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FATIGUE AND RECOVERY PATTERNS OF THE MOUTH MUSCLES USED TO PLAY THE CLARINET

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David E. Belcher
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FATIGUE AND RECOVERY PATTERNS IN THE MOUTH MUSCLES USED TO PLAY THE CLARINET

A Document APPROVED FOR THE
SCHOOL OF MUSIC

Dr. David Etheridge

Dr. Valerie Watts

Dr. Roland Barrett

Dr. Michael Lee

Dr. Roy Knapp

Dr. Michael Bemben

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FATIGUE AND RECOVERY PATTERNS IN THE MOUTH

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I. INTRODUCTION

Purpose of the Study

Although sport-science researchers have done much exploration in the area of fatigue and recovery of muscles, musicians have largely failed to apply these findings to their own physically demanding activities. Fatigue and more serious medical problems such as TMJ dysfunction, focal dystonia, and carpel tunnel syndrome can and do result from the demanding rehearsal schedules imposed on performers by teachers, conductors, and themselves. Athletes are aware that a rest/recovery period after a workout is necessary for optimal gains in strength and endurance and to prevent injury. Because of research in the field of sport science, athletic training protocols also call for tapering of strenuous workouts prior to the need for peak performance on “game day.” Musicians, however, often do not follow these same principles when preparing for a performance. Musicians often practice every day, often at the recommendation of a trusted teacher, and never take a day to allow the muscles involved in playing their instrument to rest and recover. Rehearsal schedules often become more intense and rigorous prior to a public performance. This often results in musicians suffering from fatigue which detracts from the quality of their performances or, more seriously, suffering from the previously mentioned medical problems.

For this study the fatigue and recovery patterns of one particular mouth muscle, the orbicularis oris, used while playing the clarinet was studied by using the Biopac MP 150 EMG system with non-invasive surface electrodes. Although several muscles are activated in the formation of a clarinet embouchure with the buccinator being perhaps the most active, the orbicularis oris is joined to the buccinator and is the most readily available for monitoring with non-invasive surface electrodes.[1] The purpose of this study was to examine how and when these muscles fatigue during performance, and how a period of rest affects muscle endurance.

The benefits of performing this research lie in the importance of improving clarinet pedagogy and performance. Understanding how the muscles used to play the clarinet fatigue and recover will lead to the development of rehearsal schedules with appropriate amounts of rest and will result in fewer overuse injuries, quicker gains in endurance, and increased quality of performance.

Limitations

Any instrumentalist engages in many complex physiological processes while playing his instrument. For the wind instrumentalist, these processes include the use of the arms, breathing apparatus, the fine motor control and training of the fingers, and several muscle groups involved in forming the embouchure specific to each instrument and player. Although a detailed study could be devoted to each of these areas, this study will focus on only the fatigue and recovery of one muscle group in

[1] James A. Howard and Anthony T. Lovrovich, "Wind Instruments: Their Interplay with Orofacial Structures," *Medical Problems of Performing Artists* 4 (June 1989): 60.

the clarinet embouchure because “the lips are more vulnerable to injury and fatigue than any part of the body used by the clarinetist.”[2]

Need for the Study

Ever increasing performance standards for instrumentalists place comparably increasing demands for practice and rehearsal. One result is an increasing occurrence of overuse syndromes like carpel tunnel, TMJ dysfunction, and focal dystonia. This problem calls for a more efficient and safer means to obtain high performance standards. Woodwind instrumentalists are often faced with demands of versatility of performance with more than one instrument. Although it is impractical for a musician to maintain the highest performance standards on more than one instrument at all times, the woodwind instrumentalist is often required to “double,” or play an additional contrasting instrument in performance. These demands often make it necessary for the woodwind instrumentalist to bring his performance abilities with the auxiliary instrument to an appropriate level quickly and efficiently.

Musicians often compare themselves to athletes, but this comparison is most often with respect to the mental aspects of performance. The book, *The Inner Game of Music*, for example, was modeled after a sport-related book with a similar title.[3] Both books deal with the mental aspects of performance. Although there has been some work in the area of sport science applied to musical training such as “Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet

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[2] Heston L. Wilson, “Lips,” *The Clarinet* 27 (September 2000):38.

[3] Barry Green with W. Timothy Gallwey, *The Inner Game of Music* (New York: Doubleday, 1986).

Embouchure Development," woodwind musicians have largely ignored the sport-science principles used to train athletes efficiently.[4] A small sample of recent sport-science includes: "Recovery Strategies for Sports Performance," and "Overtraining Syndrome: A Guide to Diagnosis, Treatment, and Prevention," and "Recovery - Adaptation: Strength and Power Sports," and "Proper Recovery - Ways to Avoid Fatigue."[5]

Although the areas of fatigue and recovery have largely been ignored by musicians, there has been some research involving electromyography to study activity in the muscles used in musical performance: *An Electromyographic Study of Preparatory Set in Singing as Influenced by the Alexander Technique*, *The Effect of Electromyographic Biofeedback Training on Singers with Tension Problems in the Laryngeal Musculature*, *A Spectrographic and Electromyographic Investigation of the Relationship of the Effects of Selected Parameters Upon Concurrent Study of Voice and Oboe*, *An Electromyographic Examination of Wrist Motion While Executing Selected Drumstick Techniques with Matched Grip*, *The Effects of Electromyographic Training on Violoncello Performance: Tone Quality and Muscle Tension*, *Electromyographic Investigation of Abdominal Musculature during*

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[4] John O. Pursell, "Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet Embouchure Development," *ITG Journal* 24 (March 2000).

[5] A. Calder "Recovery Strategies for Sports Performance," *Olympic Coach* 15 (Summer 2003); C. J. Hawley and R. B. Schoene, "Overtraining Syndrome: A Guide to Diagnosis, Treatment, and Prevention," *Physician and Sportsmedicine* 31(June 2003); M. H. Stone, and M. E. Stone, "Recovery-Adaptation: Strength and Power Sports," *Olympic Coach* 15 (Summer 2003); J. Turner and M. Byrne. "Proper Recovery – Ways to Avoid Fatigue and Overtraining," *Performance Conditioning Soccer* 9 (2003).

Measured Active Expiration, and *An Electromyographic Investigation of the Relationship Between Abdominal Muscular Effort, and Rate of Vocal Vibrato* [6]

A limited number of studies involving electromyography and the clarinet embouchure also exist: *An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed Through Electromyography* and *The Activity of Certain Facial Muscles in the B-flat Soprano Clarinet Embouchure: An Exploratory Study Utilizing Electromyography*.[7] These studies provide a basis for an exploration of the clarinet embouchure using electromyography, but none of them deal specifically with fatigue and recovery.

Design and Procedures

This research was approved by The University of Oklahoma Office of Human Research Participation Protection (see appendix IV).

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[6] Robert James Englehart, *An Electromyographic Study of Preparatory Set in Singing as Influencd by the Alexander Technique*, Ph.D. diss. (Ohio State University, 1989); Thomas Edwin Garrison, *The Effect of Electromyographic Biofeedback Training on Singers with Tension Problems in the Laryngeal Musculature,* D.A. diss. Ball State University, 1978 (Ann Arbor, Michigan: University Microfilms, 1978); Claude Washington Gossett, Jr., *A Spectrographic and Electromyographic Investigation of the Relationship of the Effects of Selected Parameters Upon Concurrent Study of Voice and Oboe,* Ph.D. diss. University of Southern Mississippi, 1977 (Ann Arbor, Michigan: University Microfilms, 1977); Todd Alan Johnson, *An Electromyographic Examination of Wrist Motion While Executing Selected Drumstick Techniques with Matched Grip*, D.M.A. diss. (The University of Oklahoma, 1999); James Martin Kjelland, *The Effects of Electromyographic Biofeedback Training on Violoncello Performance: Tone Quality and Muscle Tension*, Ph.D. diss. The University of Texas at Austin, 1985 (Ann Arbor, Michigan: University Microfilms, 1987); Ken Doty Peterson, *Electromyographic Investigation of Abdominal Musculature during Measured Active Expiration*, D.A. diss. (University of Northern Colorado, 2001); Ethel Closson Smith, *An Electromyographic Investigation of the Relationship Between Abdominal Muscular Effort and Rate of Vocal Vibrato*, D.M. diss. Indiana University, 1967 (Ann Arbor, Michigan: University Microfilms, 1969).

[7] Campbell, Bonnie Heather, *An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed Through Electromyography* D. M. diss. Indiana University, 1999 (Ann Arbor, Michigan: University Microfilms, 2000); William Jackson Newton, *The Activity of Certain Facial Muscles in the B-Flat Soprano Clarinet Embouchure: An Exploratory Study Utilizing Electromyography* Ed.D. diss. University of North Texas, 1972 (Ann Arbor, Michigan: University Microfilms, 1972).

The subject pool consisted of nine subjects, four men and five women. This limited number of subjects is reasonable based on two factors. Previous related studies used a similar number of subjects. Bonnie Heather Campbell in her study, "An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed through Electromyography," used ten subjects.[8] In the study, "The Activity of Certain Facial Muscles in the B-Flat Soprano Clarinet Embouchure: An Exploratory Study Utilizing Electromyography," William Newton Jackson used twelve subjects.[9] Todd Alan Johnson used nine subjects in his study, "An Electromyographic Examination of Wrist Motion While Executing Selected Drumstick Techniques with Matched Grip."[10] A. W. Kelman and S. Gatehouse studied the electromyographic activity of the orbicularis oris in a study involving phonetics, and they used only two subjects.[11] A study conducted by Frank Heuser and Jill McNitt-Gray concerning trumpet players with asymmetrical mouthpiece placement used eight subjects.[12] Finally, because of the large volume of data generated by each subject, it was impractical to use a larger number of subjects.

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[8] Campbell, Bonnie Heather, *An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed Through Electromyography* D. M. diss. Indiana University, 1999 (Ann Arbor, Michigan: University Microfilms, 2000): 6.

[9] William Jackson Newton, *The Activity of Certain Facial Muscles in the B-Flat Soprano Clarinet Embouchure: An Exploratory Study Utilizing Electromyography* Ed.D. diss. University of North Texas, 1972 (Ann Arbor, Michigan: University Microfilms, 1972): 33.

[10] Todd Alan Johnson, *An Electromyographic Examination of Wrist Motion While Executing Selected Drumstick Techniques With Matched Grip* D. M. A. diss. The University of Oklahoma, 1999, 60.

[11] A. W. Kelman and S. Gatehouse, "A Study of the Electromyographic Activity of the Musculus Orbicularis Oris," *Folia Phoniatrica* 27 (1975): 353.

[12] Frank Heuser and Jill L. McNitt-Gray, "EMG Pattern in Embouchure Muscles of Trumpet Players with Asymmetrical Mouthpiece Placement," *Medical Problems of Performing Artists* 8 (September 1993): 97.

The subjects were all clarinetists recruited from the University of Oklahoma-Norman Campus. The subjects were selected from the clarinet studio at The University of Oklahoma and were not involved in a teacher/student relationship with the researcher. All subjects were informed of risk, which was limited to some discomfort associated with an intense playing session, and protocol before the start of the testing, and they all signed an informed consent form (see appendix I).

Because the orbicularis is a small muscle, it demanded special attention in the selection of electrodes. Fine wire indwelling or needle electrodes were an option, but because they are invasive, they are unattractive to clarinetists. Surface electrodes are non-invasive and pose no threat to the delicate muscles of the embouchure. Surface electrodes are also superior to fine wire electrodes when activity of the entire muscle is a concern because the fine wire electrodes only provide data from a limited number of motor units, and fine wire electrodes demonstrate a greater intrasubject variability.[13] In early trials the commonly used self-adhesive electrodes were too large and did not keep positive contact with the skin. A. W. Kelman and S. Gatehouse studied the orbicularis oris with respect to phonetics, and they used "silver/silver chloride cup electrodes (having a 5-mm active diameter.)"[14] The decision to use the same type of electrodes was confirmed by the Biopac Product Specialist, Elie Braun. Before use a self-adhesive collar was placed on each electrode

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[13] Frank Heuser and Jill L. McNitt-Gray, "EMG Pattern in Embouchure Muscles of Trumpet Players with Asymmetrical Mouthpiece Placement," *Medical Problems of Performing Artists* 8 (September 1993): 98.

[14] A. W. Kelman and S. Gatehouse, "A Study of the Electromyographic Activity of the Musculus Orbicularis Oris," *Folia Phoniatrica* 27 (1975): 351.

so that they would adhere to the skin, and the electrode cups were filled with conductive gel.

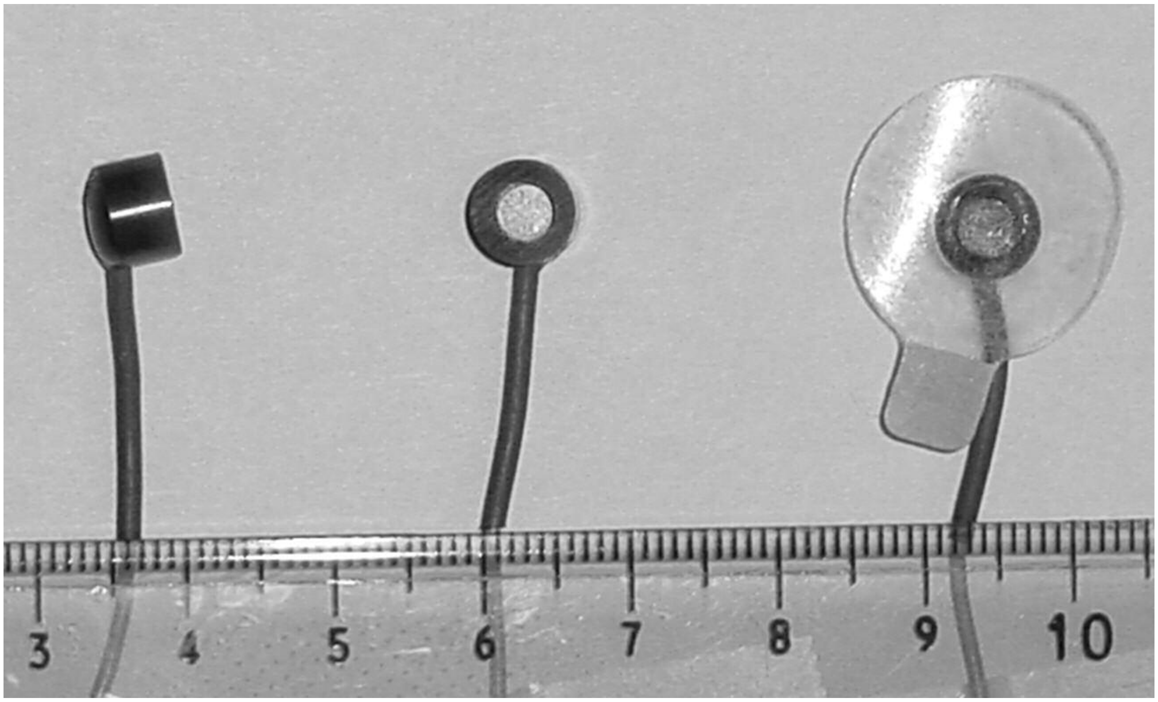

Figure 1: Side view of electrode, electrode with conductive disc facing up, electrode outfitted with adhesive collar. (Scale in centimeters)

The experimental testing for each subject occurred on three days, with at least two days of rest (no clarinet playing) between the second and third day of testing. The number of test days was limited to three because a trained adaptation effect would likely occur in the subjects if they were tested on more days. Each subject was asked to play the clarinet in individual practice, ensemble rehearsal, or performance ten to twenty hours during the week prior to testing. This playing schedule is consistent with the normal amount of playing for a college clarinetist and was necessary to insure that all subjects were in a commensurate state of fatigue for the first day of testing. Prior to the first testing session, each subject was asked to respond to a questionnaire (see appendix II) concerning their playing schedules and the types of musical tasks that they find particularly fatiguing. On each day of testing the subject's skin was prepared with alcohol to reduce impedance, and the EMG electrodes were placed over the appropriate muscles of the subject's mouth (the left and right upper orbicularis oris which surround the mouth like a ring) at a distance of 1 cm. Grounding surface electrodes were placed on the subject's forehead.

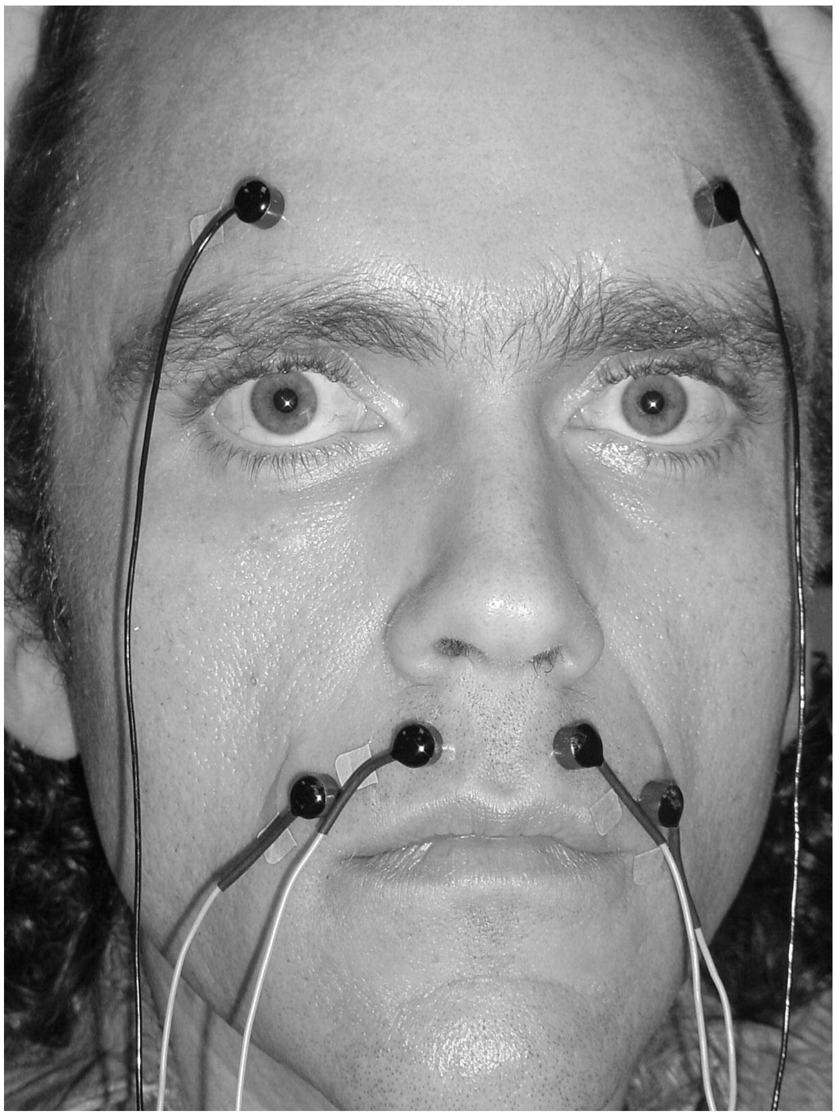

Figure 2: Arrangement of electrodes on a test subject.

Subjects were allowed to perform a playing warm-up to become accustomed to the electrodes and to make certain that their instruments were in working order. They were then asked to play a 25 minute musical exercise. This exercise consisted of the first several pages of*Practical Study of the Scales for the Clarinet* by Émile Stiévenard with the rests omitted and breaths marked every twelve to sixteen beats. The subjects were asked to play with a metronome set at sixty beats per minute and to define the eighth note as the beat unit throughout the test period. Because of the omission of rests, the controlled slow tempo, and the limited number of breaths, this was a physically demanding exercise. The EMG activity of the mouth muscles and the changes therein were measured and recorded with the Biopac MP 150 system. Because of the large amount of data involved with the 25 minute testing period, The Biopac MP 150's data acquisition software (AcqKnowledge 3.7.3, Biopac Systems, Goleta, California) was set to record only the first 10 seconds of data from every 50 second interval. This resulted in 30 trials across each day of testing. The subject's musical performance was recorded using an Audio-Technica AT822 stereo microphone with a Superscope PSD300 CD recording system. This recordingwas reviewed for loss of tone quality. The quality of musical tone and the loss therein are highly subjective. However, the presence of the hiss associated with clarinetists not being able to maintain an air seal with the embouchure is one objective indicator of a compromised tone, and the hiss caused by air leaks in the embouchure was monitored as an indicator of loss of tone quality. The recordings were also used to monitor when and how frequently pauses were made by the performer. These pauses, which were not indicated in the music, were also used as an indicator of fatigue. On the second day of testing the subjects were, again, outfitted with the electrodes, allowed to warm-up, and asked to play the musical exercise. The subjects were asked to refrain from playing clarinet for two days and return after this rest period for the third day of testing. The procedure for the third day of testing was the same as the first two. After each test session each subject was asked several questions regarding their self-perceived level of fatigue and how they felt their tone quality changed during the test session.

After testing was complete, the data from the three testing sessions for each subject was analyzed with respect to the following questions: When did fatigue occur in each day? Were subjects more fatigued after the second day of testing? Did the period of rest improve endurance? Was there a discernable difference in tone quality associated with fatigue? The answers to these questions with information gathered from sport-science research were used to synthesize a science based protocol for creating a training program which develops embouchure endurance in the clarinetist.

Explanation of Relevant Terms

Embouchure: Keith Stein, a prominent clarinet teacher defined clarinet embouchure as:

> Embouchure concerns the manner of holding the lips and associated flesh around the mouthpiece to effect a seal. More importantly, the embouchure (aided by the breath) controls the many varied tone colorings, pitch changes, degrees of tonal strength, and nuances – all by delicate fluctuations of lip pressure against the reed.[15]

[15] Keith Stein, "The Stein Corner," *The Clarinet* 7 (Fall 1979): 27

There are two basic types of clarinet embouchure in common usage, the single-lip and double-lip embouchures. In his article, "Trends in Clarinet Embouchures," John Graulty gave these descriptions of single-lip and double lip clarinet embouchures:

> There are two fundamental clarinet embouchures and in both the lower lip covers the biting edge of the bottom teeth. In a single-lip embouchure the top teeth touch the top of the mouthpiece, whereas for a double-lip embouchure the top lip tucks in between the top teeth and the top of the mouthpiece, duplicating the bottom lip's position.[16]

Graulty surveyed 347 college clarinet teachers and symphony orchestra clarinetists as to their use of single-lip embouchure or double-lip embouchure, and 75 percent said that they preferred the single-lip embouchure, 10 percent favored the double-lip embouchure and 15 percent switch back and forth between the two.[17]

Orbicularis oris: The orbicularis oris is a complicated, multi layered muscle of the lips. The fibers of the orbicularis oris run in many directions but most run circularly around the mouth. It inserts into muscles and skin around the mouth, and functions to close, purse, and protrude lips. It is the kissing and whistling muscle.[18] Although the orbicularis oris can be considered anatomically as a single unit (a sphincter muscle surrounding the oral orifice), functionally the lips must be considered as two separate muscles, the orbicularis oris superioris (the upper lip) and the orbicularis oris inferioris (the lower lip) because there are fewer fibers in the corners of the mouth.[19] In addition, the majority of the fibers in the upper and lower

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[16] John Graulty, "Trends in Clarinet Embouchures," *The Instrumentalist* 44 (April 1990): 50.

[17] Ibid.

[18] Elaine N. Marieb, *Human Anatomy & Physiology* 5th ed. (San Francisco: Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated, 2001), 334.

portions of the orbicularis oris are confined to one side, interlacing at the midline with the fibers of the other side.[20]

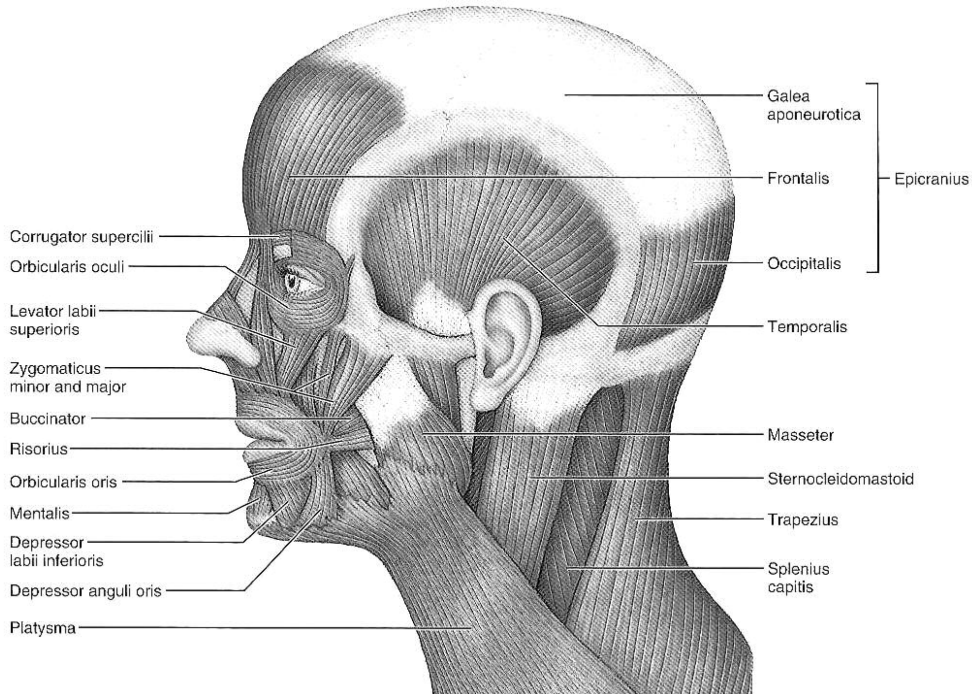

Figure 3: Lateral view of the muscles of the scalp, face, and neck.[21]

Overuse: Overuse can be defined as, "symptoms associated with activity that exceeds the biological limits of the tissue involved."[22]

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[19] Elmer R. White and John V. Basmajian, "Electromyographic Analysis of Embouchure Muscle Function in Trumpet Playing," *Journal of Research in Music Education* 22 (Winter 1974): 299.

[20] William Jackson Newton, *The Activity of Certain Facial Muscles in the B-Flat Soprano Clarinet Embouchure: An Exploratory Study Utilizing Electromyography* Ed.D. diss. University of North Texas, 1972 (Ann Arbor, Michigan: University Microfilms, 1972): 6.

[21] Elaine N. Marieb, *Human Anatomy & Physiology* 5th ed. (San Francisco: Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated, 2001), 335. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

[22] James A. Howard and Anthony T. Lovrovich, "Wind Instruments: Their Interplay with Orofacial Structures," *Medical Problems of Performing Artists* 4 (June 1989): 64.

TMJ: TMJ is the commonly used abbreviation for temporomandibular joint. TMJ is also commonly used to refer to dysfunction of this joint. Ron Odrich, a clarinetist and dentist described this joint:

> The temporomandibular joint is a complicated apparatus where the lower jaw articulates with the upper jaw. It is located just in front of your ear. Put your finger there and slowly open and close your mouth. What you feel is the head of the lower jaw joint sliding from the "fossa," the socket in which it sits, over a sloping surface as it glides forward.
>
> This slope, a part of the skull, angles downward and forward. The lower jaw slides over it as the chin is brought downward. The lower jaw, the mandible, slides forward by means of muscles, which pull its articulating part over the slope. The part that glides over this slope is shaped more or less like a small egg **–** it is called the "head of the condyle." Interposed between the condylar head and the slope is a cartilage disc. The disc is kept in place between the head of the condyle and the slope by its own set of muscles, which coordinate with the muscles of the jaw opening. That coordination ensures a smooth comfortable "ride" when opening your mouth.[23]

The dysfunction of this joint, called TMJ dysfunction or TMD or TMJ, in clarinet players often comes from players, usually those who have an overbite, who force their lower jaw forward into a strained, unnatural position to meet the reed. This strained position causes the muscles to spasm if the position is held too long, and coordination of the joint will no longer be possible, leading to pain.[24]

Focal Dystonia: Focal dystonia can be defined as, "a syndrome of sustained muscle contractions, frequently causing twisting and repetitive movements, or abnormal posture. In musicians, dystonia is usually confined to the hand or arm or to the muscles of embouchure, often experienced only with certain activities."[25] Focal Dystonia, also known as occupational cramp, is a mysterious problem with much

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[23] Ronald B. Odrich, "Claridontology," *The Clarinet* 26 (September 1999): 26.

[24] Ibid.

[25] Stephan Schule and Richard J. Lederman. "Focal Dystonia in Woodwind Instrumentalist: Long-term Outcome," *Medical Problems of Performing Artists* 18 (March 2003): 15.

controversy related to its diagnoses, treatment, and specific causes. Possible causes are genetics and overuse.[26]

Tapering: Tapering, "a technique widely used in a variety of sports and is perhaps the most critical phase of an athlete's preparation for competition," is the systematic reduction of training intensity prior to an event where peak performance is desired.[27] Athletic coaches are widely aware that performance can be increased if athletes are trained close to the point of overtraining and then allowed to recover by gradually reducing the training intensity.[28]

Anatomy of Skeletal Muscle: There are three basic types of muscle tissue in the human body: skeletal muscle, cardiac muscle and smooth muscle. Cardiac and smooth muscle tissues are involuntary (they are not subject to conscious control) and are found in the heart and in the walls of the hollow internal organs respectively. Skeletal muscle is the tissue of concern for the present study. Skeletal muscle tissues are attached to bone or, as in the case of the orbicularis oris, to surrounding tissue, and are controlled consciously. All skeletal muscles have a similar anatomy and are subject to the same physiological and chemical processes for their functioning.[29]

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[26] Frank R. Wilson, "Current Controversies on the Origin, Diagnosis and Management of Focal Dystonia in Musicians," in *International Dystonia On-line Support Group Website:* available at http://www.dystonia-support.org/LA-Focal%20Dystonia%20in%20Musicians.htm, Accessed 13 September 2004.

[27] Sue L. Hooper, Laurel T. Mackinnon, and Alf Howard, "Physiological and Psychometric Variables for Monitoring Recovery during Tapering for Major Competition," *Medicine and Science in Sports and Exerc*ise 31 (August 1999): 1205.

[28] Ibid.

[29] Elaine N. Marieb, *Human Anatomy & Physiology* 5th ed. (San Francisco: Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated , 2001), 277.

Each skeletal muscle is a discrete organ, made up of several types of tissue and can be considered a bundle of groupings of fibers each with its own outer wrapping. The largest structure, the muscle itself, is wrapped in a tissue called the epimysium that blends with surrounding tissue such as tendons and the epimysium of other muscles. Within this larger structure, there are hundreds to thousands of fibers gathered in bundles which are known as fascicles.[30]

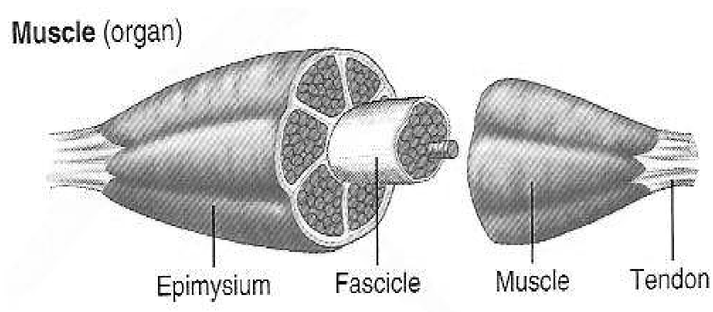

Figure 4: Diagram of muscle.[31]

These fascicles are grouped together by a covering called perimysium. Each fascicle is a bundle of the individual muscle fibers which are individual, multinucleated cells, and each fiber is wrapped in its cell membrane called the sarcolemma and covered by a fine sheath of connective tissue known as the endomysium.[32]

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[30] Ibid., 278.

[31] Ibid., 282. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

[32] Ibid., 278.

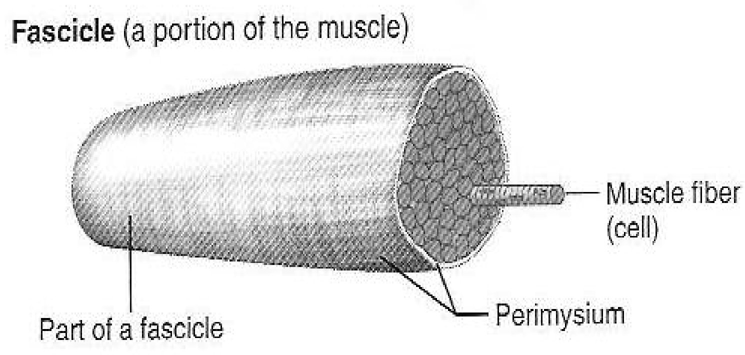

Figure 5: Diagram of fascicle.[33]

On the microscopic level each muscle fiber contains a large number (hundreds to thousands) of myofibrils which run parallel to each other, extend the entire length of the cell, and have a banded appearance.[34]

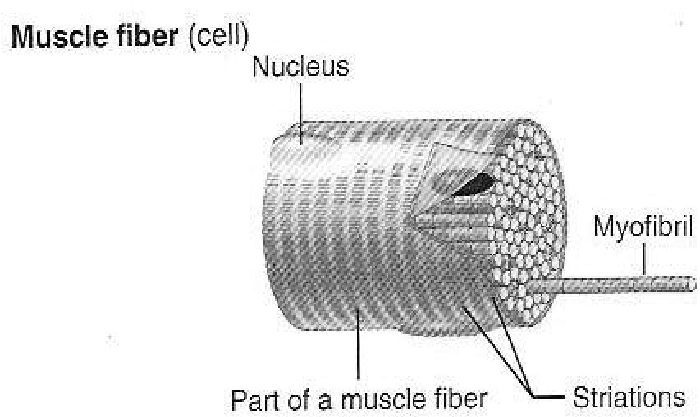

Figure 6: Diagram of muscle fiber.[35]

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[34] Ibid., 280.

[35] Ibid., 282. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

The banding pattern on the myofibrils arises from the presence of an interlocking and overlapping arrangement of thin (actin) filaments and thick (myosin) filaments. Each area of banding is the smallest functional unit of muscle tissue and is called a sarcomere.[36]

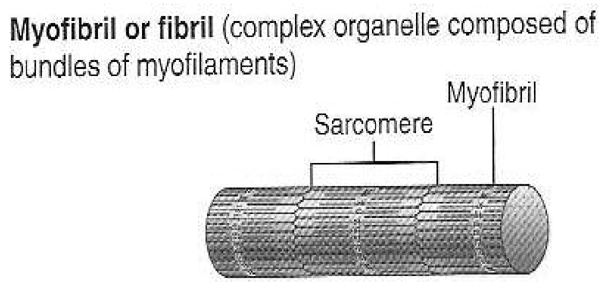

Figure 7: Diagram of myofibril.[37]

The sarcomere is the contractile unit of the muscle and is composed of myofilaments made up of contractile proteins. The vertical line bisecting the sarcomere is referred to as the M line.[38]

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[36] Ibid., 280.

[37] Ibid., 282. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

[38] Ibid., 280.

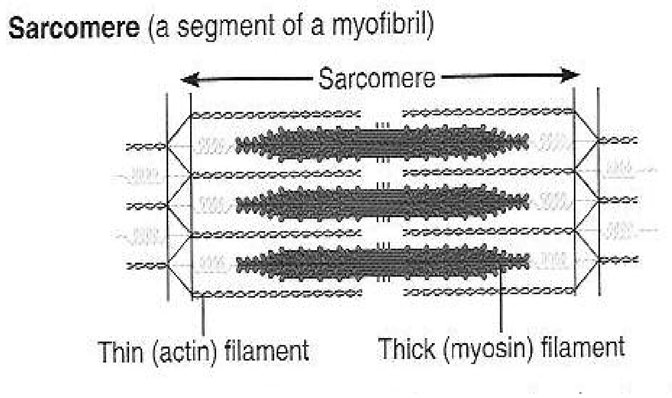

Figure 8: Diagram of sarcomere.[39]

The thin filaments within each sarcomere are made of two smaller interlocking proteins. The thick filaments have a more complex shape created by many heads, made of the protein myosin, which protrude from the side of each filament. These heads are sometimes called cross bridges because they link the thick and thin filaments together and create the tension developed by a muscle cell during contraction.[40]

[39] Ibid., 282. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

[40] Ibid. 280.

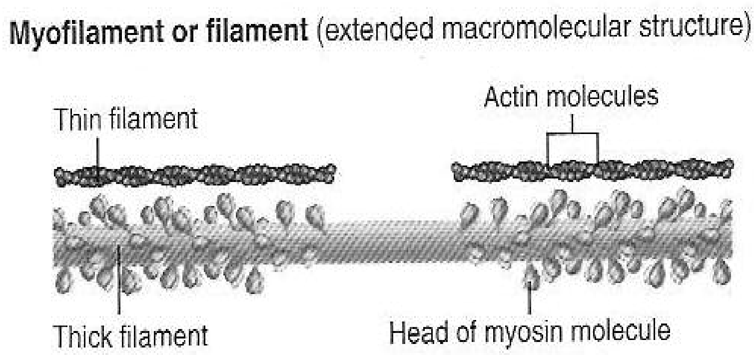

Figure 9: Diagram of filaments.[41]

Muscle Contraction: During contraction, the sarcomeres within the muscle become shorter due to a four-step electrochemical cycle involving the introduction of adenosine triphosphate (ATP), an energy rich molecule. In the first stage, the myosin heads are strongly attached chemically to the thin filaments and are in a high energy state. In the second phase, the working stroke, the myosin head pivots from this high-energy configuration to its bent, low-energy shape, which pulls on the thin filament, sliding it toward the M line (center) of the sarcomere. At the same time adenosine diphosphate (ADP) and inorganic phosphate (P_i) generated during the prior contraction cycle are released from the myosin head. During the third stage an ATP molecule binds to the myosin head, and breaks the connection of the myosin to the thin filament. In the final stage of the contraction cycle, the ATP is broken down into ADP and P_i. This provides the energy needed for the myosin head to return to its attached, high-energy position.[42]

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[41] Ibid., 282. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

[42] Ibid., 286-87.

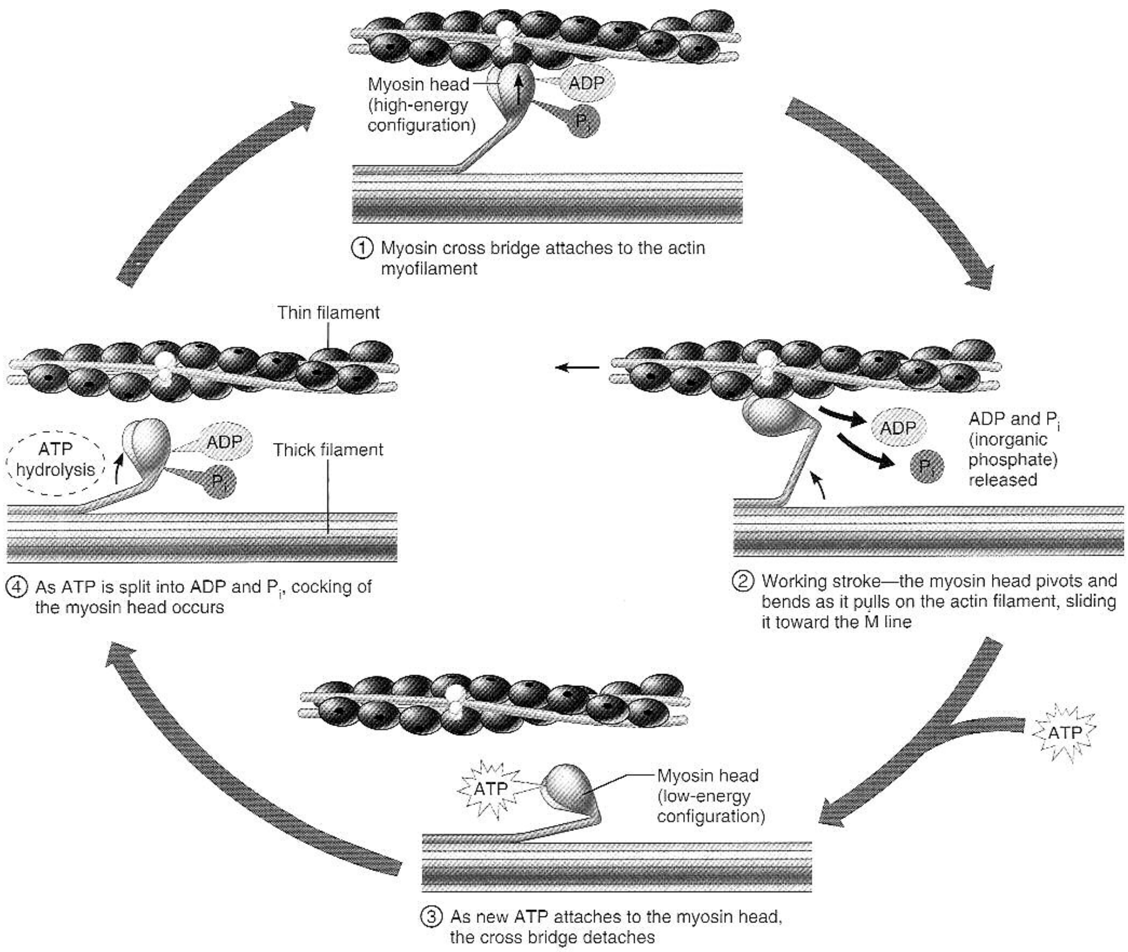

Figure 10: Diagram of muscle contraction.[43]

A single working stroke results in a shortening of the muscle by about only 1%. Because a muscle shortens by about 30% to 35% of its resting length during a

[43] Ibid., p. 287. Copyright © 2001 by Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated. Reprinted by permission of Pearson Education, Inc.

full contraction, myosin heads must detach and attach many times during a single contraction.[44]

Motor Units: Each muscle is associated with at least one nerve thatbranches to several individual muscle fibers. The nerve and all of the muscle fibers it serves is called a motor unit. A motor unit may contain several hundred individual fibers, for large load bearing muscles, or as few as four, for muscles that exert fine control. The muscle fibers in a motor unit are not clustered together. Instead, they are spread throughout the muscle. This results in a weak contraction of the entire muscle if only one motor unit is stimulated. A muscle will produce a stronger and stronger contraction as more and more motor units are recruited.[45]

Resting and Action Potentials: The sarcolemma, the muscle fiber's outer membrane, like all cell membranes, selectively permits certain ions to pass through it. When a muscle fiber is at rest, the selective permeability of the sarcolemma allows more potassium ions into the cell while leaving a higher concentration of sodium ions outside the membrane. This causes the inside of the cell to have a negative charge compared to the outside. This charge of the muscle fiber at rest is known as the resting potential.

The electrical signal from the nerve causes a series of events that cause the muscle to contract. When a nerve signal stimulates the negatively charged resting muscle fiber, the sarcolemma allows sodium ions to enter the cell and causes the cell interior to become less negative. If the nerve impulse is strong enough, this process

[44] Ibid., 288.

[45] Ibid., 293.

will propagate throughout the fiber. The change in voltage across the sarcolemma is called the action potential. The action potential lasts for only a fraction of a second before the resting potential is restored by fall in the sodium permeability of the sarcolemma and its drawing of potassium into the interior of the cell.[46] The action potentials must arrive continuously to maintain the contraction. [47]

These electrical action potentials can be measured with electromyography, and the scientific literature has documented the relationship between muscle force production and EMG amplitudes as well as the relationship between muscle fatigue and EMG activity.[48]

EMG: Electromyography or EMG is a "technique for studying live muscle function through the use of various types of electrodes and associated electronic apparatus that can detect, measure, and record minute electrical discharges (EMG potentials or action potentials) produced by muscles during contraction."[49] *Figure 11* is an example of a typical EMG output from this research project.

