific	Below Average	.83	.61	.379	-.71	2.38
		Above Average	-.82	.58	.356	-2.30	.66
UITotalExciting	Below Average	Above Average	.44	.84	.861	-1.69	2.57
		SC2 Specific	-.17	.78	.975	-2.14	1.81
	Above Average	Below Average	-.44	.84	.861	-2.57	1.69
		SC2 Specific	-.61	.74	.698	-2.49	1.28
	SC2 Specific	Below Average	.17	.78	.975	-1.81	2.14
		Above Average	.61	.74	.698	-1.28	2.49
UITotalSupportive	Below Average	Above Average	-1.61	.64	.052	-3.23	.01
		SC2 Specific	-1.80*	.59	.017	-3.30	-.30
	Above Average	Below Average	1.61	.64	.052	-.01	3.23
		SC2 Specific	-.19	.57	.938	-1.63	1.24
	SC2 Specific	Below Average	1.80*	.59	.017	.30	3.30
		Above Average	.19	.57	.938	-1.24	1.63

*. The mean difference is significant at the 0.05 level.