

HAND-HELD COGNITION: DOES LEARNING SUFFER WHEN AN EXTERNAL
REPRESENTATION INTERFACE STYLE IS USED?

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Submitted to the faculty of the School of Informatics
in partial fulfillment of the requirements
for the degree of
Master of Science in Human-Computer Interaction,
Indiana University

December 2008

Accepted by the Faculty of Indiana University,
in partial fulfillment of the requirements for the degree of Master of Science
in Human-Computer Interaction

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TABLE OF CONTENTS

LIST OF TABLES	VII
LIST OF FIGURES	VIII
ABSTRACT.....	XI
CHAPTER ONE: INTRODUCTION & BACKGROUND	1
INTRODUCTION OF TOPIC	1
IMPORTANCE OF TOPIC.....	2
CHAPTER TWO: LITERATURE REVIEW.....	3
RESEARCH HYPOTHESIS	8
CHAPTER THREE: METHODOLOGY	8
PARTICIPANTS.....	8
PROCEDURE	9
<i>Design</i>	9
<i>Implementation</i>	10
<i>Boxes and Barrels Game</i>	12
DATA ANALYSIS	15
<i>Statistical methods</i>	16
CHAPTER FOUR: RESULTS	17
CHAPTER FIVE: DISCUSSION.....	31
CHAPTER SIX: CONCLUSION.....	38

LIMITATIONS.....	38
FUTURE RESEARCH.....	39
SUMMARY.....	39
REFERENCES.....	41
APPENDIX A – CANNIBALS AND MISSIONARY THREE PERSON STATES.....	44
APPENDIX B – CANNIBALS AND MISSIONARY FIVE PERSON STATES.....	47
APPENDIX C – BOXES AND BARRELS INITIAL STATES.....	51
APPENDIX D – DEMOGRAPHIC INFORMATION.....	57
APPENDIX E – PROCEDURAL QUESTION CODES.....	60
APPENDIX F – BOXES AND BARRELS SESSION MOVEMENTS.....	61
APPENDIX G – BOXES AND BARRELS DETAIL MOVEMENTS.....	63
APPENDIX H – BOXES AND BARRELS SUMMARY COUNT BOX PLOTS.....	69
APPENDIX I – BOXES AND BARRELS MANN-WHITNEY RESULTS.....	75
APPENDIX J – POST-SESSION QUESTIONNAIRE QUALITATIVE RESULTS.....	79
APPENDIX K – PRE-SESSION QUESTIONNAIRE.....	83
APPENDIX L – POST-SESSION 1 QUESTIONNAIRE.....	84
APPENDIX M – POST-SESSION 2 QUESTIONNAIRE.....	88
APPENDIX N – POST-SESSION 3 QUESTIONNAIRE.....	92
APPENDIX O – POST-SESSION 4 QUESTIONNAIRE.....	96
APPENDIX P – POST-SESSION QUESTIONNAIRE ANSWERS.....	100

VITA..... 105

LIST OF TABLES

Table 1. Potential participant Pre-qualification Questions	10
Table 2. Post-Session Questionnaire Mean and Standard Deviation Results	17
Table 3. Summary Count Definitions	28
Table C-1. Session 1 – Initial Game States Shown.....	51
Table C-2. Session 2 – Initial Game States Shown	53
Table C-3. Session 3 – Initial Game States Shown.....	55
Table C-4. Session 4 – Initial Game States Shown.....	56
Table D-1. Demographic Information from Pre Session 1 Questionnaire.....	57
Table D-2. Demographic Information Column Code Descriptions.....	59
Table E. Textual Result Coding of the Procedural Questions.....	60
Table F-1. Summarized Session Times, Non-object, Object and Invalid Moves.....	61
Table F-2. Summarized Times, Non-object, Object and Invalid Moves with Outliers Removed	62
Table G-1. Time, Non-object, Object and Invalid Moves.....	63
Table G-2. Time, Non-object, Object and Invalid Moves with Outliers Removed.....	66
Table I-1. Time, Invalid, Non-object and Object Moves Mann-Whitney U Results.....	75
Table I-2. Time, Invalid, Non-object and Object Moves without 2X Outliers Mann- Whitney U Results.....	77
Table J-1. Post-Session Questionnaire Questions.....	79
Table J-2. Post-Session Questionnaire Likert Answer Codes.....	80
Table J-3. Post-Session Questionnaire Qualitative Answer Mean and Standard Deviation.....	81

LIST OF FIGURES

Figure 1. Samsung I607 Blackjack	12
Figure 2. I607 Main Controls.....	13
Figure 3. Pre-game trial screen	13
Figure 4. Break and continue screen.....	13
Figure 5. Internalized game screen	15
Figure 6. Externalized game screen	15
Figure 7. Total Correct Declarative Knowledge Questions per Session	18
Figure 8. Total Correct Procedural Knowledge Questions per Session.....	19
Figure 9. Question 7 Answer Results.	20
Figure 10. Question 8 Answer Results.	21
Figure 11. Question 9 Answer Result.	22
Figure 12. Question 10 Answer Results.	23
Figure 13. Question 11 Answer Results.	24
Figure 14. Question 12 Answer Results.	25
Figure 15. Question 13 Answer Results.	26
Figure 16. Question 14 Answer Results.	27
Figure 17. Scatter Plot of Time.....	29
Figure 18. Scatter Plot of Invalid Moves	30
Figure 19. Scatter Plot of Non-object Moves	30
Figure 20. Scatter Plot of Object Moves.....	31
Figure 21. Scatter plot of Time, with Outliers Removed.....	35
Figure 22. Scatter plot of Invalid Moves, with Outliers Removed.....	35

Figure 23. Scatter plot of Non-object Moves, with Outliers Removed	36
Figure 24. Scatter plot of Object Moves, with Outliers Removed.....	36
Figure A-1. Three person cannibals and missionaries group, all states shown. Boxes with diagonals signify illegal states.....	44
Figure A-2. Three-person cannibals and missionaries group, only legal states shown....	45
Figure A-3. Three-person cannibals and missionaries group, only unique, legal states shown.....	46
Figure B-1. Five-person cannibals and missionaries group, all states shown. Boxes with diagonals signify illegal states.....	47
Figure B-2. Five-person cannibals and missionaries group, only legal states shown.....	49
Figure B-3. Five-person cannibals and missionaries group, only the unique, legal states shown.....	50
Figure H-1. Time Session 1 Box Plot.....	69
Figure H-2. Time Session 2 Box Plot.....	69
Figure H-3. Time Session 3 Box Plot.....	70
Figure H-4. Time Session 4 Box Plot.....	70
Figure H-5. Invalid Moves Session 1 Box Plot.....	70
Figure H-6. Invalid Moves Session 2 Box Plot.....	71
Figure H-7. Invalid Moves Session 3 Box Plot.....	71
Figure H-8. Invalid Moves Session 4 Box Plot.....	71
Figure H-9. Non-object Moves Session 1 Box Plot.....	72
Figure H-10. Non-object Moves Session 2 Box Plot.....	72
Figure H-11. Non-object Moves Session 3 Box Plot.....	72

Figure H-12. Non-object Moves Session 4 Box Plot.....	73
Figure H-13. Object Moves Session 1 Box Plot.....	73
Figure H-14. Object Moves Session 2 Box Plot.....	73
Figure H-15. Object Moves Session 3 Box Plot.....	74
Figure H-16. Object Moves Session 4 Box Plot.....	74

ABSTRACT

Keith A. Beatty

HAND-HELD COGNITION: DOES LEARNING SUFFER WHEN AN EXTERNAL REPRESENTATION INTERFACE STYLE IS USED?

Previous research has shown that external representation of information facilitates cognitive processing by requiring less recall and reducing the need for working memory. The assumption is that all task types are better performed with an external representations interface style. Research conducted in 2004 with a personal computer found that for planning, understanding and knowledge tasks, external representations did not significantly improve task performance and that declarative knowledge was better aided by internal representation. This study hypothesized that declarative knowledge would be significantly enhanced for people who used a hand-held device coupled with an internal representation interface style. This study had 21 participants (external N = 9, internal N = 12) who completed all four sessions. The result was that there was not a significant difference between means as pertains to declarative knowledge. However, the procedural knowledge results found that the mean difference was 0.5 or greater on three of the four sessions in favor of the internal representation interface style. When the moves were examined, the external representation interface style was mostly associated with significantly better performance in certain trials in early sessions, but in later sessions the difference was not significant.

CHAPTER ONE: INTRODUCTION & BACKGROUND

Introduction of topic

Graphical user interfaces have existed for over thirty years. In that time, many improvements have been made in both hardware and software, particularly in the area of usability or user interaction. One such improvement in usability theory is the concept of showing the user only the options, actions or tools that are available in the software's current state, thus reducing the person's cognitive load by narrowing down of the problem space (Zhang and Norman, 1994). This is an external representation of the problem state. The general rule of thumb is more offloading is better; Nielsen (2005) makes this one of his top ten usability heuristics, the use of recognition in place of recall. Scaife and Rodgers (1996, p. 188) defined external cognition as "cognitive processing involved when interacting with graphical representations, the properties of the internal and external structures and the cognitive benefits of different graphical representations." The purpose of this study investigates how graphical external representations influences learning and knowledge, specifically on hand-held devices.

There are numerous examples of external representations of the interface in modern software, but one of the most common is observed in the cut, copy and paste menu. If a user tries to select the paste option without copying or cutting first, the paste option shows as unavailable. The unavailability of the paste function is an external representation of the system status. The system shows that paste is an option but it is not available in the current state. If these interface external representations did not exist, the user would have to internalize the editing state to understand why the paste option did not work when called upon. For some people, the reason for the unavailable paste option is

intuitively obvious. However when other menu options are unavailable, it can be difficult to determine the cause. Larkin (1989) similarly observed that when a device or display conceals information, the advantages of external representations are lost.

While interface external representations are helpful in many situations, it may be harmful when efficiency and learning are goals. Carrol and Rosson (1987) coined the term “active user paradox” to describe how people who learn to perform a task are often unmotivated to find a better way to achieve the task or to learn the rules behind their chosen way of performing the task. The reason given was that they did not want to go beyond what they knew; rather they just wanted to get the task done. Trudel and Payne (1996) explored this phenomenon in an experiment that sought to increase knowledge and efficiency on a device. They tested two treatments: 1) interruptions at scheduled intervals to report learning achieved and 2) interruptions to state future exploration/learning intentions. Both treatments provided significant benefits in learning to subjects when compared to subjects who did not have interruptions.

Importance of topic

The Pew Research Center estimated that in 2007 75% of people in the United States have cell phone or Personal Digital Assistant (PDA) (Horrigan, 2008). Another Pew study (Doherty, 2004) showed that in 2004 68% of people had cell phones, as compared to 53% in 2000 and 24% in 1995. Of the 75% in the 2007 study (Horrigan, 2008), 77% had used a hand-held device in a non-voice manner once, such as sending Short Message Service (SMS) text messages, and 42% did so on a typical day. The 2007 survey (Horrigan, 2008) found that people under 30 and Hispanics use hand-held devices the most. Racial usage of non-voice usage had Hispanic usage at 90%, compared to

Blacks/African-American at 79% and White usage at 73%. Age breakdown of non-voice usage was: 18 to 29 at 73%, 30 to 49 at 57%, 50 to 64 at 23%, and 65 and over at 9%.

According to a survey about the Internet's future (Anderson, 2006), respondents believed that mobile devices are key to global connection. As hand-held devices are more readily available, they will become for many an access point to a global network. A similar opinion by Vinton Cerf, an Internet founder, predicts that mobile phone devices will be a dominant force in the future, especially in rapidly developing countries (Penna, 2007).

The intent of this study is to present the results to Human-Computer Interaction (HCI) interface designers. HCI designers must know more about knowledge and learning usage patterns to ensure that user-interaction and the presentation of information on a hand-held device is optimal. Interactions with hand-held devices differ from desktop computers and large format displays and HCI designers need to be sure that this into account. While the understanding the needs for delivering learning content on hand-held devices may be new, based on the growth of hand-held devices usage, the need will not go away any time.

CHAPTER TWO: LITERATURE REVIEW

Zhang and Norman (1994) studied representations in distributed cognition tasks which require the use of information distributed both internally (inside the mind) and externally (in the environment). Differences in representation systems differences can result in different cognitive behaviors, even for the same task. This phenomenon is known as representation effect. Both internal and external representations are used in a problem solving tasks. Internal representations are in the mind. External representations

are exclusively outside of the mind, in the environment, such as written language, tools, rules, relationships, and so forth. Zhang and Norman define a distributed representation task as one or more internal representations and one or more external representations.

To test the representation interaction, Zhang and Norman (1994) took the Towers of Hanoi logic game and created several isomorphs, visually different problem structures that use identical rules. They found that external representations provide memory aids, can anchor structure and cognitive behavior and can change the nature of a task. External representations can be internalized, but internal representation is not needed if the external representations are always available. Scaife and Rodgers (1996) defined “computational offloading” as a measure of how much the external representation reduces the cognitive effort.

In a later study using Tic-Tac-Toe isomorphs, Zhang (1997) found that when affordances could be perceived based on external representations from the game, the task was easier to solve. Conversely, if the affordances of the external representations were inconsistent with the task, the task can become more complex. External representations can be perceived and used without internalization, can guide and limit invalid actions, and can change the nature of a task, which makes some isomorphic versions easier to use. However, these studies do not address the special case in which learning or internalization is the goal.

A study conducted by Mayes, Draper, McGregor, and Oatley (1988) examined the effect of experience on recall with MacWrite, a word processor. Participants ranging from novice to frequent users could not reliably recall the answers to questions pertaining to the menu labels or sequences outside of the word processor, no matter their experience

level. However, all subjects were able to use the appropriate MacWrite menus on a series of letter formatting tasks. Mayes et al. speculated that this failure to recall all needed information for document edits except via the use of the software, so that the knowledge of the task was an integral part of the interface. This study shows that, when learning is a goal, then the use of external representations is not the best method to help users recall information outside of the original environment context.

Payne (1991) found similar results when he examined user behavior in the context of character based and graphical user interface (GUI) based word processing programs. Volunteers of varying skill levels filled out a questionnaire after use on their most-used word processing program. The questionnaire asked about common functions used in word processing. He found that in the character based programs many users did not know the exact effects of commands, even those used regularly. With the GUI based word processing programs, subjects could not always recall the menu options and were uncertain about exact effects of certain menu options. The conclusion was that people do not remember details on regularly used commands and obtain details from the word processing program.

When problem solving takes place with the help of external representations from a display, the display state and the user's internal problem state are similar, because the user is employing the display information to guide his or her actions (O'Hara and Payne, 1998). However, when planning is done based on internalized rules, the internal problem state and the display state grow apart until the plan is executed, which synchronizes the display with the user's internal state. O'Hara and Payne (1998) introduce the notion of an implementation cost that measures real world interaction in time, physical effort, or

mental effort. Based on the cost / benefit explanation, it was expected that on interfaces which have high physical implementation cost, users would plan more, make fewer errors, have fewer extraneous moves, and have a higher learning factor. The study results verified their prediction and showed that the learning gained could be transferred to tasks within a similar area. The benefit for learning is low when external representations are used, because all information is readily available and is always correct.

Nimwegen, Oostendorp, and Tabachneck-Schijf. (2004) were interested in learning aspects in user interfaces. To test the internal and external representation aspects, an isomorph of the missionaries and cannibals logic game was created for use on a personal computer. The interface was the same for each group, except that for one group the interface exposed game rules with external representations. The external representation interface style showed the subject all of the available actions in the current state, whereas the internal representation interface style required the subject to either recall actions based on the current state or experimentally perform actions in a trial-and-error fashion. The research hypothesized that people who used the internal interface would have better knowledge than those who used the external interface. The test had nine trials, the post-test survey asked eight knowledge questions, separated into seven procedural knowledge questions, and one declarative knowledge question. Anderson (1993, p. 18) defines both terms “declarative knowledge as factual knowledge that people can report or describe, whereas procedural knowledge is knowledge can only manifest in their performance.” Nimwegen, et al (2004) found that neither the execution performance nor procedural knowledge significantly differed. Declarative knowledge of subjects who worked with the internal representation interface style, approximately 40% better. Eight

months later the same participants were re-tested with a different isomorph of the missionaries and cannibals game, but achieved the same result as the original study.

In a later 2005 study, Nimwegen, Oostendorp, and Tabachneck-Schijf wanted to examine if an instruction plan would influence the memory use of either the internal representation style and/or external representation interface style. The study reused the first missionaries and cannibals test isomorph in the Nimwegen et al. (2004) study. Participants were split into internal and external representation interface groups. One group was instructed to find the quickest solution, and the other was instructed to find the solution with the fewest number of moves. The post-test asked declarative and procedural questions relating to the logic game. The instruction plan was not significant, and the interface style had no significant effect on execution time, but the internal representation interface group did show significantly better results in finding the most economical solution.

Nimwegen, Burgos, Oostendorp, and Schijf (2006) received complaints that the study was not performed with a “real world” task. Based on this advice, they created a study to review representation that used a conference room scheduling task in place of the logic puzzle. The study examined representation interface style and Need For Cognition (NFC), which measures a person’s tendency to seek and perform moderate to difficult cognitive tasks. The external representation interface showed all legal conference rooms where a meeting could be held, whereas the internal interface did not. Volunteers were first assessed for their NFC. Half of the high and low NFC groups were assigned to the internal external representation interface style and the remaining half were assigned to the external representation interface style. The post-test asked declarative and procedural

questions relating to the tasks. Results found no significant effects on NFC, interface style, declarative or procedural knowledge. There were significant effects for inter-move latency time and for un-needed extra moves based on the internal interface style.

Research hypothesis

- H₀.** On a hand held device, participants who use the internal representation interface style will not have significantly more declarative knowledge than those who use the external representation interface style.
- H₁.** On a hand held device, participants who use the internal representation interface style will have significantly more declarative knowledge than those who use the external representation interface style.

CHAPTER THREE: METHODOLOGY

Participants

Thirty-one people participated in this study, of which 21 completed all four sessions. All participants either worked or resided in the Indianapolis, Indiana metropolitan area. Of the twenty-one people who completed all four sessions, there were thirteen men and eight women who were between the ages of 19 and 48 (mean age = 31.0). Volunteers were not paid, but all persons that completed all four sessions were entered into a drawing for 25 prizes (mean value = US \$20.40). All participants had had some experience with a hand-held device; a digital camera was cited most often.

Of the twenty-one people who completed all four sessions, 9 people were assigned to the external representation interface, 12 people were assigned to the internal representation interface. Of the twelve assigned to the internal representation interface,

there were seven men and five women who were between the ages of 19 and 48 (mean age = 32.4). Of the nine assigned to the external representation interface, there were six men and three women who were between the ages of 21 and 42 (mean age = 29).

Procedure

Boxes and barrels game, which the author created, is an isomorph of the classic logic puzzle, missionaries and cannibals. The puzzle places three missionaries and three cannibals on the bank of a river. There is a boat on the river that can have either one or two people in it, but must have at least one person in it to row to the opposing bank. The cannibals will eat any missionary if the total number of cannibals outnumbers the number of missionaries on either bank or within the boat. The goal of the game is to get all of the missionaries and cannibals to the opposite bank without any of the missionaries dying. Moves for the three person missionaries and cannibals puzzles are shown in Figures A-1, A-2, and A-3 in Appendix A, and the five person missionaries and cannibals puzzles are shown in Figures B-1, B-2, and B-3 in Appendix B.

Design

This was a between-subjects longitudinal study. Each participant was alternately assigned to one of two groups and took part in a series of four sessions, with each subsequent session taking place between six and eight days after the previous session. The reason for the six to eight day wait between sessions allowed time for the participant to forget some or all of the rules between in the sessions. See Appendix C for all session and trial initial states (or beginning box and barrel placement). The first session consisted of six trials. The first two trials started near the end state, which is where all boxes and all barrels on the right side. That allowed the participant to learn the game interface while he

or she played the game. The four remaining trials started from an earlier point. The goals for the second, third, and fourth sessions was the same as session 1, to move from a given starting point to the end state. The independent variable was the interface style and the dependent variables were declarative and procedural knowledge scores. Information collected included age, gender, hand-held knowledge categorization from the pre-test questionnaire, and automatically collected data from each trial as well as from the post-session questionnaire.

Implementation

The candidate certified that the study's pre-qualifications were met as set forth in the study definition; see Table 1 for more information. If the person was within the study group bounds, they entered into the study. The proctor and participant agreed upon the session time and location. It was decided that the location should not distract the participant and should be available for use at the appointment time.

Table 1. Potential participant Pre-qualification Questions

Are you aged between 18 and 49 inclusive?

Can you read, write, speak and understand English as a primary language?

Can you view small images and text?

Can you manipulate a small hand-held device, such as a cell or smart phone or PDA?

Can you dedicate at least 90 minutes for four sessions? Subsequent sessions must be between six to eight days after the previous session.

During the first session, the subject read then signed the informed consent form and became a study participant. The participant was alternately assigned to use either the internal representation interface or the external representation interface. Prior to the start of the first session, the participant completed the pre-test questionnaire, which captured his or her gender, age, and experience level with hand held devices, form shown in Appendix K. The results are presented in Appendix D. Study background and game interface instruction information was available to the participant for the selected treatment in both video and text formats. After the review was finished, the proctor asked the participant if they had any questions, and if so the questions were answered. The participant then confirmed that he or she did not wish to further review the background information and had no more questions. The proctor entered the session information into the I607 Samsung Blackjack smart phone; see Figure 1. The proctor instructed the participant prior to the first game trial:

“If you need to take a break, please do so between trials. The goal is to move all of the boxes and barrels from the left side to the right side. There are rules, not all moves are allowed. Some of the rules are shown in the help. Begin the game.”



Figure 1. Samsung I607 Blackjack

The participant then started the first trial. The proctor could answer questions during the game, but could not give specific moves to make or answer any specific questions about the help text. If the participant was either frustrated or tired of the game, the proctor reminded them that they could quit at any time. If the session went on for over two-hours, the proctor asked if the participant wanted to finish the uncompleted trials. If the participant wanted to complete the remaining trials, four days were allotted for their completion. Once all trials were completed, the participant filled in the post-session questionnaire, shown in Appendix L. The proctor did not answer any questions on the post-session questionnaire that were not related to the test question. Once completed, the next session was scheduled.

For the remainder of the sessions, the participant received the smart phone and was given the final instructions. The participant completed all trials and then the post-session questionnaire, shown in Appendix M, N, and O. If the session was not the last session, the next session was scheduled. Otherwise, the participant filled out the prize drawing entry form.

Boxes and Barrels Game

The proctor entered the participant's information into the smart phone, such as the participant's test identity number, the session number, and the starting trial number. This information helped to create a dataset of summary count data. The participant received the smart phone showing the pre-trial screen; see Figure 3. The continue option was pressed, and the first game trial screen was displayed; see tables in Appendix C for all initial game states. All initial trial states within each session were unique. After each game trial was solved, except the last trial, the break and continue screen was shown,

allowing the participant to take a break and then continue to the next trial; see Figure 4. Once the continue button was pressed, the next game trial in the session was shown.

