THE DEVELOPMENT OF A METHOD TO ENCODE BODY MOVEMENT OF AUTOMOTIVE VEHICLE OPERATORS

by

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ABSTRACT

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Measurements of subjective comfort levels experienced by the vehicle operator are critical when evaluating seats. The most common method of recording this information is through the use of questionnaires. Questionnaires can be intrusive and are time consuming for the subject when administered periodically throughout the drive. Since comfort levels change over time, a method is needed to record these changes into data that will allow for quantitative analysis of comfort. This paper describes a method to encode body movement so it can be used as a tool to continuously and objectively record the subjective comfort levels of the vehicle operator providing data for quantitative analysis.

Dedicated to my parents for their love and support

Acknowledgments

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Introduction

Body movement is an accepted area of study in the social sciences. Psychologists and communication scholars study body movement to learn more about relationships, social influence, and social regulation. Body movement is a method of nonverbal communication thus, it sends a message. Unlike verbal communication, body movement is a continuous form of communication as long as visual contact is maintained. A continuous form of communication allows observers to detect subtle changes in the message that are often undetected in non-continuous forms of communication. Since body movement is continuous and often subtle, the sender is typically not aware of the message they are sending and thus it is hard for the sender to mask the message. Body movement studies are premised "...on the view that information about a subject's affective state could be reliably obtained...even when he sought to deceive the investigator" Ekman & Friesen, 1969 (cited in Weitz, 1979). Thus, body movement gives a continuous, undiminished view of the subject's interaction with people and the immediate environment.

Body movement is a form of communication that relays information that may or may not be intentional on the part of the sender. According to DeVito and Hecht, 1990, nonverbal communication involves all messages other than words, including body movement. They state that nonverbal communication occurs when we interpret a message, whether or not a message was intentionally sent. A prime example of unintended nonverbal communication was the focus of a study performed by Montepare, Goldstein, and Clausen, (1987). The study demonstrated that "observers were able to identify specific emotions from variations in walking styles". By observing body movement we are able to obtain a view as to what a person is feeling. For example if a person touches a hot plate they immediately pull their hand away. By observation alone, one would conclude that the surface was hot and caused pain due to the manner in which the hand was removed from the hot plate. Since a message is interpreted this would be considered a form of communication. By studying body movement, one would be able to assess what a person is feeling about their surroundings due to their reaction to the environment. Through nonverbal communication, one should be able to asses the person's comfort levels when the person is directly reacting to an element in the environment such as a seat.

When defining an environment that humans desire, comfort is often listed as a criterion. This is especially true when the user is in direct physical contact with the environment, such as in sitting. Sitting is an activity that one engages in frequently. We typically sit when we eat, travel, work and relax, therefore a comfortable seat is strongly desired, (Branton and Grayson 1967; Richards 1980), but comfort in seating is hard to define. Everyone continuously experiences levels of comfort and discomfort but when asked to give a definition, terminology becomes vague. Unfortunately there is no accepted theoretical definition for sitting comfort and no agreed upon method for its measure (Lueder 1983). For the purpose of this paper comfort will be defined as a positive sensation which is on the same continuum as discomfort. Since they are on the same continuum, comfort will be the term used to describe both comfort and discomfort unless discomfort is the only sensation being discussed. Comfort is a continuous sensation (negative or positive) that is always present in a person but not always consciously recognized. Being a continuous sensation, comfort is in constant flux. People try to maintain a level of comfort by minimizing or eliminating levels of discomfort.

To better understand sitting comfort it is important to understand how the seat affects the user. Numerous studies have been conducted measuring the effects of the seat on the subject. For example, studies focus on pressure (Shen and Galer 1993) and muscle activity (Zimmermann et al., 1993). If the seat is in a vehicle, other factors are considered such as vibration (Zimmermann et al., 1993). Despite objectivity in physiological measures, they are not a direct indication of the subjective experience of comfort, (Lueder 1983).

To study the subjective aspect of sitting comfort, questionnaires are frequently used to assess comfort levels. Branton notes that comparisons between seats are dependent upon the subject's memory capacity. For short term sitting the results may be stable but "...judgments of long-term comfort would be very unstable and unreliable." (Branton 1969). He also points out that comfort is "very primitive and deeply ingrained...not readily accessible to introspection and verbalizations". Based on Branton's experience, it follows that questionnaires are not the most accurate tools with which to record changes in comfort levels over long periods of time. Another argument against using questionnaires to track comfort levels is that sensations of comfort are not static, but dynamic over time. Since feelings of discomfort are in continuous flux, questionnaires which are given at one moment in time would only capture the discomfort levels experienced at that particular moment. To more accurately assess the comfort levels of a subject, continuous data collection is needed to allow researchers to identify patterns of change in comfort levels over time. Both Branton (1969) and Jurgens (1980) suggest observing subject sitting behavior, or body movement as a means of assessing comfort over long periods of time.

When observing body movement of the seated subject over time it becomes evident that movement is purposeful. Branton (1969) states "...behavior is not random but purposeful, motivated or expressing needs." One motivation for movement as stated by Schoberth (Lueder, 1983) is "Movement serves as a pump to improve blood circulation." When circulation is reduced in muscle tissue this can lead to feelings of discomfort. Discomfort caused by reduced blood circulation would typically be found in a specific body area such as the buttocks. To alleviate or avoid this discomfort requires a change in pressure in the buttocks which is achieved through movement. Body movement could alleviate a general feeling of discomfort experienced by the seated subject.

Seating comfort studies are used in the automotive industry but there is no established method for evaluating seating comfort. Some studies use only questionnaires to rate comfort levels (Hall, 1972). Other studies rely on many types of data such as pressure distribution, static load and deflection as well as vibration (Kamijo et al., 1982) to assess comfort. Lee et al., (1995) suggest using pressure distribution, electromyography (EMG), and spinal loading to measure the physiological effects of seating. They support in theory, the use of body movement to rate the comfort levels achieved by vehicle operators in automotive seats.

The primary purpose of the driver's seat is to support the occupant for vehicle operation, however, comfort has become a selling point and can affect customer loyalty. "As the mean comfort of the trip deteriorates, so does the proportion of passengers willing to use the vehicle again" (Richards, 1980). Since people avoid discomfort, it is important that the driver finds the vehicle not only operable and safe, but also comfortable. The driver's body is in direct contact with and supported by the seat so the seat should not be a source of discomfort for the driver. Comfort research in automotive seating also supports an attentiveness to the driving task without a great degree of distraction from the inability to perform a needed activity due to discomfort (Branton 1969).

There are some major drawbacks to most automotive seat comfort studies. First, testing is often not carried out in the driving environment thus reducing many of the stresses of roadway driving (Kamijo, et al., 1982). Reduction of the driving task during laboratory simulations greatly changes the requirements placed on the driver and thus changes the driver's interaction with the seat. For example, automotive seat tests are often conducted in a laboratory with the driver's seat placed on a platform so the effects of the packaging are eliminated along with effects caused by roadway travel such as vibration. Even if the interior of an automobile is simulated, the conditions to which a driver must respond when driving are reduced, or in some cases eliminated. Thus, the driver interacts with a seat differently when pretending to drive in a laboratory than when driving on a road. Second, the length of time people sit in an automotive driving seat is not often recreated in a testing situation, thus eliminating the effects of time on comfort. Continuously recording the vehicle operator's body movement eliminates these problems by allowing for unobtrusive data collection during on-road testing for long periods of time.