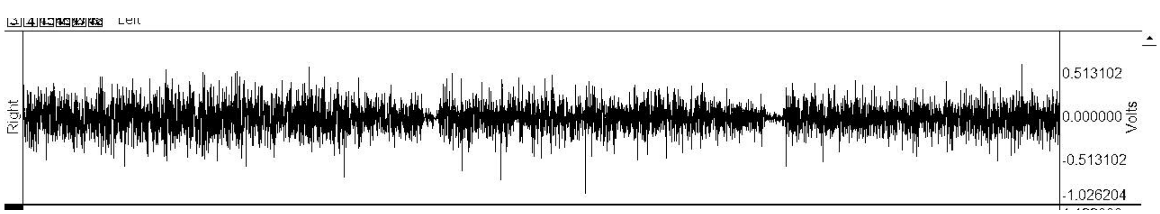

Figure 11: Typical EMG output.

[46] Ibid., 289.

[47] Ibid., 292.

[48] *RSI Clinic*. Homepage for the RSI Clinic. Available at http://www.rsiclinic.com/index.html. Accessed 7 March 2004.

[49] Elmer R. White and John V. Basmajian, "Electromyographic Analysis of Embouchure Muscle Function in Trumpet Playing," *Journal of Research in Music Education* 22 (Winter 1974): 293.

EMG requires the use of either needle electrodes which penetrate the skin to measure the activity in only one isolated motor unit, or surface electrodes which are non-invasive and adhere to the skin. Surface electrodes measure the firing of many motor units at one time and provide a better statistical sampling than the use of needle electrodes.[50] There are two characteristics of the EMG signal which are of interest to researchers: the amplitude of the signal (measured in micro volts, μv) and the frequency of the signal (measured in Hertz, Hz). The amplitude of the signal is an indication of how many motor units are being recruited to perform a particular contraction. During a sustained maximal effort (working a muscle as hard as possible) there may be an increase in EMG amplitude (especially in large muscles) because more and more motor units are recruited as others fatigue. Eventually, however, there will be a decrease in EMG amplitude as the entire muscle fatigues. Because the orbicularis oris is a small muscle, and most of its motor units are recruited from the beginning of each contraction, a decrease in EMG amplitude indicates its fatigue. The frequency of the EMG signal is an indication of how fast the electrical impulses from the brain stimulate each contraction. As a muscle fatigues, these impulses travel slower. Therefore, a decrease in EMG frequency is an indication of fatigue.

Integrated EMG: Integrated EMG or IEMG is a processed version of the EMG signal which is graphically more useful. The first step of integrating the signal

[50] Housh, Terry J., Dona J. Housh, and Herbert A. deVries, *Applied Exercise and Sport Physiology* (Scottsdale, Arizona: Holcomb Hathaway, 2003), 231.

is to render all values as positive values by inverting the negative values.[51] The area under the rectified signal is calculated; values are summed over time and then divided by the total number of values.[52] The result is a graphic output thatis always positive. As with the amplitude of the EMG signal, a decrease in IEMG indicates fatigue.

Fatigue: Elaine N. Marieb defined muscular fatigue as, "a state of physiological inability to contract."[53] This is caused by the demand for ATP in the muscle exceeding the production of ATP. A small amount of ATP is always present in the muscles, but it quickly becomes depleted during muscle activity. By the time the ATP in a muscle is depleted through activity, the body will have begun producing more ATP through the breakdown of carbohydrates which are also stored in the muscle. These carbohydrates are used to produce lactic acid which in time release energy to produce more ATP. If the muscles become saturated with lactic acid, however, fatigue will set in and the muscle will not able to contract. A time of recovery is needed to allow the bloodstream to carry away excess lactic acid.[54]

Marieb also differentiated between physiological muscle fatigue as described above and psychological fatigue "in which we voluntarily stop exercising when we feel tired."[55]

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[51] John V. Basmajian and Carlo J. De Luca, *Muscles Alive: Their Functions Revealed by Electromyography*, 5th ed. (Baltimore: Williams and Wilkins, 1985), 95.

[52] Ibid., 97.

[53] Elaine N. Marieb, *Human Anatomy and Physiology*, 5th ed. (San Francisco: Benjamin and Cumming, an Imprint of Addison Wesley Longman, Incorporated), 300.

[54] John O. Pursell, "Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet Embouchure Development," *ITG Journal* 24 (March 2000): 55.

[55] Elaine N. Marieb, *Human Anatomy and Physiology*, 5th ed. (San Francisco: Benjamin and Cumming, an Imprint of Addison Wesley Longman, Incorporated, 2001), 300.

Symptoms of fatigue include tremors, loss of muscle strength, loss of coordination, and feelings of weariness and irritability.[56]

Measuring fatigue with EMG is a complicated issue. As motor units begin to fatigue, additional motor units are recruited to continue the same task, especially in large muscles. This increase in recruitment of motor units, caused by fatigue, can actually appear as an increase in integrated EMG voltage. Over a prolonged period of sustained muscle activity, however, the general trend in voltage is downward.

Endurance: Endurance is the time limit that a person is able to maintain a specific muscle contraction or power level involving combinations of muscle contractions and relaxations.[57]

Training Principles: The goal of training, for either athletic performance or musical performance, is to bring about a biologic adaptation that improves performance. Although there are different training regimens designed to bring about different adaptations depending on the goals of each individual, several principals are common to any successful program. These common principles are: Overload principle, specificity principle, individual differences principle, and reversibility principle. Overload is training at an intensity higher than normal which causes an adaptation toward more efficient body function. An appropriate overload for an individual can be achieved by increasing the frequency, intensity, and duration of training. Specificity refers to the fact that specific adaptations result from the specific type of overload imposed. For the clarinetist an example of this principle would be

[56] Terry J. Housh, Dona J. Housh, and Herbert A. deVries, *Applied Exercise and Sport Physiology* (Scottsdale, Arizona: Holcomb Hathaway, 2003), 225.

[57] William D. McArdle, Frank I. Katch, and Victor L. Katch, *Exercise Physiology: Energy, Nutrition, and Human Performance*, 4th ed. (Baltimore: Williams and Wilkins, 1996), 702.

that effective and specific practice focused on endurance at soft dynamic levels would bring about an adaptation in that area and would not likely have an effect on endurance at loud dynamic levels. Individual differences refers to the fact that each person will benefit in an individual way from different types of training, and that successful training programs should be designed for each individual to meet the specific needs of each individual. The reversibility principle deals with the loss of training benefits when a person ceases participation in a training program. Measurable losses in training benefits can occur after as little as one week of not training.[58]

Recovery: This term can be difficult to define because, as stated by Kellmann, "A clear and sufficient definition of recovery can rarely be found in the literature. Authors discussing overtraining, especially in the field of sports medicine, often refer to recovery but do not provide detailed information on what physiological and psychological recovery is about."[59] Kellmann did, however, generally define recovery as, "the compensation of deficit states of an organism (e.g., fatigue or decrease in performance) and according to the homeostatic principle, a re-establishment of the initial state."[60]

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[58] William D. McArdle, Frank I. Katch, and Victor L. Karch, *Exercise Physiology: Energy, Nutrition, and Human Performance*, 4th ed. (Baltimore: Williams and Wilkins, 1996), 393-96.

[59] Michael Kellmann. "Underrecovery and Overtraining: Different Concepts-Similar Impact?" *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/2SEPT03; Internet; accessed 29 June 2004.

[60] Ibid.

Stone and Stone offered a very direct definition of recovery: "regaining what was lost."[61] They noted that this concept becomes frustrating because it returns the athlete only to where they started.

Recovery-Adaptation: Stone and Stone went on to define adaptation as, "the process of adjustment to a specific stimulus … which ultimately lead[s] to improved performance."[62] This is a much more satisfying prospect, and in a situation of training for an increased level of performance, "recovery-adaptation becomes paramount."[63]

Underrecovery: Kellmann described underrecovery as, "the failure to fulfill current recovery demands. Underrecovery can be the result of excessively prolonged and/or intense exercise, stressful competition, or other stressors."[64] Kellmann also noted that "underrecovery is the precursor/cause of overtraining."[65]

Overtraining: Kellmann described overtraining as, "an imbalance between stress and recovery."[66] Stress in this definition can take the form of all training, competition and additional non-training stress factors such as social, nutritional and other environmental factors.[67]

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[61] Michael H. Stone and Margaret. E. Stone. "Recovery-Adaptation: Strength and Power Sports." *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/4Sept03; Internet; accessed 29 June 2004.

[62] Ibid.

[63] Ibid.

[64] Michael Kellmann. "Underrecovery and Overtraining: Different Concepts-Similar Impact?" *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/2SEPT03; Internet; accessed 29 June 2004.

[65] Ibid.

[66] Ibid.

The 1998 United States Olympic Committee defined overtraining as, "the syndrome that results when an excessive, usually physical, overload on an athlete occurs without adequate rest, resulting in decreased performance and the inability to train."[68]

Periodization: Periodization is a training concept first revealed by a Russian scientist in 1972. It involves subdividing a training period, such as a year (macrocycle), into smaller phases (mesocycles). Each mesocycle is further divided into weekly microcycles. The purpose of this fractioning of the mesocycle is to manipulate the training intensity, volume, frequency, rest periods, and variety of workouts. The desired result is the reduction of overtraining related to physiological muscle fatigue and staleness related to psychological muscle fatigue. This approach to training has been successfully used by both novice and champion athletes.[69]

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[67] Ibid.

[68] Kristen Peterson. "Athlete Overtraining and Underrecovery: Recognizing the Symptoms and Strategies for Coaches." *Olympic Coach* 15 Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/5Sept03; Internet; accessed 29 June 2004.

[69] William D. McArdle, Frank I. Katch, and Victor L. Katch, *Exercise Physiology: Energy Nutrition, and Human Performance*, 4th ed. (Baltimore: William and Wilkins, 1996), 428.

II. REVIEW OF RELATED LITERATURE

Literature relevant to this study comes from several diverse fields: Clarinet pedagogy, musical performance endurance, overuse injuries, medical studies involving the orbicularis and EMG, studies involving EMG and musicians, and sport-science studies involving fatigue, recovery, and training protocols.

Clarinet Pedagogy

Steven W. Allen began his discussion of clarinet embouchure by describing three distinct types of clarinet embouchures, the French double-lip embouchure, the German, and the American single lip embouchure, each having its own distinct timbre. His article continued and focused on the American embouchure which was a fusion of the French and German styles. He gave four essential steps for achieving the American embouchure and subsequently the characteristic timbre:

> (1) the top teeth must be firmly planted on the top of the clarinet mouthpiece; (2) the chin must be pulled flat and firm to keep excess lip away from the reed; (3) just enough bottom lip must be placed over the bottom teeth so that a cushion for the teeth is provided; (4) the corners of the mouth must be held firm and pushed in toward the mouthpiece.[70]

This last step shows the importance of the orbicularis oris in forming the clarinet embouchure because it is this muscle that creates the action of pushing the corners of the mouth toward the mouthpiece.

John Graulty discussed the differences in the single-lip and the double-lip clarinet embouchures, and he noted that some teachers use the double-lip embouchure

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[70] Steven W. Allen, "Embouchure and Tone Production," *The Instrumentalist* 28 (January 1974): 51.

"as a way of encouraging players to engage the top lip muscles when forming the embouchure."[71] The top lip is, of course, the obicularis oris, and Graulty stated that, "one thing all clarinetists seem to agree on is that the top lip serves as more than an air seal on the top of the mouthpiece…the most important function of the top lip in embouchure formation is to provide muscular support as well as an air seal on the top of the mouthpiece."[72] Graulty highlighted the importance of the muscular activity of the orbicularis oris, but he offered no suggestions to develop the appropriate control.

Because "intonation is a critical and ever-changing situation," Kalman Bloch offered several suggestions to clarinetists in his article "Clarinet Intonation."[73] He stated that:

> The first and most obvious way of changing a note's pitch is with the embouchure. Tightening the lips around the reed and mouthpiece sharpens a pitch, relaxing flattens it. Because most clarinetists play with a firm embouchure it is easier to flatten than sharpen; lowering a pitch by as much as a semi-tone is not difficult. You should be able to increase or diminish embouchure pressure by infinitesimal degrees as a small shift results in appreciable pitch change.[74]

These embouchure control requirements rely on the effective use of the orbicularis oris muscle, and these fine tuning adjustments become more difficult or impossible if the muscle is fatigued. Although Bloch gave reasons for the importance of the embouchure muscles, he did not offer any suggestions to develop the muscles.

Walter Boeykens addressed the issue of air escaping around the mouthpiece while playing the clarinet.

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[71] John Graulty, "Trends in Clarinet Embouchures," *The Instrumentalist* 44 (April 1990): 50.

[72] Ibid.

[73] Kalman Bloch, "Clarinet Intonation," *The Instrumentalist* 46 (November 1991): 42.

[74] Ibid., 44.

> Most clarinetists, even professionals, make this airy sound, especially when playing loudly. The slur or liason [sic] between notes is easier to play when more air is allowed to escape. When the mouth is closed more firmly, it becomes more difficult to make a nice liason [sic]. Clarinetists think it's not serious, but non-clarinetists are disturbed and unnerved by this noisy escape of air.
>
> A good teacher reminds the student not to allow the air to escape out of the sides of the mouth.[75]

Closing the mouth "more firmly" implies increased muscle activity, and this already difficult task becomes more difficult as fatigue sets in. Escaping air is therefore an indicator of and associated with fatigue. Boeykens suggested that the clarinetist "approach the problem as an athlete would, developing one area (like the biceps) at a time" and focus on this one problem for several weeks.[76] This suggestion is flawed because he offered no athletic training regimen to correct the problem, and athletes, in general do not focus on just one area for several weeks. If an athlete trains one muscle group more than an opposing muscle group, there is a greater chance for injury due to imbalance, loss of flexibility, and there is less time for recovery for the muscle of focus.[77]

James Collis wrote his article, "On Clarinet Embouchures," in 1969, and began his discussion making it clear that, "no two [professional clarinetists] use the same embouchures."[78] He pointed out that any good embouchure must produce good tone, attack, articulation, and intonation, and a "flabby, soft, and lumpy lip will give

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[75] Walter Boeykens, "Playing the Clarinet with Finesse," *The Instrumentalist* 42 (November 1987): 28.

[76] Ibid.

[77] Elaine N. Marieb, *Human Anatomy & Physiology* 5th ed. (San Francisco: Benjamin Cummings, an Imprint of Addison Wesley Longman, Incorporated, 2001), 306.

[78] James Collis, "On Clarinet Embouchures," *The Instrumentalist* 23 (May 1969): 58.

us none of these results."[79] The descriptors of an inadequate embouchure he used are associated with a lack of muscle activity, and he went on to state that, "a firm lip is a requirement."[80] Firmness is associated with sustained muscle activity. Much of his article was concerned with flexibility which can be increased by nerve impulse speed. The speed of the nerve impulses can be encouraged by proper training.[81] Although he stated that, "the lip muscles alone have sufficient strength, when developed, for all playing requirements," he offered no suggestions for the proper development of these muscles.[82] His use of the word "strength" is perhaps erroneous because Fuhrimann, Schüpbach, Thüer and Ingervall found that in a study of clarinetists, trumpeters, and a control group of non-musicians, that the musicians had the same lip strength as the control group.[83] Collis may have been more accurate if he had emphasized the development of endurance.

Clarinet pedagogue David Pino studied with Keith Stein for fifteen years, and presented a summary of Stein's ideas on clarinet embouchure in *The Clarinet*. Although he acknowledged that there is little information about exactly how the embouchure should function for maximal results, and ideas regarding embouchure vary greatly from teacher to teacher, he observed that to achieve maximal results the embouchure should have "the flexibility to encompass the widest intervals with ease,

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[79] Ibid.

[80] Ibid.

[81] John Pursell, "Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet Embouchure Development," *ITG Journal* 24 (March 2000): 56.

[82] James Collis, "On Clarinet Embouchures," *The Instrumentalist* 23 (May 1969): 58.

[83] Susanne Fuhrimann, Andres Schüpbach, Urs Thüer and Bengt Ingervall, "Natural Lip Function in Wind Instrument Players," *European Journal of Orthodontics* 9 (August 1987): 216.

and [maintain] relatively the same degree of muscular firmness in all registers." [84] This points to the fact that the embouchure muscles must perform a static contraction with little rest during rests and breathing. These rest periods are exceedingly short compared to the time spent actually playing. Pino divided the procedure for forming a clarinet embouchure into steps pertaining to the "lower half" and the "upper half." He describes the "upper half" as the "rectangular area of flesh and musculature bounded by the mouth line below, the nostrils above, and ranging outward to the mouth corners."[85] Although he did not name the muscle involved, he is clearly describing and illuminating the importance of the orbicularis oris superioris. He further emphasized the importance of this muscle by stating that one of three factors for the success of an embouchure is "maintaining sufficient firmness in the upper lip."[86] This is not possible if the orbicularis oris becomes fatigued.

In an earlier article in *The Clarinet*, Tom Ridenour disagreed with Pino on the point of pedagogical agreement. Ridenour claimed, "there is general agreement among clarinet teachers about the basic elements of a correct clarinet embouchure."[87] He then contradicted himself by describing "two methods which are used in exerting pressure to control the reed."[88] He did, however, agree with Pino that the upper lip plays an important role in the formation of a good embouchure, and that players who

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[84] David Pino, "The Clarinet Teaching of Keith Stein, Part Two: The Embouchure," *The Clarinet* 30 (December 2002): 82

[85] Ibid., 84.

[86] Ibid., 85.

[87] Tom Ridenour, "The Hidden Embouchure: A Monograph on Clarinet Embouchure," *The Clarinet* 9 (Summer 1982): 16.

[88] Ibid.

use a single-lip embouchure "should develop the upper lip to share control of the mouthpiece."[89] He did not, however, address any issues concerning the consequences of fatigue and how to develop the upper lip.

Thomas Gerbino also agreed with the importance of the upper lip in the clarinet embouchure. He deemphasized the role of the lower lip stating that it is often a source of too much tension and unnecessary pain. He stated that "the use of the upper lip" answers the question of how to gain maximum embouchure control without pain.[90] He noted that in a good clarinet embouchure the upper lip should appear "curled, and rather tight against the upper teeth."[91] This description certainly indicates that a relatively high and steady level of muscle activity is required from the orbicularis oris to form a clarinet embouchure.

Earl M. Thomas captured the foundation of the present study when he opened his article:

> One of the most gratifying clarinet teaching experiences I know is that which comes when I observe my student maintain a sameness of embouchure angle and a firmness of chin throughout a long period of playing time. There are many factors involved in achieving this satisfaction – one of the most significant is careful and patient development of the student's muscles of facial expression.[92]

He also named and diagramed all of the muscles used in forming a clarinet embouchure, including the orbicularis oris. In his closing he related athletic training to training the embouchure muscles and emphasized the importance allowing

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[89] Ibid., 17.

[90] Thomas Gerbino, "Clarinet Embouchure Control through Use of the Upper Lip," *The Clarinet* 1 (August 1974): 10.

[91] Ibid.

[92] Earl M. Thomas, "Anatomical Essentials in Clarinet Embouchure," *The Clarinet* 8 (Winter 1981): 10.

"sufficient rest during practice sessions."[93] Although he recognized fatigue as a negative factor in developing a proper embouchure, he did not propose any suggestions for how to implement a practice schedule with an appropriate amount of rest.

Michael Webster also made an athletic training connection to clarinet pedagogy. His, however, was focused on developing speed of the fingers. He related the interval training of runners, where runners train with an alternation of sprints and walks to build speed while minimizing fatigue, to building technical speed on the clarinet. For sprinting on the clarinet, he suggested that the player limit the number of notes attempted and start with easy fingering combinations. These short bursts of quick technique should be alternated with slower passages that give the fingers a chance to rest and to allow the player to recover mentally.[94] This musical training approach, based in well-established athletic training protocols, is supported by the idea that all skeletal muscles respond in a similar manner to conditioning regardless of where they are located.

Bonnie Heather Campbell conducted a study similar to the present project, and she drew some relevant conclusions in her survey of clarinet literature. She found a variety of explanations of clarinet embouchure because there is a "wide range of opinion on various aspects of embouchure formation such as the position and function of the upper and lower lips, tongue position, amount of mouthpiece in the mouth (often referred to as 'bite'), the oral cavity, angle at which the instrument is

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[93] Ibid., 11.

[94] Michael Webster, "Gaining Speed (A New Kind of Interval Training)," *The Clarinet* 29 (September 2002): 12.

held, and jaw position and function."[95] She cited several authors who believed that the embouchure should remain in a steady state of tension at all times while playing the clarinet, and she cited several authors who believed that the embouchure should be more flexible. She found that some authors gave explanations that were paradoxical in nature because at times some authors seemed to be "saying, 'The embouchure should remain stable during playing, but there are certain adjustments that need to be made.'" [96] Campbell concluded her discussion on clarinet embouchure pedagogy by acknowledging that "although some of the seeming contradictions in explanations of embouchure function may be largely semantic, the issue of muscular adjustments during playing is, indeed, complex."[97] This agrees with Basmajian, an electromyography expert, that "neuromuscular control of skillful motor performance reaches its acme in music"[98]

Musical Performance Endurance

David Baldwin, Professor of Trumpet at The University of Minnesota at Minneapolis, divulged his "Seven Secrets of Endurance" in a recent article. Although he offered no scientific basis for his suggestions, several of his secrets followed the principles of athletic training. He suggested that players, "ease mouthpiece pressure

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[95] Bonnie Heather Campbell. *An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed Through Electromyography* D.M. diss. Indiana University, 1999 (Ann Arbor, Michigan: University Microfilms, 2000): 25.

[96] Ibid., 27.

[97] Ibid., 29.

[98] Elmer R. White and John V. Basmajian, "Electromyographic Analysis of Embouchure Muscle Function in Trumpet Playing," *Journal of Research in Music Education* 22 (Winter 1974): 293.

at all rests and phrase endings," to allow the blood to re-circulate back into the lips.[99] He also recommended that players, "Practice in specific chunks of time – play then rest," and to "use pedal tones and a 10-20 [sic] minute break …"[100] These suggestions encourage the prevention of excessive fatigue and are similar to a pre-determined athletic training regimen involving a specific number of repetitions of a particular exercise followed by a rest period. His last suggestion was for the player to "do isometric exercises with the lips" twice a day.[101] This last suggestion is not in agreement with athletic training protocols because he does not suggest a break or recovery period from this exercise.

Andrew Pelletier offered several suggestions in his article, "Embouchure Health and Maintenance." He suggested that players be sensitive to the feel of the embouchure and adjust practice strategies accordingly. He suggested that long practice sessions be divided into smaller sessions interspersed with periods of rest. He also suggested that performers get enough rest at the end of each day.[102] Although he did address the issue of rest, he did not consider the idea of not playing for a day or two on occasion. This is interesting because the introduction of his article describes one of Pelletier's personal experiences with sharp muscle pain around his mouth which lead to a nine month recovery period. He recognized that he had inured muscle tissue and that the injury was avoidable, much like a sport-related injury.

[99] David Baldwin, "Clinic: The Seven Secrets of Endurance," *ITG Journal* 21 (December 1996): 58.

[100] Ibid.

[101] Ibid.

[102] Andrew J. Pelletier, "Embouchure Health and Maintenance," *The Horn Call* 3 (May 1999): 65.

John Pursell, the Senior Ceremonial Trumpet Player in the U. S. Air Force Band in Washington, D. C., published an article titled, "Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet Embouchure Development," in the *ITG Journal*. In the introduction to this article Pursell stated that, "For both the athlete and the trumpet player, the two most important elements of physical conditioning are strength and endurance. No athlete or trumpet player can perform successfully if one of these attributes is absent."[103] Although Pursell was writing for an audience trumpet players, many of his comments are relevant to this study because both trumpet and clarinet embouchures use common muscles, specifically the orbicularis oris.[104] In the first section of the article, Pursell gave a clear description of the physiological aspects of muscle function. He discussed catabolism, where substances are broken down and anabolism where larger molecules are built from smaller ones. He discussed the catabolic process in which the chemical adenosine triphosphate (ATP), the "most important source of chemical energy for all living organisms" is produced and used by the muscles.[105] He discussed the effects of exercise on muscles and pointed to several effects including the muscle becoming larger, the muscle becoming stronger, the muscle gaining endurance, the nerve impulses traveling more quickly, and an increase in the number of capillaries in a trained muscle, and therefore, better circulation of blood to the muscle. Pursell highlighted the last two effects with respect to their specialrelation to embouchure

[103] John Pursell, "Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet Embouchure Development," *ITG Journal* 24 (March 2000): 55.

[104] Ibid., 57.

[105] Ibid., 55.

development because “the rapid flow of nerve impulses to the muscle fibers would seem to be an aid to flexibility and …a greater number of capillaries would mean increased blood flow to the embouchure muscles, thereby increasing the amount of oxygen flow. This would aid in quicker production of ATP, reducing recovery time.”[106] Pursell continued his article with a section sub-titled, “Necessity of Rest.” He stated that, “Rest is essential to the proper function of the muscles. It is during the rest period that the muscles ‘recharge’ themselves with ATP.”[107] He made a distinction between short rest periods within a practice session and longer periods of rest between sessions, and he emphasized that both were necessary. He thoroughly discussed how the short periods of rest should be worked into a practice session. He did not, however, make any comments about how to design a practice routine with an appropriate amount of rest between practice sessions.[108]

Chase Sanborn, another trumpet player, wrote about building endurance because “endurance is often cited as a weakness by trumpet students.”[109] Although he equated endurance with strength, which is not how sport-scientists use these terms, he related building endurance in trumpet playing to building endurance in an athlete. He used an accurate example of a long-distance runner who would gradually increase the length of daily runs, running increasingly longer distance on some days, allowing for shorter runs on others, and allowing sufficient rest time for the muscles to rebuild. He reminded the reader that the embouchure is made of flesh and tissue and “it is

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[106] Ibid., 56.

[107] Ibid., 57.

[108] Ibid., 58.

[109] Chase Sanborn, “Brass: Endurance,” *Canadian Musician* 21 (January/February 1999): 28.

going to get tired with extended playing, and needs rest."[110] He failed to cite, however, how much rest is necessary for the runner or trumpet player. In the conclusion of his articles he stated that "the really great days are few and far between, and rarely occur when we most need them."[111] Although Sanborn made some accurate parallels to athletic and musical training, he seemed to fail to realize that the "great days" could be intentionally placed by an effective training regimen.

Because the question of endurance came up most at his clinics, trumpet player Mike Vax also wrote on endurance. Although Vax did not make any direct sport-science relationships, he did note, "Rest is of primary importance in your practice schedule. The practice period becomes much more meaningful if you are not fighting fatigue while trying to concentrate on improvement."[112] Although Vax did make suggestions for planning periods of rest during a practice session, he made no comments on how much to rest between practice sessions.

Overuse Injuries

In his article titled, "What Every Musician Needs to Know about the Body," David Nesmith discussed a process known as body mapping which is intended to help prevent overuse injuries. The body map is, "one's self‑ representation in one's own brain." The body map can be accurate, which would encourage proper use of the body, or the body map can be erroneous, which can lead to improper use of the body

[110] Ibid.

[111] Ibid.

[112] Mike Vax, "Endurance - - The Key to Better Playing," *Crescendo International* 18 (October 1979): 34.

and injury.[113] This recently popularized concept of body mapping and related subjects such as the Alexander Technique, which also involves proper usage of the body, is similar to the idea of self-perceived endurance levels. It is very important for performers to be aware of not only their anatomy and how to properly use their bodies, but also their own endurance limitations.

Susan Betz, an amateur clarinetist, wrote about her temporomandibular joint (TMJ) dysfunction. She described the general symptoms which included severe headaches; pain in the back, shoulder, arm, chest, around the ears, face, and neck; difficulty in opening the mouth; fatigue in the tongue, and general fatigue. She also described problems specific to clarinetists such as eyes blurring while playing, feeling fatigued while playing, dropping the clarinet due to pain, and embouchure muscles shaking while playing.[114] Many of these symptoms are related to fatigue and can be exacerbated by fatigue and overuse.[115] Because of the serious nature of this problem, Betz was careful not to offer any medical advice, but instead referred clarinetists to competent medical authorities.

Ron B. Odrich, clarinetist and periodontist, gave a very good description of TMJ dysfunction, which appears in the introduction. The simple solution to the pain caused by forcing the lower jaw forward he gave is, "don't do that."[116] He continued

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[113] David Nesmith, "What Every Musician Needs to Know about the Body," *The Horn Call* 4 (August 1999): 71.

[114] Susan Betz, "Are You a Victim of T. M. J. Dysfunction?" *The Clarinet* 16 (February/March 1989): 44.

[115] Terry J. Housh, Dona J. Housh, and Herbert A. deVries, *Applied Exercise and Sport Physiology* (Scottsdale, Arizona: Holcomb Hathaway, 2003), 225.

[116] Ronald B. Odrich, "Claridontology," *The Clarinet* 26 (September 1999): 26.

by suggesting that players who suffer from this condition play with a natural orientation of their jaws. Finally he pointed out that this new arrangement could seem awkward at first, and to "approach it slowly because another set of muscles needs to be developed to support the reed."[117] He approached the topic of fatigue and building endurance, but he did not offer a sample training regimen to effectively and safely train the embouchure into proper usage.

Two dentists, James A. Howard and Anthony T. Lovrovich, reported on a varied collection of surveys involving the problems of the facial muscles suffered by wind musicians. They reported that overuse or misuse of orofacial structures can become a medical malady and that, "poor lip control, muscle fatigue … can all compromise the embouchure."[118] They also found that rapidly increased practice time for a wind musician predisposes the musician to overuse injuries.[119]

Spahn, Hildebrandt, and Seidenglanz studied an elective course at the Zürich Conservatory. The course designed to prevent playing-related health problems, consisted of a "combination of practice and theory, integrating methods of physical training and physical awareness and performance training with basic knowledge in anatomy, physiology, psychology, and learning techniques."[120] They found that not only did the students involved find "the subject of 'Physiology of Music and Performing Arts Medicine,' regular courses in it, and their institutionalization

[117] Ibid.

[118] James A. Howard and Anthony T. Lovrovich, "Wind Instruments: Their Interplay with Orofacial Structures," *Medical Problems of Performing Artists* 4 (June 1989): 59.

[119] Ibid., 64.

[120] Claudia Spahn, Horst Hildebrandt, and Karin Seidenglanz, "Effectiveness of a Prophylactic Course to Prevent Playing-Related Health Problems of Music Students," *Medical Problems of Performing Artists* 16 (March 2001): 24.

important," but also that "all the participants of the course-independently of any symptoms initially present-profited in areas of significance to musicians."[121] This study supports the notions that musicians are interested in playing related concepts of physical conditioning and that musicians can benefit from such training.

Joann Marie Kirchner conducted a survey of pianists who suffer from performance anxiety, and although performance anxiety is not an overuse injury, it could be related. Kirchner enumerated symptoms of performance anxiety that included muscle reactions. In this area she found that respondents suffered from shaking where "the anxiety within the individual resulted in movements over which they had no control. These physiologic manifestations included involuntary shaking or tremors, of various body parts, especially the hands and legs."[122] She also found that "in addition to involuntary shaking or trembling, the participants reported increased muscle tension. Several pianist specifically mentioned tension in the arms, back, and shoulders. At times, the tension would be noted by the pianists for several days before subsiding."[123] These symptoms are very closely related to those of fatigue, and a pianist who practices excessively prior to a performance would be more susceptible to fatigue, especially under the stress of performance.[124] It is possible that proper endurance-building training could alleviate these symptoms.

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[121] Ibid., 30.

[122] Joann Marie Kirchner, "A Qualitative Inquiry into Musical Performance Anxiety," *Medical Problems of Performing Artists* 18 (June 2003): 80.

[123] Ibid.

[124] Terry J. Housh, Dona J. Housh, and Herbert A. deVries, *Applied Exercise and Sport Physiology* (Scottsdale, Arizona: Holcomb Hathaway, 2003), 225.

Janet Davies and Sandra Magion surveyed 240 professional musicians for causes of playing-related pain. The most common reply for causes of pain was long sessions of playing or practice, and the situations that triggered the most severe episodes of pain and subsequent recurrences of pain were heavy professional schedules and long sessions.[125] The topics of endurance and recovery time are critical here and should not be ignored. This type of pain can possibly be prevented if the body is properly conditioned and allowed to recover regularly.

In an excerpt from his book titled *Medical Problems of the Instrumentalist Musician*, Frank R. Wilson described several issues related to focal dystonia in musicians. His research indicated that "there is now considerable anecdotal evidence associating occupational cramps [focal dystonia] with cumulative trauma disorder (CTD), overuse syndrome (OS), repetitive strain injuries (RSI)."[126]

Medical Studies Involving EMG

A. W. Kelman and S. Gatehouse highlighted the extensive use of EMG in the field of phonetics, but they noted that different electrode placements made it difficult to correlate results of different studies. In their study involving the activity of the orbicularis oris in the production of certain phonetic sounds, they used small standard silver/silver chloride cup electrodes filled with electrode jelly and attached with

[125] Janet Davies and Sandra Magion, "Predictors of Pain and Other Musculoskeletal Symptoms Among Professional Instrumental Musicians: Elucidating Specific Effects," *Medical Problems of Performing Artists* 17 (December 2002): 158.

[126] Frank R. Wilson, "Current Controversies on the Origin, Diagnosis and Management of Focal Dystonia in Musician," in *International Dystiona On-line Support Group Website:* available at http://www.dystoniasupport.org/LAFocal%20Dystonia%20in%20Musicians.htm; Internet: accessed 10 June 2004.

adhesive disks. They also used a grounding electrode attached to the forehead.[127] They found that there was very little difference in the activity of the left and right sides of the orbicularis oris.[128]

EMG feedback has been used in therapeutic settings. A study published in the *American Journal of Physical Medicine* showed that subjects with facial palsy benefited from the use of visual displays of EMG feedback for muscle reeducation.[129] EMG feedback may, therefore, also be useful in clarinet pedagogy to correct embouchure deficiencies.

Studies Involving EMG and Musicians

Patrice Berque and Heather Gray used electromyography to study how the use of the trapezius muscle and pain are related in violin and viola players. Their research indicated that the musculoskeletal problems suffered by instrumentalists are no different than those suffered by those who have any other occupation.[130] This supports the idea that muscular problems and conditioning issues are the same throughout the body regardless of endeavor. Berque and Gray studied the upper-trapezius muscles in violin and viola players under three conditions: rest, performance of an easy piece, and performance of a difficult piece. Their subjects

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[127] A. W. Kelman and S. Gatehouse, "A Study of the Electromyographic Activity of the Musculus Orbicularis Oris," *Folia Phoniatrica* 27 (1975): 351.

[128] Ibid., 361.

[129] Michael Brown, Foad Nahai, Steven Wolf, and John V. Basmajian, " Electromyographic Biofeedback in the Reeducation of Facial Palsy," *American Journal of Physical Medicine* 57 (August 1978): 189.

[130] Patrice Berque and Heather Gray, "The Influence of Neck-Shoulder Pain on Trapezius Muscle Activity among Professional Violin and Viola Players: An Electromyographic Study," *Medical Problems of Performing Artists* 17 (June 2002): 68.

were divided into two groups: those with playing-related pain and those who were pain-free. They prepared their subject's skin with alcohol to reduce impedance and placed two self-adhesive electrodes on both the left and right upper trapezius parallel to the muscle fibers. Two grounding electrodes were placed on the bony area of the spine. They found that their pain-free subjects developed more upper trapezius muscle activity while playing than the subjects who complained of playing-related pain.[131]

White and Basmajian noted that "neuromuscular control of skillful motor performance reaches its acme in music" and they observed that, "the pedagogical literature consist of contradictory and highly controversial theories concerning virtually all of the physical and physiological functions in brass playing, leading one writer to characterize brass pedagogy as being in a 'state of chaos.'"[132] This "state of chaos" and "controversial theories" regarding physiological function are also present in clarinet pedagogy. In their study of trumpeter's lips they utilized electromyography to study the muscles orbicularis oris superioris (the upper lip), orbicularis oris inferioris (the lower lip), levator anguli oris, and depressor anguli oris during fifty-one playing tasks.[133] Although the specific findings of their trumpet study are not relevant to the present study, they did successfully measure muscle activity of the orbicularis oris superioris to the benefit of musical teaching. Although

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[131] Ibid.

[132] Elmer R. White and John V. Basmajian, "Electromyographic Analysis of Embouchure Muscle Function in Trumpet Playing," *Journal of Research in Music Education* 22 (Winter 1974): 293.

[133] Ibid., 297.

White and Basmajian studied muscles in common with the present study, they did not address fatigue or the development of endurance in these muscles.

Frank Heuser and Jill L. McNitt-Gray also used EMG to study the embouchures of trumpet players. They used pairs of miniature silver-silver chloride surface electrodes placed parallel to muscle fibers of interest in their study, and they placed a grounding electrode for each pair on the collar bone. Their 1991 study was concerned with the patterns of embouchure muscle activity just prior to the production of a tone. They found that players who have trouble with accurate tone commencement also exhibit patterns of EMG embouchure activity which differ from players who do not have tone commencement difficulties.[134]

In 1993 Heuser and McNitt-Gray published a study thatdealt with trumpet players with asymmetrical mouthpiece placement. The 1993 study was designed similarly to the 1991 study. This second EMG study found that trumpet players with asymmetrical mouthpiece placement exhibit similar embouchure activity to players with centered placement.[135]

Heuser and McNitt-Gray integrated the findings of their EMG studies into trumpet pedagogy. They hypothesized that EMG data could be used to improve embouchure muscle activation by showing the data to students, and that EMG data could be used to evaluate instruction by allowing the instructor to see the gains made in embouchure muscle activation after specific instruction. Using EMG patterns of

[134] Frank Heuser and Jill McNitt-Gray, “EMG Potentials Prior to Tone Commencement in Trumpet Players,” *Medical Problems of Performing Artists* 6 (June 1991): 56.

[135] Frank Heuser and Jill L. McNitt-Gray, “EMG Pattern in Embouchure Muscles of Trumpet Players with Asymmetrical Mouthpiece Placement,” *Medical Problems of Performing Artists* 8 (September 1993): 102.

professional players as models and comparing them with those of student trumpet players, Heuser and McNitt Gray were successful in improving the playing abilities of the students, thus proving their assumptions.[136]

Bonnie Heather Campbell used surface electromyography to study the activity of jaw muscles used during clarinet performance. Although she did not address fatigue or overuse, she focused on the possibility of misuse of the jaw as a cause of jaw disorders. She compared patterns of EMG activity collected from her subjects with standard pedagogical practices.[137]

Sport-Science Studies Involving Fatigue, Recovery, and Training Protocols

Wayne Goldsmith, a swimming trainer, wrote an article discussing the benefits of recovery-based training. He began his article by describing a common but inappropriate style of training called work-based training which "focuses on the volume and intensity of work that an athlete can endure in a specific time."[138] This style of training is not effective because the athlete is subjected to more stress than recovery and is exposed to higher risk of injury and strain on the immune system.[139] This work-based concept of training is also the approach that musicians take in their practice regimens when they practice as much and as often as they feel they are able.

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[136] Frank Heuser and Jill McNitt-Gray, "Enhancing and Validating Pedogical Practice: The Use of Electromyography during Trumpet Instruction," *Medical Problems of Performing Artists* 13 (December 1998): 156.

[137] Bonnie Heather Campbell. *An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed Through Electromyography*, D.M. diss. Indiana University, 1999 (Ann Arbor, Michigan: University Microfilms, 2000): 1.

[138] Wayne Goldsmith. "Recovery-Based Training: By Developing a Training Program Based on an Athlete's Ability to Recover, Every Training Session Becomes an Opportunity to Maximize Performance Through Individualized Training," *Swimming Technique* 39 (January/March 2003): 16.

[139] Ibid.

Goldsmith suggested a different approach called recovery-based training in which a proactive attitude is taken with respect to recovery and restoration practices. He stated that the goal of this system, which is probably the same goal of many clarinetists, is to "find ways to train athletes to achieve their maximum potential without pushing them 'over the edge' (i.e., overtraining, which can lead to health issues)."[140] In describing recovery-based training, Goldsmith emphasized that training programs should be individualized and based on each athlete's own ability to recover. This allows the athlete to eventually train even harder as the natural process of recovery is enhanced. He also noted that technique can be more easily monitored and improved if the athlete is not working out in a continuous state of fatigue.[141] Although the concepts of swimming technique are obviously different from those of clarinet technique, it is clear that the performer in either field can more easily focus on refinement of technique during a practice session if he has had an appropriate amount of recovery and is not fatigued. Goldsmith avoided any suggestions of a specific amount of recovery, probably because of the individuality of an effective training program, but he did offer several methods to evaluate the need for recovery including self-monitoring of level of fatigue after a work-out and monitoring of psychological issues like mood because this can be a sign "of overtraining and overstraining in the pursuit of excellence."[142]

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[140] Ibid.

[141] Ibid., 17.

[142] Ibid., 21.

Sue L. Hooper, who also emphasized individualized training programs, began her article titled, "Physiological and Psychometric Variables for Monitoring Recovery during Tapering for Major Competition" with the following statement:

> Regeneration from the negative aspects of intense training is an important focus of tapering, the period of reduced training load before major competition. It has long been known that performance may be best optimized if athletes are trained close to the point of overtraining and then allowed to recover while training load is tapered. The taper allows supercompensation [sic] processes to maximize the positive effects of training and recovery processes to eliminate fatigue and other negative effects of training. Runners, swimmers, and cyclists who taper show significant improvements in performance, muscular strength and power, and factors such as sleep disturbances, stress, fatigue, ratings of perceived exertion, and mood states.[143]

The effectiveness of tapering is widely known in the field of sport-science and Hooper's study was concerned with the refinement of this type of training regimen. Her study involved elite swimmers who decreased their training time and intensity over a period of two weeks prior to a major competition. Although each swimmer was placed on an individual tapering plan as programmed by his or her coach, the average swimming distance decreased from 47 km to 30.5 km per week, average gym work-out time decreased from 5.3 hours to 0.4 hours per week, and self perceived intensity levels decreased from 5.3 to 4.2 on a 7 point scale. The result of this study showed that there were improvements, but these improvements were not as great as those shown in studies with less competitive athletes.[144]

T. Reilly agreed with Hooper that tapering is a beneficial tool in physical training. With regard to soccer training, Reilly stated that there is a need "to regulate

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[143] Sue L. Hooper, Laurel T. Mackinnon, and Alf Howard, "Physiological and Psychometric Variables for Monitoring Recovery during Tapering for Major Competition," *Medicine and Science in Sports and Exerc*ise 31 (August 1999): 1205.

