INTERRATER RELIABILITY OF THE UTAH ERGO ANALYZER

by

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of a thesis submitted by

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This thesis has been read by each member of the following supervisory committee and by majority vote has been found to be satisfactory.

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FINAL READING APPROVAL

To the Graduate Council of the University of Utah:

I have read the thesis of Bryan Keith Adams in its final form and have found that (1) its format, citations, and bibliographic style are consistent and acceptable; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the supervisory committee and is ready for submission to The Graduate School.

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ABSTRACT

Various studies have been done in an ongoing effort to assist ergonomists in determining risk factors for the development of Upper Extremity Cumulative Trauma Disorders (UECTDs). The University of Utah developed a methodology to assist ergonomists in determining these occupational risk factors; this methodology was built around a computer program that has been named the Utah Ergo Analyzer. The Utah Ergo Analyzer has the ability to systematically analyze video segments of jobs and perform detailed analysis. In order to have a method that is capable of adequately predicting occupational risk factors, that method must be repeatable and reliable.

In order to determine the reliability of the Utah Ergo Analyzer, this study evaluated the use of this program among two separate groups within two separate time periods or phases. The two groups included Novice users and trained Analysts. The Novice group had little or no training or experience with the Utah Ergo Analyzer, while the trained Analysts had various levels of experience and training with the Ergo Analyzer program. The Novice group included occupational safety and health students with some knowledge of ergonomics. The analyst group was composed of students studying ergonomics specifically.

The reliability of the Ergo Analyzer (EA) method was evaluated through two phases. The results of the study for both groups were compared to a "Gold Standard," which was used to evaluate agreement among raters as well as establish a standard to assess the competency of individual raters. The reliability of the EA method was

evaluated in both phases using Intraclass Correlation Coefficients as the statistical test for agreement.

Overall results demonstrated that as the amount of EA training and experience increased, the ICC values of the individual rater would increase, indicating higher levels of agreement and competency. Overall agreement was substantial. However analysis of individual elements indicated that some factors were more reliable than others and there was a tendency for some ICC values to behave somewhat erratically. This is partially explained by relatively small sample size and lack of element variation for some of the analyzed tasks.

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CHAPTER 1

INTRODUCTION

Background

Various studies have been done in an ongoing effort to assist ergonomists in determining risk factors for the development of Upper Extremity Cumulative Trauma Disorders (UECTDs). The University of Utah developed a methodology to assist ergonomists in determining these occupational risk factors; this methodology was built around a computer program that has been named the Utah Ergo Analyzer. The UEA features the ability to analyze video segments frame by frame and systematically observe elements determined to be potential risk factors for UECTDs. The purpose of this study is to verify that the UEA is a reliable method for collecting ergonomic data. Rodriquez [1] evaluated reliability using an earlier version of the UEA. Several improvements have been made to the UEA. This study seeks to determine the reliability of the latest version of the UEA. In addition, this study explores the effect of UEA experience on reliability.

Upper Extremity Cumulative Trauma Disorders (UECTD)

Upper Extremity Cumulative Trauma Disorders can be defined as injuries or disorders to the muscles, tendons, blood vessels, nerves, etc. of the upper extremities [2]. UECTDs are often referred to as repetitive motion or repetitive strain injuries and a

common example is carpal tunnel syndrome. Other examples include, but are not limited to, tendonitis, epicondylitis and Thoracic outlet syndrome.

The assessment of risk can be a difficult task given the number of potential causes for UECTDs. These disorders are classified as multifactorial involving "Physical, psychosocial/organizational and individual occupational 'risk factors' for the development of work related musculoskeletal disorders." [3] Some of the physical causal factors or 'risk factors' have been determined to be repetitive motion, awkward postures, excessive force or exertion as well as grip postures, to name a few. In order to reduce the risk of developing UECTDs, employers seek to reduce the exposure to physical risk factors or, when possible, to eliminate them all together. Therefore, a methodology that can effectively identify and quantify related risk factors is important for reducing the occupational risk factors for UECTDs.

In the United Kingdom the Health and Safety Executive found that nearly 1 million people per year are affected by musculoskeletal disorders that are either caused or made worse by the work environment [4]. With an increasing number of people either developing CTDs or just being made more aware of an already existing condition, it is becoming more critical that methods are developed to help identify, and therefore help to reduce or eliminate the causes of these disorders. It has been said that the "focus of any ergonomic program is the development of engineering controls for identified ergonomic hazards" [2]. In an effort to aid ergonomists in determine what those "ergonomic hazards" are and thus further the development of better controls, the UEA was developed.

Utah Ergonomic Analyzer (UEA)

The UEA program, developed by the University of Utah, provides a systematic method of analyzing video data from jobs to determine the presence of factors related to musculoskeletal hazards. The UEA program has undergone various degrees of improvement based on user input and use. It has consistently stepped forward in becoming a more useable tool for ergonomists. A key feature of the UEA allows the user to review and analyze individual segments of video frame by frame or multiple frames at a time, as shown in Figure 1. Another unique feature of the UEA is the interface that allows the user to classify the various factors such as posture, grip and a perceived level of effort [5]. In addition to being able to classify risk factors, the user can also move forward and backward through the video segment to better analyze the task at hand. The user can then return to the current state without losing any previously input data. Figure 2 shows a screen shot of the user input interface. Since the creation of UEA, user feedback has been incorporated into the UEA user interface to improve usability and human factors. These improvements made the tool quicker and easier to use. Several error checking algorithms have been incorporated to minimize the likelihood of incorrect data input. However, the purpose of this study was to evaluate the reliability of the overall UEA method, not the specific human factors improvements that have been made.

Figure 1 shows a view of the initial user input interface. This input screen allows the user to precisely align the initial starting point by selecting the exact frame from which to start in addition to setting the parameters for data collection (e.g.,, frame skip rate, which is the number of frames between observations).

Figure 2 shows a view of the user interface screen in which users will input their choices for the individual components using multiple dropdown menus. Each data entry point contains a dropdown menu that provides anywhere between 3 and 12 possible selections. This data input screen allows users to input their specific choices for each observation as well as systematically step through the video by the predetermined frame skip rate.

Raw and Intermediate Outputs

The initial raw outputs of the Utah Ergo Analyzer are saved to a comma separated file that can be imported into a spreadsheet for further processing. Data were further processed using the UEA Distiller, another program developed by the University of Utah; the raw data were then compiled into an intermediate stage of outputs. This is not the final output of risk but gives the observer a better understanding of time spent in particular postures and perceived levels of effort. The intermediate outputs can then be used to calculate outputs for established ergonomic assessment methods such as the Strain Index developed by Moore and Garg [6]. At the time of this research, the final ergonomic assessment output calculations, such as Strain Index, had not been fully developed by the research team. Therefore, reliability analysis was focused on raw and intermediate data from the UEA.

Purpose of the Research

This study is part of a larger ongoing study funded by the National Institute for Occupational Safety and Health (NIOSH) to develop tools to assist in the assessment of risk factors contributing to the development of UECTDs. The study involved the

participation of hundreds of subjects who were chosen from a variety of different production facilities including but not limited to aluminum extrusion, meat processing, garage door manufacturing, medical equipment manufacturing and garment production. Each individual was examined first by medical professionals and subsequently reexamined by a second set of medical professionals in order to confirm their initial state of health [7]. The individuals were then videotaped performing their daily tasks with interruption. Institutional Review Board (IRB) consent was obtained from the subjects in the overall study. Additionally all of the raters used for this study received Health Insurance Probability and Privacy Act (HIPPA) and IRB training prior to beginning their analysis.

The videos recorded were then used for analysis with the UEA. Six different video segments were selected from actual jobs in the larger study, to be used for this study, each representing a variety of postures, forces, grips etc. The intent was to provide a representative sample of videos for the raters to analyze. This particular study used both the raw and intermediate outputs provided by the UEA as well as the UEA Distiller to examine the reliability of the UEA method for collecting risk factor data. The purpose of the study was to evaluate the effectiveness of the UEA method for producing reliable and repeatable outputs for the research team and to evaluate individual user performance, as compared to a "Gold Standard." Each rater in this study had varying degrees of understanding with respect to ergonomics and all were given a basic set of instructions to aid in the application of the UEA method. Further explanation of the study design is described in Chapter 2.

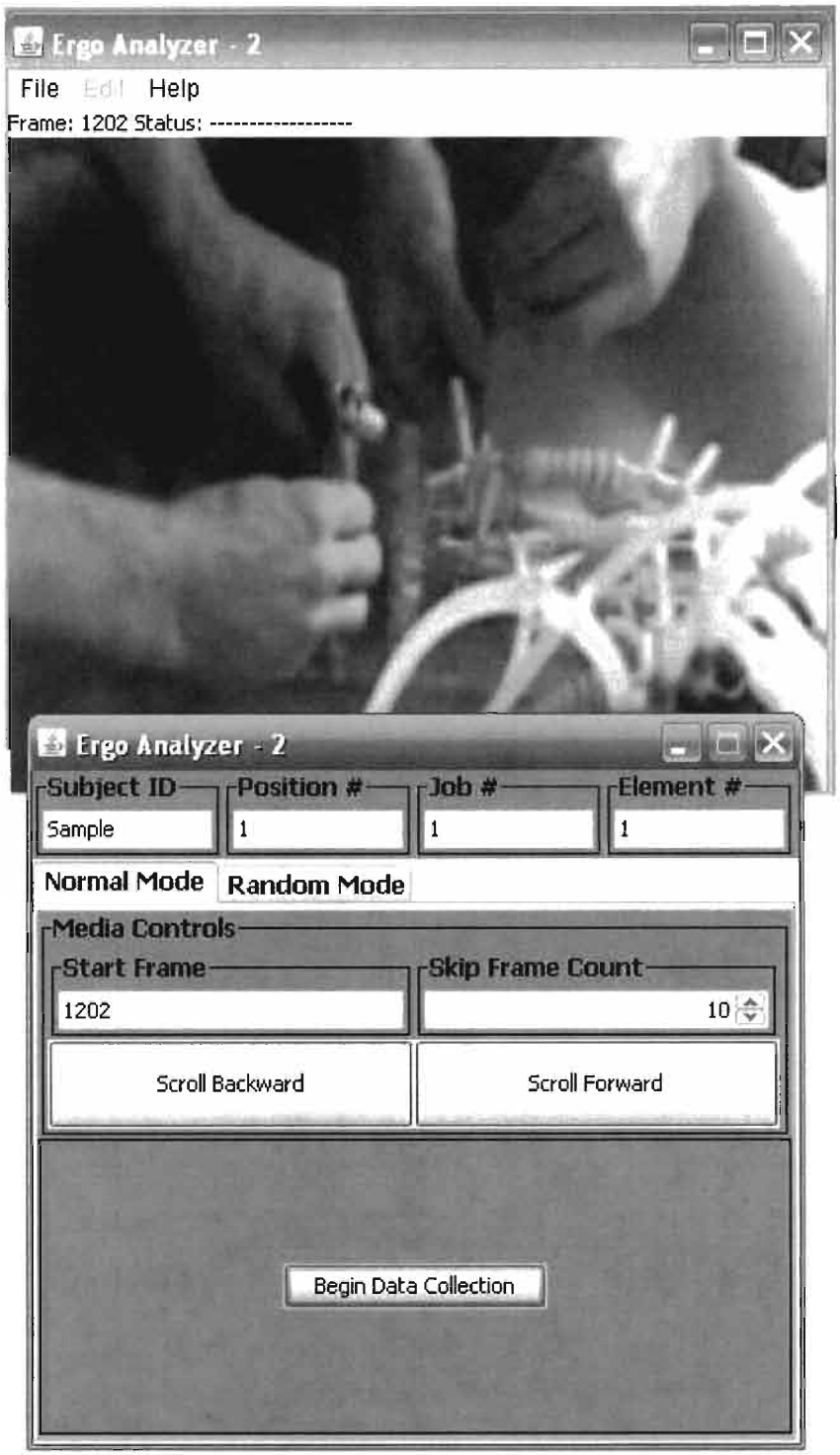

Figure 1: Initial input of frame rate

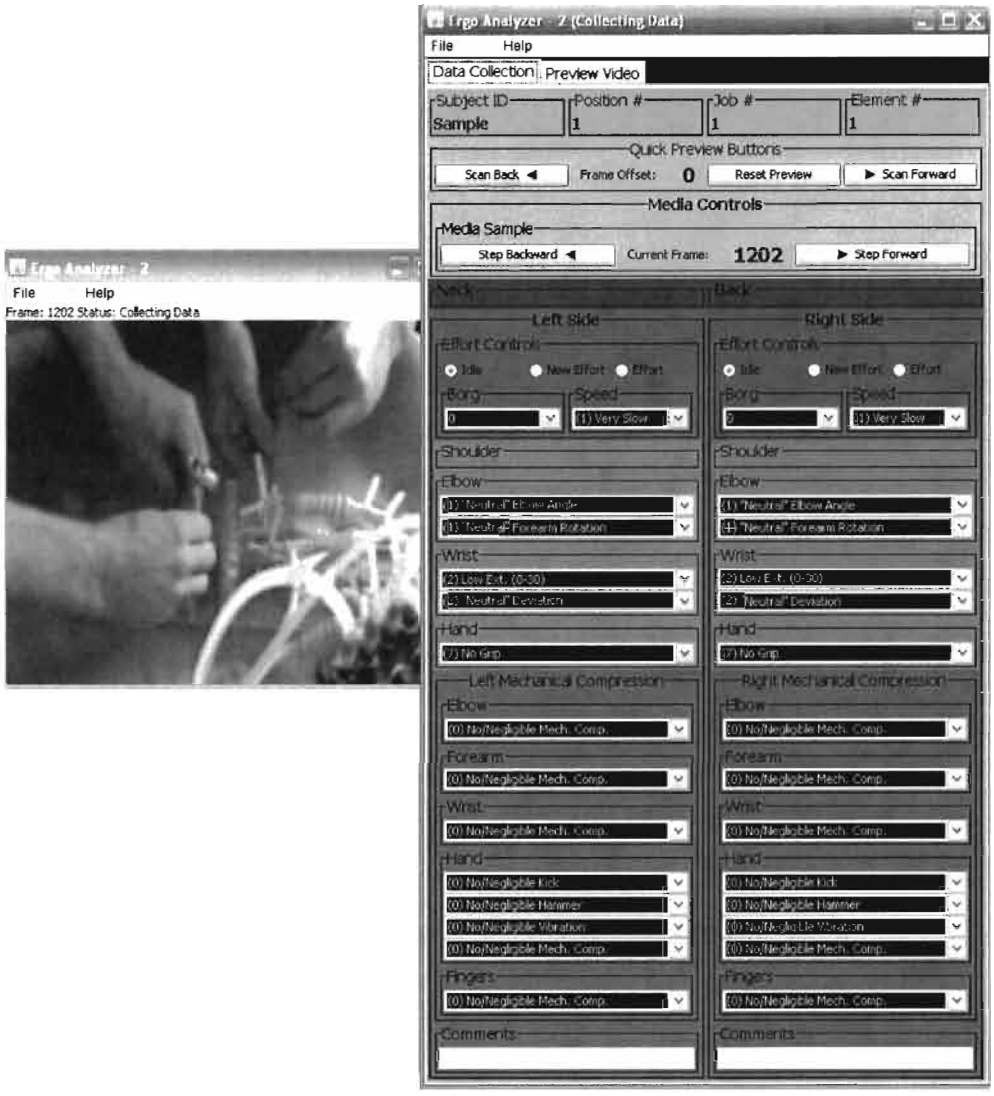

Figure 2: UEA user input interface

Hypotheses

This study set out to evaluate three different hypotheses with regard to the reliability of the UEA method. The hypotheses tested are as follows:

1. The Utah Ergo Analyzer program is a repeatable and reliable tool as measured by Intraclass Correlation Coefficients (ICCs).
2. The UEA, when used by trained Analysts is more repeatable and reliable than when used by Novices.
3. Repeatability and reliability, as measured by ICC, will increase with experience.

The primary hypothesis was that the UEA is a repeatable and reliable tool that can be used to assist in the assessment and quantification of physical risk factors. In order to demonstrate the reliability of the UEA, ICCs were calculated and compared between groups of raters. This study explored how the ICCs compared for each of the individual jobs or videos evaluated by the raters. For the purpose of this hypothesis, an ICC greater than 0.60 was considered reliable and supported this hypothesis. An ICC value greater than 0.60 falls within the substantial to almost perfect categories as defined by Landis and Koch [8] and by this definition ICC values greater than 0.60 were considered to support this hypothesis. Chapter 2 described the full range of ICC values.

The second objective evaluated the relation to calculated ICC and the relative amount of training that the individual rater had. Since each of the raters had varying degrees of training and experience with respect to the UEA and ergonomics in general, one would expect that the ICCs of the more experienced raters would be greater than those of the more Novice group ($ICC_{Trained} > ICC_{Novice}$.). For the purpose of this research

the more experienced raters were labeled as Analysts while those with less experience were grouped into the Novices.

The final objective for the study was to evaluate the relationship between the ICCs and the experience with the UEA. The trained Analysts had varying levels of experience with the UEA, and all were students in the Ergonomics and Safety program at the University of Utah. The Novice group was composed of occupational safety and health students with some, but relatively less exposure to ergonomics and no previous experience with the UEA. Some of the trained Analysts had evaluated only a few video segments while others had evaluated hundreds. The idea is that those with more experience with the tool will show a greater level of agreement and thus demonstrate increased ICC values. To establish this hypothesis the same videos were evaluated during a second phase. To support this hypothesis phase two ICCs should be greater then phase one for both raw and intermediate data ($ICC_{phaseI} > ICC_{phaseII}$).

CHAPTER 2

METHODOLOGY

Study Design

Raters for this study were given six video segments and asked to analyze them in a randomly selected, assigned order. This was done in an effort to better manage the results of the individual raters and minimize bias. For the Novice group, who had never seen or used the UEA program previously, a brief training session was conducted to familiarize them with the UEA program. They were subsequently given a copy of the UEA program in addition to the list of videos and the order in which they should view them. Each of the raters, both Novice and Analysts, were instructed to evaluate a preselected practice video to further familiarize themselves with how the program worked and to make sure that it was performing correctly prior to beginning any analysis of the evaluated jobs. Additionally each rater was instructed to review each video a minimum of six times prior to beginning the analysis. Appendix A has a copy of the instructions given to the raters in addition to a brief description of each of the video segments. As part of the instructions, each rater was instructed to pay careful attention to the postures, speeds, efforts etc. while previewing each of the videos. This afforded the raters an increased awareness as to what selections would be needed while performing the analysis.

In an effort to account for the different levels of experience with the UEA, each rater was given additional training materials to aid them in classifying the different risk factors evaluated within the program. The training material titled "Guidance" gave picture examples of various, more common grip postures used, as well as an explanatory flow chart to help the rater determine when a new effort had occurred. The Guidance material was simply a guide to be used at the raters' discretion and allowed for all raters to have the same basis for which to classify risk factors. The guidance material, as shown in Appendix A, was presented to the Novice group in an abbreviated training conducted by Dr. Sesek. The guidance material provided definitions of terms as well as examples of grip postures and additional instructions on how to adequately define efforts. The trained Analysts were given a more comprehensive training and "coached" through the analysis of several videos with more experienced Analysts. Even though raters were allowed to perform the analysis at their own speed they were given a deadline for which to complete the analysis, such that enough time would be allowed to pass between Phase I and phase II of the study.

For Phases I and II, the video segments were kept to a standard length of 10 seconds which yielded a total of 300 frames for each analysis. In a previous reliability study, segments were evaluated at three different frame rates for the raters [1]; however for the purpose of this study all raters were instructed to use a frame skip rate of 10. The frame skip rate of 10 had been established as the standard analysis rate for the overall study. This provided a total of 30 observations for each rater for each video segment.

Description of Sample

Raters – Phase I

Phase I of the study included a total of 16 raters. There were 8 of the raters in the Novice group and 8 raters in the trained Analysts group. As mentioned in Chapter 1, all 8 raters in the Novice group were Occupational Safety and Health students with varying levels of educations. Novice raters included medical doctors, industrial hygiene students and mechanical engineers studying Ergonomics and Safety. All 8 of the raters from the Analysts group were Master's or Doctoral students in the Ergonomics program at the University of Utah. Raters from both groups ranged in age from the mid 20s to the mid 50s. Of all 16 raters only 2 of them had additional insight and understanding into the scope of the study while the remaining raters were blind to the objectives and simply asked to participate.

Five of the original group of Novice raters, although initially selected for the study, were not included in the results. This was due to unforeseen variations and corruption of data that made their individual results unusable. In some cases, students did not properly use the UEA program (e.g., incorrect frame skip rate used, etc.) It is uncertain as to what caused the variations but possible contributing factors might include a misunderstanding of the brief training and lack of motivation, since Novice raters were not compensated and their research did not depend on these data.

Jobs – Phase I

Six jobs were selected from a total of three different manufacturing facilities. Jobs 1 and 2 were chosen from a medical equipment manufacturing plant. Jobs 3 and 4

were selected from an aluminum extrusion plant. Finally, jobs 5 and 6 came from a garage door manufacturer. Each of the 6 videos were reviewed and then segmented into 10 second clips for use in the study. As mentioned previously, the videos were analyzed at a frame rate of 10 yielding a total of 30 observations for each video.

The jobs were chosen based on several criteria. Since the study reviewed data for both the left and right sides it was important to select jobs in which both the left and right sides could be viewed for the majority of the video segment. In the cases where one side may have been removed from sight, raters were instructed to carefully review the segments prior to and after the point at which the view of the body segment was obstructed.

For each of the 6 jobs chosen, an attempt was made to capture a representative portion of the cycle for the given job. Since all jobs in their original format varied in length from 2 to 15 minutes, it was not possible to have the raters review the entire job. Thus, the 10-second portions of the video were selected in an attempt to capture a representative sampling of the overall job activity. This may not have always been possible given the limited length of the segments used in the study. A previous study has been done to demonstrate the usefulness of creating representative jobs based on the overall job and the number of repeated cycles within a job [9].

Raters – Phase II

From the original group of raters used in Phase I of the study, only 5 raters where chosen to participate in Phase II of the study. The 5 raters were selected from the 8 raters in the trained Analysts group. The reduction in raters for Phase II was due to several

reasons. First the initial 8 Novice raters were taken from a capstone course for Occupational Safety and Health students, most of whom had graduated prior to Phase II. Second, 2 of the original trained Analysts had also graduated prior to the beginning of Phase II. The last rater removed from Phase II was one of the trained Analysts who had participated in the consensus creation of the Gold Standard comparison. The Gold Standard was created between both phases and therefore to remove bias from the overall results the last rater was removed from the study.

Jobs – Phase II

For Phase II of the study, 3 jobs were selected from the original 6 to be reanalyzed by the 5 of the same trained raters as in Phase I. The jobs were labeled A, B and C and represent the original Jobs 1, 4 and 6 from Phase I, respectively. Jobs for Phase II were selected based on a review of Phase I data and the individual videos themselves. Jobs were in part selected to minimize obstructed views.