To continuously record the body movement of vehicle operators, video tape is useful. Questionnaires capture an instant in time and may not be representative of the seated occupant's experience during long term sitting. Video tape records body movement continuously throughout lengthy testing periods so the whole event can be understood. A second benefit of recording data on video tape is that it does not directly interact with the observer. When gathering subjective data with questionnaires, subjects are often interrupted during their tasks to complete the questionnaire or are asked to recall information after long periods of testing. These drawbacks are eliminated by recording body movement with video tape. The third benefit of recording the seated occupant's body movement is that data collection can occur while operating the vehicle on-road.

Sitting comfort is a continuous subjective phenomenon influenced in part by the person's contact with the seat. Thus, the purpose of this thesis is to develop a method to encode body movement of vehicle operators. Body movement offers a means of collecting objective, continuous, quantitative data for the purpose of investigating long term sitting comfort as experienced by automotive operators. There are few well documented methods for recording and encoding body movement and none for the task of automotive operators. Therefore a methodology for encoding recorded movement of automotive operators into a meaningful format must be developed. The developed method will be modified from existing methods for encoding body movement. Once refined, this methodology will be tested for both inter and intra reliability.

Literature Review

Recording Movement

Atha, (1984) outlines the process involved when analyzing movement:

1. Select the phenomenon to be examined
2. Identify a representative characteristic that can be monitored to give insight about the phenomenon.
3. Design a suitable transducer that will record the primary information required to analyze motion.
4. Describe and transform the data recorded into other variables so that all the desired information may be obtained.
5. Assemble the collected data with information gathered from other sources so it may be interpreted for the selected purposes.

Atha focuses on instruments to record movement for the sports sciences. Even though the goals for sitting comfort are different from sports sciences, the approach to the analysis of movement overlap and the methods of recording movement are the same. There are two ways in which to record movement:

1. record the movements by hand at the time they occur
2. record the movement on tape and then analyze the tapes.

When movement is to be quantified, devices that allow for the play back of the movement are optimal since data can be gathered unobtrusively, remotely and at a low cost. The three general categories of instruments that gather movement data are:

1. Photographic and video, which are remote sensors of movement,

2. Specialized transducers, which convert one form of energy into another for analysis; and

3. On-line movement analyzers, which are second generation multi-channel instruments that continuously measure and automatically analyze angular or three dimensional coordinate data.

These three methods are highly sensitive to different aspects of movement. All three allow data to be played back as many times as needed for analysis. The mechanical methods tend to result in less subjective evaluations of data.

Encoding Methods

Once the method for recording movement is achieved, one must encode the data in a meaningful manner. This is especially true in dance which relies greatly on the ability to record movement for future dancers. Two highly acknowledged methods of dance notation are Labanotation developed by Laban, (Hutchinson, 1977) and the Benesh Movement Notation , (cited in Kember, 1976). Developed separately, these methods record choreography for dance. Both methods rely on symbolic representations of movements to record dance positions and direction of movement. Movements are recorded on a musical staff that is tied into the musical score so time is a dependent function of the music, (Figure 1). The symbols for both methods are abstract but highly detailed. Both methods are capable of recording small changes in position required for dance, such as the position of fingers.

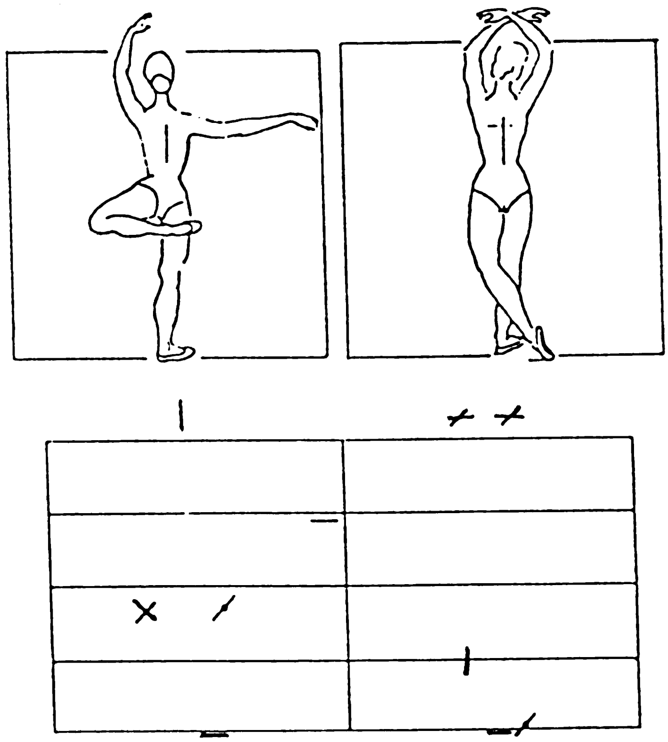

Figure 1. An example of the Benesh Notation Method for recording choreography.

P. A. Kember, (1976), adapted the Benesh Movement Notation for recording movement and posture of seated subjects. The five line stave, derived from musical notation, is retained along with the basic signs developed by Benesh. The posture of the body during movement is not actually recorded, but is indicated by lines that trace the path of the body between two different postures. All the movements are recorded independent of time. A series of signs was specifically developed to indicate the body segments supported by the seat.

To fully master either the Benesh Movement Notation requires a minimum of two years of intensive study. Kember estimated that "good" students could master enough of the Benesh Movement Notation in a rigorous three month study to record seated body movements. Kember's article focuses on the method and training for recording seated behavior so no mention is made of any analysis based on this recording method.

E. N. Corlett (1979) designed a method for coding frequency, duration and sequence of standing work postures in industrial tasks based on the standard posture assumed by the subject. Any changes in the standard posture are considered either vertical or directional deviations from the standard position. The vertical deviations are indicated by concentric circles while the directional deviations are marked on the radii of the diagram, (Figure 2). The portions of the circle may also be assigned numbers. Thus, each of the body segments is represented by two numbers creating a total of ten pairs of numbers. This method is designed for analyzing a particular movement during a task, not several movements over an extended period of time.

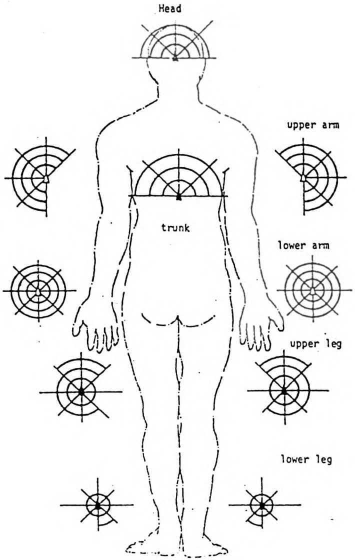

Figure 2. Corlett's chart for recording standing work posture in industry.

Corlett realized that recording only the typical posture of a worker was not enough information to assess postural work loads so he developed a 5-point discomfort rating scale. When gathering information, subjects are first asked to indicate their discomfort level on the 5-point scale. Then the subject is given a chart of the body broken into segments and is asked to indicate all painful segments listing the most painful and proceeding to the least painful. The purpose of this questionnaire is to gather subjective information on bodily discomfort.

Testing and Application

An important part of recording movement through human observation is to achieve a high level of inter-observer reliability among observers. Genaidy et al., 1993, studied the amount of inter-observer reliability in subjects recording the estimated amount of angular deviation of a body segment from the neutral position. Data were recorded on video ensuring consistency in angular deviation for the encoders. Twenty engineering students were chosen for the study and had no previous training in recording postural angles by sight. All twenty subjects were briefed in the objective of the study and experimental procedures were explained. A male engineering student modeled the different shoulder angles in a standing position. Each subject was shown a video tape of the model who held each pose for 30 seconds. There was a pause of 30 seconds between postures. The subjects viewed a total of four video tapes, each with 18 positions. The order of the video tapes was randomized.