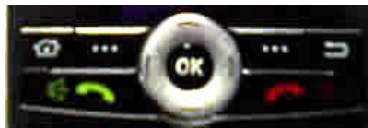


Figure 2. I607 Main Controls

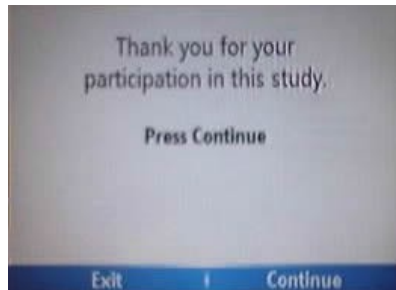


Figure 3. Pre-game trial screen

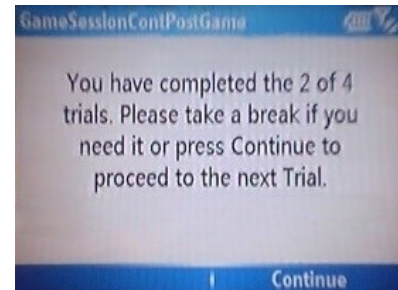


Figure 4. Break and continue screen.

This isomorph of the missionaries and cannibals game used boxes in place of missionaries, barrels instead of cannibals, and a pallet as the boat. The four-way navigation key performed all game mechanics, except opening the help display; see Figure 2. The game had two sides, separated by a wall, with the pallet that indicated the active side. Only the barrels or boxes on the active side could be manipulated. Only one box or barrel on the bottom could be manipulated at a time, which simplifies actions and allowed better use of the small screen. The user knows their current location within the game by the icon shrinking and expanding, similar to the blinking I-bar in a text-processing program. Selectable locations were current side barrel, current side box, the pallet, and any objects on the pallet, if any objects were on the pallet. If the current side bottom did not have any boxes or barrels, then that position showed no icon.

The box or barrel was moved from the current side bottom of the screen to the pallet by pressing the center “OK” button, which was located in the middle of the

navigation key. Conversely, any box or barrel on the pallet could be moved to the current side bottom of the screen by pressing the center “OK” button. When the current position was on the pallet, the participant pressed the “OK” button to move the pallet from the current side to the opposite side of the screen. A violation of the game rules could never occur, as any attempted illegal action was not executed and tone was sounded. Any pressing of the telephone off hook (answer call), telephone on hook (end call), and back keys were disabled. These moves were treated similar to an invalid move, except that there was no tone.

The game trial screen shown differed depending on the participant’s interface style assignment. The internal representation interface style screen, (Figure 5), did not show any hints as to the available moves; the color of the barrels were always red, the color of the boxes was always yellow, and the colors were always displayed on both sides of the screen. The external representation interface screen, (Figure 6), differed from the internal style screen in these ways: 1) the barrels and boxes on the inactive screen side did not show any color, which would indicate to the participant that the side should be ignored for the present 2) on the active screen side, the boxes and barrels, on the bottom showed two different colors to indicate if it was possible to move: yellow = OK to move to the pallet, red = not possible to move to the pallet, as a violation of the rules would occur 3) on the pallet the boxes and barrels showed two different colors to indicate if it was possible to move: yellow = OK to move to the bottom, red = not possible to move to the bottom, as a violation of the rules would occur 4) in the middle of the pallet, there are four circles, either yellow or red, that indicate if the pallet is able to move: yellow = OK to move, red = not possible to move, a violation of the rules would occur.



Figure 5. Internalized game screen



Figure 6. Externalized game screen

On the game screen, there was a help menu option that the participant could use.

The help button displayed the following text: “Rules: The pallet can transport a maximum of three objects: three boxes; three barrels; or a combination of boxes and barrels. The pallet must have at minimum one box or barrel. Barrels can never outnumber boxes in any location.” The rule that was not in the help text: the count of boxes and barrels on the pallet needed to be combined with the count of boxes and barrel count on the ground, to determine if the pallet could be moved to the opposite side.

The solution to the three-object game is shown in Appendix A, and the solution to the five-object game is shown in Appendix B. There were many states where to solve the puzzle required a move to a prior state. The key to solving this puzzle was to understand the crossover section, states 1.9.3.6 through 1.9.3.6.3.9.9.9 in Figure B-3. Many of these moves were not intuitive, as progress seemed to be reversed. The crossover section was a series of moves that started from a state with a majority of barrels and no boxes on the right side to a state where all the boxes are on the right side. From this point, there were several possible paths to complete the game.

Data Analysis

Each post-session questionnaire had a quantitative section with three declarative and three procedural knowledge questions and a qualitative section that asked about the

participant's thoughts on the trials in the session. The declarative answers were multiple-choice. The procedural questions were yes/no answer with text verification. The text verification was performed via use of game rules or by an explanation of what a better move was. The IUPUI Research Center answer coded the text answers. Appendix E shows the codes used; Appendix P shows the post-session questionnaire answers. Summary counts collected via the Boxes and Barrels program were reviewed for patterns. The statistical methods used for analysis in this study consist of mean (M), standard deviation (SD), median, and the Mann-Whitney U test.

Statistical methods

The answers from the post-session questionnaire quantitative questions are of a nominal / categorical type, either correct or incorrect. Since there were three questions for declarative knowledge and procedural knowledge, the possible numbers of correct answers set were 0, 1, 2 or 3. The mean and standard deviation was selected to analyze declarative knowledge, procedural knowledge, and qualitative answers due to the low number of completed participants.

The information gathered by the Boxes and Barrels game was a set of trial data that contains counts and time information. Because the data was widely skewed, the use of the student t test would have been imprudent. The non-parametric version of the student t test is the Mann-Whitney U test. The Mann-Whitney U test has less statistical power and is acknowledged. The Mann-Whitney U test looks for differences in two different sets of data to see if they are from the same distribution. In this way, the author compared the data from each session and trial combination separately to determine if there was any significant difference with the interface type when tested against the total

time, total invalid moves, total non-object moves and total object moves. This study used 0.05 as the significance level when reviewing the Mann-Whitney U test results.

CHAPTER FOUR: RESULTS

This study created two datasets, the post-session questionnaire results and the Boxes and Barrels test program summary counts. Table 2 shows the mean and standard deviation for the post-session questionnaire results. Figures 7 and 8 show counts of the correct declarative knowledge and procedural knowledge per session respectively.

In the declarative knowledge results, the internal representation interface style always had a higher mean than the external representation interface style. Session 1, session 2 and session 4 had less than a 0.3 difference in their means, while session 3 mean had a difference of 0.45. Declarative knowledge standard deviation never exceeded 1.0 for any session on either interface type. The standard deviation in sessions 1 and 2 was smaller on the external representation interface, while for sessions 3 and 4 the internal representation interface had a smaller standard deviation.

The procedural knowledge results mean difference equaled or exceeded 0.5 for sessions 1, 2, and 4. For session 2, the mean difference was 0.28. Procedural knowledge standard deviation never exceeded .90 or differed by less than 0.25 for any session. The standard deviation in sessions 1, 2, and 3 was smaller for the external representation interface, whereas for session 4 the internal representation interface had the smaller standard deviation.

Table 2. Post-Session Questionnaire Mean and Standard Deviation Results

Declarative Knowledge	Procedural Knowledge
-----------------------	----------------------

Group	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Internal Interface Type (<i>n</i> = 12)				
Session 1	1.50	1.00	1.50	0.67
Session 2	1.92	0.90	1.50	0.80
Session 3	1.67	0.49	1.83	0.84
Session 4	2.83	0.39	2.08	0.51
External Interface Type (<i>n</i> = 9)				
Session 1	1.33	0.87	1.00	0.50
Session 2	1.89	0.78	1.78	0.67
Session 3	1.22	0.83	1.33	0.50
Session 4	2.56	0.73	1.33	0.71

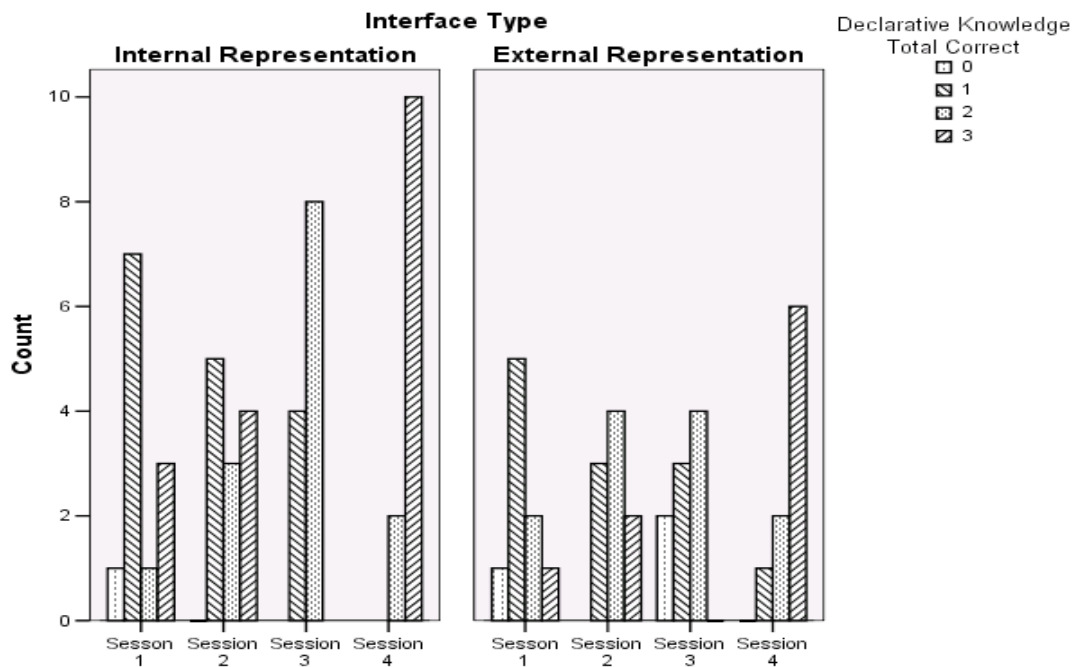


Figure 7. Total Correct Declarative Knowledge Questions per Session

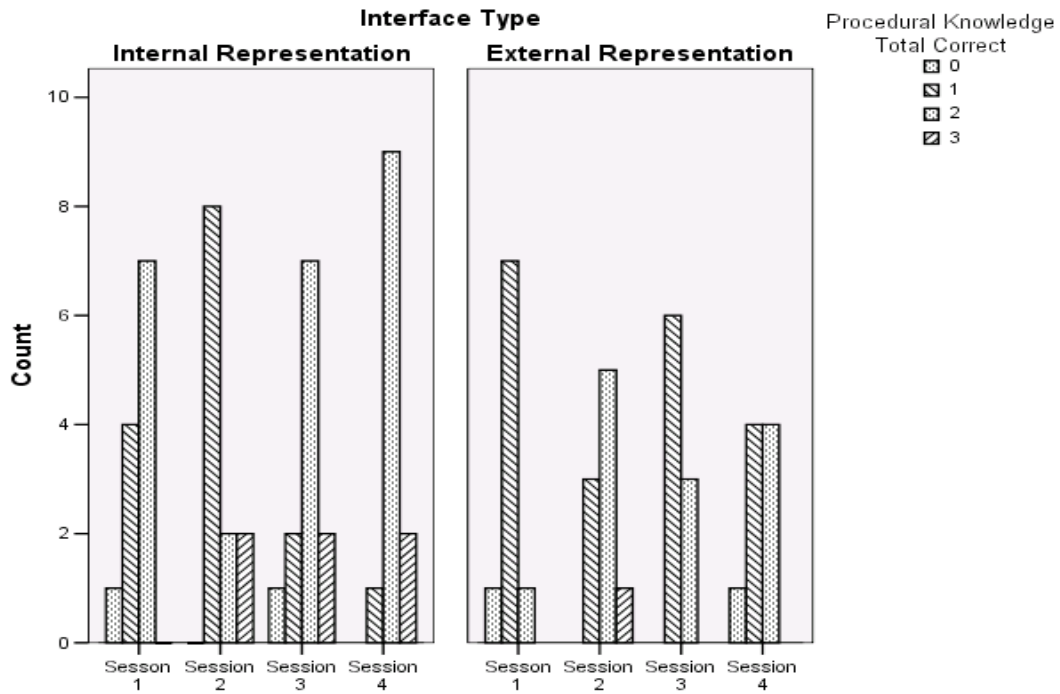


Figure 8. Total Correct Procedural Knowledge Questions per Session

For the qualitative mean and standard deviation figures used for analysis, see Table J-3 in Appendix J. Also, note that questions 8, 11 and 13 are negative or reversed questions. The qualitative questions are listed in Table J-1 and coded answers are in Table J-2, both in Appendix J. Review Figures 9, 10, 11, 12, 13, 14, 15, 16 for answer results for questions 7, 8, 9, 10, 11, 12, 13 and 14, respectively.

Question 7: I always looked how I should solve a task and then started working on it

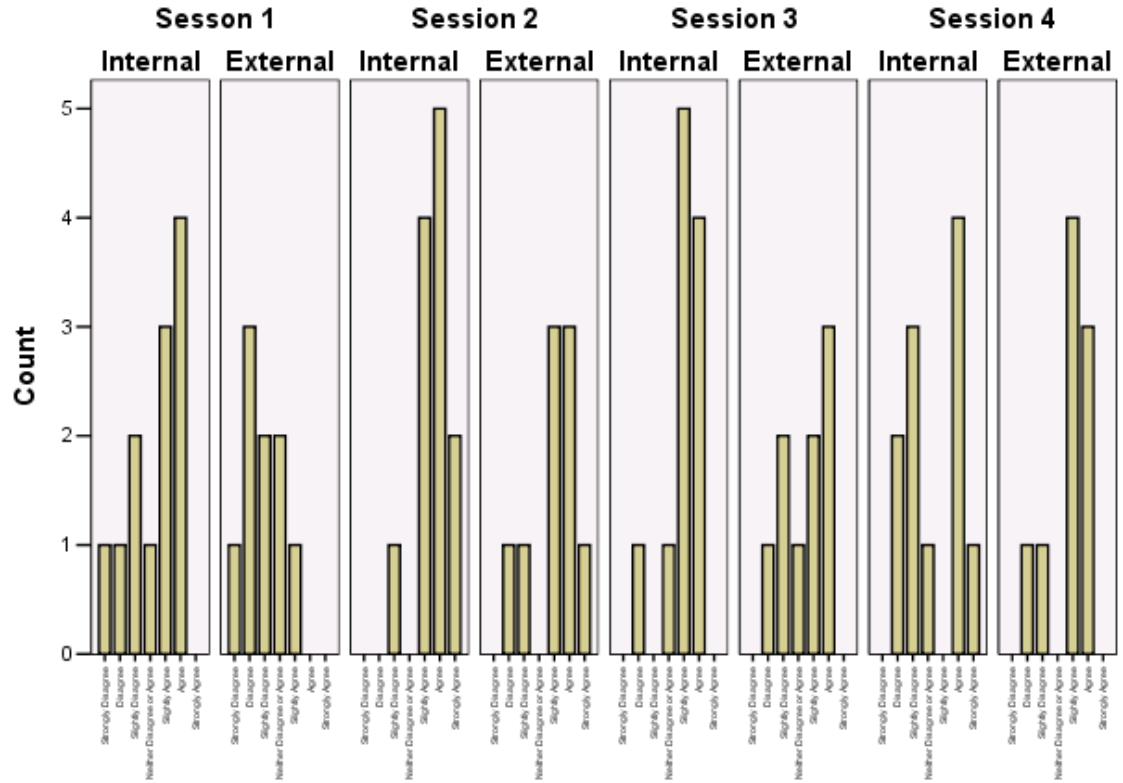


Figure 9. Question 7 Answer Results.

Question 8: I found the trials difficult to solve

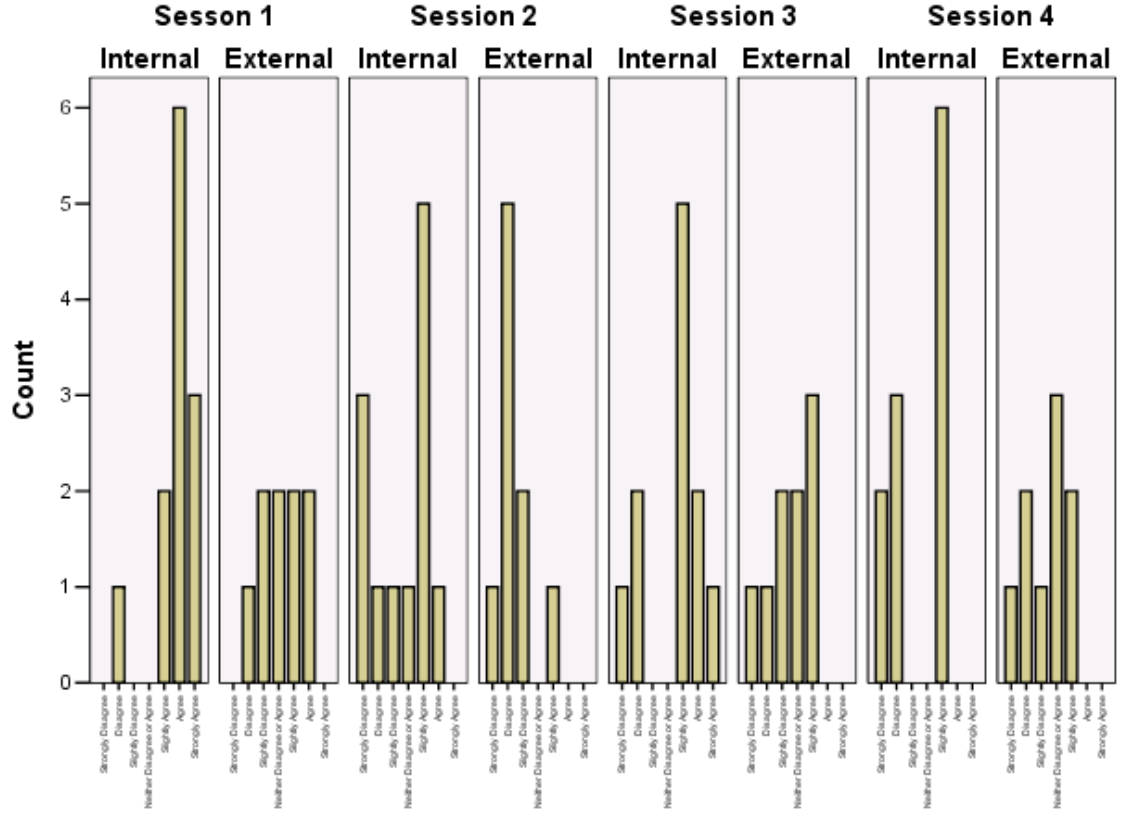


Figure 10. Question 8 Answer Results.

Question 9: I think I succeeded in solving the tasks with as few moves as possible

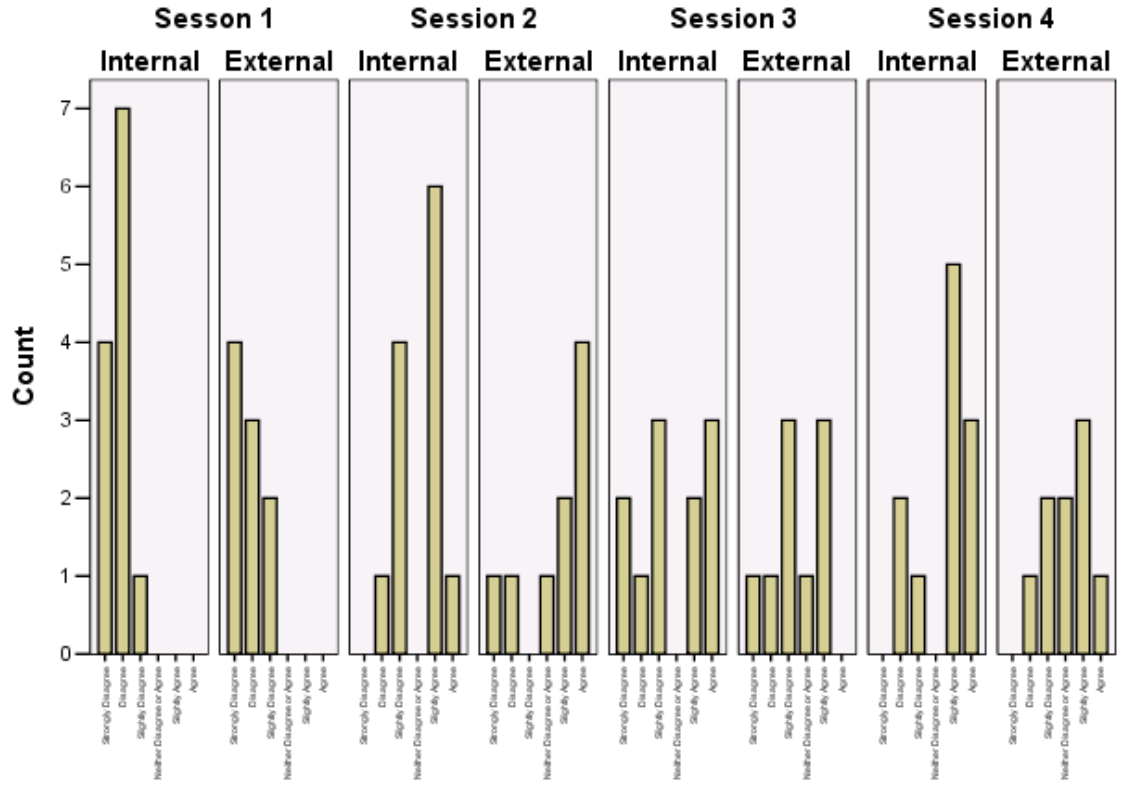


Figure 11. Question 9 Answer Result.