Each rater was given instructions similar to Phase I, and given a random order in which to analyze each of the Phase II videos. The renaming and rerandomization of the jobs was done to protect the data from bias towards their original Phase I observations.

Gold Standard

In an effort to create a competency score for individual raters a "Gold Standard" was created for comparison. The Gold Standard was created by a consensus of three raters, a professor and two Analysts, reviewing and imputing data for all six videos each of whom had various levels of experience with the UEA program and had reviewed each

of the six jobs from Phase I. All six were analyzed with the Analysts discussing each observation and explaining their selections when disagreements occurred. Consensus was reached for each observation prior to moving on to the next. It should be noted that differences in consensus selections were never more than two adjacent categories (e.g., low vs. moderate flexion, etc.)

The purpose for creating such a standard was to obtain the most "correct" and accurate response for each element so that individual ratings could be deemed correct or incorrect. Once the Gold Standard was created it was compared to both the raw and intermediate outputs from both Phases I and II. The Gold Standard would allow further support to the reliability of the EA method by comparing the ICCs among raters for both groups and both phases. The Gold Standard was used to ensure that the individual Analysts were performing at adequate levels. In future research, the Gold Standard will be used for comparison with future Analysts to determine if and when additional training is needed.

Data Analysis

Data Compiling

The data from the UEA and the UEA Distiller were output into comma separated files that could be imported into a spreadsheet for data analysis. Once imported into the spreadsheet raw data were separated out into a column format, in order to be used with the SPSS software program. From the single column of raw data, individual components were placed in a format to facilitate the calculation of ICCs. Table 1 shows a complete list of components that were evaluated for the raw data. Table 2 shows the list of elements evaluated from the intermediate data.

Each of the elements that were evaluated from the raw data represents the line by line analysis from the individual raters. The raw data analysis represents each observation from the individual raters. The elements evaluated from the intermediate set of data represent percentages of time spent in a particular category under that element. For example the Flexion / Extension element would have high, neutral and low categories within that element. The intermediate output represents the percentage of time that the individual spent in each respective category for the duration of the video.

ICC Calculations

A commonly used analysis technique in Reliability studies is known as the Intraclass Correlation Coefficients (ICCS). ICCs are ratios between individual element variance and total variance. Fleiss and Shrout [10] presented guidelines for selecting the proper ICC in which to measure rater reliability. Their first recommendation was to determine whether a one-way or two-way analysis of variance was appropriate and second how the "judges" and "targets" were related to the purpose of the study. Similarly Yaffe [11] provided insight to the Fleiss and Shrout model with respect to use with the statistical software program SPSS. For the purpose of this study ICCs (3, 1) were used. For the (3, 1) ICCs the 3 means third case, or two-way mixed while the 1 represents single measure reliability. This methodology for calculating ICCs follows that used in a previous reliability study of the UEA [1].

Table 1: Raw data elements of interest

Components of Interest (raw data)
All raw data
Borg level for each effort
Overall Posture (Elbow and Wrist)
Left/Right/Combined Elbow posture
Left/Right/Combined Wrist posture
Left/Right/Combined Wrist Flexion
Left/Right/Combined Wrist Deviation
Left/Right/Combined Efforts
Left/Right/Combined Speed
Left/Right/Combined Grip

Table 2: Intermediate elements of interest

Components of Interest (intermediate data)
Forearm Rotation Percentage under the category of effort
Elbow Angle Percentage under the category of effort
Flexion/Extension Percentage under the category of effort
Grip Percentage for under the category of effort
Wrist Deviation Percentage under the category of effort
Average Effort for a Job
Efforts Per Minute
Duration of Exertions
Average Hand Wrist Posture
Average Speed for an Effort

The ICCs for this study were calculated using the statistical software program SPSS 16.0.1 for Windows. While calculating the ICCs for this study, the option of absolute agreement was selected because it reflected the variance between the raters with respect to total variance. This variance, as mentioned, was considered relevant to this study. This also represents the worst case scenario and will not artificially inflate the ICC values.

In the process of computing ICCs, several characteristics were discovered with respect to SPSS 16.0 software and the calculation of ICCs. When analyzing the raw data, various raters were discovered to have no variance between their individual observations for a respective element. When this was the case, the SPSS 16.0.1 software would exclude them from the ICC calculation for that respective element. Comparisons were made between the Gold Standard and individual raters, for any data that had no variance would not result in an ICC. This result allowed for two conclusions when the raw data was compared side by side. Either the rater being evaluated had complete agreement with the Gold Standard or there was little to no agreement between the two. In the case where complete agreement would have been reached and yet no ICC was calculated, both the rater and the Gold Standard actually had perfect agreement among observations yet the results appeared to demonstrate no agreement. This was a result of having zero variance between the observations from the rater and the Gold Standard.

ICC Interpretation

Various researchers have provided interpretations for calculated ICC values. Fleiss [12] took a simple approach to classifying ICC values. Fleiss classified ICC values

Table 1: Raw data elements of interest

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All raw data
Borg level for each effort
Overall Posture (Elbow and Wrist)
Left/Right/Combined Elbow posture
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Left/Right/Combined Wrist Flexion
Left/Right/Combined Wrist Deviation
Left/Right/Combined Efforts
Left/Right/Combined Speed
Left/Right/Combined Grip

Table 2: Intermediate elements of interest

Components of Interest (intermediate data)
Forearm Rotation Percentage under the category of effort
Elbow Angle Percentage under the category of effort
Flexion/Extension Percentage under the category of effort
Grip Percentage for under the category of effort
Wrist Deviation Percentage under the category of effort
Average Effort for a Job
Efforts Per Minute
Duration of Exertions
Average Hand Wrist Posture
Average Speed for an Effort

into three separate categories, poor, fair to good and excellent. For the respective categories ICCs less than 0.4 were considered poor, ICCs between 0.4 and 0.75 fell into the fair to good category and finally ICCs greater than 0.75 were considered excellent. Landis and Koch [8] further distinguished ICC values by separating them into six different categories. Table 3 shows the six different categories and their respective ICCs that were presented by Landis and Koch. For the purpose of this study, a modified version of the ICC interpretation from Landis and Koch, was used to classify the various ICC values obtained. This modified version can be seen in Table 4.

Table 3: ICC Interpretations by Landis and Koch

ICC value	Interpretation
<0.00	Poor
0.00 - .20	Slight
0.21 – 0.40	Fair
0.41 – 0.60	Moderate
0.61 – 0.80	Substantial
0.81 – 1.00	Almost perfect

Table 4: Modified ICC interpretations

ICC value	Interpretation
< or =0.00	Poor
>0.00 - 0.20	Slight
>0.20 - 0.40	Fair
>0.40 - 0.60	Moderate
>0.60 - 0.80	Substantial
>0.80 - 1.00	Almost perfect

CHAPTER 3

RESULTS

Phase I Raw Results

Table 5 demonstrates the ICCs calculated among the groups of Analysts for the individual videos that were reviewed. The ICCs for Table 5 were calculated from the raw data for each of the six videos from Phase I.

From the results represented in Table 5 it is clear that videos 1, 2 and 6 had the best overall agreement between the raters when compared with the Gold Standard model. The average ICCs among the Analysts for all 6 videos were higher and statistically significantly higher than the ICCs for the Novice group. For all videos, other than video 2, the Analysts group had greater agreement as compared with the gold standard. The 95% confidence intervals also demonstrate that ICC values for the trained Analysts were statistically significantly higher, since the 95% confidence intervals between Analysts and Novices do not overlap.

The results in Table 5 support the first hypothesis of this study by demonstrating reliability through an average ICC for both the Novice and Analysts greater than 0.60. As previously mentioned, reliability is defined with an ICC greater than 0.60. The first hypothesis is further supported by the majority of ICC values, for individual videos, among both groups falling within the "substantial" to "almost perfect" ranges. Videos 1, 2 and 6 all show ICCs greater than 0.84.

Table 5: Raw ICCs by Video

Raw ICCs	Video 1	Video 2	Video 3	Video 4	Video 5	Video 6	Average
All w/Gold	0.884 (.870 - .898)	0.898 (.885 - .910)	0.553 (.519 - .588)	0.513 (.479 - .549)	0.706 (.679 - .734)	0.861 (.845 - .877)	0.736
Analyst w/Gold	0.939 (.931 - .947)	0.897 (.884 - .910)	0.600 (.564 - .636)	0.617 (.579 - .654)	0.755 (.729 - .780)	0.888 (.874 - .901)	0.766
Novice w/Gold	0.859 (.833 - .871)	0.910 (.899 - .921)	0.552 (.515 - .589)	0.470 (.433 - .509)	0.686 (.655 - .716)	0.849 (.831 - .867)	0.721

The raw ICCs also support the second hypothesis which states; "The UEA, when used by trained Analysts is more repeatable and reliable than when used by Novices." The Analysts consistently had higher ICCs than the Novice group, with the exception of video 2.

Raw ICCs by Job

Tables 6 through 11 represent ICC values calculated for the individual elements of interest that were presented in Tables 1 and 2 in aggregate. These Tables, 6 through 11, represent the raw data ICCs for each observation of the raters, and are separated into tables based on the respective video.

Video 1

The results in Table 6 present interesting findings with respect to the individual elements of interest and their respective ICCs for both the Novice and Analysts groups. Hypothesis 2 is supported by the results presented in Table 6 since the majority of ICCs for the elements of interest, for the Analysts group were statistically significantly higher than the ICCs for the Novice group. The Analysts group had 11 of 20 ICCs that fell into the substantial to almost perfect categories, while the Novice group had only 4 of 20 ICCs in that same two categories.

The results in Table 6 show that various elements of interest demonstrated fair to poor levels of ICCs for both groups. Left wrist flexion showed that both groups fell in the "slight" category having levels between 0 and 0.20.

It is difficult to fully support the first hypothesis given the individual results in Table 6. This is because only the Analysts group had the majority of individual elements

Table 6: Video 1 Raw ICCs (Confidence Interval)

Video/Job	1				
Rater	Novice w/Gold	Analysts w/Gold	All w/Gold	Novice (avg)	Analysts (avg)
Raw	0.859 (.833 - .871)	0.939 (.931 - .947)	0.884 (.870 - .898)	0.878	0.956
Borg	0.289 (.155 - .439)	0.574 (.361 - .730)	0.289 (.182 - .417)	0.316	0.671
Efforts	0.598 (.499 - .699)	0.951 (.931 - .967)	0.752 (.680 - .821)	0.771	0.967
Elbow Posture	0.429 (.357 - .508)	0.527 (.455 - .603)	0.465 (.399 - .538)	0.576	0.614
Grip	0.796 (.721 - .859)	0.941 (.917 - .960)	0.853 (.802 - .898)	0.840	0.962
Posture	0.628 (.575 - .679)	0.793 (.758 - .825)	0.692 (.648 - .735)	0.728	0.852
Speed	0.267 (.171 - .386)	0.630 (.472 - .754)	0.353 (.256 - .469)	0.378	0.697
Wrist Deviation	0.120 (.057 - .209)	0.429 (.309 - .558)	0.247 (.167 - .352)	0.415	0.614
Wrist Flexion	0.202 (.125 - .306)	0.325 (.220 - .450)	0.211 (.142 - .305)	0.310	0.554
Wrist Posture	0.251 (.182 - .333)	0.517 (.434 - .601)	0.340 (.271 - .419)	0.360	0.630
Left Efforts	0.761 (.655 - .856)	0.985 (.975 - .992)	.862 (.795 - .920)	0.842	0.991
Left Grip	0.935 (.897 - .964)	0.971 (.953 - .984)	0.949 (.921 - .972)	0.956	0.984
Left Elbow Posture	0.389 (.291 - .507)	0.683 (.596 - .769)	0.507 (.414 - .612)	0.531	0.763
Left Speed	0.210 (.109 - .365)	0.692 (.556 - .814)	0.364 (.246 - .525)	0.347	0.809
Left Wrist Deviation	0.157 (.061 - .309)	0.417 (.258 - .599)	0.295 (.184 - .455)	0.383	0.614
Left Wrist Flexion	0.062 (.012 - .155)	0.002 (-.016 - .039)	0.028 (.006 - .072)	0.048	-0.107
Left Wrist Posture	0.308 (.215 - .424)	0.633 (.520 - .737)	0.439 (.343 - .551)	0.425	0.711
Right Efforts	0.032 (-.019 - .126)	0.856 (.776 - .918)	0.178 (.090 - .318)	0.188	0.932
Right Elbow Posture	0.441 (.327 - .564)	0.312 (.217 - .429)	0.368 (.279 - .478)	0.658	0.498
Right Grip	0.084 (.021 - .194)	0.856 (.776 - .918)	0.175 (.094 - .308)	0.082	0.932
Right Speed	.208 (.097 - .374)	0.231 (.097 - .413)	0.178 (.096 - .313)	0.291	0.399
Right Wrist Deviation	*	*	*	*	*
Right Wrist Flexion	*	*	*	*	*
Right Wrist Posture	*	*	*	*	*

* Indicates that ICCs could not be calculated due to zero variance in the data.

rank within the substantial to almost perfect range. The first hypothesis does not differentiate between the two groups, and only says that the reliability of the UEA is determined by ICC values. However, since the UEA methodology will be used by ergonomists or trained personnel, hypothesis 1 could be supported by the results from the Analysts group, from video 1.

It is interesting to note that when comparing the overall raw data ICCs for both groups, the values were between the substantial and almost perfect categories of agreement. However, variation in ICC values increased between the individual elements of interest. These ICCs range from poor to almost perfect, for both groups. This could be partially explained by the lack of variation of some of the elements of interest. Some elements had no variation, and therefore ICC values were not calculated.

Video 2

The results for Video 2 are compiled in Table 7. As noted earlier, the overall raw data results in Table 5 show the Novice group having a higher yet not statistically significantly higher overall ICC than the Analysts. Comparing the individual elements of interest for video 2, both the Novice and Analysts groups have an equal number of elements with higher ICCs. This would make sense given that the overall ICC values for both groups are within the almost perfect range and had overlapping confidence intervals. The first hypothesis is supported by the overall results from Video 2 in that both groups produced ICC values above the determined limit of 0.60. These results show that the reliability of the UEA method is supported.

Wrist flexion was an area in which both groups, primarily Analysts, struggled to produce consistent correlation. Separating wrist flexion into the left and right

Table 7: Video 2 Raw ICCs (Confidence Interval)

Video/Job	2				
Rater	Novice/Gold	Analysts/Gold	All/Gold	Novice (avg)	Analysts (avg)
Raw	0.910 (.899 - .921)	0.897 (.884 - .910)	0.898 (.885 - .910)	0.915	0.922
Borg	0.379 (.257 - .513)	0.584 (.473 - .693)	0.429 (.325 - .547)	0.564	0.715
Efforts	0.640 (.546 - .735)	0.684 (.593 - .771)	0.644 (.556 - .734)	0.736	0.782
Elbow Posture	0.624 (.549 - .696)	0.573 (.493 - .652)	0.590 (.522 - .660)	0.623	0.611
Grip	0.725 (.645 - .802)	0.683 (.591 - .771)	0.690 (.609 - .772)	0.788	0.789
Posture	0.777 (.741 - .811)	0.766 (.729 - .802)	0.762 (.726 - .797)	0.801	0.816
Speed	0.150 (.084 - .242)	0.278 (.169 - .409)	0.211 (.138 - .310)	0.299	0.535
Wrist Deviation	0.247 (.148 - .371)	0.538 (.406 - .664)	0.319 (.224 - .436)	0.444	0.659
Wrist Flexion	0.292 (.117 - .470)	0.014 (-.025 - .075)	0.091 (.036 - .170)	0.415	0.067
Wrist Posture	0.491 (.405 - .580)	0.256 (.168 - .355)	0.336 (.256 - .424)	0.548	0.414
Left Efforts	0.780 (.679 - .869)	0.715 (.598 - .825)	0.731 (.625 - .833)	0.807	0.792
Left Grip	0.786 (.687 - .873)	0.715 (.598 - .825)	0.734 (.629 - .836)	0.807	0.792
Left Elbow Posture	0.680 (.587 - .769)	0.548 (.429 - .625)	0.599 (.503 - .698)	0.626	0.601
Left Speed	0.101 (.029 - .225)	0.472 (.306 - .650)	0.188 (.103 - .326)	0.243	0.575
Left Wrist Deviation	0.302 (.171 - .480)	0.459 (.287 - .642)	0.350 (.28 - .516)	0.524	0.561
Left Wrist Flexion	0.575 (.399 - .738)	0.073 (.002 - .194)	0.143 (.050 - .289)	0.702	0.120
Left Wrist Posture	0.610 (.507 - .712)	0.303 (.194 - .432)	0.410 (.308 - .527)	0.672	0.439
Right Efforts	0.517 (.369 - .678)	0.651 (.485 - .792)	0.561 (.426 - .709)	0.664	0.953
Right Elbow Posture	0.560 (.452 - .671)	0.609 (.504 - .712)	0.583 (.489 - .684)	0.614	0.636
Right Grip	0.611 (.478 - .750)	0.637 (.453 - .788)	0.613 (.480 - .750)	0.704	0.915
Right Speed	0.282 (.161 - .452)	0.320 (.147 - .523)	0.240 (.138 - .393)	0.355	0.521
Right Wrist Deviation	*	*	*	*	*
Right Wrist Flexion	0.144 (.005 - .343)	0.116 (-.019 - .312)	0.087 (.020 - .203)	0.202	0.018
Right Wrist Posture	0.447 (.292 - .595)	0.420 (.266 - .571)	0.364 (.226 - .510)	0.401	0.470

* Indicates that ICCs could not be calculated due to zero variance in the data.

components, it appears as though the groups still lacked adequate correlation. However, the Novice group ICC values are within the moderate range of correlation for the left component. Similar results can be seen for speed and other wrist posture components for the Novice group of raters. The Analysts did not demonstrate similar correlations.

Video 3

The results for Video 3 raw data are presented in Table 8. The overall ICC values for Video 3 are in the moderate category for both groups. Although the Analysts have a higher ICC overall, it was not statistically significantly different. Seventeen of the 23 total elements produced valid ICCs for Video 3. Seven of the ICCs for the Novice group are in the fair category of agreement. For the same 7 elements of the Novice group the Analysts also produced fair to moderate ICC outcomes.

The results from Table 8 do not fully support hypotheses 1 or 2 for this study. This is because there is a lack of consistent results within the Substantial to Almost perfect categories. However, when looking at the raw values, and not comparing them to Table 5, hypothesis 2 can be supported by the results from Video 3. For example, the Analysts have an ICC of 0.921, 95% CI (.861 - .959) for right grip, while the Novice group have an ICC of 0.731, 95% CI (.613 - .838). While both ICC values meet the 0.60 criteria, the Analysts had an almost perfect correlation while the Novice had substantial. When comparing just the ICC values for Video 3, the Analysts group consistently had higher ICCs than the Novice group. This further supports hypothesis 2 in that the ICCs for trained Analysts are higher than those for the Novices.

Table 8: Video 3 Raw ICCs (Confidence Interval)

Video/Job	3				
Rater	Novice/Gold	Analysts/Gold	All/Gold	Novice (avg)	Analysts (avg)
Raw	0.552 (.515 - .589)	0.600 (.564 - .636)	0.553 (.519 - .588)	0.661	0.706
Borg	0.271 (.152 - .409)	0.225 (.121 - .354)	0.197 (.120 - .300)	0.412	0.368
Efforts	0.487 (.381 - .603)	0.547 (.449 - .654)	0.542 (.450 - .644)	0.486	0.508
Elbow Posture	0.353 (.282 - .434)	0.488 (.497 -.572)	0.418 (.352 - .493)	0.455	0.669
Grip	0.498 (.349 - .638)	0.539 (.362 - .687)	0.520 (.393 - .645)	0.655	0.734
Posture	0.710 (.669 - .751)	0.730 (.687 - .771)	0.696 (.656 - .737)	0.764	0.788
Speed	0.452 (.320 - .586)	0.327 (.205 - .465)	0.396 (.293 - .515)	0.329	0.322
Wrist Deviation	NEG 0.035 (-.094 - .051)	0.226 (.134 - .343)	0.064 (.023 - .126)	0.189	0.002
Wrist Flexion	0.244 (.118 - .391)	0.117 (.055 - .206)	0.143 (.084 - .228)	0.280	0.313
Wrist Posture	0.201 (.126 - .289)	0.403 (.329 - .486)	0.323 (.261 - .396)	0.327	0.381
Left Efforts	*	*	*	*	*
Left Grip	*	*	*	*	*
Left Elbow Posture	*	*	*	*	*
Left Speed	0.158 (-.109 - .442)	0.181 (-.094 - .467)	0.331 (.088 - .571)	0.158	0.181
Left Wrist Deviation	*	*	*	*	*
Left Wrist Flexion	*	*	*	*	*
Left Wrist Posture	*	*	*	*	*
Right Efforts	0.473 (.326 - .642)	0.531 (.393 - .686)	0.527 (.399 - .677)	0.471	0.489
Right Elbow Posture	0.330 (.235 - .448)	0.554 (.449 - .662)	0.446 (.355 - .555)	0.466	0.688
Right Grip	0.731 (.613 - .838).	0.921 (.861 - .959)	0.823 (.738 - .896)	0.781	0.948
Right Speed	0.277 (.132 - .464)	0.373 (.222 - .555)	0.271 (.160 - .431)	0.166	0.295
Right Wrist Deviation	0.015 (-.056 - .140)	0.019 (-.070 - .168)	0.041 (-.009 - .133)	0.194	0.161
Right Wrist Flexion	0.093 (-.028 - .276)	0.144 (.052 - .291)	0.102 (.038 - .216)	0.008	0.283
Right Wrist Posture	0.229 (.125 - .359)	0.538 (.433 - .649)	0.369 (.277 - .482)	0.316	0.601

* Indicates that ICCs could not be calculated due to zero variance in the data.

Video 4

Table 9 displays the ICCs calculated for both groups from the raw data of Video 4. The Analysts proved to be better at evaluating the individual elements for Video 4 than the Novice. This is demonstrated by consistently higher ICC values for the Analysts as compared to the Novice group. However, the element of wrist deviation seemed to be difficult for both groups. The ICCs produced for the components of wrist deviation are all within the poor to slight categories with the Analysts group having a negative ICC for the left component of wrist deviation.

Because the Analysts consistently have higher agreement for both the overall and individual elements of Video 4, hypothesis 2 is supported. The second hypothesis states that the UEA will be more repeatable and reliable when used by Analysts. This is shown by the higher ICC values. Only the overall agreement, as well as the agreement for efforts and posture, can support the first hypothesis by having ICC values within the substantial to almost perfect range. These ICC values demonstrate increased repeatability and reliability of the UEA method. In a consistent trend, as the elements of interest are separated into their individual components from raw to left and right portions, agreement seems to vary and potentially decline for both groups.

Video 5

As presented in Table 10, the overall results for raw data support both the first and second hypotheses since the ICC for both groups was the substantial category (hypothesis 1) and the Analysts had a higher level of agreement than the Novice group for Video 5 (hypothesis 2).