Results for this study show that there was no significant difference in error between the low, medium and high positions. The average perceived angle demonstrated that subjects without prior experience tended to overrate low level positions and underrate high level positions. The average geometric error was -1.3 degrees. In conclusion future studies are recommended to compare the abilities of engineers to non-engineers when estimating body segment angles.

Branton & Grayson (1967) coded subject behavior to detect and quantify the differences in subjects' posture while riding on a train. Two types of seats, soft and firm, were installed to record subjects postural response to difference in support. A numerical system was created for coding static posture. A majority of the coding took place in real time with researchers recording over 5000 real-time observations of 682 female subjects and 818 male. while riding the train with the subjects. The second technique for recording data consisted of filming 18 pre-selected subjects who were recorded continuously throughout the five hour journey. These subjects were instructed to move about the train normally. The cameras were set with a time lapse unit exposing one frame every 10 seconds. After subject data were recorded on film, body posture was coded using the same numerical coding as used on movement coded from real time subjects. High correlations were found between the two techniques.

Branton and Grayson's method for encoding the behavior of seated subjects on the train recorded the subject's use of specific seat features to support the subject's desired posture. A series of numbers coded the subject's use of the headrest, armrests, backrest, and the floor to support the body. This coding method divided the body into the following regions, the head, arms, trunk and legs. All recording was done with respect to time. The Branton and Grayson method recorded only static postures. Movement made while moving from one posture to another was not recorded.

To quantify differences in the subjects' postures, the frequency and duration of the postures were calculated from recorded data. The frequency of use for particular seat features was also calculated. An attempt was made to look at subjective comfort levels in conjunction with subject behavior. Unfortunately there was not enough time to administer all the questionnaires. From the information that was collected Branton and Grayson stated that "the difference in (subject) attitudes (towards the seats) were not as great as the differences in behavior observed."

As shown by the collection of articles presented here, recording and encoding body language is not a new concept, but it has not been frequently used in the scientific investigation of seating comfort. As stated earlier, the purpose of this paper is to develop a method to encode body movement in a meaningful format that will allow for future investigation of sitting comfort.

Methods and Procedures

Methods

Notes from video tapes of sixteen subjects driving an automotive vehicle served as the basis for the development of terms that define information to be encoded from body movement. The following is a list of the boundaries, terms, and some basic insight on the thought process for encoding body movement from video tape.

Two types of movement will be encoded:

a. Movement that occur when the subject alters the environment

1. radio
2. temperature control
3. seat position/steering wheel position

(any time the subject removed his or her hand from a control, a second change in the environment was recorded)

b. Movement that occurs as the subject changes position or posture in the seat independent of a change in the environment.

This movement is further broken down into in-seat movement or out-of-seat movement.

1. Out-of-seat movement is defined as any movement that lifts the body out of the seat.
2. In-the-seat movement is any movement that occurs in the seat:

   a. Pushing the body segment into the seat

b. A movement in which the body stays in contact with the seat, e.g. sliding on the seat or squirming.

If the movement ended in the same posture, but there is no break in the movement then it is counted as one movement. If the movement ended in the same posture but there is a break in the movement, then it will be counted as two movements. Movements made in order to operate the vehicle, such as moving the foot from the gas pedal to the break pedal, are not recorded since they are required of the subject to safely operate the vehicle and thus are fairly uniform for all automotive vehicle operators.

Some changes in posture are very obvious while others are small and/or subtle. Detection of the small, subtle movements can be made by noting changes in background shapes. This is especially true if the subject's clothing contrasts with the interior color of the car. For example if the subject wears dark clothing and the interior of the car is a lighter color this creates a contrast with the dark fabric. By looking for changes in the amount of the lighter background it is possible to tell if movement has occurred.

To study the effects of time on comfort requires that time be recorded in a systematic method:

1. To permanently locate the body movement in the video tape, the frame number is recorded at the first frame that a change in body position occurs.
2. The length of the movement begins as identified in #1 and continues until the subject ceases to move. The time for this event is recorded from the VCR display of internal tape play time.

To study the interaction between the subject and the seat, the first step is to determine which body segments best describe this interaction. Body segments in direct contact with the seat pan and seat back have been selected. These segments are further divided symmetrically into the right and left sides of the body (Figure 3). The body segments are:

1. Right shoulder region
2. Left shoulder region
3. Back
4. Right buttock
5. Left buttock
6. Right thigh
7. Left thigh

The following is a list of information that comes from the encoding process:

1. Segment of the body that moved
2. Side of the body that moved, (right or left)
3. Direction of the movement in a vertical plane or horizontal plane.
4. Time in relation to the drive that the movement occurred
5. Duration of the movement

From this information, one can also calculate the frequency of movement in a particular body segment as well as look for patterns in the data which are created over time. Since this method for recording movement is new, data are needed to test for intra-observer error and inter-observer error.

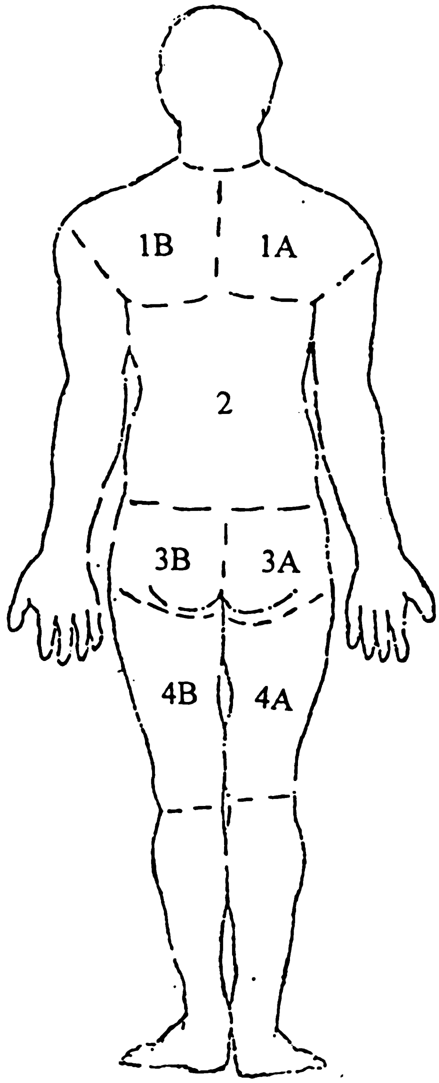

Figure 3. Defined body segments for recording body movement.

To test the method a total of six drives performed by three subjects were viewed in their entirety. The primary observer viewed all the tapes once and then the first drive for each subject was encoded a second time by the primary observer to test for intra-observer error. Only three drive subjects have been selected due to the time involved with viewing and encoding the three hour video tapes of vehicle operators and due to the quality of the tapes. These three subjects each have two complete three hour drives recorded on video tape.

Inter-observer reliability was tested after a second observer is instructed in the encoding method. Instruction consists of viewing two pages of notes that describe the encoding method. For training purposes the second observer viewed two hours of video tape not used in the analysis with the primary observer. The two observers critiqued subject movement and then discussed the method for encoding. To test inter-observer repeatability the second viewer encoded drive tapes of the three subjects. The first and second drive tapes for each of the three selected subjects were viewed individually in their entirety by both observers at separate times.