Question 10: I tried to think ahead about my steps as much as possible

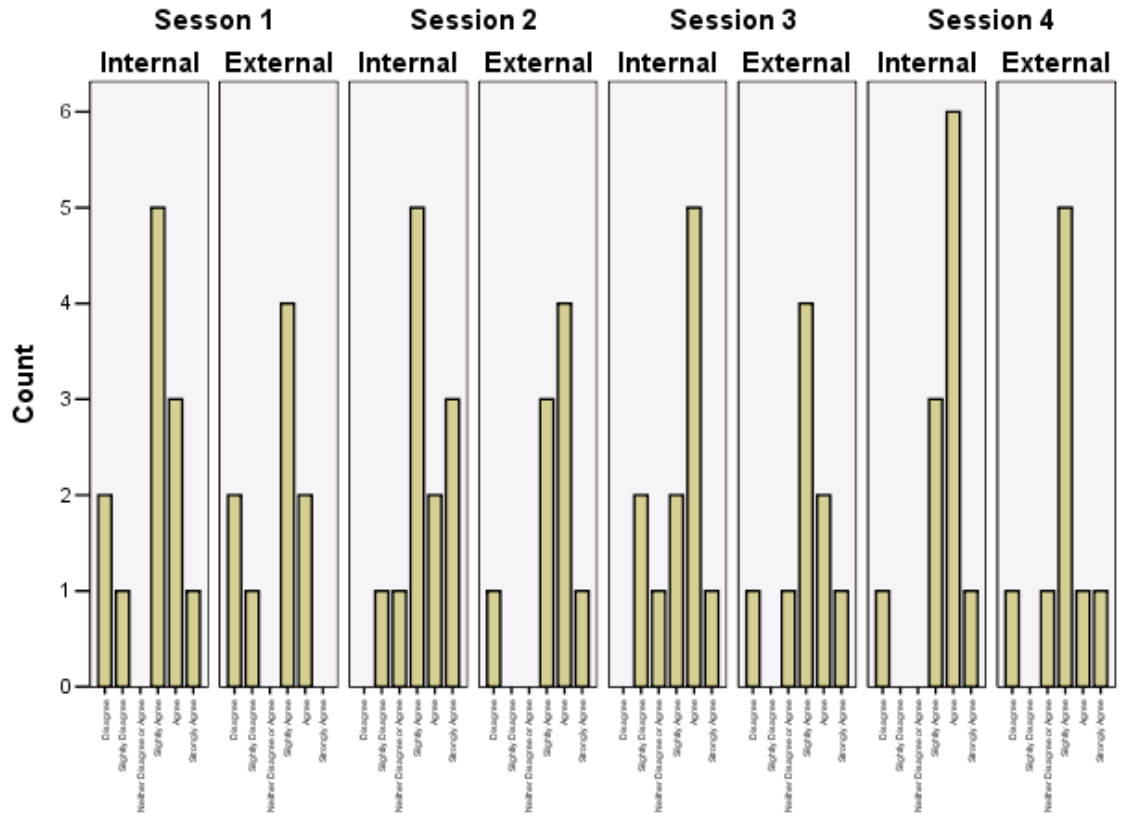


Figure 12. Question 10 Answer Results.

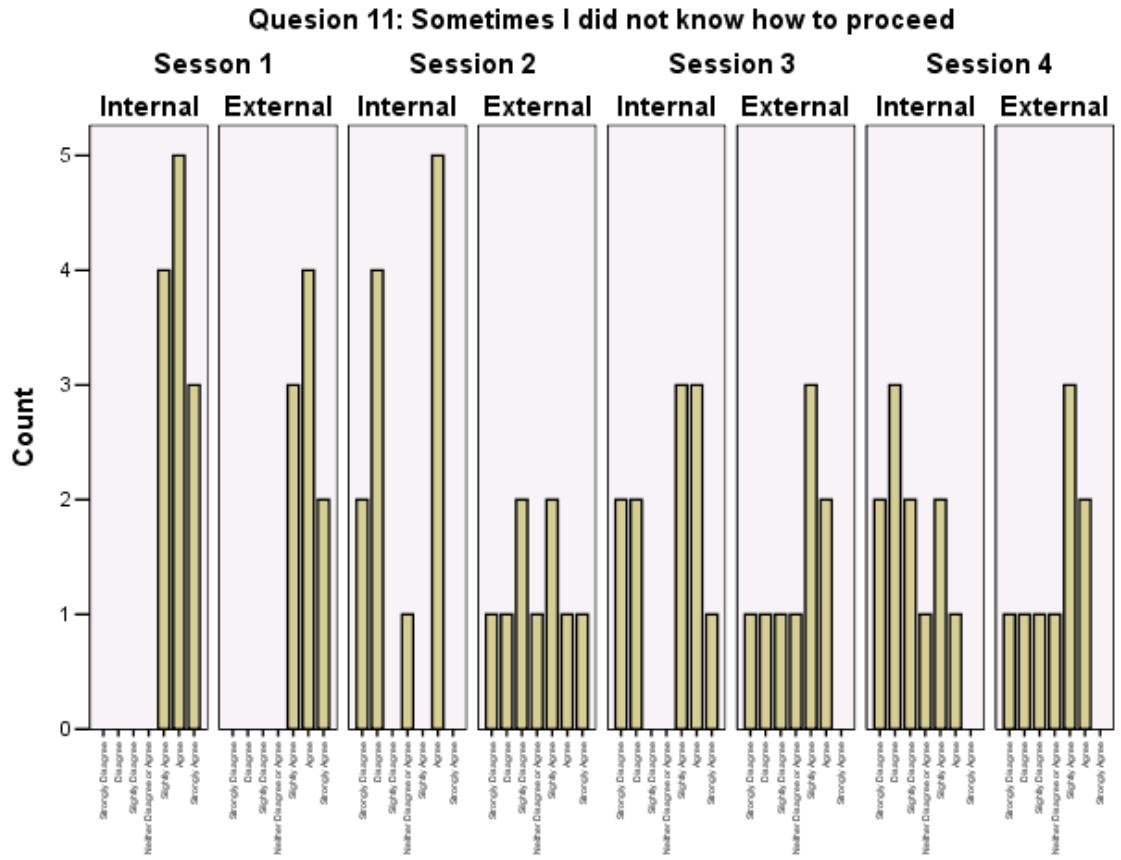


Figure 13. Question 11 Answer Results.

Question 12: It was easy to control the movement of barrels, boxes and pallet

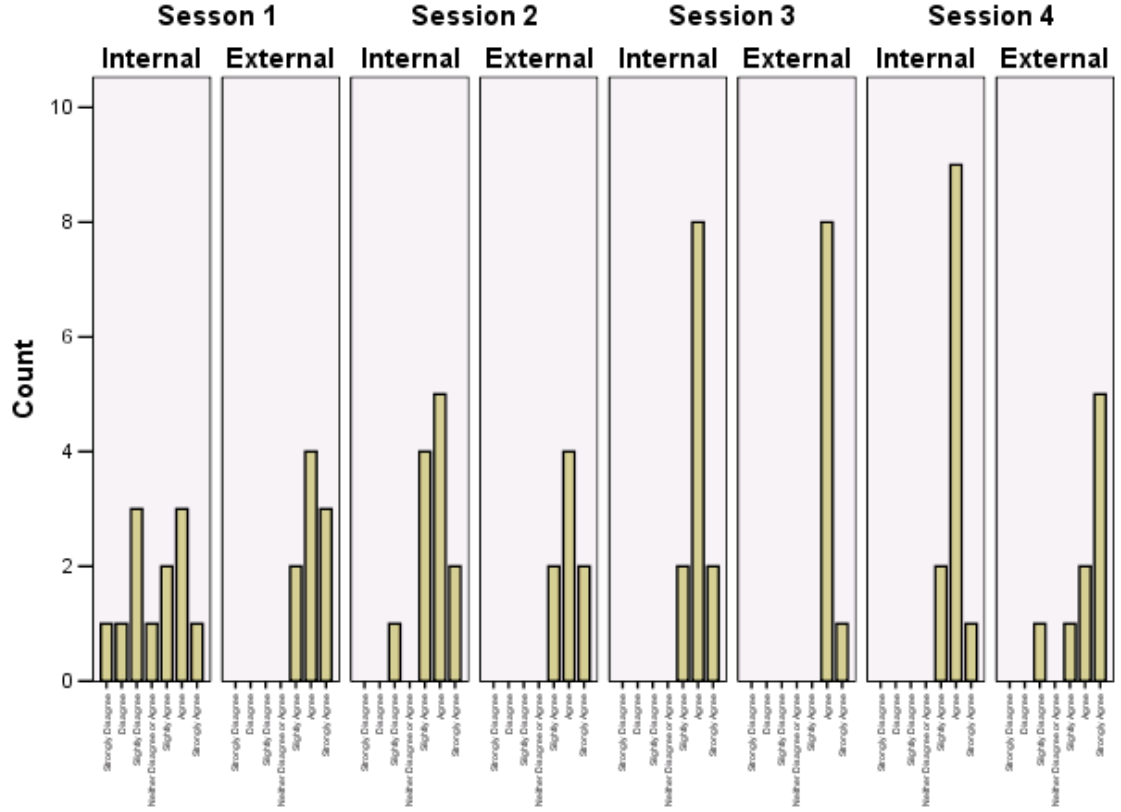


Figure 14. Question 12 Answer Results.

Question 13: I often felt like I was stuck and could not find the solution

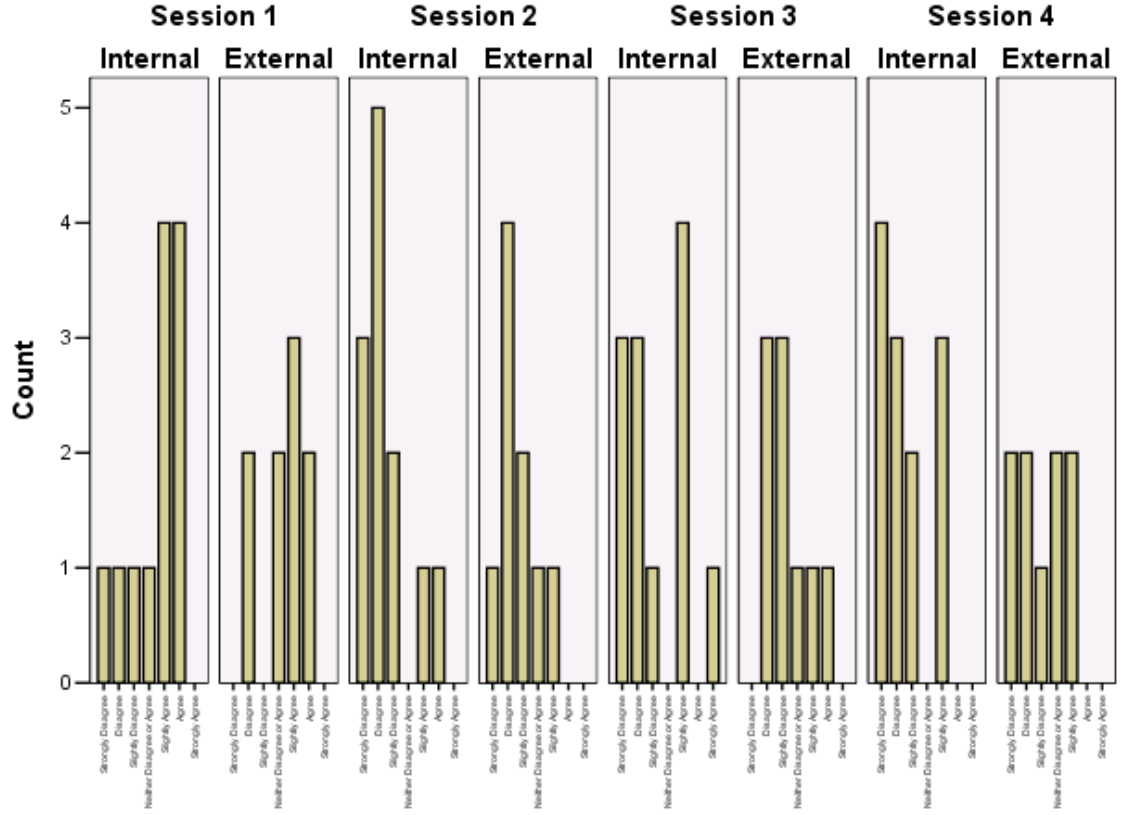


Figure 15. Question 13 Answer Results.

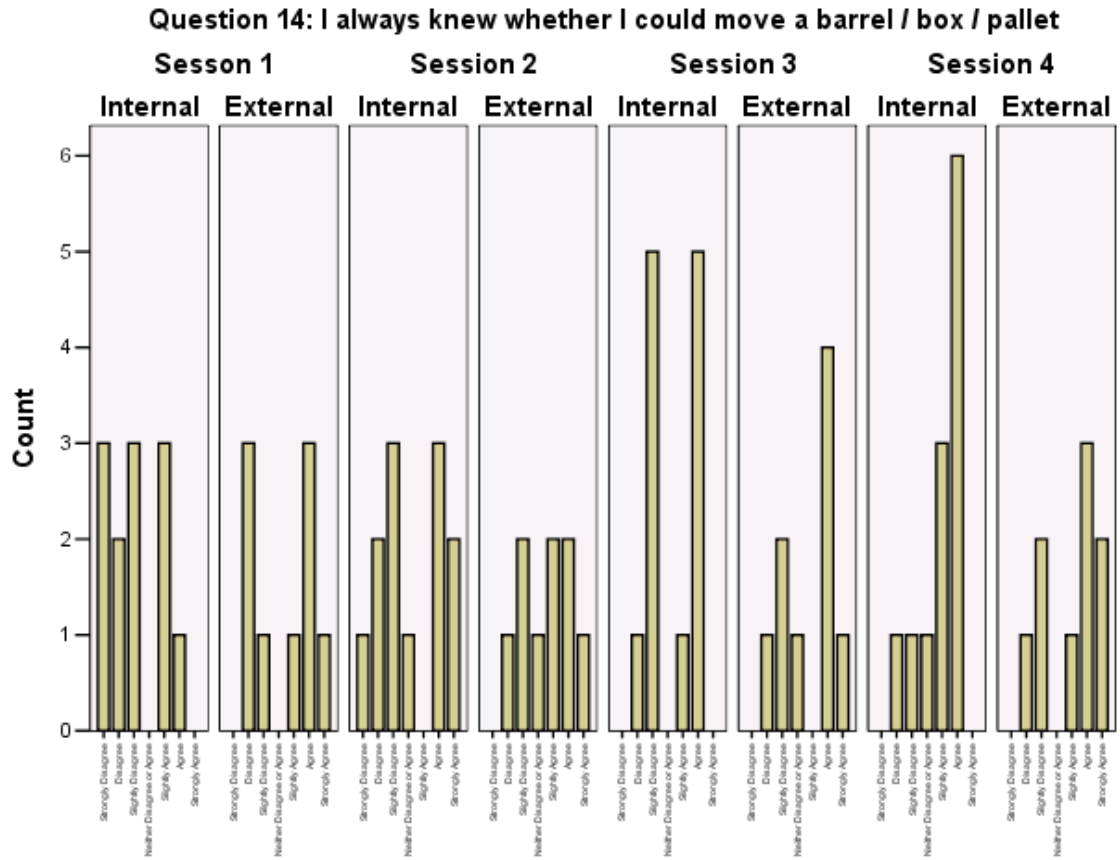


Figure 16. Question 14 Answer Results.

In the summary counts, there are four variables to review: time, invalid moves, non-object moves, and object moves. Time was defined as the trial’s completed date/time minus the date/time when the participant pressed pushed either the start first trial or start next trial option button, expressed in hours, minutes and seconds. The formula is:

$$T_c = DT_{\text{finish}} - DT_{\text{start}}$$

Invalid moves were defined as the total of invalid or un-allowed moves within the game and smart phone hardware button presses of home, telephone off hook (answer call), telephone on hook (end call) and back. Non-object moves were defined as the total number of times the user’s current position moved to a different location without movement of an object or the pallet. The object moves were defined as the total number

of times an object (box or barrel) moved to or from the pallet and the total number of times that the pallet was moved to the opposite side. The session summary information is in Appendix F; the session and trial detail information is in Appendix G. Figures 17, 18, 19 and 20 show scatter plots for time, invalid moves, non-object moves, and object moves respectively, using all data. For box plots of this data, see Appendix H.

Each trial was subjected to a Mann-Whitney U test to compare the interface style with the summary count information via the Boxes and Barrels program; comparisons are shown in Table 3. Mann-Whitney U test results are shown in Appendix I.

Table 3. Mann-Whitney U Test Summary Count Comparisons

Interface Style	Time
Interface Style	Invalid Moves
Interface Style	Non-object Moves
Interface Style	Object moves

Session 1, trial 5 showed a significant effect on object moves (internal median = 271; external median = 171) $U = 20.5$, $p = .01$. Session 1, trial 6 showed a significant effect on time (internal median = 10:01; external median = 5:46) $U = 28.50$, $p = .04$ and object moves (internal median = 244; external median = 174) $U = 26.50$, $p = .03$. Session 2, trial 1 showed significant effect on all four variables: time (internal median = 1:44; external median = 0:41) $U = 20.50$, $p = .01$, non-object moves (internal median = 26; external median = 9) $U = 15.50$, $p = .02$, object moves (internal median = 26; external median = 12) $U = 11.00$, $p < .01$ and invalid moves (internal median = 11; external median = 4) $U = 22.50$, $p = .01$. Session 2, trial 3 showed a significant effect on object

moves (internal median = 160; external median = 125) $U = 30.0$, $p = .05$. Session 3, trial 1 showed a significant effect on non-object moves (internal median = 4; external median = 2) $U = 23.50$, $p = .01$. Session 3, trial 3 showed a significant effect on invalid moves (internal median = 40; external median = 17) $U = 28.50$, $p = .04$.