Table 9: Video 4 Raw ICCs (Confidence Interval)

Video/Job	4				
Rater	Novice/Gold	Analysts/Gold	All/Gold	Novice (avg)	Analysts (avg)
Raw	0.470 (.433 - .509)	0.617 (.579 - .654)	0.513 (.479 - .549)	0.558	0.691
Borg	0.087 (.032 - .166)	0.239 (.153 - .351)	0.103 (.056 - .172)	0.195	0.312
Efforts	0.249 (.161 - .362)	0.674 (.585 - .762)	0.381 (.289 - .493)	0.516	0.827
Elbow Posture	0.245 (.181 - .322)	0.294 (.202 - .395)	0.280 (.218 - .355)	0.484	0.591
Grip	0.261 (.174 - .372)	0.358 (.252 - .482)	0.293 (.212 - .397)	0.401	0.470
Posture	0.674 (.622 - .724)	0.813 (.780 - .843)	0.729 (.689 - .768)	0.734	0.863
Speed	0.083 (.032 - .156)	0.354 (.216 - .502)	0.137 (.079 - .221)	0.269	0.601
Wrist Deviation	0.124 (.045 - .231)	0.020 (-.017 - .077)	0.071 (.033 - .129)	0.100	0.220
Wrist Flexion	0.142 (.061 - .250)	0.280 (.171 - .410)	.128 (.075 - .205)	0.123	0.455
Wrist Posture	0.290 (.201 - .389)	0.470 (.395 -.551)	0.321 (.250 - .402)	0.281	0.593
Left Efforts	0.331 (.207 - .501)	0.767 (.662 - .860)	0.441 (.319 - .599)	0.558	0.893
Left Grip	0.258 (.146 - .422)	0.299 (.176 - .468)	0.257 (.161 - .405)	0.350	0.454
Left Elbow Posture	0.257 (.170 - .370)	0.286 (.177 - .416)	0.289 (.208 - .395)	0.455	0.515
Left Speed	0.043 (.004 - .117)	0.322 (.152 - .523)	0.088 (.040 - .178)	0.193	0.596
Left Wrist Deviation	0.151 (.037 - .321)	-.007 (-.061 - .092)	0.079 (.022 - .182)	0.156	0.143
Left Wrist Flexion	0.176 (.052 - .355)	0.259 (.132 - .433)	0.146 (.070 - .271)	0.295	0.428
Left Wrist Posture	0.205 (.103 - .332)	0.459 (.359 - .574)	0.274 (.187 - .384)	0.321	0.581
Right Efforts	0.308 (.183 - .480)	0.635 (.502 - .769)	0.461 (.336 - .618)	0.608	0.809
Right Elbow Posture	0.324 (.224 - .445)	0.307 (.201 - .433)	0.312 (.227 - .420)	0.624	0.665
Right Grip	0.384 (.248 - .557)	0.413 (.271 - .585)	0.396 (.276 - .556)	0.550	0.480
Right Speed	0.189 (.083 - .349)	0.365 (.212 - .551)	0.238 (.138 - .390)	0.371	0.604
Right Wrist Deviation	0.200 (.058 - .393)	0.047 (-.015 - .157)	0.102 (.041 - .210)	0.042	0.293
Right Wrist Flexion	-.012 (-.056 - .070)	0.369 (.206 - .559)	0.126 (.058 - .242)	-0.111	0.535
Right Wrist Posture	0.425 (.273 - .574)	0.487 (.382 - .602)	0.403 (.304 - .519)	0.241	0.608

Table 10: Video 5 Raw ICCs (Confidence Interval)

Video/Job	5				
Rater	Novice/Gold	Analysts/Gold	All/Gold	Novice (avg)	Analysts (avg)
Raw	0.686 (.655 - .716)	0.755 (.729 - .780)	0.706 (.679 - .734)	0.663	0.791
Borg	0.303 (.164 - .456)	0.315 (.201 - .447)	0.286 (.186 - .408)	0.374	0.442
Efforts	0.390 (.276 - .519)	0.568 (.470 - .672)	0.449 (.355 - .558)	0.490	0.651
Elbow Posture	0.425 (.354 - .505)	0.613 (.545 - .682)	0.520 (.454 - .592)	0.431	0.630
Grip	0.517 (.406 - .633)	0.471 (.368 - .586)	0.457 (.364 - .565)	0.414	0.602
Posture	0.591 (.533 - .648)	0.751 (.711 - .789)	0.674 (.629 - .718)	0.634	0.740
Speed	0.171 (.093 - .276)	0.231 (.148 - .340)	0.209 (.141 - .203)	0.248	0.274
Wrist Deviation	0.104 (.034 - .202)	0.058 (.011 - .128)	0.078 (.040 - .135)	-0.069	0.086
Wrist Flexion	0.063 (-.002 - .156)	0.172 (.102 - .268)	0.136 (.084 - .213)	-0.127	-0.059
Wrist Posture	0.077 (.033 - .134)	0.111 (.068 - .167)	0.113 (.079 - .159)	-0.071	0.042
Left Efforts	0.651 (.520 - .781)	0.717 (.600 - .827)	0.662 (.545 - .784)	0.710	0.807
Left Grip	0.366 (.218 - .547)	0.359 (.229 - .531)	0.330 (.217 - .489)	0.224	0.573
Left Elbow Posture	0.443 (.337 - .561)	0.523 (.411 - .639)	0.493 (.398 - .601)	0.431	0.566
Left Speed	0.204 (.094 - .367)	0.307 (.176 - .482)	0.249 (.150 - .400)	0.363	0.342
Left Wrist Deviation	0.127 (.023 - .287)	0.214 (.106 - .379)	0.135 (.065 - .256)	-0.057	0.165
Left Wrist Flexion	0.148 (.042 - .312)	0.110 (.030 - .244)	0.186 (.101 - .325)	-0.254	-0.226
Left Wrist Posture	0.169 (.090 - .275)	0.199 (.120 - .305)	0.192 (.128 - .282)	-0.071	0.084
Right Efforts	0.178 (.080 - .328)	0.362 (.233 - .533)	0.229 (.139 - .371)	0.285	0.456
Right Elbow Posture	0.132 (.068 - .222)	0.401 (.298 - .520)	0.240 (.166 - .340)	0.185	0.446
Right Grip	0.666 (.535 - .793)	0.568 (.432 - .717)	0.586 (.461 - .726)	0.623	0.640
Right Speed	0.093 (.031 - .202)	0.100 (.030 - .221)	0.116 (.060 - .218)	0.078	0.180
Right Wrist Deviation	- 0.127 (-.168 - .097)	-0.04 (.077 0 ,031)	- 0.010 (-.036 - .043)	-0.129	-0.136
Right Wrist Flexion	*	*	*	*	*
Right Wrist Posture	-0.094 (-.123 - -049)	0.045 (.006 - .105)	0.029 (.002 - .071)	-0.027	-0.066

* Indicates that ICCs could not be calculated due to zero variance in the data.

Of the individual elements reviewed, wrist deviation, wrist flexion, and wrist posture produced the lowest level of agreement for each of the two groups. Wrist posture, which is a composition of both flexion and deviation, has levels of agreement within the slight range for both groups. Consequently, both wrist flexion and wrist deviation have similar results. Furthermore, the right wrist deviation displayed no agreement, by producing negative ICCs for both groups. The right wrist posture for the Novice group also has no agreement or poor agreement with an ICC of -0.094. It is difficult to determine the reason for lower ICC values when the data are represented in individual components. These results suggest that the EA method does not facilitate discrimination of wrist deviation categories. Both the Analysts and the Novice groups performed consistently poorly on wrist deviation classification. This may suggest a trend worthy of further study and will be discussed in subsequent chapters.

Video 6

From the results in Table 11, hypothesis 2 can be supported based on the Analysts having consistently higher agreement than the Novice group. ICC values for both wrist posture and wrist deviation, as shown in Table 11, were greater for the Novice group as compared to the Analysts. Even though both elements had statistically significantly higher ICCs, neither element had an ICC within the substantial category which would be the minimum requirement to be considered reliable agreement.

The asterisk (*) found in Tables 6 through 11 indicates that either all raters or the Gold Standard had zero variation in their observations and therefore no ICC could be

Table 11: Video 6 Raw ICCs (Confidence Interval)

Video/Job	6				
Rater	Novice/Gold	Analysts/Gold	All/Gold	Novice (avg)	Analysts (avg)
Raw	0.849 (.831 - .867)	0.888 (.874 - .901)	0.861 (.845 - .877)	0.880	0.910
Borg	0.369 (.236 - .511)	0.502 (.372 - .631)	0.379 (.273 - .502)	0.439	0.603
Efforts	0.627 (.532 - .723)	0.729 (.650 - .805)	0.662 (.579 - .749)	0.713	0.810
Elbow Posture	,320 (.241 - .408)	0.562 (.491 - .635)	0.418 (.350 - .495)	0.406	0.585
Grip	0.622 (.528 - .719)	0.649 (.558 - .741)	0.610 (.522 - .704)	0.704	0.778
Posture	0.639 (.585 - .692)	0.744 (.737 - .809)	0.691 (.648 - .733)	0.725	0.831
Speed	0.123 (.063 - .209)	0.329 (.222 - .454)	0.208 (.142 - .300)	0.171	0.299
Wrist Deviation	0.486 (.375 - .605)	0.216 (.111 - .346)	0.299 (.202 - .417)	0.412	0.481
Wrist Flexion	*	*	*	*	*
Wrist Posture	0.386 (.311 - .470)	0.211 (.148 - .286)	0.273 (.213 - .345)	0.393	0.437
Left Efforts	0.492 (.354 - .653)	0.771 (.667 - .863)	0.608 (.485 - .742)	0.591	0.872
Left Grip	0.528 (.389 - 684)	0.711 (.591 - .823)	0.585 (.459 - .724)	0.662	0.796
Left Elbow Posture	0.377 (.258 - .510)	0.605 (.508 - .704)	0.486 (.389 - .596)	0.492	0.686
Left Speed	0.070 (.013 - .174)	0.324 (.185 - .503)	0.179 (.102 - .307)	0.113	0.247
Left Wrist Deviation	0.132 (.050 - .268)	0.134 (.050 - .270)	0.104 (.049 - .202)	0.130	0.381
Left Wrist Flexion	*	*	*	*	*
Left Wrist Posture	0.301 (.208 - .418)	0.219 (.137 - .238)	0.227 (.158 - .322)	0.310	0.470
Right Efforts	0.638 (.501 - .773)	0.664 (.536 - .790)	0.646 (.524 - .772)	0.736	0.753
Right Elbow Posture	0.331 (.236 - .448)	0.523 (.421 - .633)	0.401 (.313 - .510)	0.368	0.483
Right Grip	0.654 (.525 - .782)	0.586 (.449 - .731)	0.596 (.471 - .733)	0.703	0.736
Right Speed	0.168 (.075 - .314)	0.327 (.194 - .503)	0.225 (.134 - .368)	0.255	0.373
Right Wrist Deviation	*	*	*	*	*
Right Wrist Flexion	*	*	*	*	*
Right Wrist Posture	*	*	*	*	*

* Indicates that ICCs could not be calculated due to zero variance in the data.

calculated. The zero variance may have been present on the left or right side observation and therefore would not enable an ICC calculation. However, if the zero variance was only true for one side, left or right, and not the other then ICCs could be calculated when both were used as input. Uncalculated ICCs, as indicated by the asterisk do not necessarily indicate that there was no agreement. In fact it is entirely possible to have absolute agreement and have an ICC of 1.0 but without variance in the observation, column data, SPSS cannot calculate ICCs.

Implications

In Tables 5 through 11 the raw data tend to support both the first and second hypotheses, primarily based on the overall raw data ICCs. However, as individual elements are compared agreement trends downward for both the Novice and Analysts groups. This can be a difficult trend to explain. It is fair to say that the ICCs related to the individual elements of posture specifically appear to be the lower than when evaluated at the higher level.

In evaluating video segments the elements of interest such as posture, grip, and level of effort can change rapidly and be difficult to catch. In evaluating each of the six videos, the Gold Standard consensus would have been more capable of determining slight changes in posture or other elemental categories, and would have documented those changes at the first observation in which it occurred (frame 20 for example). On the opposite end individual raters may potentially miss the change initially and not notice it until several observations later, or even the next observation (frame 30). This would cause an offset in the individual rater's results. Even if the value for the posture were to be of the same category, the offset in data would result in an ICC lower than if the change

would have been detected at the same time. This simple example may provide some insight as to what would cause ICCs to decrease as the elements are simplified into left and right components.

Phase I Intermediate Results

Table 12 is a synopsis of all of the intermediate data for all jobs. Overall intermediate results support both the first and second hypotheses for this study. Both groups of raters have higher levels of agreement that can be classified as substantial per Table 4. This higher level of agreement is supportive documentation that even at the intermediate level of outputs the UEA is a reliable method for use in assessing occupational risk factors.

The results in Table 12 also support the second hypothesis of this study in that the ICC values for Analysts group are higher as compared to those of the Novice group. However, it may be questionable as to how significant the higher level of agreement really is, by comparing the 95% CI for each of the groups. These data show an overlap in the 95% CI between the two groups.

Table 12: Intermediate ICCs (Confidence Interval) All data all jobs

Intermediate ICCs	All jobs/ All data
All w/Gold	0.682 (.641 - .723)
Analyst w/Gold	0.713 (.675 - .749)
Novice w/Gold	0.686 (.642 - .728)

Similar to the raw data results, the intermediate data were segmented by video for all data, Table 13, and elements of interest, Table 14. The results in Table 13 are somewhat predictable in the sense that levels of agreement should be closely related between the raw and intermediate outputs. For the majority of the results in Table 13 this assessment is true. However, Video 3 shows an inverse relationship when comparing raw to intermediate data. The ICC value for the Analysts group in Video 3 is lower than that for the Novice group for the intermediate data. This is not the case for the raw data. There is no attributable cause for the shift in results.

Despite the shift in results for Video 3, the remainder of the results for both groups help support hypothesis 1 of this study. Reiterating that the reliability of the UEA method is supported by ICC values greater than 0.60. Since both groups had the majority of ICC values (across videos) meeting this criterion (>0,60), the first hypothesis is supported. Further support is provided by the agreement for the Analysts being within the substantial to almost perfect categories, with the exception of Video 3, which had agreement in the moderate category.

As mentioned previously, Table 14 presents agreement results for all jobs separated into the elements of interest for the intermediate data. All ICCs for the Analysts' group show agreement to lie within the top two levels: substantial to almost perfect. This provides adequate support for the first hypothesis of the study in that the tool is considered reliable based on ICCs of 0.60 and greater. Additionally, the second hypothesis can be supported by the Analysts having greater agreement between elements of interest, with the exception of elbow angle, as compared to the Novice group.

Table 13: Intermediate ICCs (Confidence Interval) All Data by Video

Intermediate ICCs	Video 1: All Data	Video 2: All Data	Video 3: All Data	Video 4: All Data	Video 5: All Data	Video 6: All Data
All/Gold	0.775 (.700 - .846)	0.692 (.602 - .782)	0.646 (.551 - .745)	0.578 (.478 - .688)	0.620 (.522 - .724)	0.729 (.645 - .811)
Analyst/Gold	0.835 (.771 - .891)	0.682 (.585 - .778)	0.592 (.485 - .705)	0.701 (.606 - .792)	0.709 (.616 - .799)	0.796 (.722 - .863)
Novice/Gold	0.742 (.655 - .824)	0.687 (.590 - .782)	0.757 (.673 - .834)	0.536 (.425 - 657)	0.524 (.410 - .648)	0.698 (.603 - .790)

Table 14: Intermediate ICCs (Confidence Interval) All videos

Intermediate ICCs	All videos: All data	All videos: ~Strain~	All videos: Flex/Ext	All videos: Dev	All videos: Elbow Angle	All videos: Grip
All/Gold	0.682 (.641 - .723)	0.658 (.564 - .755)	0.583 (.493 - .680)	0.621 (.540 - .707)	0.891 (.835 - .937)	0.623 (.548 - .703)
Analyst/Gold	0.713 (.675 - .749)	0.775 (.704 -.841)	0.629 (.543 - .716)	0.693 (.621 - .764)	0.826 (.748 - .893)	0.664 (.593 - .734)
Novice/Gold	0.686 (.642 - .728)	0.570 (.461 - .687)	0.650 (.559 - .742)	0.585 (.495 - .679)	0.904 (.851 - .946)	0.607 (.524 - .692)

For the Novice group the two elements of interest that fall below the substantial category were "strain" and deviation. All other element ICC values are in the substantial to almost perfect range. This lends support to the first hypothesis of this study.

The "strain" category, as labeled in 14 and subsequent tables representing intermediate results, does not represent the final strain index output calculation. The strain ICC actually represents the ICC value for the compilation of elements of interest. These include the average effort for a job, efforts per minute, duration of exertions, average hand/ wrist posture, and the average speed for an effort. These are the preliminary outputs for estimating the strain index and not the final output to predict risk. However, their results may suggest risk prediction and therefore have been included in this study. For simplicity, the remaining intermediate output tables will refer to these elements under the category of strain.

Appendices B through D provide a more comprehensive compilation of results for both raw and intermediate data, respectively. Similar to Tables 6 through 11, Appendix C contains tables with the intermediate results, separated into individual videos.

Implications

Based on the results presented in Tables 5 through 14, hypothesis 1 of this study can be supported, since the ICC values greater than 0.60 represent a repeatable and reliable method of analysis. It is shown that for the majority of results, both raw and intermediate ICCs demonstrate levels of agreement within the substantial to almost perfect categories.

Tables 5 through 14 help to support hypothesis 2 by demonstrating that the Analysts produced higher levels of agreement, as represented by ICC values, in comparison to the Novice group.

Individual Results Phase I

In an effort to support hypothesis 2, Tables 15 and 16 were compiled to show that the individual Analysts have higher agreement with respect to the Gold Standard when compared to the Novice group. Appendix B gives a more detailed representation of results for the individual raters in Phase I.

From the results in Table 15, the Analysts all have average ICC values within the range of substantial to almost perfect. The Novice group more consistently has ICCs in the fair to moderate categories ranging from 0.385 to 0.565. Only rater A5 had consistent ICCs in the substantial category. These results support the idea that trained raters will produce higher levels of agreement as compared to the Novice raters. The intermediate results for the individual raters are represented in Table 16 and separated into the elements of interest. These results do not represent an average ICC, as those shown in Table 15. For the intermediate results, rater A5's data did not include ICCs for Video 5. This was due to data corruption while running the raw data through the UEA Distiller.

The results shown in Table 16 support both hypotheses 1 and 2 by the high level of agreement for individual raters overall and higher agreement among the Analysts. Overall higher levels of agreement are consistent with the first hypothesis stating that the UEA is repeatable and reliable as measured by ICCs greater than 0.60. The higher

Table 15: Phase I raw ICCs by rater

Rater	Video 1 Average	Video 2 Average	Video 3 Average	Video 4 Average	Video 5 Average	Video 6 Average
G1	0.699	0.686	0.668	0.650	0.652	0.634
G2	0.805	0.795	0.787	0.778	0.773	0.763
G3	0.679	0.664	0.676	0.661	0.671	0.655
G6	0.785	0.775	0.766	0.753	0.769	0.756
G7	0.741	0.728	0.729	0.715	0.741	0.729
G9	0.741	0.730	0.747	0.737	0.754	0.744
G14	0.701	0.689	0.701	0.689	0.679	0.666
G15	0.778	0.769	0.784	0.774	0.768	0.758
A2	0.406	0.387	0.401	0.421	0.408	0.385
A3	0.560	0.538	0.565	0.543	0.539	0.525
A4	0.514	0.498	0.519	0.497	0.488	0.467
A5	0.644	0.629	0.640	0.628	0.625	0.612
A8	0.489	0.463	0.467	0.444	0.441	0.417
A9	0.531	0.512	0.515	0.492	0.487	0.463
A10	0.519	0.498	0.493	0.477	0.492	0.477
A11	0.483	0.461	0.468	0.447	0.434	0.419

Table 16: Phase I intermediate ICC by rater, all jobs

Rater	All data	Strain	Flex/ext	Dev	elbow angle	Grip
G1	0.703	0.932	0.660	0.712	0.710	0.667
G2	0.760	0.898	0.679	0.786	0.897	0.599
G3	0.775	0.891	0.739	0.757	0.929	0.622
G6	0.808	0.971	0.596	0.816	0.964	0.913
G7	0.643	0.825	0.819	0.407	0.723	0.682
G9	0.839	0.774	0.725	0.858	0.908	0.855
G14	0.843	0.462	0.682	0.917	0.890	0.815
G15	0.771	0.500	0.464	0.842	0.865	0.859
A2	0.768	0.496	0.617	0.755	0.878	0.804
A3	0.719	0.655	0.620	0.814	0.806	0.472
A4	0.768	0.496	0.617	0.755	0.878	0.804
A5	0.765	0.351	0.757	0.748	0.933	0.566
A8	0.669	0.304	0.603	0.576	0.809	0.744
A9	0.778	0.454	0.605	0.819	0.919	0.725
A10	0.758	0.655	0.613	0.817	0.923	0.623
A11	0.571	0.873	0.314	0.427	0.800	0.848

agreement among Analysts supports the second hypothesis in comparison to the Novice group.

Phase II Raw Results

For Phase II Videos A, B, and C represent Videos 1, 4, and 6, from Phase I, respectively. These videos were chosen based on careful review of Phase I results and a consensus between those who participated in the creation of the Gold Standard. The reasons for selecting those videos for Phase II as previously discussed in Chapter 2 were in part to reduce the videos with obstructed views of the subject in order to better facilitate the analysis of the upper extremity.

Similar to the calculations done in Phase I, all results for Phase II were compared with the Gold Standard to produce the ICC values found in Tables 17 through 20. For the purpose of this study, Phase II results are primarily focused towards hypotheses 1 and 3, which are that the UEA is repeatable and reliable as measured by ICC values, and the increased training with the UEA program will produce more repeatable and reliable results. The primary reason for this is that the Novice group of raters did not participate in Phase II of the study, as discussed in Chapter 2.

The results in Table 17 reflect ICCs for the 5 Analysts chosen for Phase II. Based on the criteria established with hypothesis 1, Phase II raw results fully support that hypothesis by having all ICCs within the substantial to almost perfect categories of agreement.

Table 17: Phase II raw ICCs (Confidence Interval)

Raw ICCs	Video A	Video B	Video C
All w/Gold	0.926 (.915 - .936)	0.618 (.581 - .654)	0.927 (.917 - .936)

For Video A, the support for hypothesis 1 may only be true for the overall raw data ICC values and only 8 of the 23 individual elements of interest. This is because, as in Phase I, all videos for Phase II have reduced ICC values as the elements were separated into left and right components. However, the exception to this statement comes when the ICC values for individual elements are found to be near the top of the almost perfect category of agreement. This was the case in Video A for grip and efforts as well as the left components for each of the two elements both having ICC values of 0.909 and 0.937, respectively.