Procedures

To test the newly developed method previously described, data collected during a fall, 1993 comfort study drive in an on-road automotive vehicle laboratory will be used. Subject body movement was collected continuously throughout the three hour drive in a 1992 mid-sized vehicle with a NEC TI-24A CCD camera fitted with a Fujinon auto-iris 1:1.8/4.8 mm lens. The camera was mounted half way up the right B pillar, (the B pillar supports the roof and separates the front and back door) to completely capture the subject's body movement independent of seat placement. Images collected by the camera were recorded on VHS video tape using a Toshiba video cassette recorder model M-449.

Each subject participated in the three hour, non-stop, test drives which were repeated one week after the first drive to determine the amount of repeatability between the first and second drive. The subjects were paid a flat rate for their efforts after the completion of two drives. Subjects were required to fill out a form indicating their level of physical activity, general health, distance of typical travel in an automotive vehicle, make of their vehicle and it seat features. Before driving, the subjects were informed of the video camera recording their movement continuously during the drive. Subjects were instructed to drive during testing as they would in their own vehicles. Spandex bike shorts/running pants and cotton tank tops were required clothing for all subjects during the test drive so body movements would not be hidden by bulky or loose fitting clothing. It is important to note that subjects had full control over air circulation and temperature controls in the vehicle to help reduce thermal discomfort due to the nature of the clothing and the weather conditions. This also gave subjects a level of control over their environment in a testing situation. None of the subjects complained of any thermal discomfort.

During the drive other data were collected which created an environment different from daily driving. Subjects wore 17 dime sized surface electrodes attached to four major muscle regions on the right and left sides of their necks and backs to measure muscle activity. Nine quarter size reflective targets marked the centers of joint rotation on the right side of the body, along with the right anterior superior iliac spine of the pelvis, the suprasternale and the mesosternum. These targets were photographed periodically throughout the drive by four NEC TI-24A CCD cameras mounted on the right side of the car. The cameras were visible to the subjects, but none of the subjects said they were bothered by their presence. The camera on the right B pillar collected both the anthropometric data and the continuous body movement data throughout the drive. This camera was chosen to use for collecting body movement data for two reasons. First, the image collected by camera four was a straight side view of the body that allowed the observers to determine vertical movement. The other three cameras captured images of the subject at angles and thus did not allow for the observers to determine horizontal movement. Second, camera four completely captured the subject body regardless of subject size or seat position while the other cameras only captured regions determined by the use of video anthropometry. The collection of the video anthropometric images did not interfere with the continuous collection of body movement on video tape. There was no indication from the subjects or in the data that the testing procedures or equipment, such as the cameras altered regular driving habits.

The driver's seat in the test vehicle was a multi-adjustable seat. Once the subject was seated in the car, ride technicians demonstrated the seat controls. The subjects were then asked to operate each control and then adjust the seat to a comfortable position. Subjects were informed that they could move the seat at any time during the drive.

During the drive a ride technician sat in the back seat on the left side and collected data at set intervals with the aid of a 486 computer mounted in the trunk. This did not interrupt the continuous recording of body movement. Subjects indicated that they were not interrupted by the data collection with the exception of the verbal questionnaire. The verbal questionnaire was administered at half hour intervals throughout the drive and required that the subject answer questions asked by the ride technician by speaking into a tape recorder.

Drives of three subjects, two males and one female, have been selected based on the completeness of tapes for both the first and second drive for each subject. A total of 6, three hour tapes were viewed in their entirety and information encoded by the primary observer. A second observer was trained to use the encoding procedures. After training the second observer viewed and encoded the two tapes for each of the three subjects, encoding a total of six video tapes.

As stated earlier, the purpose of this thesis is to further develop a method to encode the body movement of automotive vehicle operators in a meaningful format allowing for further investigation of automotive operator comfort as related to the seat. Tapes of three hour drives will be viewed in their entirety using the developed method to encode the body movement observed on the tapes. Statistical testing for inter and intra observer reliability will be conducted. Based on the information gathered and the results of the analysis, suggestions are made for the future study of body movement as related to the comfort level of the automotive vehicle operator in relation to the seat.

Results

Correlations were performed for drives 009, 025 and 031, each of which was performed by a different driver. Each of these drives were encoded three times and therefore can be checked for both inter and intra-observer reliability. Data were grouped based on the number of movements recorded for each body segment during the entire three hour drive period. The data is ordinal so a Spearman correlation is used. The results are in Tables 1, 2, and 3.

Table 1 Correlation Between Observers for Recorded Body Movement in Drive 009

	Observer 1, Trial 1	Observer 2, Trial 1
Observer 1, Trial 1		
Observer 2, Trial 1	.400	
Observer 1, Trial 2	.927	.444

Table 2 Correlation Between Observers for Recorded Body Movements in Drive 025

	Observer 1, Trial 1	Observer 2, Trial 1
Observer 1, Trial 1		
Observer 2, Trial 1	.438	
Observer 1, Trial 2	.585	.388

Table 3 Correlation Between Observers for Recorded Body Movement in Drive 031

	Observer 1, Trial 1	Observer 2, Trial 1
Observer 1, Trial 1		
Observer 2, Trial 1	.929	
Observer 1, Trial 2	.955	.847

Cumulative frequency graphs show the accumulated movement for each body segment per 15 minute interval. When plotted, (Figures 4, 5 & 6) the results demonstrate that each observation mirrors the other two. These charts represent the total number of movements over time.