[144] Ibid., 1208.

training loads between games so that a balance is achieved between maintaining training stimuli and optimizing preparation for competition."[145] This is the same type of balance that clarinetists might seek while preparing for performances. Reilly noted that the body's organs are stressed and muscles are depleted of glycogen reserves during strenuous activity. Because of this, "high intensity training should be avoided the day after a game but can be gradually stepped up in subsequent days, and that "hard training on successive days may prevent the normal restoration of energy stores. He cited a specific effective training regimen for an English soccer team in which there was "a systematic build up to a mid-week peak, followed by a tapering off as the match day [approached]."[146] He noted, "This practice helps to avoid the circumstance of a player starting a game low in muscle glycogen."[147] In his concluding comments he also highlighted the importance of psychological rest in an effective training program.[148]

Michael Kellmann detailed the causes and effects of underrecovery and overtraining in his article titled "Underrecovery and Overtraining: Different Concepts – Similar Impact." He stated that in sports there is an obvious connection between recovery and performance and that, "to avoid overtraining and to optimize performance in sports, physiological and psychological recovery should be programmed as an integral component of training."[149] Although these observations

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[145] T. Reilly, "Recovery from Strenuous Training and Matches." *Sports Exercise and Injury* 4 (November 1998): 156.

[146] Ibid., 158.

[147] Ibid.

[148] Ibid.

are generally accepted by physical trainers and coaches, they are not in widespread use by clarinet teachers. Clarinet pedagogy often suggests a steady schedule of individual practice, rehearsals, and performances without an adequate amount of rest. This type of heavy workload can result in the same type "training mistakes" that Kellmann listed:

1. Monotonous training programs,
2. More than three hours of training per day,
3. More than a 30 percent increase in training load each week,
4. Ignoring the training principle of alternating hard and easy training days or by following two hard days with an easy day,
5. No training periodization and respective regeneration microcycles after two or three weeks of training, or
6. No rest days.[150]

Kellmann also reported that in a 1998 survey of 298 United States Olympic athletes, twenty-eight percent felt that overtraining had a negative impact on their performance, and of these overtrained athletes, more than a third cited lack of rest as the number one action that hurt their performance. The same survey also revealed that the need to taper, rest, and to not overtrain were changes that they would make if given the opportunity to prepare again for the Olympics.[151]

Stone and Stone agreed with Kellmann. They stated, "The training process is to enhance performance… and it may be argued that enhancing performance is actually a process of intentionally repeating stimuli (exercise), which result in

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[149] Michael Kellmann. "Underrecovery and Overtraining: Different Concepts-Similar Impact?" *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/2SEPT03; Internet; accessed 29 June 2004.

[150] Ibid.

[151] Ibid.

recovery-adaptation, while attempting to avoid overstress-overtraining."[152] They emphasized that an effective training program must include "built in rest."[153]

Angela Calder also agreed with Kellmann, and she began her article with a quote from Barry Barnes, the Head Coach of the Australian Men's 1996 Olympic Basketball Team: "If there was one single factor that helped this team to perform to the level they did at Atlanta, it was the recovery program that was put in place … and monitored throughout our 1996 program."[154] Calder noted that many athletes forget or ignore the known benefits of recovery which is "one of the basic principles in training methodology."[155] She, therefore, approached this subject as a coach should, to monitor an athlete's fatigue, recovery, and adaptation for optimal performance. She listed several observations that a coach could use to evaluate an athlete's level of fatigue. These observable signs included direct communication, such as complaints of not feeling well or being tired; body language, such as posture or signs of frustration; performance, such as poor skill execution or slow response time; and psychological signs, like low motivation or lack of self-confidence.[156] These signs which Calder suggested be monitored by a coach, are also observable by a clarinet instructor working with a student or by a clarinetist monitoring his own level of

[152] Michael H. Stone and Margaret E. Stone. "Recovery-Adaptation: Strength and Power Sports." *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/4Sept03; Internet; accessed 29 June 2004.

[153] Ibid.

[154] Angela Calder. "Recovery Strategies for Sports Performance." *Olympic Coach* 15, 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/3Sept03; Internet; accessed 29 June 2004.

[155] Ibid.

[156] Ibid.

fatigue. Calder concluded her discussion of the importance of monitoring recovering by stating, "Rest days are essential. Ideally at least one day per week should be a non-training day. This allows time for physical and psychological recovery as well as time for other interests and personal and family relationships."[157]

Kristen Peterson also reported that athletes, at times, fail to monitor their own recovery needs. She listed several overtraining symptoms which included: apathy, lethargy, depression, decreased self-esteem, emotional instability, impaired performance, restlessness, irritability, increased vulnerability to injuries, and muscle pain/soreness.[158] Although Peterson was describing the symptoms of an overtrained athlete, all of the symptoms listed here could also apply to the overtrained clarinetist.

Scott Riewald wrote about strength training for young athletes, and although he did not specifically mention rest, he did suggest that the "initial goal of any program should be to build some muscular endurance" and that training should occur "three times a week."[159] Later in his article he cited the National Strength and Conditioning Association's Recommendations for Youth Strength Training which included the suggestion that training occur "on two-three non-consecutive days [each week.]" This certainly implies the necessity for days of rest in a program designed to build endurance and strength regardless of the muscles involved.

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[157] Ibid.

[158] Kristen Peterson. "Athlete Overtraining and Underrecovery: Recognizing the Symptoms and Strategies for Coaches." *Olympic Coach* 15 Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/5Sept03; Internet; accessed 29 June 2004.

[159] Scott Riewald. "Strength Training for Young Athletes." *Olympic Coach* 15, Winter 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/March03-5; Internet; accessed 29 June 2004.

III. PRESENTATION AND ANALYSIS OF DATA

Questionnaire Summary

Each subject was asked to respond to a questionnaire (see appendix II) involving the subject's personal profile, playing habits, and self-perceived levels of fatigue and tone depreciation following each day of testing. The following is a compilation of all responses. Free responses were transcribed exactly as written on the questionnaire.

	Age	Sex	Height (in.)	Weight
Subject 1	19	F	64	130
Subject 2	19	F	67	198
Subject 3	21	M	70	155
Subject 4	21	F	69	150
Subject 5	22	M	68	235
Subject 6	28	F	71	165
Subject 7	22	M	68	185
Subject 8	36	M	72	200
Subject 9	24	F	66	150

How long have you been playing the clarinet?

Subject 1 8 years

Subject 2 9 years

Subject 3 8 years

Subject 4	9 years
Subject 5	10 years
Subject 6	17years
Subject 7	10 years
Subject 8	24 years
Subject 9	14 years

Do you play with a single-lipped embouchure or a double-lipped embouchure? If both, what percentage of your playing time is spent with each?

Subject 1	99% single lip
Subject 2	both about 50%
Subject 3	single-lipped
Subject 4	single-lipped
Subject 5	single-lipped
Subject 6	single-lipped
Subject 7	10% double-lipped, 90% single-lipped
Subject 8	single-lipped
Subject 9	single-lipped

On average, on how many **days** each week do you play the clarinet? (Include individual practice, rehearsals and performance – everything.)

Subject 1	5
Subject 2	7
Subject 3	6
Subject 4	6

Subject 5	5
Subject 6	7
Subject 7	6
Subject 8	5
Subject 9	6

On average, how many **hours** per week do you play the clarinet? (Again, include all practice, rehearsal and performance.)

Subject 1	8.5
Subject 2	28
Subject 3	9
Subject 4	14
Subject 5	9
Subject 6	30
Subject 7	30
Subject 8	10
Subject 9	22

In the few weeks prior to an important performance do you find that the time you spend playing: (Increases, decreases, or stays about the same)

Subject 1	Increases
Subject 2	Stays about the same
Subject 3	Stays about the same
Subject 4	Increases
Subject 5	Increases

Subject 6 Increases

Subject 7 Stays about the same

Subject 8 Increases

Subject 9 Increases

Do you ever experience fatigue (muscle "burn" or loss of strength) in your embouchure while you play the clarinet? If yes, please explain.

Subject 1 Yes! Mostly in lower lip, low sides – presumably due to old bad embouchure habits and occasional inattention to detail.

Subject 2 Occasionally, when I feel tired I change double-lip/single-lip.

Subject 3 Yes I do. When I've been focusing on litle embouchure movement for 45 minutes or more, the muscles above my upper lip begins to burn.

Subject 4 Yes. If I practice for a long time, my ability to control my embouchure becomes harder.

Subject 5 Yes, if I practice for a long period of time, I will get tired and want to relax my mouth

Subject 6 Yes, if I spend a considerable amount of time continuously playing without rest.

Subject 7 Yes. Loss of strength in 4^{th} consecutive hour of playing.

Subject 8 Yes. I feel fatigue if play for a long period of time, or if I haven't been playing for several days, I don't have the endurance I had before the long break.

Subject 9 Yes. When I first start playing. Or if I've taken a week or so off practicing. I'll also experience fatigue after 40 or 50 min. of playing.

Is endurance ever a problem for you during public performance? If yes, please explain.

Subject 1 Yes, stress builds up easily in performance situations for me, and I get tense … it just makes it worse. Also, dealing with old embouchure issues gets harder in long performances.

Subject 2	No.
Subject 3	Yes. It is usually a problem for me in the band setting because the clarinet section plays most of the time.
Subject 4	Yes. If there are not a lot of breaks to rest my "chops," I easily become tired.
Subject 5	No, my performances usually aren't very long.
Subject 6	No.
Subject 7	No.
Subject 8	Yes, I get tired and have trouble maintaining good tone and tuning especially on slow stuff.
Subject 9	No. I usually try to work up my endurance b/f a performance.

Many performers take a short break (a few days perhaps) from playing following an important performance for which they have prepared especially intensely. Is this something that you do? Please comment on why or why not.

Subject 1	Yes. For me, it's often more about the stress than anything. I try to keep a decent balance, but it's always nice to take a day off after working that hard.
Subject 2	Yes, I feel my endurance increase after a few days of rest.
Subject 3	No. I don't because I try to do something to better my playing everyday.
Subject 4	Yes. This is to decrease the possibility of burn-out while playing the clarinet. I don't do primarily to rest anything.
Subject 5	Yes. I have been doing so much with that music that I want to have a break where I don't think about it.
Subject 6	Yes. Mentally I need a break after strenuous psychological and physical preparation.
Subject 7	No. I need to stay in shape. Performances are rather close together

Subject 8	Yes. I get very tired – mentally and physically after a performance. I feel like I need the rest.
Subject 9	Yes. Release. Need an emotional and mental break.

If you do take a break after one of these important performances how do you feel with respect to endurance after you resume your normal playing routine?

Subject 1	About the same endurance, to far lower. If the break is more than 3 – 4 days. I find endurance to be a real issue.
Subject 2	I can generally play longer.
Subject 3	N/A
Subject 4	I feel like I loose some of my endurance.
Subject 5	I don't notice much difference.
Subject 6	If I break for a couple of days, there is usually no difference physically, but mentally I feel refreshed.
Subject 7	N/A
Subject 8	More energetic
Subject 9	Great.

Has it ever been suggested to you by a music educator (private instructor, band director, conductor, method book author, etc) that you should play every day? If yes, please explain.

Subject 1	Yes. Everyone seems to say that. Personally, I don't always do it, but to me it's so normal that I can & will do it if I need to.
Subject 2	Yes. I've been told to practice little bits of music every day.
Subject 3	Yes. It is something that I have always heard about. Never really explained very well though.
Subject 4	Yes. Every director has mentioned that at one time or another.
Subject 5	Yes. It is usually recommended to play for a set amount of time every day to keep up technique.

Subject 6	Yes. I was told to play at least a little bit every day.
Subject 7	Yes. Stay focused on music
Subject 8	Yes. I once had a band director who posted a sign in the band hall that read, “Play only on the days you eat.”
Subject 9	No.

Do you have a specific individual practice schedule? If yes, please describe.

Subject 1	End of semester testing has disrupted it, but I usually practice for several hours on Tuesday & Thursday with breaks and for 30 mins or so on M/W/F.
Subject 2	No.
Subject 3	No.
Subject 4	Yes. Usually I practice about 1½ hr. each day, except Saturdays.
Subject 5	No.
Subject 6	No.
Subject 7	No.
Subject 8	No.
Subject 9	Yes. M – S, 3 – 4 hours a day in 1½ – 2 hour sessions

If you have a specific practice schedule does it ever change? If yes, please describe the factors which affect a change in this schedule.

Subject 1	Yes. All the time! It’s flexible. My mood, if I have a performance to prepare for or that I just finished.
Subject 2	N/A
Subject 3	N/A
Subject 4	Yes. Busyness and schedule overload.

Subject 5 N/A

Subject 6 N/A

Subject 7 N/A

Subject 8 N/A

Subject 9 Yes. Unanticipated changes to schedule

What types of performance tasks do you find particularly fatiguing?

Subject 1 High-stress (solos, juries)

Subject 2 big/loud ensembles

Subject 3 Sustained passages fatigue me the most. Loud passages often result in a bit of fatigue as well.

Subject 4 Tonguing a lot and playing a lot of long tones in the higher register.

Subject 5 Long passages without rest and holding long notes.

Subject 6 Slow, sustained pieces or exercise that last for several minutes.

Subject 7 None.

Subject 8 Soft playing, high notes, and music with few rests.

Subject 9 Slow and high.

After First, Second, and Third Day of Testing:

How do you feel with respect to embouchure fatigue now? (On a scale of 1 to 10; 1 = not fatigued at all, 10 = completely fatigued.)

	After first day	After second day	After third day
Subject 1	7	8	5.5
Subject 2	2	3.5	2
Subject 3	9.5	8	6.5
Subject 4	7	6	5
Subject 5	8	10	8
Subject 6	7	7	9
Subject 7	3	2	2
Subject 8	7	8	6
Subject 9	8	6	4

Estimate at what point your embouchure began to feel tired? (Within the first five minutes of testing, after 5 minutes of testing, after10 minutes of testing, after 15 minutes of testing, after 20 minutes of testing, or did not experience any fatigue.)

	After first day	After second day	After third day
Subject 1	After 5 minutes	Within first 5 minutes	Within first 5 min.
Subject 2	No fatigue	After 15 minutes	After 15 minutes
Subject 3	Within first 5 minutes	Within first 5 minutes	After 5 minutes
Subject 4	Within first 5 minutes	Within first 5 minutes	After 5 minutes
Subject 5	After 15 minutes	Within first 5 minutes	Within first 5 min.
Subject 6	Within first 5 minutes	Within first 5 minutes	Within first 5 min.
Subject 7	After 10 minutes	After 15 minutes	After 20 minutes

Subject 8	After 5 minutes	Within first 5 minutes	After 15 minutes
Subject 9	After 15 minutes	After 5 minutes	After 5 minutes

How much do you feel that your tone quality deteriorated during this test session? (On a scale of 1 to 10; 1 = tone improved or there was no change, 10 = tone deteriorated to your worst possible sound.)

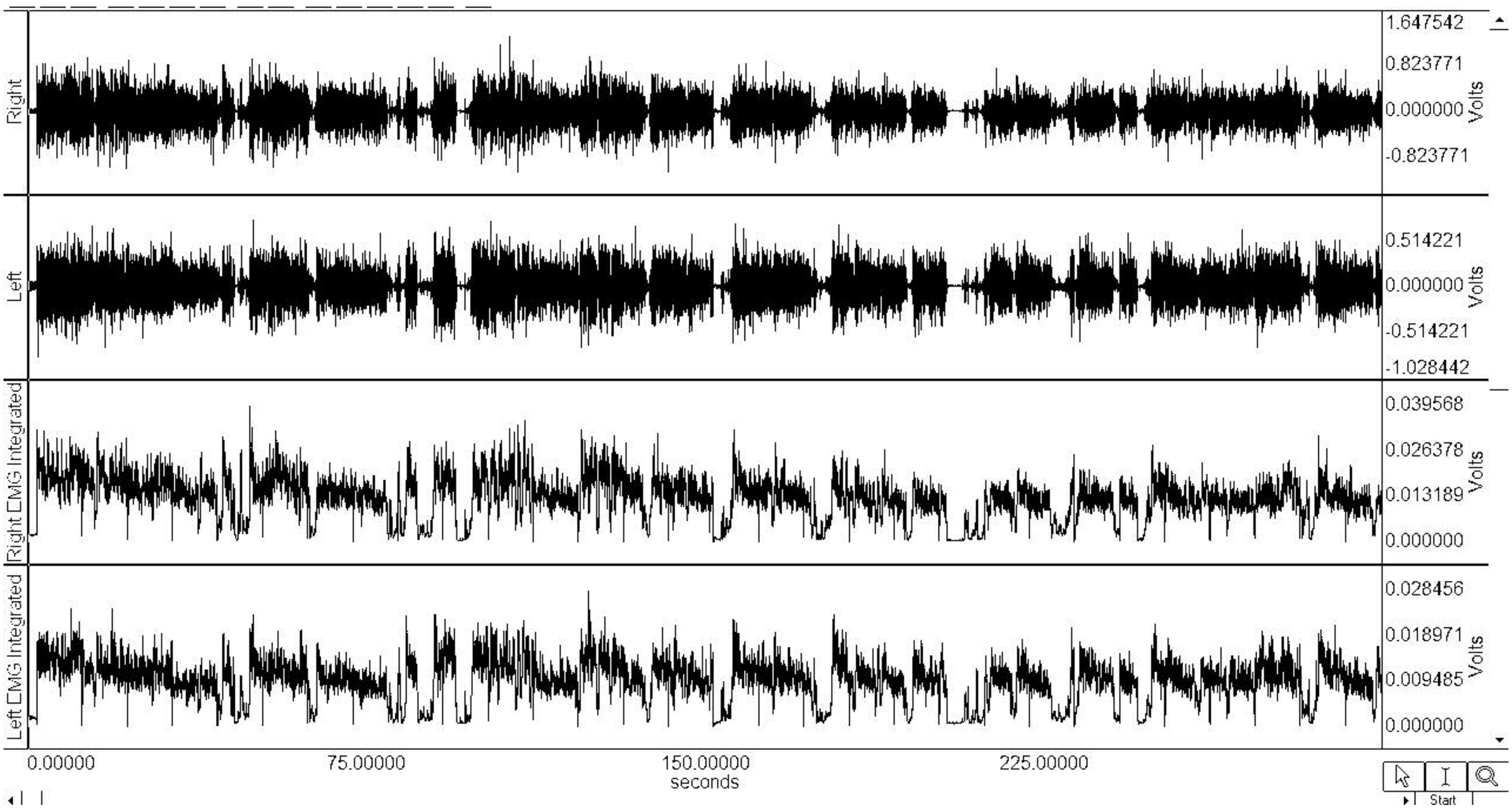
	After first day	After second day	After third day
Subject 1	9	8	8
Subject 2	1	5	3.5
Subject 3	10	8	6
Subject 4	7	8	8
Subject 5	6	8	7
Subject 6	3	4	1
Subject 7	7	4	2
Subject 8	6	8	5
Subject 9	8	6	3

The subject's responses to questionnaire provide evidence that clarinetists could benefit from an endurance building protocol that would correct training mistakes and is based in sport-science. Five of the nine subjects found endurance to be a problem during important performances. Six of the subjects reported some type of psychological fatigue related to preparing for an important performance. Four subjects played for more than eighteen hours each week, and this could create an overtraining effect. Although seven of the subjects actually took at least one day of rest each week, eight of the nine had been taught at some point during their playing career that the individual should practice every day. Only three subjects claimed to have a regular practice schedule, and all of the three reported that the regular schedule is likely to change due to environmental or psychological factors. All of the subjects reported experiencing some type of fatigue, none of them tapered their training schedule prior to an important performance; six subjects actually increased training prior to a performance.

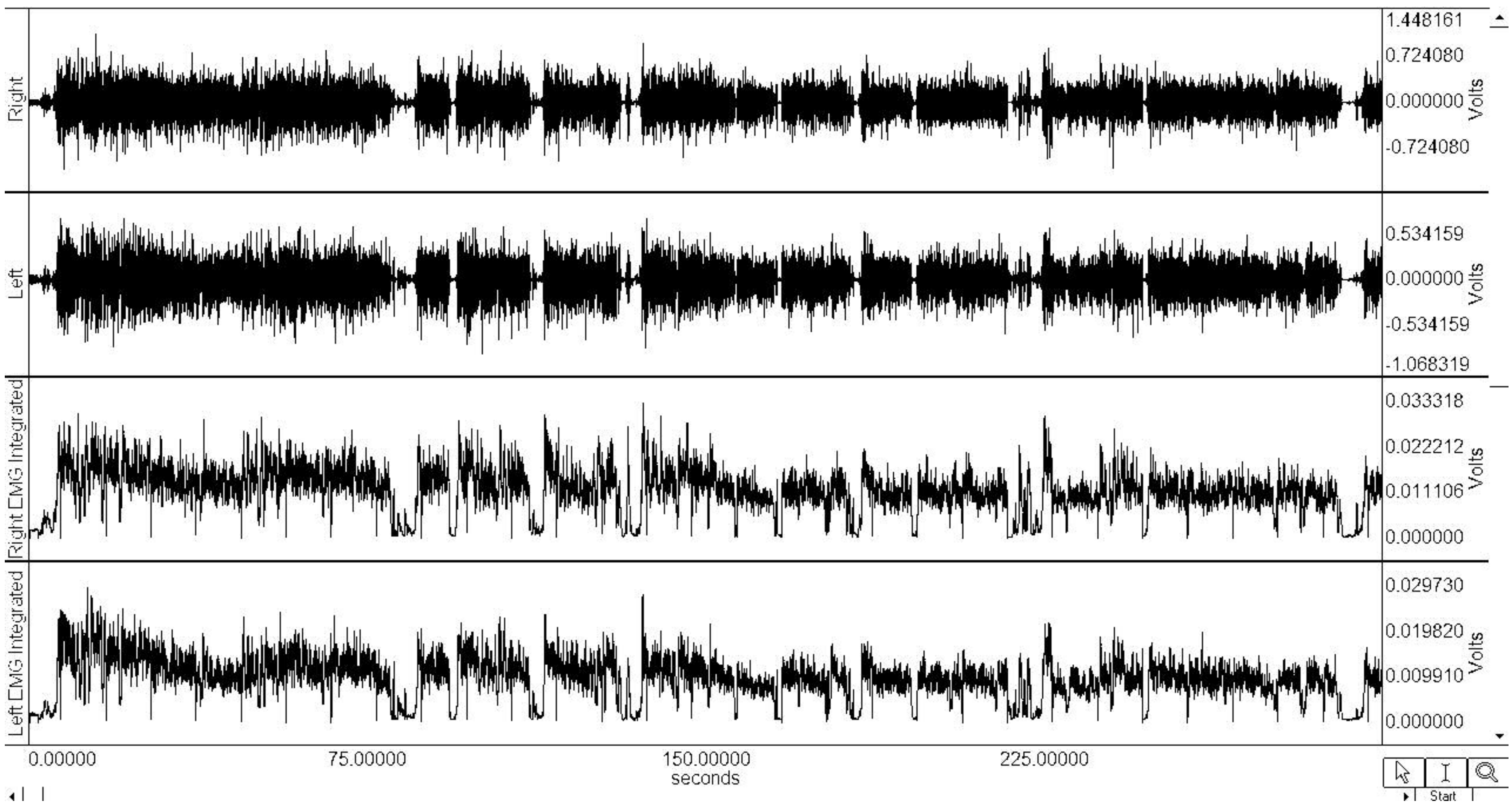
EMG Output

The following graphs represent the EMG output for each subject on each of three days of testing. The first and second lines of information on each chart represent the raw EMG signal from the right and left sides of the of the upper orbicularis oris. The lower two lines of information represent the integrated EMG for the right and left sides of the upper orbicularis oris.