The overall results for Video B support the first hypothesis in that the ICC values are in the substantial to almost perfect levels of agreement. The ICC values, for Video B, do not maintain a consistent level of agreement for the individual elements of interest. ICC values for the individual elements of interest in Video B varied from 0.172 (slight agreement) to 0.859 (almost perfect), indicating sporadic agreement.

The opposite seems to be true for the results of Video C. ICCs values for Video C are consistently in the substantial to almost perfect range with only five ICC values dropping into the moderate category. This suggests that the results for Video C support hypothesis 1 of this study in that the UEA is repeatable and reliable based on the higher ICC values.

All three of the videos for Phase II exhibit variations in ICC values as the analyses narrow to the individual elements of interest and the left and right components. There does not appear to be a specific trend towards one element or the left and right side being better than the other, with the exception of wrist deviation, which was consistently lower than other elements. As shown in Table 18, ICC values fluctuate for both the left

Table 18: Video A Raw ICCs (Confidence Interval)

_Video/Job	Va		Vb		Vc	
Rater	All w/Gold	Average	All w/Gold	Average	All w/Gold	Average
Raw	0.926 (.915 - .936)	0.942	0.618 (.581 - .654)	0.663	0.927 (.917 - .936)	0.941
Borg	0.488 (.315 - .641)	0.568	0.311 (.140 - .487)	0.453	0.449 (.276 - .607)	0.586
efforts	0.937 (.911 - .958)	0.958	0.799 (.729 - .861)	0.867	0.794 (.722 - .856)	0.849
elbow posture	0.540 (.455 - .624)	0.608	0.509 (.417 - .600)	0.600	0.654 (.583 - .722)	0.673
grip	0.909 (.873 - .939)	0.943	0.331 (.219 - .461)	0.386	0.817 (.751 - .873)	0.870
Posture	0.729 (.680 - .770)	0.776	0.859 (.832 - .883)	0.896	0.798 (.762 - .831)	0.828
Speed	0.617 (.514 - .719)	0.677	0.390 (.154 - .594)	0.595	0.564 (.407 - .698)	0.504
Wrist Deviation	0.472 (.355 - .596)	0.622	0.219 (.126 - .338)	0.249	0.664 (.521 - .775)	0.576
Wrist Flexion	0.225 (.097 - .376)	0.202	0.672 (.545 - .777)	0.729	*	*
Wrist posture	0.372 (.265 - .480)	0.459	0.517 (.433 - .602)	0.570	0.489 (.395 - .582)	0.445
Left efforts	0.977 (.961 - .987)	0.986	0.704 (.575 - .821)	0.828	0.816 (.720 - .894)	0.873
Left Grip	0.977 (.963 - .988)	0.987	0.263 (.132 - .445)	0.360	0.818 (.723 - .895)	0.878
Left elbow posture	0.670 (.574 - .762)	0.677	0.501 (.372 - .629)	0.564	0.696 (.603 - .782)	0.724
Left speed	0.721 (.543 - .847)	0.758	0.268 (.076 - .493)	0.501	0.403 (.203 - .609)	0.346
Left wrist deviation	0.433 (.265 - .618)	0.617	0.239 (.094 - .432)	0.461	0.415 (.202 - .625)	0.349
Left wrist flexion	0.120 (.029 - .265)	-0.117	0.510 (.321 - .691)	0.582	*	*
Left wrist posture	0.491 (.352 - .625)	0.512	0.622 (.514 - .726)	0.640	0.429 (.289 - .570)	0.394
Right efforts	0.594 (.436 - .747)	0.741	0.843 (.758 - .911)	0.913	0.743 (.623 - .848)	0.806
Right elbow posture	0.525 (.387 - .655)	0.616	0.521 (.043 - .642)	0.650	0.621 (.518 - .721)	0.639
Right grip	0.330 (.185 - .517)	0.589	0.387 (.230 - .573)	0.419	0.800 (.699 - .884)	0.850
Right speed	0.134 (.024 - .299)	0.269	0.480 (.207 - .701)	0.675	0.709 (.537 - .837)	0.693
Right wrist deviation	*	*	0.172 (.061 - .340)	0.148	*	*
Right wrist flexion	*	*	0.811 (.693 - .896)	0.861	*	*
Right wrist posture	*	*	0.546 (.429 - .623)	0.620	*	*

* Indicates that ICCs could not be calculated due to zero variance in the data.

and right sides, leaving no conclusion as to whether raters are better at specific elements over others. This may suggest that the variation is task specific.

Phase II Intermediate Results

Similar to Phase I of the study, Phase II evaluated the intermediate results of the rates as compared with the Gold Standard. Tables 19 and 20 show the group result ICC values for the intermediate data. Table 19 represents all intermediate data for all jobs with the respective calculated ICC and 95% confidence interval. The average ICC for the raters of Phase II is also shown in Table 19.

Table 20 presents the ICCs for the group of raters for the individual components of interest. The strain category, as discussed earlier, does not represent the final output for predicting risk. As shown by Table 20, all ICCs for the Analysts fall within the substantial to almost perfect categories. Only the flexion /extension and grip columns had levels within the substantial category. This suggests a strong support for hypothesis 1 of the study and potentially additional support for hypothesis 3, hypothesis 1 being that the UEA is repeatable and reliable as represented by ICCs, with hypothesis 3 stating that the UEA method is more repeatable and reliable with increased experience.

The higher ICC values for Phase I are supportive of hypothesis 1. In support of hypothesis 3 of this study, each of the raters from Phase II had increased their experience with the UEA program between phases. This simply means that each rater used the program numerous times to analyze other videos, between the two phases of this study. Thus, the increased experience and higher ICC values provide support for the third hypothesis.

Table 19: Phase II intermediate results

Rater	All Videos / All data
All w/Gold	0.829 (.790 - .864)
Average	0.869

Table 20: Phase II intermediate results by element

Rater	All Videos / All data	~Strain~	Flex/ext	Deviation	Elbow angle	Grip
All w/Gold	0.829 (.790 - .864)	0.887 (.821 - .937)	0.767 (.667 - .856)	0.828 (.753 - .892)	0.906 (.830 - .958)	0.749 (.657 - .832)
Average	0.869	0.923	0.790	0.875	0.946	0.813

Individual Results

Tables 21 and 22 present the average and calculated ICCs for the individual raters, respectively. These results can be used to demonstrate support for the hypotheses of this study, by demonstrating high levels of agreement among the raters, as some agreement increasing between Phases I and II. The primary purpose of evaluating individual rater ICCs was to determine the rater's level of competency. The basis for competency score was established much like the basis for reliability in the first hypothesis of this study. A rater is considered more competent in utilizing the UEA if their calculated ICC, as compared with the Gold Standard, is greater than 0.60.

From the results in Table 21, each rater from Phase II could be considered competent with the use of the UEA program, if the results for Video C were the only results to be used. However, the only rater to produce consistently adequate competency scores for Phase II raw data was G8. Raters G6, G7 and G8 produced adequate competency scores for two of the three videos.

The intermediate results show higher competency scores overall for each of the individual raters. Perhaps the intermediate results are a better method of determining competency since the results are not based on line by line data.

Phase I and Phase II Comparison

In an effort to support the third hypothesis of this study, a brief comparison is shown between Phases I and II for both raw and intermediate ICC results. This hypothesis would be supported by ICC values increasing between the two respective phases. This would support the repeatability and reliability of the UEA as experienced increased.

Table 21: Phase II Raw ICCs by rater

Video/Job	Rater	Average ICC (all elements)
Va	G3	0.451
	G6	0.701
	G7	0.535
	G8	0.724
	G15	0.771
Vb	G3	0.419
	G6	0.600
	G7	0.619
	G8	0.736
	G15	0.587
Vc	G3	0.688
	G6	0.683
	G7	0.653
	G8	0.699
	G15	0.695

Table 22: Phase II intermediate ICCs by rater

Rater	All data	~Strain~	Flex/ext	Deviation	Elbow angle	Grip
G3	0.772	0.940	0.528	0.789	0.963	0.784
G6	0.910	0.979	0.821	0.921	0.978	0.784
G7	0.909	0.932	0.855	0.917	0.934	0.927
G9	0.920	0.905	0.870	0.896	0.959	0.934
G15	0.835	0.861	0.876	0.851	0.897	0.637
Average	0.869	0.923	0.790	0.875	0.946	0.813

Although Tables 23 and 24 represent small increases in ICC values, the increases shown are not statistically significant and the third hypothesis could not be supported by the current data set. Since agreement was already highly significant (high ICCs for all jobs), a very large sample size would be needed to demonstrate statistically significant increases. Since all of the raters for Phase II were taken from the original group of trained Analysts, the lack of marked improvement may suggest that a plateau had already been reached. The third hypothesis states that increased experience will increase the reliability and repeatability of the UEA method. It was already clear that the trained Analysts had more training and experience with the UEA than the Novices and the data from Phase I supports the idea that increased training can increase the reliability of the UEA method. However, Phase II results are inconclusive as to whether a greater amount of experience with the already trained Analysts will further increase the already high reliability of the UEA method, but it also does not appear to harm the performance as performance based on ICCs remained high.

Since hypothesis 3 is based on the idea that increased experience will increase the reliability as measured by ICCs, Figures 3 and 4 were created to show the comparison between ICCs and use of the UEA method. Figure 3 represents a comparison between the average ICC for the individual rater and the number of videos analyzed between Phases I and II.

Since Figure 3 represents both Phase I and Phase II ICC values, the graph suggests that the trained Analysts may have already reached the plateau in which ICC values may have stabilized. The average ICC value for both phases is 0.730 with a standard deviation of 0.058. Based on the results in Figure 3, all of the data points, for

Table 23: Raw ICC comparison for Phase I and II

Raw ICCs	Video A	Video B	Video C
Phase I Analysts w/Gold	0.939 (.931 - .947)	0.617 (.579 - .654)	0.888 (.874 - .901)
Phase II All w/Gold	0.926 (.915 - .936)	0.618 (.581 - .654)	0.927 (.917 - .936)

Table 24: Intermediate ICC comparison for Phase I and II

Intermediate ICCs	Video A	Video B	Video C
Phase I Intermediate ICC	0.835 (.771 - .891)	0.701 (.606 - .792)	0.796 (.722 - .863)
Phase II Intermediate ICC	0.853 (.791 - .905)	0.764 (.676 - .843)	0.862 (.803 - .911)

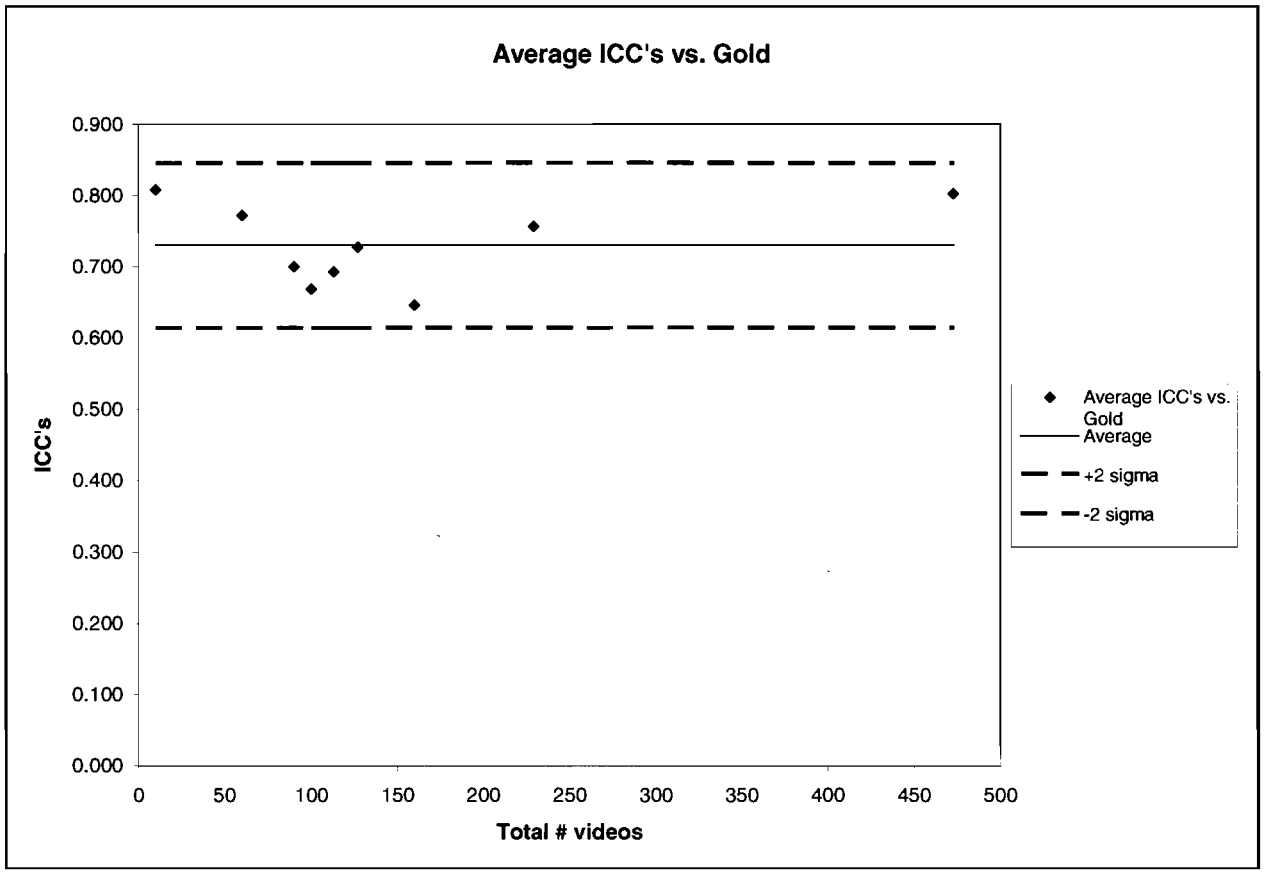

Figure 3: Average ICCs Pre/Post

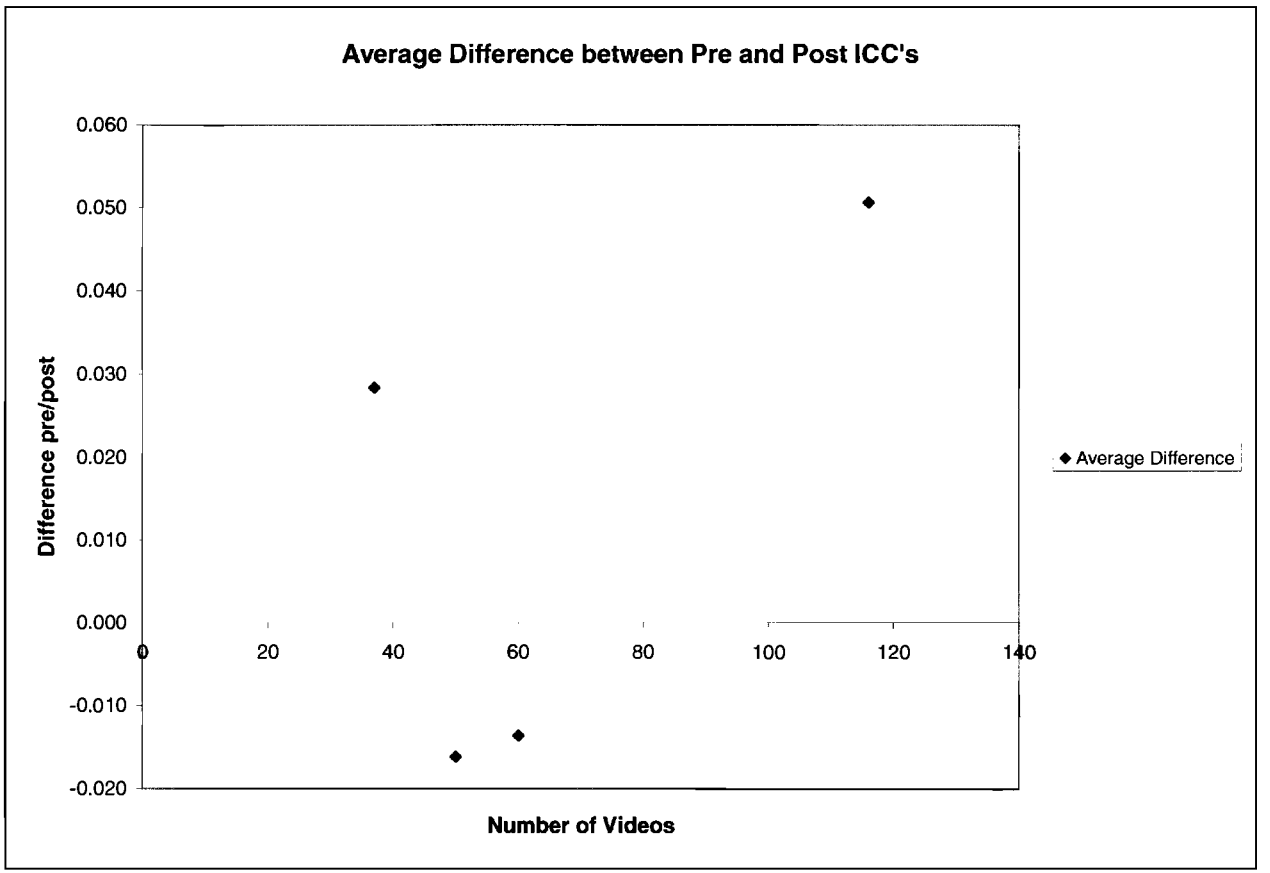

Figure 4: Average Difference between Pre and Post ICCs

both phases, fall within the ±2 σ limits for normal variation. In fact, there are an equal number of data points above and below the mean. This further suggests that the results for Phase II comparison may indicate that the Analysts had reached a point at which a marked increase would not occur. In other words, the Analysts had a stabilized method of analyzing in which relatively high and consistent ICC values would be produced.

Figure 4 evaluates the delta ICC for each rater from Phase I to Phase II with respect to the number of videos analyzed. The data represented in Figure 4 are minimal (n = 4) and do not suggest support for the third hypothesis of this study. Two ICC delta values above zero and two below zero support the idea that the Analysts already had reached a plateau in their agreement.

CHAPTER 4

DISCUSSION

General Discussion

Overall results for both phases demonstrate ICCs in which the first and second hypotheses for this study are supported. The majority of ICCs for individuals, jobs or videos as well as various individual elements of interest, have values within the substantial to almost perfect categories of agreement. Even though not all data supported the full range of first two hypotheses, the broad range of data tends to support the main idea behind each of these hypotheses. To restate, the first hypothesis explains that ICCs greater than 0.60 indicate repeatability and reliability of the UEA method. The second hypothesis states that when used by trained Analysts the UEA is more repeatable and reliable than when used by Novice raters.

The third hypothesis was not supported by the results of this study, stating that repeatability and reliability as measured by ICCs will increase with experience. The data representing the increased experience as compared to ICC values for both phases does not allow adequate justification to make a solid conclusion with regard to the third hypothesis.

In the evaluation of the raw data, a higher level of agreement is present in the higher level (aggregate of jobs) of data. This means that greater agreement is found for the overall data as compared to the individual elements. This held true for both the

trained Analysts and Novice groups of raters. The exception to this is found in the data for Videos 3 and 4. The overall raw data results for Video 3 are in the moderate category for both the Analysts and Novice groups. The results for Video 4 place the Analysts group in the substantial level of agreement, while the Novice group is in the moderate level of agreement. In general, evaluating data at the higher level the hypotheses of this study can be supported. This was not always the case when evaluating the individual elements of interest.

Evaluating data at a lower level, e.g., individual elements of interest, agreement among the groups demonstrate ICCs with a tendency to decrease indicating lower levels of agreement. This holds true for the majority of instances. However, it is not true all of the time. For example, several raw ICC values show high levels of agreement for elements such as efforts, grip and overall posture. On the opposite side of the spectrum, wrist deviation with the left and right components appears to be a common area of difficulty, producing consistently lower levels of agreement. This may indicate that wrist deviation is difficult for raters to evaluate using the UEA method or is inherently difficult to evaluate from video. It may also indicate that raters simply are not capable of reaching the level of resolution requested for the study. Finally, this may not be a reflection of the raters or UEA program, but potentially a result of the videos that were selected for this study.

Lower levels of agreement may be a result of several factors that were discovered during the research. First, it became apparent that the initial set of instructions labeled "Guidance" did not adequately define what constituted an effort. While the trained Analysts may have already had a substantial understanding as to what defined an effort,

the Novice group did not have adequate information to assist them in properly defining an effort during their analysis. This error may have lead raters to miss the observation in which the effort began and potentially miss the associated postures, as changes in posture will generally result in a new effort. An improved effort flow chart, with greater explanation, was provided for Phase II of the study. However, this may not have been reflected in Phase II results, since only Analysts participated in Phase II and they would have already had a significant understanding of how to define an effort. This may suggest the improved flow chart had little to no effect on the results for Phase II.

From the broad spectrum, Analysts who experienced increased use with the UEA demonstrate higher levels of agreement when compared to those raters with less experience. This idea lends partial support for hypothesis 3 of the study. The data from Phase II of the study did not provide adequate support for the third hypothesis. However, the results from Phase 1 may indicate that increased training and experience does increase the reliability of the UEA method, but more data would be needed to demonstrate any improvements in a statistically significant manner.

This partial support for the third hypothesis comes from the idea that all of the trained Analysts had some level of experience with the UEA, greater than that of the Novice, prior to performing their analysis on the six videos selected for this study. Additionally the Analysts were all participating in part of the larger study and continuing to analyze other videos during Phase I of this study. This provided the trained Analysts significantly more experience with the UEA over the Novice group, both from the beginning as well as during Phase I. As a result higher levels of agreement are shown in

the results. Therefore, the third hypothesis, greater experience results in increase reliability, may be partially supported from the results of Phase I of the study.

Phase I

For Phase I, not all ICC values met the level of agreement that was set as a goal at the start of this study. However, low levels of agreement within the groups do not represent poor or unusable data. In fact, the opposite is true of the lower calculated ICCs found in both raw and intermediate data.

The Gold Standard was designed to create a standard by which individual raters could be assessed on their competency with respect to the use of the UEA. Since all results or ICCs were computed with the Gold Standard in place ICCs may have been reduced to a more accurate level. This is demonstrated by the example of efforts for Video 4, Table 9. In Table 9, the Novice group average ICC was 0.512. However, when the ICC for the group, with the Gold Standard included, was calculated it resulted in a much lower value of 0.249. This decrease in ICC value demonstrated a move across levels of agreement from Moderate to Fair, respectively. The Gold Standard has a tendency to reduce the ability for incorrect ICCs to demonstrate false levels of higher agreement.

Beyond the idea that the Gold Standard can have a tendency to normalize ICC calculations, one possible reason for some of the lower ICCs at the individual elements of interest may be the videos selected. As discussed previously videos for Phase II of the study were selected partially based on the ability to more fully view the subject in the video. For all of the six videos used in Phase I, variations existed in the obstruction or obscurity of the subject and their relative postures. This obscurity may have presented

some ambiguity in the raw results, leading to lower levels of agreement. This low level of agreement would have translated to the intermediate results. Based on the choices made for Phase II, it became evident that several videos had better views than others with respect to the subject and their respective postures.