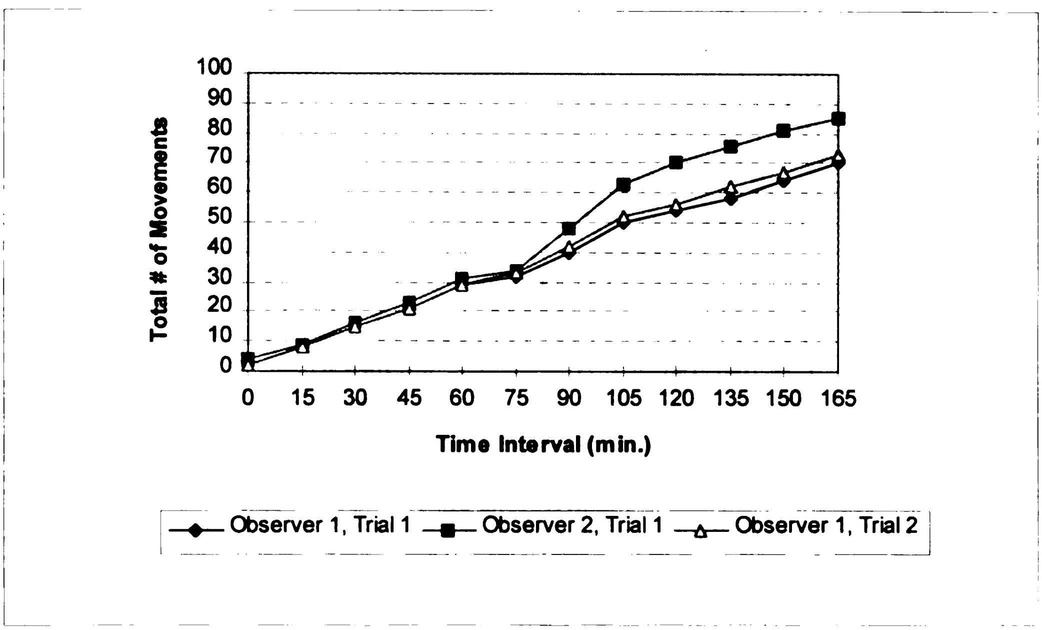

Figure 4. Cumulative frequency chart of subject movement recorded in Drive 009

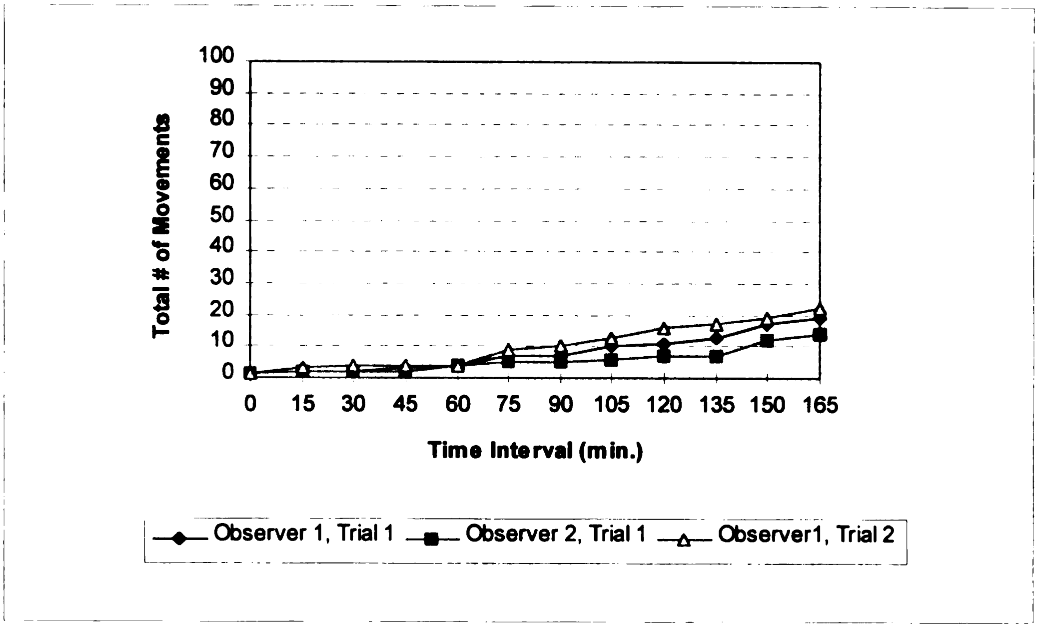

Figure 5. Cumulative frequency chart of subject movement recorded in Drive 025

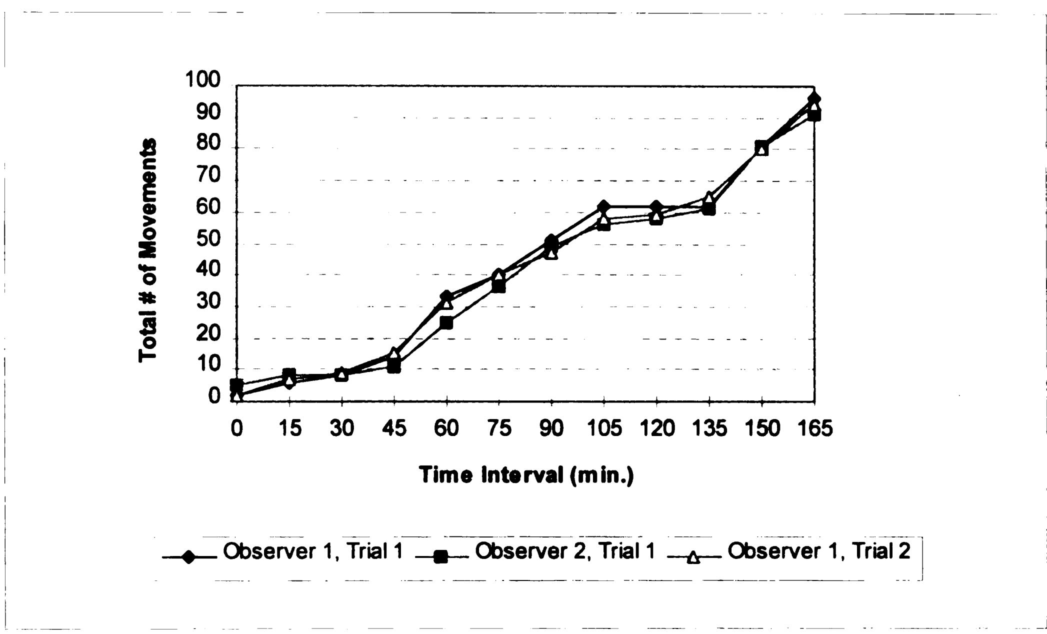

Figure 6. Cumulative frequency chart of subject movement recorded in Drive 031

Body movement charts also show the movement of each body segment in relation to the 15 minute time period as well as the direction of the body movement in relation to the seat, (Figures 7, 8, and 9). For example, any movement that raises the body out or away from the seat is marked above the darkened horizontal line. Movement that pushed the body segment into the seat or slide the segment across the surface of the seat is recorded below the horizontal line. Movement is recorded in the order in which it occurred. For example, movement marked closest to the horizontal line occurred first in the 15 minute time period. Movement furthest away from the line, either above or below the line, was the last to occur in the 15 minute period. Movements made to alter the environment, such as adjusting the heat, were recorded and are shown coded as shades of gray in the second, narrower column.

Legend for Body Movement Charts

1A	=	Right Shoulder	4A	=	Right Thigh
1B	=	Left Shoulder	4B	=	Left Thigh
2	=	Back		=	Thermal Adjustment
3A	=	Right Buttock		=	Radio Adjustment
3B	=	Left Buttock		=	Seat Adjustment