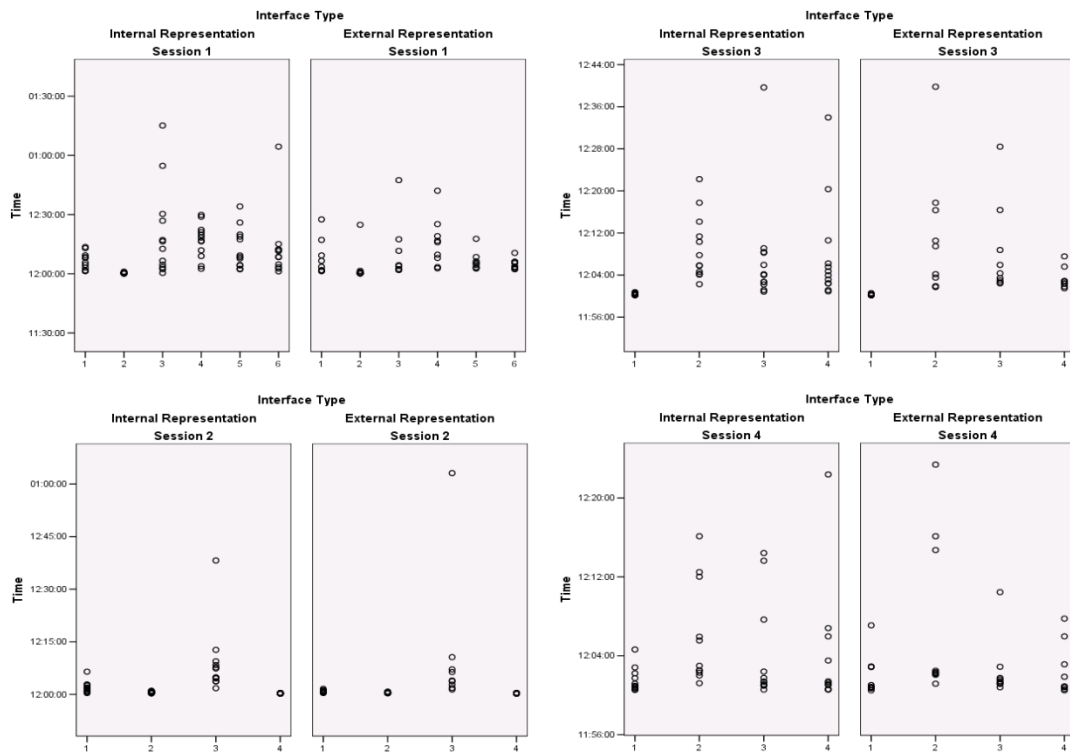


Figure 17. Scatter Plot of Time

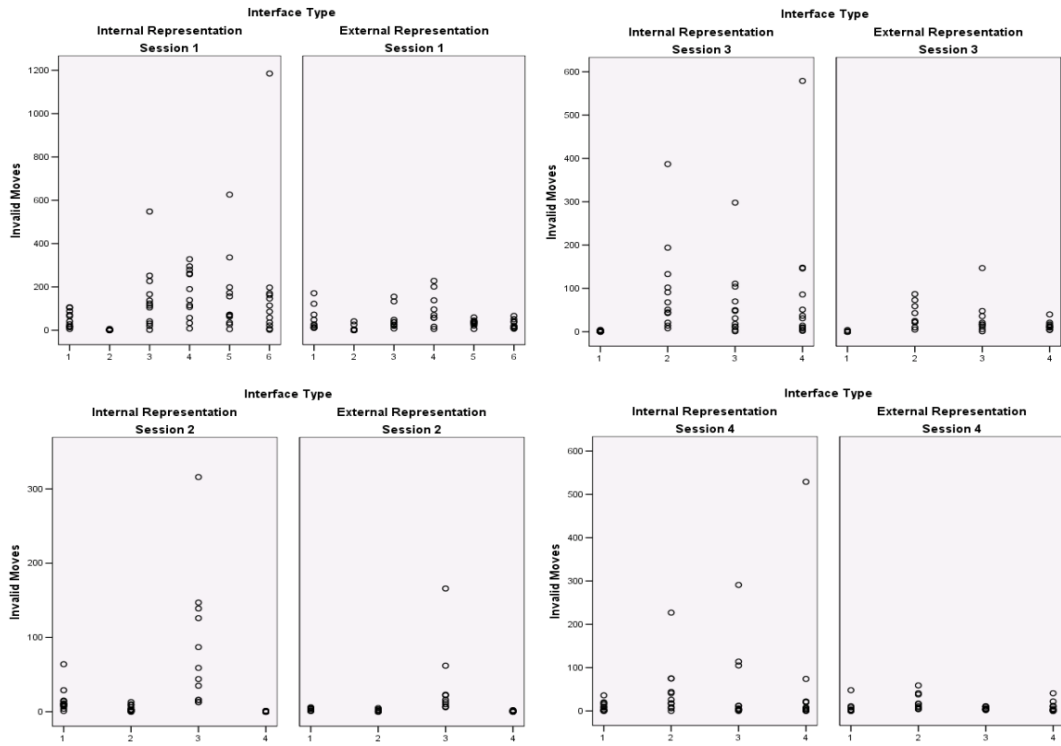


Figure 18. Scatter Plot of Invalid Moves

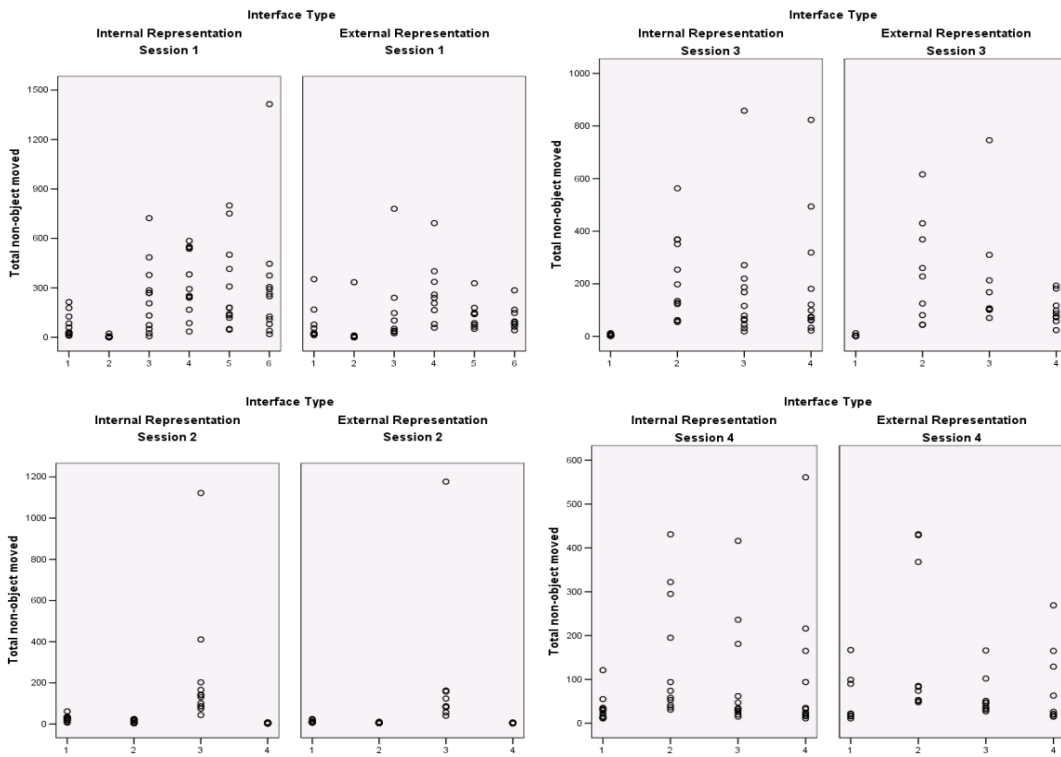


Figure 19. Scatter Plot of Non-object Moves

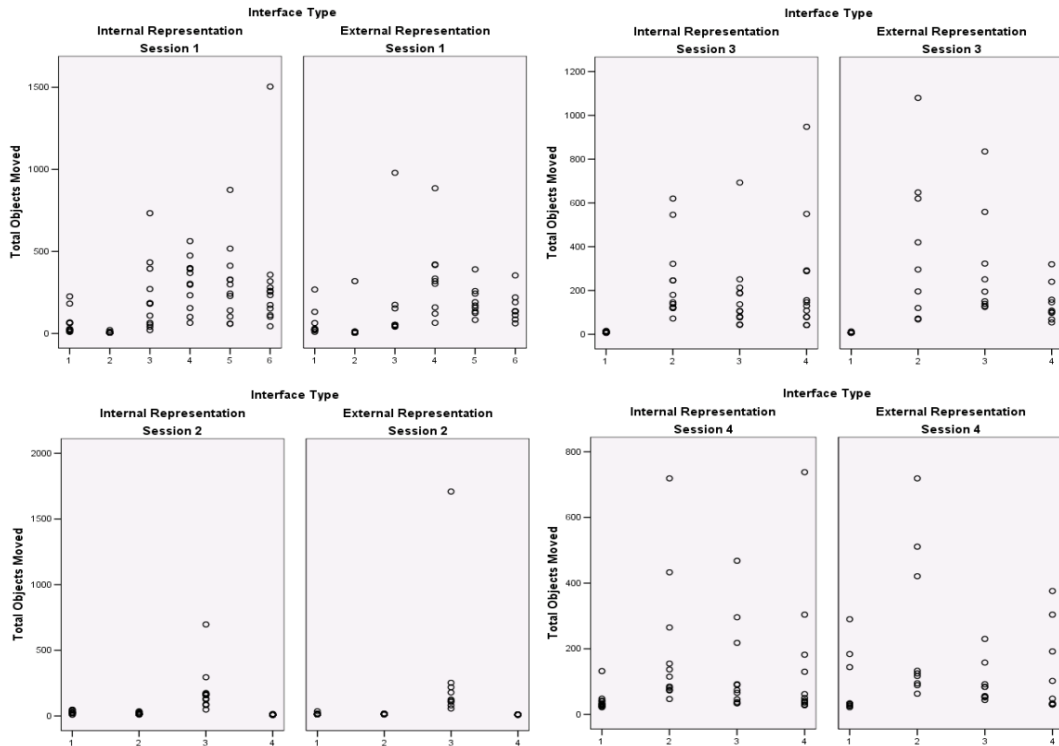


Figure 20. Scatter Plot of Object Moves

CHAPTER FIVE: DISCUSSION

The declarative knowledge results in Table 2 show that the means did not sufficiently differ when comparing the internal representation interface style with the external representation interface style. Based on this, the hypothesis (H_1), that the people who use the internal representation interface style will have significantly more declarative knowledge than those who use the external representation interface style, cannot be accepted. This result contrasts with the Nimwegen et al. 2004 result, where there was a significant difference favoring the internal representation interface style. There could be several reasons for this: low number of participants in this study, geographical location, higher variance in participants' age, differences in rules on the

test. It could also mean that there is a cognitive learning difference in the usage of a personal computer versus a hand-held device.

The procedural knowledge results in Table 2 shows for session 2 the internal representation interface style mean did not greatly differ from the external representation interface style. In sessions 1, 3 and 4, the mean did differ by 0.5 or more when the internal representation interface style and the external representation interface style were contrasted. This difference in sessions 1, 3, and 4 was surprising, since the procedural knowledge was gained throughout when using the device and both groups had to perform the same process to solve the puzzle. Nimwegen et al. 2004, and Nimwegen et al. 2006 test results showed no significant difference in procedural knowledge between the internal representation and external representation groups. This appears to be effect for procedural knowledge favoring the internal representation interface on sessions 1, 3, and 4, but could be a localized for region or for the participants who took part in this study. The author recommends a similar study with a larger group of participants.

The answers to the qualitative questions in the post-session questionnaire were interesting. Question 7 asks if they reviewed and thought about how to solve the puzzle before starting upon it. In session 1 there was a difference in the answer of the internal representation interface response of between “neither disagree or agree” and “slightly agree” ($M = 4.33$, $SD = 1.72$) and external representation interface response of between “slightly disagree” and “disagree” ($M = 2.89$, $SD = 1.27$) are compared. This contrasts with sessions 2, 3, and 4, where the internal representation interface was very similar to the external representation interface style where both evaluated the answer between

“neither disagree or agree” and “slightly agree”. In question 7, the external representation interface showed a greater change and became more conscious of their move choices.

A similar question, 9, asked if they succeeded in solving the task with as fewest possible moves. In session 1 both representations gave almost the same response of close to “disagree”, internal representation interface ($M = 1.75, SD = 0.62$) and external representation interface ($M = 1.78, SD = 0.83$). In session 2, both representation interfaces increased with the internal style ($M = 4.17, SD = 1.28$) responded close to “neither disagree or agree” and the external style ($M = 4.56, SD = 1.88$) were between “neither disagree or agree” and “slightly agree”. The response in session 3 decreased on both interface representations to between “slightly disagree” to “neither disagree or agree”. Session 4 saw the response in both interface representations increase to a level similar to session 2 and was between “neither disagree or agree” and “slightly agree”. In question 9, both representation interfaces showed a similar mean response in all sessions. It showed that both groups had difficulty in the start, and became more confident as they went along.

Another similar question, 10, asked if they thought out and planned their steps. In session 1 the internal representation interface ($M = 4.75, SD = 1.60$) and the external representation interface ($M = 4.33, SD = 1.58$) had a similar answer of between “neither disagree or agree” to “slightly agree”. In session 2, both exceeded “slightly agree” and in session 3, both scores were slightly lower when compared to session 2. In session 4, we see that the external representation interface style continues to decrease ($M = 4.89, SD = 1.36$) and is slightly below “Slightly Agree”. The session 4 internal representation interface style had risen again and had a score similar to session 2 ($M = 5.45, SD = 1.29$)

and is between “Slightly Agree” and “Agree”. This question showed that the response changed along with the session. The responses in session 1 had the highest result, which was very closely followed by session 4.

Questions 7 and 10 showed less of a change than question 9; however, the mean response of question 10 was usually greater in all sessions than for question 7 and 9. This comparison showed that participants thought more about future moves than either about the puzzle as a whole (question 7) or about along the line of many future moves, which was similar to the results of O'Hara and Payne's 1998 study.

In graphs shown in Figure 17, Figure 18, Figure 19, Figure 20, and the figures in Appendix H, many outliers are exposed. To deal with this issue, outliers that were more than two standard deviations away from the other data were removed, and the Mann-Whitney U test was performed on the remaining data; see results in Table I-2 in Appendix I. Figure 21, Figure 22, Figure 23 and Figure 24 show the Time, Invalid Moves, Non-object Moves and Object Moves scatter plot graphs respectively. Each graph shows that some extreme values remain within two standard deviations of the original data.

The removal of outliers was done to verify if there was a significant effect on object moves in session 1, trial 5; on time and invalid moves in session 1, trial 6; on all variables in session 2 trial 1; on object moves session 2, trial 3; on non-object in moves session 3, trial 1; and on invalid moves in session 3, trial 3. None of the significant effects became insignificant.

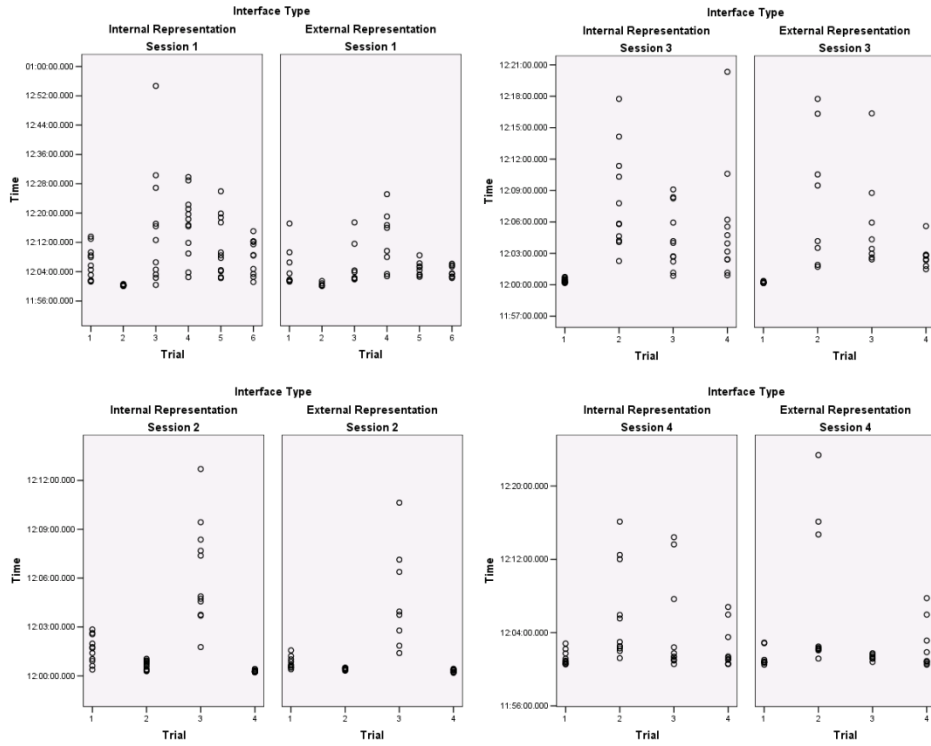


Figure 21. Scatter plot of Time, with Outliers Removed

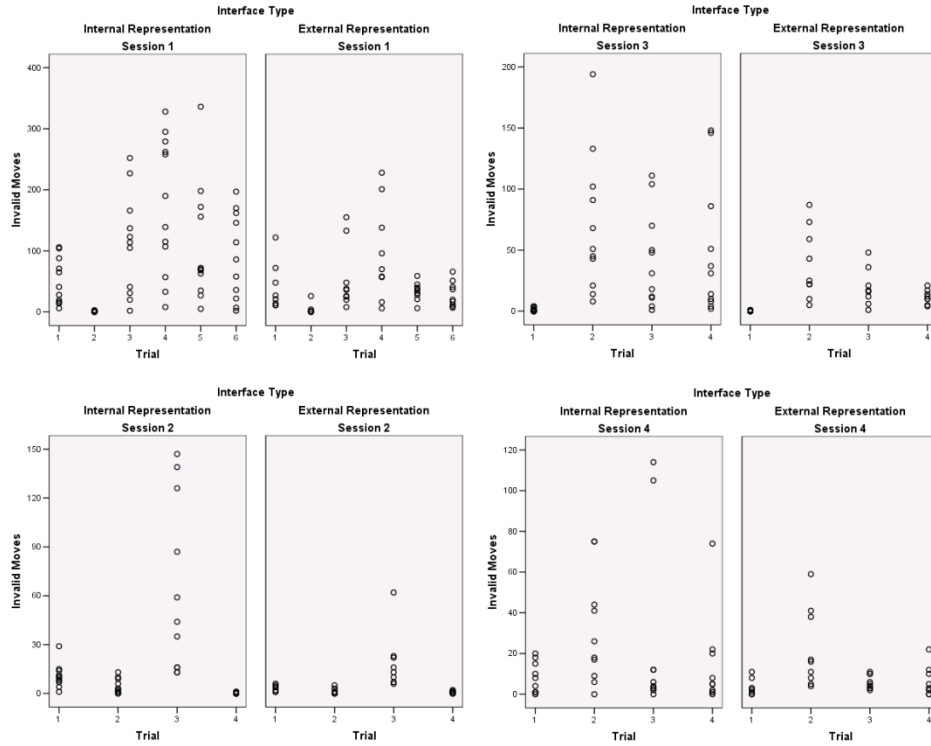


Figure 22. Scatter plot of Invalid Moves, with Outliers Removed

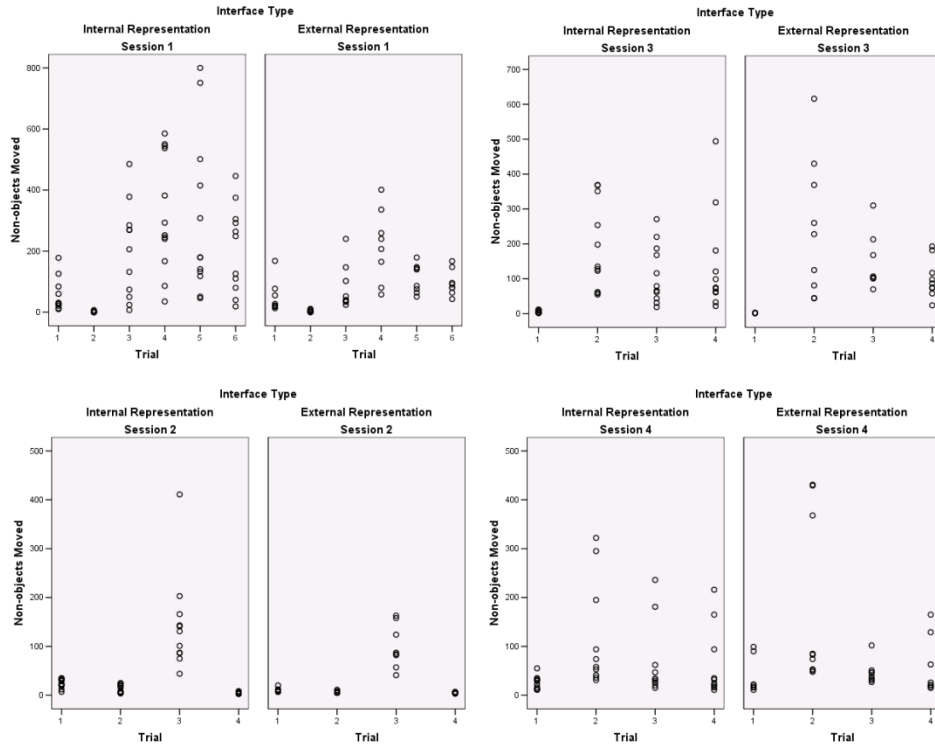


Figure 23. Scatter plot of Non-object Moves, with Outliers Removed

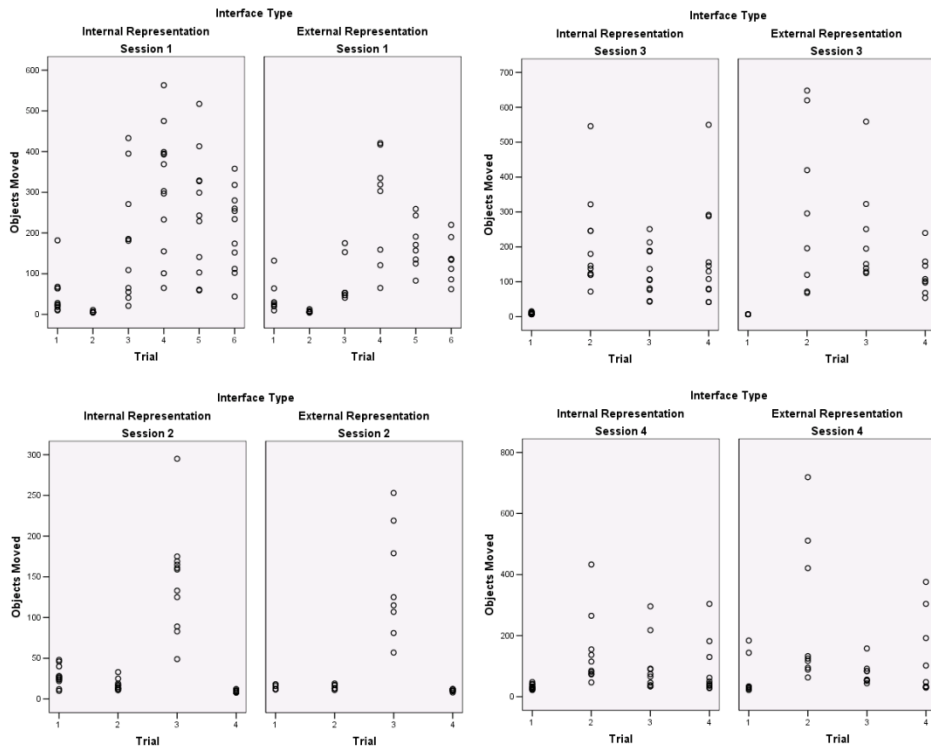


Figure 24. Scatter plot of Object Moves, with Outliers Removed

Session 1, trial 3 results were almost significant on time (internal median = 14:31; external median = 3:55) $U = 33.50$, $p = .08$, object moves (internal median = 183; external median = 53) $U = 31.50$, $p = .06$ and invalid moves (internal median = 119; external median = 36) $U = 33.50$, $p = .08$. All three had significant Mann-Whitney U effects with the outliers removed. Session 3, trial 1 results were almost significant with time (internal median = 0:21; external median = 0:12) $U = 32.0$, $p = .06$ and invalid moves (internal median = 1; external median = 0) $U = 33.5$, $p = .06$; both had significant Mann-Whitney U effects with the outliers removed. Appendix G shows the movement information with and without removal of outliers. For all of the session and trial combinations, except session 2, trial 3, that achieved a significant effect, the external representation interface style always had a lower mean time or mean count. The exception of session 2, trial 3 achieved a significant effect where the internal representation interface style had a lower mean object move count.

Session 1, trial 3 significant effect was the first trial that required the participants to go through the crossover section to complete the trial. This was expected, as the external representation interface would help the participant by externalization of the rules on the first difficult trial in the session. Session 2, trial 1 and session 3, trial 1 had a significant effect, due to the 6 to 8 day recess between the sessions and were anticipated. The external representation interface style would help the participant recall how to complete the puzzle after the recess, while the internal representation interface style would require more effort to recall the rules and procedures to complete the trial. This was not the case for session 4, trial 1, perhaps because internal representation interface participants had learned and internalized the rules and procedures from the prior sessions.

The author believes the reason for the two significant effects on Session 1, trial 6, is that it was the first screen that required thoughtful reversal from the initial state to move forward within the game. Session 1, trial 5 had significant effects, but there were still some extreme values present in the data even after the outliers were removed; see Appendix G. As such, session 1, trial 5 was considered a false positive significant effect. Session 2, trial 3 as well as session 3, trial 3 had an initial state of all boxes and barrels on the left side, and had a significant effect because of this.

CHAPTER SIX: CONCLUSION

The declarative knowledge results for the external interface style did not differ significantly from the declarative knowledge results for the internal representation interface. However, the internal representation interface always had a higher mean, and in sessions 3 and 4 their standard deviation was lower than the external representation interface. The procedural knowledge results did not show a significant effect, but the mean difference was 0.5 or greater on three of the four sessions in favor of the internal representation interface style. These results alone are encouraging for those pursuing this line of inquiry and further research should be done in this area.

Limitations

The number of participants who completed the study was low. Because of the nature of this study requiring four sessions that were 6 to 8 days apart, the number of possible participants was limited when contrasted with a non-longitudinal study. This study required scheduling and interaction with a proctor, which also limited the

availability of potential participants. The budget funds were from the author, so it was not possible to offer monetary compensation for each session of the study.

Future Research

If this study were done again with more participants, an increased timeframe, and a higher budget to pay the participants per session better results would be possible. One possible improvement would upgrade the capability of the test program to record all moves that the participant makes, for a more detailed movement analysis. Another improvement would be to allow the program to vary the number of objects used in each trial, to see if this alteration would either help or hinder declarative and procedural learning.

Since this research started, new smart phone devices have appeared on the market, such as the Apple iPhone and Google's Android based G-phones. The iPhone multi-touch interface and the open source G phones are both easier to use and have more functionality than the Windows Mobile 5.x and 6.x based smart phones that were used in this study. A study using these hand-held devices may be of more use to people who design interfaces for these new hand-held devices.

Summary

This study addressed the needs of learning when using a hand-held device. This work is important as the usage of hand-held devices is increasing over the use of desktop and traditional size laptop computers, especially in third-world countries. This study created a program to test the hypothesis that when learning is the goal, internal representation is better than external representation. This program was installed on a

popular smart phone, the Samsung I607 Blackjack. Participants were assigned to two different groups, the internal representation interface style and the external representation style, and their declarative knowledge was tested after each session. The result was that there was not a large difference in the means between these groups. When the moves were examined, those participants who used the external representation interface was significantly better in some trials in the early sessions, but in later sessions their performance was were not significantly different from the participants who use the internal representation interface.