Not all camera angles or distances were the same for each of the six videos. Several videos had camera angles directly over the upper extremities for easy analysis, while other angles made it difficult to interpret adequate postures. The distance of the camera also played a key role in assessing upper extremity postures. The greater the distance between the subject and the camera the less clear the postures of both elbow and wrist became. Both of these issues may simply be caused by a lack of flexibility in the various occupational environments to obtain the most appropriate camera angle and distance. Physical limitations may have prevented the film crew from obtaining the ideal view of the subject.

For Phase I and II of this study, all raters were compared to the Gold Standard for their individual raw and intermediate results. A synopsis of the results for Phase I is presented in Tables 15 and 16 while similar results are presented in Tables 21 and 22 for Phase II. The comparison of the individual raters to the Gold Standard demonstrates adequate competency scores for raters in both phases. However, Novice raters from Phase I had lower than adequate competency scores (e.g.,, less than 0.60) for the raw data with the majority of the scored falling within the fair to moderate levels of agreement. The competency scores for the Novice group appears to increase slightly when comparing the raw to intermediate data.

As Phase I of the study completed, it became apparent that several errors had the potential to create negative issues with the results. As data were received from the various raters, it was discovered that there existed a defect in the naming scheme of the videos and the order in which to view them. Figure 5 gives an example of how the initial naming scheme was structured and presented to each of the raters. The purpose of the instructions was to have the rater rate each "video" in the order listed. For example, rater 1 should have viewed Video 2 first, Video 6 second and so on until all six videos were analyzed. Raters were instructed to save the file such that it indicated the particular "video" reviewed. However, it is apparent that some raters may have become confused with the numbering and naming scheme and may have viewed Video 3, sixth and Video 6, fifth (rater 2, Figure 5).

This potential error was be avoided by a careful review of each individual rater's results for each of the videos. Errors in their naming scheme were corrected quickly such that the calculated ICCs would not be poorly represented.

Phase II

In an effort to prevent the naming scheme issues found in Phase I, the second phase implemented an alpha numeric naming scheme to ensure raters were clear as to which video should be viewed and in what order. This also helped in the naming of the .CSV files such that it was clear as to which file represented the results for the respective video.

Similar to the results in Phase I, Phase II results produced viable support for the hypotheses stated for this study. Hypothesis 1 states that the UEA is repeatable and reliable as measured by ICCs. Hypothesis 2 states that the UEA is more repeatable and

Student	IRR Analyst Number	Video 1	Video 2	Video 3	Video 4	Video 5	Video 6
Rater 1	R1	4	1	3	5	6	2
Rater 2	R2	2	1	4	5	6	3
Rater 3	R3	6	1	2	5	4	3
Rater 4	R4	1	6	2	4	3	5
Rater 5	R5	4	3	2	5	6	1
Rater 6	R6	3	2	6	1	4	5

Figure 5: Sample of Phase I Video layout

reliable when used by trained Analysts versus Novice raters. The third hypothesis states that repeatability and reliability will increase with increased training. This can be seen from the levels of agreement, as measured by ICCs, ranging from 0.618 to 0.927 for overall raw data. Phase II also suffered similar downturns in ICC values when individual elements of interest and their left and right components were reviewed. This result was to be expected since both raters and videos from Phase I to Phase II only experience slight differences. The videos themselves were not modified only the naming scheme and the number of videos used in Phase II.

As with Phase I, Phase II experienced similar issues with decreasing ICC values as individual elements of interest were reviewed. Likewise, the cause of this may be attributed to the issues with the camera. Although Phase II made an effort to reduce the confusion for the ratings of posture and other elements of interests, the results stand to show that this may not have been completely effective. Again limitations in positioning the camera may have resulted in the lower levels of agreement found when evaluating individual elements of interest.

In addition to the raw and intermediate outputs for all raters, the individual competency scores for Phase II are presented in Tables 21 and 22. It was to be expected that competency scores for Phase II would be considered adequate. However, not all raters produced exceptional competency scores consistently. It is unclear what caused the inconsistent scores. It may be attributable to increased complacency with the UEA tool. Webster's [13] defines complacency as "self-satisfaction accompanied by unawareness of actual dangers or deficiencies." It is entirely possible that with increased use or experience with the UEA, an individual rater may experience some complacency

in their analysis. This may cause the rater to begin relying on self taught principles and develop a sense of pride in their own knowledge. The results of such an approach can often lead to mistakes in analysis. Selecting the incorrect posture or grip or speed may result in inaccurate results and ultimately incorrect projections of risk.

Phase I and II Comparison

It was important to compare the results for the raters between the two phases to help provide additional support, if possible, for the third hypothesis. All of the raters in Phase II were taken from the original group of Analysts, all of whom were actively utilizing the UEA program to further support the larger study. Each of the Analysts had viewed anywhere from 10 to 182 videos prior to beginning Phase I of this study. By the time data were collected from Phase II, those numbers had increased from 60 to nearly 500 between the raters. These data represent a vast range of experience with the UEA program.

Overall the data represented in Figures 3 and 4 give relatively inconclusive results with regard to support for the third hypothesis. The data do potentially suggest that the raters from Phase II, all Analysts, had already reached a plateau in which normal variation would occur. There did not appear to be any apparent shift in the data nor a distinctive trend towards increasing ICC values. Therefore, the data were not able to support the third hypothesis in that increased experience would increase the reliability of the UEA method.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Ultimately, the UEA can be said to be a repeatable and reliable method when used to evaluate the development of occupational risk factors. While this study did not evaluate the final outputs of the UEA, as those have yet to be determined, the results from both Phases I and II of this particular study have provided adequate support for the first and second hypotheses stated in Chapter 2. First, the UEA is repeatable and reliable as measured by ICCs, and ICC value greater than 0.60 providing support for this hypothesis. The second hypothesis states that the UEA method is more reliable when used by trained Analysts than when used by Novices.

The third hypothesis for this study states that increased experience with the UEA will increase the reliability of the UEA method as measured by ICC values. This hypothesis, however, was not supported from the results of the study. However, the results did suggest that the trained Analysts used for the study may have already reached a high steady state performance level.

Based on the calculated ICCs, the trained Analysts group consistently outperformed the Novice group when comparing raw and intermediate outputs for both the groups as well as the individual raters. This is not, however, stating that the Novice group was incapable of producing adequate results. The ability of the Novice group to

produce ICCs in the substantial to almost perfect categories of agreement provided additional overall support for the first hypothesis, in that the UEA is a repeatable and reliable tool as measured by calculated ICCs.

The ultimate goal of producing a repeatable and reliable method of assessing risk is well underway with the continuing development and research with respect to the UEA.

Recommendations

Throughout this study various questions were answered and other new questions formulated. The results of both phases make it vastly apparent that ICCs decreased as the level of analysis narrowed (from overall job down to the individual elements of interest and their left and right components). While this was not always the case, it seemed to hold true for the majority of the results. Several causes may have been attributed to these results, one being the effect of the camera position. Further research should evaluate the effects of camera position with respect to the ICCs calculated for the individual elements of interests. This may provide insight as to how to better increase the overall reliability of the UEA method in evaluating all elements and not just overall data.

In addition to reviewing the effect of camera positioning and the UEA outputs, future research should evaluate the general strengths and weakness of the program and Analysts. It may be possible that when evaluating the individual left and right components, raters may not have clear instruction as to how to adequately evaluate those components. On the other hand, future research may demonstrate a need for continuous improvement with the UEA program itself. Future research should also evaluate the effects of predicting risk by comparing UEA outputs to actual injury data.

As future research develops the final output results for the UEA, researchers should consider the overall effects that individual components have on risk prediction. If research demonstrates the usefulness of individual components, then that would suggest the need to maintain their functions within the program. Conversely, research may show that modifications to the software are necessary.

Initially, this study did not plan to evaluate the ICCs for efforts for the raw data because the raw data outputs did not present the efforts in a usable format. A simple modification to the results allowed the efforts to be defined in a numerical format that could be used. However, efforts were only defined as a "1" for effort or new effort and a "0" for idle. As these data were input to the statistical software package (SPSS 16.0.1), it became apparent that errors were introduced into the ICC calculations. Additionally, the labeling of efforts did not actually capture the entire range of efforts for the task. Future researchers may wish to develop an appropriate labeling scheme to fully capture efforts in the raw data and allow the SPSS program to adequately calculate ICCs for that task parameter.

The Gold Standard for this study was based on a consensus between three different Analysts and attempted to obtain the most accurate set of results for the videos used in this study. While it provided valuable insight and assistance to developing competency of raters and supporting the hypothesis of this study, the Gold Standard could be improved upon through future research. The development of a greater standard could be done in a laboratory study in which a person is videotaped performing a task and the actual postures, forces and other elements of interest are measured using a multi-camera motion capture system for improved accuracy. From there, researchers would

have more precise values as to what the results should be for the various elements of interest. These data could then be used as a "true" comparison for all future raters. This greater standard would allow for true competency of raters to be determined and provide additional information for how the competency of Novice raters increases with experience.

Phase II of this study was limited in the number of raters available for the research. Their results, although valuable to the study, proved to be inconclusive and unable to support the third hypothesis. Since only the trained Analysts were used for the second phase, and not the Novice group, it is unclear how training and experience truly effect the reliability of the UEA method, since the results showed no significant increases in ICC values between Phases 1 and 2. However, future research should explore the true effects of training and experience on the output of the results.

This could be done by maintaining a Novice group through both phases. This would have to be done in a shorter period of time, one semester, if the Novice group were to be pulled from a similar group of students. The Novice group would be able to represent a control group since it would be known that they would not have any experience with the UEA program prior to the first phase and their exposure to the UEA program, prior to Phase II, would also be limited and somewhat controlled. A more detailed graph similar to Figures 3 and 4 could then be used to show the true effects of training and experience on the outputs of the UEA.

In addition to creating a control group for both phases, the trained Analysts could be evaluated multiple times over a longer period of time. This would help to provide additional data points to compare their calculated ICCs and the number of videos

analyzed with the UEA. This type of additional research would provide critical information and insight into whether or not experience generates a true shift in the data or whether or not the increases and decreases in ICCs are just part of normal variation in a set of data.

Extended reliability research could also provide insight into the development of a plateau with regard to ICC values and agreement. A plateau would indicate that increased experience and training have a breaking point at which the individual rater no longer increases their agreement with the Gold Standard. As with any set of data, improved processes would help to tighten the analysis set of data and therefore increase the capability of a process to produce repeatable and reliable results. If the UEA were to be treated as a process of improvement, then extended research could fully evaluate the idea that a plateau truly exists and that the tool could become more reliable over time through improved usability.

Ultimately the goal of the larger UEA study is to produce final outputs that are capable of predicting risk in the occupational setting. As future research develops these outputs, an additional study could be done to compare the final outputs to the intermediate and raw outputs of the UEA method. Final outputs could also be used in similar reliability studies and subsequently compared to previous studies. This comparison could provide additional support for all reliability studies done with respect to the UEA method by demonstrating consistent repeatable results for raw, intermediate and final outputs.

Final output comparison can be used to help increase the usability of the program. Increasing the usability of the UEA program may allow it to be used by nonexperienced

raters in evaluating risk for their own occupational setting. This could then produce a product that was marketable to many employers. Such a program would allow them to assess the risks of jobs and tasks at their various occupational settings. Thus an invaluable method of evaluating risk would then be available to help modify work environments such that ergonomic risk factors could be reduced and potentially eliminated.

APPENDIX A

VIDEO INSTRUCTIONS AND DESCRIPTION

You must complete IRB and HIPPA training prior to beginning this assignment!

Videos should be analyzed in the order
shown
Videos should be analyzed from start to finish (with long pauses)
Videos are 10 seconds in duration
Each video should be reviewed for at least 6 cycles prior to analysis (1 min)
You are encouraged to use preview features whenever necessary
For each video enter the following:

- Subject ID as IRR Analyst number (e.g.,, "G3")
- Position as video number
- Job as video number
- Element as video number
- Each video should be watched at a frame rate of "10"

Each analyzed video should be saved as:

- "Your Analyst Number" - "video number" - ".csv"
  (e.g.,," G3-
  4.csv")
- ".csv" is very important, it tells the program to properly save the data

Completed videos should be emailed directly to Bryan Adams
at:

- adamsbryan10@comcast.net

If you have any questions about the program or assignment:
You can call Rich (718-4863 cell, 587-9643 office) or Bryan Adams (631-3268 cell)

Figure 6: Instructions on analyzing videos

Brief description of the video segments:

Video 1: Production worker placing a protective covering over a needle type device.

Video 2: Production worker utilizing a press to assemble medical supply equipment.

Video 3: Production worker filing the sharp metal edges of an aluminum item.

Video 4: Production worker cutting the ends of an aluminum rod.

Video 5: Garage door assembly worker inserting foam insulation into a door panel.

Video 6: Assembly worker pressing two parts together with a hand operated press.

Guidance Information

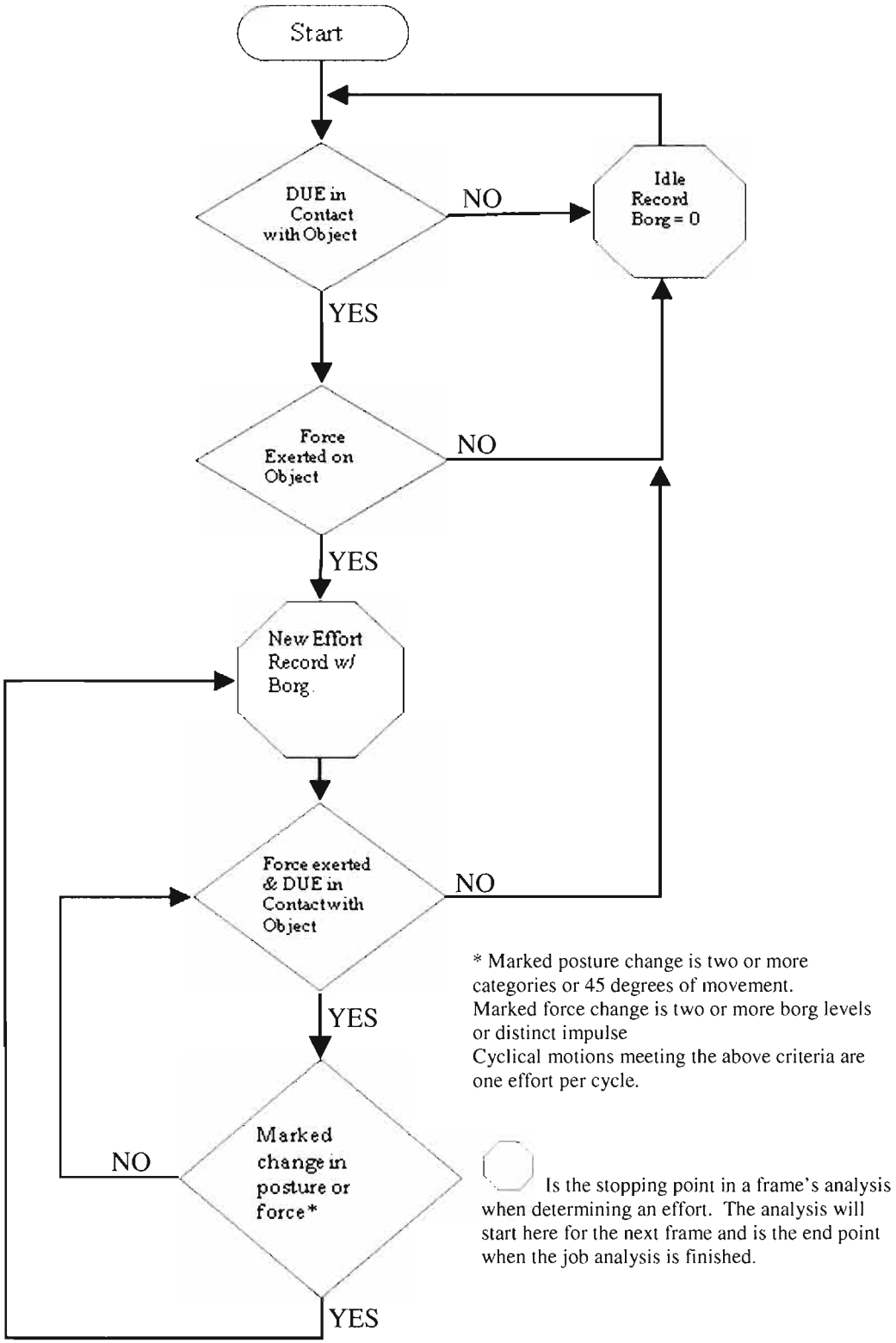

Figure 7: Effort flow chart from phase II

Speed

Speed is a function of DUE movement (e.g., changes from one posture to another or one grip type to another) and changes in the direction of forces transmitted through the DUE (e.g., a rapid circular motion of the hand with the wrist relatively static would still indicate a high speed of work for the DUE since force direction is continuously changing). Speed is dictated by the motion or force generation/reaction of the DUE. It is possible to have very high speed (5) with long pauses in between efforts. Guidance on multiple efforts/actions is provided for clarification when multiple efforts of a given sub-task are performed.

1

very slow motion of the fingers and wrist
very relaxed pace
multiple efforts or actions are infrequent and spaced

2

slow motion of the fingers and wrist
motion at a comfortable pace
multiple efforts or actions are punctuated with frequent and consistent pauses or breaks in activity

3

"normal" speed of motion
the "average industrial worker" could easily maintain this pace
sustainable work pace
multiple efforts or actions involve steady motion with possible brief pauses

4

rapid, deliberate motion
demanding work pace
multiple efforts or actions are steady with little opportunity for rest
the worker is rushed due to speed of work (not intensity or "skill" limited) (but worker is able to keep up)
little time for discretionary work

5

very rapid, deliberate motions
exhausting work pace
worker near their maximum speed
multiple efforts or actions are steady with nearly continuous use of the fingers and wrist
difficulty keeping up (barely or unable) due to speed of work (not intensity or "skill" limited)
no time for discretionary work
very little rest time or pauses in activity

Figure 8: Speed definition

Borg Scale

Borg CR-10

0	Nothing at All
0.5	Very, Very Light
1	Very Light
2	Light
3	Moderate
4	Somewhat Hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

Figure 9: Borg Scale

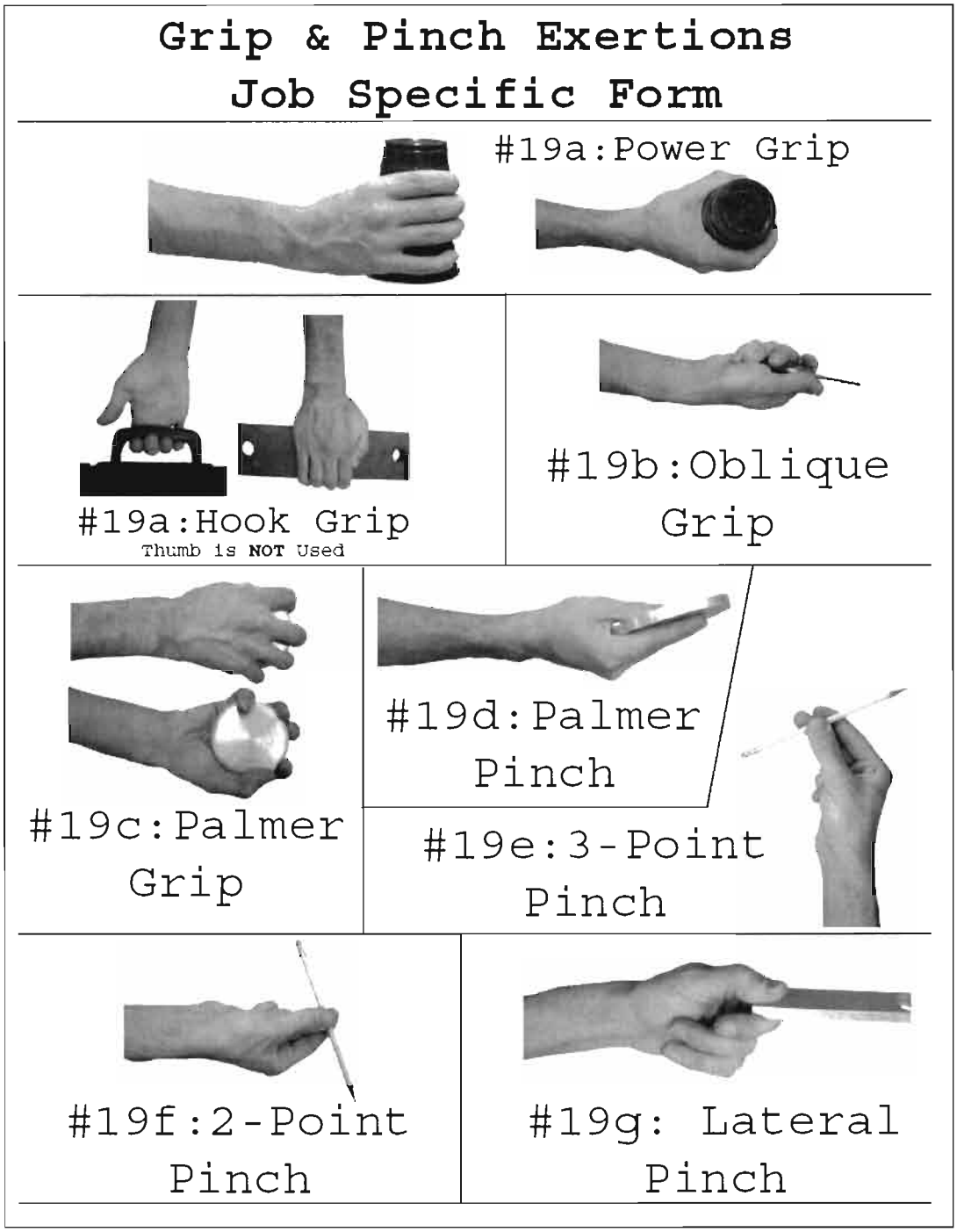

Figure 10: Various grip postures

APPENDIX B

PHASE I RESULTS

Table 25: Video 1 Raw ICCs by rater

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
1	A2	0.812	0.098	-0.015	0.690	0.896	0.698	0.514	0.164	0.368	0.407
	A3	0.878	0.138	0.897	0.607	0.741	0.763	0.692	ZV*	ZV*	ZV*
	A4	0.815	0.092	0.947	0.690	0.896	0.698	0.514	0.153	0.368	0.407
	A5	0.947	0.402	0.897	0.683	0.897	0.914	0.412	0.691	0.836	0.856
	A8	0.903	0.396	0.830	0.500	0.830	0.760	-0.080	0.487	ZV*	0.212
	A9	0.923	0.454	1.000	0.582	1.000	0.728	0.337	0.384	-0.175	-0.074
	A10	0.903	0.593	0.781	0.200	0.766	0.711	0.360	0.609	ZV*	0.461
	A11	0.845	0.352	0.830	0.657	0.695	0.551	0.276	ZV*	0.151	0.252
	G1	0.94	1.000	1.000	0.602	0.984	0.793	ZV*	0.764	-0.086	0.425
	G2	0.973	0.947	0.947	0.871	0.947	0.933	0.727	0.535	0.902	0.833
	G3	0.946	0.446	0.947	0.495	0.947	0.853	0.475	0.556	0.854	0.786
	G6	0.966	0.952	1.000	0.466	1.000	0.797	0.791	0.898	ZV*	0.470
	G7	0.945	0.722	0.947	0.290	0.947	0.835	0.415	0.458	0.902	0.643
	G9	0.961	0.408	0.947	0.394	0.947	0.860	0.894	0.164	0.902	0.763
	G14	0.961	0.443	0.950	0.886	0.950	0.869	0.786	0.795	0.062	0.499
	G15	0.959	0.449	1.000	0.911	0.972	0.878	0.791	0.744	0.343	0.620