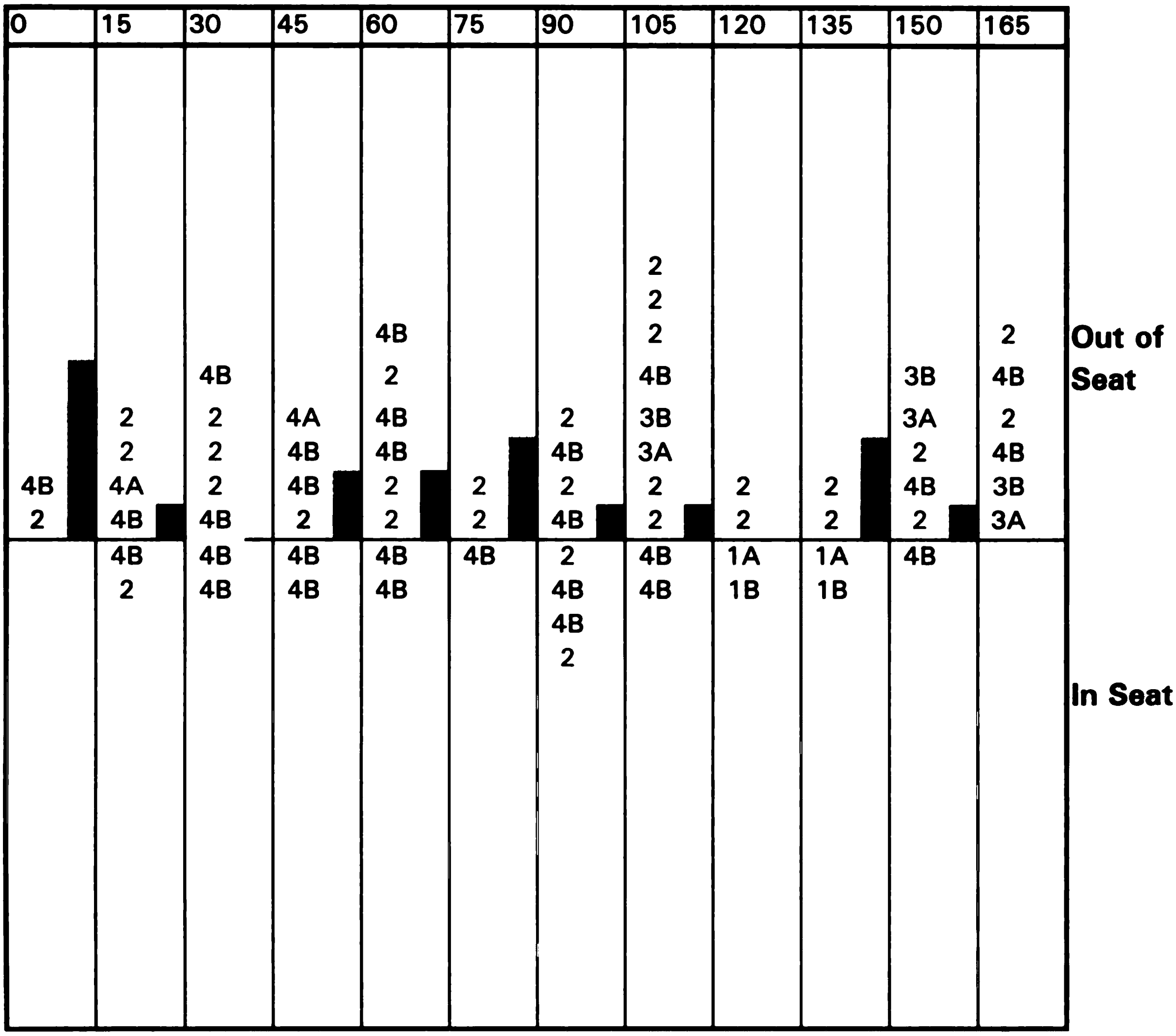

Figure 7. Body movement by body segment over time, Drive 009, Observer 1, Trial 1

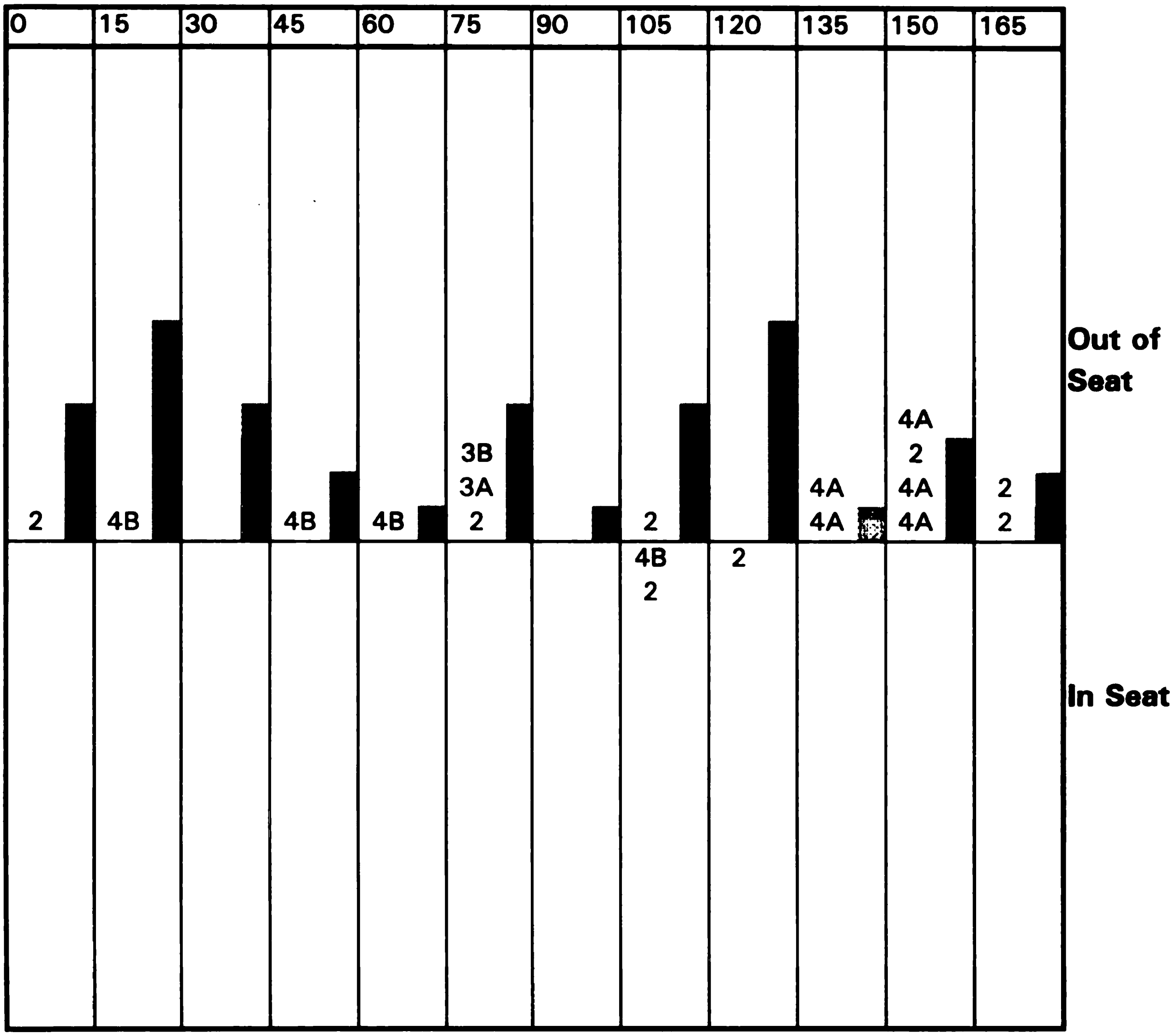

Figure 8. Body movement by body segment over time, Drive 025, Observer 1, Trial 1