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APPENDIX A – CANNIBALS AND MISSIONARY THREE PERSON STATES

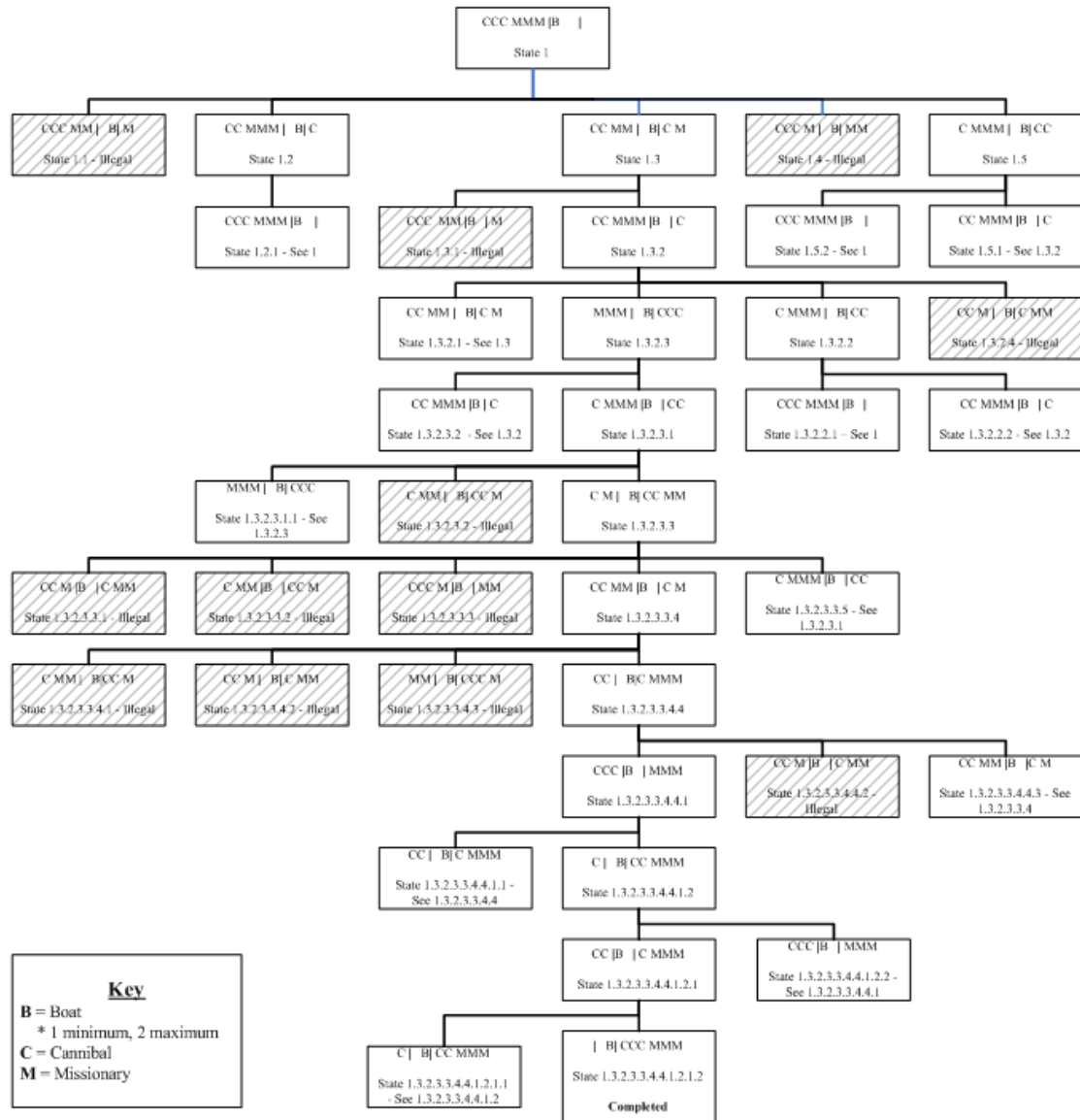


Figure A-1. Three person cannibals and missionaries group, all states shown. Boxes with diagonals signify illegal states.

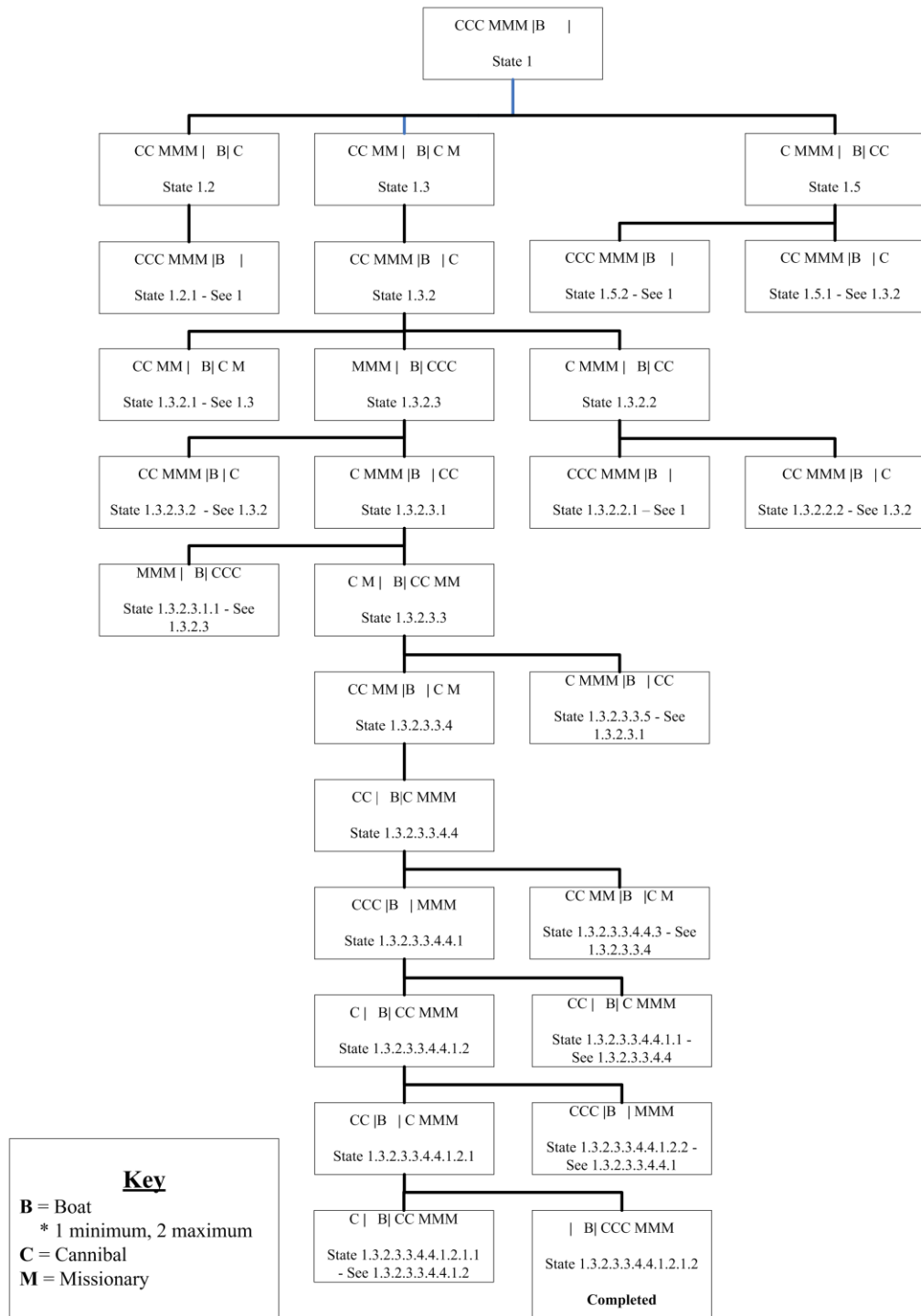


Figure A-2. Three-person cannibals and missionaries group, only legal states shown

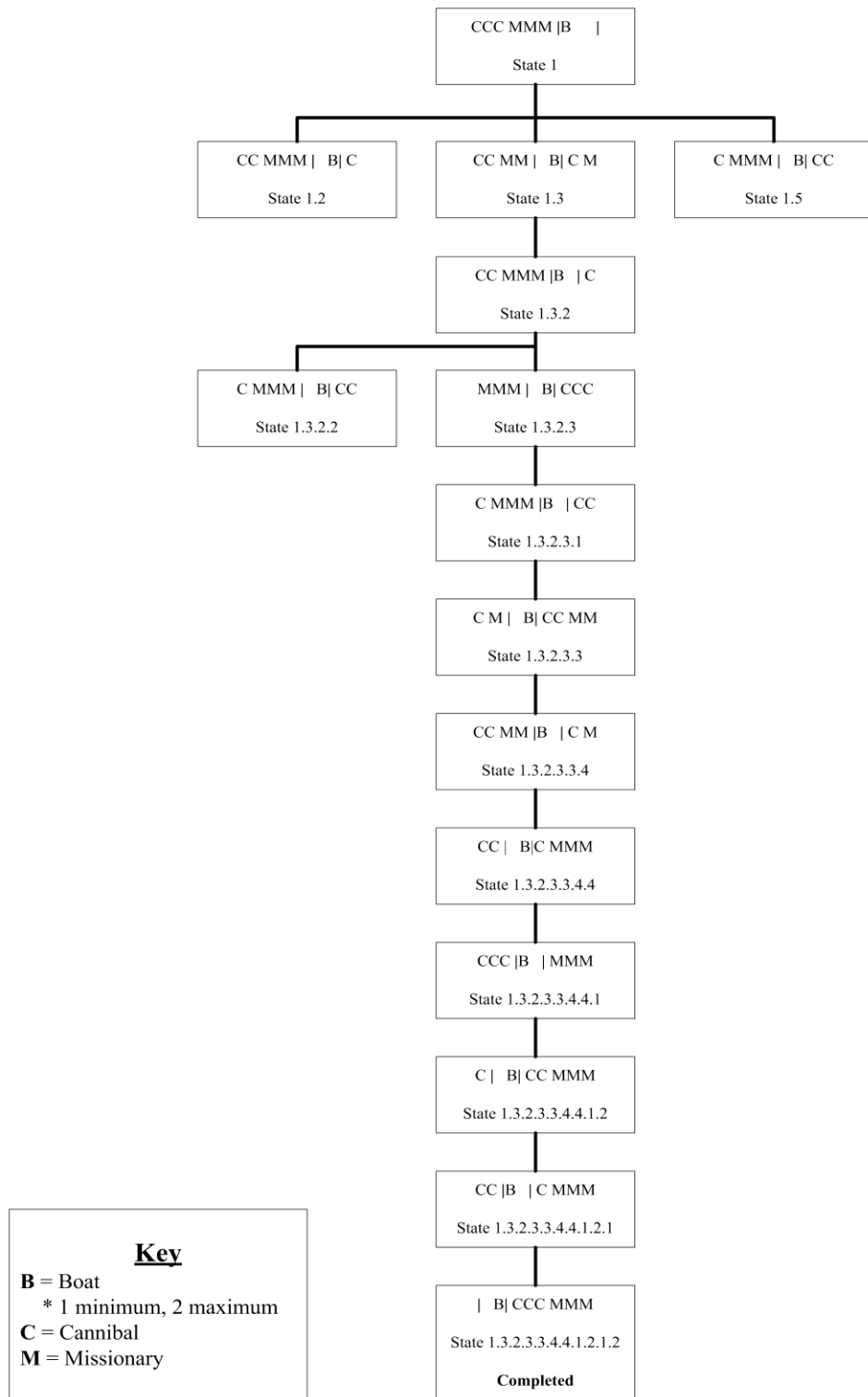


Figure A-3. Three-person cannibals and missionaries group, only unique, legal states shown

APPENDIX B – CANNIBALS AND MISSIONARY FIVE PERSON STATES

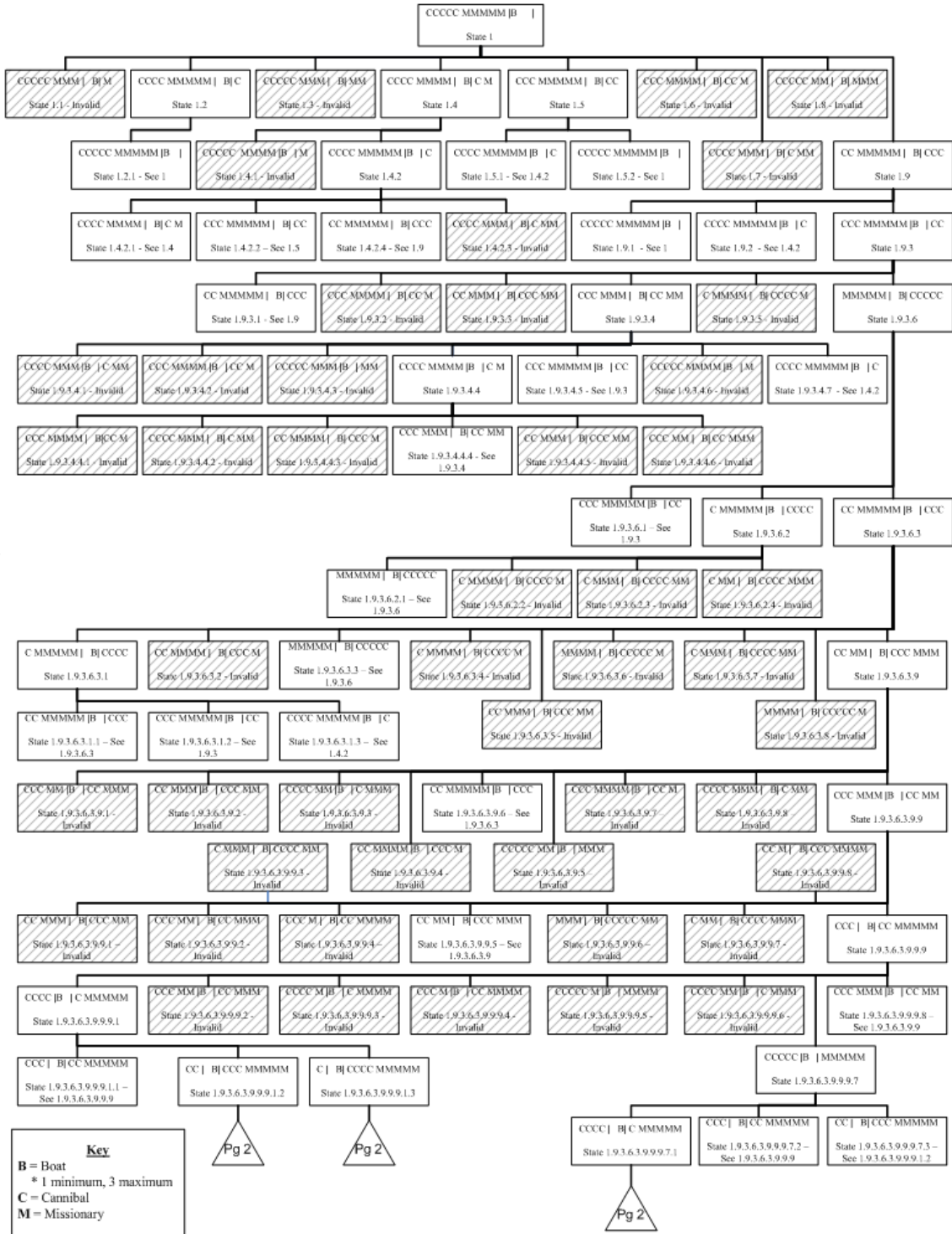


Figure B-1. Five-person cannibals and missionaries group, all states shown, page 1.

Boxes with diagonals signify illegal states.

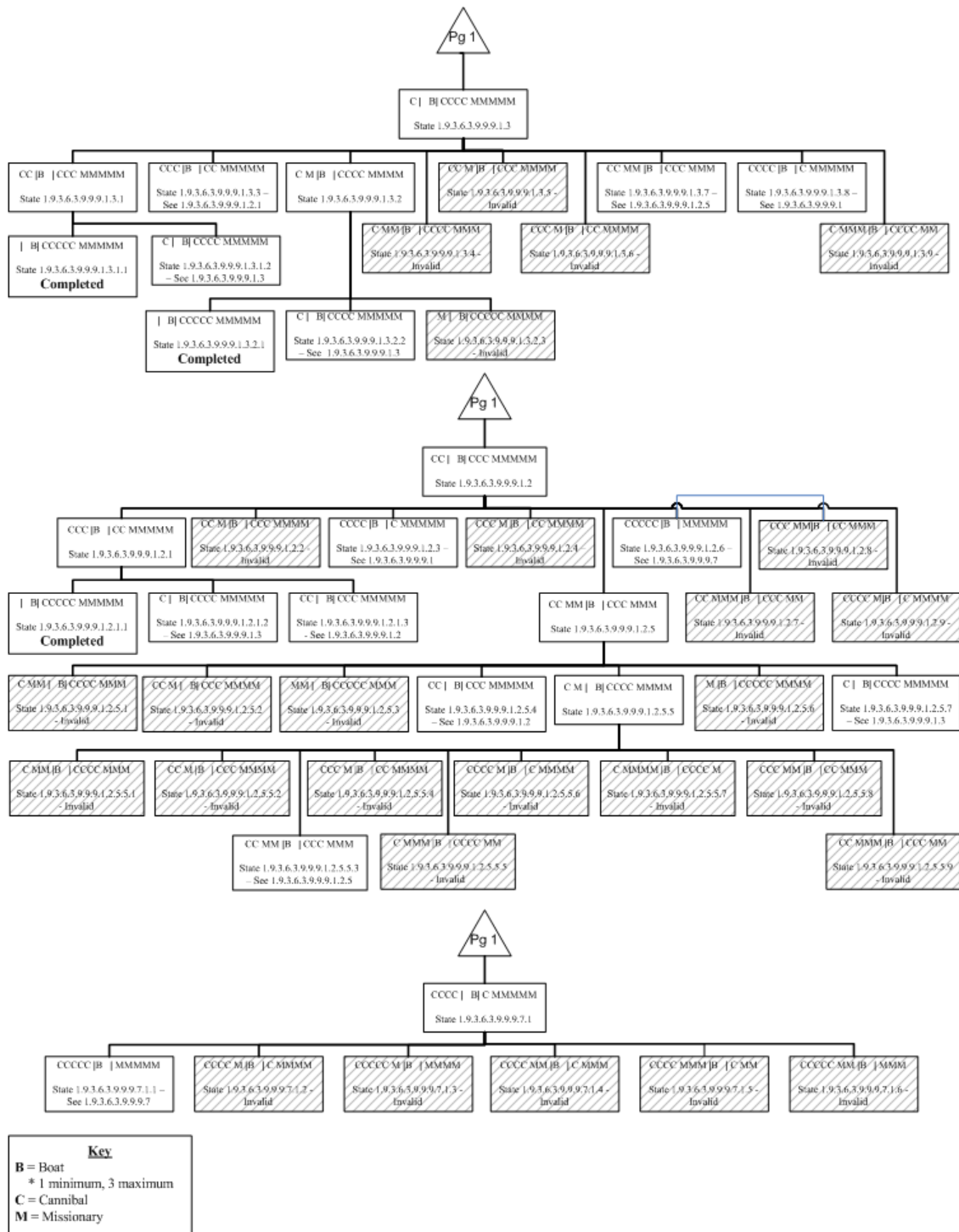


Figure B-1. Five-person cannibals and missionaries group, all states shown, continued.

Boxes with diagonals signify illegal states.

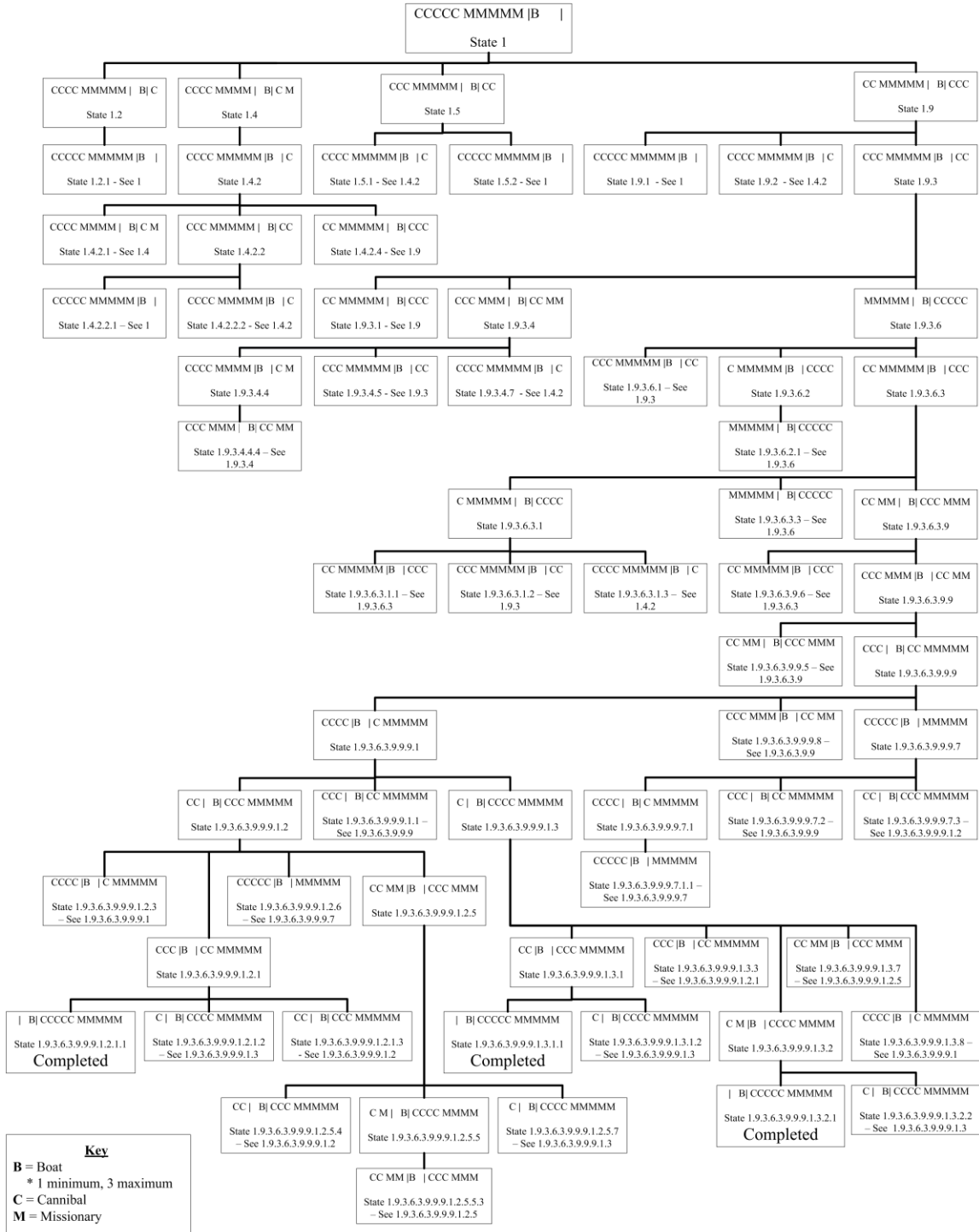


Figure B-2. Five-person cannibals and missionaries group, only legal states shown.