Table 26: Video 2 raw ICCs by rater

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
2	A2	0.926	0.573	0.573	0.619	0.766	0.911	0.061	0.334	0.580	0.832
	A3	0.928	0.263	0.900	0.595	0.882	0.785	0.900	0.526	ZV*	0.260
	A4	0.924	0.521	0.573	0.619	0.766	0.911	0.061	0.334	0.580	0.832
	A5	0.938	0.803	0.803	0.548	0.843	0.857	0.342	0.777	0.086	0.676
	A8	0.889	0.866	0.866	ZV*	0.877	0.612	ZV*	ZV*	ZV*	ZV*
	A9	0.933	0.580	0.866	0.454	0.863	0.762	0.543	0.670	ZV*	0.330
	A10	0.863	0.441	0.441	0.768	0.417	0.808	0.007	ZV*	ZV*	ZV*
	A11	0.915	0.461	0.864	0.755	0.887	0.765	0.180	0.021	ZV*	0.359
	G1	0.955	0.898	0.898	0.702	0.911	0.922	ZV*	0.585	0.087	0.826
	G2	0.806	0.017	0.017	0.303	-0.010	0.796	-0.048	0.711	-0.020	0.647
	G3	0.912	0.804	0.804	0.722	0.827	0.814	ZV*	0.624	ZV*	0.307
	G6	0.960	0.933	0.933	0.528	0.931	0.788	0.933	0.716	ZV*	0.351
	G7	0.907	0.933	0.933	0.627	0.916	0.761	ZV*	ZV*	0.074	-0.311
	G9	0.945	0.620	0.901	0.547	0.913	0.757	0.792	ZV*	ZV*	ZV*
	G14	0.95	0.612	0.869	0.688	0.894	0.790	0.869	ZV*	ZV*	ZV*
	G15	0.942	0.901	0.901	0.769	0.928	0.897	0.131	ZV*	0.127	0.662

Table 27: Video 3 raw ICCs by rater

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
3	A2	0.563	0.206	0.491	0.789	0.300	0.858	0.415	0.377	0.492	0.584
	A3	0.737	0.451	0.379	0.092	0.898	0.756	0.000	ZV*	ZV*	ZV*
	A4	0.603	0.212	0.491	0.789	0.300	0.858	0.415	0.377	0.492	0.584
	A5	0.422	0.306	0.574	0.720	0.330	0.705	0.192	0.030	-0.143	0.103
	A8	0.793	0.682	0.491	ZV*	0.911	0.748	0.357	ZV*	ZV*	ZV*
	A9	0.860	0.645	0.491	0.112	0.988	0.748	0.504	ZV*	ZV*	ZV*
	A10	0.633	0.381	ZV*	0.111	0.555	0.751	0.422	ZV*	ZV*	ZV*
	A11	0.674	ZV*	ZV*	0.569	0.961	0.691	ZV*	-0.030	ZV*	0.037
	G1	0.414	-0.054	0.491	0.372	0.280	0.635	0.076	-0.023	0.285	0.429
	G2	0.709	0.024	0.379	0.633	0.794	0.754	0.000	ZV*	-0.727	-0.194
	G3	0.544	0.512	0.574	0.910	0.325	0.925	0.522	0.087	0.762	0.702
	G6	0.840	0.773	0.379	0.676	0.970	0.697	0.000	-0.136	ZV*	0.140
	G7	0.596	0.106	0.491	0.580	0.643	0.709	0.397	-0.171	0.666	0.374
	G9	0.840	0.712	0.653	0.723	0.890	0.924	0.446	ZV*	0.737	0.748
	G14	0.885	0.100	0.794	0.790	0.991	0.886	0.765	0.388	0.383	0.478
	G15	0.820	0.772	0.302	0.667	0.978	0.770	0.369	-0.132	0.083	0.370

Table 28: Video 4 raw ICCs by rater

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
4	A2	0.542	0.040	0.705	0.691	0.606	0.800	0.085	0.096	0.114	0.376
	A3	0.789	0.480	0.785	0.388	0.767	0.789	0.785	ZV*	ZV*	ZV*
	A4	0.542	0.040	0.705	0.691	0.606	0.800	0.085	0.096	0.114	0.376
	A5	0.510	0.223	0.086	0.211	0.250	0.812	0.039	0.306	0.456	0.551
	A8	0.431	-0.222	0.151	ZV*	0.034	0.621	0.550	ZV*	ZV*	ZV*
	A9	0.708	0.569	0.253	0.585	0.636	0.796	-0.093	-0.023	0.083	0.142
	A10	0.286	0.316	0.705	0.118	-0.275	0.660	0.395	ZV*	ZV*	ZV*
	A11	0.659	0.113	0.735	0.702	0.587	0.593	0.306	0.025	-0.150	-0.042
	G1	0.758	0.441	0.851	0.506	0.650	0.873	0.116	0.100	0.431	0.595
	G2	0.728	0.375	0.882	0.728	0.561	0.912	0.479	0.057	0.605	0.503
	G3	0.415	0.199	0.705	0.000	-0.022	0.531	ZV*	0.478	0.378	0.534
	G6	0.456	0.209	0.882	0.816	-0.110	0.940	0.882	ZV*	0.707	0.729
	G7	0.784	0.919	1.000	0.757	0.610	0.920	ZV*	0.000	0.313	0.556
	G9	0.846	0.560	0.415	0.587	0.837	0.873	0.393	0.663	-0.047	0.359
	G14	0.834	0.213	0.882	0.578	0.743	0.928	0.882	ZV*	0.758	0.793
	G15	0.706	-0.423	1.000	0.755	0.489	0.924	0.851	0.022	0.494	0.676

Table 29: Video 5 raw ICCs by rater

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
5	A2	0.526	0.212	0.572	0.500	0.386	0.568	0.144	0.044	-0.049	-0.034
	A3	0.816	0.497	0.576	0.457	0.537	0.730	0.273	ZV*	ZV*	ZV*
	A4	0.530	0.174	0.572	0.500	0.386	0.568	0.144	0.044	-0.049	-0.034
	A5	0.675	0.452	0.437	0.552	0.310	0.750	0.461	0.009	-0.132	0.000
	A8	0.801	0.631	0.576	0.031	0.462	0.653	0.297	ZV*	ZV*	ZV*
	A9	0.727	0.655	0.287	0.521	0.351	0.658	0.577	ZV*	-0.058	0.000
	A10	0.682	0.247	0.393	0.378	0.462	0.661	0.014	-0.555	ZV*	-0.383
	A11	0.550	0.122	0.504	0.507	0.420	0.485	0.071	0.113	-0.348	0.023
	G1	0.669	0.432	0.696	0.596	0.395	0.768	0.065	0.203	-0.255	0.155
	G2	0.771	0.351	0.354	0.540	0.481	0.719	0.234	0.188	-0.033	0.174
	G3	0.643	0.357	0.711	0.757	0.386	0.756	0.130	0.075	-0.129	0.000
	G6	0.923	0.829	0.955	0.787	0.898	0.778	0.517	-0.073	0.119	0.000
	G7	0.762	0.525	0.504	0.633	0.574	0.635	0.040	-0.280	-0.079	-0.208
	G9	0.887	0.528	0.832	0.480	0.874	0.754	0.593	0.350	0.213	0.294
	G14	0.868	0.364	0.748	0.583	0.695	0.769	0.476	0.080	0.018	0.059
	G15	0.805	0.148	0.408	0.665	0.510	0.740	0.138	0.141	-0.323	-0.135

Table 30: Video 6 raw ICCs by rater

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
6	A2	0.902	0.523	0.932	0.486	0.858	0.627	0.335	0.232	*	0.163
	A3	0.909	0.422	0.899	0.000	0.867	0.721	0.173	0.556	*	0.641
	A4	0.898	0.468	0.932	0.486	0.858	0.627	0.335	0.232	*	0.163
	A5	0.870	0.545	0.530	0.683	0.404	0.855	0.119	0.513	*	0.525
	A8	0.840	0.422	0.653	0.249	0.573	0.737	0.103	0.556	*	0.502
	A9	0.903	0.482	0.611	0.396	0.660	0.819	0.361	ZV*	*	ZV*
	A10	0.914	0.494	0.735	0.599	0.653	0.824	-0.092	0.456	*	0.483
	A11	0.805	0.158	0.408	0.345	0.759	0.590	0.033	0.341	*	0.276
	G1	0.901	0.635	0.897	0.377	0.867	0.792	ZV*	0.530	*	0.500
	G2	0.779	0.164	0.349	0.482	0.056	0.830	0.069	0.540	*	0.610
	G3	0.915	0.749	0.865	0.605	0.882	0.823	0.006	0.601	*	0.622
	G6	0.941	0.835	0.966	0.720	0.795	0.918	0.411	0.777	*	0.809
	G7	0.933	0.674	0.966	0.496	0.974	0.694	0.456	-0.044	*	-0.215
	G9	0.946	0.474	0.899	0.603	0.917	0.857	0.550	0.087	*	0.148
	G14	0.946	0.798	0.932	0.658	0.897	0.882	0.398	0.699	*	0.625
	G15	0.918	0.498	0.606	0.742	0.836	0.853	0.203	0.654	*	0.399

Table 31: Video 1 Intermediate group ICCs

Video 1 Intermediate ICCs	All data	Strain	Flex/Ext	Dev	Elbow Angle	Grip
All/Gold	0.775 (.700 - .846)	0.763 (.589 - .917)	0.574 (.381 - .803)	0.626 (.451 - .819)	1	0.910 (.842 - .961)
Analyst/Gold	0.835 (.771 - .891)	0.866 (.735 - .957)	0.641 (.434 - .847)	0.730 (.560 - .881)	1	0.997 (.994 - .999)
Novice/Gold	0.742 (.655 - .824)	0.697 (.487 - .890)	0.612 (.402 - .831)	0.539 (.340 - .768)	1	0.832 (.713 - .925)

Table 32: Video 2 Intermediate group ICCs

Video 2 Intermediate ICCs	All data	Strain	Flex/Ext	Dev	Elbow Angle	Grip
All/Gold	0.692 (.602 - .782)	0.831 (.688 - .943)	0.485 (.297 - .742)	0.599 (.422 - .801)	0.975 (.928 - .997)	0.846 (.712 - .931)
Analyst/Gold	0.682 (.585 - .778)	0.916 (.825 - .974)	0.361 (.166 - .657)	0.640 (.449 - .832)	0.966 (.899 - .996)	0.895 (.812 - .955)
Novice/Gold	0.687 (.590 - .782)	0.751 (.558 - .914)	0.496 (.283 - .759)	0.588 (.391 - .800)	0.963 (.898 - .994)	0.820 (.696 - .919)

Table 33: Video 3 Intermediate group ICCs

Video 3 Intermediate ICCs	All data	Strain	Flex/Ext	Dev	Elbow Angle	Grip
All/Gold	0.646 (.551 - .745)	0.538 (.333 - .803)	0.570 (.378 - .800)	0.729 (.566 - .883)	0.871 (.708 - .976)	0.426 (.267 - .654)
Analyst/Gold	0.592 (.485 - .705)	0.687 (.475 - .886)	0.450 (.241 - .727)	0.807 (.661 - .922)	0.748 (.483 - .950)	0.366 (.193 - .614)
Novice/Gold	0.757 (.673 - .834)	0.393 (.184 - .711)	0.802 (.646 - .925)	0.747 (.582 - .890)	0.999 (.998 - 1.00)	0.487 (.301 - .715)

Table 34: Video 4 Intermediate group ICCs

Video 4 Intermediate ICCs	All data	Strain	Flex/Ext	Dev	Elbow Angle	Grip
All/Gold	0.578 (.478 - .688)	0.771 (.580 - .935)	0.479 (.291 - .737)	0.644 (.470 - .829)	0.659 (.398 - .924)	0.345 (.200 - .578)
Analyst/Gold	0.701 (.606 - .792)	0.904 (.802 - .970)	0.568 (.355 - .806	0.795 (.649 - .914)	0.750 (.485 - .950)	0.387 (.211 - .634)
Novice/Gold	0.536 (.425 - 657)	0.637 (.391 - .886)	0.583 (.370 - .814)	0.522 (.323 - .757)	0.580 (.280 - .902)	0.360 (.188 - .609)

Table 35: Video 5 Intermediate group ICCs

Video 5 Intermediate ICCs	All data	Strain	Flex/Ext	Dev	Elbow Angle	Grip
All/Gold	0.620 (.522 - .724)	0.749 (.570 - .911)	0.712 (.537 - .881)	0.641 (.466 - .828)	0.447 (.198 - .842)	0.518 (.349 - .730)
Analyst/Gold	0.709 (.616 - .799)	0.815 (.652 - .939)	0.901 (.807 - .964)	0.666 (.480 -.847)	0.514 (.217 - .878)	0.584 (.399 - .784)
Novice/Gold	0.524 (.410 - .648)	0.653 (.429 - .871)	0.515 (.294 - .774)	0.595 (.393 - .806)	0.363 (.015 - .812)	0.460 (.269 - .697)

Table 36: Video 6 Intermediate group ICCs

Video 6 Intermediate ICCs	All data	Strain	Flex/Ext	Dev	Elbow Angle	Grip
All/Gold	0.729 (.645 - .811)	0.803 (.647 - .933)	0.854 (.737 - .945)	0.604 (.427 - .805)	0.873 (.712 - .977)	0.558 (.086 - .822)
Analyst/Gold	0.796 (.722 - .863)	0.912 (.817 - .973)	0.916 (.834 - .970)	0.664 (.477 - .846)	0.920 (.795 - .986)	0.664 (.489 - .834)
Novice/Gold	0.698 (.603 - .790)	0.725 (.523 - .903)	0.832 (.691 - .937)	0.575 (.377 - .792)	0.826 (.608 - .968)	0.562 (.376 - .769)

Table 37: Intermediate ICCs all videos

Rater	Posture (all)	Strain	Flex/ext	Dev	elbow angle	Grip
Exp/Gold	0.713 (.675 - .749)	0.775 (.704 -.841)	0.629 (.543 - .716)	0.693 (.621 - .764)	0.826 (.748 - .893)	0.664 (.593 - .734)
G1	0.703	0.932	0.660	0.712	0.710	0.667
G2	0.760	0.898	0.679	0.786	0.897	0.599
G3	0.775	0.891	0.739	0.757	0.929	0.622
G6	0.808	0.971	0.596	0.816	0.964	0.913
G7	0.643	0.825	0.819	0.407	0.723	0.682
G9	0.839	0.774	0.725	0.858	0.908	0.855
G14	0.843	0.462	0.682	0.917	0.890	0.815
G15	0.771	0.500	0.464	0.842	0.865	0.859
Nov/Gold	0.686 (.642 - .728)	0.570 (.461 - .687)	0.650 (.559 - .742)	0.585 (.495 - .679)	0.904 (.851 - .946)	0.607 (.524 - .692)
a2	0.768	0.496	0.617	0.755	0.878	0.804
A3	0.719	0.655	0.620	0.814	0.806	0.472
a4	0.768	0.496	0.617	0.755	0.878	0.804
A5	0.765	0.351	0.757	0.748	0.933	0.566
A8	0.669	0.304	0.603	0.576	0.809	0.744
a9	0.778	0.454	0.605	0.819	0.919	0.725
A10	0.758	0.655	0.613	0.817	0.923	0.623
a11	0.571	0.873	0.314	0.427	0.800	0.848
All/Gold	0.682 (.641 - .723)	0.658 (.564 - .755)	0.583 (.493 - .680)	0.621 (.540 - .707)	0.891 (.835 - .937)	0.623 (.548 - .703)

Table 38: Video 1 Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
	G1	0.94	1.000	1.000	0.602	0.984	0.793	ZV*	0.764	-0.086	0.425	0.887	0.886	0.496	0.986	0.999	0.992
	G2	0.973	0.947	0.947	0.871	0.947	0.933	0.727	0.535	0.902	0.833	0.962	0.877	0.994	0.860	1.000	0.999
	G3	0.946	0.446	0.947	0.495	0.947	0.853	0.475	0.556	0.854	0.786	0.936	0.866	0.991	0.762	1.000	0.999
	G6	0.966	0.952	1.000	0.466	1.000	0.797	0.791	0.898	ZV*	0.470	0.830	0.981	0.508	0.863	1.000	1.000
	G7	0.945	0.722	0.947	0.290	0.947	0.835	0.415	0.458	0.902	0.643	0.829	0.953	0.994	0.317	1.000	0.999
	G9	0.961	0.408	0.947	0.394	0.947	0.860	0.894	0.164	0.902	0.763	0.928	0.866	0.994	0.740	1.000	0.999
	G14	0.961	0.443	0.950	0.886	0.950	0.869	0.786	0.795	0.062	0.499	0.919	0.819	0.701	0.988	1.000	0.999
	G15	0.959	0.449	1.000	0.911	0.972	0.878	0.791	0.744	0.343	0.620	0.841	0.817	0.320	0.979	1.000	0.997
	Exp (avg)	0.956	0.671	0.967	0.614	0.962	0.852	0.697	0.614	0.554	0.630	0.892	0.883	0.750	0.812	1.000	0.998
1	A2	0.812	0.098	-0.015	0.690	0.896	0.698	0.514	0.164	0.368	0.407	0.854	0.736	0.539	0.794	1.000	0.996
	A3	0.878	0.138	0.897	0.607	0.741	0.763	0.692	ZV*	ZV*	ZV*	0.679	0.017	0.508	0.767	1.000	0.352
	A4	0.815	0.092	0.947	0.690	0.896	0.698	0.514	0.153	0.368	0.407	0.854	0.736	0.539	0.794	1.000	0.996
	A5	0.947	0.402	0.897	0.683	0.897	0.914	0.412	0.691	0.836	0.856	0.964	0.887	0.995	0.853	1.000	1.000
	A8	0.903	0.396	0.830	0.500	0.830	0.760	-0.080	0.487	ZV*	0.212	0.815	0.517	0.508	0.806	1.000	0.996
	A9	0.923	0.454	1.000	0.582	1.000	0.728	0.337	0.384	-0.175	-0.074	0.867	0.960	0.549	0.929	1.000	1.000
	A10	0.903	0.593	0.781	0.200	0.766	0.711	0.360	0.609	ZV*	0.461	0.785	0.820	0.508	0.700	1.000	0.993
	A11	0.845	0.352	0.830	0.657	0.695	0.551	0.276	ZV*	0.151	0.252	0.485	0.990	0.193	-0.036	1.000	0.828
	Nov (avg)	0.878	0.316	0.771	0.576	0.840	0.728	0.378	0.415	0.310	0.360	0.788	0.708	0.542	0.701	1.000	0.895
	All Average	0.917	0.493	0.869	0.595	0.901	0.790	0.528	0.527	0.449	0.503	0.840	0.796	0.646	0.756	1.000	0.947

Table 39: Video 2 Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
	G1	0.955	0.898	0.898	0.702	0.911	0.922	ZV*	0.585	0.087	0.826	0.933	0.999	0.907	0.922	0.963	0.993
	G2	0.806	0.017	0.017	0.303	-0.010	0.796	-0.048	0.711	-0.020	0.647	0.694	0.909	0.352	0.808	0.941	0.669
	G3	0.912	0.804	0.804	0.722	0.827	0.814	ZV*	0.624	ZV*	0.307	0.651	0.934	-0.143	0.941	0.941	0.977
	G6	0.960	0.933	0.933	0.528	0.931	0.788	0.933	0.716	ZV*	0.351	0.626	1.000	-0.143	0.860	0.941	1.000
	G7	0.907	0.933	0.933	0.627	0.916	0.761	ZV*	ZV*	0.074	-0.311	0.540	0.969	0.543	0.264	0.916	0.999
	G9	0.945	0.620	0.901	0.547	0.913	0.757	0.792	ZV*	ZV*	ZV*	0.574	0.930	-0.143	0.708	0.941	0.993
	G14	0.95	0.612	0.869	0.688	0.894	0.790	0.869	ZV*	ZV*	ZV*	0.613	0.930	-0.143	0.803	0.941	0.990
	G15	0.942	0.901	0.901	0.769	0.928	0.897	0.131	ZV*	0.127	0.662	0.775	0.821	0.339	0.816	0.941	0.994
	Exp (avg)	0.922	0.715	0.782	0.611	0.789	0.816	0.535	0.659	0.067	0.414	0.676	0.937	0.196	0.765	0.941	0.952
2	A2	0.926	0.573	0.573	0.619	0.766	0.911	0.061	0.334	0.580	0.832	0.837	0.987	0.987	0.728	0.979	0.644
	A3	0.928	0.263	0.900	0.595	0.882	0.785	0.900	0.526	ZV*	0.260	0.621	-0.092	-0.143	0.861	0.941	0.999
	A4	0.924	0.521	0.573	0.619	0.766	0.911	0.061	0.334	0.580	0.832	0.837	0.987	0.987	0.738	0.979	0.644
	A5	0.938	0.803	0.803	0.548	0.843	0.857	0.342	0.777	0.086	0.676	0.779	0.794	0.351	0.882	0.941	0.987
	A8	0.889	0.866	0.866	ZV*	0.877	0.612	ZV*	ZV*	ZV*	ZV*	0.374	0.981	-0.143	0.185	0.941	1.000
	A9	0.933	0.580	0.866	0.454	0.863	0.762	0.543	0.670	ZV*	0.330	0.581	0.919	-0.143	0.742	0.941	0.991
	A10	0.863	0.441	0.441	0.768	0.417	0.808	0.007	ZV*	ZV*	ZV*	0.614	0.930	-0.143	0.816	0.949	0.923
	A11	0.915	0.461	0.864	0.755	0.887	0.765	0.180	0.021	ZV*	0.359	0.566	0.894	-0.143	0.740	0.941	0.970
	Nov (avg)	0.915	0.564	0.736	0.623	0.788	0.801	0.299	0.444	0.415	0.548	0.651	0.800	0.201	0.712	0.952	0.895
	All Average	0.919	0.644	0.760	0.616	0.788	0.809	0.408	0.542	0.198	0.476	0.663	0.868	0.199	0.738	0.946	0.923