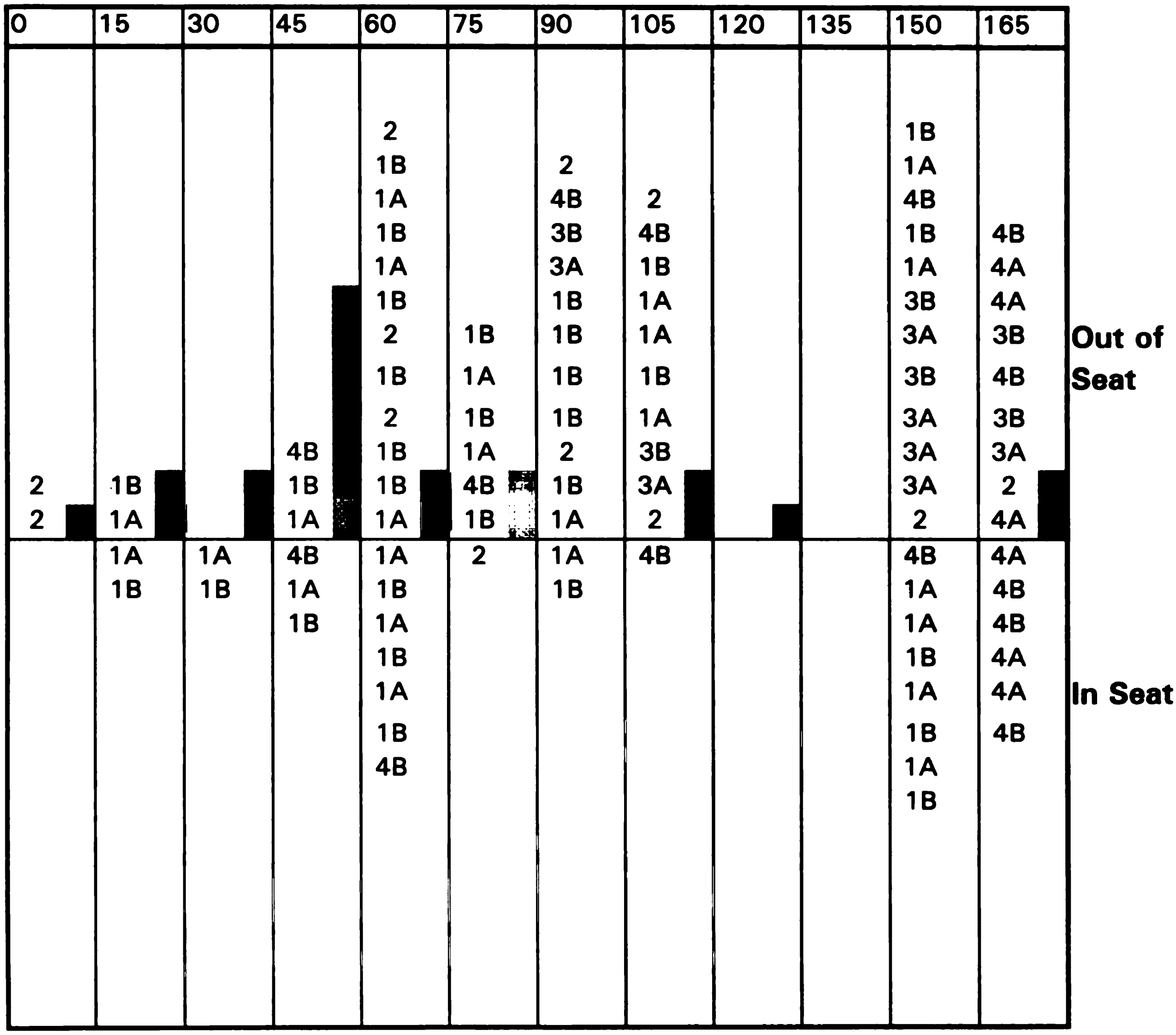

Figure 9. Body movement by body segment over time, Drive 031, Observer 1, Trial 1

Discussion

The purpose of this thesis was to develop a method to encode body movement. An important part of methodology development is to test the reliability of the method. The correlations of the three drives as shown in the results' section are explained here. Only three drives were observed for both inter and intra-observer reliability due to the time intensive encoding process. On average it took the viewer 6 to 8 hours to encode body movement from the video tapes.

The largest difference between the correlations for inter-observer and intra-observer reliability was found in drive 009. The intra-observer correlation was high but the inter-observer correlations were relatively low. Since this was the first of the three drives to be encoded, this suggests the presence of a learning curve for the second observer during the encoding procedure. A higher correlation for the intra-observer reliability is attributed to the fact that the primary observer also developed the method for encoding the data and was thus familiar with the procedure. The average number of body movements recorded in drive 009 was 76. The range of encoded body movements between viewers was 15. It is important to note that most of the difference in the of body movements recorded occurred during the 75 minute to 120 minute period. This difference may be due to observer fatigue.

Drive 025 showed the lowest correlation between both inter-observer and intra-observer reliability. The lower correlations are attributed to the lack of body movement exhibited by the drive subject. The average number of body movements encoded for drive 025 per viewing was 18. The minimum number of body movements encoded was

14 while the maximum number was 21. The low number of total body movements magnifies any difference in the encoding process thus lowering the correlations.

Drive 031 had the highest correlations for both inter-observer and intra-observer reliability. This is due to two factors. First, drive 031 had the highest number of body movements encoded averaging 93 per viewing. Second, the range of recorded body movement was 5, the least of all three drives. Drive 031 was the last drive to be encoded supporting the presence of a learning curving, especially for the second observer.

These correlations suggest inter-observer reliability and intra-observer reliability so the method developed for encoding body movement from video tape is consistent. The method was developed to investigate the type of information that the body movement of a vehicle operator can give in relation to comfort. This information is depicted graphically to show trends and patterns in the data over time. Data used for the correlations are found in the Appendix. When studying the appendix it is important to note the robustness of the data as well as the potential value. From this data comfort profiles establishing a baseline of movement for each subject could be determined.

Cumulative frequency graphs show the number of body movements made by each driver with respect to time. Body movements are grouped into 15 minute increments. This graphical representation shows that each body movement was recorded at relatively the same time by each observer. The graphs also show periods of more intense movement. For example during drive 031 the driver moved the most during the 30 to 45 minute time period and the 135 to 150 minute period. Only the total number of body movements per 15 minute period is presented in this graph. Specific body regions and the direction of the movement are contained in the other graphs.

The time of each body movement in relation to the three hour drive is shown on the cumulative frequency graphs. Time for each body movement was recorded off the VCR. Lack of a set zero when recording the video tape made it difficult for the observers to synchronize time. Constant rewinding of the tape also altered the time according to the VCR by tenths of a second. This may have been due to a stretching of the actual tape. Some differences in the number of movements per 15 minute period may be due to these timing errors. For future encoding a continuous time stamp on each frame of the video tape is recommended. Overall the cumulative frequency graphs show that body movement when recorded with respect to time is consistent between viewers.

The body movement graphs show body movement in relation to the three hour drive. The differences and patterns of movement in the level of body movement changes over time creating a pattern. Body movement is made to maintain a level of comfort, alleviating discomfort. Drive 031 distinctly shows increased levels of movement at the 90 minute and 150 minute interval with no movement in the following two 15 minute time periods. This may indicate that through body movement the subject was able to decrease the level of discomfort leading to periods of comfort which in turn are followed by periods of great amounts of movement towards the end of the drive. These particular charts seem to indicate that comfort levels are not constant but vary over time. This supports the idea that sitting comfort is variable over time. Changes in comfort depicted in the graphs might not be detected with pre- and post- evaluation questionnaires.

Body movement graphs show frequent movement in particular body segments throughout the drive. This might lead to a direct application of the body movement encoding tool. For example, in drive 031, the subject moves the right and left shoulder much more than any other body segment, (see Appendix). High frequencies of movement in the shoulders might indicate a level of discomfort in the shoulders. In the design context of the seat, this would indicate that the current design of the shoulder region in this particular seat aggravated the subject and needs to be studied and possibly redesigned. Recording body movement in this way creates a valuable tool with which seat designers can evaluate prototype seats.

Individual differences are reflected in both sets of graphs. Just as people have different personalities, they also have different thresholds for discomfort which are exhibited over time through different frequencies of movement Discomfort beyond the subject's threshold in situations where the subject is unable to leave the environment is often manifested in movement to minimize the level of discomfort. Through movement, subjects redistribute their weight or change their posture in the seat, attempting to minimize the level of discomfort, possibly obtaining a level of comfort. Differences in personal discomfort thresholds may be due, in part, to body size, level of physical and mental well-being and tolerance of the discomfort sensations. For subject demographics see Table 4. When personal discomfort thresholds are surpassed movement occurs in attempts to change the body's interaction with the seat.

It seems possible to establish a baseline discomfort threshold for an individual. For example, an average of 18 body movements were recorded for the subject on drive

025 while an average of 76 body movements were recorded during drive 009. Drive 031 averaged 94 body movements during the three hour period. This does not necessarily mean that the subject in drive 031 experienced the highest level of discomfort. Instead, the high number of movements might indicate that this subject moves frequently, even when comfortable. Further investigation of body movement includes establishing a baseline of movement for each subject in a comfortable environment. Movement above the baseline would then be attributed to levels of discomfort. This information would be especially valuable for comparison studies of seats.