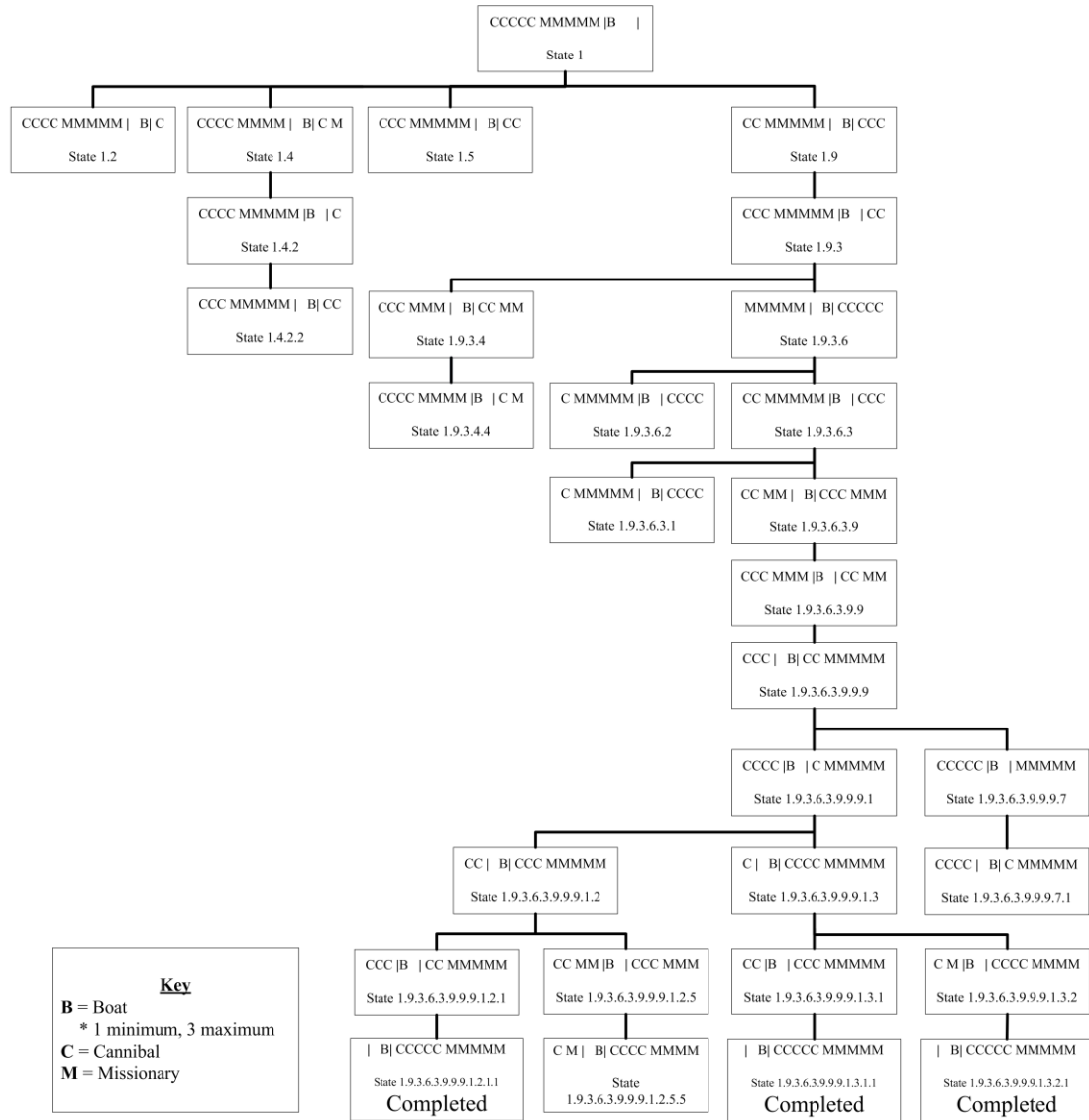







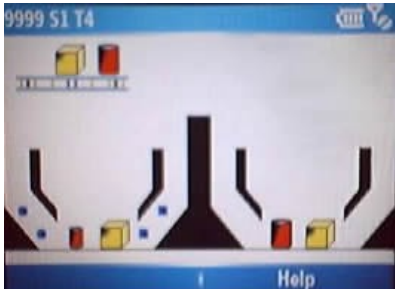


Figure B-3. Five-person cannibals and missionaries group, only the unique, legal states shown.

APPENDIX C – BOXES AND BARRELS INITIAL STATES

Table C-1. Session 1 – Initial Game States Shown

Trial	Externalized Interface Style	Internalized Interface Style	Possible States
1			1.9.3.6.3.9.9. 9.1.3, 1.9.3.6.3.9.9. 9.1.2.1.2, 1.9.3.6.3.9.9. 9.1.3.1.2
2			1.9.3.6.3.9.9. 9.1.3.2
3			1.9.3.6.3.9.9, 1.9.3.6.3.9.9. 9.8
4			1.9.3.4.4

5



1.9.3,
1.9.3.4.5,
1.9.3.6.1,
1.9.3.6.3.1.2

6



1.9.3.4,
1.9.3.4.4.4

Table C-2. Session 2 – Initial Game States Shown

Trial	Externalized Interface Style	Internalized Interface Style	Possible States
1			<p>1.9.3.6.3.9.9 .9.1.2.5.5</p>
2			<p>1.9.3.6.3.9.9. 9.1.2.5, 1.9.3.6.3.9.9. 9.1.2.5.5.3, 1.9.3.6.3.9.9. 9.1.3.7</p>
3			<p>1</p>

4



1.9.3.6.3.9.9.

9.1.2,

1.9.3.6.3.9.9.

9.7.3,

1.9.3.6.3.9.9.

9.1.2.1.3,

1.9.3.6.3.9.9.

9.1.2.5.4

Table C-3. Session 3 – Initial Game States Shown

Trial	Externalized Interface Style	Internalized Interface Style	Possible States
1			<p>1.9.3.6.3.9.9.9. 1.2, 1.9.3.6.3.9.9.9. 7.3, 1.9.3.6.3.9.9.9. 1.2.1.3, 1.9.3.6.3.9.9.9. 1.2.5.4</p>
2			<p>1.9, 1.4.2.4, 1.9.3.1</p>
3			1
4			1

Table C-4. Session 4 – Initial Game States Shown

Trial	Externalized Interface Style	Internalized Interface Style	Possible States
1			1.9.3.6.3.9, 1.9.3.6.3.9.9.5
2			1
3			1.9.3.6, 1.9.3.6.2.1, 1.9.3.6.3.3
4			1.9.3.6.3, 1.9.3.6.3.1.1, 1.9.3.6.3.9.6

APPENDIX D – DEMOGRAPHIC INFORMATION

Table D-1. Demographic Information from Pre Session 1 Questionnaire

	S										G
											P
											S
ID	Age	Sex	PDA	Cell	Smart Phone	Inv. Equip	HH Game	Digital Camera	MP3 Player	Video Player	
101	32	F	2	5	1	1	5	4	1	1	1
102	23	F	1	5	1	1	3	5	5	5	1
103	48	M	5	4	1	2	4	5	5	2	1
104	26	F	1	5	1	4	5	5	3	1	1
105	35	M	2	5	1	1	2	5	4	1	2
106	21	F	1	5	1	1	5	5	5	5	1
107	35	M	4	5	3	5	2	5	5	2	1
108	23	M	1	5	1	1	5	5	5	5	1
109	33	F	5	5	1	1	2	5	2	1	1
110	44	M	5	5	1	5	4	5	5	5	3
111	19	F	1	5	2	1	3	2	2	2	1
112	42	M	5	5	5	1	1	5	5	1	1
113	24	M	5	5	3	1	5	5	5	1	2
114	29	M	1	5	1	2	2	5	1	1	1
115	26	M	2	5	3	1	4	4	4	1	1
116	29	M	4	5	3	1	2	5	4	1	1
117	29	F	1	4	1	1	5	5	2	1	1

118	29	F	1	5	1	5	1	5	2	1	1
119	32	M	4	5	4	N/A	5	5	4	2	3
120	33	M	1	5	1	5	5	5	2	2	1
121	36	M	1	1	1	5	1	3	1	1	1
122	29	M	4	5	2	1	1	5	5	2	4
123	31	F	2	5	5	1	4	5	5	3	1
124	29	M	1	5	2	4	5	5	5	1	2
125	40	F	1	5	1	1	1	5	5	1	2
126	29	M	2	5	5	2	5	5	5	1	2
127	36	F	1	5	1	2	2	2	1	2	1
128	48	F	1	5	1	1	2	3	1	1	1
129	37	M	1	5	1	5	5	5	4	3	1
130	33	M	2	5	4	4	5	5	4	2	1
131	24	M	5	5	4	2	5	5	5	5	2

Table D-2. Demographic Information Column Code Descriptions

Coded Answer	Description
1	Never Used
2	1 to 6 months experience
3	7 to 12 months experience
4	1 to 2 years of experience
5	3 or more years of experience

APPENDIX E – PROCEDURAL QUESTION CODES

Table E. Textual Result Coding of the Procedural Questions

Code	Code Answer Explanations
1	<p>Answer does not have the best move to make (if any) or the best move to make is incorrect.</p> <p>Answer does not have any part of the point correct</p>
2	<p>Answer does not have the best move to make (if any) or the best move to make is incorrect.</p> <p>Answer has a part of the point correct.</p>
3	<p>Answer does not have the best move to make (if any) or the best move to make is incorrect.</p> <p>Answer has the point correct.</p>
4	<p>Answer does not have the best move to make (if any) or the best move to make is incorrect.</p> <p>Answer does not have any part of the point correct</p>
5	<p>Answer has the correct best move to make.</p> <p>Answer has a part of the point correct.</p>
6	<p>Answer has the correct best move to make.</p> <p>Answer has the point correct.</p>

Note: Codes 4, 5 and 6 considered correct answer verification.

APPENDIX F – BOXES AND BARRELS SESSION MOVEMENTS

Table F-1. Summarized Session Times, Non-object, Object and Invalid Moves

	N	Median Time	Median Non-Object Moves	Median Object Moves	Median Invalid Moves
Internal Interface Style					
Session 1 ^{1,2}	71	8:25	132.00	152.00	68.00
Session 1	48	12:10	250.50	248.50	111.50
Session 2	48	0:54	20.50	23.00	7.50
Session 3	48	3:58	69.00	114.00	19.50
Session 4 ²	44	1:44	35.00	64.00	9.50
External Interface Style					
Session 1 ¹	54	3:44	80.00	123.00	29.50
Session 1	36	5:19	121.00	155.00	37.50
Session 2	36	0:30	8.00	13.00	2.00
Session 3	36	2:48	92.50	127.00	12.00
Session 4	36	1:41	49.50	86.50	5.50

¹ Note. Trials 1 and 2 in Session 1 are included, but were used for training purposes.

² Note. Data was missing for one participant.

Table F-2. Summarized Times, Non-object, Object and Invalid Moves with Outliers

Removed

	Non-Object							
	Time		Moves		Object Moves		Invalid Moves	
	N	Median	N	Median	N	Median	N	Median
Internal Interface Style								
Session 1 ^{1,2}	67	7:59	67	126	66	127	67	65
Session 1	45	11:52	46	247	45	234	45	114
Session 2	46	0:53	46	20	45	22	45	7
Session 3	45	3:10	45	63	45	107	45	14
Session 4 ²	42	1:34	40	34	40	49	40	8
External Interface Style								
Session 1 ¹	48	3:22	48	70	48	85	52	28
Session 1	32	4:24	32	94	32	136	36	38
Session 2	34	0:30	34	7	34	13	35	2
Session 3	32	2:41	34	93	32	123	33	12
Session 4	33	1:26	33	47	34	84	34	5

¹ Note. Trials 1 and 2 in Session 1 are included, but used for training purposes.

² Note. Data was missing for one participant.

APPENDIX G – BOXES AND BARRELS DETAIL MOVEMENTS

Table G-1. Time, Non-object, Object and Invalid Moves

	<u>N</u>	<u>Median Time</u>	<u>Median Non-Object Moves</u>	<u>Median Object Moves</u>	<u>Median Invalid Moves</u>
Session 1					
Internal Interface Style					
Trial 1 ¹	11	5:41	31	28	41
Trial 2	12	0:17	2	5	1
Trial 3	12	14:31	238	183	119
Trial 4	12	17:32	273	336	165
Trial 5	12	8:52	180	271	71
Trial 6	12	10:01	257	244	100
External Interface Style					
Trial 1	9	3:32	27	26	27
Trial 2	9	0:18	2	5	1
Trial 3	9	3:55	52	53	36
Trial 4	9	16:44	252	319	115
Trial 5	9	5:14	140	171	35
Trial 6	9	5:46	126	174	41
Session 2					
Internal Interface Style					
Trial 1	12	1:44	26	26	11

Trial 2	12	0:38	12	16	3
Trial 3	12	6:08	136	160	52
Trial 4	12	0:16	6	10	0

External Interface Style

Trial 1	9	0:41	9	12	4
Trial 2	9	0:28	5	13	1
Trial 3	9	3:57	87	125	16
Trial 4	9	0:20	5	10	1

Session 3

Internal Interface Style

Trial 1	12	0:21	4	8	1
Trial 2	12	6:48	167	163	60
Trial 3	12	4:05	98	122	40
Trial 4	12	4:20	87	138	34

External Interface Style

Trial 1	9	0:12	2	7	0
Trial 2	9	9:28	228	296	25
Trial 3	9	4:19	107	195	17
Trial 4	9	2:46	87	108	12

Session 4

Internal Interface Style

Trial 1 ¹	11	0:56	29	32	8
Trial 2 ¹	11	2:59	74	115	26

Trial 3 ¹	11	1:22	34	74	6
Trial 4 ¹	11	1:16	32	50	5
External Interface Style					
Trial 1	9	0:51	21	32	3
Trial 2	9	2:20	83	125	16
Trial 3	9	1:26	46	84	5
Trial 4	9	0:54	26	48	5

Note. Trials 1 and 2 in Session 1 used for training purposes.

¹ *Note.* Data was missing for one participant.

Table G-2. Time, Non-object, Object and Invalid Moves with Outliers Removed

	Non-Object							
	Time		Moves		Object Moves		Invalid Moves	
	N	Median	N	Median	N	Median	N	Median
Session 1								
Internal Interface Style								
Trial 1 ¹	11	5:41	10	30	10	26	11	41
Trial 2	11	0:16	11	2	11	5	11	1
Trial 3	11	12:38	11	206	11	181	11	114
Trial 4	12	17:32	12	273	12	336	12	165
Trial 5	11	8:28	12	180	11	243	11	70
Trial 6	11	8:34	11	249	11	234	11	86
External Interface Style								
Trial 1	8	2:41	8	25	8	24	8	24
Trial 2	8	0:16	8	2	8	5	8	1
Trial 3	8	3:07	8	46	8	53	9	36
Trial 4	8	12:49	8	224	8	311	9	70
Trial 5	8	4:50	8	113	8	164	9	35
Trial 6	8	3:28	8	86	8	135	9	20
Session 2								
Internal Interface Style								
Trial 1	11	1:42	11	23	12	26	11	10
Trial 2	12	0:38	12	12	11	15	11	3

Trial 3	11	4:53	11	131	11	159	11	44
Trial 4	12	0:17	12	6	11	10	12	0

External Interface Style

Trial 1	9	0:41	8	9	8	12	9	4
Trial 2	8	0:26	9	5	9	13	9	1
Trial 3	8	3:51	8	86	8	120	8	15
Trial 4	9	0:20	9	5	9	10	9	1

Session 3

Internal Interface Style

Trial 1	12	0:21	12	4	12	8	12	1
Trial 2	11	5:50	11	135	11	146	11	51
Trial 3	11	4:00	11	79	11	107	11	31
Trial 4	11	3:57	11	75	11	130	11	31

External Interface Style

Trial 1	8	0:12	8	2	8	7	8	0
Trial 2	8	6:50	9	228	8	246	9	25
Trial 3	8	3:53	8	105	8	173	8	17
Trial 4	8	2:36	9	87	8	105	8	11

Session 4

Internal Interface Style

Trial 1 ¹	10	0:54	10	26	10	31	10	6
Trial 2 ¹	11	2:59	10	66	10	100	10	22
Trial 3 ¹	11	1:22	10	34	10	70	10	5

Trial 4 ¹	10	1:11	10	28	10	46	10	5
External Interface Style								
Trial 1	8	0:49	8	19	8	32	8	3
Trial 2	9	2:20	9	83	9	125	9	16
Trial 3	7	1:18	8	43	8	70	9	5
Trial 4	9	0:54	8	24	9	48	8	4

Note. Trials 1 and 2 in Session 1 used for training purposes.