Table 40: Video 3 Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
	G1	0.414	-0.054	0.491	0.372	0.280	0.635	0.076	-0.023	0.285	0.429	0.243	0.891	0.044	0.643	-0.150	0.272
	G2	0.709	0.024	0.379	0.633	0.794	0.754	0.000	ZV*	-0.727	-0.194	0.574	0.892	-0.051	0.934	0.999	0.057
	G3	0.544	0.512	0.574	0.910	0.325	0.925	0.522	0.087	0.762	0.702	0.822	0.880	0.978	0.978	0.998	0.212
	G6	0.840	0.773	0.379	0.676	0.970	0.697	0.000	-0.136	ZV*	0.140	0.757	0.951	0.674	0.546	0.999	0.963
	G7	0.596	0.106	0.491	0.580	0.643	0.709	0.397	-0.171	0.666	0.374	0.576	0.871	0.994	0.439	0.656	0.273
	G9	0.840	0.712	0.653	0.723	0.890	0.924	0.446	ZV*	0.737	0.748	0.890	0.733	0.951	0.978	0.998	0.574
	G14	0.885	0.100	0.794	0.790	0.991	0.886	0.765	0.388	0.383	0.478	0.985	0.176	0.942	0.995	0.998	0.995
	G15	0.820	0.772	0.302	0.667	0.978	0.770	0.369	-0.132	0.083	0.370	0.719	0.259	0.226	0.638	0.998	0.997
	Exp (avg)	0.706	0.368	0.508	0.669	0.734	0.788	0.322	0.002	0.313	0.381	0.696	0.707	0.595	0.769	0.812	0.543
3	A2	0.563	0.206	0.491	0.789	0.300	0.858	0.415	0.377	0.492	0.584	0.965	0.168	0.997	0.905	0.999	0.984
	A3	0.737	0.451	0.379	0.092	0.898	0.756	0.000	ZV*	ZV*	ZV*	0.744	0.845	0.674	0.900	0.998	0.273
	A4	0.603	0.212	0.491	0.789	0.300	0.858	0.415	0.377	0.492	0.584	0.965	0.171	0.997	0.905	0.999	0.984
	A5	0.422	0.306	0.574	0.720	0.330	0.705	0.192	0.030	-0.143	0.103	0.609	0.087	0.542	0.586	0.999	0.275
	A8	0.793	0.682	0.491	ZV*	0.911	0.748	0.357	ZV*	ZV*	ZV*	0.803	0.061	0.674	0.888	0.998	0.586
	A9	0.860	0.645	0.491	0.112	0.988	0.748	0.504	ZV*	ZV*	ZV*	0.889	0.176	0.674	0.901	0.998	0.991
	A10	0.633	0.381	ZV*	0.111	0.555	0.751	0.422	ZV*	ZV*	ZV*	0.744	0.571	0.674	0.940	0.999	0.170
	A11	0.674	ZV*	ZV*	0.569	0.961	0.691	ZV*	-0.030	ZV*	0.037	0.809	0.815	0.674	0.642	0.999	0.990
	Nov (avg)	0.661	0.412	0.486	0.455	0.655	0.764	0.325	0.189	0.280	0.327	0.816	0.362	0.738	0.833	0.999	0.657
	All Average	0.683	0.389	0.683	0.568	0.695	0.776	0.683	0.080	0.302	0.362	0.756	0.534	0.667	0.801	0.905	0.600

Table 41: Video 4 Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow poslure	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
	G1	0.758	0.441	0.851	0.506	0.650	0.873	0.116	0.100	0.431	0.595	0.672	0.971	0.144	0.837	0.793	0.381
	G2	0.728	0.375	0.882	0.728	0.561	0.912	0.479	0.057	0.605	0.503	0.868	0.933	0.914	0.912	0.930	0.590
	G3	0.415	0.199	0.705	0.000	-0.022	0.531	ZV*	0.478	0.378	0.534	0.477	0.872	0.732	0.310	0.933	0.317
	G6	0.456	0.209	0.882	0.816	-0.110	0.940	0.882	ZV*	0.707	0.729	0.912	0.993	0.853	0.997	0.894	0.668
	G7	0.784	0.919	1.000	0.757	0.610	0.920	ZV*	0.000	0.313	0.556	0.791	0.856	0.325	0.981	0.926	0.560
	G9	0.846	0.560	0.415	0.587	0.837	0.873	0.393	0.663	-0.047	0.359	0.852	0.933	0.503	0.976	0.734	0.839
	G14	0.834	0.213	0.882	0.578	0.743	0.928	0.882	ZV*	0.758	0.793	0.862	0.757	0.890	0.988	0.593	0.580
	G15	0.706	-0.423	1.000	0.755	0.489	0.924	0.851	0.022	0.494	0.676	0.774	0.725	0.275	0.987	0.883	0.324
	Exp (avg)	0.691	0.312	0.827	0.591	0.470	0.863	0.601	0.220	0.455	0.593	0.776	0.880	0.580	0.874	0.836	0.532
4	A2	0.542	0.040	0.705	0.691	0.606	0.800	0.085	0.096	0.114	0.376	0.689	0.878	0.405	0.722	0.896	0.826
	A3	0.789	0.480	0.785	0.388	0.767	0.789	0.785	ZV*	ZV*	ZV*	0.704	0.561	0.752	0.979	0.315	-0.004
	A4	0.542	0.040	0.705	0.691	0.606	0.800	0.085	0.096	0.114	0.376	0.689	0.878	0.405	0.722	0.896	0.826
	A5	0.510	0.223	0.086	0.211	0.250	0.812	0.039	0.306	0.456	0.551	0.535	0.314	0.844	0.586	0.594	-0.036
	A8	0.431	-0.222	0.151	ZV*	0.034	0.621	0.550	ZV*	ZV*	ZV*	0.515	0.448	0.752	0.430	0.315	0.599
	A9	0.708	0.569	0.253	0.585	0.636	0.796	-0.093	-0.023	0.083	0.142	0.756	0.833	0.620	0.841	1.000	0.377
	A10	0.286	0.316	0.705	0.118	-0.275	0.660	0.395	ZV*	ZV*	ZV*	0.777	0.673	0.752	0.765	0.833	0.778
	A11	0.659	0.113	0.735	0.702	0.587	0.593	0.306	0.025	-0.150	-0.042	0.612	0.889	0.382	0.500	0.894	0.935
	Nov (avg)	0.558	0.195	0.516	0.484	0.401	0.734	0.269	0.100	0.123	0.281	0.660	0.684	0.614	0.693	0.718	0.538
	All Average	0.625	0.253	0.671	0.540	0.436	0.798	0.414	0.165	0.322	0.468	0.718	0.782	0.597	0.783	0.777	0.535

Table 42: Video 5 Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
	G1	0.669	0.432	0.696	0.596	0.395	0.768	0.065	0.203	-0.255	0.155	0.751	0.997	0.979	0.557	0.726	0.415
	G2	0.771	0.351	0.354	0.540	0.481	0.719	0.234	0.188	-0.033	0.174	0.635	0.949	0.975	0.399	0.448	0.649
	G3	0.643	0.357	0.711	0.757	0.386	0.756	0.130	0.075	-0.129	0.000	0.853	0.937	0.963	0.846	0.801	0.570
	G6	0.923	0.829	0.955	0.787	0.898	0.778	0.517	-0.073	0.119	0.000	0.805	0.996	0.853	0.699	0.902	0.758
	G7	0.762	0.525	0.504	0.633	0.574	0.635	0.040	-0.280	-0.079	-0.208	0.413	0.569	0.874	0.006	0.264	0.151
	G9	0.887	0.528	0.832	0.480	0.874	0.754	0.593	0.350	0.213	0.294	0.848	0.690	0.942	0.849	0.602	0.989
	G14	0.868	0.364	0.748	0.583	0.695	0.769	0.476	0.080	0.018	0.059	0.797	0.586	0.959	0.805	0.670	0.462
	G15	0.805	0.148	0.408	0.665	0.510	0.740	0.138	0.141	-0.323	-0.135	0.698	0.601	0.919	0.767	0.238	0.625
	Exp (avg)	0.791	0.442	0.651	0.630	0.602	0.740	0.274	0.086		0.042	0.725	0.791	0.933	0.616	0.581	0.577
5	A2	0.526	0.212	0.572	0.500	0.386	0.568	0.144	0.044	-0.049	-0.034	0.464	0.590	-0.104	0.831	0.374	0.313
	A3	0.816	0.497	0.576	0.457	0.537	0.730	0.273	ZV*	ZV*	ZV*	0.738	0.705	0.976	0.655	0.523	0.674
	A4	0.530	0.174	0.572	0.500	0.386	0.568	0.144	0.044	-0.049	-0.034	0.464	0.590	-0.104	0.831	0.374	0.313
	A5	0.675	0.452	0.437	0.552	0.310	0.750	0.461	0.009	-0.132	0.000	N/A	N/A	N/A	N/A	N/A	N/A
	A8	0.801	0.631	0.576	0.031	0.462	0.653	0.297	ZV*	ZV*	ZV*	0.721	0.423	0.976	0.621	0.523	0.708
	A9	0.727	0.655	0.287	0.521	0.351	0.658	0.577	ZV*	-0.058	0.000	0.718	0.375	0.976	0.752	0.621	0.095
	A10	0.682	0.247	0.393	0.378	0.462	0.661	0.014	-0.555	ZV*	-0.383	0.813	0.626	0.976	0.723	0.689	0.614
	A11	0.550	0.122	0.504	0.507	0.420	0.485	0.071	0.113	-0.348	0.023	0.358	0.973	0.394	0.072	0.385	0.638
	Nov (avg)	0.663	0.374	0.490	0.431	0.414	0.634	0.248				0.611	0.612	0.584	0.641	0.498	0.479
	All Average	0.727	0.408	0.570	0.530	0.508	0.687	0.261	0.024			0.671	0.706	0.769	0.628	0.542	0.531

Table 43: Video 6 Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
6	G1	0.901	0.635	0.897	0.377	0.867	0.792	ZV*	0.530	*	0.500	0.798	0.958	0.896	0.599	0.968	0.939
	G2	0.779	0.164	0.349	0.482	0.056	0.830	0.069	0.540	*	0.610	0.874	0.865	0.999	0.672	0.996	0.768
	G3	0.915	0.749	0.865	0.605	0.882	0.823	0.006	0.601	*	0.622	0.873	0.940	0.997	0.869	0.808	0.610
	G6	0.941	0.835	0.966	0.720	0.795	0.918	0.411	0.777	*	0.809	0.974	0.999	1.000	0.963	0.990	0.916
	G7	0.933	0.674	0.966	0.496	0.974	0.694	0.456	-0.044	*	-0.215	0.677	0.969	1.000	0.143	0.727	0.997
	G9	0.946	0.474	0.899	0.603	0.917	0.857	0.550	0.087	*	0.148	0.954	0.986	1.000	0.875	0.999	0.979
	G14	0.946	0.798	0.932	0.658	0.897	0.882	0.398	0.699	*	0.625	0.883	0.970	0.976	0.932	0.977	0.404
	G15	0.918	0.498	0.606	0.742	0.836	0.853	0.203	0.654	*	0.399	0.837	0.903	0.684	0.919	0.992	0.727
	Exp (avg)	0.910	0.603	0.810	0.585	0.778	0.831	0.299	0.481	*	0.437	0.859	0.949	0.944	0.747	0.932	0.793
	A2	0.902	0.523	0.932	0.486	0.858	0.627	0.335	0.232	*	0.163	0.678	0.985	0.666	0.586	0.900	0.578
	A3	0.909	0.422	0.899	0.000	0.867	0.721	0.173	0.556	*	0.641	0.841	-0.100	1.000	0.672	0.932	0.819
	A4	0.898	0.468	0.932	0.486	0.858	0.627	0.335	0.232	*	0.163	0.678	0.985	0.666	0.586	0.900	0.578
	A5	0.870	0.545	0.530	0.683	0.404	0.855	0.119	0.513	*	0.525	0.931	0.930	0.993	0.941	0.994	0.660
	A8	0.840	0.422	0.653	0.249	0.573	0.737	0.103	0.556	*	0.502	0.795	0.824	0.956	0.676	0.989	0.498
	A9	0.903	0.482	0.611	0.396	0.660	0.819	0.361	ZV*	*	ZV*	0.821	0.972	1.000	0.777	0.932	0.180
	A10	0.914	0.494	0.735	0.599	0.653	0.824	-0.092	0.456	*	0.483	0.876	0.987	0.989	0.924	0.942	0.435
	A11	0.805	0.158	0.408	0.345	0.759	0.590	0.033	0.341	*	0.276	0.517	0.821	0.515	0.529	0.343	0.558
	Nov (avg)	0.880	0.439	0.713	0.406	0.704	0.725	0.171	0.412	*	0.393	0.767	0.801	0.848	0.711	0.867	0.538
	All Average	0.895	0.521	0.761	0.495	0.741	0.778	0.231	0.448	*	0.417	0.813	0.875	0.896	0.729	0.899	0.665

APPENDIX C

PHASE II RESULTS

Table 44: Phase II Raw Results

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture
Va	All/Gold	0.926 (.915 - .936)	0.488 (.315 - .641)	0.937 (.911 - .958)	0.540 (.455 - .624)	0.909 (.873 - .939)	0.729 (.680 - .770)	0.617 (.514 - .719)	0.472 (.355 - .596)	0.225 (.097 - .376)	0.372 (.265 - .480)
	G3	0.892	0.286	0.897	0.163	0.897	0.497	0.592	0.614	0.189	0.308
	G6	0.968	0.874	1.000	0.746	1.000	0.825	0.838	0.666	0.015	0.343
	G7	0.936	0.796	0.947	0.587	0.823	0.809	0.480	0.225	0.253	0.393
	G8	0.961	0.433	0.947	0.717	0.994	0.866	0.795	1.000	0.102	0.570
	G15	0.955	0.449	1.000	0.828	1.000	0.882	0.682	0.605	0.451	0.680
	Exp (avg)	0.942	0.568	0.958	0.608	0.943	0.776	0.677	0.622	0.202	0.459
Vb	All/Gold	0.618 (.581 - .654)	0.311 (.140 - .487)	0.799 (.729 - .861)	0.509 (.417 - .600)	0.331 (.219 - .461)	0.859 (.832 - .883)	0.390 (.154 - .594)	0.219 (.126 - .338)	0.672 (.545 - .777)	0.517 (.433 - .602)
	G3	0.389	0.269	0.785	0.705	-0.254	0.900	0.191	0.055	0.694	0.631
	G6	0.525	0.481	0.882	0.846	0.030	0.924	0.882	0.487	0.463	0.549
	G7	0.792	0.889	1.000	0.321	0.702	0.817	ZV*	0.487	ZV*	0.050
	G8	0.857	0.425	0.882	0.605	0.815	0.944	0.882	0.169	0.905	0.827
	G15	0.754	0.201	0.785	0.524	0.635	0.895	0.426	0.045	0.852	0.793
	Exp (avg)	0.663	0.453	0.867	0.600	0.386	0.896	0.595	0.249	0.729	0.570
Vc	All/Gold	0.927 (.917 - .936)	0.449 (.276 - .607)	0.794 (.722 - .856)	0.654 (.583 - .722)	0.817 (.751 - .873)	0.798 (.762 - .831)	0.564 (.407 - .698)	0.664 (.521 - .775)	*	0.489 (.395 - .582)
	G3	0.935	0.604	0.830	0.767	0.779	0.783	0.579	0.553	*	0.501
	G6	0.961	0.712	0.966	0.682	0.975	0.865	0.425	ZV*	*	-0.044
	G7	0.931	0.508	0.653	0.610	0.735	0.873	ZV*	0.611	*	0.683
	G8	0.932	0.416	0.932	0.652	0.934	0.866	0.398	0.670	*	0.621
	G15	0.947	0.688	0.862	0.652	0.925	0.754	0.614	0.468	*	0.462
	Exp (avg)	0.941	0.586	0.849	0.673	0.870	0.828	0.504	0.576	*	0.445

Table 45: Phase II Intermediate results all data (CI)

Rater	Posture (all)	Strain	Flex/ext	Deviation	Elbow angle	Grip
All/Gold	0.829 (.790 - .864)	0.887 (.821 - .937)	0.767 (.667 - .856)	0.828 (.753 - .892)	0.906 (.830 - .958)	0.749 (.657 - .832)
G3	0.772	0.940	0.528	0.789	0.963	0.784
G6	0.910	0.979	0.821	0.921	0.978	0.784
G7	0.909	0.932	0.855	0.917	0.934	0.927
G9	0.920	0.905	0.870	0.896	0.959	0.934
G15	0.835	0.861	0.876	0.851	0.897	0.637
Average	0.869	0.923	0.790	0.875	0.946	0.813

Table 46: Phase II Video A intermediate results

Video A	All Data	Strain	Flex/ext	Deviation	Elbow angle	Grip
All/Gold	0.853 (.791 - .905)	0.880 (.749 - .963)	0.555 (.314 - .805)	0.838 (.703 - .935)	1.000 (1.00 - 1.00)	0.989 (.979 - .996)
Average	0.865	0.924	0.575	0.871	1.000	0.993

Table 47: Phase II Video B intermediate results

Video B	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
All/Gold	0.764 (.676 - .843)	0.897 (.781 - .968)	0.811 (.637 - .934)	0.888 (.786 - .956)	0.658 (.323 -.929)	0.371 (.169 - .365)
Average	0.838	0.917	0.869	0.917	0.819	0.557

Table 48: Phase II Video C intermediate results

Video C	All Data	Strain	Flex/ext	Dev	elbow angle	Grip
All/Gold	0.862 (.803 - .911)	0.901 (.789 - .970)	0.965 (.924 - .988)	0.770 (.598 - .903)	0.937 (.821 - .989)	0.772 (.615 - .897)
Average	0.906	0.942	0.964	0.843	0.948	0.857

Table 49: Phase II Raw vs. Intermediate

Video/Job	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Deviation	Elbow angle	Grip
Va	G3	0.892	0.286	0.897	0.163	0.897	0.497	0.592	0.614	0.189	0.308	0.698	0.979	-0.062	0.714	1.000	1.000
	G6	0.968	0.874	1.000	0.746	1.000	0.825	0.838	0.666	0.015	0.343	0.869	1.000	0.618	0.882	1.000	1.000
	G7	0.936	0.796	0.947	0.587	0.823	0.809	0.480	0.225	0.253	0.393	0.903	0.934	0.778	0.881	1.000	0.966
	G8	0.961	0.433	0.947	0.717	0.994	0.866	0.795	1.000	0.102	0.570	0.914	0.960	0.727	0.937	1.000	0.999
	G15	0.955	0.449	1.000	0.828	1.000	0.882	0.682	0.605	0.451	0.680	0.943	0.745	0.813	0.940	1.000	1.000
	Average	0.942	0.568	0.958	0.608	0.943	0.776	0.677	0.622	0.202	0.459	0.865	0.924	0.575	0.871	1.000	0.993
Vb	G3	0.389	0.269	0.785	0.705	-0.254	0.900	0.191	0.055	0.694	0.631	0.794	0.971	0.850	0.810	0.904	0.543
	G6	0.525	0.481	0.882	0.846	0.030	0.924	0.882	0.487	0.463	0.549	0.928	0.962	0.885	0.998	0.930	0.712
	G7	0.792	0.889	1.000	0.321	0.702	0.817	ZV*	0.487	ZV*	0.050	0.909	0.956	0.752	0.976	0.882	0.947
	G8	0.857	0.425	0.882	0.605	0.815	0.944	0.882	0.169	0.905	0.827	0.918	0.813	0.948	0.934	0.815	0.916
	G15	0.754	0.201	0.785	0.524	0.635	0.895	0.426	0.045	0.852	0.793	0.640	0.885	0.908	0.867	0.565	-0.331
	Average	0.663	0.453	0.867	0.600	0.386	0.896	0.595	0.249	0.729	0.570	0.838	0.917	0.869	0.917	0.819	0.557
Vc	G3	0.935	0.604	0.830	0.767	0.779	0.783	0.579	0.553	*	0.501	0.855	0.888	0.910	0.868	0.937	0.571
	G6	0.961	0.712	0.966	0.682	0.975	0.865	0.425	ZV*	*	-0.044	0.944	0.986	0.994	0.869	0.970	0.997
	G7	0.931	0.508	0.653	0.610	0.735	0.873	ZV*	0.611	*	0.683	0.920	0.907	1.000	0.883	0.863	0.871
	G8	0.932	0.416	0.932	0.652	0.934	0.866	0.398	0.670	*	0.621	0.931	0.984	0.983	0.826	0.991	0.992
	G15	0.947	0.688	0.862	0.652	0.925	0.754	0.614	0.468	*	0.462	0.882	0.945	0.935	0.768	0.977	0.855
	Average	0.941	0.586	0.849	0.673	0.870	0.828	0.504	0.576	*	0.445	0.906	0.942	0.964	0.843	0.948	0.857