Table 4 Demographics of the drive subjects.

	Sub. 1, Drive 009	**Sub. 2, Drive 025**	**Sub. 3, Drive 031**
Sex	Male	Male	Female
Age	26	22	43
Stature	173.4 cm	177.5 cm	159.2 cm
Weight	80.8 kg	75.4 kg	51.9 kg

Future Study

Recommendations for future study include tracking and correlating changes in seat position with body movement. Seat position was recorded in this study, but due to the absence of a set zero time mark for both the body movement data and the seat position data there was no way in which to accurately relate the two. The addition of seat position data adds a third dimension to determining comfort levels through the body movement of a subject. A change in seat position changes the position of the body as well, thus creating body movement. By changing seat position, an immediate environmental element that the subject is reacting to is also altered. Changes in seat position could affect the frequency and range of movement as well as the body segment moved. Thus one could study patterns of change in the position of the seat in relation to body movement. Perhaps altering the environment decreases the level of discomfort experienced by the subject.

Future studies of body movement should also include other measures of movement and discomfort such as pressure mats and questionnaires. Pressure data gathered from pressure mats in the seat could be collected continuously. High peak pressures indicate that body mass is not well distributed in the seat pan causing discomfort in the high peak areas. Low peak pressures with well distributed body mass usually indicate a more comfortable seat. Pressure data would show changes in pressure distribution caused by body movement. Pressure data also picks up slight changes in pressure distribution caused by subtle movement that can not be detected by the human eye. Recording changes in pressure should allow for a direct comparison with body movement as encoded by humans provided a mutual start time is defined. If successful, pressure could possibly enhance body movement data by detecting shifts in weight from movement that is too small to be noticed on video tape.

Encoding body movement from the video is time consuming and expensive. Future plans for the study of body movement include converting the method developed in this study to a computer program to make the encoding process less time consuming and less expensive. Computerizing the encoding process changes the evaluation of the movement as encoded by humans in two ways. First, the accuracy in the detection of movement frequency will be improved by automating the system, thus removing human error. The length of the tapes often causes viewer fatigue which affects the accuracy of the encodement. Second, judgments made intuitively by humans about movement detected in the video tapes might be lost in the conversion to automation by computer. For example light levels in the car change continuously due to weather conditions, position of the sun and direction of travel. Humans are able to distinguish changing shadows from human movement. Currently computer vision is not powerful enough to distinguish the difference. Changes of scenery in the windows might also be confused as body movement by the computer. These problems might by solved by tinting the windows or adding more light to the interior.

Though specifically designed to encode the vehicle operator, the method described in this paper could be adapted to other long term seated tasks. This method tracks continuous movement over long periods of time, so with modification it could be used for evaluating long term sitting required for such tasks such as data entry or word processing.

Analyzing long periods of nonverbal behavior is time and labor intensive, time constraints did not allow for a large enough sample size for more sophisticated statistical analysis. Further statistical testing should be conducted to better understand the body movement data prior to creating computer applications for encoding body movement.

Conclusion

The main objective of this study was to determine if encoded body movement of the vehicle operator would provide information regarding comfort. The first step was the development of a reliable method to encode body movement from video tape over long periods of time. The use of two observers demonstrated reliability of the method. Both cumulative frequency graphs and body movement graphs show interesting patterns of movement. These patterns suggest that comfort does change over time. When body movement can be encoded with less effort, the result will be objective data that can be quantitatively analyzed to further understand the changes in comfort experienced during long term seating.

Appendix

Body movement as recorded by each observer with respect to body segment and time.

Table 5 Body Movement Recorded by Observer 1, Trial 1, for Drive 009

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			1				1	2
15			3			1	2	6
30			3				4	7
45			1			1	4	6
60			3				5	8
75			2			1		3
90			4				4	8
105			5	1	1		3	10
120	1	1	2					4
135	1	1	2					4
150			2	1	1		2	6
165			2	1	1		2	6
	2	2	30	3	3	3	27	70

Table 6 Body Movement Recorded by Observer 2, Trial 1, for Drive 009

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			2				2	4
15			3				2	5
30			3				4	7
45			1			1	5	7
60			5				3	8
75			3					3
90	2	2	7				3	14
105			13				2	15
120	1	1	4				1	7
135			4				2	6
150			3				2	5
165			2				2	4
	3	3	50	0	0	1	28	85

Table 7 Body Movement Recorded by Observer 1, Trial 2, for Drive 009

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			1				1	2
15			3			1	2	6
30			3				4	7
45			1			1	4	6
60			3				5	8
75			2				2	4
90			4			1	4	9
105			6			1	3	10
120	1	1	2					4
135			5				1	6
150			2	1	1		1	5
165			2	1	1		2	6
	1	1	34	2	2	4	29	73

Table 8 Body Movement Recorded by Observer 1, Trial 1, for Drive 025

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			1					1
15							1	1
30								0
45							1	1
60							1	1
75			1	1	1			3
90								0
105			2				1	3
120			1					1
135						2		2
150			1			3		4
165			2					2
	0	0	8	1	1	5	4	19

Table 9 Body Movement Recorded by Observer 2, Trial 1, for Drive 025

Time	Right Shoulder	Left Shoulder	Back	Right I	Left I	Right Thigh	Left Thigh	Totals
0			1					1
15			1					1
30								0
45								0
60							2	2
75			1					1
90								0
105			1					1
120			1					1
135								0
150	1		3		1			5
165			2					2
	1	0	10	0	1	0	2	14

Table 10 Body Movement Recorded by Observer 1, Trial 2, for Drive 025

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			1					1
15						1	1	2
30							1	1
45								0
60								0
75	1	1	1		1	1		5
90						1		1
105			2			1		3
120	1	1	1					3
135						1		1
150			1			1		2
165			2			1		3
	2	2	8	0	1	7	2	22

Table 11 Body Movement Recorded by Observer 1, Trial 1, for Drive 031

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			2					2
15	2	2						4
30	1	1						2
45	2	2					2	6
60	6	9	3				1	19
75	2	3	1				1	7
90	2	4	2	1	1		1	11
105	3	2	2	1	1		2	11
120								0
135								0
150	6	5	1	4	1		2	19
165			1	1	2	6	5	15
	24	28	12	7	5	6	14	96

Table 12 Body Movement Recorded by Observer 2, Trial 1, for Drive 031

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			5					5
15	1	1					1	3
30								0
45	1		1				1	3
60	4	5	3				2	14
75	4	6					1	11
90	3	4	4	1	1			13
105	1	1	1	1	1		2	7
120						2		2
135			1				2	3
150	5	4	1	5	3		2	20
165			2	1	1	3	3	10
	19	21	18	8	6	5	14	91

Table 13 Body Movement Recorded by Observer 1, Trial 2, for Drive 031

Time	Right Shoulder	Left Shoulder	Back	Right Buttock	Left Buttock	Right Thigh	Left Thigh	Totals
0			2					2
15	2	2				1		5
30	1	1						2
45	2	2					2	6
60	5	6	3			1	1	16
75	4	4					1	9
90	1	2	1	1	1		1	7
105	3	2	2	1	1		2	11
120						1		1
135	1	1	1			1	2	6
150	4	3	1	4	1		2	15
165			1	1	2	6	4	14
	23	23	11	7	5	10	15	94

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