¹ *Note.* Data was missing for one participant

APPENDIX H – BOXES AND BARRELS SUMMARY COUNT BOX PLOTS

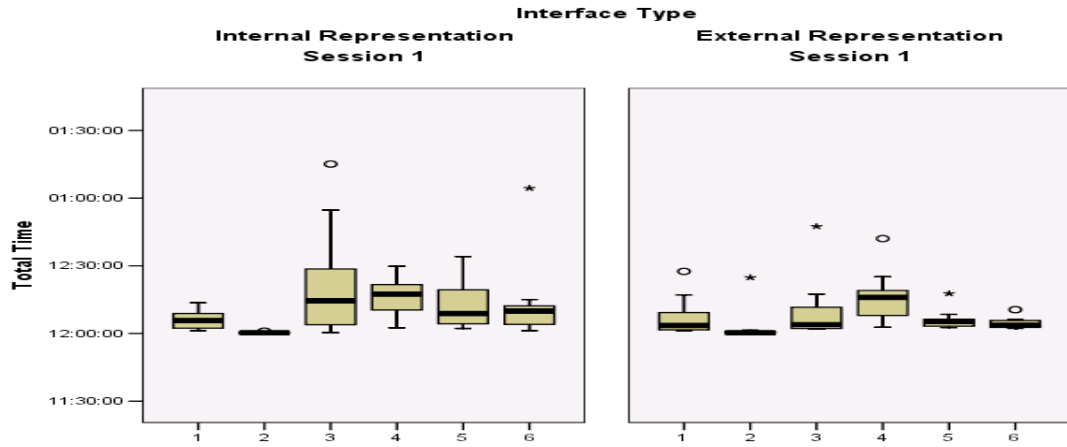


Figure H-1. Time Session 1 Box Plot

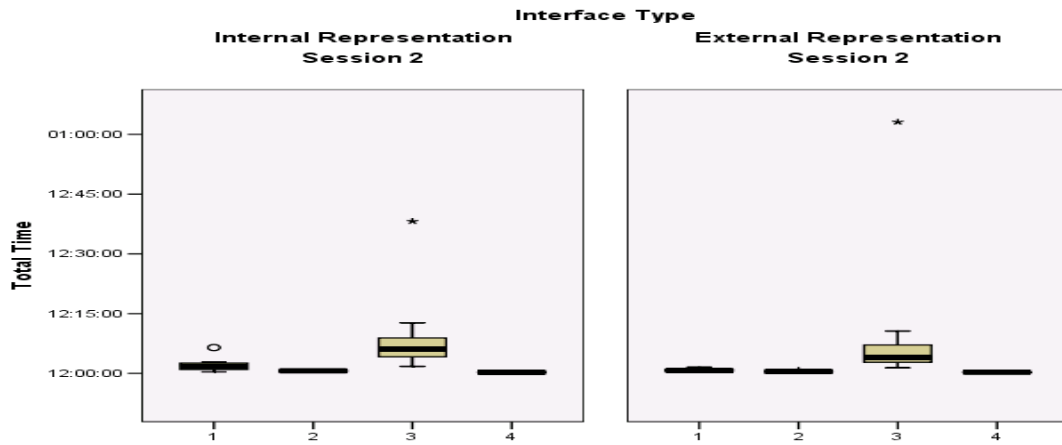


Figure H-2. Time Session 2 Box Plot

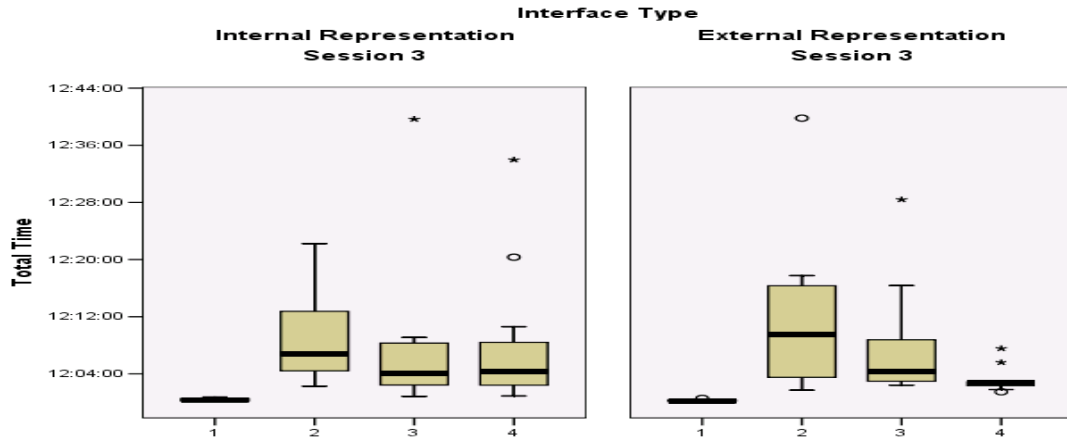


Figure H-3. Time Session 3 Box Plot

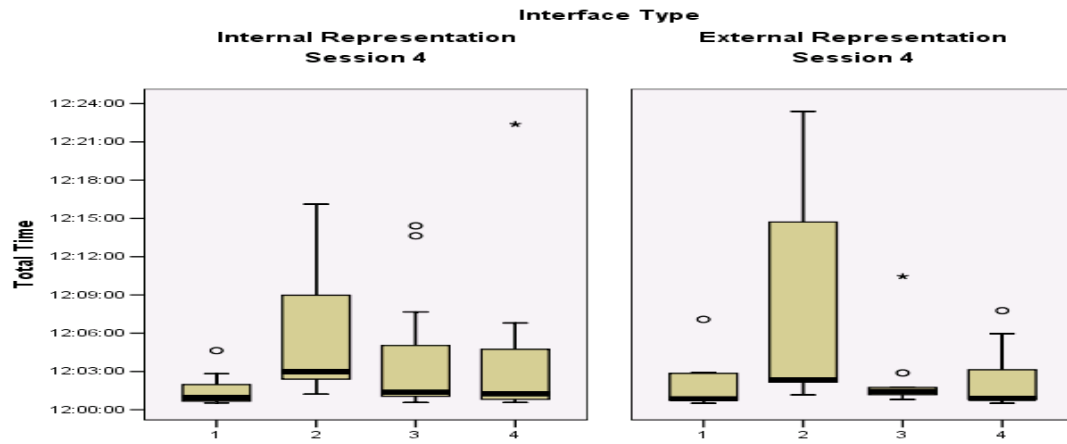


Figure H-4. Time Session 4 Box Plot

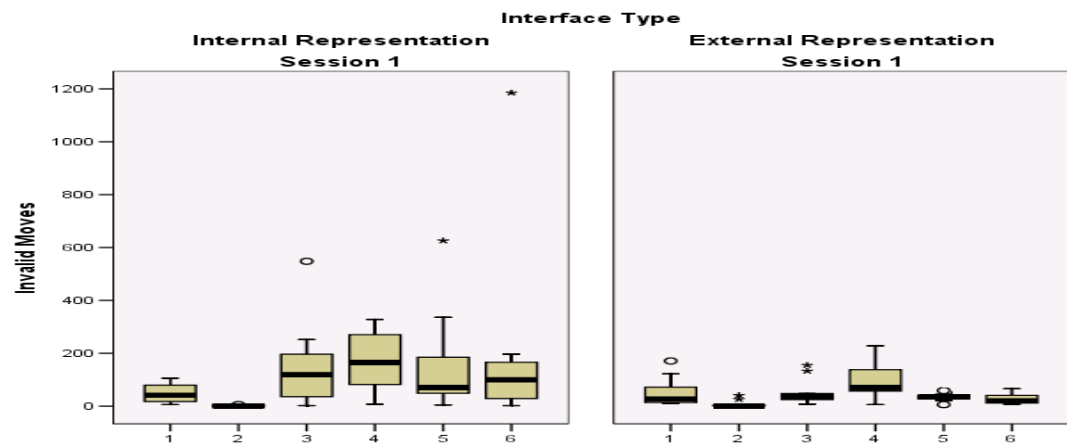


Figure H-5. Invalid Moves Session 1 Box Plot

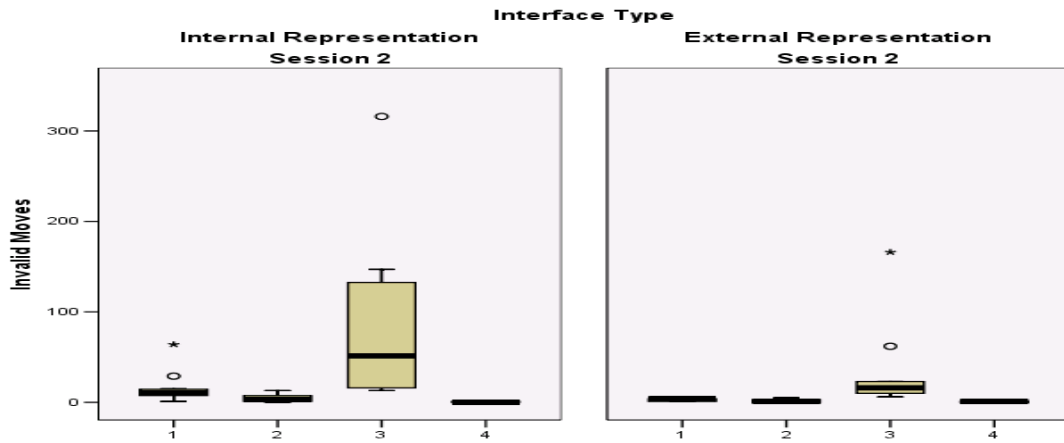


Figure H-6. Invalid Moves Session 2 Box Plot

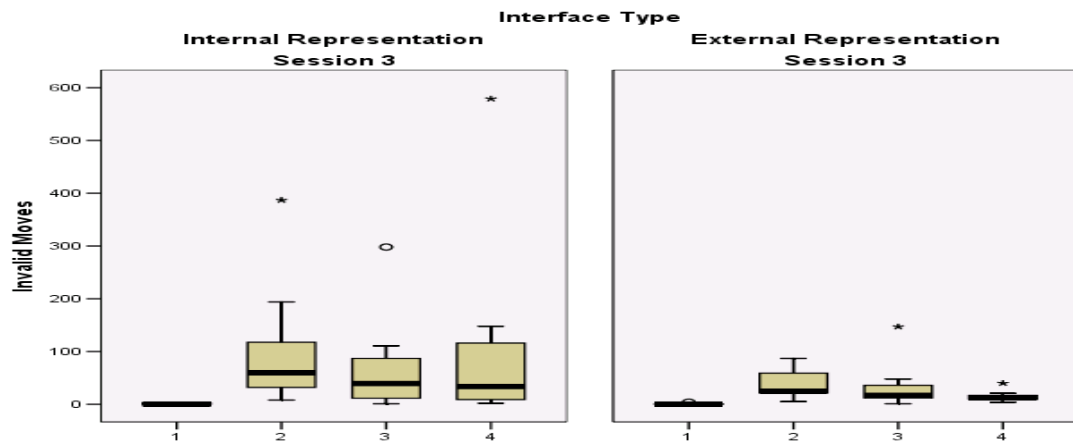


Figure H-7. Invalid Moves Session 3 Box Plot

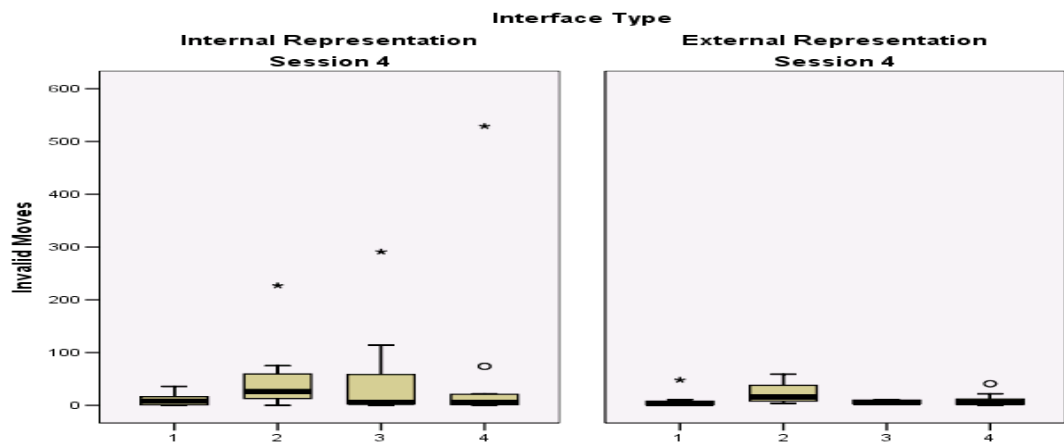


Figure H-8. Invalid Moves Session 4 Box Plot

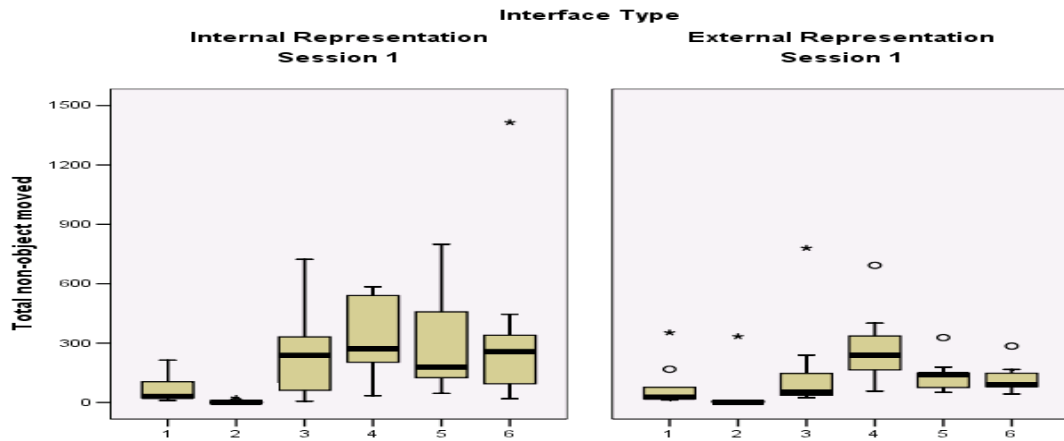


Figure H-9. Non-object Moves Session 1 Box Plot

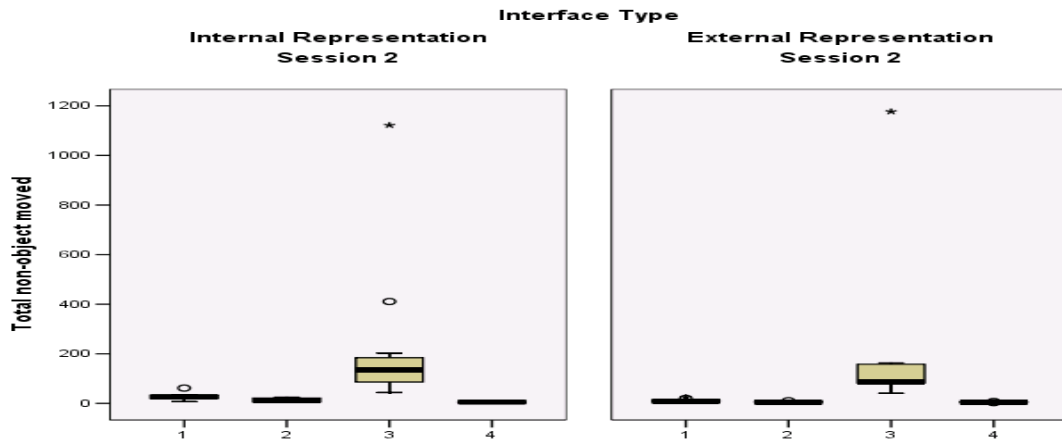


Figure H-10. Non-object Moves Session 2 Box Plot

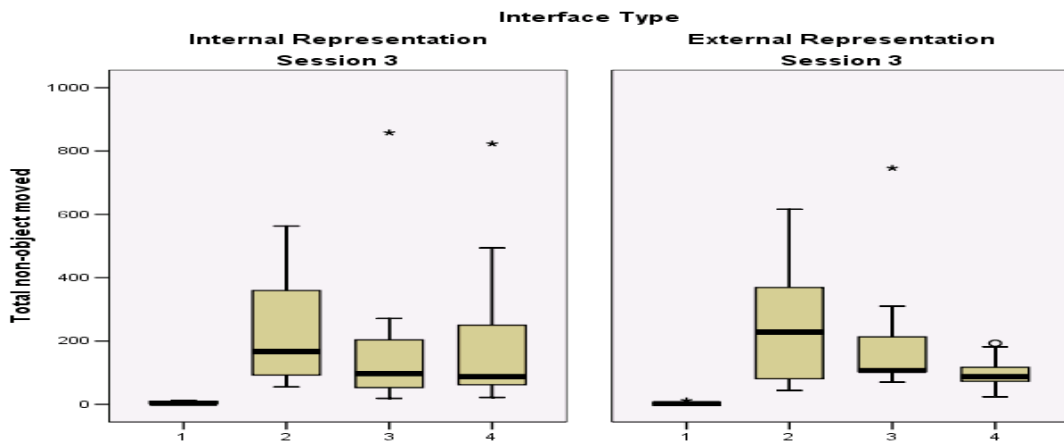


Figure H-11. Non-object Moves Session 3 Box Plot

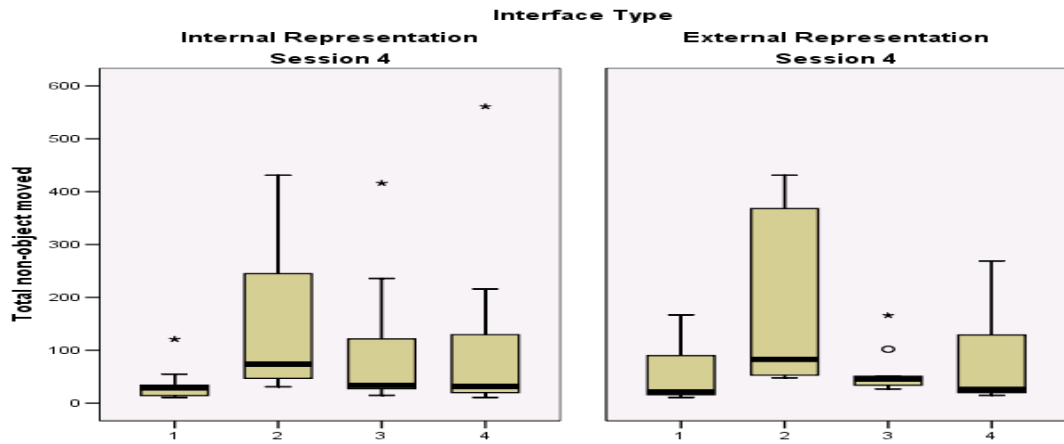


Figure H-12. Non-object Moves Session 4 Box Plot

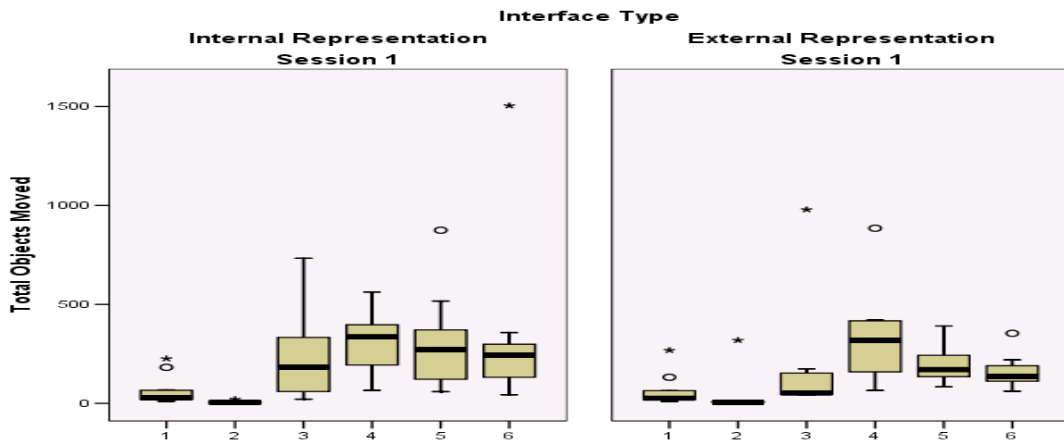


Figure H-13. Object Moves Session 1 Box Plot

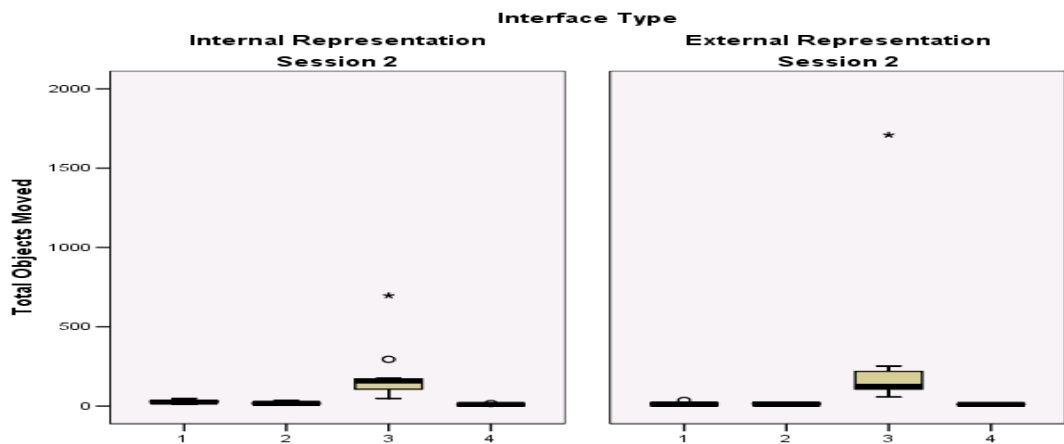


Figure H-14. Object Moves Session 2 Box Plot

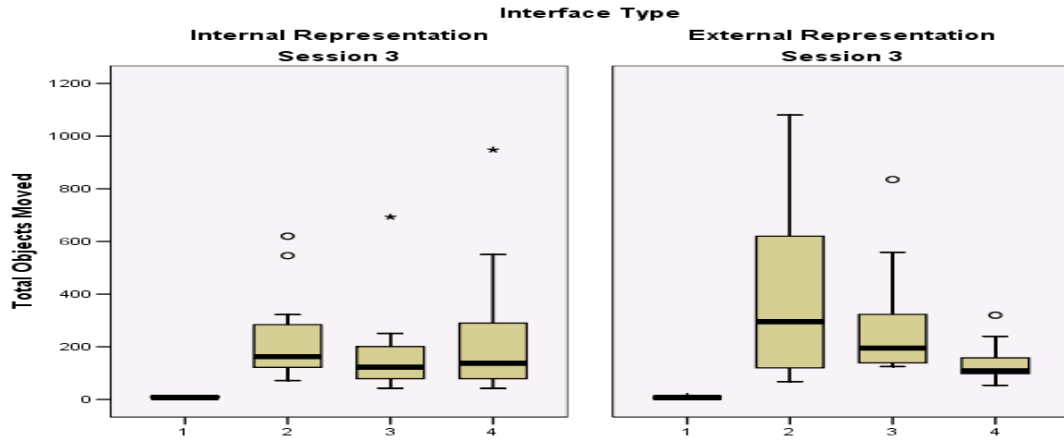


Figure H-15. Object Moves Session 3 Box Plot

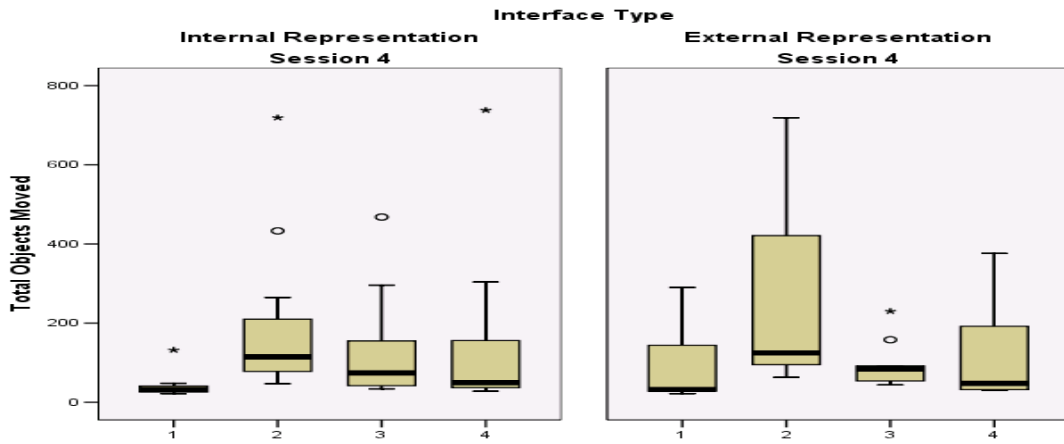


Figure H-16. Object Moves Session 4 Box Plot

APPENDIX I – BOXES AND BARRELS MANN-WHITNEY RESULTS

Table I-1. Time, Invalid, Non-object and Object Moves Mann-Whitney U Results

Grouping	Non-Object								
	Time		Moves		Object Moves		Invalid Moves		
	Exact		Exact		Exact		Exact		
	U	Sig. 1-tailed	U	Sig. 1-tailed	U	Sig. 1-tailed	U	Sig. 1-tailed	
Session 1									
Trial 1	47.50	0.45	45.50	0.39	47.50	0.45	48.50	0.48	
Trial 2	47.00	0.33	39.00	0.15	48.00	0.34	43.00	0.20	
Trial 3	33.50	0.08	37.50	0.13	31.50	0.06	33.50	0.08	
Trial 4	45.50	0.28	43.50	0.24	31.50	0.12	53.00	0.48	
Trial 5	35.00	0.09	35.00	0.09	20.50	0.01	40.50	0.18	
Trial 6	28.50	0.04	32.00	0.06	26.50	0.03	33.50	0.08	
Session 2									
Trial 1	20.50	0.01	15.50	0.02	11.00	0.00	22.50	0.01	
Trial 2	41.00	0.19	34.50	0.09	33.00	0.07	44.50	0.26	
Trial 3	41.50	0.20	41.50	0.20	30.00	0.05	53.50	0.49	
Trial 4	49.00	0.37	54.00	0.52	41.50	0.19	40.00	0.17	
Session 3									
Trial 1	32.00	0.06	23.50	0.01	43.00	0.22	33.50	0.06	
Trial 2	50.50	0.41	52.50	0.47	33.50	0.08	44.00	0.25	

Trial 3	45.50	0.28	40.50	0.18	42.50	0.22	28.50	0.04
Trial 4	38.50	0.14	50.50	0.41	36.00	0.11	49.00	0.37
Session 4								
Trial 1	47.00	0.43	48.00	0.46	39.00	0.22	41.50	0.28
Trial 2	43.50	0.33	41.50	0.28	34.00	0.13	40.50	0.26
Trial 3	48.50	0.49	45.00	0.38	40.50	0.26	47.50	0.45
Trial 4	44.50	0.36	47.00	0.43	45.00	0.38	47.50	0.45

Note. Trials 1 and 2 in Session 1 used for training purposes.

Table I-2. Time, Invalid, Non-object and Object Moves without 2X Outliers Mann-Whitney U Results

Grouping	Non-Object								
	Time		Moves		Invalid Moves		Object Moves		
	Exact		Exact		Exact		Exact		
	U	Sig. 1-tailed	U	Sig. 1-tailed	U	Sig. 1-tailed	U	Sig. 1-tailed	
Session 1									
Trial 1	36.50	0.28	34.50	0.33	36.50	0.28	37.50	0.43	
Trial 2	40.00	0.39	31.00	0.14	41.00	0.40	35.00	0.20	
Trial 3	23.50	0.05	25.50	0.07	31.50	0.09	21.50	0.03	
Trial 4	33.50	0.14	31.50	0.11	31.50	0.06	43.00	0.36	
Trial 5	27.00	0.09	27.00	0.06	20.50	0.01	31.50	0.16	
Trial 6	22.50	0.04	25.00	0.06	26.50	0.04	23.50	0.05	
Session 2									
Trial 1	20.50	0.01	9.50	0.00	11.00	0.00	13.50	0.00	
Trial 2	33.00	0.13	34.50	0.09	31.00	0.08	44.50	0.36	
Trial 3	29.50	0.12	29.50	0.12	19.00	0.02	41.50	0.44	
Trial 4	49.00	0.37	48.00	0.34	41.50	0.19	31.00	0.10	
Session 3									
Trial 1	22.50	0.02	12.00	0.00	32.00	0.10	24.00	0.02	
Trial 2	38.50	0.34	44.50	0.36	33.50	0.12	37.50	0.31	
Trial 3	36.50	0.28	31.50	0.16	31.50	0.16	20.50	0.03	

Trial 4	29.50	0.12	48.50	0.48	29.00	0.11	39.00	0.35
Session 4								
Trial 1	39.00	0.47	40.00	0.51	28.00	0.15	35.50	0.36
Trial 2	43.50	0.33	33.00	0.17	34.00	0.19	32.00	0.16
Trial 3	31.50	0.28	34.00	0.31	40.50	0.37	37.50	0.42
Trial 4	44.50	0.49	37.00	0.41	36.00	0.37	42.50	0.43

Note. Trials 1 and 2 in Session 1 used for training purposes.

APPENDIX J – POST-SESSION QUESTIONNAIRE QUALITATIVE RESULTS

Table J-1. Post-Session Questionnaire Questions

Question	
Number	Question Text
7	I always looked how I should solve a task and then started working on it.
8	I found the trials difficult to solve.
9	I think I succeeded in solving the tasks with as few moves as possible.
10	I tried to think ahead about my steps as much as possible.
11	Sometimes I did not know how to proceed.
12	It was easy to control the movement of barrels, boxes and pallet.
13	I often felt like I was stuck and could not find the solution.
14	I always knew whether I could move a barrel / box / pallet.