Table 50: Pre and Post ICCs

	Rater	Raw	Borg	efforts	elbow posture	grip	Posture	Speed	Wrist Deviation	Wrist Flexion	Wrist posture	All Data	Strain	Flex/ext	Deviation	elbow angle	Grip
Pre	G3	0.946	0.446	0.947	0.495	0.947	0.853	0.475	0.556	0.854	0.786	0.936	0.866	0.991	0.762	1.000	0.999
Post	G3	0.892	0.286	0.897	0.163	0.897	0.497	0.592	0.614	0.189	0.308	0.698	0.979	-0.062	0.714	1.000	1.000
Difference								0.117	0.058				0.113			0	0.001
Pre	G6	0.966	0.952	1.000	0.466	1.000	0.797	0.791	0.898	-	0.470	0.830	0.981	0.508	0.863	1.000	1.000
Post	G6	0.968	0.874	1.000	0.746	1.000	0.825	0.838	0.666	0.015	0.343	0.869	1.000	0.618	0.882	1.000	1.000
Difference		0.002		0.000	0.280	0.000	0.028	0.047		-		0.039	0.019	0.110	0.019	0.000	0.000
Pre	G7	0.945	0.722	0.947	0.290	0.947	0.835	0.415	0.458	0.902	0.643	0.829	0.953	0.994	0.317	1.000	0.999
Post	G7	0.936	0.796	0.947	0.587	0.823	0.809	0.480	0.225	0.253	0.393	0.903	0.934	0.778	0.881	1.000	0.966
Difference		[illegible]	0.074	0.000	0.297			0.065				0.074			0.564	0.000	
Pre	G15	0.959	0.449	1.000	0.911	0.972	0.878	0.791	0.744	0.343	0.620	0.841	0.817	0.320	0.979	1.000	0.997
Post	G15	0.955	0.449	1.000	0.828	1.000	0.882	0.682	0.605	0.451	0.680	0.943	0.745	0.813	0.940	1.000	1.000
Difference			0.000	0.000		0.028	0.004			0.108	0.060	0.102		0.493		0.000	0.003
Pre	G3	0.415	0.199	0.705	0.000	-0.022	0.531	ZV*	0.478	0.378	0.534	0.477	0.872	0.732	0.310	0.933	0.317
Post	G3	0.389	0.269	0.785	0.705	-0.254	0.900	0.191	0.055	0.694	0.631	0.794	0.971	0.850	0.810	0.904	0.543
Difference		[illegible]	0.070	0.080	0.705		0.369	-		0.316	0.097	0.317	0.099	0.118	0.500		0.226
Pre	G6	0.456	0.209	0.882	0.816	-0.110	0.940	0.882	ZV*	0.707	0.729	0.912	0.993	0.853	0.997	0.894	0.668
Post	G6	0.525	0.481	0.882	0.846	0.030	0.924	0.882	0.487	0.463	0.549	0.928	0.962	0.885	0.998	0.930	0.712
Difference		0.069	0.272	0.000	0.030	0.140		0.000	-			0.016		0.032	0.001	0.036	0.044
Pre	G7	0.784	0.919	1.000	0.757	0.610	0.920	ZV*	0.000	0.313	0.556	0.791	0.856	0.325	0.981	0.926	0.560
Post	G7	0.792	0.889	1.000	0.321	0.702	0.817	ZV*	0.487	ZV*	0.050	0.909	0.956	0.752	0.976	0.882	0.947
Difference		0.008	[illegible]	0.000		0.092		-	0.487	-		0.118	0.100	0.427			0.387
Pre	G15	0.706	-0.423	1.000	0.755	0.489	0.924	0.851	0.022	0.494	0.676	0.774	0.725	0.275	0.987	0.883	0.324
Post	G15	0.754	0.201	0.785	0.524	0.635	0.895	0.426	0.045	0.852	0.793	0.640	0.885	0.908	0.867	0.565	-0.331
Difference		0.048	0.624			0.146			0.023	0.358	0.117		0.160	0.633			
Pre	G3	0.915	0.749	0.865	0.605	0.882	0.823	0.006	0.601	*	0.622	0.873	0.940	0.997	0.869	0.808	0.610
Post	G3	0.935	0.604	0.830	0.767	0.779	0.783	0.579	0.553	*	0.501	0.855	0.888	0.910	0.868	0.937	0.571
Difference		0.020			0.162			0.573		-						0.129	
Pre	G6	0.941	0.835	0.966	0.720	0.795	0.918	0.411	0.777	*	0.809	0.974	0.999	1.000	0.963	0.990	0.916
Post	G6	0.961	0.712	0.966	0.682	0.975	0.865	0.425	ZV*	*	-0.044	0.944	0.986	0.994	0.869	0.970	0.997
Difference		0.020		0.000		0.180		0.014	-	-							0.081
Pre	G7	0.933	0.674	0.966	0.496	0.974	0.694	0.456	-0.044	*	-0.215	0.677	0.969	1.000	0.143	0.727	0.997
Post	G7	0.931	0.508	0.653	0.610	0.735	0.873	ZV*	0.611	*	0.683	0.920	0.907	1.000	0.883	0.863	0.871
Difference					0.114		0.179	-	0.655	-	0.898	0.243		0.000	0.740	0.136	
Pre	G15	0.918	0.498	0.606	0.742	0.836	0.853	0.203	0.654	*	0.399	0.837	0.903	0.684	0.919	0.992	0.727
Post	G15	0.947	0.688	0.862	0.652	0.925	0.754	0.614	0.468	*	0.462	0.882	0.945	0.935	0.768	0.977	0.855
		0.029	0.19	0.256		0.089		0.411		-	0.063	0.045	0.042	0.251			0.128

APPENDIX D

LEFT AND RIGHT COMPONENT RESULTS

Table 51: Phase I - Intermediate Left/Right results all videos

	Left				Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.606 (.483 - .734)	0.640 (.529 - .751)	0.814 (.696 - .911)	0.543 (.432 - .663)	0.656 (.539 - .773)	0.747 (.654 - .832)	0.848 (.744 - .929)	0.793 (.717 - .861)
G1	0.441	0.591	0.562	0.474	0.830	0.823	0.908	0.885
G2	0.731	0.725	0.836	0.531	0.635	0.837	0.972	0.674
G3	0.746	0.691	0.879	0.355	0.738	0.813	0.988	0.900
G6	0.595	0.706	0.943	0.921	0.605	0.911	0.990	0.907
G7	0.763	0.458	0.686	0.464	0.873	0.366	0.783	0.919
G9	0.765	0.836	0.972	0.997	0.689	0.880	0.839	0.703
G14	0.671	0.858	0.971	0.719	0.700	0.970	0.805	0.919
G15	0.447	0.693	0.772	0.848	0.490	0.957	0.983	0.874
Nov/Gold	0.639 (.518 - .761)	0.610 (.486 - .739)	0.896 (.811 - .957)	0.579 (.460 - .705)	0.621 (.497 - .747)	0.567 (.440 - .704)	0.919 (.849 - .967)	0.642 (.529 - .756)
a2	0.652	0.820	0.781	0.761	0.588	0.702	0.988	0.849
A3	0.588	0.699	0.884	0.491	0.658	0.911	0.728	0.458
a4	0.652	0.820	0.781	0.761	0.588	0.702	0.988	0.849
A5	N/A	0.829	0.972	0.344	N/A	0.688	0.896	0.758
A8	0.551	0.532	0.883	0.796	0.658	0.618	0.731	0.691
a9	0.577	0.813	0.982	0.640	0.637	0.828	0.852	0.811
A10	0.572	0.784	0.886	0.404	0.658	0.848	0.972	0.861
a11	0.256	0.552	0.640	0.957	0.373	0.329	0.985	0.726
All/Gold	0.559 (.443 - .609)	0.609 (.494 - .733)	0.883 (.795 - .950)	0.548 (.439 - .674)	0.630 (.518 - .749)	0.640 (.529 - .758)	0.906 (.833 - .961)	0.705 (.609 - .801)
EXP Avg	0.645	0.695	0.828	0.664	0.695	0.820	0.909	0.848
Nov Avg	0.550	0.731	0.851	0.644	0.594	0.703	0.893	0.750

Table 52: Phase I - V1 Intermediate Left/Right results

	V1 Left				V1 Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.543 (.244 - .889)	0.779 (.552 - .948)	1.000 (.999 - 1.000)	0.993 (.982 - .998)	0.768 (.513 - .955)	0.729 (.479 - .933)	1.000	0.999 (.997 - 1.000)
G1	0.255	0.971	0.999	0.975	0.719	0.995	1.000	1.000
G2	0.989	0.654	1.000	1.000	1.000	0.954	1.000	0.999
G3	0.989	0.665	1.000	1.000	0.995	0.818	1.000	0.999
G6	-0.110	0.886	1.000	1.000	1.000	0.866	1.000	1.000
G7	0.989	0.878	1.000	1.000	1.000	0.070	1.000	0.999
G9	0.989	0.867	1.000	0.998	1.000	0.688	1.000	1.000
G14	0.245	0.969	1.000	1.000	1.000	0.999	1.000	0.999
G15	0.916	0.956	1.000	0.992	-0.258	0.991	1.000	1.000
Nov/Gold	0.433 (.149 - .844)	0.457 (.189 - .825)	1.000 (1.00 - 1.00)	0.992 (.979 - .998)	0.792 (.550 - .960)	0.624 (.349 - .898)	1.000	0.759 (.540 - .933)
a2	0.654	0.532	1.000	0.992	0.499	0.954	1.000	0.999
A3	-0.110	0.624	1.000	1.000	1.000	0.861	1.000	-0.043
a4	0.654	0.532	1.000	0.992	0.499	0.954	1.000	0.999
A5	0.989	0.980	1.000	1.000	1.000	0.802	1.000	1.000
A8	-0.110	0.897	1.000	0.991	1.000	0.780	1.000	0.999
a9	-0.184	0.836	1.000	1.000	1.000	0.996	1.000	1.000
A10	-0.110	0.917	1.000	0.990	1.000	0.620	1.000	0.995
a11	-0.109	0.070	1.000	0.990	0.499	-0.116	1.000	0.735
All/Gold	0.409 (.173 - .821)	0.598 (.352 - .884)	1.000 (.999 - 1.00)	0.992 (.980 - .998)	0.765 (.534 - .953)	0.672 (.433 - .912)	1.000	0.877 (.745 - .968)

Table 53: Phase I - V2 Intermediate Left/Right results

	V2 Left				V2 Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.383 (.112 - .819)	0.555 (.277 - .871)	0.956 (.818 - .999)	0.993 (.982 - .998)	0.384 (.113 - .820)	0.743 (.499 - 937)	0.970 (.872 - .999)	0.800 (.602 - .946)
G1	0.839	0.979	0.923	0.991	0.970	0.886	0.978	0.997
G2	0.994	0.460	0.923	0.998	-0.207	0.993	0.978	0.443
G3	-0.110	0.840	0.923	0.991	-0.207	0.999	0.978	0.964
G6	-0.110	0.926	0.923	1.000	-0.207	0.824	0.978	1.000
G7	-0.024	0.286	0.953	1.000	1.000	0.275	0.915	0.997
G9	-0.110	0.540	0.923	0.998	-0.207	0.871	0.978	0.988
G14	-0.110	0.592	0.923	0.991	-0.207	0.993	0.978	0.991
G15	-0.022	0.592	0.923	0.998	0.721	0.997	0.978	0.991
Nov/Gold	0.498 (.202 - .872)	0.613 (.337 - .894)	0.939 (.760 - .998)	0.993 (.982 - .998)	0.54 (.241 - .888)	0.603 (.326 - .890)	0.995 (.979 - 1.00)	0.630 (.374 - .885)
a2	0.999	0.988	0.975	0.998	0.978	0.545	0.987	0.218
A3	-0.110	0.803	0.923	1.000	-0.207	0.912	0.978	0.997
a4	0.999	0.988	0.975	0.998	0.978	0.545	0.987	0.218
A5	0.937	0.967	0.923	0.998	-0.118	0.835	0.978	0.975
A8	-0.110	-0.114	0.923	1.000	-0.207	0.432	0.978	1.000
a9	-0.110	0.881	0.923	0.993	-0.207	0.683	0.978	0.988
A10	-0.110	0.613	0.923	0.991	-0.207	0.999	0.994	0.851
a11	-0.110	0.982	0.923	0.983	-0.207	0.592	0.978	0.957
All/Gold	0.492 (.237 - .862)	0.579 (.333 - .876)	0.952 (.826 - .999)	0.991 (.979 - .998)	0.524 (.264 - .876)	0.652 (.410 - .904)	0.984 (.938 - 1.000)	0.698 (.479 - .908)

Table 54: Phase I - V2 Intermediate Left/Right results

	V3 Left				V3 Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.444 (.158 - .849)	0.672 (.405 - .915)	0.750 (.337 - .992)	0.217 (.032 - .615)	0.515 (.218 - .879)	0.854 (.678 - .967)	0.833 (.482 - .995)	0.676 (.429 - .903)
G1	-0.250	0.333	-1.000	-0.167	0.717	0.803	0.701	0.976
G2	-0.250	1.000	1.000	-0.167	0.196	0.838	0.999	0.598
G3	1.000	0.973	1.000	-0.167	0.945	0.993	0.996	0.940
G6	1.000	0.333	1.000	0.951	0.196	0.963	0.999	0.986
G7	1.000	0.333	1.000	-0.167	0.984	0.808	-0.126	0.992
G9	1.000	1.000	1.000	1.000	0.887	0.941	0.996	-0.280
G14	1.000	1.000	1.000	1.000	0.815	0.986	0.996	0.986
G15	-0.250	0.447	1.000	1.000	0.945	0.948	0.996	0.992
Nov/Gold	0.948 (.860 - .991)	0.915 (.798 - .982)	1.000	0.364 (.130 - .740)	0.646 (.351 - .923)	0.504 (.229 - .848)	0.999 (.993 - 1.000)	0.722 (.487 - .920)
a2	1.000	0.994	1.000	1.000	0.992	0.681	0.999	0.964
A3	1.000	1.000	1.000	-0.167	0.196	0.767	0.996	0.986
a4	1.000	0.994	1.000	1.000	0.992	0.681	0.999	0.964
A5	0.669	0.597	1.000	-0.167	0.418	0.628	0.999	0.977
A8	1.000	1.000	1.000	1.000	0.196	0.744	0.996	-0.273
a9	1.000	1.000	1.000	1.000	0.196	0.766	0.996	0.976
A10	1.000	1.000	1.000	-0.167	0.196	0.853	0.999	0.875
a11	1.000	0.973	1.000	1.000	0.196	-0.175	0.999	0.974
All/Gold	0.652 (.391 - .922)	0.747 (.528 - .97)	0.875 (.618 - .996)	0.288 (.114 - .657)	0.513 (.254 - .871)	0.646 (.404 - .902)	0.916 (.719 - .998)	0.700 (.482 - .909)

Table 55: Phase I - V4 Intermediate Left/Right results

	V4 Left				V4 Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.654 (.360 - .925)	0.778 (.551 - .947)	0.854 (.527 - .996)	0.318 (.098 - .706)	0.533 (.234 - .886)	0.837 (.647 - .963)	0.734 (.315 - .991)	0.501 (.243 - .825)
G1	0.212	0.728	0.865	0.378	0.114	0.945	0.779	0.422
G2	0.941	0.883	0.892	0.650	0.901	0.950	0.996	0.553
G3	0.573	0.338	0.892	0.308	0.935	0.318	1.000	0.367
G6	0.817	0.998	0.846	0.587	0.914	0.996	0.983	0.788
G7	0.801	0.963	0.892	0.488	0.071	0.999	0.995	0.672
G9	0.621	0.969	0.892	0.988	0.435	0.987	0.692	0.681
G14	0.932	0.978	0.846	0.509	0.867	0.999	0.534	0.693
G15	0.369	0.998	0.846	-0.187	0.212	0.979	0.962	0.855
Nov/Gold	0.717 (.439 - .942)	0.602 (.326 - .890)	0.641 (.200 - .987)	0.370 (.135 - .745)	0.502 (.206 - .874)	0.489 (.215 - .841)	0.626 (.184 - .986)	0.383 (.145 - .754)
a2	0.742	0.626	0.846	0.725	0.065	0.828	0.995	0.987
A3	0.724	0.959	0.217	0.078	0.812	0.999	0.500	-0.093
a4	0.742	0.626	0.846	0.725	0.065	0.828	0.995	0.987
A5	0.962	0.989	0.931	-0.017	0.812	0.322	0.500	-0.049
A8	0.724	0.589	0.217	0.602	0.812	0.322	0.500	0.638
a9	0.610	0.832	1.000	-0.171	0.675	0.869	1.000	0.771
A10	0.724	0.801	0.895	0.988	0.812	0.760	0.821	0.506
a11	-0.146	0.688	0.846	0.925	0.825	0.397	0.983	0.957
All/Gold	0.523 (.263 - .876)	0.683 (.447 - .916)	0.735 (.375 - .991)	0.309 (.128 - .677)	0.483 (.230 - .858)	0.642 (.399 - .901)	0.682 (.311 - .989)	0.415 (.204 - .762)

Table 56: Phase I - V5 Intermediate Left/Right results

	V5 Left				V5 Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.864 (.678 - .976)	0.581 (.303 - .881)	0.497 (.074 - .978)	0.421 (.175 - .779)	0.952 (.870 - .992)	0.760 (.523 - .942)	0.635 (.193 - .987)	0.766 (.549 - .935)
G1	0.955	0.087	0.528	0.233	1.000	0.891	1.000	0.634
G2	0.992	-0.204	-0.187	0.703	0.966	0.774	0.914	0.629
G3	0.974	0.695	0.683	0.330	0.961	0.979	0.997	0.842
G6	0.950	0.552	0.852	0.940	0.765	0.871	0.990	0.496
G7	0.684	0.170	-0.561	-0.224	0.989	-0.095	0.950	0.555
G9	0.964	0.659	0.984	0.996	0.930	0.962	0.049	0.983
G14	0.950	0.631	0.995	0.302	0.974	0.941	0.049	0.628
G15	0.839	0.470	-0.561	0.653	0.979	0.931	0.980	0.627
Nov/Gold	0.543 (.233 - .891)	0.495 (.211 - .846)	0.448 (.018 - .975)	0.290 (.068 - .689)	0.534 (.224 - .887)	0.682 (.410 - .919)	0.384 (-.021 - .969)	.601 (.334 - .873)
a2	-0.163	0.796	-0.289	-0.351	-0.079	0.859	0.980	0.838
A3	0.950	0.209	0.988	0.770	1.000	0.966	-0.228	0.573
a4	-0.163	0.796	-0.289	-0.351	-0.079	0.859	0.980	0.838
A5	NA				NA			
A8	0.950	0.636	0.988	0.741	1.000	0.643	-0.228	0.701
a9	0.946	0.509	0.993	-0.049	0.999	0.961	0.049	0.191
A10	0.950	0.233	0.438	0.386	1.000	0.966	0.997	0.767
a11	0.886	-0.741	-0.289	0.710	0.000	0.353	0.966	0.615
All/Gold	0.714 (.463 - .940)	0.578 (.330 - .875)	0.500 (.144 - .977)	0.349 (.153 - .713)	0.749 (.510 - .949)	0.713 (.482 - .926)	0.505 (.147 - .978)	0.672 (.447 - .899)

Table 57: Phase I - V6 Intermediate Left/Right results

	V6 Left				V6 Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.959 (.888 - .993)	0.645 (.373 - .905)	0.921 (.703 - .998)	0.616 (.358 - .879)	0.886 (.721 - .980)	0.709 (.452 - .927)	0.961 (.837 - .999)	0.755 (.533 - .931)
G1	0.765	0.715	0.964	0.992	1.000	0.559	0.997	0.876
G2	1.000	0.998	1.000	0.929	0.999	0.482	0.989	0.558
G3	0.995	0.701	0.770	0.076	0.999	0.970	0.969	0.963
G6	1.000	0.943	0.988	0.997	1.000	0.978	1.000	0.829
G7	1.000	0.216	0.651	0.997	1.000	0.104	0.969	0.997
G9	1.000	0.849	1.000	0.997	1.000	0.907	0.997	0.962
G14	1.000	0.974	1.000	-0.195	0.950	0.914	0.944	0.988
G15	0.989	0.957	0.996	0.986	0.310	0.906	0.987	0.384
Nov/Gold	0.627 (.329 - .917)	0.406 (.147 - .797)	0.843 (.503 - .995)	0.429 (.181 - .784)	0.990 (.972 - .998)	0.762 (.527 - .943)	0.876 (.579 - .996)	0.700 (.458 - .912)
a2	0.279	0.821	0.894	0.184	0.972	0.446	0.969	0.914
A3	1.000	0.239	1.000	0.972	1.000	0.990	0.859	0.683
a4	0.279	0.821	0.894	0.184	0.972	0.446	0.969	0.914
A5	0.989	0.853	0.995	0.233	0.999	0.997	0.997	0.974
A8	0.905	0.239	0.999	-0.186	1.000	0.981	0.969	0.991
a9	1.000	0.723	1.000	-0.240	1.000	0.843	0.859	0.660
A10	0.979	0.888	0.946	-0.147	1.000	0.957	0.969	0.965
a11	-0.413	0.283	-0.114	0.980	1.000	0.749	1.000	0.096
All/Gold	0.781 (.558 - .957)	0.492 (.253 - .834)	0.884 (.638 - .997)	0.446 (.228 - .783)	0.936 (.841 - .989)	0.734 (.510 - .933)	0.915 (.717 - .998)	0.714 (.500 - .915)

Table 58: Phase II - All data Intermediate Left/Right results

	Left				Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.737 (.577 - .872)	0.768 (.631 - .881)	0.920 (.816 - .978)	0.705 (.558 - .835)	0.761 (.610 - .885)	0.878 (.793 - .941)	0.901 (.776 - .972)	0.840 (.741 - .916)
G3	0.576	0.726	0.937	0.607	0.446	0.830	1.000	0.903
G6	0.637	0.879	0.964	0.888	1.000	0.951	0.999	0.958
G7	0.752	0.909	0.899	0.948	1.000	0.926	0.988	0.925
G8	0.704	0.922	0.970	0.954	1.000	0.881	0.948	0.994
G15	0.918	0.699	0.977	0.583	0.727	0.946	0.823	0.690
Average	0.717	0.827	0.949	0.796	0.835	0.907	0.952	0.894

Table 59: Phase II - Video A Intermediate Left/Right results

	Va Left				VA Right			
Rater	**Flex/ext**	**Dev**	**elbow angle**	**Grip**	**Flex/ext**	**Dev**	**elbow angle**	**Grip**
Exp/Gold	0.631 (.278 - .941)	0.871 (.690 - .972)	1.000 (1.00 - 1.00)	0.981 (.951 - .996)	0.593 (.248 - .911)	0.838 (.626 - .964)	1.000 (1.00 - 1.00)	0.995 (.986 - .999)
G3	0.176	0.683	1.000	1.000	-0.224	0.750	1.000	1.000
G6	0.075	0.947	1.000	1.000	1.000	0.866	1.000	1.000
G7	0.428	0.942	1.000	0.937	1.000	0.866	1.000	0.983
G8	0.305	0.916	1.000	0.998	1.000	0.954	1.000	1.000
G15	0.296	0.897	1.000	1.000	0.697	0.973	1.000	1.000
Average	0.256	0.877	1.000	0.987	0.695	0.882	1.000	0.997

Table 60: Phase II - Video B Intermediate Left/Right results

	Vb Left				Vb Right			
Rater	Flex/ext	Dev	elbow angle	Grip	Flex/ext	Dev	elbow angle	Grip
Exp/Gold	0.692 (.368 - .938)	0.873 (.695 - .973)	0.744 (.247 - .992)	0.327 (.059 - .732)	0.882 (.692 - .979)	0.917 (.788 - .983)	0.670 (.144 - .989)	0.448 (.155 - .806)
G3	0.704	0.861	0.846	0.581	0.979	0.785	1.000	0.539
G6	0.853	0.999	0.892	0.628	0.945	0.997	0.996	0.819
G7	0.724	0.969	0.865	0.927	0.812	0.986	0.962	0.978
G8	0.902	0.976	0.865	0.864	0.997	0.902	0.821	0.977
G15	0.918	0.668	0.846	-0.423	0.898	0.993	0.500	-0.289
Average	0.820	0.895	0.863	0.515	0.926	0.933	0.856	0.605

Table 61: Phase II - Video C Intermediate Left/Right results

	Vc Left				Vc Right			
Rater	Flex/ext	Dev	elbow angle	Grip	Flex/ext	Dev	elbow angle	Grip
Exp/Gold	0.945 (.843 - .991)	0.596 (.280 - .892)	0.945 (.745 - .999)	0.743 (.490 - .929)	0.987 (.959 - .998)	0.916 (.787 - .983)	0.956 (.790 - .999)	0.826 (.624 - .955)
G3	0.844	0.579	0.923	-0.045	0.979	0.989	1.000	0.956
G6	0.989	0.708	0.964	0.997	1.000	0.992	1.000	0.997
G7	1.000	0.821	0.832	0.994	1.000	0.941	0.987	0.727
G8	0.966	0.867	1.000	0.989	1.000	0.816	0.969	0.997
G15	0.904	0.617	1.000	0.997	0.972	0.875	0.944	0.693
Average	0.941	0.718	0.944	0.786	0.990	0.923	0.980	0.874

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