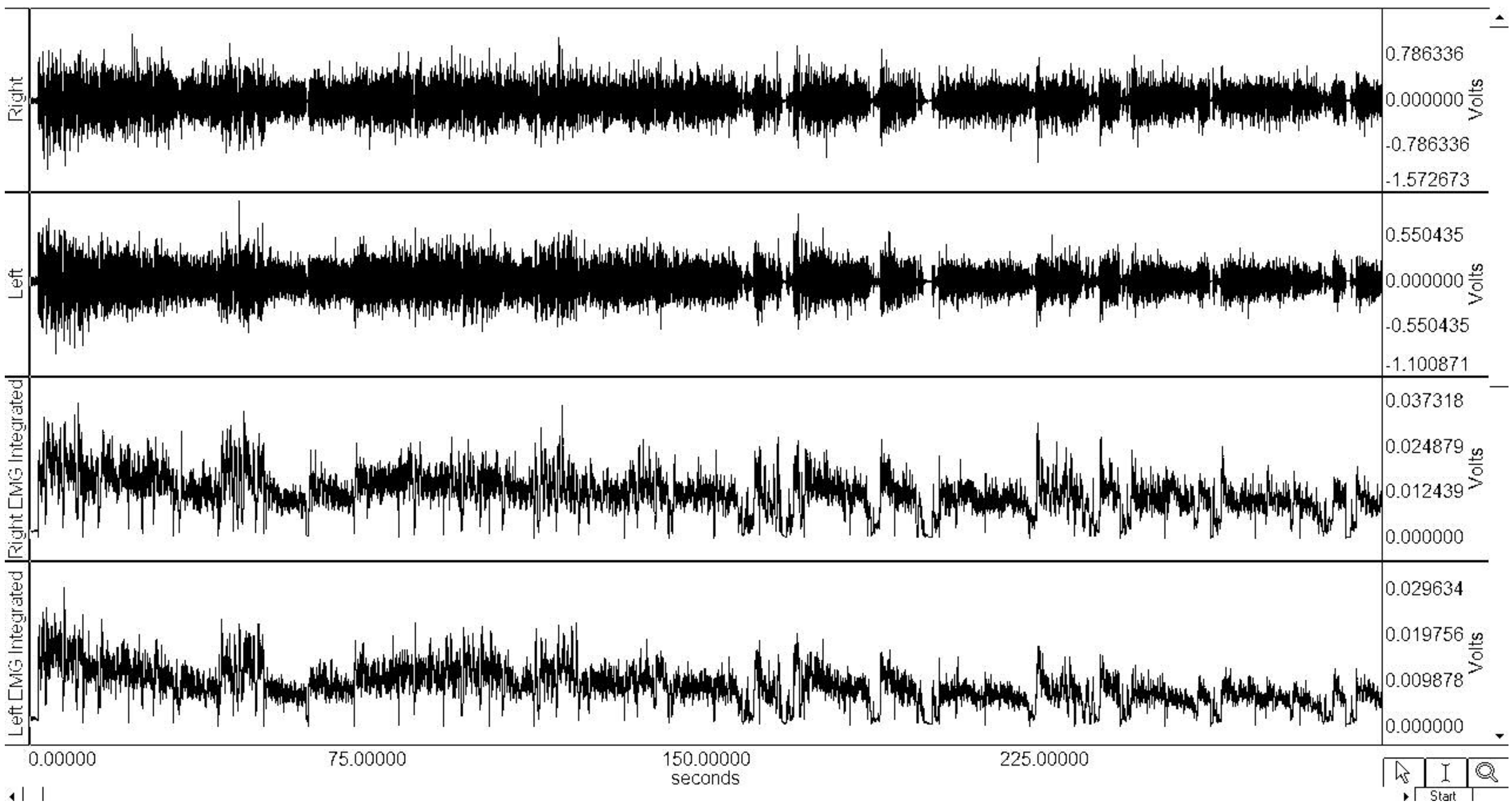
Subject 1, Day 1



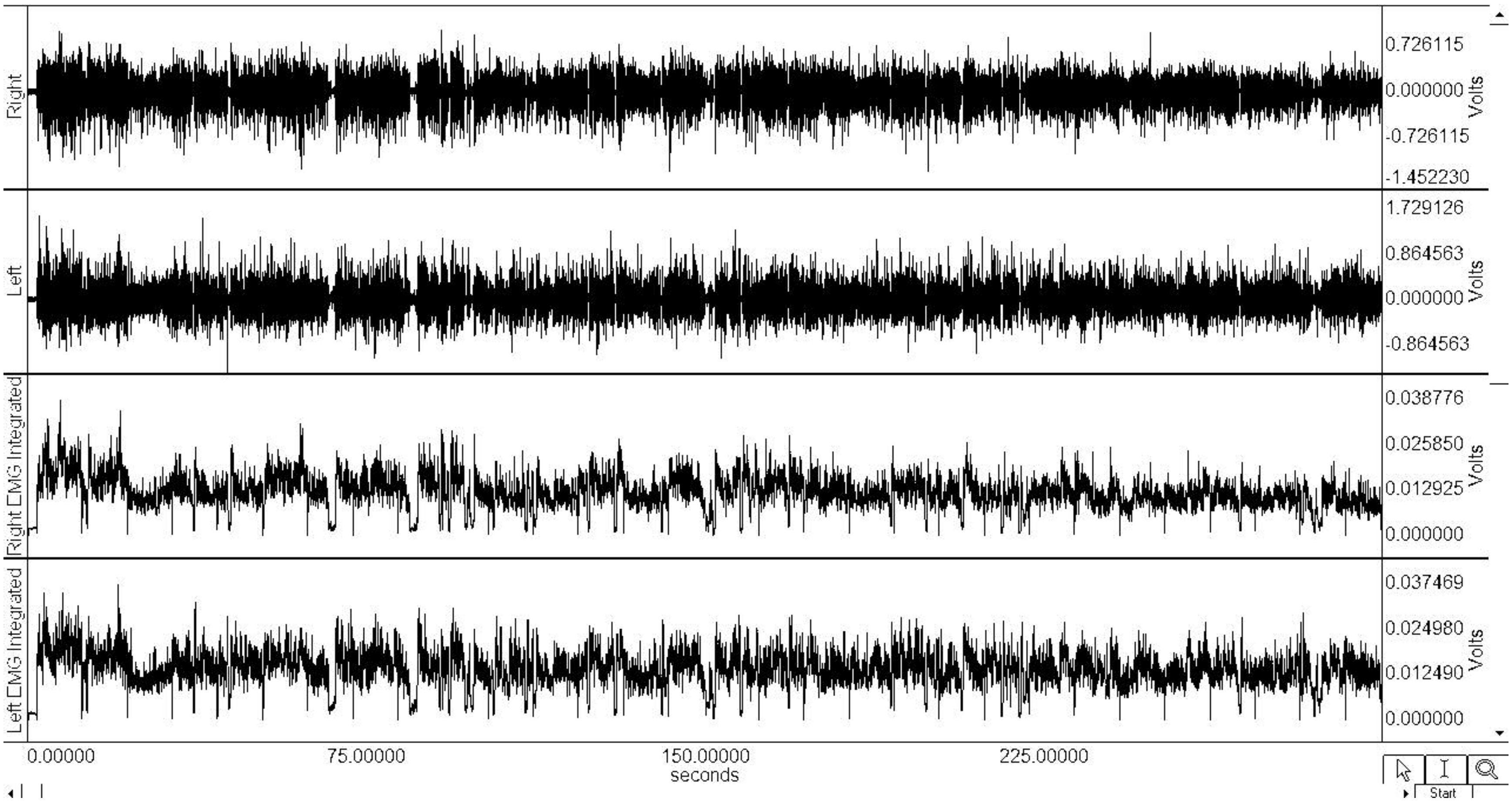
Subject 1, Day 2



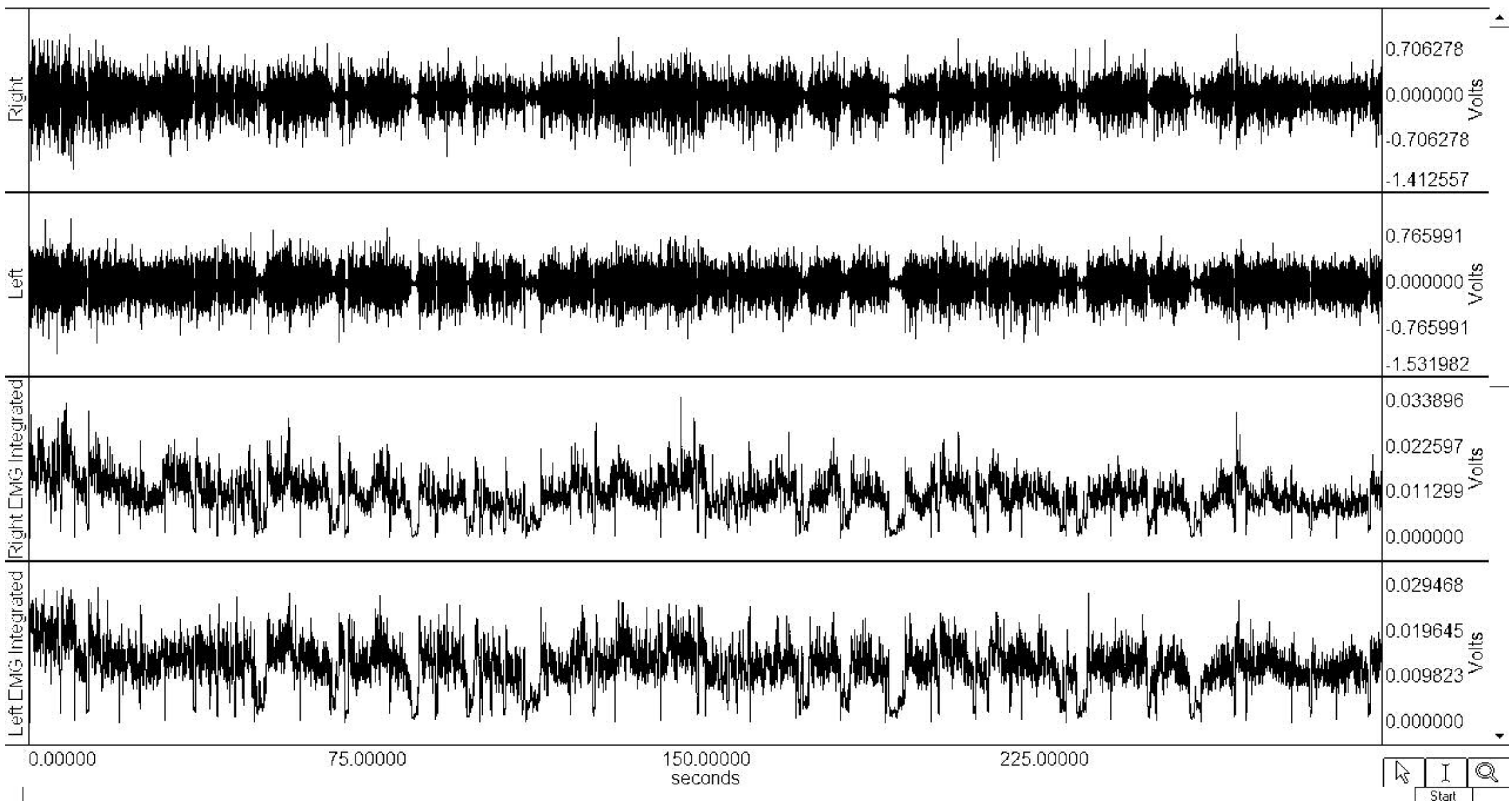
Subject 1, Day 3



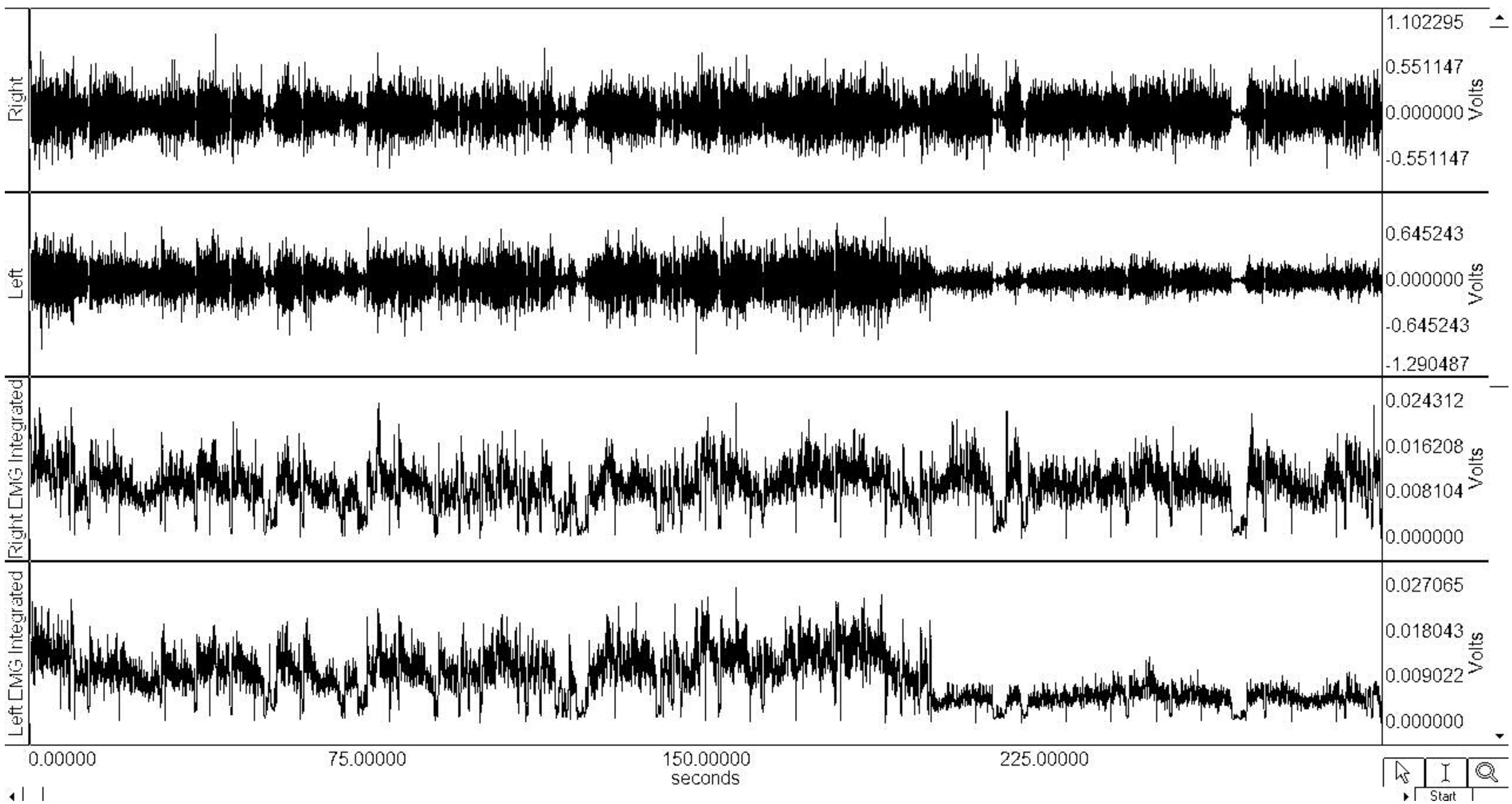
Subject 2, Day 1



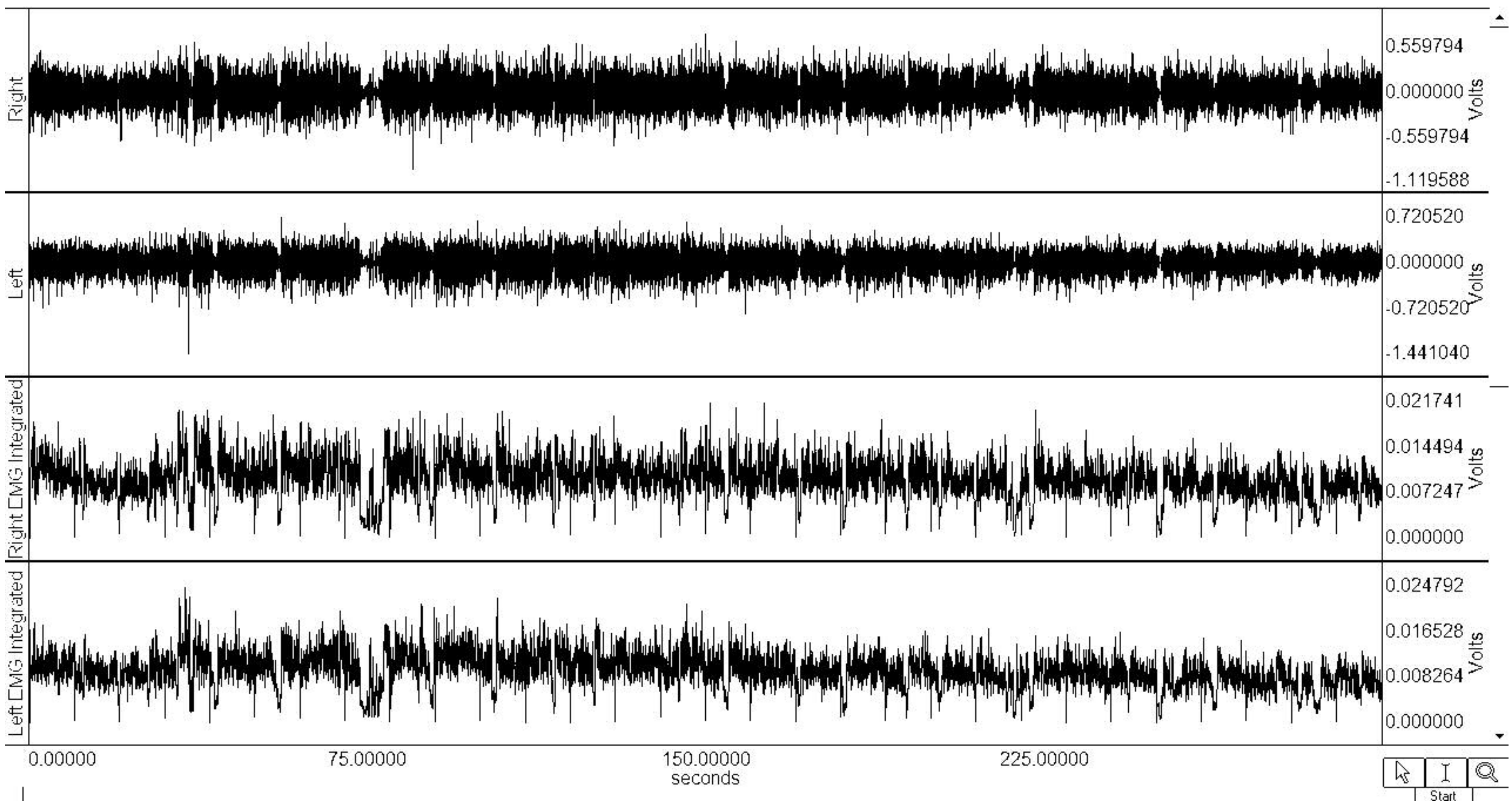
Subject 2, Day 2



Subject 2, Day 3



Subject 3, Day 1



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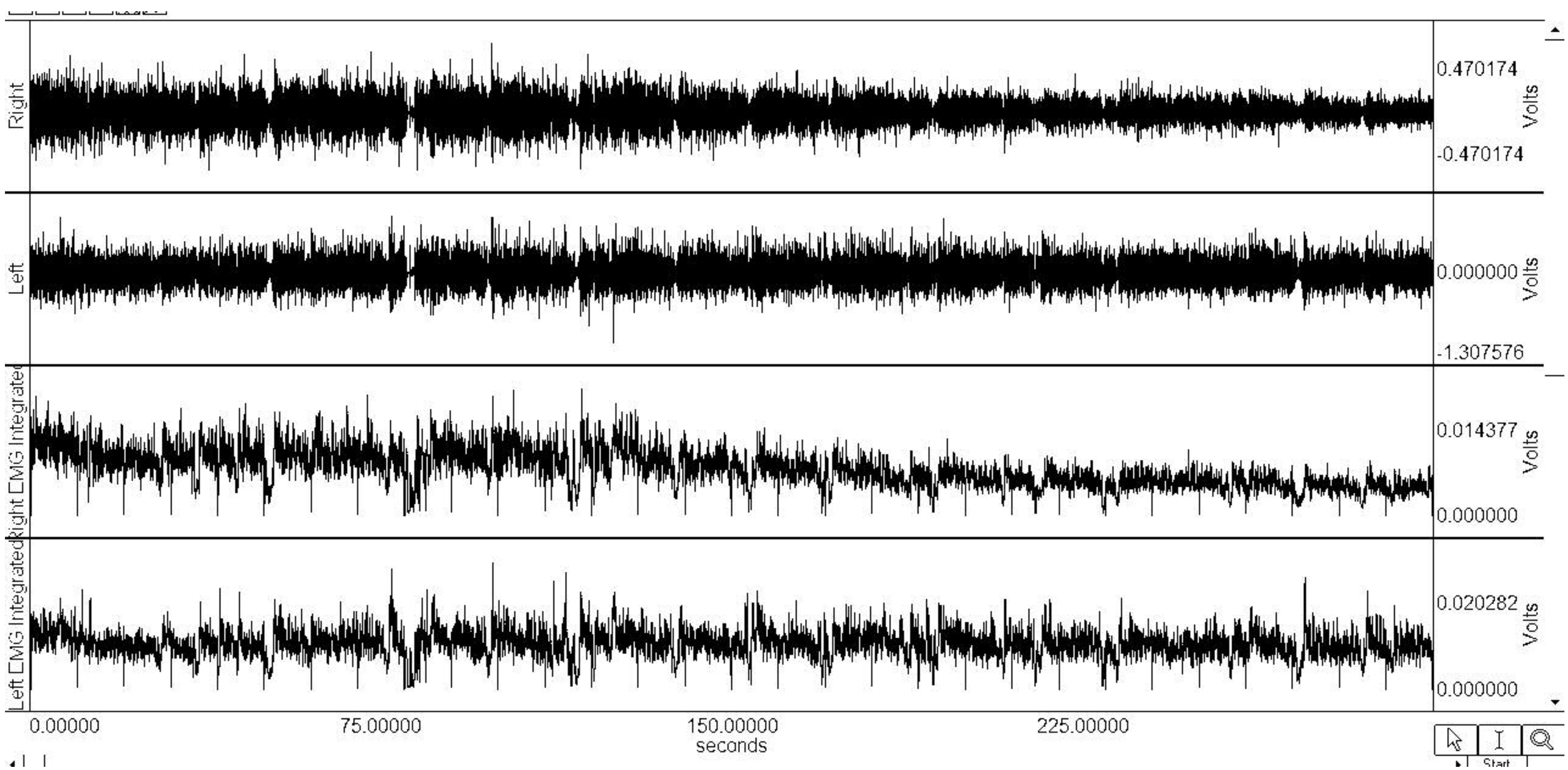
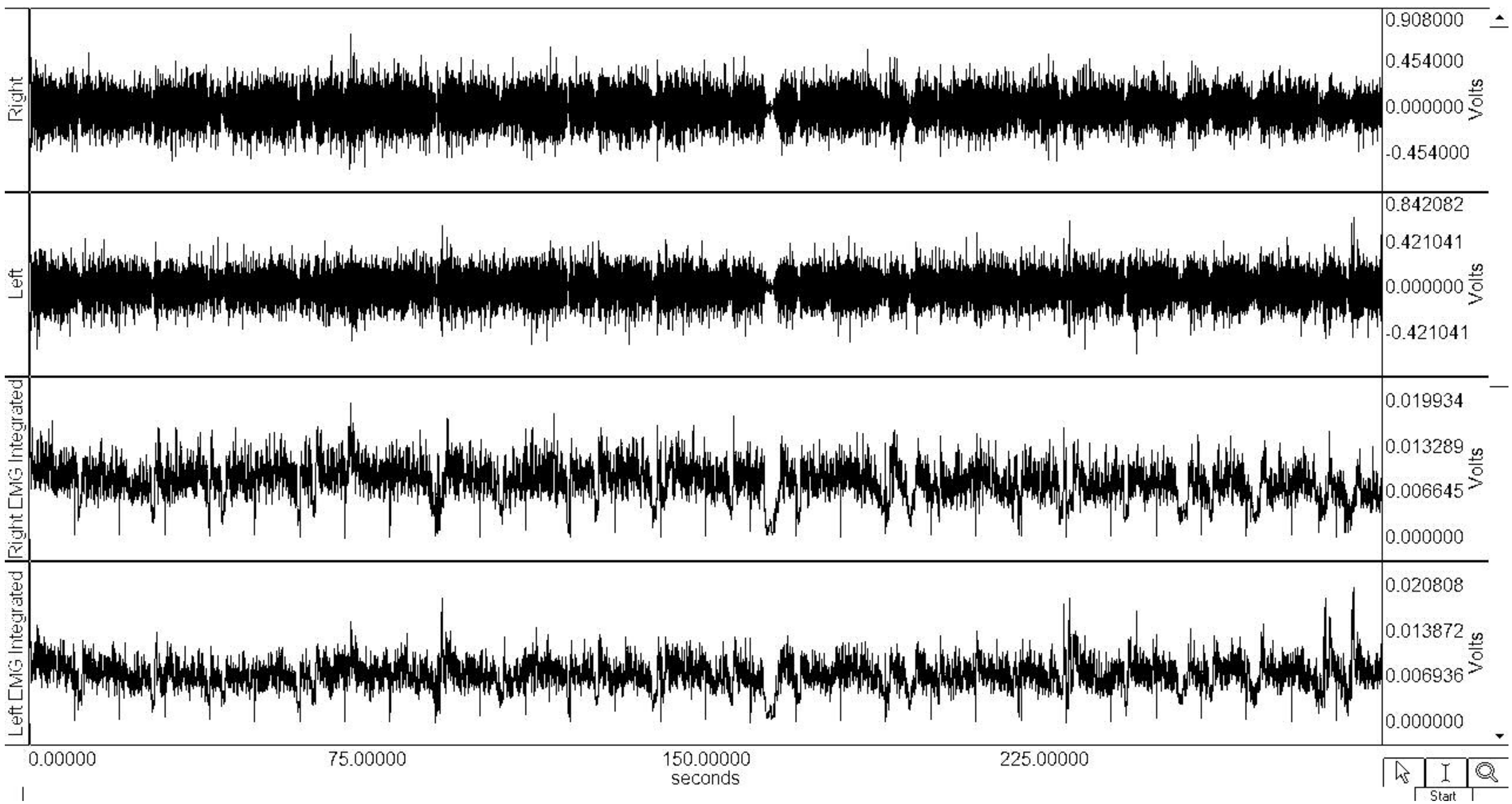
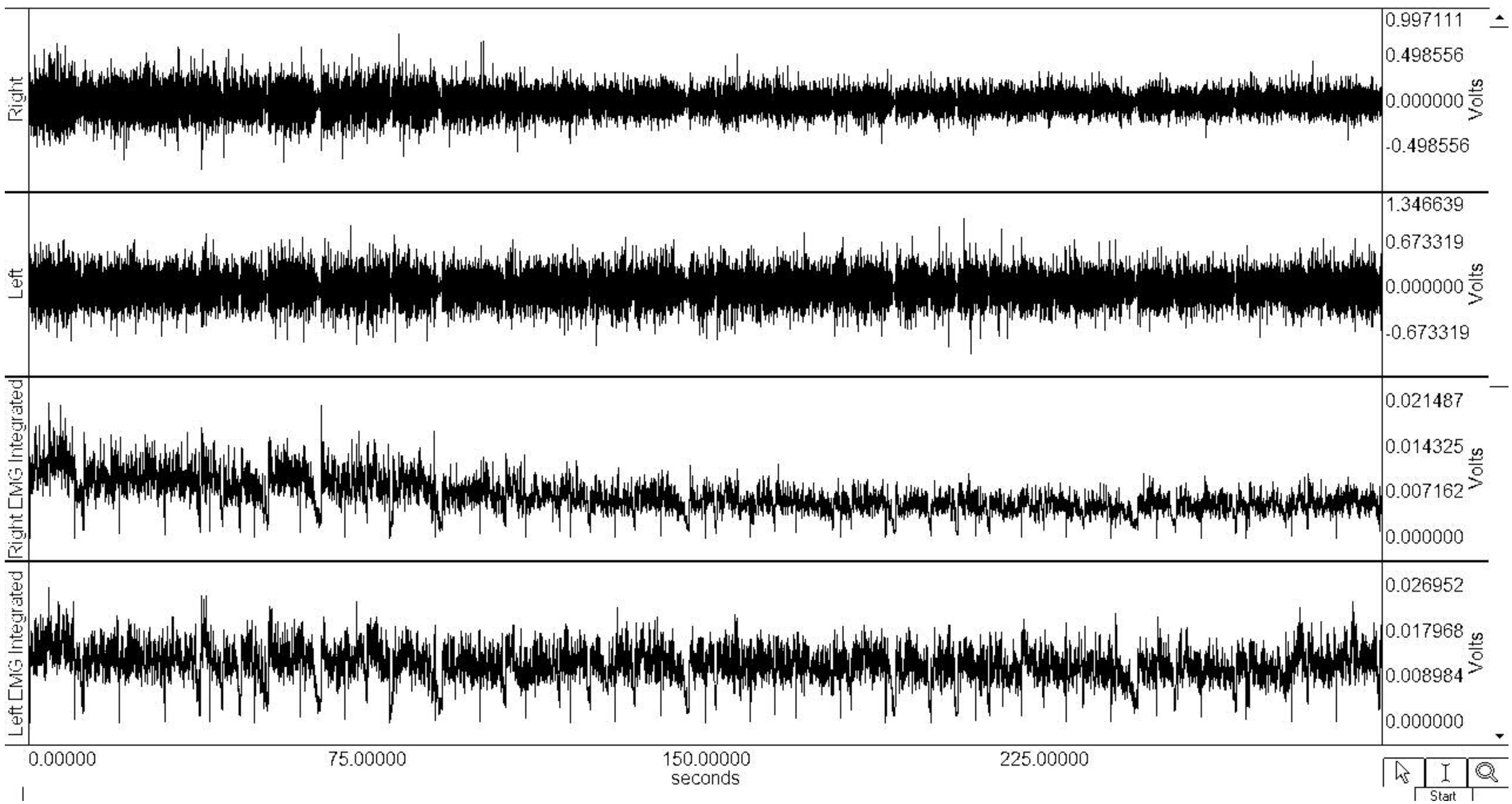
Subject 3, Day 2