Table J-2. Post-Session Questionnaire Likert Answer Codes

Answer	
Code	Likert Answer Category
1	Strongly Disagree
2	Disagree
3	Slightly Disagree
4	Neither Disagree or Agree
5	Slightly Agree
6	Agree
7	Strongly Agree

Table J-3. Post-Session Questionnaire Qualitative Answer Mean and Standard Deviation

Question / Session	Internal Interface Style			External Interface Style			
	<i>N</i>	<i>M</i>	<i>SD</i>	<i>N</i>	<i>M</i>	<i>SD</i>	
Question 7	1	12	4.33	1.72	9	2.89	1.27
	2	12	5.58	1.08	9	5.00	1.58
	3	11	5.00	1.18	9	4.44	1.51
	4	11	4.36	1.86	9	4.78	1.39
Question 8	1	12	5.75	1.36	9	4.22	1.39
	2	12	3.58	1.88	9	2.44	1.13
	3	11	4.45	1.92	9	3.56	1.42
	4	11	3.45	1.81	9	3.33	1.42
Question 9	1	12	1.75	0.62	9	1.78	0.83
	2	12	4.17	1.28	9	4.56	1.88
	3	11	3.73	1.95	9	3.44	1.42
	4	11	4.55	1.51	9	4.11	1.27
Question 10	1	12	4.75	1.60	9	4.33	1.58
	2	12	5.42	1.24	9	5.33	1.41
	3	11	5.18	1.33	9	5.00	1.41
	4	11	5.45	1.29	9	4.89	1.36
Question 11	1	12	5.92	0.79	9	5.89	0.78
	2	12	3.67	2.19	9	4.00	1.94
	3	11	4.18	2.23	9	4.11	1.76
	4	11	3.09	1.70	9	4.11	1.76

Question 12	1	12	4.25	1.87	9	6.11	0.78
	2	12	5.58	1.08	9	6.00	0.76
	3	12	6.00	0.60	9	6.11	0.33
	4	12	5.92	0.52	9	6.11	1.36
Question 13	1	12	4.50	1.68	9	4.33	1.50
	2	12	2.50	1.57	9	2.67	1.23
	3	12	3.25	2.05	9	3.33	1.41
	4	12	2.58	1.62	9	3.00	1.58
Question 14	1	12	3.08	1.78	9	4.33	2.06
	2	12	4.17	2.13	9	4.56	1.67
	3	12	4.33	1.61	9	4.78	1.79
	4	12	5.00	1.35	9	5.00	1.87

APPENDIX K – PRE-SESSION QUESTIONNAIRE

PRE-SESSION 1 QUESTIONNAIRE

Participant ID: _____

Date: _____










Participant Information

Age: _____

Gender: Male Female

Hand-held device Experience

Circle time period for all devices used

		Never Used	1-6 Mo	7-12 Mo	1-2 Yrs	3+ Yrs
	Personal Digital Assistant [PDA] (iPaq, Blackberry)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Cell Phone	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Smart phone [PDA & phone] (Trio, Motorola Q, Sidekick)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Inventory scanner or other hand-held work device	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Hand-held game (PSP, DS, GameBoy)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Digital Camera	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	MP3/Digital Audio Player (iPod, Sansa, Zen)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Portable Video Player (Archos, iPod 30/60/80 Gig)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
	Hand-held GPS (Tom-Tom, Garmin)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

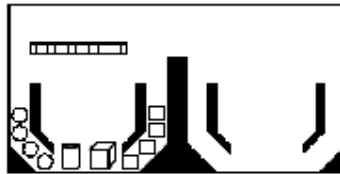
APPENDIX L – POST-SESSION 1 QUESTIONNAIRE

Session 1: Post Questionnaire

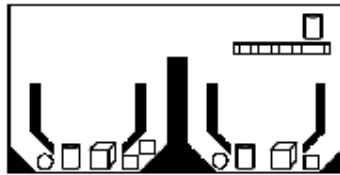
Participant ID: _____

Date: _____

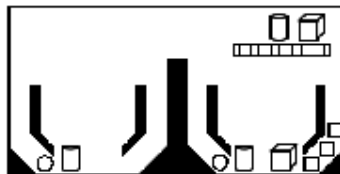
Section A: Please circle the best answer



1. What is the minimum number of boxes or barrels that are needed to move the pallet to the opposite side?
 - a. 0
 - b. 1
 - c. 2
 - d. 3

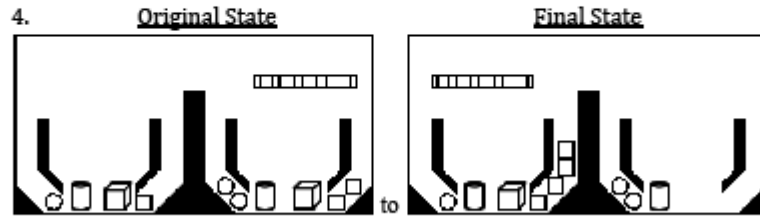


2. If this position is not permissible, what should occur to correct this?
 - a. It is currently in a permissible state
 - b. Move the pallet to the opposite side
 - c. Move one barrel onto the pallet
 - d. Move one box onto the pallet



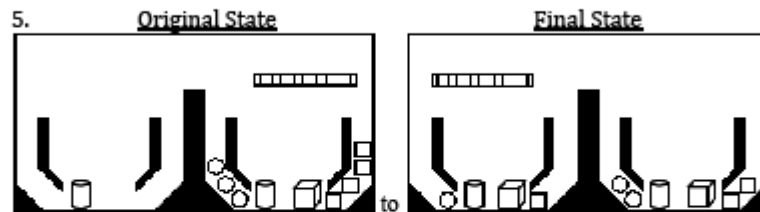
3. Can the pallet be moved to the opposite side?
 - a. Yes
 - b. Yes, if one barrel is added to the pallet
 - c. Yes, if one box is added to the pallet
 - d. No

Section B: Please write your answer



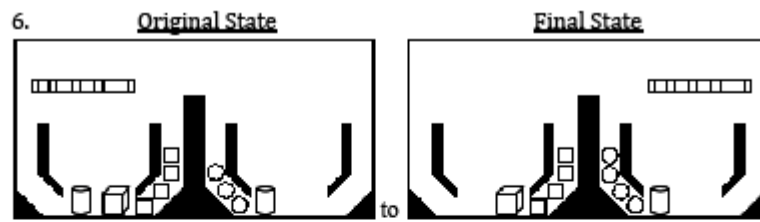
Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?

Section C: Please write your answer

7. I always looked how I should solve a task and then started working on it.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

8. I found the trials difficult to solve.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

9. I think I succeeded in solving the tasks with as few moves as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

10. I tried to think ahead about my steps as much as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

11. Sometimes I did not know how to proceed.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

12. It was easy to control the movement of barrels, boxes and pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

13. I often felt like I was stuck and could not find the solution.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

14. I always knew whether I could move a barrel / box / pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

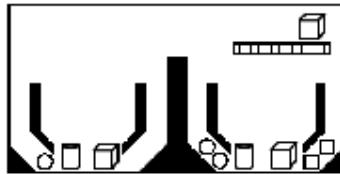
APPENDIX M – POST-SESSION 2 QUESTIONNAIRE

Session 2: Post Questionnaire

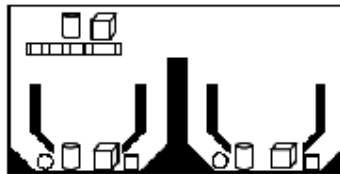
Participant ID: _____

Date: _____

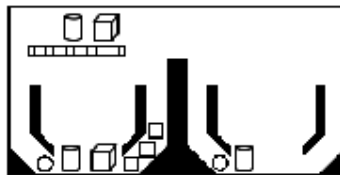
Section A: Please circle the best answer



1. Can the pallet be moved to the opposite side?
 - a. Yes
 - b. Yes, if one box is added to the pallet
 - c. Yes, if one box and one barrel is added to the pallet
 - d. No

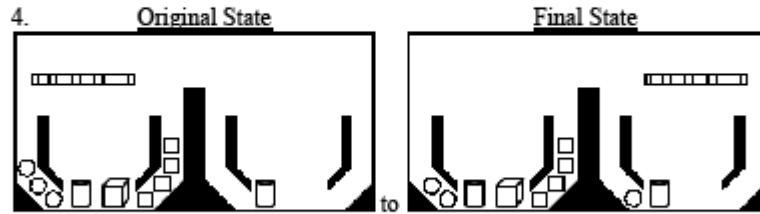


2. Can the pallet be moved to the opposite side?
 - a. Yes
 - b. Yes, if an additional box is added to the pallet
 - c. Yes, if an additional barrel is added to the pallet
 - d. No



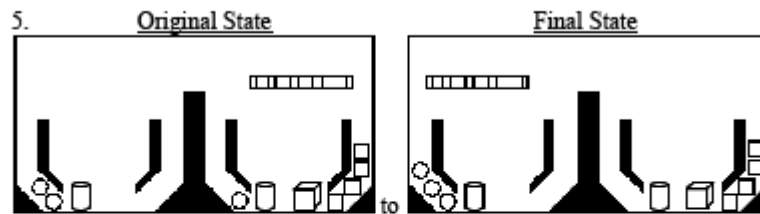
3. Can the pallet be moved to the opposite side?
 - a. Yes
 - b. Yes, if one box is removed from the pallet
 - c. Yes, if one barrel is removed from the pallet
 - d. Yes, if one barrel is added to the pallet

Section B: Please write your answer



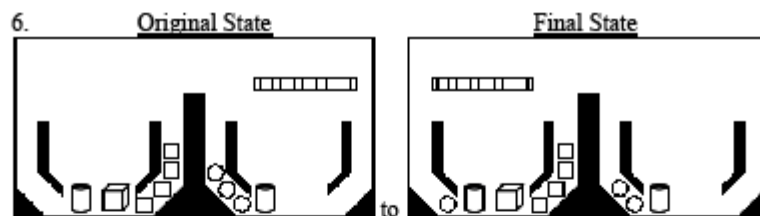
Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?

Section C: Please write your answer

7. I always looked how I should solve a task and then started working on it.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

8. I found the trials difficult to solve.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

9. I think I succeeded in solving the tasks with as few moves as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

10. I tried to think ahead about my steps as much as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

11. Sometimes I did not know how to proceed.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

12. It was easy to control the movement of barrels, boxes and pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

13. I often felt like I was stuck and could not find the solution.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

14. I always knew whether I could move a barrel / box / pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

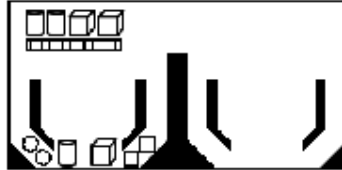
APPENDIX N – POST-SESSION 3 QUESTIONNAIRE

Session 3: Post Questionnaire

Participant ID: _____

Date: _____

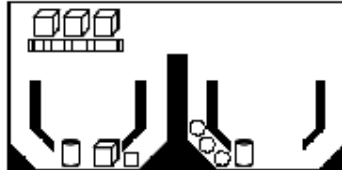
Section A: Please circle the best answer



1. Can the pallet be moved to the opposite side?
- a. Yes
 - b. Yes, if one box is removed
 - c. Yes, if one barrel is removed
 - d. No

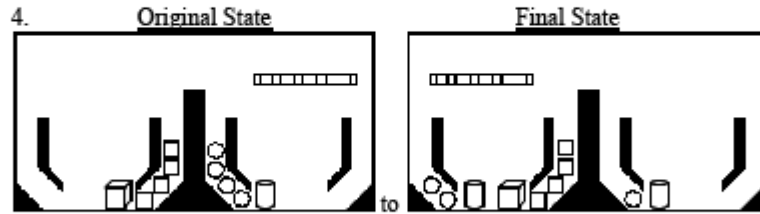


2. Can the pallet be moved to the opposite side?
- a. Yes
 - b. Yes, if one barrel is added to the pallet.
 - c. Yes, if one barrel is removed from the pallet.
 - d. Yes, if the barrel and box are removed from the pallet.



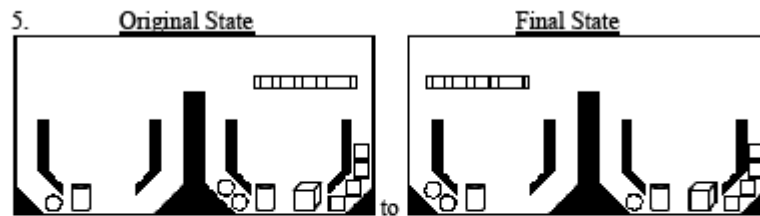
3. Can the pallet be moved to the opposite side?
- a. Yes, if one box is added to the pallet.
 - b. Yes, if one barrel is added to the pallet.
 - c. Yes, if one box is removed and one barrel is added to the pallet.
 - d. No

Section B: Please write your answer



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?

Section C: Please write your answer

7. I always looked how I should solve a task and then started working on it.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

8. I found the trials difficult to solve.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

9. I think I succeeded in solving the tasks with as few moves as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

10. I tried to think ahead about my steps as much as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

11. Sometimes I did not know how to proceed.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

12. It was easy to control the movement of barrels, boxes and pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

13. I often felt like I was stuck and could not find the solution.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

14. I always knew whether I could move a barrel / box / pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

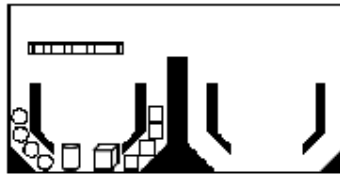
APPENDIX O – POST-SESSION 4 QUESTIONNAIRE

Session 4: Post Questionnaire

Participant ID: _____

Date: _____

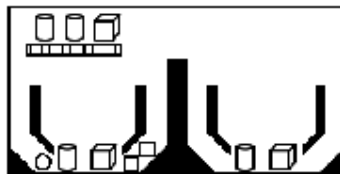
Section A: Please circle the best answer



1. What is the maximum number of boxes or barrels that can be moved on the pallet?
- a. two
 - b. four
 - c. one
 - d. three

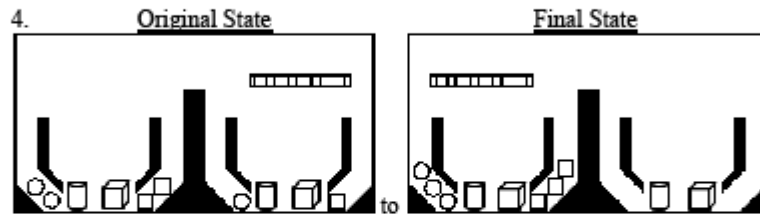


2. Can the pallet be moved to the opposite side?
- a. Yes, if one box is added to the pallet
 - b. Yes, if one barrel is added to the pallet
 - c. Yes, if one box is added and one barrel is removed from the pallet
 - d. Yes, if one barrel is removed from the pallet



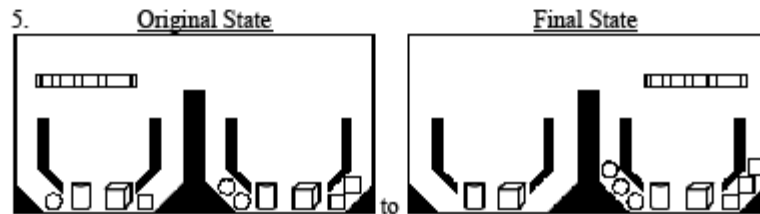
3. Can the pallet be moved to the opposite side?
- a. Yes, if one box is added to the pallet
 - b. Yes, if one barrel is added to the pallet
 - c. Yes, if one box is removed from the pallet
 - d. Yes, if one barrel is removed from the pallet

Section B: Please write your answer



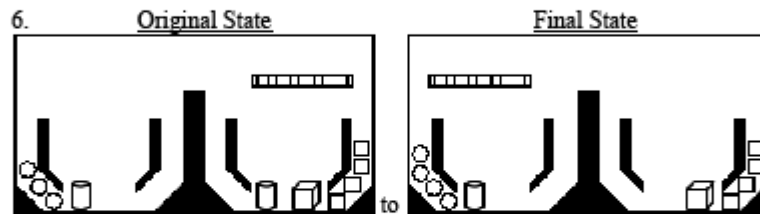
Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?



Do you think that this was the best move to make?

- Yes or No (circle your answer)
- Why?

Section C: Please write your answer

7. I always looked how I should solve a task and then started working on it.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

8. I found the trials difficult to solve.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

9. I think I succeeded in solving the tasks with as few moves as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

10. I tried to think ahead about my steps as much as possible.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

11. Sometimes I did not know how to proceed.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
----------------------	----------	----------------------	------------------------------	-------------------	-------	-------------------

Comments (Optional):

12. It was easy to control the movement of barrels, boxes and pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

13. I often felt like I was stuck and could not find the solution.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
-------------------	----------	-------------------	---------------------------	----------------	-------	----------------

Comments (Optional):

14. I always knew whether I could move a barrel / box / pallet.

Strongly Disagree	Disagree	Slightly Disagree	Neither Disagree or Agree	Slightly Agree	Agree	Strongly Agree
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Comments (Optional):

APPENDIX P – POST-SESSION QUESTIONNAIRE ANSWERS

Session 1 Answers:

1. Answer: B.
Testing Rule: The pallet must have one to three objects on it. [B, C, D]
2. Answer: B.
Testing Rule:
 - *Boxes or barrels are transported between the two sides via the pallet.*
 - *To move the pallet to the opposite side of the screen, the pallet must have between 1 and 3 Boxes or barrels on it.*
 - *The number of barrels cannot exceed the number of boxes on the pallet [A, C].*
 - *The number of barrels cannot exceed the number of boxes on either side of the wall [D].*
3. Answer: D.
Testing Rule:
 - *The number of barrels cannot exceed the number of boxes on the pallet. [C]*
 - *The number of barrels cannot exceed the number of boxes on either side of the wall. [B]*
4. Answer: No.

Main point: This move will cause an extra two moves to achieve the same goal.
Best Move (optional): Move one of box and barrel to the opposite side.
Operationalize of main point: {more, additional, extra} moves to achieve {(game) goal, win (the game)}
5. Answer: No.

Main point: This move will require three additional moves from the end state to achieve the goal of moving all objects to the right side.
Best Move (optional): From the original state, the puzzle could have been solved in two moves.
Operationalize of main point:
 - *{more, additional, extra} moves to {(game) goal, win (the game)}*
 - *Postpone {finish, completion} {(game) goal, win (the game)}*
6. Answer Main point: *Only the barrel can legally be moved to the opposite side.*
Operationalize: {only, single} legal move

Session 2 Answers:

1. Answer: A.
Testing Rule(s):
 - *The number of barrels cannot exceed the number of boxes on either side of the wall. [B, C]*

2. Answer: A.
Testing Rule:
 - *The number of barrels cannot exceed the number of boxes on the pallet. [C]*
 - *The number of barrels cannot exceed the number of boxes on either side of the wall. [B]*

3. Answer: B. The original status is permissible; however, once the pallet is moved to the opposite side, the barrels will outnumber the boxes [A, C, D].
Testing Rule:
 - *The number of barrels cannot exceed the number of boxes on the pallet. [D]*
 - *The number of barrels cannot exceed the number of boxes on either side of the wall. [A, C]*

4. Answer: No.

Information Only (optional):

While this move gets closer to the crossover state, in order to move the pallet back to the opposite side, a barrel must be moved back to the opposite side.

Main point:

This move will need to be un-done to get back to the right side.

Or:

This will not move forward to the goal of all objects to the right hand side.

Best Move (optional):

The best move would have been to move 3 barrels to the opposite (right) side.

Operationalize:

- {more, additional, extra} move to {(game) goal, win (the game)}

5. Answer: Yes.

Information Only:

This is the best available move, moving the fewest barrels back to the left side.

Main point:

Boxes should not be moved to the left side, as this will require extra moves to get back to the before state position.

Operationalize of main point:

- {fewest, less, least} barrels
- Boxes {more, additional, extra} moves

6. Answer: Yes.

Main point:

This is the best available move, moving the fewest barrels back to the left side.

Best Move (optional):

Move three boxes over to the right side, which is the crossover state.

Operationalize:

- {fewest, less, least} barrels {other, opposite, left} side

Session 3 Answers:

1. Answer: C.

Testing Rule:

- *To move the pallet to the opposite side of the screen, the pallet must have between 1 and 3 Boxes or barrels on it. [A]*
- *The number of barrels cannot exceed the number of boxes on the pallet. [B]*
- *The number of barrels cannot exceed the number of boxes on either side of the wall. [C]*

2. Answer: C.

Testing Rule(s):

- *The pallet must have one to three objects on it. [D]*
- *The number of barrels cannot exceed the number of boxes on the pallet. [C]*
- *The number of barrels cannot exceed the number of boxes on either side of the wall. [A]*

3. Answer: D.

Testing Rule:

- *To move the pallet to the opposite side of the screen, the pallet must have between 1 and 3 Boxes or barrels on it. [A]*
- *The number of barrels cannot exceed the number of boxes on either side of the wall. [B, C]*

4. Answer: No.

Information Only (optional): *The opening move starts the cross-over state.*

Main point: *The next move will require re-doing a move to get to the originating state.*

Best Move (optional): *Move two barrels to the opposite side.*

Operationalize:

- {more, additional, extra} moves to achieve {(game) goal, win (the game)}

5. Answer: Yes.

Main point:

Next move will allow all of the remaining barrels can be moved to the right side, achieving the game goal.

Operationalize:

- {next} move achieves {(game) goal, win (the game)}
- Most {other, different} moves postpone {finish, completion} {(game) goal, win (the game)}

6. Answer: No.

Main point:

This move will cause an extra two moves to achieve the same goal.

Best Move (optional):

The best move from the original state is to move either two or three barrels to the opposite side.

Operationalize:

- {more, additional, extra} moves to achieve {(game) goal, win (the game)}

Session 4 Answers:

1. Answer: D.

Testing Rule: The pallet must have one to three objects on it. [A, C, D]

2. Answer: D.

Testing Rule:

- *To move the pallet to the opposite side of the screen, the pallet must have between 1 and 3 Boxes or barrels on it. [A, B]*
- *The number of barrels cannot exceed the number of boxes on either side of the wall. [C]*

3. Answer: D.

- *To move the pallet to the opposite side of the screen, the pallet must have between 1 and 3 Boxes or barrels on it. [A, B]*
- *The number of barrels cannot exceed the number of boxes on either side of the wall. [C]*

4. Answer: No.

Main point:

This move will postpone getting to the completed state.

Best Move (optional):

The best move would have moved the two boxes to the opposite (left) side.

Operationalize:

- postpone crossover
- {best} move two boxes {other, opposite, left} side

5. Answer: No.

Main point:

This move will postpone getting to the completed state.

Best Move (optional):

The best move would have moved the two boxes and one barrel to the opposite (right) side.

Operationalize:

- {more, additional, extra} moves to {(game) goal, win (the game)}
- Postpone {finish, completion} {(game) goal, win (the game)}

6. Answer: Yes.

Main point:

This is the only legal move that can be made.

Operationalize:

- Only {legal} move

VITA

Keith A. Beatty

Education

Master's of Science in Human-Computer Interaction, December 2008
Indiana University-Purdue University at Indianapolis
Advisor: Dr. Anthony Faiola

Bachelor of Science, Computer Science, May 1989
Illinois State University, Normal IL

Research Interests

Hand-held Computing
Business Intelligence

Professional

Electronic Data Systems
1989 – Present, Technical Analyst / Programmer

Areas of Experience:

- Aerospace
- Financial
- Manufacturing
- Telephony
- Medical Insurance

Publications

News on the internet: Do people seek a news bias? In the Proceedings of the Sixth International Conference on Cultural Attitudes towards Technology and Communication conference in July 2006 at Tatu, Estonia, pp. 130-141.