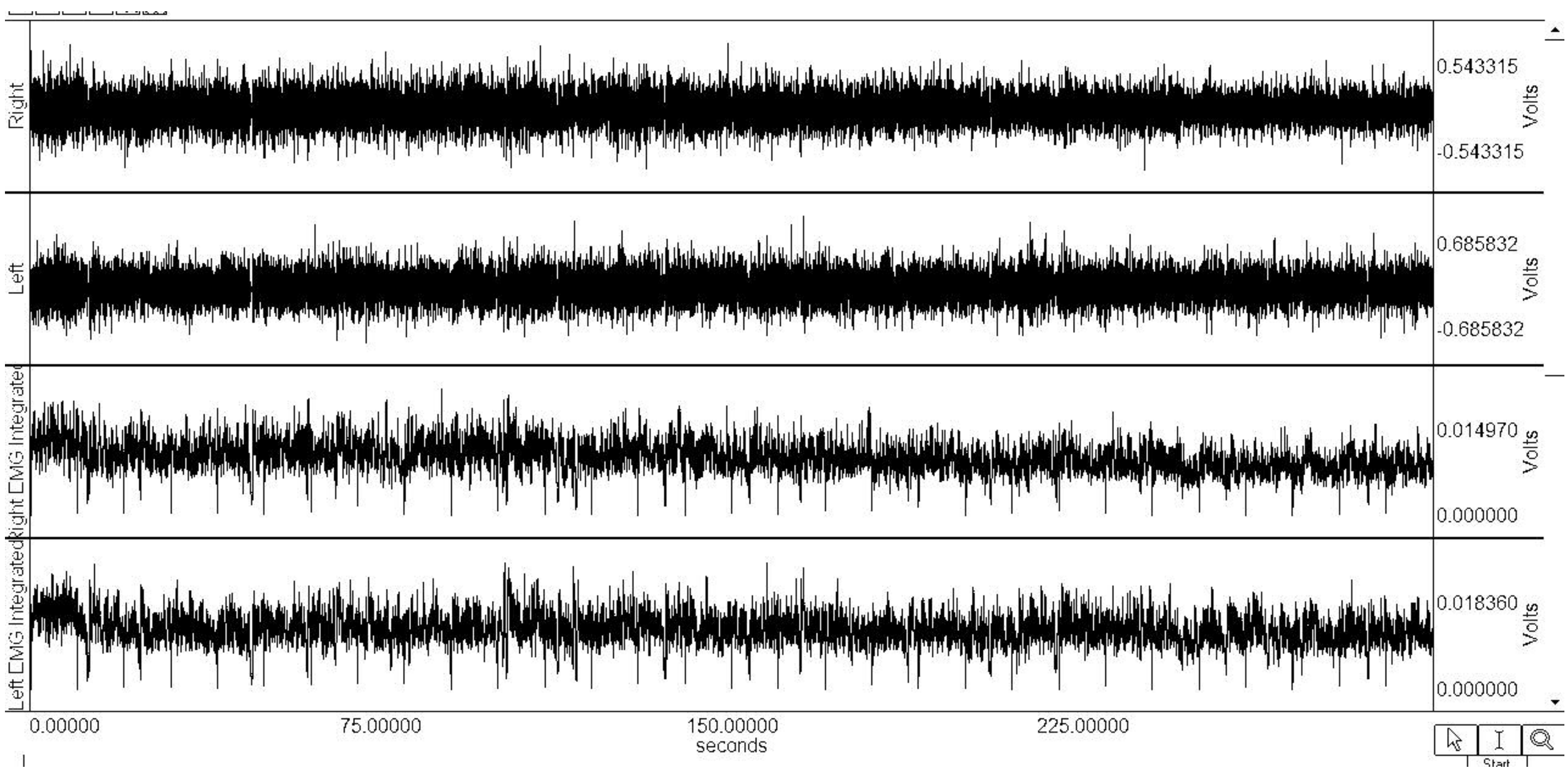
Subject 3, Day 3



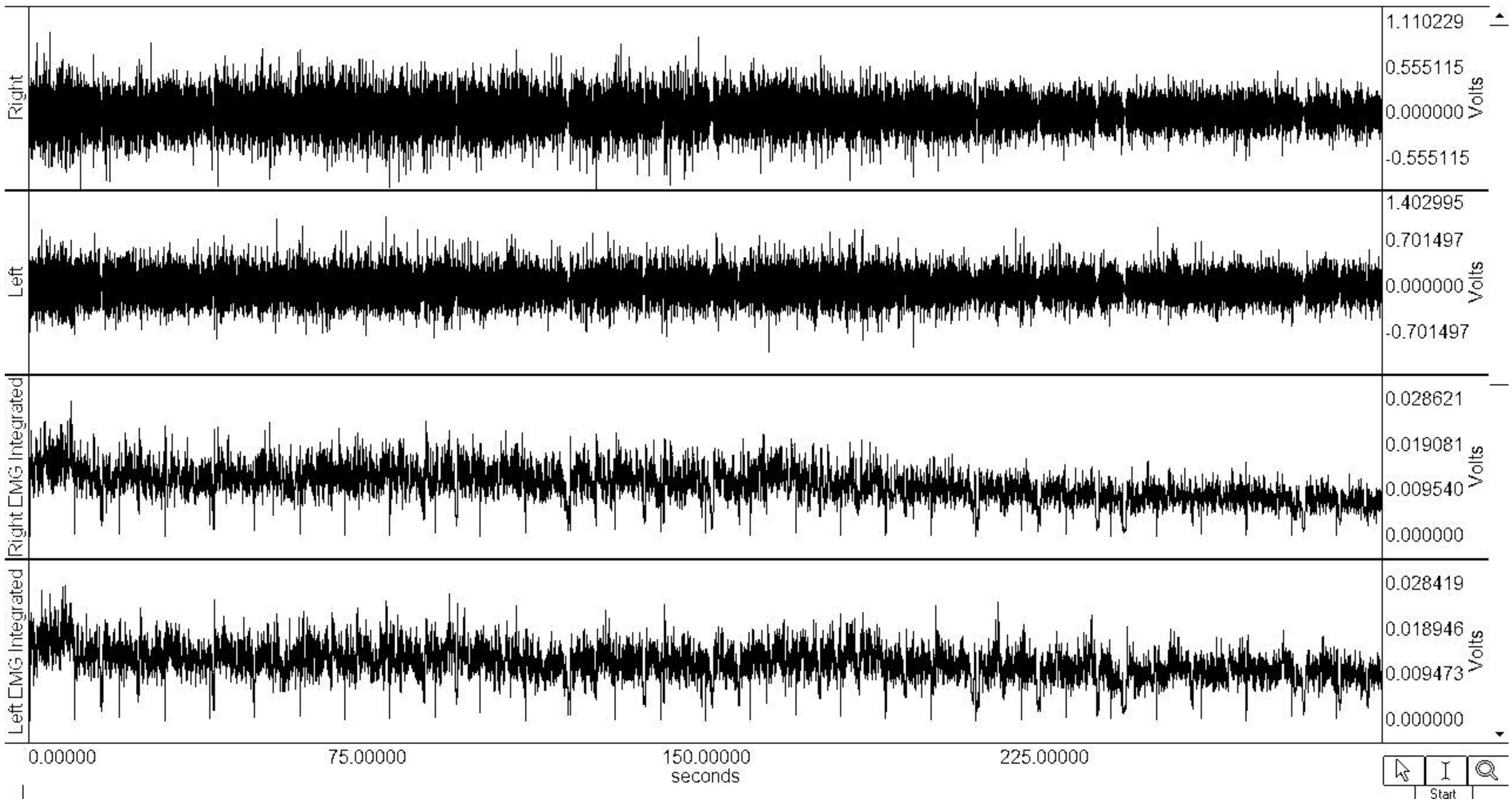
Subject 4, Day 1



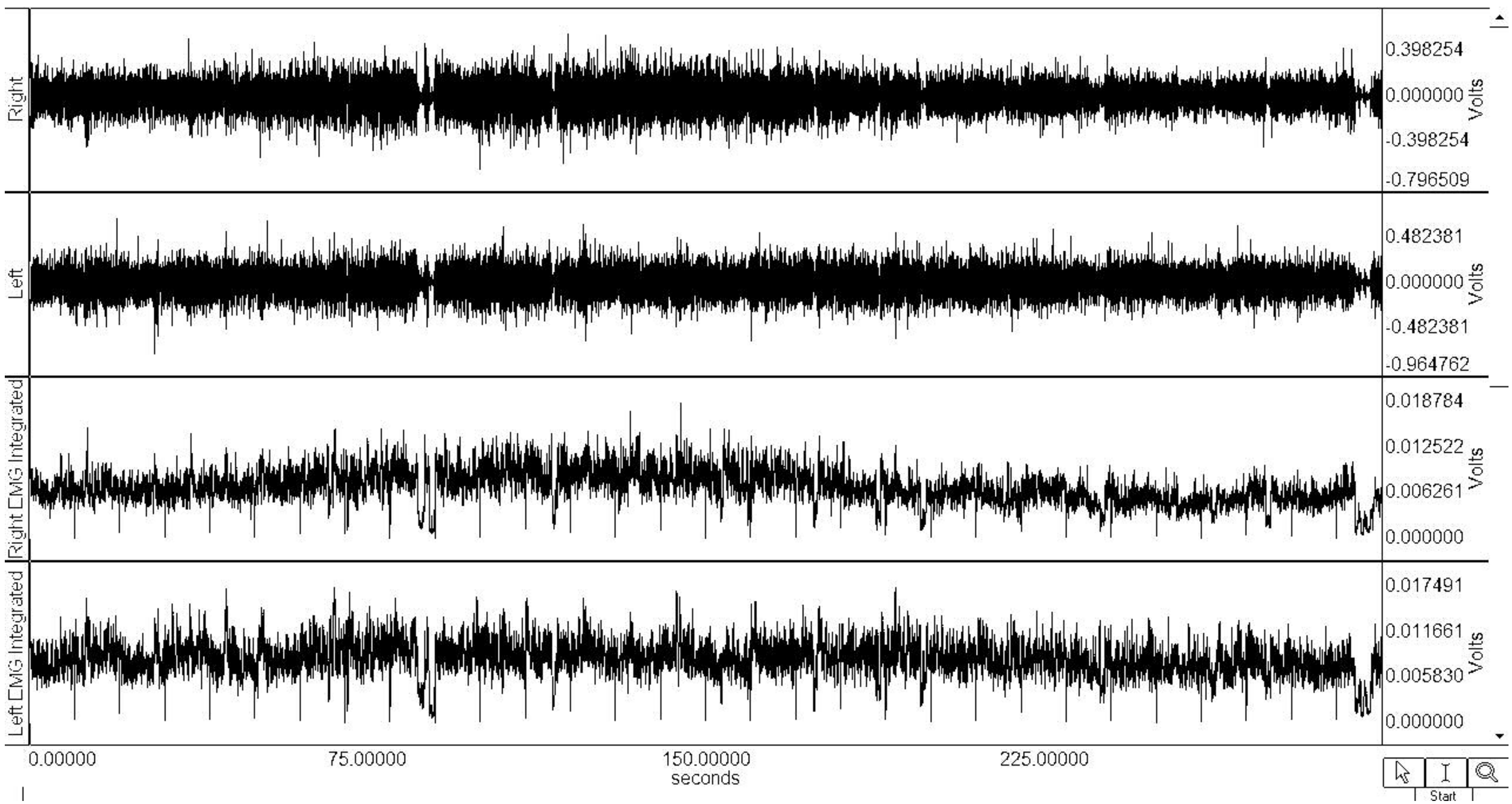
Subject 4, Day 2



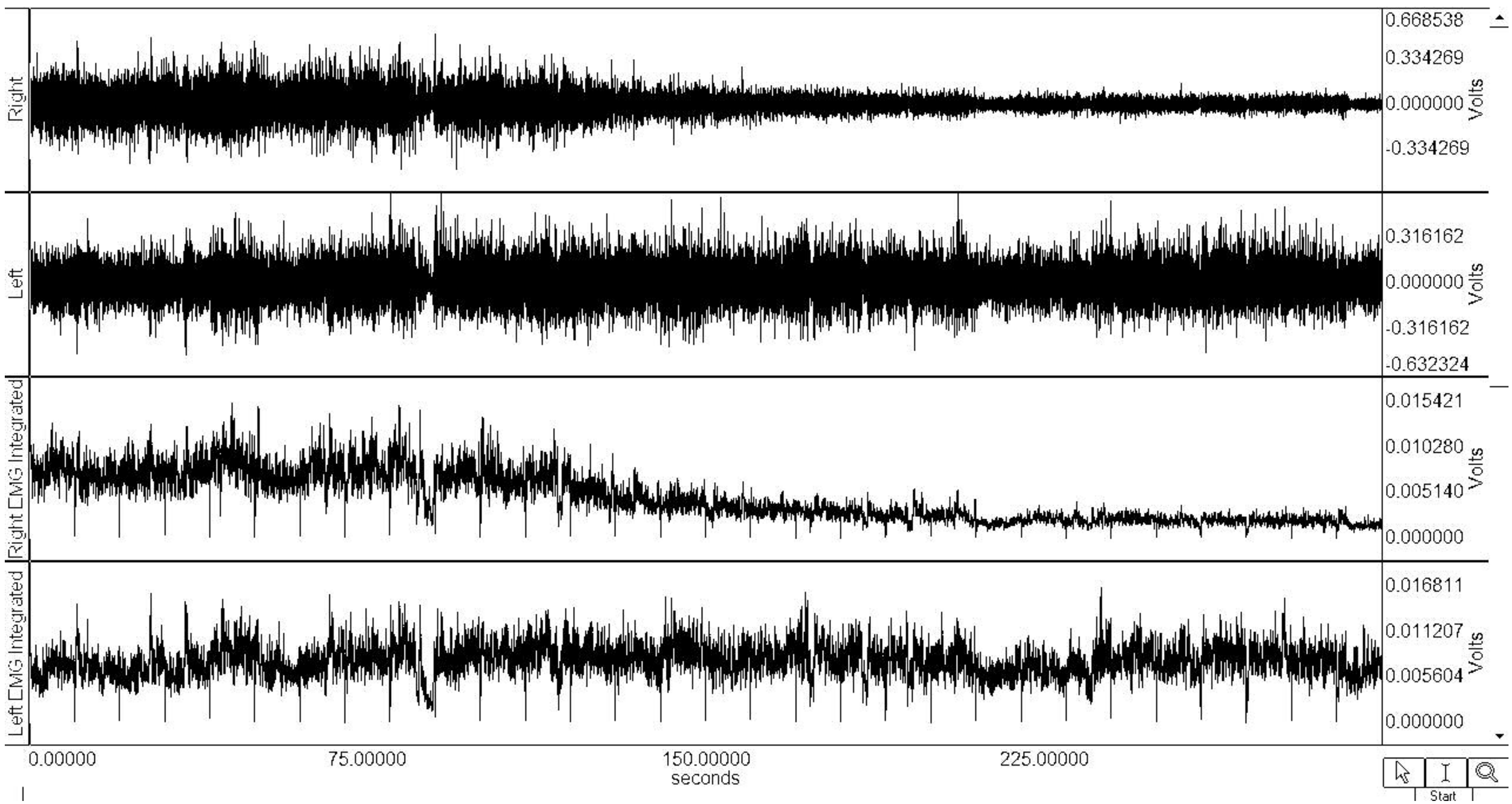
Subject 4, Day 3



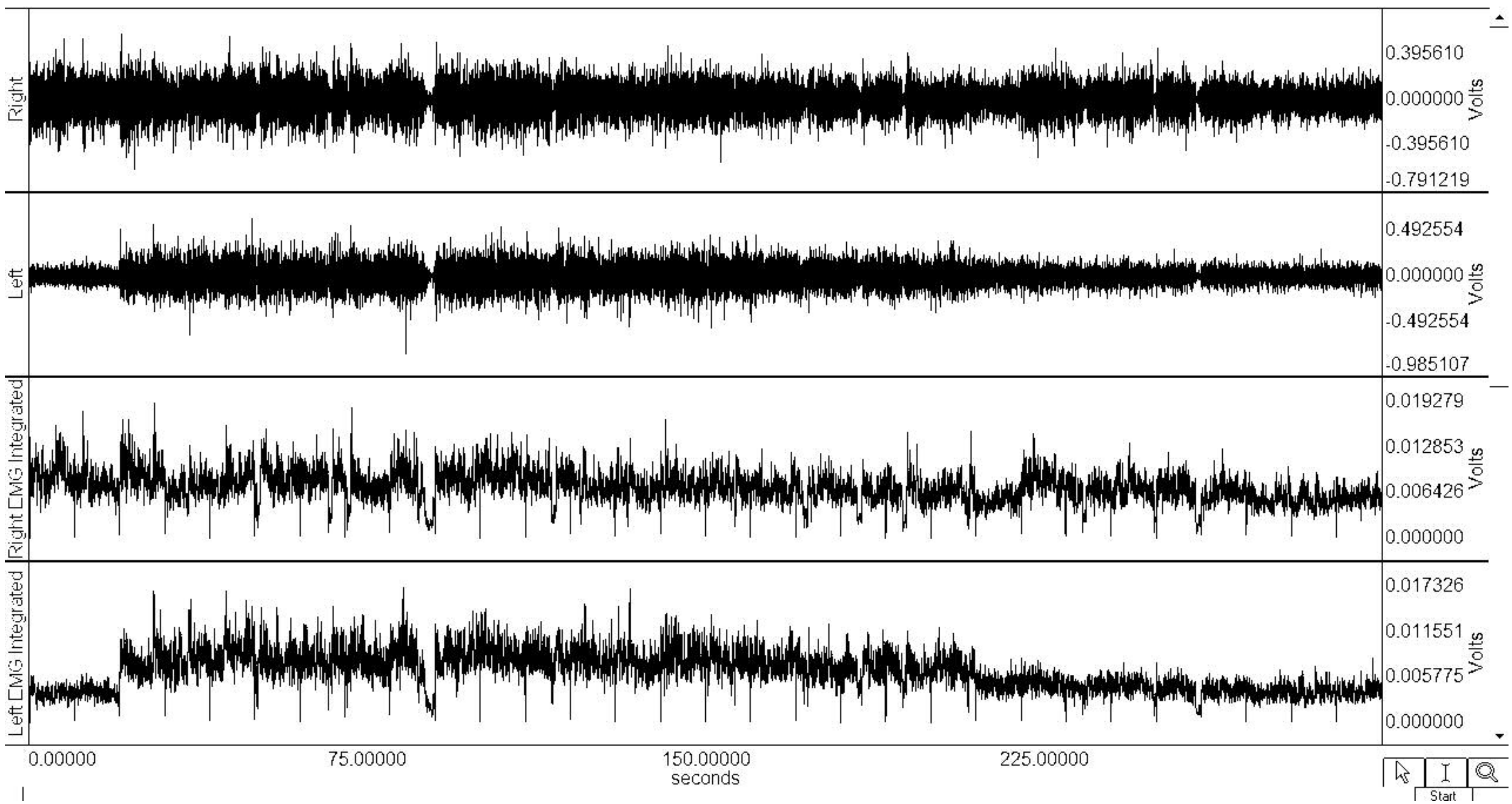
Subject 5, Day 1



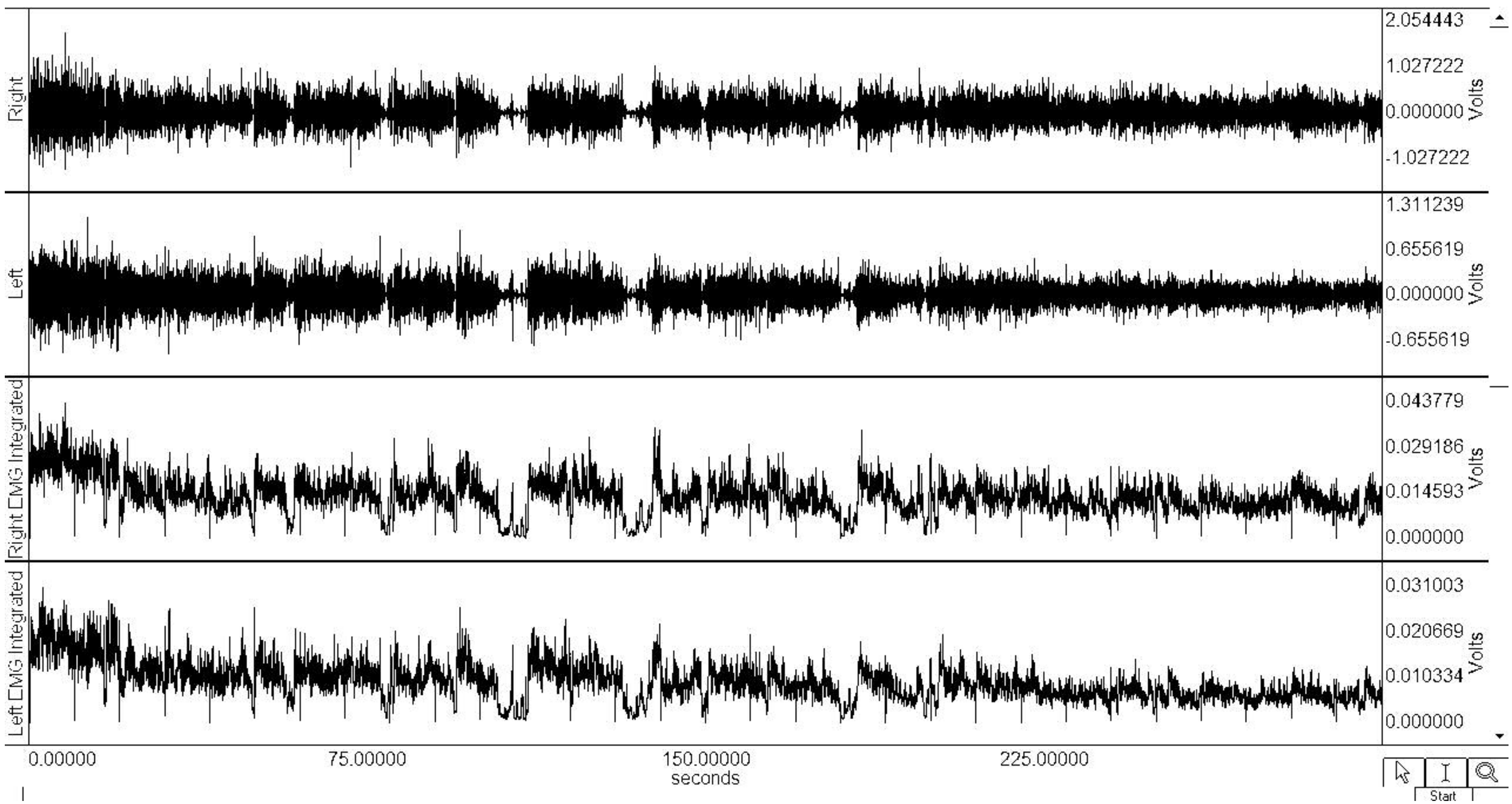
Subject 5, Day 2



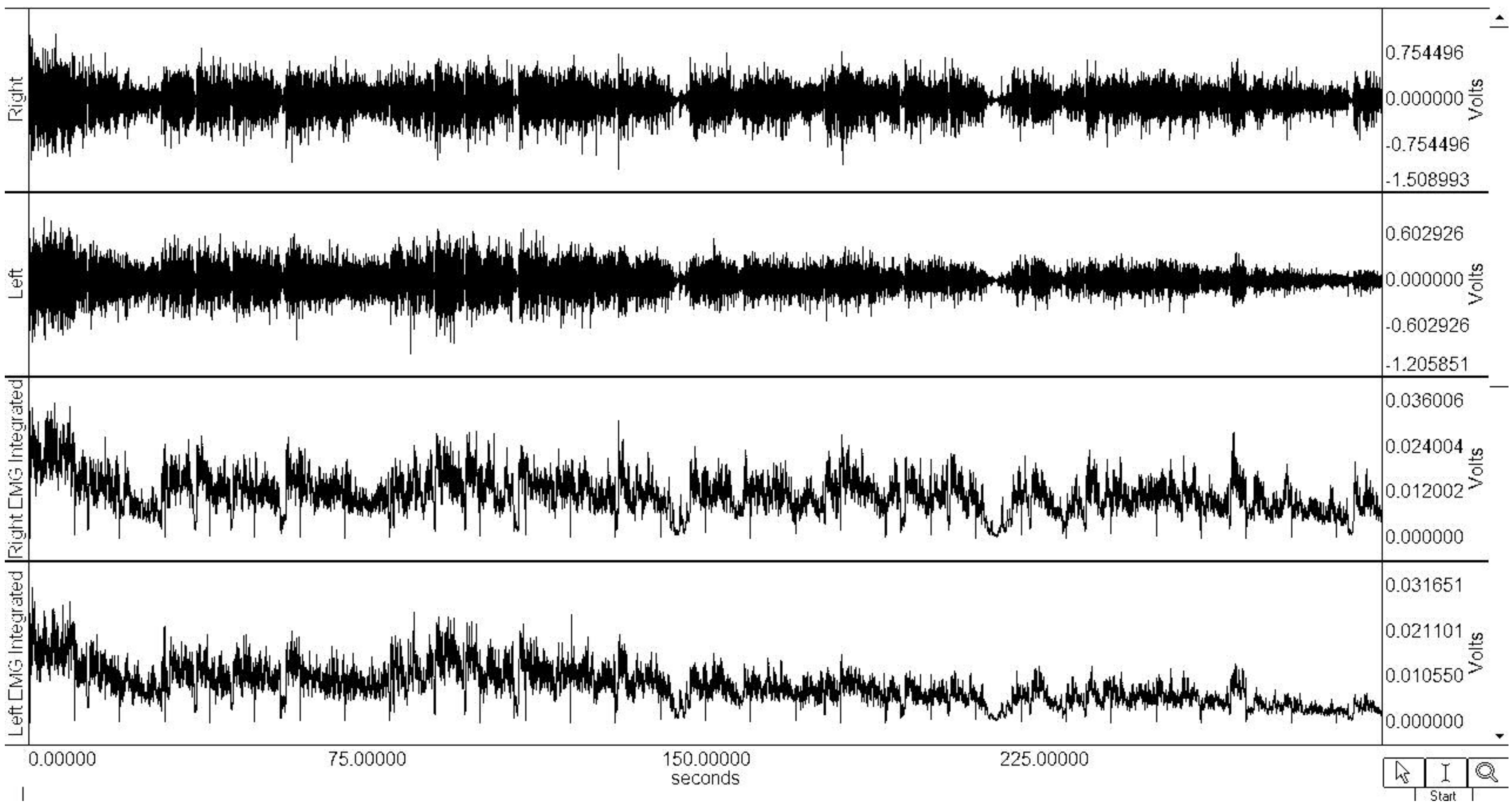
Subject 5, Day 3



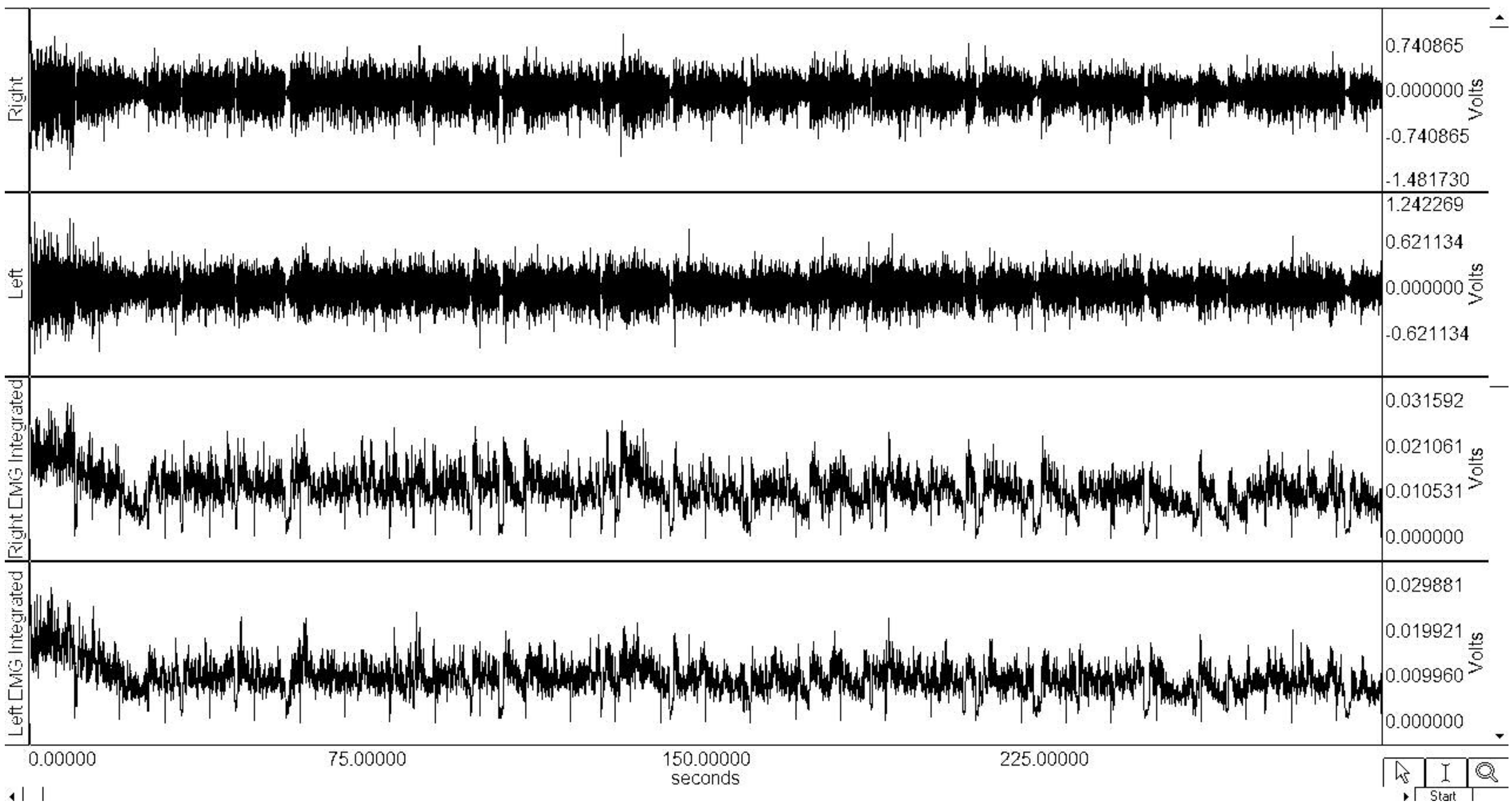
Subject 6, Day 1



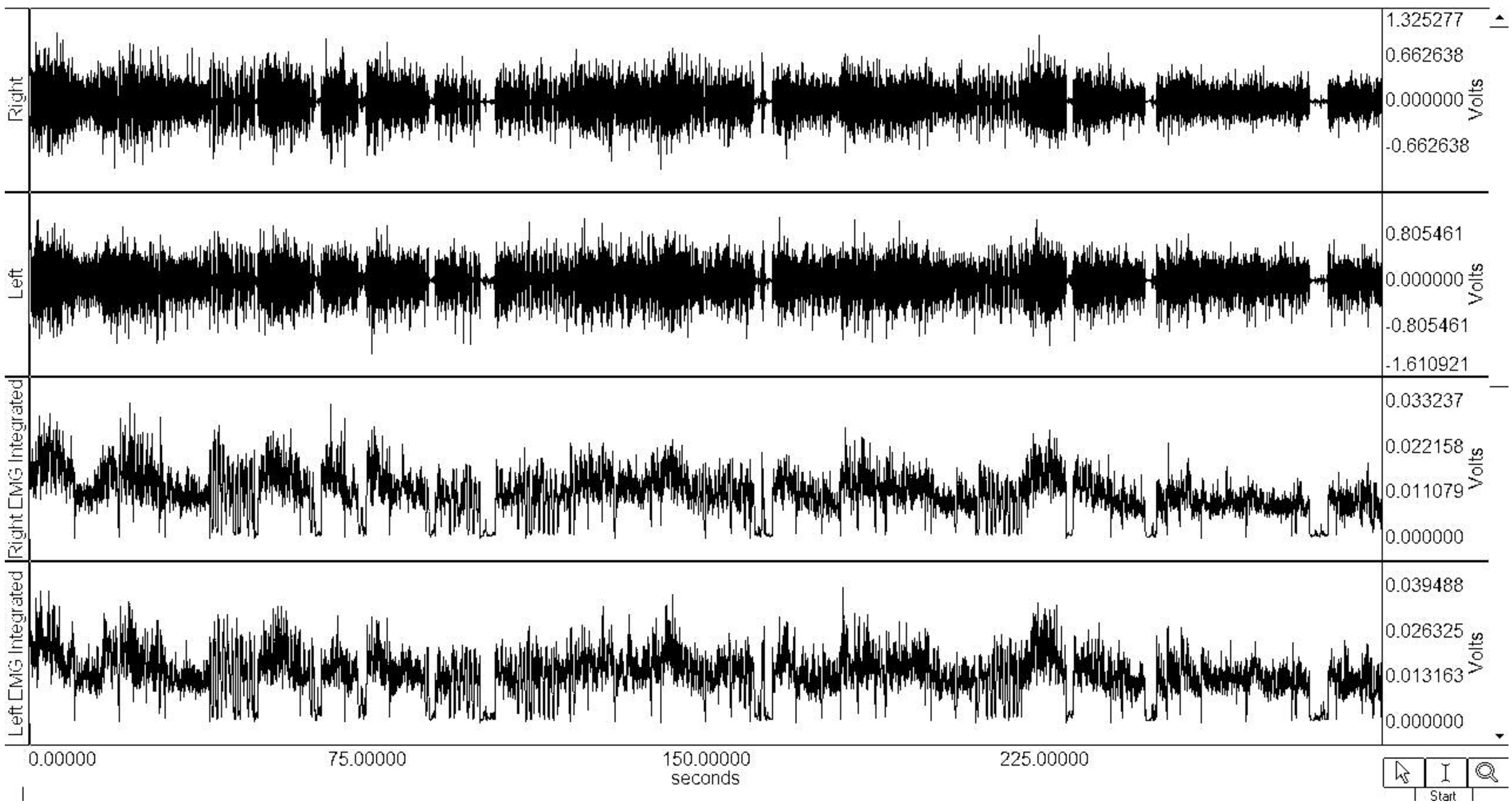
Subject 6, Day 2



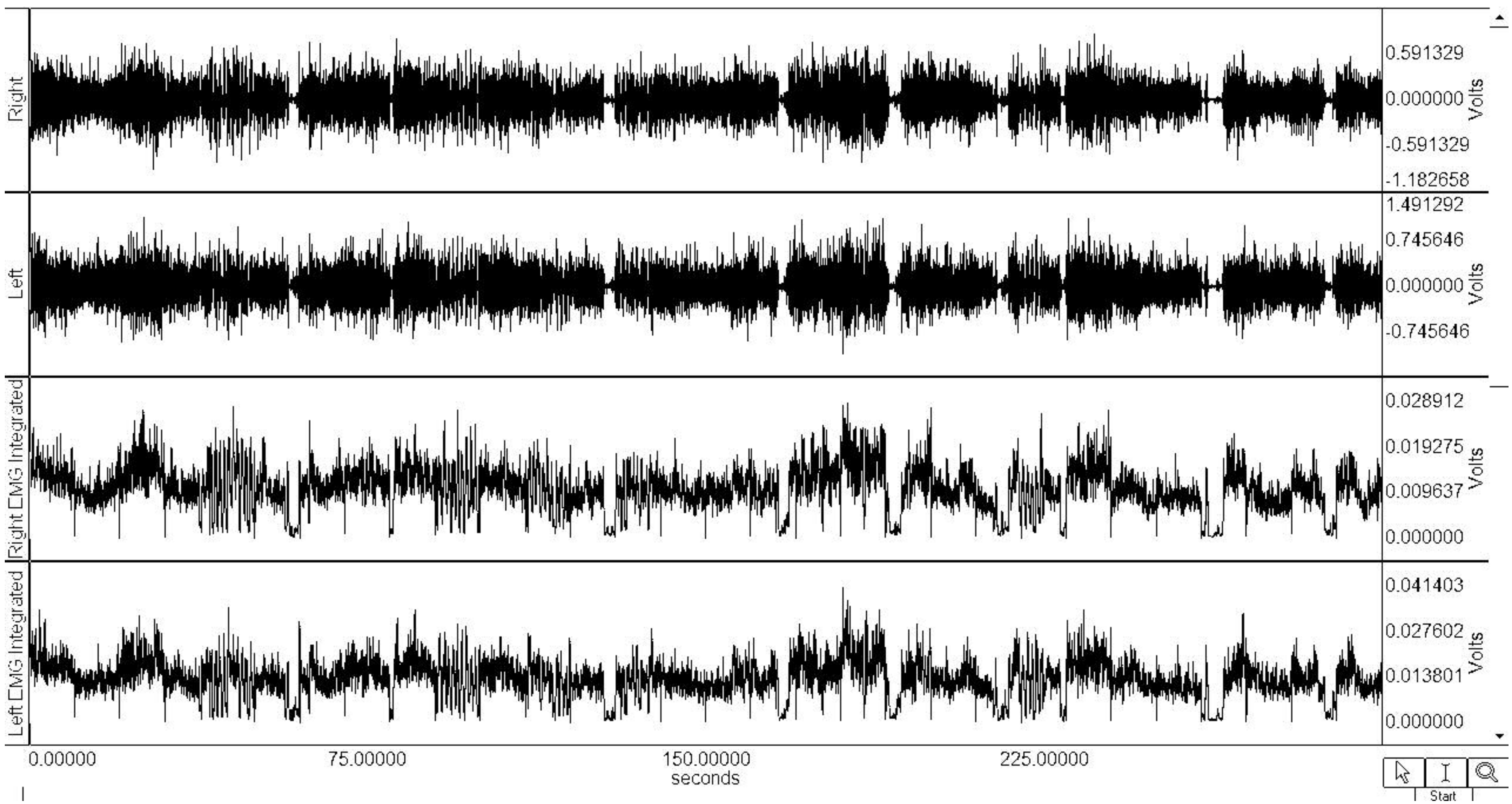
Subject 6, Day 3



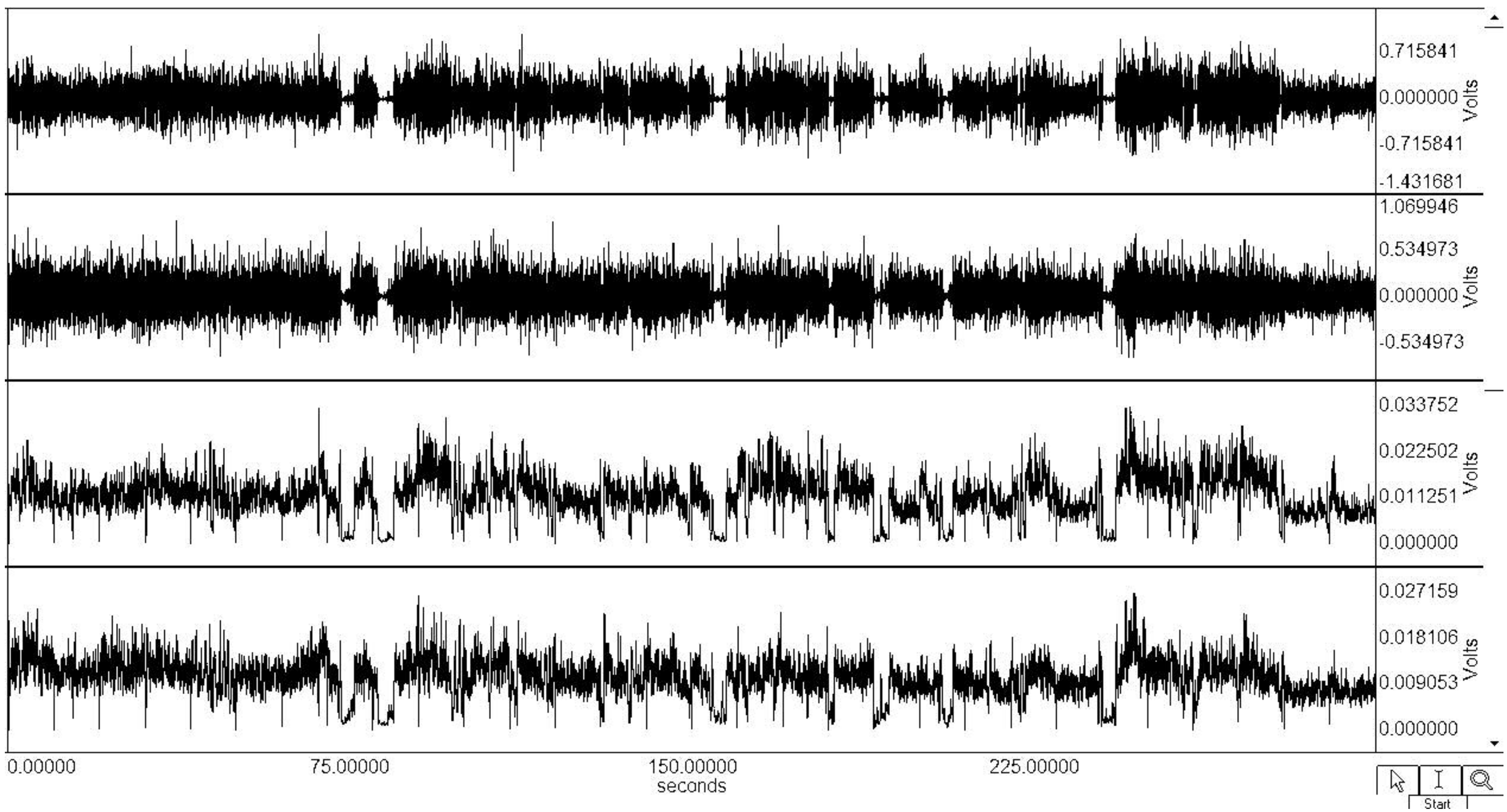
Subject 7, Day 1



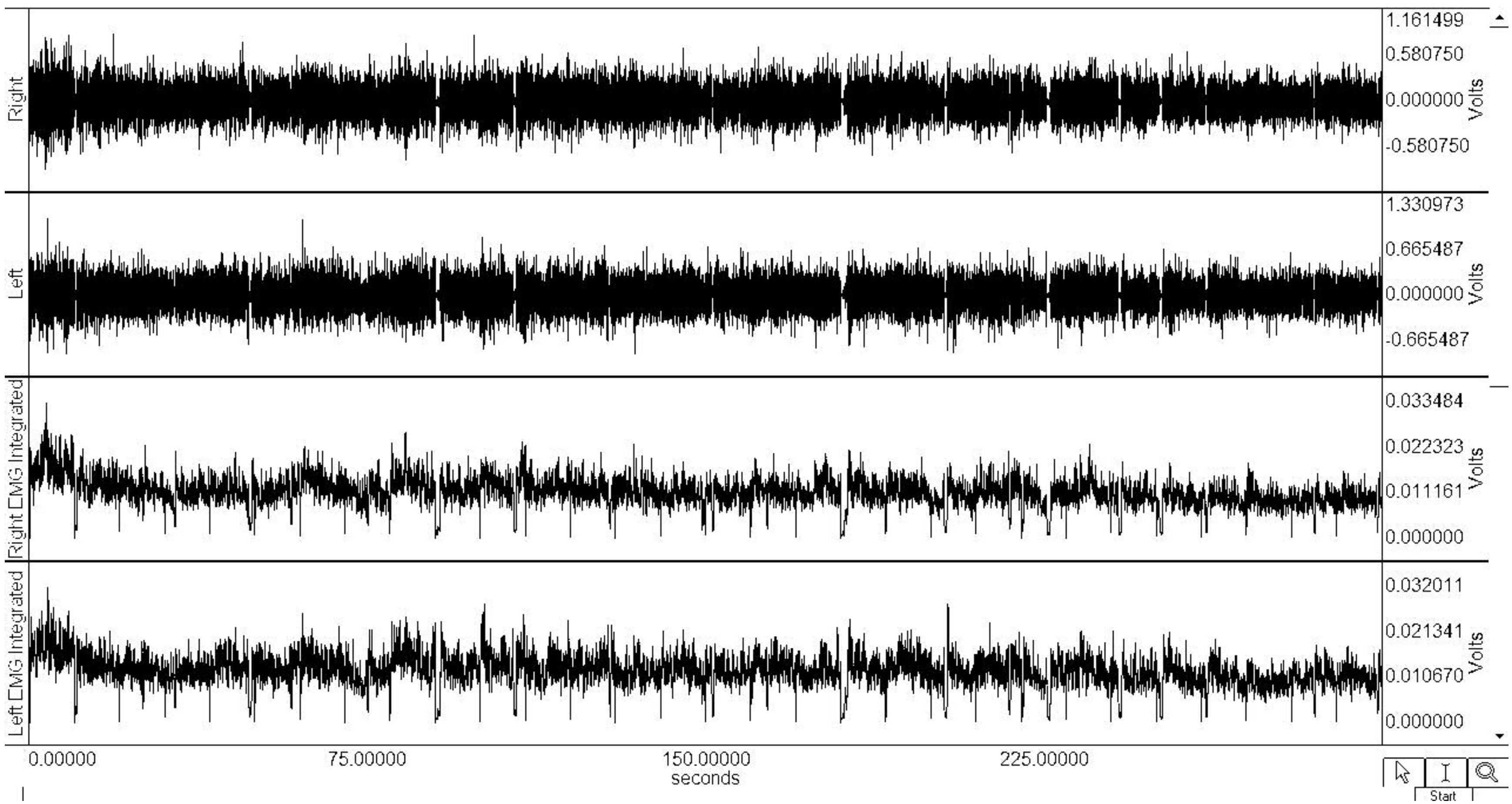
Subject 7, Day 2



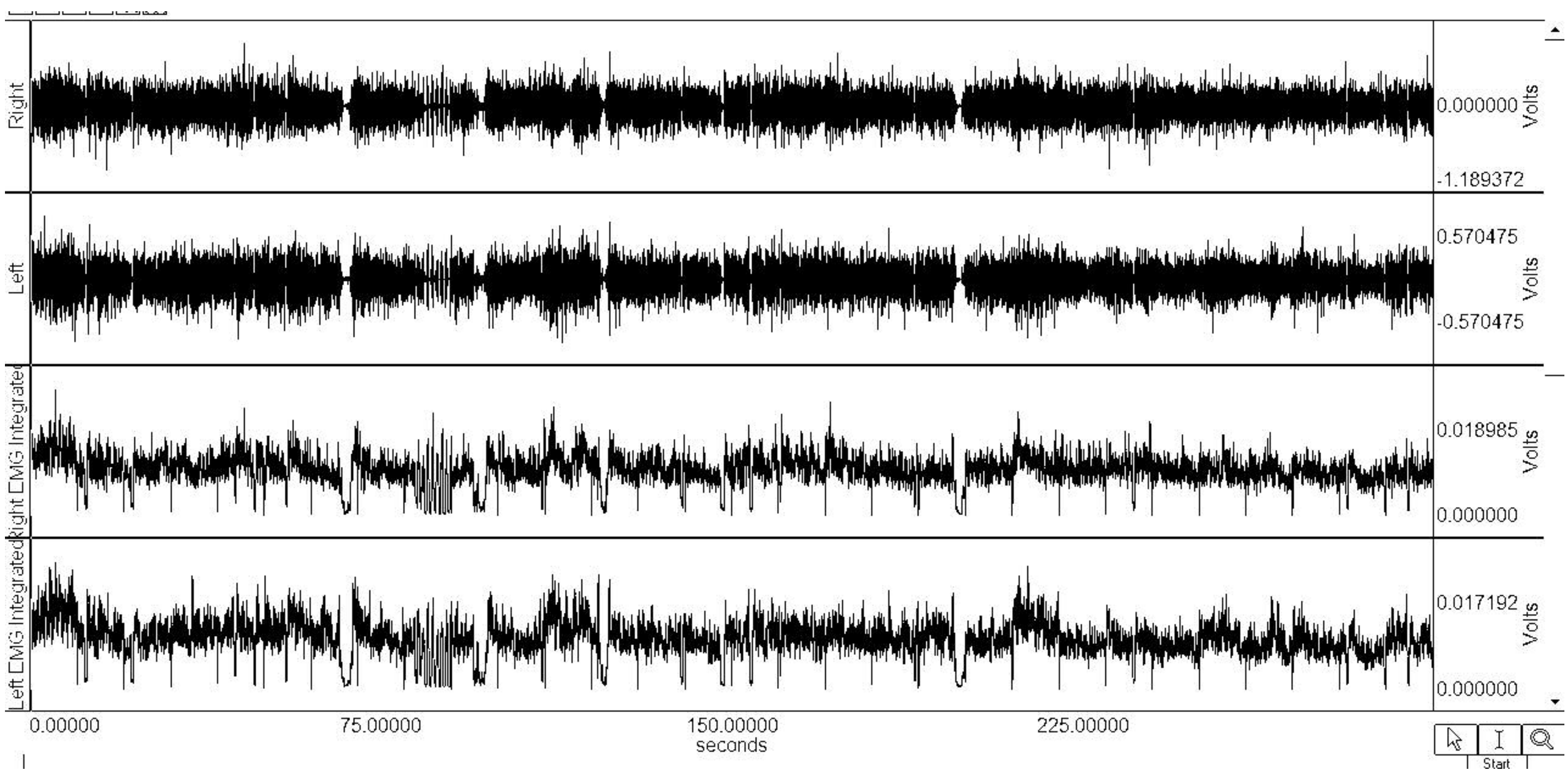
Subject 7, Day 3



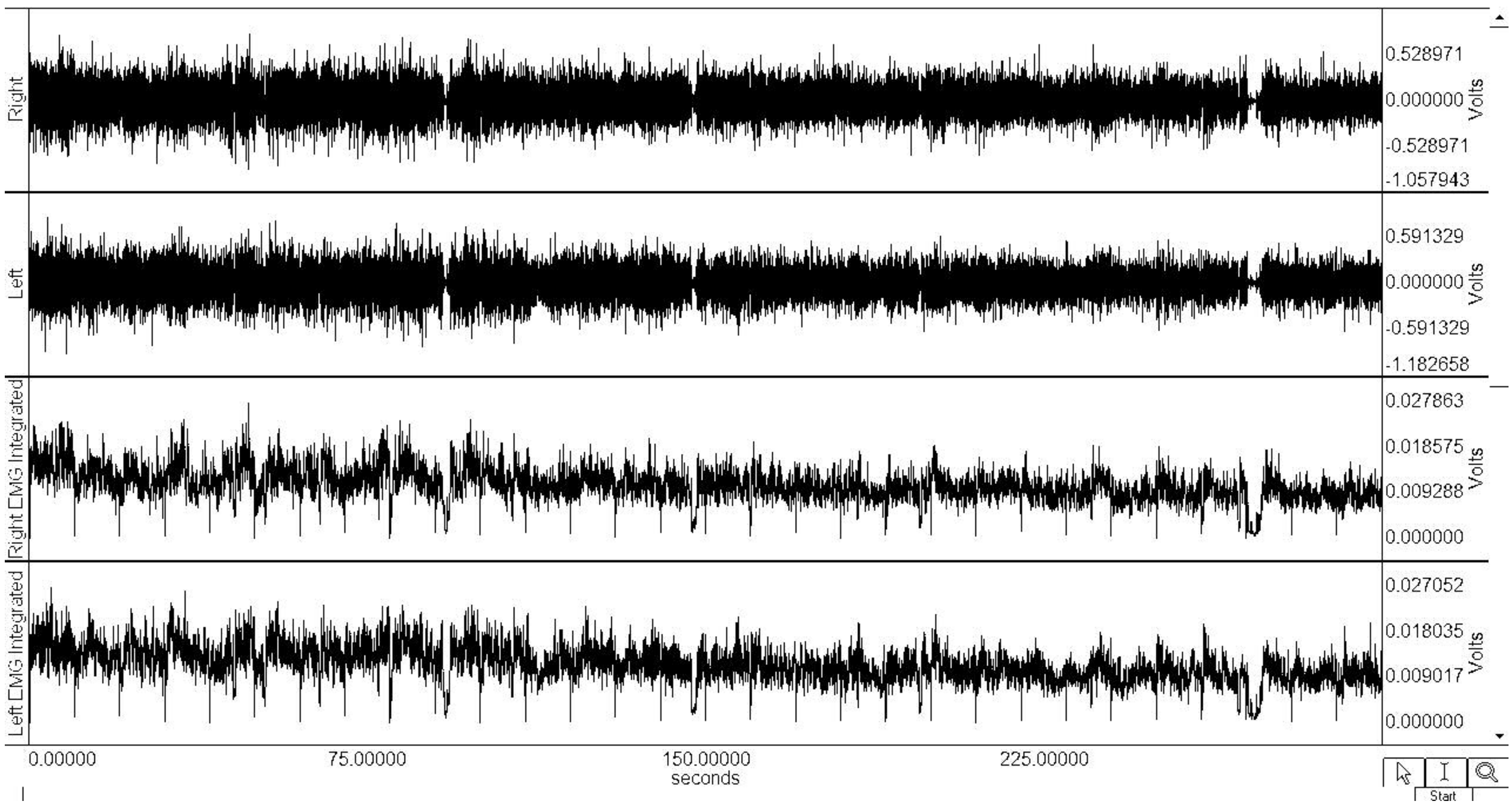
Subject 8, Day 1



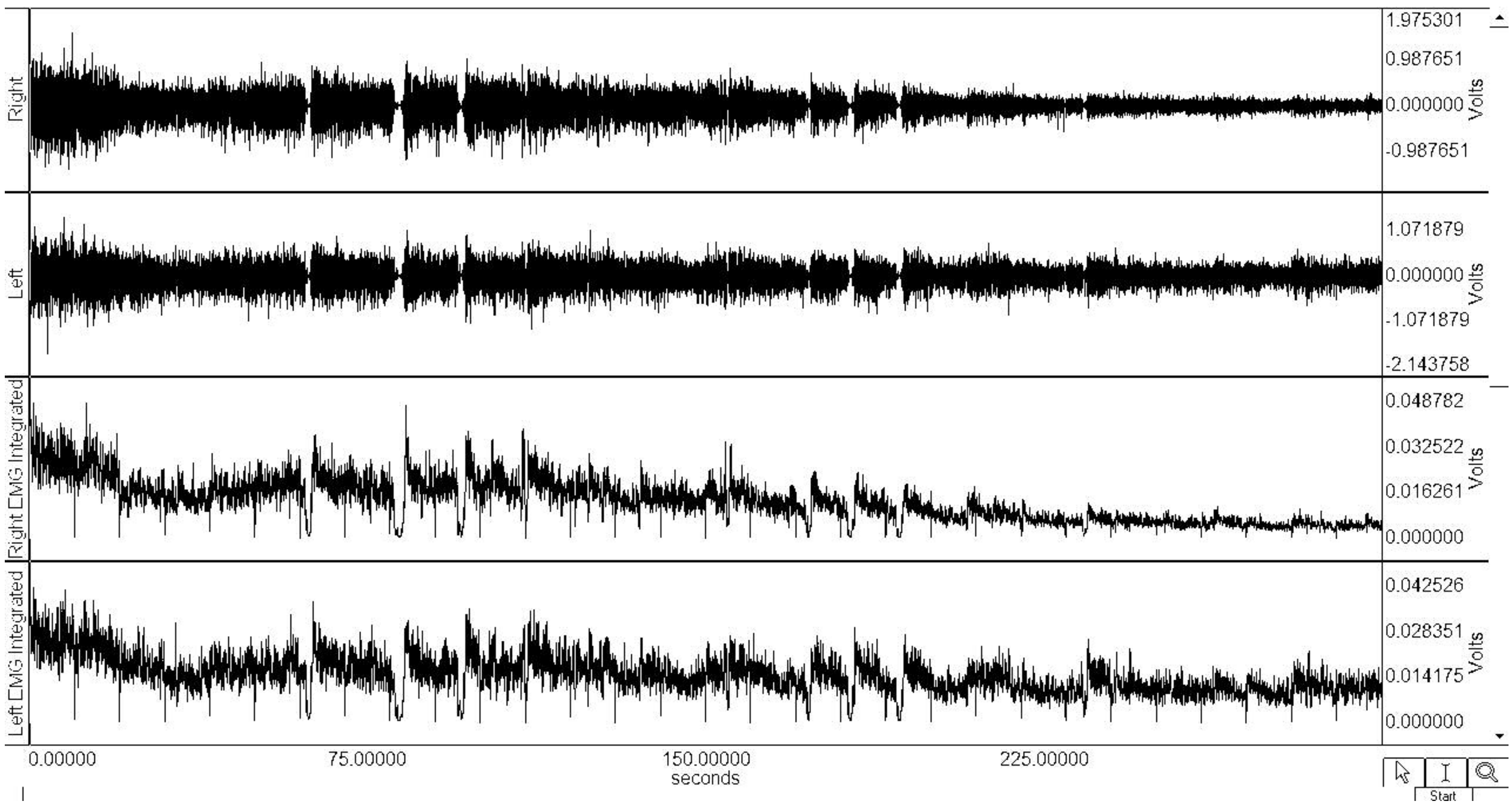
Subject 8, Day 2



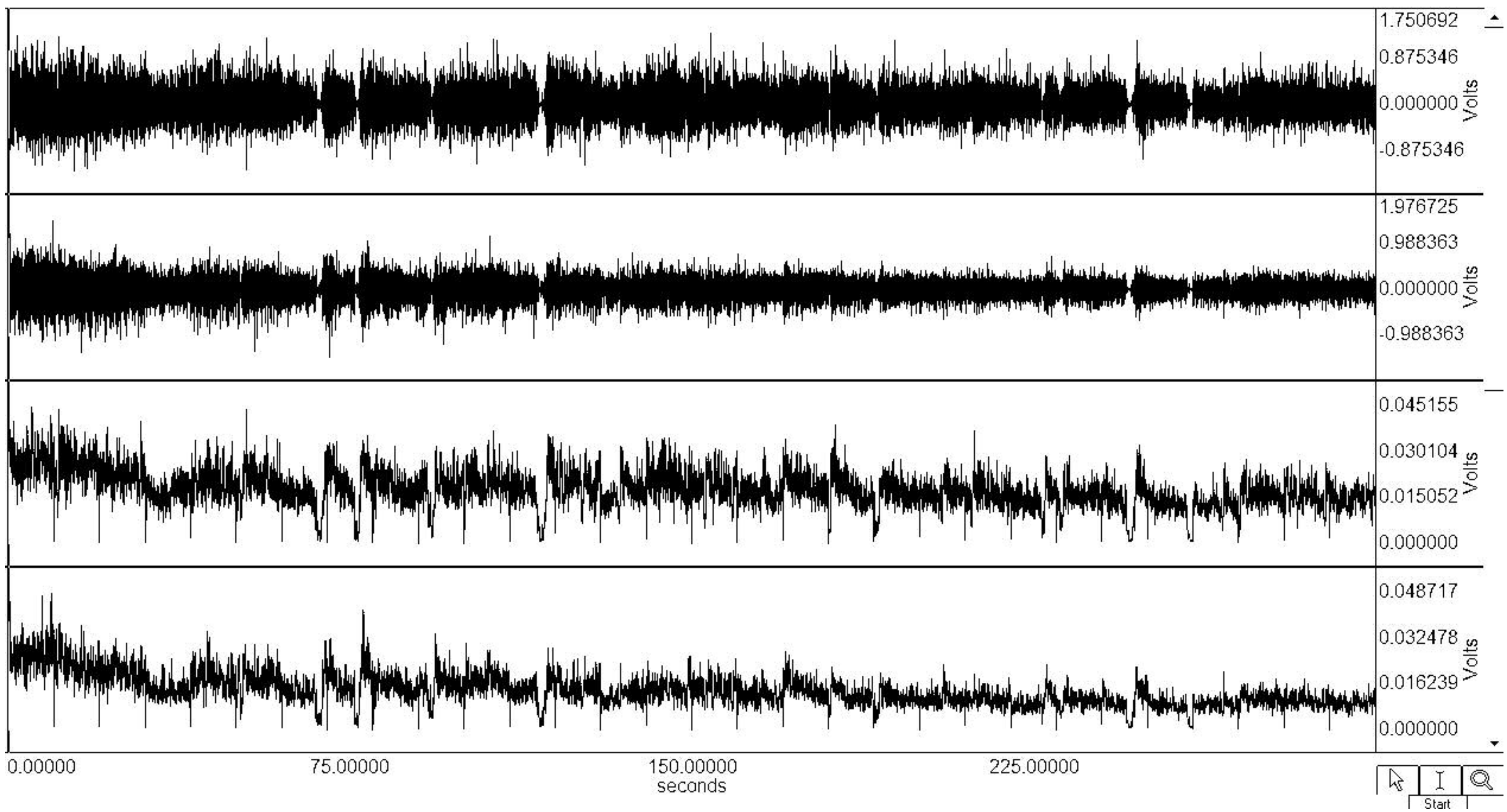
Subject 8, Day 3



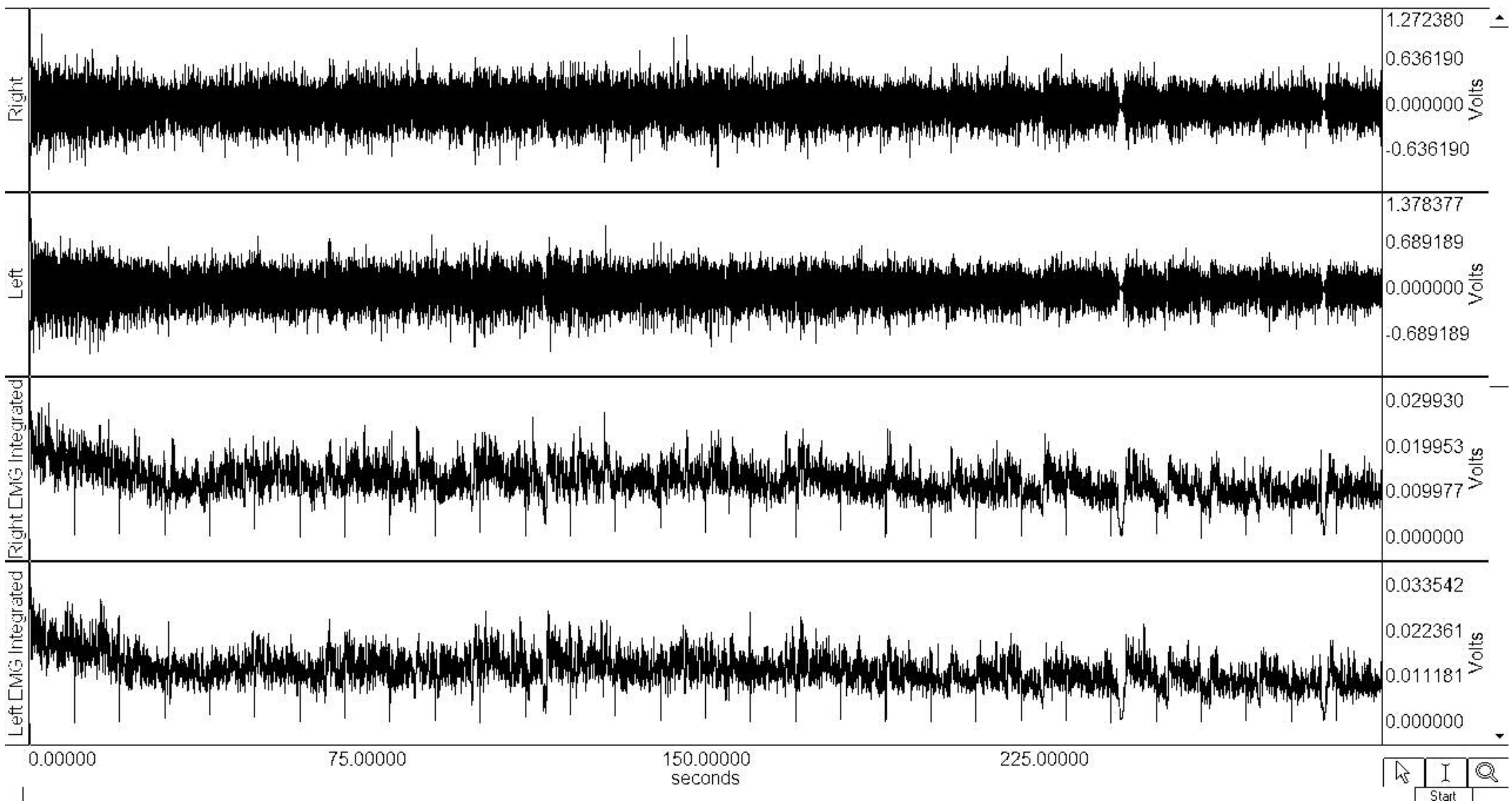
Subject 9, Day 1



Subject 9, Day 2



Subject 9, Day 3



Integrated EMG Data

EMG data was collected from the left and right sides of the upper portion of the orbicularis oris. The following charts present the average integrated EMG values and maximum integrated EMG value for each of the thirty ten-second intervals during each of the three testing sessions.

Subject 1

Interval Averages and Interval Maximums (measured in volts)

	Day 1			Day 2			Day 3	
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.01957	0.03263	1	0.01844	0.02863	1	0.01959	0.03399
2	0.01882	0.03188	2	0.01674	0.03062	2	0.01701	0.03732
3	0.0168	0.03021	3	0.016	0.02774	3	0.01668	0.02798
4	0.01439	0.02613	4	0.01376	0.02915	4	0.01344	0.02939
5	0.01159	0.03957	5	0.0137	0.02648	5	0.01615	0.03503
6	0.01771	0.03217	6	0.01562	0.0297	6	0.01204	0.02898
7	0.01309	0.02764	7	0.01546	0.025	7	0.01204	0.02438
8	0.01262	0.02148	8	0.01398	0.02664	8	0.01419	0.02621
9	0.00781	0.02931	9	0.00779	0.02556	9	0.01536	0.02655
10	0.01254	0.02911	10	0.01356	0.02886	10	0.01479	0.02782
11	0.01777	0.03388	11	0.01411	0.0278	11	0.01421	0.02416
12	0.01453	0.0354	12	0.01131	0.03035	12	0.01419	0.03648
13	0.0166	0.03251	13	0.01314	0.02525	13	0.01253	0.02223
14	0.01466	0.03149	14	0.00955	0.03332	14	0.01353	0.02723
15	0.01447	0.02329	15	0.01503	0.03	15	0.01202	0.02314
16	0.01086	0.0327	16	0.01207	0.02566	16	0.01014	0.02429
17	0.01446	0.02882	17	0.00916	0.01807	17	0.00936	0.02781
18	0.00968	0.02521	18	0.01134	0.02145	18	0.01446	0.02702
19	0.01284	0.02681	19	0.00978	0.02193	19	0.01057	0.02718
20	0.01064	0.02036	20	0.00996	0.02041	20	0.00978	0.02312
21	0.00514	0.01956	21	0.01131	0.02121	21	0.01039	0.02294
22	0.01025	0.02138	22	0.00871	0.02293	22	0.01069	0.01804
23	0.0094	0.02039	23	0.00963	0.03022	23	0.01168	0.03163
24	0.01232	0.0255	24	0.01043	0.02319	24	0.0104	0.02804
25	0.00909	0.02814	25	0.01173	0.02693	25	0.01038	0.0245
26	0.01296	0.02325	26	0.01134	0.01882	26	0.01106	0.01945
27	0.01207	0.02312	27	0.0113	0.0188	27	0.00963	0.02526
28	0.01318	0.02378	28	0.01068	0.01984	28	0.01051	0.02016
29	0.01212	0.03107	29	0.01079	0.01835	29	0.00819	0.01853
30	0.01132	0.02202	30	0.00638	0.02037	30	0.00879	0.02005
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01285	0.03957		0.0118	0.0333		0.01233	0.03732
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.003289025	0.005121024		0.002810082	0.004376407		0.002756334	0.00503469

	Day 1			Day 2			Day 3	
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.01435	0.02465	1	0.01612	0.02483	1	0.01568	0.03051
2	0.01295	0.02471	2	0.01509	0.02973	2	0.01285	0.02457
3	0.01156	0.01956	3	0.01416	0.02511	3	0.01181	0.02019
4	0.0092	0.01802	4	0.01156	0.02042	4	0.00909	0.01581
5	0.00773	0.02346	5	0.01052	0.02338	5	0.01204	0.02364
6	0.0116	0.02007	6	0.01254	0.02419	6	0.00867	0.0226
7	0.0094	0.02025	7	0.01216	0.02353	7	0.00842	0.0149
8	0.00877	0.01569	8	0.01163	0.02098	8	0.01047	0.01887
9	0.00575	0.02316	9	0.00653	0.0208	9	0.01166	0.02292
10	0.01017	0.02351	10	0.01117	0.0221	10	0.01186	0.0217
11	0.01323	0.02226	11	0.01193	0.02329	11	0.01071	0.02204
12	0.01038	0.01987	12	0.0096	0.02375	12	0.01129	0.02233
13	0.01214	0.02846	13	0.01132	0.01985	13	0.00983	0.02274
14	0.01006	0.01954	14	0.00768	0.02803	14	0.0101	0.01917
15	0.01098	0.02122	15	0.01171	0.02015	15	0.009	0.0168
16	0.00825	0.02259	16	0.00943	0.02177	16	0.00734	0.01544
17	0.01108	0.01985	17	0.00772	0.01601	17	0.00702	0.01908
18	0.00784	0.02352	18	0.00963	0.01742	18	0.0104	0.02046
19	0.01049	0.02029	19	0.00799	0.01785	19	0.00726	0.01646
20	0.00874	0.01812	20	0.00839	0.01586	20	0.00705	0.01685
21	0.00463	0.01753	21	0.00932	0.01608	21	0.0068	0.01532
22	0.00801	0.01669	22	0.00772	0.01537	22	0.00685	0.01199
23	0.00734	0.01839	23	0.00763	0.02195	23	0.00768	0.0178
24	0.01015	0.0207	24	0.00852	0.01899	24	0.00668	0.01601
25	0.00684	0.02146	25	0.00963	0.02107	25	0.00676	0.01364
26	0.0099	0.01905	26	0.01015	0.01643	26	0.0062	0.01173
27	0.00983	0.01669	27	0.00998	0.01998	27	0.00627	0.01317
28	0.01128	0.02017	28	0.00874	0.01495	28	0.00655	0.01134
29	0.00921	0.02124	29	0.00868	0.01504	29	0.00518	0.01283
30	0.00938	0.0169	30	0.00501	0.01658	30	0.00604	0.01298
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.00963	0.02846		0.0098	0.0297		0.00881	0.03051
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.002159402	0.002858345		0.002480753	0.00388607		0.002532827	0.00459774

Subject 2

Interval Averages and Interval Maximums (measured in volts)

	Day 1			Day 2			Day 3	
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.01917	0.03878	1	0.01762	0.0339	1	0.01266	0.02338
2	0.01663	0.02916	2	0.01435	0.03164	2	0.01014	0.01967
3	0.01207	0.03582	3	0.0109	0.02455	3	0.00836	0.01904
4	0.01322	0.02525	4	0.01405	0.025	4	0.01027	0.01794
5	0.01226	0.02616	5	0.01052	0.0232	5	0.00985	0.02101
6	0.0151	0.02636	6	0.01208	0.02991	6	0.00828	0.01893
7	0.01275	0.03198	7	0.01105	0.0258	7	0.00795	0.01716
8	0.01482	0.02609	8	0.01178	0.02365	8	0.0087	0.02431
9	0.01257	0.0267	9	0.00904	0.01897	9	0.00952	0.02052
10	0.01297	0.0305	10	0.00886	0.0205	10	0.00768	0.01838
11	0.01174	0.02441	11	0.0081	0.02027	11	0.00939	0.01937
12	0.01088	0.02238	12	0.00852	0.0224	12	0.00667	0.01773
13	0.01382	0.02399	13	0.01224	0.02883	13	0.00761	0.01804
14	0.0118	0.02771	14	0.01258	0.02332	14	0.00872	0.01619
15	0.01394	0.02355	15	0.01487	0.03538	15	0.00902	0.01829
16	0.01231	0.02868	16	0.00963	0.02414	16	0.01118	0.02423
17	0.01429	0.02885	17	0.01253	0.02644	17	0.00911	0.01614
18	0.01347	0.0254	18	0.0105	0.02501	18	0.01202	0.02133
19	0.01143	0.02018	19	0.01031	0.02086	19	0.0119	0.0197
20	0.01295	0.02556	20	0.00744	0.02027	20	0.00788	0.01687
21	0.01251	0.02665	21	0.0119	0.02629	21	0.01126	0.02128
22	0.01068	0.02405	22	0.01164	0.02239	22	0.0088	0.02276
23	0.0121	0.02527	23	0.01024	0.01766	23	0.00869	0.01553
24	0.01208	0.02532	24	0.00912	0.0186	24	0.00928	0.01596
25	0.01091	0.02091	25	0.01011	0.02071	25	0.0104	0.01847
26	0.01118	0.0243	26	0.00808	0.01687	26	0.00979	0.02011
27	0.01136	0.02091	27	0.01171	0.03158	27	0.00652	0.01422
28	0.01069	0.02006	28	0.01035	0.01821	28	0.01083	0.02244
29	0.00982	0.02141	29	0.0086	0.01841	29	0.00877	0.01617
30	0.00954	0.01932	30	0.00912	0.02099	30	0.01032	0.02383
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01248	0.03878		0.01093	0.03538		0.00939	0.02431
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001997097	0.004416231		0.002279539	0.004927885		0.001520478	0.00276425

	Day 1			Day 2			Day 3	
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.02033	0.03506	1	0.01915	0.02947	1	0.01422	0.0247
2	0.01725	0.03431	2	0.01426	0.02932	2	0.01018	0.01922
3	0.01312	0.03747	3	0.01295	0.0256	3	0.00914	0.01972
4	0.01495	0.03253	4	0.01398	0.02264	4	0.0102	0.01758
5	0.01493	0.02869	5	0.0131	0.02733	5	0.01095	0.01966
6	0.01604	0.02654	6	0.01335	0.02813	6	0.00914	0.02031
7	0.01368	0.02859	7	0.01254	0.02383	7	0.00821	0.02104
8	0.01611	0.03068	8	0.01342	0.0276	8	0.00943	0.02291
9	0.01366	0.03079	9	0.01138	0.02334	9	0.01061	0.02152
10	0.01396	0.03101	10	0.01182	0.02573	10	0.00917	0.01995
11	0.01336	0.02859	11	0.01102	0.02122	11	0.01168	0.02157
12	0.01297	0.02768	12	0.00972	0.02502	12	0.00804	0.01882
13	0.01495	0.02693	13	0.01332	0.02571	13	0.00883	0.02154
14	0.01285	0.02529	14	0.01497	0.02669	14	0.01117	0.02389
15	0.01507	0.02782	15	0.01546	0.02576	15	0.01122	0.02435
16	0.01338	0.02895	16	0.01152	0.02529	16	0.01332	0.02706
17	0.01463	0.02902	17	0.01264	0.02337	17	0.01133	0.02113
18	0.01432	0.02757	18	0.01164	0.02413	18	0.01402	0.02421
19	0.01385	0.0246	19	0.01121	0.02272	19	0.01466	0.02564
20	0.01509	0.02836	20	0.0096	0.02394	20	0.0092	0.02061
21	0.01402	0.02666	21	0.0136	0.02381	21	0.00466	0.00814
22	0.01362	0.0273	22	0.01299	0.02415	22	0.00413	0.00807
23	0.01362	0.02719	23	0.01155	0.0235	23	0.00433	0.00811
24	0.01378	0.02493	24	0.01015	0.02808	24	0.00542	0.00995
25	0.01337	0.02538	25	0.01184	0.02365	25	0.00668	0.01323
26	0.01309	0.02466	26	0.00986	0.01934	26	0.00542	0.01066
27	0.014	0.02839	27	0.01191	0.0266	27	0.00381	0.00795
28	0.0129	0.02281	28	0.01277	0.02256	28	0.00563	0.00943
29	0.01265	0.02968	29	0.01054	0.01974	29	0.00477	0.00917
30	0.01363	0.0231	30	0.01179	0.01966	30	0.00502	0.01029
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01414	0.03747		0.01247	0.02947		0.00882	0.02431
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001563199	0.003374392		0.001953111	0.002670634		0.003231938	0.006290695

Subject 3

Interval Averages and Interval Maximums (measured in volts)

Day 1			Day 2			Day 3		
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.01096	0.01864	1	0.01237	0.02036	1	0.01003	0.01731
2	0.00839	0.01613	2	0.00991	0.01723	2	0.00848	0.01469
3	0.00856	0.01677	3	0.00957	0.01606	3	0.00802	0.01613
4	0.01092	0.02052	4	0.00989	0.01831	4	0.00882	0.01606
5	0.01025	0.01963	5	0.01026	0.01916	5	0.00862	0.01635
6	0.01054	0.01983	6	0.00971	0.01782	6	0.00928	0.01564
7	0.01121	0.0187	7	0.01059	0.01889	7	0.00961	0.01643
8	0.00778	0.0178	8	0.00997	0.02068	8	0.00999	0.01993
9	0.01045	0.02044	9	0.0087	0.01823	9	0.00918	0.0159
10	0.0116	0.02002	10	0.01036	0.02051	10	0.00887	0.0177
11	0.01007	0.02032	11	0.01076	0.02154	11	0.00817	0.0145
12	0.01039	0.01785	12	0.00906	0.02157	12	0.00909	0.01837
13	0.01008	0.01962	13	0.01095	0.01919	13	0.00902	0.01626
14	0.01034	0.01615	14	0.00885	0.0161	14	0.00895	0.0166
15	0.01016	0.01801	15	0.00877	0.01419	15	0.00946	0.0166
16	0.0101	0.02161	16	0.00804	0.01513	16	0.00853	0.01804
17	0.01038	0.02174	17	0.00763	0.01394	17	0.00689	0.01504
18	0.00976	0.01736	18	0.00779	0.01341	18	0.00843	0.01463
19	0.00985	0.01908	19	0.00661	0.01126	19	0.00839	0.01564
20	0.00962	0.0168	20	0.00665	0.01329	20	0.00791	0.01598
21	0.00891	0.01719	21	0.0063	0.01054	21	0.0079	0.01511
22	0.00792	0.0166	22	0.00585	0.01033	22	0.00816	0.0155
23	0.0093	0.02056	23	0.00576	0.01017	23	0.00829	0.01629
24	0.00937	0.01743	24	0.00583	0.00964	24	0.00766	0.01463
25	0.00923	0.01644	25	0.00597	0.0115	25	0.008	0.01389
26	0.00826	0.01603	26	0.00571	0.00953	26	0.00738	0.01528
27	0.00848	0.01537	27	0.00562	0.00957	27	0.00779	0.01507
28	0.00821	0.01446	28	0.00497	0.00907	28	0.00704	0.01448
29	0.00713	0.01383	29	0.00497	0.00959	29	0.00755	0.0157
30	0.00844	0.01342	30	0.00476	0.00869	30	0.00635	0.0136
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.00956	0.02174		0.00807	0.02156		0.0084	0.01993
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001128034	0.002223382		0.002174523	0.004371363		0.000885121	0.001373945

Day 1			Day 2			Day 3		
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.01056	0.01832	1	0.01362	0.02187	1	0.00897	0.01504
2	0.00866	0.01624	2	0.01101	0.02408	2	0.00762	0.01271
3	0.00919	0.01701	3	0.01056	0.01894	3	0.00674	0.01392
4	0.01115	0.02479	4	0.01012	0.02111	4	0.00714	0.01261
5	0.01013	0.02046	5	0.01092	0.02426	5	0.00676	0.01175
6	0.01047	0.01881	6	0.01066	0.02175	6	0.00693	0.01171
7	0.01158	0.02049	7	0.01181	0.02118	7	0.00753	0.01222
8	0.00792	0.01803	8	0.01203	0.02893	8	0.00796	0.01556
9	0.01106	0.02147	9	0.01031	0.02396	9	0.00733	0.01373
10	0.01236	0.02122	10	0.01194	0.03042	10	0.00796	0.01922
11	0.0102	0.02284	11	0.01227	0.02146	11	0.00675	0.01323
12	0.01127	0.01918	12	0.01072	0.02794	12	0.00772	0.01474
13	0.01052	0.01923	13	0.01244	0.02358	13	0.00759	0.01368
14	0.01118	0.0179	14	0.01108	0.02025	14	0.00714	0.01329
15	0.01124	0.02178	15	0.01125	0.01694	15	0.00828	0.01331
16	0.01002	0.0186	16	0.01198	0.02363	16	0.00735	0.01318
17	0.00994	0.01661	17	0.01088	0.02141	17	0.00583	0.01346
18	0.00899	0.01469	18	0.01165	0.02056	18	0.0073	0.01187
19	0.00942	0.0162	19	0.0117	0.0208	19	0.00772	0.01251
20	0.00921	0.01684	20	0.01152	0.02182	20	0.00698	0.01245
21	0.00865	0.016	21	0.01056	0.02168	21	0.00716	0.01335
22	0.008	0.01737	22	0.01064	0.02136	22	0.00759	0.01418
23	0.00883	0.01606	23	0.01079	0.01889	23	0.00749	0.01826
24	0.0092	0.01622	24	0.01053	0.0221	24	0.00784	0.01912
25	0.00886	0.01673	25	0.01037	0.0162	25	0.00773	0.01725
26	0.00732	0.01382	26	0.01044	0.01843	26	0.0072	0.01442
27	0.00814	0.01564	27	0.01111	0.01995	27	0.00794	0.01349
28	0.00796	0.01353	28	0.00993	0.02692	28	0.00748	0.01513
29	0.00642	0.01268	29	0.0106	0.02381	29	0.00781	0.01911
30	0.00795	0.01316	30	0.01016	0.02028	30	0.00807	0.02081
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.00955	0.02479		0.01112	0.030423		0.00747	0.02081
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001431995	0.002933644		0.000828626	0.003253314		0.000578133	0.002505363

Subject 4

Interval Averages and Interval Maximums (measured in volts)

	Day 1			Day 2			Day 3	
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.01198	0.02149	1	0.01335	0.02044	1	0.01555	0.02862
2	0.00909	0.0169	2	0.01104	0.02002	2	0.01248	0.02177
3	0.00993	0.01646	3	0.01138	0.01884	3	0.01256	0.02295
4	0.00936	0.01752	4	0.01101	0.01918	4	0.01221	0.02338
5	0.00836	0.0155	5	0.01122	0.0197	5	0.01246	0.02312
6	0.00902	0.01607	6	0.0117	0.02077	6	0.01248	0.02408
7	0.00832	0.02103	7	0.01166	0.01872	7	0.01289	0.02283
8	0.00912	0.01705	8	0.01092	0.02061	8	0.01334	0.02196
9	0.00828	0.017	9	0.01186	0.02245	9	0.01266	0.02435
10	0.00659	0.0121	10	0.01165	0.01913	10	0.01289	0.02236
11	0.00745	0.01346	11	0.01174	0.02158	11	0.01305	0.02248
12	0.00672	0.01225	12	0.01017	0.01749	12	0.01085	0.01801
13	0.00611	0.01236	13	0.0113	0.01905	13	0.01198	0.02156
14	0.0062	0.01133	14	0.01129	0.0196	14	0.01207	0.02193
15	0.0056	0.01169	15	0.01099	0.01949	15	0.01152	0.02061
16	0.00601	0.01109	16	0.01062	0.0194	16	0.01112	0.02063
17	0.0059	0.01178	17	0.01037	0.01783	17	0.01299	0.02174
18	0.00531	0.0096	18	0.01053	0.01928	18	0.01119	0.01962
19	0.00573	0.0095	19	0.00966	0.01571	19	0.01127	0.02048
20	0.00488	0.00912	20	0.01002	0.01651	20	0.01009	0.0175
21	0.00553	0.0103	21	0.00903	0.01538	21	0.01003	0.01744
22	0.00487	0.00832	22	0.00959	0.01529	22	0.00931	0.01461
23	0.00549	0.00896	23	0.00997	0.01698	23	0.00881	0.01646
24	0.00501	0.00885	24	0.00975	0.01857	24	0.00839	0.01475
25	0.00464	0.01044	25	0.00897	0.01602	25	0.00779	0.0159
26	0.00509	0.0088	26	0.00903	0.01487	26	0.00835	0.0146
27	0.00522	0.00992	27	0.00886	0.01584	27	0.00851	0.01585
28	0.00516	0.00907	28	0.00872	0.01577	28	0.00825	0.01385
29	0.00563	0.01037	29	0.00921	0.01636	29	0.0073	0.01302
30	0.0058	0.00985	30	0.00895	0.01602	30	0.0071	0.01341
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.00675	0.02149		0.01049	0.02245		0.01099	0.02862
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.00187749	0.003745313		0.001151795	0.002077034		0.002144649	0.003949774

	Day 1			Day 2			Day 3	
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.01522	0.02695	1	0.01688	0.02559	1	0.01738	0.02842
2	0.01247	0.0213	2	0.01381	0.02733	2	0.01369	0.02239
3	0.01266	0.0207	3	0.01288	0.02247	3	0.01312	0.02383
4	0.0128	0.02527	4	0.013	0.02374	4	0.01343	0.02111
5	0.01152	0.0205	5	0.01286	0.02161	5	0.01295	0.02554
6	0.01248	0.02314	6	0.01362	0.02344	6	0.01279	0.02247
7	0.01127	0.02113	7	0.01406	0.02381	7	0.01368	0.0229
8	0.01314	0.02415	8	0.01331	0.0244	8	0.01341	0.02524
9	0.01145	0.01951	9	0.01346	0.02416	9	0.01338	0.02223
10	0.0105	0.01861	10	0.0132	0.02108	10	0.0136	0.02657
11	0.01119	0.01957	11	0.01478	0.02735	11	0.01292	0.02431
12	0.01151	0.01946	12	0.01291	0.02659	12	0.0111	0.01931
13	0.01118	0.01857	13	0.01389	0.02571	13	0.01248	0.02312
14	0.01264	0.02297	14	0.01385	0.02321	14	0.01206	0.01947
15	0.01087	0.01931	15	0.01333	0.02459	15	0.01183	0.02446
16	0.01173	0.0215	16	0.01305	0.02754	16	0.0112	0.01986
17	0.01175	0.01864	17	0.01388	0.02644	17	0.01322	0.02136
18	0.01125	0.01862	18	0.01274	0.02396	18	0.01288	0.0226
19	0.01224	0.01937	19	0.01248	0.02124	19	0.01337	0.02261
20	0.01012	0.01906	20	0.01305	0.02195	20	0.01166	0.01929
21	0.01109	0.01952	21	0.012	0.02188	21	0.01144	0.02427
22	0.01034	0.0182	22	0.01272	0.02252	22	0.01102	0.02494
23	0.01176	0.02053	23	0.01358	0.02298	23	0.0106	0.02031
24	0.01089	0.01934	24	0.01358	0.02262	24	0.01091	0.02215
25	0.00943	0.02168	25	0.01158	0.02306	25	0.00899	0.0197
26	0.01116	0.02117	26	0.01251	0.02225	26	0.0106	0.01933
27	0.01026	0.01693	27	0.01247	0.02133	27	0.01066	0.01763
28	0.01021	0.01819	28	0.01184	0.01995	28	0.01092	0.01914
29	0.01225	0.02287	29	0.01245	0.0238	29	0.0096	0.01781
30	0.01274	0.0242	30	0.01238	0.0208	30	0.00933	0.01521
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01161	0.02695		0.01321	0.02754		0.01215	0.02842
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001150366	0.002352193		0.000992697	0.002076371		0.001695993	0.002934265

Subject 5

Interval Averages and Interval Maximums (measured in volts)

	Day 1			Day 2			Day 3	
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.00668	0.01172	1	0.0079	0.01308	1	0.00904	0.01604
2	0.00698	0.01528	2	0.00704	0.01219	2	0.00785	0.0181
3	0.00667	0.01179	3	0.00742	0.01297	3	0.00958	0.01928
4	0.00705	0.01451	4	0.00755	0.01278	4	0.0073	0.01329
5	0.00706	0.01256	5	0.00889	0.01542	5	0.00832	0.01615
6	0.00772	0.01272	6	0.00698	0.01497	6	0.00838	0.01552
7	0.00817	0.01526	7	0.00796	0.01422	7	0.00831	0.01557
8	0.00827	0.01513	8	0.00771	0.01374	8	0.00705	0.01859
9	0.00711	0.0151	9	0.00708	0.01514	9	0.00729	0.01538
10	0.00853	0.01447	10	0.00731	0.0111	10	0.00858	0.01347
11	0.00944	0.01467	11	0.00695	0.01385	11	0.00939	0.01504
12	0.00853	0.01477	12	0.00685	0.01252	12	0.00797	0.01477
13	0.00926	0.01483	13	0.0053	0.01071	13	0.00737	0.01305
14	0.00879	0.01759	14	0.00441	0.0081	14	0.00711	0.01419
15	0.00894	0.01878	15	0.00416	0.00683	15	0.00779	0.01687
16	0.00822	0.01525	16	0.0035	0.00651	16	0.00752	0.01236
17	0.00877	0.01423	17	0.00334	0.00589	17	0.00706	0.01272
18	0.00771	0.0143	18	0.00313	0.00519	18	0.00669	0.01203
19	0.00653	0.01334	19	0.00278	0.00532	19	0.00632	0.01132
20	0.00617	0.01296	20	0.00269	0.00568	20	0.00651	0.01515
21	0.00638	0.01067	21	0.00271	0.00552	21	0.00668	0.01519
22	0.00588	0.01065	22	0.00177	0.00298	22	0.00533	0.00867
23	0.00672	0.0102	23	0.00225	0.00386	23	0.00813	0.01478
24	0.00526	0.01016	24	0.00211	0.0043	24	0.00649	0.01072
25	0.00567	0.00949	25	0.00229	0.00356	25	0.00694	0.01352
26	0.00496	0.00984	26	0.00197	0.00385	26	0.0065	0.0123
27	0.00512	0.00901	27	0.00214	0.00346	27	0.00657	0.01285
28	0.00582	0.01012	28	0.00204	0.0037	28	0.00575	0.01023
29	0.00561	0.00951	29	0.00208	0.00355	29	0.00533	0.00946
30	0.00463	0.01062	30	0.00168	0.0037	30	0.00593	0.00962
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.00709	0.01878		0.00467	0.01542		0.08378	0.01927
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001382065	0.002562411		0.002478553	0.004497513		0.001109364	0.002682889

	Day 1			Day 2			Day 3	
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.00774	0.01375	1	0.00674	0.01142	1	0.04727	0.08052
2	0.00899	0.01607	2	0.00694	0.0148	2	0.04926	0.08718
3	0.00776	0.01481	3	0.00679	0.0161	3	0.10072	0.21214
4	0.00909	0.01542	4	0.00684	0.01507	4	0.10655	0.20293
5	0.00807	0.01736	5	0.00899	0.01526	5	0.11377	0.21597
6	0.00814	0.01497	6	0.007	0.01287	6	0.1012	0.18967
7	0.00925	0.01742	7	0.0078	0.01589	7	0.10509	0.19738
8	0.00938	0.0168	8	0.00818	0.01418	8	0.09848	0.17627
9	0.00787	0.01617	9	0.00716	0.01506	9	0.09217	0.22259
10	0.00915	0.01619	10	0.00833	0.01422	10	0.10941	0.17444
11	0.00905	0.0147	11	0.0084	0.013	11	0.11053	0.16878
12	0.00887	0.01617	12	0.00869	0.01414	12	0.10725	0.17454
13	0.00925	0.01613	13	0.00835	0.01431	13	0.10441	0.20656
14	0.00843	0.0143	14	0.00782	0.01397	14	0.09876	0.22477
15	0.0092	0.01698	15	0.00911	0.01559	15	0.11075	0.17627
16	0.00762	0.01296	16	0.00778	0.01264	16	0.10353	0.18651
17	0.009	0.01572	17	0.00838	0.01304	17	0.09787	0.17669
18	0.00865	0.01522	18	0.0084	0.01616	18	0.08881	0.15021
19	0.00869	0.01426	19	0.00782	0.01311	19	0.08874	0.15593
20	0.00883	0.01749	20	0.00779	0.0139	20	0.08564	0.14535
21	0.00861	0.01383	21	0.00773	0.01371	21	0.08885	0.15106
22	0.00846	0.01406	22	0.00615	0.01027	22	0.06284	0.10239
23	0.00846	0.01441	23	0.00658	0.01079	23	0.06432	0.11422
24	0.00727	0.01322	24	0.00735	0.01681	24	0.05784	0.0883
25	0.00772	0.01353	25	0.00811	0.01357	25	0.05928	0.0936
26	0.00728	0.01373	26	0.00741	0.01283	26	0.05221	0.10921
27	0.00734	0.01319	27	0.00854	0.0137	27	0.05369	0.08456
28	0.00784	0.01289	28	0.00827	0.01554	28	0.05036	0.08176
29	0.00723	0.01242	29	0.00779	0.01318	29	0.04992	0.08556
30	0.00572	0.01278	30	0.00649	0.01199	30	0.05284	10148
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.0083	0.01749		0.00773	0.01681		0.08378	0.22477
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.000838808	0.001526093		0.000777789	0.001586848		0.02382035	1852.734915

Subject 6

Interval Averages and Interval Maximums (measured in volts)

	Day 1			Day 2			Day 3	
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.02584	0.04378	1	0.02221	0.03601	1	0.01986	0.03159
2	0.02183	0.03517	2	0.01422	0.02705	2	0.01356	0.02468
3	0.01493	0.03242	3	0.00898	0.0252	3	0.00954	0.02071
4	0.01507	0.02797	4	0.01488	0.02712	4	0.01215	0.02272
5	0.01149	0.02374	5	0.01277	0.0222	5	0.0124	0.02502
6	0.01425	0.02765	6	0.01253	0.02688	6	0.01146	0.02408
7	0.01538	0.02444	7	0.01318	0.02375	7	0.01235	0.02545
8	0.013	0.02781	8	0.01021	0.02099	8	0.0129	0.02394
9	0.0152	0.03231	9	0.01283	0.02465	9	0.01225	0.02584
10	0.01518	0.02867	10	0.01634	0.0284	10	0.01252	0.02621
11	0.00638	0.01935	11	0.01276	0.02786	11	0.01177	0.02331
12	0.01634	0.02925	12	0.01411	0.024	12	0.01291	0.0235
13	0.01576	0.03285	13	0.01228	0.02207	13	0.01125	0.02506
14	0.00918	0.03594	14	0.01236	0.03113	14	0.01414	0.02741
15	0.01256	0.02431	15	0.00856	0.02458	15	0.01017	0.02249
16	0.01489	0.03047	16	0.01165	0.02339	16	0.00953	0.01928
17	0.01416	0.02798	17	0.01204	0.0207	17	0.01125	0.02007
18	0.01178	0.02307	18	0.01097	0.02313	18	0.01103	0.02262
19	0.01257	0.03513	19	0.01371	0.02744	19	0.0104	0.01941
20	0.01169	0.02744	20	0.01141	0.0216	20	0.01173	0.02469
21	0.01329	0.02412	21	0.01204	0.02255	21	0.01142	0.02321
22	0.01436	0.02424	22	0.00585	0.01916	22	0.01091	0.02214
23	0.01307	0.02358	23	0.00972	0.02192	23	0.00994	0.02396
24	0.01126	0.02341	24	0.01046	0.02345	24	0.00999	0.01686
25	0.01248	0.02325	25	0.01138	0.02156	25	0.0102	0.01802
26	0.01179	0.02118	26	0.01149	0.0219	26	0.0084	0.02059
27	0.01192	0.02085	27	0.011	0.02806	27	0.00843	0.01645
28	0.01122	0.0186	28	0.00943	0.01995	28	0.01132	0.02077
29	0.01313	0.02214	29	0.00748	0.01434	29	0.01075	0.02068
30	0.01072	0.02154	30	0.00805	0.02058	30	0.00842	0.01738
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.0137	0.04378		0.01184	0.03601		0.01144	0.03199
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.003511432	0.005746341		0.003005283	0.004080644		0.002161719	0.003348764

	Day 1			Day 2			Day 3	
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.01835	0.031	1	0.01775	0.03165	1	0.0181	0.02988
2	0.01658	0.02804	2	0.01183	0.02068	2	0.01266	0.02581
3	0.01155	0.02275	3	0.00854	0.02264	3	0.0089	0.01716
4	0.01177	0.02611	4	0.01179	0.02079	4	0.0097	0.01886
5	0.01048	0.02627	5	0.01073	0.02072	5	0.01054	0.0233
6	0.01076	0.02156	6	0.01115	0.02141	6	0.00912	0.01867
7	0.01126	0.02076	7	0.01018	0.01808	7	0.01098	0.0232
8	0.01006	0.01965	8	0.00906	0.01642	8	0.01024	0.0163
9	0.01088	0.02095	9	0.01164	0.02577	9	0.01037	0.0243
10	0.01133	0.02631	10	0.015	0.02483	10	0.01026	0.01796
11	0.00525	0.01784	11	0.01119	0.02302	11	0.00982	0.02024
12	0.01277	0.02362	12	0.01165	0.02021	12	0.01064	0.01814
13	0.01115	0.01961	13	0.01097	0.02523	13	0.01047	0.01962
14	0.00713	0.02257	14	0.01025	0.02061	14	0.01191	0.02207
15	0.00871	0.01704	15	0.00675	0.0141	15	0.00949	0.01977
16	0.00994	0.02027	16	0.00814	0.01638	16	0.0082	0.0141
17	0.00902	0.01761	17	0.00814	0.01525	17	0.00964	0.01707
18	0.008	0.01716	18	0.00737	0.01312	18	0.00998	0.02032
19	0.00803	0.01871	19	0.00849	0.01608	19	0.00972	0.01638
20	0.00689	0.01507	20	0.00656	0.01215	20	0.01055	0.02316
21	0.00924	0.02029	21	0.00661	0.01207	21	0.00945	0.01863
22	0.00894	0.01633	22	0.00368	0.01213	22	0.00899	0.01859
23	0.00748	0.01565	23	0.00589	0.01335	23	0.00842	0.01666
24	0.00652	0.01268	24	0.00633	0.01335	24	0.00912	0.01757
25	0.00715	0.01475	25	0.00631	0.01203	25	0.00918	0.0178
26	0.00633	0.01304	26	0.00639	0.01288	26	0.00765	0.01948
27	0.00679	0.0119	27	0.0063	0.01398	27	0.00796	0.01492
28	0.00592	0.01102	28	0.00421	0.00854	28	0.00946	0.01716
29	0.00673	0.0128	29	0.0031	0.00714	29	0.00978	0.02065
30	0.00621	0.01305	30	0.00323	0.00717	30	0.00714	0.01513
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.00938	0.031		0.00865	0.03165		0.00996	0.02988
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.003025622	0.005164321		0.00340667	0.00592108		0.001929664	0.003468395

Subject 7

Interval Averages and Interval Maximums (measured in volts)

Interval	Day 1 Right EMG Integrated	Day 1 Interval Maximum	Interval	Day 2 Right EMG Integrated	Day 2 Interval Maximum	Interval	Day 3 Right EMG Integrated	Day 3 Interval Maximum
1	0.01772	0.0307	1	0.01375	0.02371	1	0.01341	0.02547
2	0.01238	0.0229	2	0.00995	0.01966	2	0.01093	0.01874
3	0.01512	0.03324	3	0.01486	0.02746	3	0.01234	0.0202
4	0.01077	0.01785	4	0.01024	0.01976	4	0.01363	0.02477
5	0.01166	0.02781	5	0.01116	0.02822	5	0.012	0.02534
6	0.01446	0.02701	6	0.00817	0.0216	6	0.01158	0.01851
7	0.0121	0.03283	7	0.01144	0.02521	7	0.01264	0.03331
8	0.01181	0.02738	8	0.01253	0.02173	8	0.00913	0.02378
9	0.01029	0.02316	9	0.01264	0.02447	9	0.00869	0.0297
10	0.00934	0.01843	10	0.01056	0.02735	10	0.01602	0.03118
11	0.00799	0.02244	11	0.01222	0.02089	11	0.01326	0.02744
12	0.00921	0.01967	12	0.00973	0.02138	12	0.01285	0.02578
13	0.01361	0.02354	13	0.00747	0.01679	13	0.01034	0.02077
14	0.01274	0.02236	14	0.01017	0.01876	14	0.01146	0.0214
15	0.01346	0.02431	15	0.01011	0.0214	15	0.01147	0.02013
16	0.01125	0.01979	16	0.01062	0.01922	16	0.00814	0.02004
17	0.00896	0.02113	17	0.00888	0.02044	17	0.01538	0.02717
18	0.00972	0.01792	18	0.01335	0.02404	18	0.01427	0.02776
19	0.01333	0.02714	19	0.01664	0.02891	19	0.01233	0.02461
20	0.01241	0.02253	20	0.01	0.0278	20	0.00683	0.01918
21	0.0091	0.01747	21	0.01078	0.0201	21	0.00882	0.02061
22	0.00879	0.01913	22	0.00734	0.02141	22	0.01044	0.02052
23	0.01521	0.02672	23	0.00831	0.02653	23	0.01315	0.02721
24	0.01089	0.02057	24	0.01457	0.02748	24	0.00923	0.02383
25	0.00662	0.01668	25	0.00956	0.01644	25	0.0134	0.03375
26	0.0097	0.02355	26	0.00895	0.01823	26	0.01519	0.03084
27	0.00889	0.0177	27	0.00816	0.02248	27	0.01551	0.02743
28	0.00848	0.01552	28	0.00833	0.01618	28	0.01527	0.02912
29	0.00561	0.01481	29	0.00858	0.01917	29	0.00792	0.01532
30	0.00863	0.01845	30	0.01044	0.01853	30	0.00882	0.02172
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01101	0.03324		0.01065	0.02891		0.01182	0.03375
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.002726829	0.004930002		0.002311934	0.00378446		0.002547618	0.004713769

Interval	Day 1 Left EMG Integrated	Day 1 Interval Maximum	Interval	Day 2 Left EMG Integrated	Day 2 Interval Maximum	Interval	Day 3 Left EMG Integrated	Day 3 Interval Maximum
1	0.02136	0.0385	1	0.01789	0.03466	1	0.01377	0.02407
2	0.01559	0.03199	2	0.01281	0.02413	2	0.01125	0.01929
3	0.01841	0.03501	3	0.01871	0.03282	3	0.01273	0.02266
4	0.01284	0.02401	4	0.01294	0.02324	4	0.01243	0.02026
5	0.01408	0.03174	5	0.01315	0.03531	5	0.01064	0.02177
6	0.01805	0.03391	6	0.0107	0.03083	6	0.01074	0.01548
7	0.01357	0.03117	7	0.01376	0.02495	7	0.01217	0.0216
8	0.0148	0.03095	8	0.01586	0.02639	8	0.00863	0.01792
9	0.01252	0.02318	9	0.01633	0.03446	9	0.0083	0.02656
10	0.01231	0.02276	10	0.01264	0.03028	10	0.01188	0.0242
11	0.01008	0.02456	11	0.01553	0.02645	11	0.01234	0.02252
12	0.01237	0.02804	12	0.01235	0.02753	12	0.01062	0.02164
13	0.01671	0.03413	13	0.00977	0.01954	13	0.01005	0.01765
14	0.01598	0.03144	14	0.01302	0.0288	14	0.01038	0.02307
15	0.01751	0.03735	15	0.01253	0.0229	15	0.01099	0.0212
16	0.01464	0.02612	16	0.01267	0.02494	16	0.00805	0.0171
17	0.0121	0.03103	17	0.01163	0.02611	17	0.01138	0.0233
18	0.01273	0.0232	18	0.01635	0.03017	18	0.01051	0.02058
19	0.01705	0.03949	19	0.02046	0.0414	19	0.01031	0.01823
20	0.01727	0.02967	20	0.01244	0.03025	20	0.00734	0.01542
21	0.01224	0.02248	21	0.0135	0.0264	21	0.00772	0.0171
22	0.01196	0.02584	22	0.00996	0.0287	22	0.00898	0.01782
23	0.01954	0.03496	23	0.01122	0.02789	23	0.01021	0.01843
24	0.01386	0.02931	24	0.01843	0.03472	24	0.00891	0.01785
25	0.00966	0.02397	25	0.01326	0.02396	25	0.01116	0.02716
26	0.01366	0.02812	26	0.01128	0.02395	26	0.01148	0.01988
27	0.01333	0.02398	27	0.00987	0.03335	27	0.01122	0.01888
28	0.01296	0.02379	28	0.01252	0.0218	28	0.01113	0.02315
29	0.00808	0.02335	29	0.01079	0.02611	29	0.00759	0.01259
30	0.01165	0.02424	30	0.01312	0.02704	30	0.00797	0.01589
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01424	0.03949		0.01352	0.0414		0.01037	0.02716
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.003019688	0.005163987		0.002758022	0.004836488		0.001691579	0.003417294

Subject 8

Interval Averages and Interval Maximums (measured in volts)

	Day 1			Day 2			Day 3	
Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum	Interval	Right EMG Integrated	Interval Maximum
1	0.01772	0.03348	1	0.01436	0.02848	1	0.01565	0.02397
2	0.01301	0.0221	2	0.01092	0.01903	2	0.01242	0.02159
3	0.01207	0.02293	3	0.0105	0.01873	3	0.01208	0.02103
4	0.01101	0.02156	4	0.01077	0.01759	4	0.01266	0.02442
5	0.01151	0.02121	5	0.0118	0.02414	5	0.01349	0.02786
6	0.0116	0.01901	6	0.0116	0.02145	6	0.01226	0.02252
7	0.01365	0.02281	7	0.00868	0.02128	7	0.01221	0.02168
8	0.01099	0.01956	8	0.01064	0.01921	8	0.01322	0.0233
9	0.01411	0.02621	9	0.00752	0.02317	9	0.01285	0.0241
10	0.01105	0.02051	10	0.0088	0.01858	10	0.01203	0.02454
11	0.013	0.0239	11	0.01035	0.02174	11	0.01226	0.02212
12	0.01271	0.02294	12	0.01285	0.02452	12	0.01077	0.01947
13	0.01152	0.02119	13	0.01004	0.01927	13	0.01184	0.01933
14	0.01192	0.02325	14	0.01062	0.01823	14	0.01132	0.02068
15	0.01087	0.01906	15	0.00912	0.01865	15	0.01004	0.01749
16	0.01064	0.01705	16	0.01092	0.02078	16	0.01108	0.01766
17	0.01157	0.02091	17	0.01152	0.02295	17	0.0108	0.01991
18	0.01189	0.02112	18	0.01164	0.02566	18	0.0103	0.01623
19	0.01088	0.02198	19	0.00987	0.01685	19	0.00944	0.01806
20	0.01212	0.02011	20	0.00819	0.01849	20	0.00994	0.01737
21	0.00988	0.01832	21	0.01057	0.01651	21	0.01078	0.01909
22	0.01221	0.02158	22	0.01229	0.02338	22	0.01064	0.01687
23	0.00987	0.01945	23	0.0106	0.01821	23	0.00965	0.018
24	0.0119	0.02326	24	0.0112	0.02112	24	0.01048	0.01925
25	0.01029	0.0191	25	0.00998	0.0184	25	0.00871	0.01521
26	0.00944	0.01858	26	0.01017	0.01826	26	0.00976	0.01894
27	0.00956	0.0158	27	0.00985	0.01889	27	0.00949	0.01684
28	0.00959	0.01865	28	0.00988	0.01569	28	0.00787	0.01844
29	0.00918	0.01609	29	0.00844	0.01512	29	0.009	0.01435
30	0.0097	0.01684	30	0.00946	0.01761	30	0.00895	0.01574
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01152	0.03348		0.01044	0.02848		0.01107	0.02786
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001732789	0.003396513		0.001428556	0.003102785		0.001690626	0.003225658

	Day 1			Day 2			Day 3	
Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum	Interval	Left EMG Integrated	Interval Maximum
1	0.01772	0.03201	1	0.01508	0.02579	1	0.01541	0.02705
2	0.0134	0.02177	2	0.01118	0.02001	2	0.01367	0.02277
3	0.01235	0.0196	3	0.00969	0.01657	3	0.01362	0.02331
4	0.01171	0.01983	4	0.01198	0.02296	4	0.01446	0.0262
5	0.01311	0.02248	5	0.01155	0.02155	5	0.01354	0.02328
6	0.01261	0.0194	6	0.01275	0.02296	6	0.01356	0.02411
7	0.01389	0.02586	7	0.00938	0.0229	7	0.01327	0.02344
8	0.01119	0.02213	8	0.01066	0.02023	8	0.01432	0.02338
9	0.01529	0.02504	9	0.00713	0.01858	9	0.01429	0.02345
10	0.01188	0.02383	10	0.00889	0.0199	10	0.01295	0.02361
11	0.0142	0.02816	11	0.00966	0.01952	11	0.01344	0.02303
12	0.01291	0.02419	12	0.01379	0.0234	12	0.01147	0.0218
13	0.01308	0.0232	13	0.00968	0.0232	13	0.01289	0.02329
14	0.01156	0.02072	14	0.01017	0.01731	14	0.01222	0.02068
15	0.01245	0.02203	15	0.0092	0.01815	15	0.01045	0.01781
16	0.01199	0.02016	16	0.01081	0.02036	16	0.01147	0.02108
17	0.01317	0.02048	17	0.01106	0.01783	17	0.01116	0.01886
18	0.01217	0.02253	18	0.01092	0.01814	18	0.0104	0.0166
19	0.01177	0.02448	19	0.01005	0.0202	19	0.00982	0.02004
20	0.01348	0.02212	20	0.00916	0.01971	20	0.0104	0.01781
21	0.01121	0.02796	21	0.0101	0.01681	21	0.01098	0.02155
22	0.0128	0.02367	22	0.01335	0.02502	22	0.01054	0.01754
23	0.01061	0.02038	23	0.00915	0.01395	23	0.0098	0.01694
24	0.0126	0.02173	24	0.00969	0.01713	24	0.01019	0.01823
25	0.01074	0.02165	25	0.00873	0.01492	25	0.00905	0.01539
26	0.01089	0.02136	26	0.01081	0.01945	26	0.01011	0.01741
27	0.0104	0.01978	27	0.0092	0.01873	27	0.00946	0.01971
28	0.00973	0.01548	28	0.00938	0.01801	28	0.00793	0.01696
29	0.01068	0.01833	29	0.00775	0.01611	29	0.00966	0.0163
30	0.0108	0.01825	30	0.00995	0.01944	30	0.00965	0.01993
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01235	0.03201		0.01037	0.02578		0.01168	0.02705
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.001619924	0.003307364		0.001727103	0.002876823		0.001963981	0.003142472

Subject 9

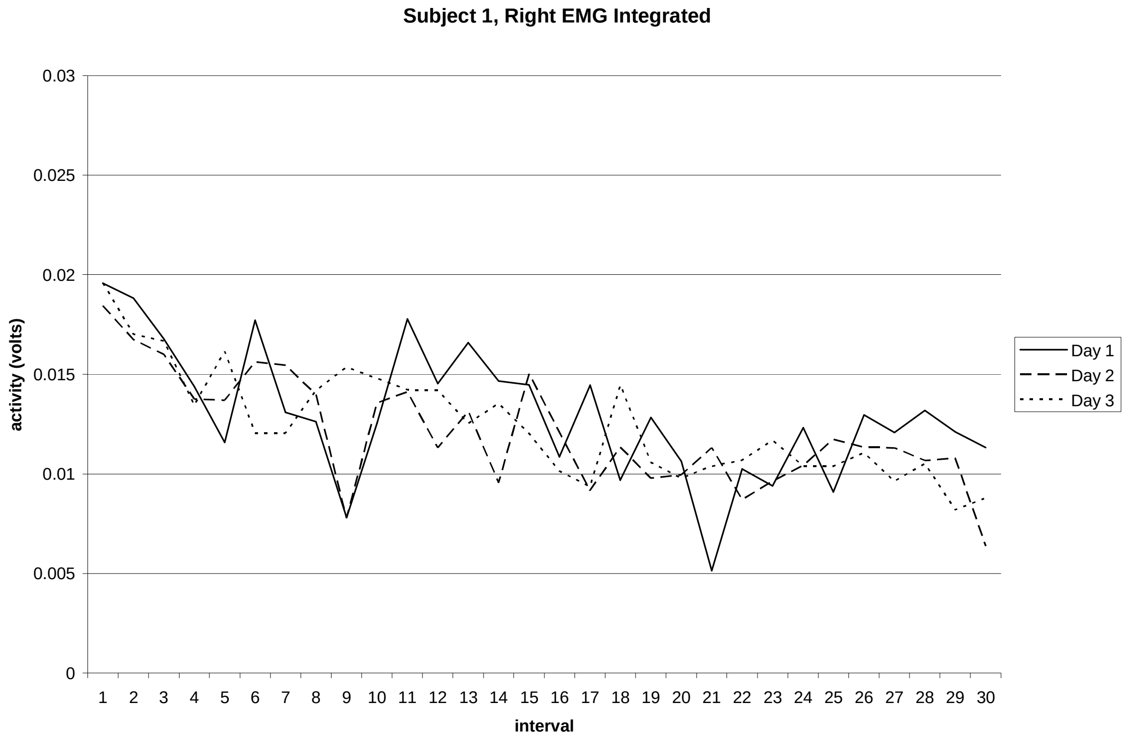
Interval Averages and Interval Maximums (measured in volts)

Interval	Day 1 Right EMG Integrated	Day 1 Interval Maximum	Interval	Day 2 Right EMG Integrated	Day 2 Interval Maximum	Interval	Day 3 Right EMG Integrated	Day 3 Interval Maximum
1	0.02884	0.04862	1	0.02685	0.04516	1	0.01853	0.02993
2	0.02556	0.04878	2	0.0253	0.04445	2	0.01665	0.02619
3	0.01628	0.02576	3	0.02271	0.0403	3	0.01363	0.02429
4	0.01453	0.02738	4	0.01663	0.02581	4	0.01158	0.02201
5	0.01699	0.03045	5	0.02015	0.03549	5	0.01345	0.02277
6	0.01931	0.03171	6	0.02083	0.04433	6	0.01417	0.02236
7	0.01821	0.03724	7	0.01496	0.03279	7	0.0128	0.02178
8	0.01803	0.03023	8	0.01924	0.03554	8	0.0141	0.02495
9	0.01639	0.04765	9	0.01843	0.03216	9	0.01358	0.02473
10	0.01816	0.03842	10	0.01785	0.03235	10	0.01281	0.02308
11	0.01928	0.03943	11	0.02028	0.03728	11	0.01482	0.02355
12	0.01971	0.03543	12	0.01668	0.03604	12	0.01319	0.02669
13	0.0172	0.03049	13	0.01979	0.03332	13	0.01444	0.02787
14	0.01443	0.02798	14	0.0169	0.03221	14	0.01279	0.0193
15	0.01399	0.02474	15	0.021	0.03497	15	0.01405	0.02399
16	0.01599	0.0349	16	0.01931	0.03164	16	0.01395	0.02389
17	0.01255	0.02054	17	0.01664	0.03175	17	0.01249	0.02365
18	0.01189	0.02394	18	0.01987	0.03442	18	0.01379	0.02423
19	0.01109	0.02385	19	0.01761	0.0391	19	0.01183	0.01924
20	0.01003	0.01982	20	0.01624	0.02797	20	0.01187	0.02433
21	0.0085	0.01881	21	0.01653	0.02822	21	0.01119	0.02026
22	0.00893	0.01626	22	0.01682	0.03717	22	0.01195	0.02171
23	0.00671	0.01414	23	0.01425	0.02916	23	0.01139	0.02312
24	0.00661	0.01302	24	0.01536	0.02905	24	0.01155	0.01974
25	0.00628	0.01055	25	0.01406	0.03254	25	0.01075	0.02009
26	0.00573	0.01058	26	0.01198	0.02109	26	0.01116	0.01864
27	0.0059	0.01185	27	0.0132	0.02699	27	0.01014	0.01932
28	0.00474	0.00923	28	0.01597	0.02802	28	0.01029	0.01796
29	0.00515	0.01076	29	0.01587	0.0277	29	0.00986	0.01957
30	0.00491	0.00918	30	0.01467	0.02369	30	0.01072	0.01838
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01341	0.04878		0.01788	0.04516		0.01279	0.02993
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.006303319	0.012076969		0.003365935	0.005914823		0.001922777	0.002963999

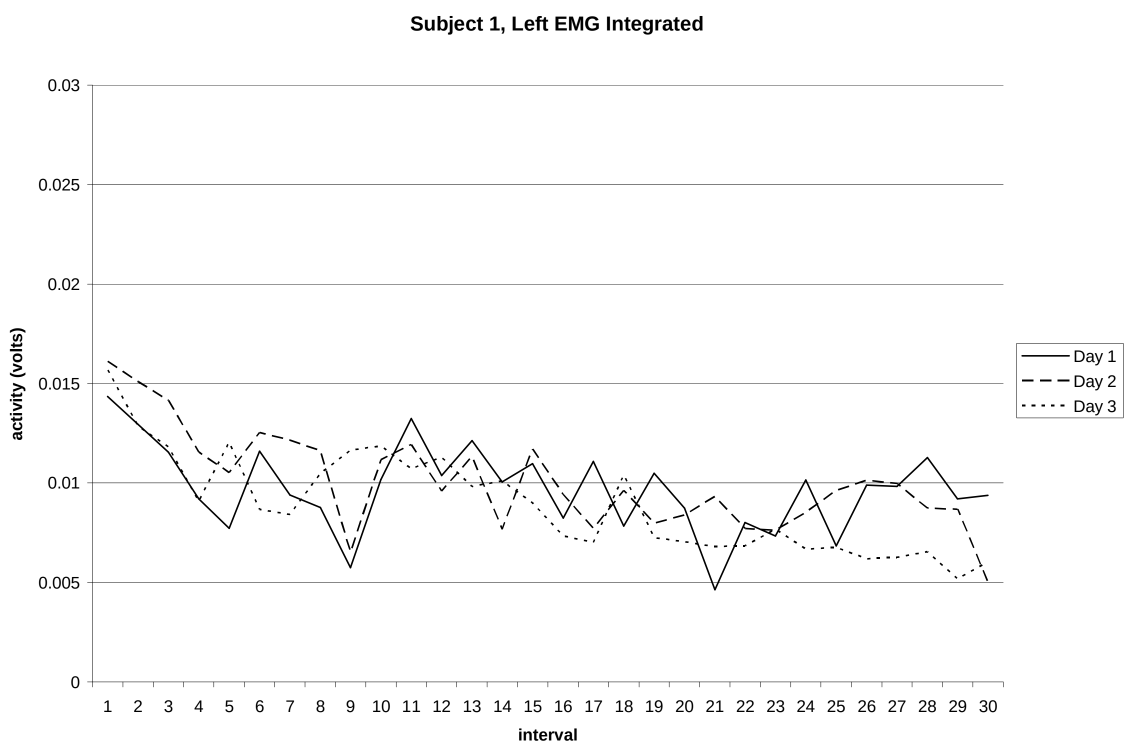
Interval	Day 1 Left EMG Integrated	Day 1 Interval Maximum	Interval	Day 2 Left EMG Integrated	Day 2 Interval Maximum	Interval	Day 3 Left EMG Integrated	Day 3 Interval Maximum
1	0.0262	0.04253	1	0.02704	0.04872	1	0.0205	0.03354
2	0.02375	0.03841	2	0.02324	0.03802	2	0.0179	0.03031
3	0.01767	0.03038	3	0.02045	0.03276	3	0.0137	0.02198
4	0.01401	0.03136	4	0.01413	0.02702	4	0.01234	0.02509
5	0.01708	0.02695	5	0.01852	0.03514	5	0.01339	0.02275
6	0.01758	0.0339	6	0.018	0.03069	6	0.01399	0.02211
7	0.01765	0.03808	7	0.01311	0.03203	7	0.01297	0.02558
8	0.01681	0.03071	8	0.01711	0.04237	8	0.01464	0.02319
9	0.01527	0.03219	9	0.01543	0.02503	9	0.01318	0.02233
10	0.01667	0.03585	10	0.01587	0.03456	10	0.01375	0.02464
11	0.01693	0.03076	11	0.01775	0.03081	11	0.01518	0.02756
12	0.0191	0.03531	12	0.01353	0.02935	12	0.01401	0.0277
13	0.01751	0.02966	13	0.01537	0.02622	13	0.01482	0.02528
14	0.01487	0.02687	14	0.01234	0.02369	14	0.01336	0.02142
15	0.01343	0.02209	15	0.01488	0.02654	15	0.01449	0.02425
16	0.01661	0.02753	16	0.0146	0.02567	16	0.01366	0.02738
17	0.01428	0.02805	17	0.01242	0.02174	17	0.01317	0.02409
18	0.0142	0.02749	18	0.0149	0.02823	18	0.01413	0.02637
19	0.01391	0.02991	19	0.01247	0.02249	19	0.01245	0.02172
20	0.01309	0.02793	20	0.01142	0.02069	20	0.01234	0.02147
21	0.01135	0.02044	21	0.01106	0.0236	21	0.0109	0.0197
22	0.01375	0.02421	22	0.0113	0.02016	22	0.01259	0.02212
23	0.01	0.02044	23	0.00994	0.02334	23	0.01063	0.02032
24	0.01228	0.02631	24	0.01046	0.0192	24	0.01154	0.01851
25	0.01098	0.02321	25	0.01006	0.02276	25	0.0112	0.0241
26	0.01003	0.01775	26	0.00816	0.01566	26	0.01125	0.02037
27	0.01041	0.01775	27	0.00918	0.02081	27	0.00992	0.01917
28	0.00983	0.01721	28	0.01117	0.01836	28	0.01047	0.01882
29	0.01187	0.02268	29	0.01066	0.01845	29	0.00957	0.02056
30	0.01092	0.01771	30			30	0.00989	0.01873
	Mean	Absolute Max.		Mean	Absolute Max.		Mean	Absolute Max.
	0.01494	0.04253		0.01415	0.04872		0.01307	0.03354
	Std. dev.	Std. dev.		Std. dev.	Std. dev.		Std. dev.	Std. dev.
	0.003870379	0.006639762		0.00429398	0.007599166		0.002314471	0.003561196

Integrated EMG Data Graphs

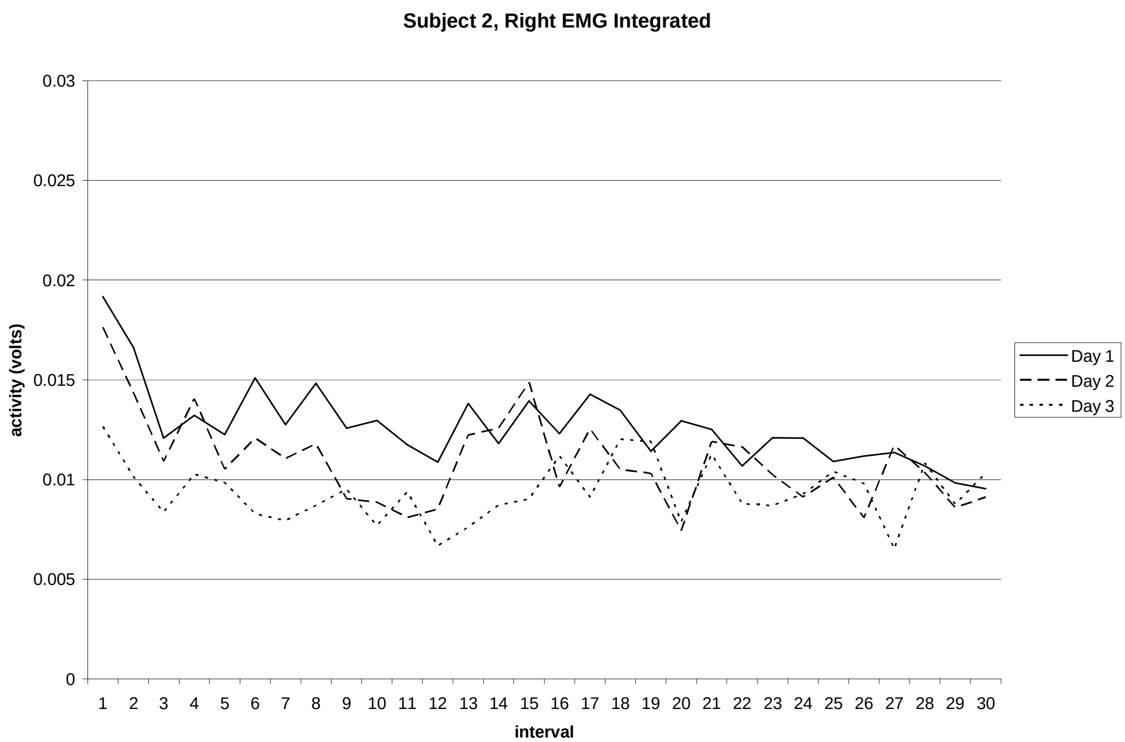
The following graphs were created by plotting the above integrated EMG values. Each graph contains only data from one side of the orbicularis oris. The data from all three testing sessions for each subject are plotted on the same chart for comparison. A general downward tendency can be observed in each chart indicating a decline of muscle activity, and therefore, fatigue.

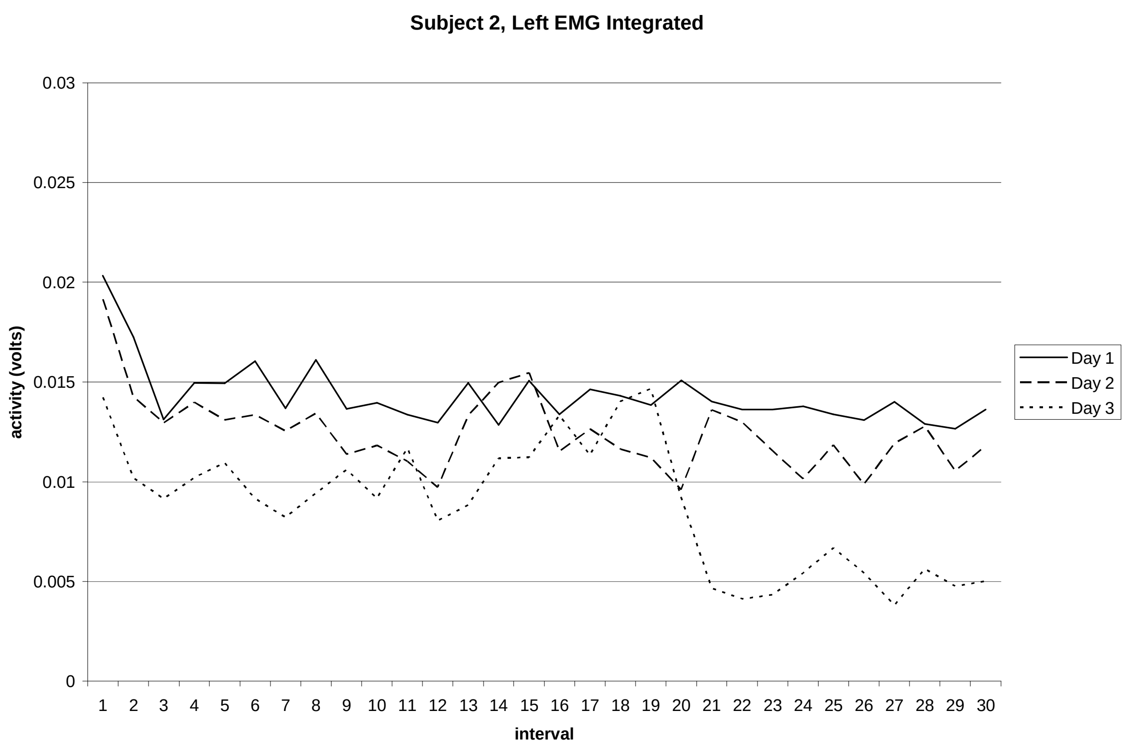


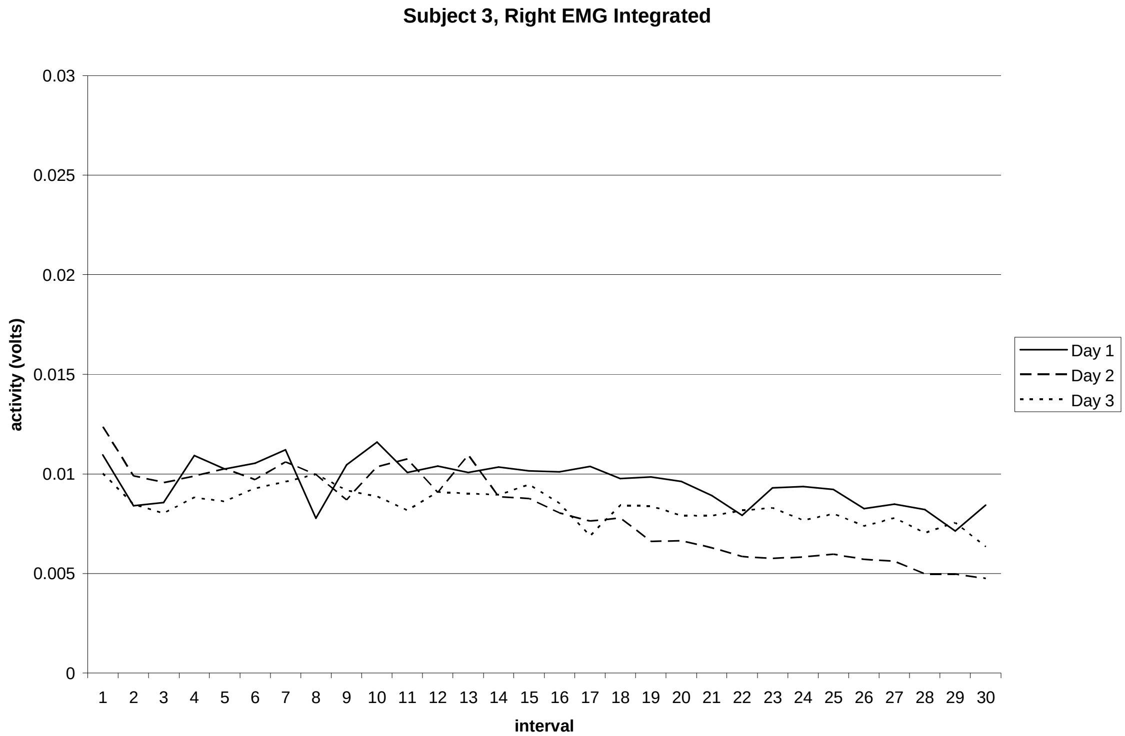
Subject 1, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

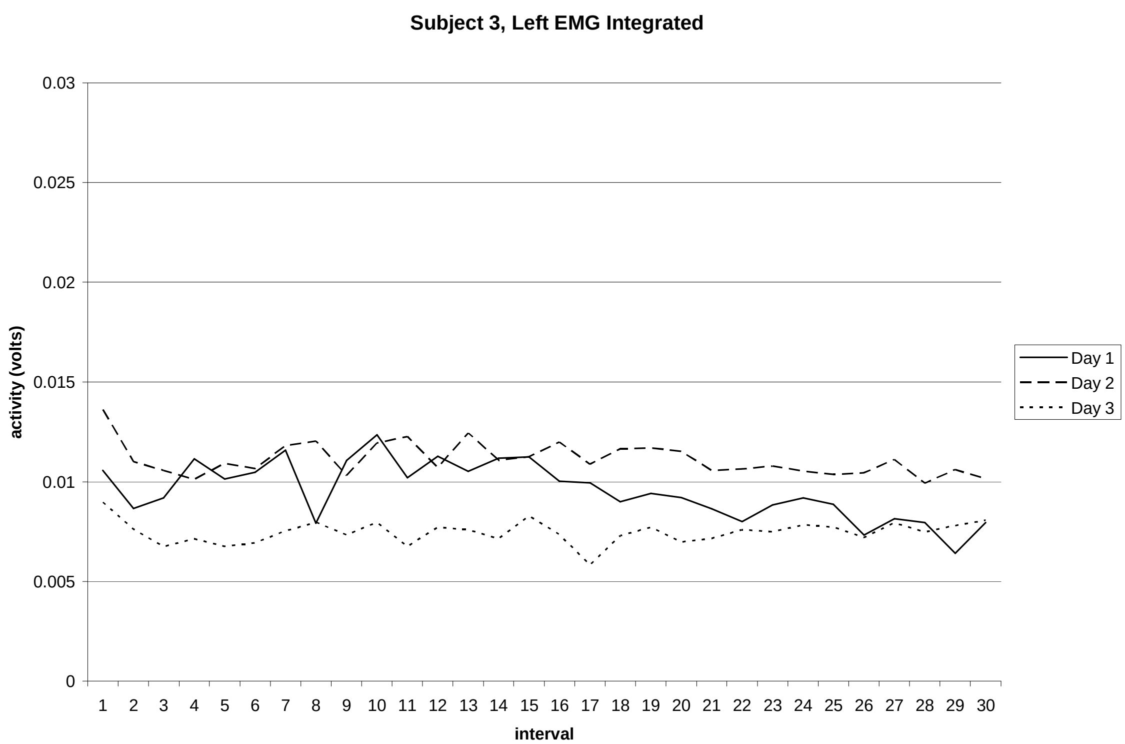


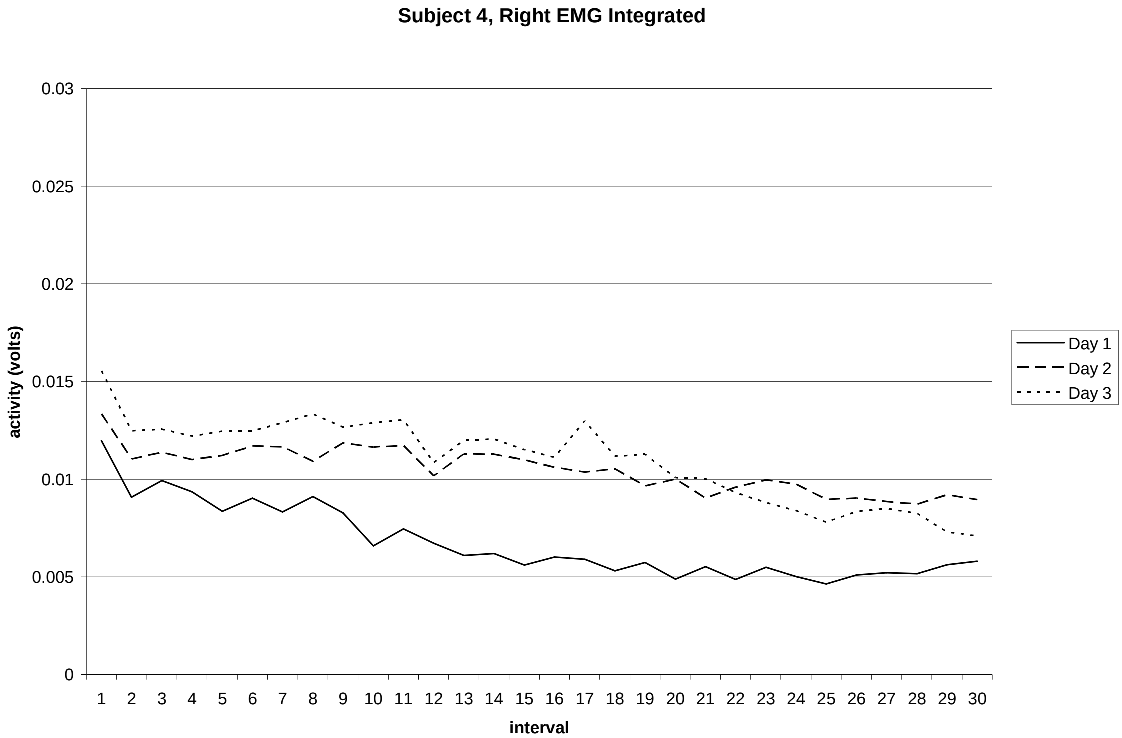
Subject 1, Left EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

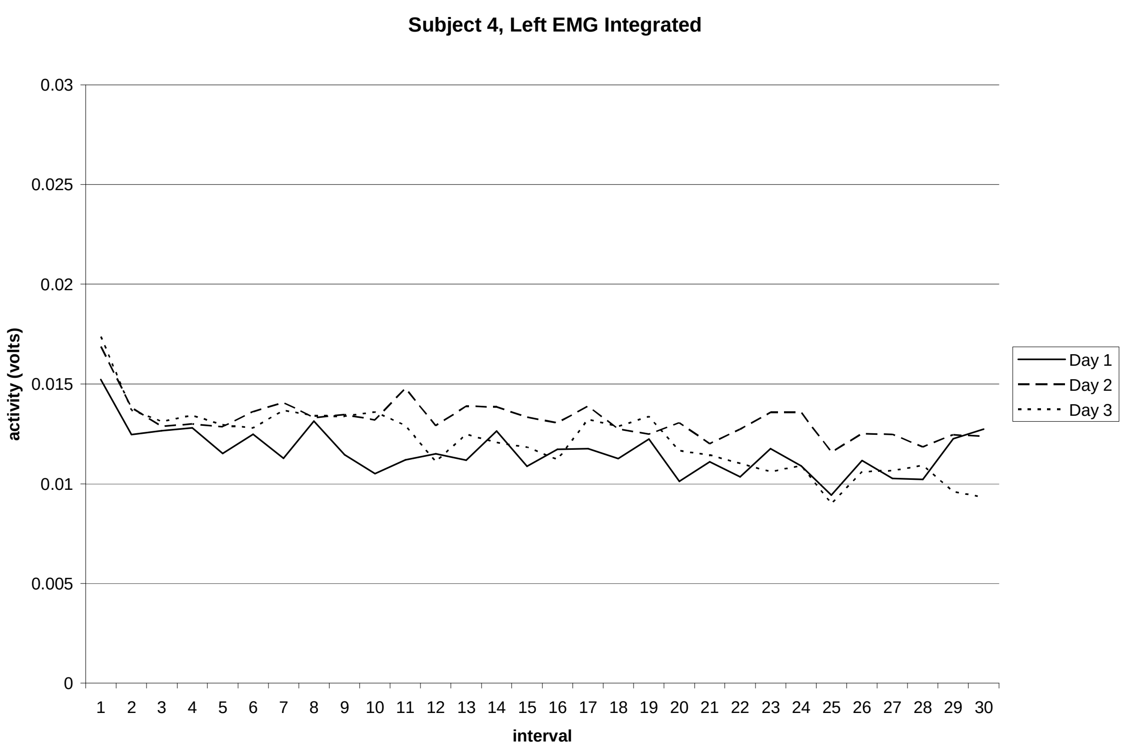

Subject 2, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

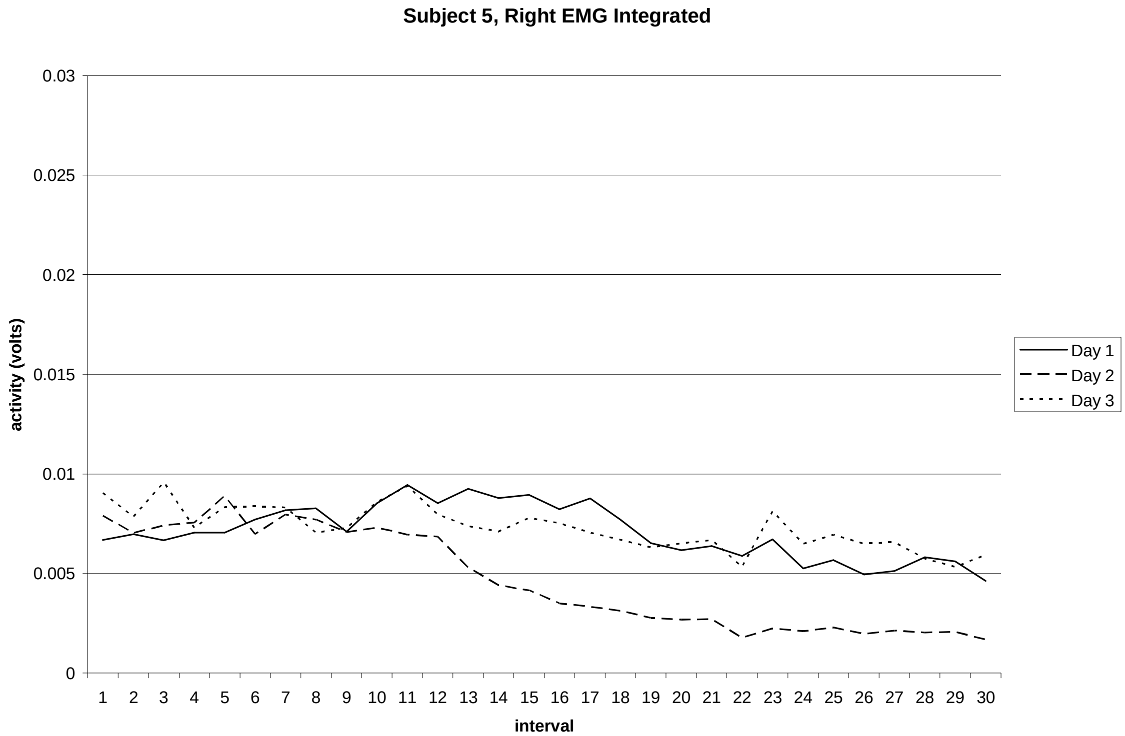

Subject 2, Left EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

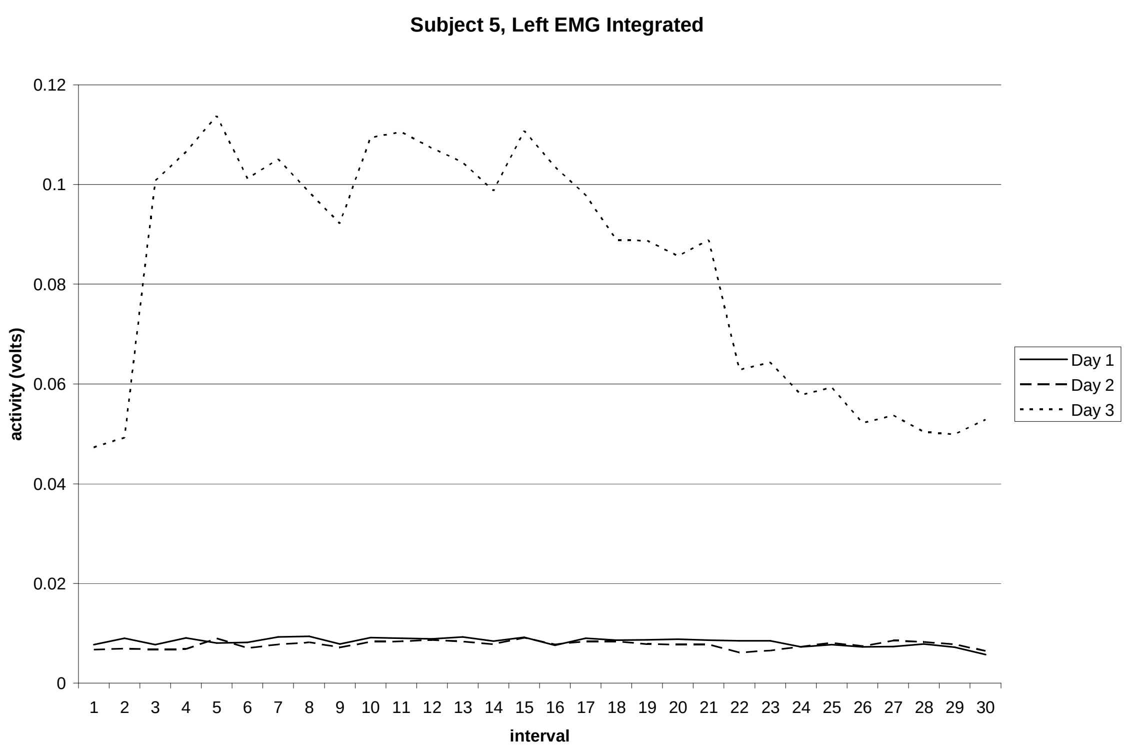

Subject 3, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

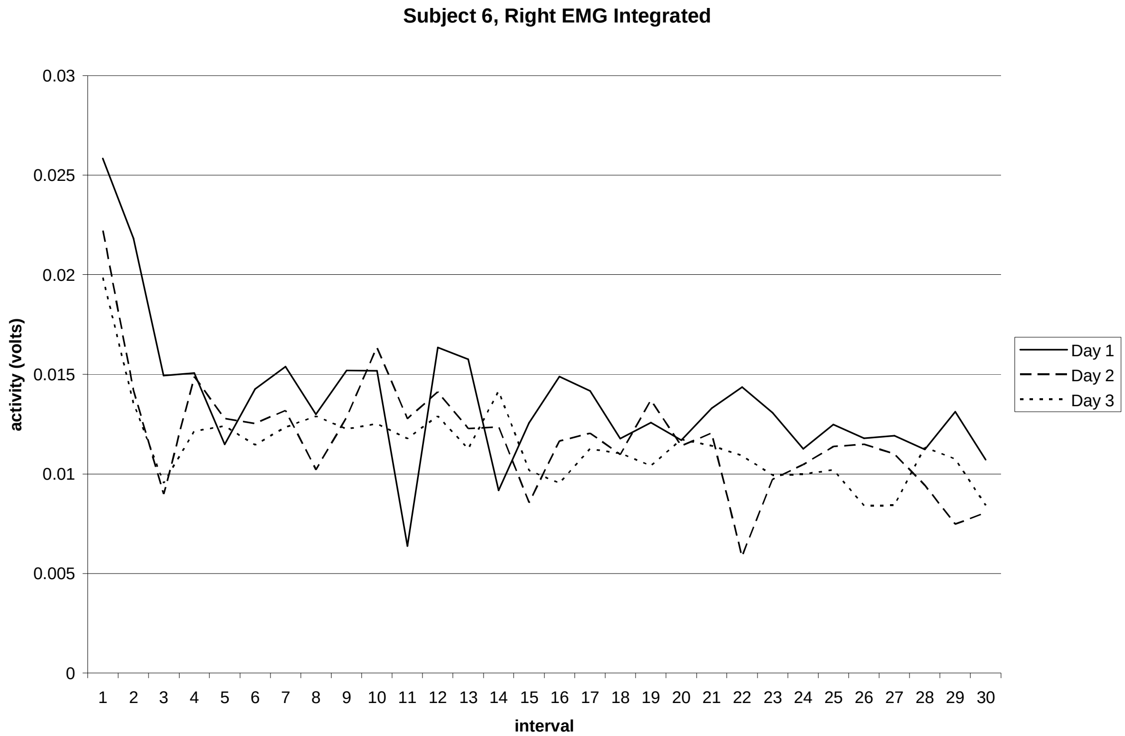

Subject 3, Left EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

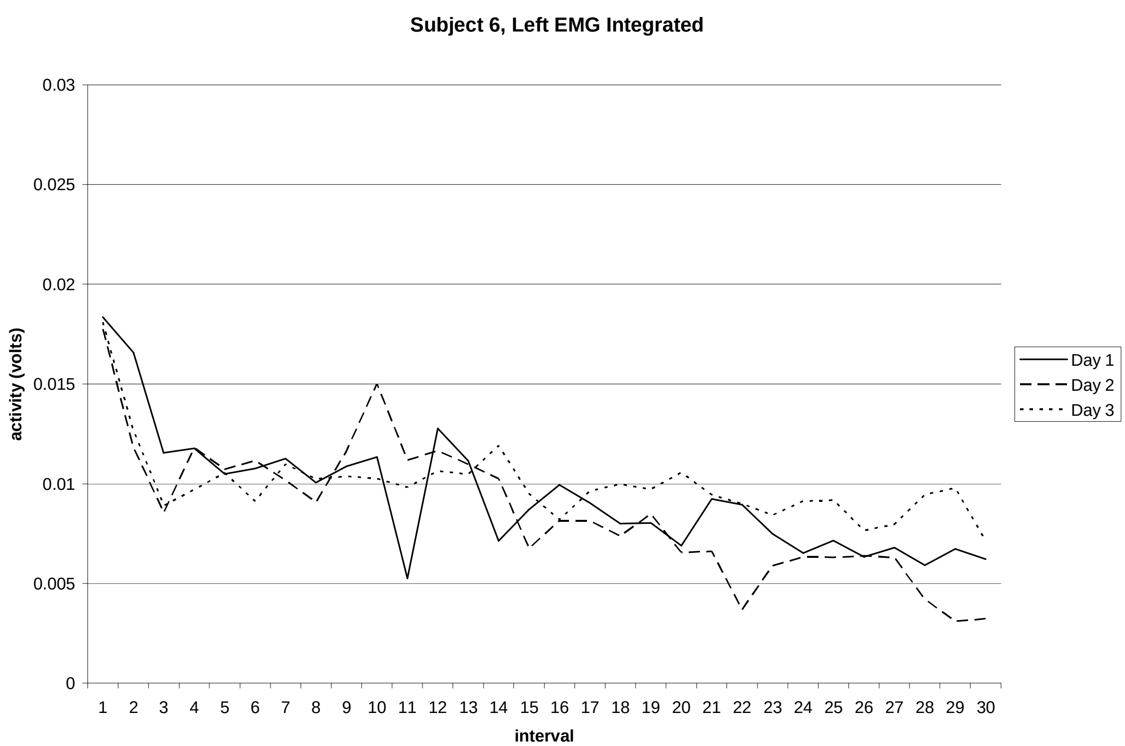

Subject 4, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3


Subject 4, Left EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

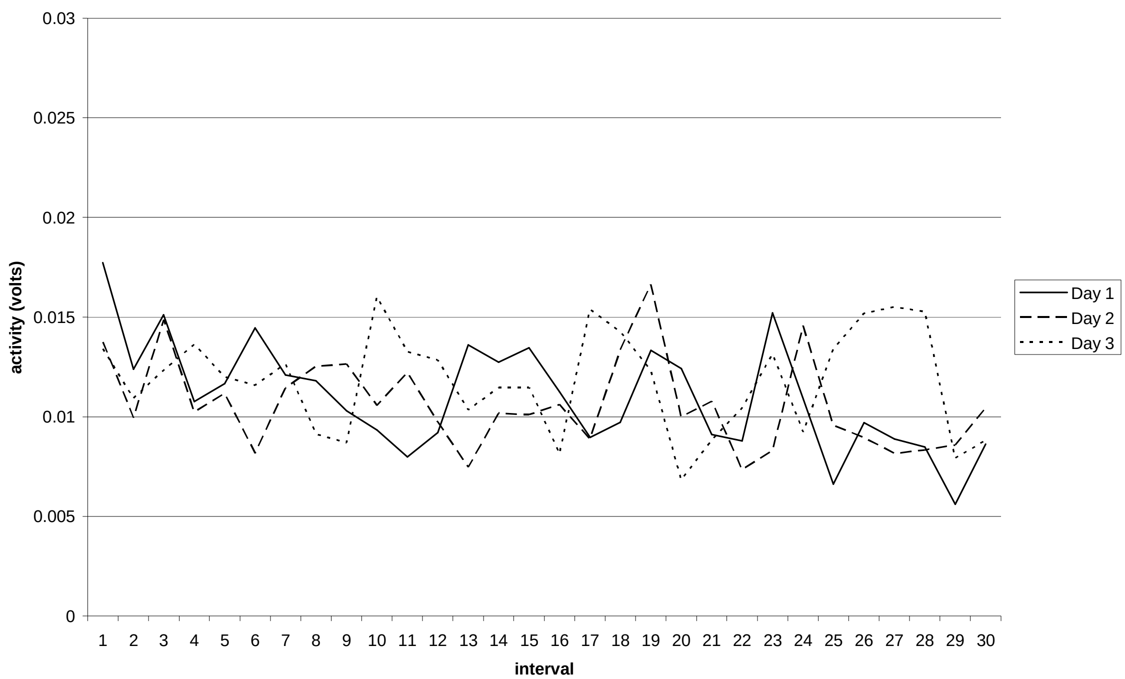

Subject 5, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3


Subject 5, Left EMG Integrated
0.12
0.1
0.08
0.06
0.04
0.02
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

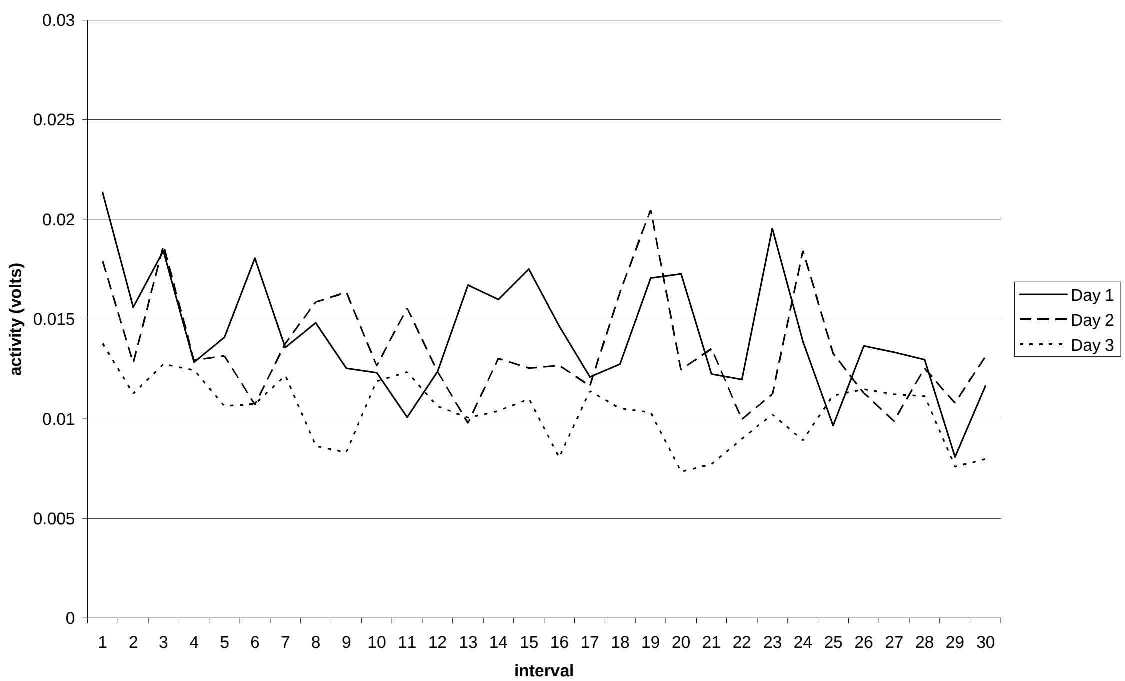

Subject 6, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

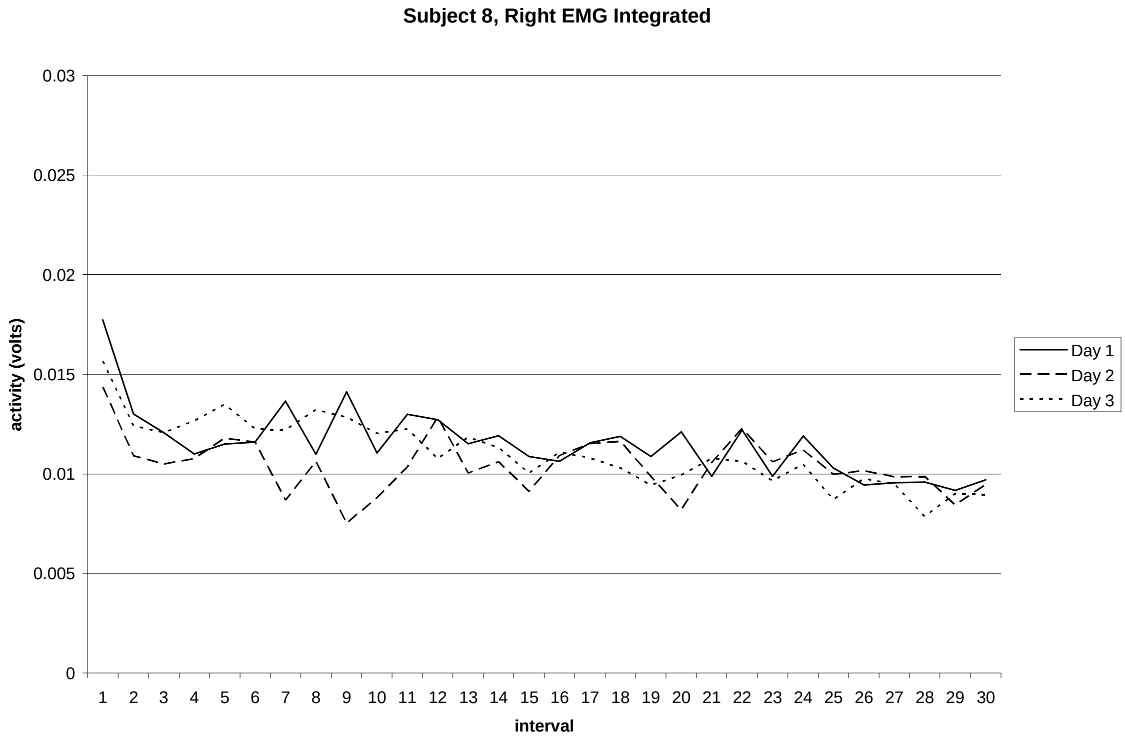

Subject 6, Left EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

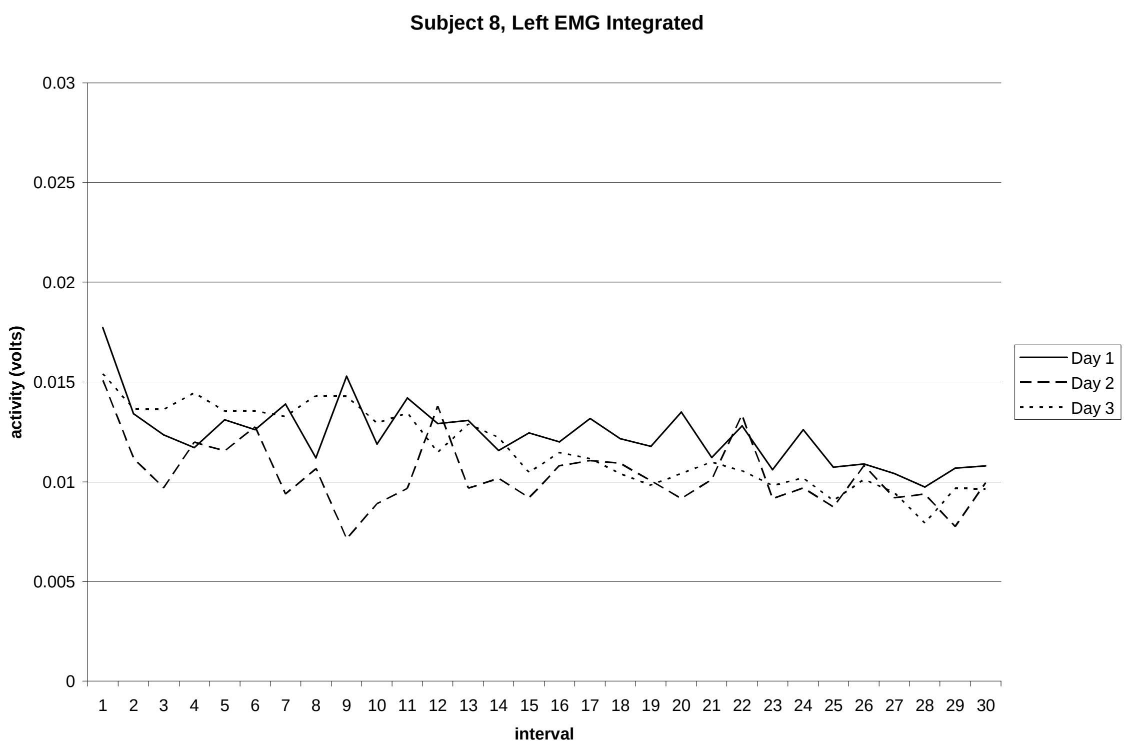
Subject 7, Right EMG Integrated

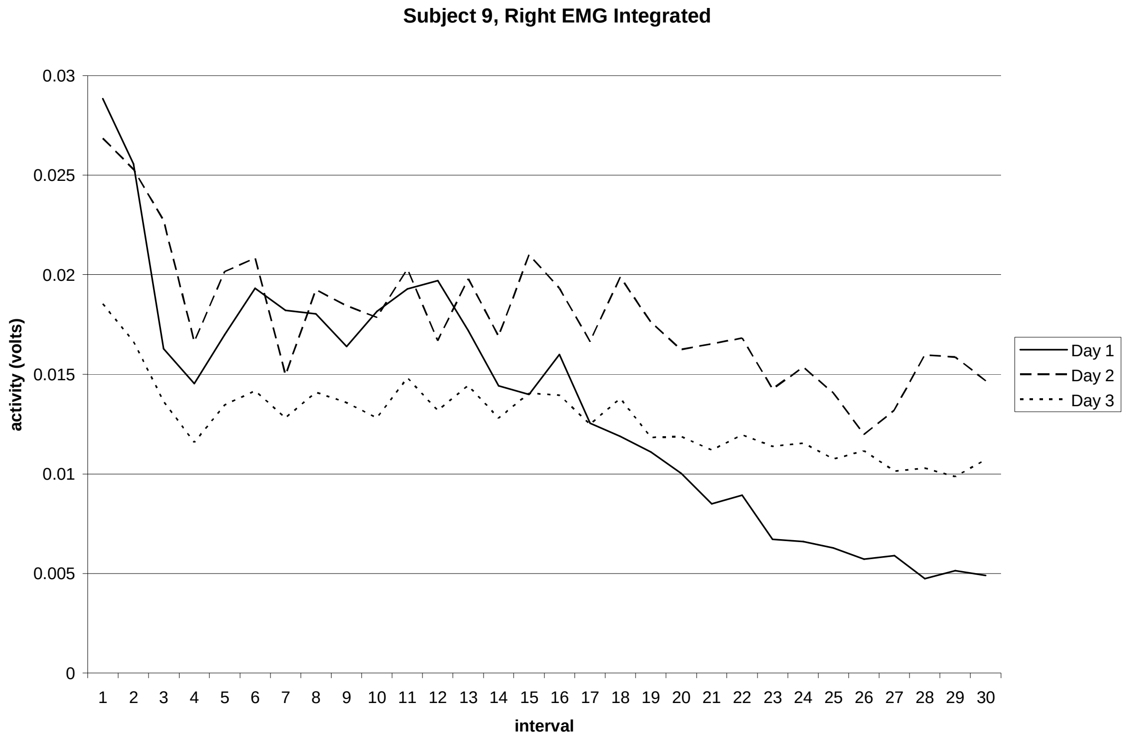


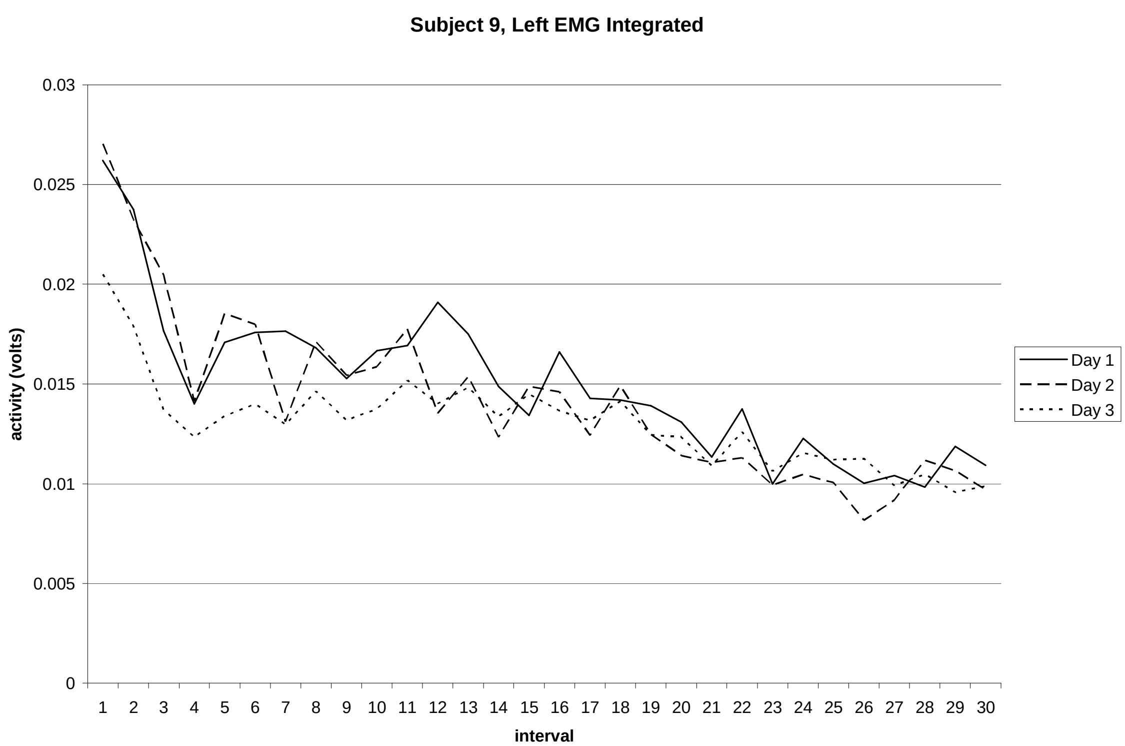
Subject 7, Left EMG Integrated




Subject 8, Right EMG Integrated
activity (volts)
0.03
0.025
0.02
0.015
0.01
0.005
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3


Subject 8, Left EMG Integrated
activity (volts)
0.03
0.025
0.02
0.015
0.01
0.005
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3


Subject 9, Right EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3


Subject 9, Left EMG Integrated
0.03
0.025
0.02
0.015
0.01
0.005
0
activity (volts)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30
interval
Day 1
Day 2
Day 3

Tone Quality Data

Tone quality is a subjective matter, and the researcher has made no attempt to make an absolute evaluation of the subjects' tone quality or the depreciation of tone quality during the testing session. Quantifiable observations, however, were made with respect to elements related to tone quality. Walter Boeykens addressed the problem of air escaping around the mouthpiece and noted that listeners are often unnerved and disturbed by the noise it creates.[160] This problem is related to fatigue and instances of escaping air during the testing sessions were recorded. Theses instances were of two types: a very short air leak lasting for a second or less or a long hiss lasting several beats and usually being corrected after the player took a breath. The exact length of the long air leaks was difficult to measure because the noise was often intermittent and would fade and reappear slowly during a phrase. In both cases, long leak or short leak, only the beginning time of the leak was noted.

Another problem related to tone that appeared during the test sessions was that of the players taking un-notated pauses. These pauses may have been related to psychological fatigue and became more frequent toward the end of each testing session.

The following time lines show the instances of these events (short air leaks, long air leaks, and un-notated pauses.) Each subject's chart contains three distinct time lines for each of the three trials. In most cases the density of the events in question become greater at the end of each trial, and in most cases the second day of testing, in general, has a higher density of events than the first or the third.

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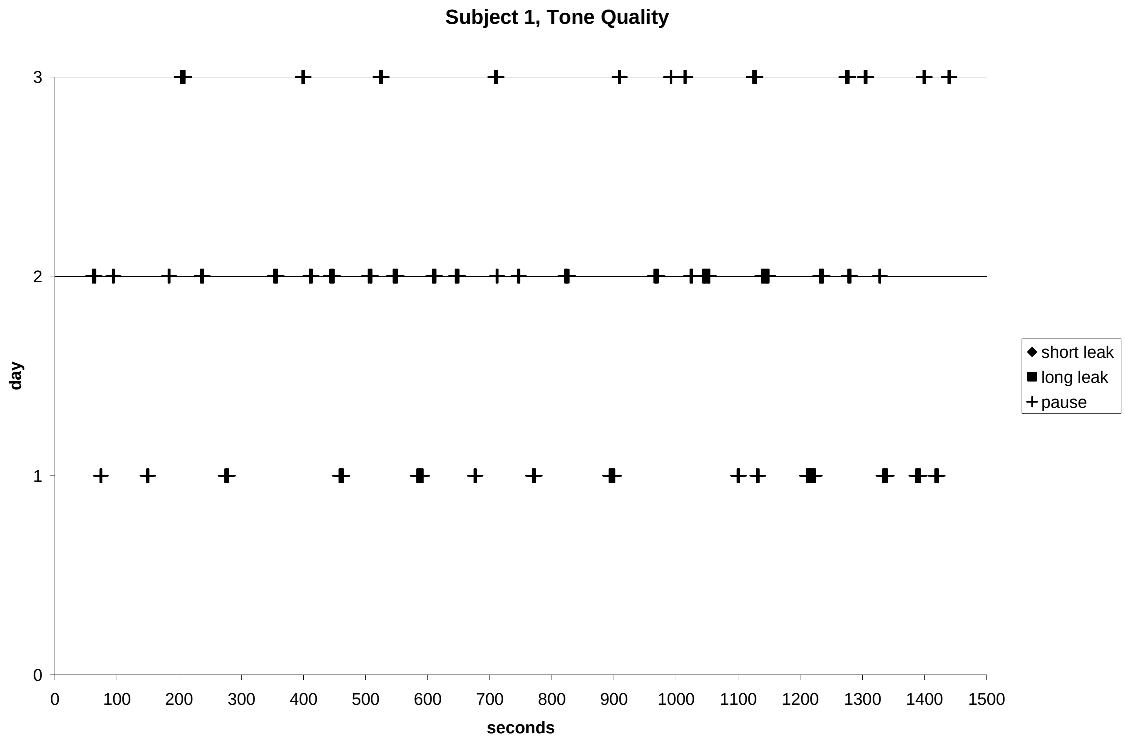
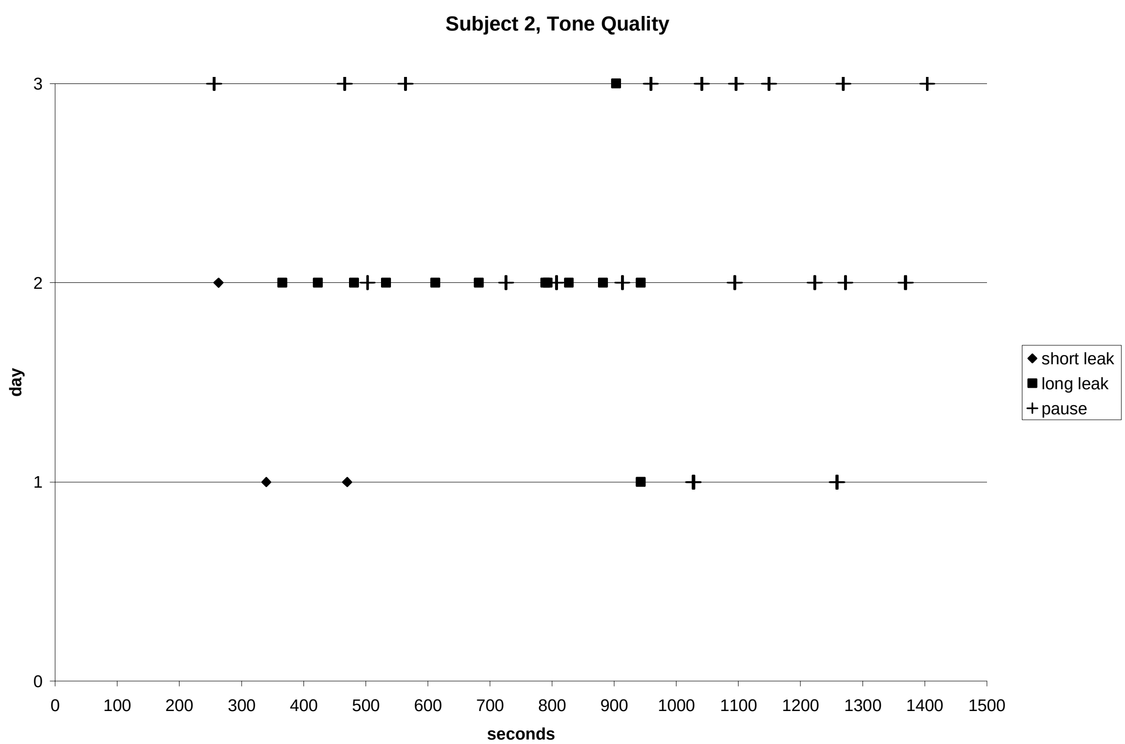
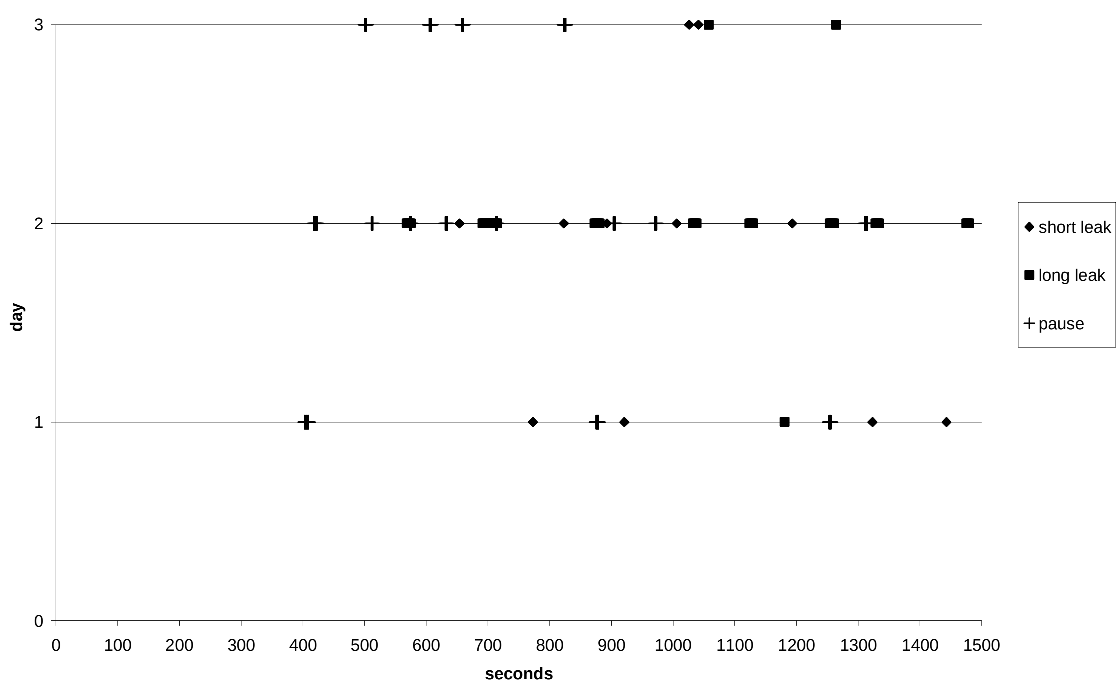
[160] Walter Boeykens, "Playing the Clarinet with Finesse," *The Instrumentalist* 42 (November 1987): 28.

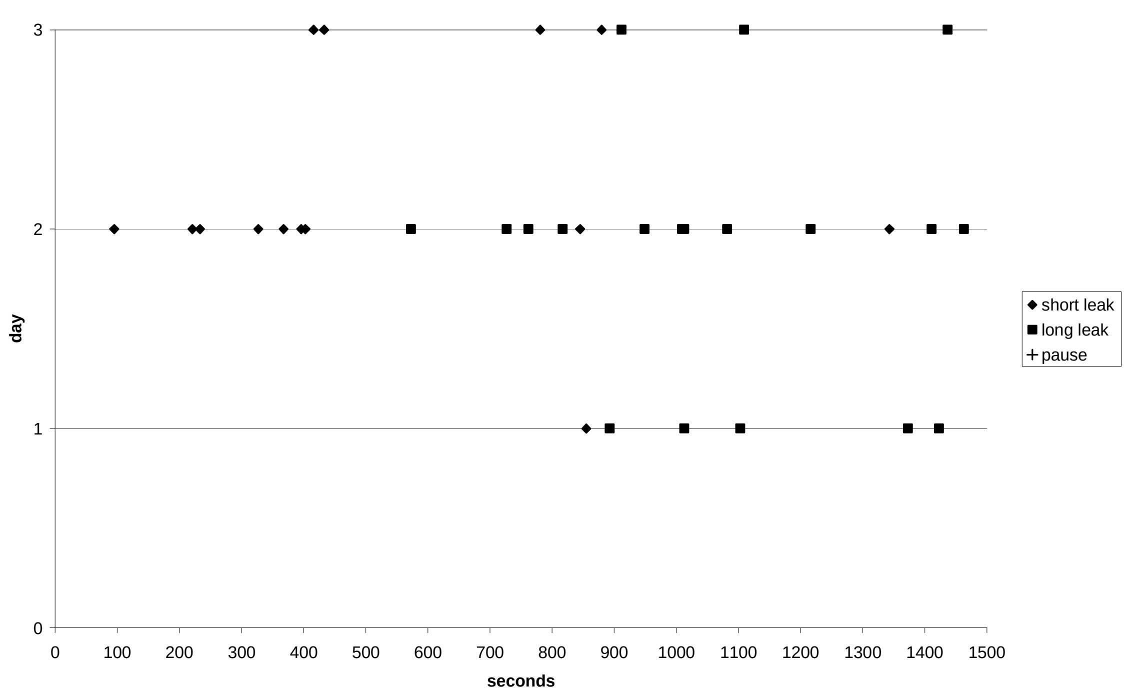

Subject 1, Tone Quality
day
seconds
0
1
2
3
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
short leak
long leak
pause

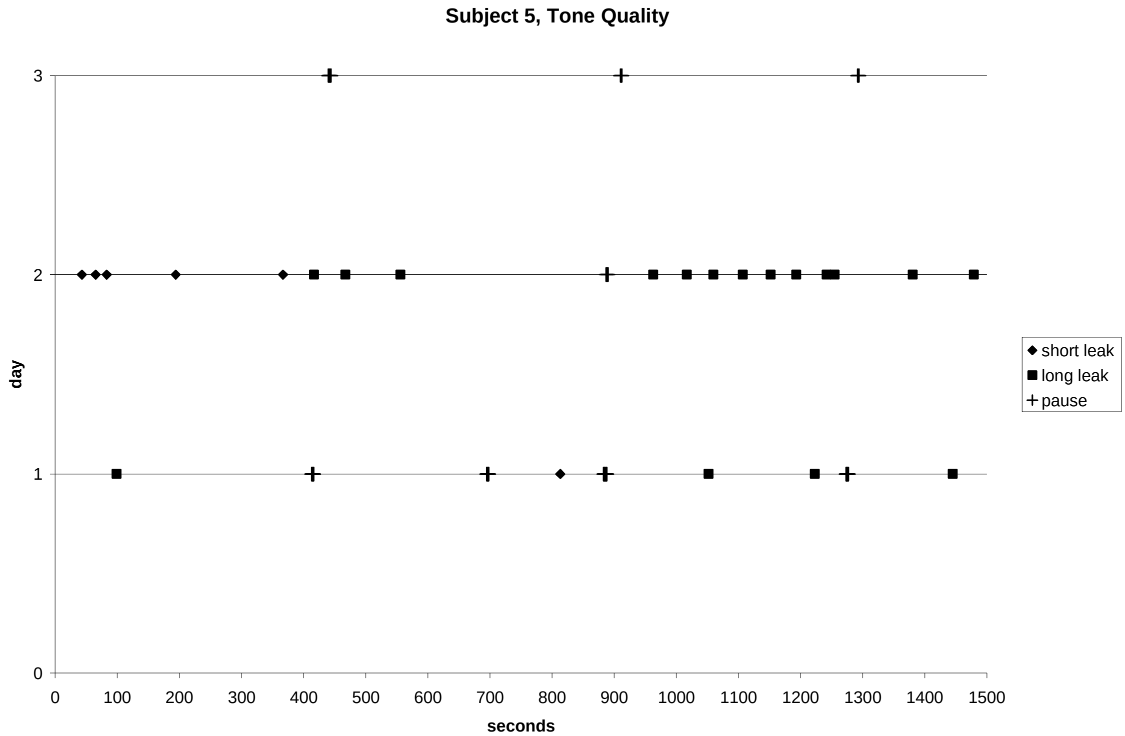

Subject 2, Tone Quality
day
seconds
0
1
2
3
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
short leak
long leak
pause

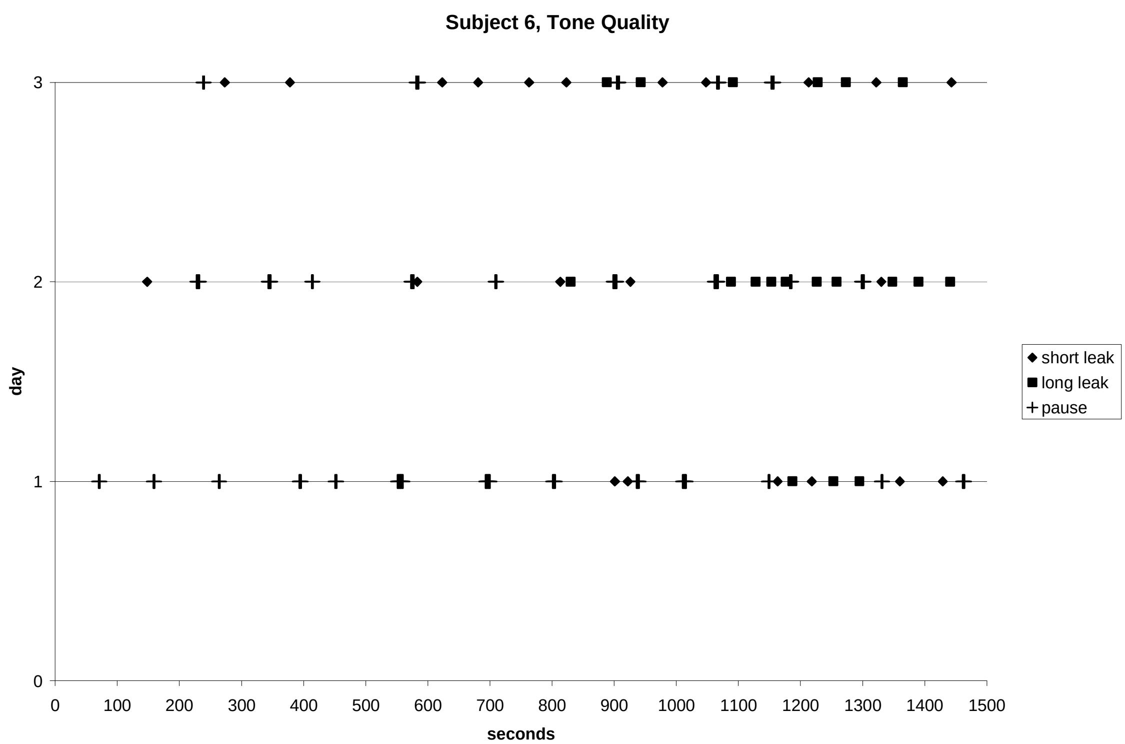
Subject 3, Tone Quality

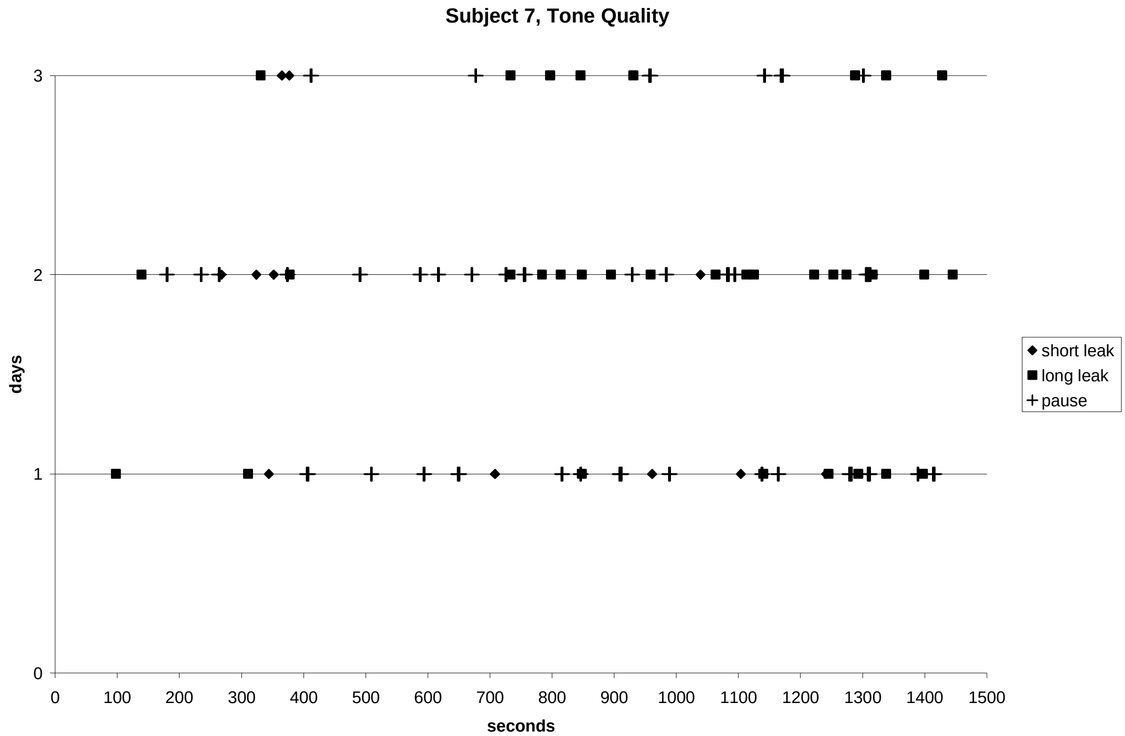


Subject 4, Tone Quality




Subject 5, Tone Quality
day
3
2
1
0
seconds
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
short leak
long leak
pause


Subject 6, Tone Quality
day
3
2
1
0
seconds
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
short leak
long leak
pause


Subject 7, Tone Quality
3
2
1
0
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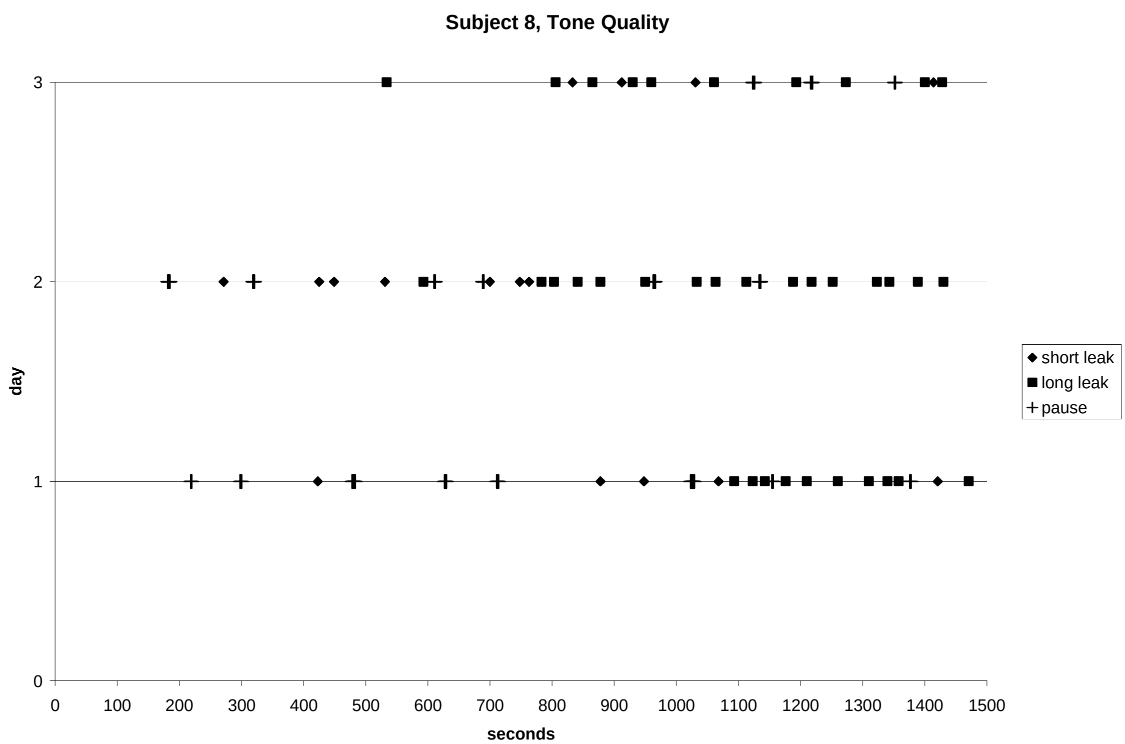
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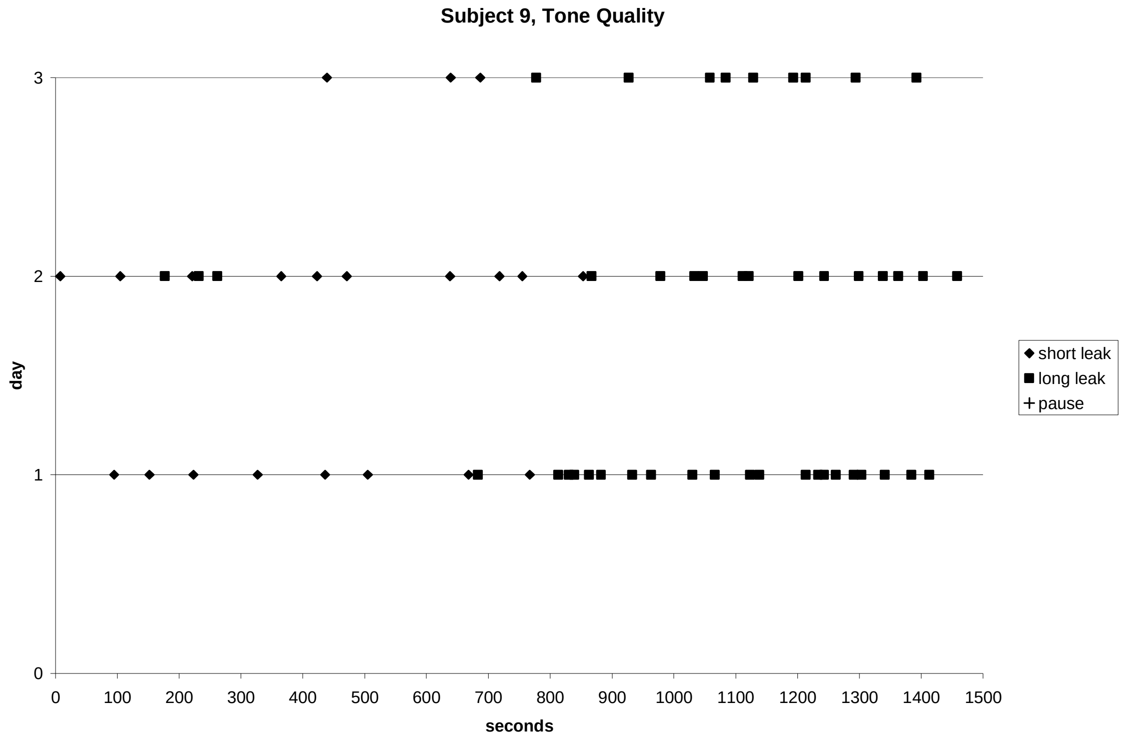

Subject 9, Tone Quality
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Signal Processing

The raw EMG signals were collected using the Biopac MP 150 and its related software (AcqKnowledge 3.7.3, Biopac Systems, Goleta, California). The raw EMG signals were bandpass filtered (4^{th} – order Butterworth) using Labview software (version 7 Express, National Instruments, Austin, Texas). This software yielded the average amplitude (μv) and average frequency (Hz) values for each trial. The AcqKnowledge software was used to generate the average IEMG (v) values for each trial.

A. W. Kelman and S. Gatehouse found that while performing EMG testing on the orbicularis oris, there were very little differences in left-side and right-side data.[161] The data collected in this project is consistent with that finding with the exception of the data collected on subject five on the third day. The left-side data for this trial was obviously inconsistent and was probably affected by some type of equipment failure or researcher error. Because of the large amount of data involved, the findings of Kelman and Gatehouse, and the one instance of inconsistent left-side data, only right-side data was used for statistical analysis.

Statistical Analysis

The descriptive data (age, height, weight, experience, time spent playing the clarinet, and self-perceived levels of fatigue and tone depreciation) are reported as means ± SD (Standard Deviation). The percent change over trials for the outcome variables of IEMG (v), amplitude (μv), and frequency (Hz) were calculated by

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[161] A. W. Kelman and S. Gatehouse. "A Study of the Electromyographical Activity of the Musculus Orbicularis Oris," *Folia Phonaitrica* 27 (1975): 361.

subtracting post value (mean of values for trials 29 and 30) from initial value (mean of values for trials 1 and 2) and dividing the sum by the initial data value (mean of values for trials 1 and 2). Statistical analyses were performed using SPSS 11.5 for Windows. Comparisons between the days (3) over trials (30) were accomplished using 2-way ANOVA with repeated measures. If the main effect of day was found to be significant, a Bonferoni, post-hoc, pair-wise comparison was used to determine differences. If the main effect of trial was found to be significant, then a post-hoc trend analysis (linear, quadratic, or cubic) was used to describe the overall shape of the trends. Statistical significance was set at an alpha level of $p = 0.05$.[162]

Based on the 2-way (day{3} and trial {30}) repeated measures ANOVA, there were no significant day effects for IEMG ($p = .91$), amplitude ($p = .42$), frequency ($p = .32$), percent decline in IEMG ($p = .54$), or percent decline in amplitude ($p = .51$). This indicates that these variables from all three days exhibited a similar pattern with respect to the 30 trials on each day, and that the rest period did not have an effect.

There was, however, a significant day effect for the percent decline in frequency ($p = .007$). Post-hoc analysis indicated that day 1 had a greater decline in frequency compared to the declines in frequency of day 2 and day 3. This indicates, with respect to frequency, that the subjects were more fatigued at the end of day 1 than either day 2 or 3 and that the level of fatigue for day 2 and 3 were similar. The rest period had no significant effect on the frequency, and the lower declines in

[162] Significance levels show how likely a result is due to chance. The most common level, used by statisticians to mean that something is good enough to be believed, is .95. This means that the finding has a 95% chance of being true. It is reported, however, as p = .05 meaning that the finding has a 5% (0.05) chance of not being true.

frequency on days 2 and 3 could be, perhaps, due to a training effect in which the subjects adapted to the repeated playing task.

There were significant trial effects for both IEMG ($p = .000$) and amplitude ($p = .036$) but no trial effect for frequency ($p = .222$). Post-hoc trend analysis indicated that there was only a significant linear decline from trial 1 toward trial 30 for both IEMG and amplitude. This indicates that fatigue was a steady process from beginning to end of each day, and there was not a period of no fatigue followed by a specific point where fatigue set in. There were no significant day by trial interactions for IEMG, amplitude or frequency indicating that the pattern of decline across trials for IEMG and amplitude were similar for each day of testing.

Descriptive Statistics			
Variable	N = 9	Mean	Std. Deviation
		Statistic	Statistic
subject age		23.6	5.4
subject height in inches		68.3	2.5
subject weight in pounds		174.2	32.8
years subject has played clarinet		12.1	5.4
days each week subject plays		5.9	0.8
hours spent playing each week		17.2	8.8
perceived fatigue level, day 1		6.5	2.4
perceived fatigue level, day 2		6.5	2.5
perceived fatigue level, day 3		5.3	2.4
perceived beginning of fatigue (minutes), day 1		8.7	8.3
perceived beginning of fatigue (minutes), day 2		4.6	6.1
perceived beginning of fatigue (minutes), day 3		7.6	7.2
perceived depreciation of tone, day 1		6.3	2.8
perceived depreciation of tone, day 2		6.6	1.8
perceived depreciation of tone, day 3		4.8	2.6
percent decline in v, day 1 (Integrated EMG)		44.2	17.8
percent decline in v, day 2 (Integrated EMG)		44.5	17.6
percent decline in v, day 3 (Integrated EMG)		36.5	11.6
percent decline in amplitude, day 1		35.2	18.1
percent decline in amplitude, day 2		41.1	20.6
percent decline in amplitude, day 3		30.6	11.3
percent decline in frequency, day 1		14.2	12.5
percent decline in frequency, day 2		-0.1	7.9
percent decline in frequency, day 3		1.0	11.8

Figure 12: Descriptive Statistics.

Discussion of Descriptive Statistics

At the end of each day, subjects were asked to report their perceived level of fatigue on a scale of 1 to 10, with 1 representing no fatigue and 10 representing complete fatigue. The mean for all subjects was 6.5 for both the first and second days. After the period of rest, however, the mean perceived level of fatigue was only 5.3 indicating, by observation of the means, that, as a group, subjects were less fatigued at the end of the third day of testing than after either of the first two. Because of the high standard deviations, the level of significance when comparing perceived level of fatigue across days ($p = .057$) was just slightly higher than the set level of significance ($p = .05$) causing this comparison to be not statistically significant. At the end of each day, subjects were asked to estimate at what point they began to experience fatigue during the 30 trials. The mean for the first day was 8.7 minutes. Perceived fatigue set in more quickly, at a mean time of 4.6 minutes for the group on the second day. The time of perceived beginning of fatigue of 7.6 minutes for the third day shows by observation of the means an improvement of endurance compared to the second day and is close to the endurance level indicated for the first day. For perceived beginning of fatigue, the statistical level of significance ($p = .20$) was too high to make this comparison statistically significant. After each day subjects were also asked to evaluate their perceived depreciation of tone quality during the 30 trials on a scale of 1 to 10, with 1 representing no depreciation in tone quality and 10 representing their worst possible sound. The mean for the first day was 6.3, and there was a similar mean of 6.5 for the second day. The mean for level of perceived depreciation of tone of 4.8 for the third day indicates by observation of the means that the subjects as a group perceived less tone quality depreciation during the third day than during the first two days. Although the comparison of the variable of perceived depreciation of tone across days was not statistically significant, the level of statistical significance for perceived depreciation of tone ($p = .06$) was very close to set level of significance ($p = .05$). Although statistical significance was not achieved in the subject reported variables of perceived fatigue level, perceived beginning of fatigue and perceived depreciation of tone compared across the three days, observation of the means indicates that endurance was improved after two days of rest. Statistical significance could be, perhaps, improved with a larger pool of subjects.

The declines in integrated EMG, amplitude, and frequency data for the three days follow a similar pattern as the subject-reported data (see *Figure 12*). Although statistical significance is not present, observation of the means supports the conclusion that endurance was improved after the rest period.

IV. SUMMARY

In the introduction four questions were posed. The answers to these questions are based on the EMG data collected, researcher observations of the live and recorded musical performances, and information provided by the subjects.

When did fatigue occur in each day? Due to the linear declines of IEMG and amplitude values, this data indicates that fatigue was a steady process from beginning to end of each day. The information provided by the subjects, however, indicates that they began to experience fatigue at different times during each day of testing. For the first day of testing, the mean time for perceived beginning of fatigue was 8.7 minutes. Perceived fatigue set in more quickly with a mean time of 4.6 minutes on the second day. On the third day, after the rest period, there was an improvement in endurance compared with the second day with perceived fatigue beginning at a mean time of 7.6 minutes on the third day. Because of the small number of subjects and the relatively high standard deviations for this data, the alpha level for statistical significance ($p = 0.05$) was not met.

Were subjects more fatigued after second day of testing? Observation of the mean values indicates that the subject-reported level of fatigue was the same for both the first and second day. Observation of mean values also indicates there were greater declines on the second day in IEMG values and amplitude than on the first day. Although statistical significance was not met, there is some evidence that subjects were more fatigued after the second day than after the first.

Did the period of rest improve endurance? Observation of mean values for perceived beginning of fatigue, perceived level of fatigue, percent decline in IEMG, and percent decline in voltage all indicate that there was some improvement in endurance after the rest period. Although statistical significance was not met with these variables, the consistent trend does connect improved endurance to the rest period.

Was there a discernable difference in tone quality associated with fatigue? Observation of mean values for perceived depreciation of tone quality indicate that the subjects believed that their tone suffered the most on the second day and depreciated the least on the third day which was after the rest period. Tone quality inhibiting factors such as air leaks and non-notated pauses in the performance tended to be most frequent on the second day and least frequent on the third day

Protocol for Developing an Endurance Building Program

The established sport-science practices of periodization and tapering with the principles of training can be used to design a program to improve endurance systematically. Because each individual responds to training in a unique manner, each program should be custom designed to fit the needs and physical responses to training of the individual. An effective program should include: cycles, varied practice sessions, control of intensity, control of practice time, tapering, rest, and consistency. Cycles involve gradually increasing practice intensity to produce a reasonable overload effect and maintaining a reasonable amount of practice time. Practice sessions can be varied by time, intensity, literature, and performance focus.

Varying practice sessions will help to avoid the staleness which can lead to psychological fatigue. Intensity of practice sessions can be controlled through the use of non-performance related activities such as mental practice, score-study, and the evaluation of recordings. A low intensity practice session might include 30% actual playing time and 70% non-performance activities, and a moderate intensity practice session could include 60% actual playing time and 40% non-performance activities. A high intensity session would, perhaps, include up to 90% actual playing time and 10% non-performance activities. The control of practice time is often not easily obtained due to lifestyle issues and work-related demands. Michael Kellmann suggested that athletes limit training time to no more than three hours a day.[163] This limitation of training time could also be a reasonable maximum for the clarinetist. The amount of practice time should, however, be adjusted according to the intensity level. As the intensity of practice increases, the amount of time spent practicing should decrease. The weekly increase of either time or intensity should be approximately 10% to achieve an effective overload effect. To prevent overtraining, these weekly increases should not exceed 30%. During the two or three weeks before an important performance such as a solo recital, practice time and intensity should be tapered to allow for the body to make a recovery adaptation. This will allow for optimum endurance at the important performance. Rest days should also be included as a regular feature of an effective program. Rest days allow the body to recover from overload, adapt and reduce the risk of overuse injuries. Because the effects of

[163] Michael Kellmann. "Underrecovery and Overtraining: Different Concepts-Similar Impact?" *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/2SEPT03; Internet; accessed 29 June 2004.

any training are reversible after the training ceases, consistency must be continued to achieve and maintain the desired adaptation.

V. FUTURE RESEARCH

The conclusions of this study, supported by well-established sport-science training practices, indicate that rest days are necessary for an effective endurance building training regimen. The optimal amount of rest or frequency of rest periods for effective endurance building in clarinetists has not been established by this study. Further study involving different rest periods is necessary to establish such a protocol.

EMG feedback could be used as a valuable tool in clarinet pedagogy especially in the areas of reed selection, embouchure control during staccato-style playing and relaxation during breaths.

In his article, "Hard or Soft Clarinet Reeds," James Collis addressed the issue of reed selection. This is a complicated issue because of the variables involved, such as mouthpiece design and the strength of the individual's embouchure. With regard to embouchure Collis stated:

> If lip pressure is very heavy, a very strong reed must be used to counterbalance it; if lip pressure is light, only a soft reed is needed. One player will pick up an instrument and jam the reed closed against the mouthpiece, or perhaps play flat on the upper tones; another player will pick up the same instrument and play it easily and skip up lightly to the highest *C*. The difference is in the embouchure.[164]

EMG feedback could be used in aiding clarinetists in selection of reed strength. If a clarinetist exhibited a relatively high level of embouchure muscle activity, that player would be a candidate for harder reeds. Conversely, if a clarinetist exhibited low embouchure muscle activity, a softer reed would possibly be a better choice.

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[164] James Collis. "Hard or Soft Clarinet Reeds," *The Instrumentalist* 20 (December 1965): 70.

Heuser and McNitt-Gray found that electromyography is a useful tool in trumpet instruction because it "has the potential to provide empirical evidence validating relationships between pedagogical information and improvements in performance-related motor skills."[165] This same approach could be taken with clarinet instruction. The proper performance of notes articulated in staccato-style, notes separated with a very brief silence, is a point of concern. With regard to articulating a single note, John Davies and Paul Harris instructed clarinetists to "form your embouchure before articulation and not actually at the moment of articulation" and to "not allow the embouchure to relax in any way until after ending a note."[166] When a clarinetist plays a series of staccato-style (separated) notes, the pause between the notes is so brief that it is impractical to allow the embouchure to relax and still maintain the highest quality of sound. The embouchure must remain formed because the brief pause does not allow for a relaxation followed by another preparation. Because the embouchure must form an air tight seal around the mouthpiece, Daniel Bonade implied that the formation of the embouchure remains intact throughout a staccato passage when he reminded clarinetists "that the wind pressure never relaxes" when playing staccato style.[167] Some clarinetists, however, have difficulty producing a proper staccato style when they allow the embouchure to relax between the production of individual notes. The effect created is often a

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[165] Frank Heuser and Jill L. McNitt-Gray. "Enhancing and Validating Pedagogical Practice: The Use of Electromyography during Trumpet Instruction," *Medical Problems of Performing Artists* 13 (December 1998): 155.

[166] John Davies and Paul Harris, *Essential Clarinet Technique: Tone, Intonation, Articulation, Finger Technique* (London: Faber Music Limited, 1985), 37.

[167] Daniel Bonade *The Clarinetist's Compendium: Including Method of Staccato and Art of Adjusting Reeds* (Kenosha, Wisconsin: Leblanc Publications, Incorporated, 1962), 9.

distorted or less clear sound due to the reforming of the embouchure at the moment of articulation. *Figure 13* shows the EMG of a test subject performing a staccato excerpt with poor technique.

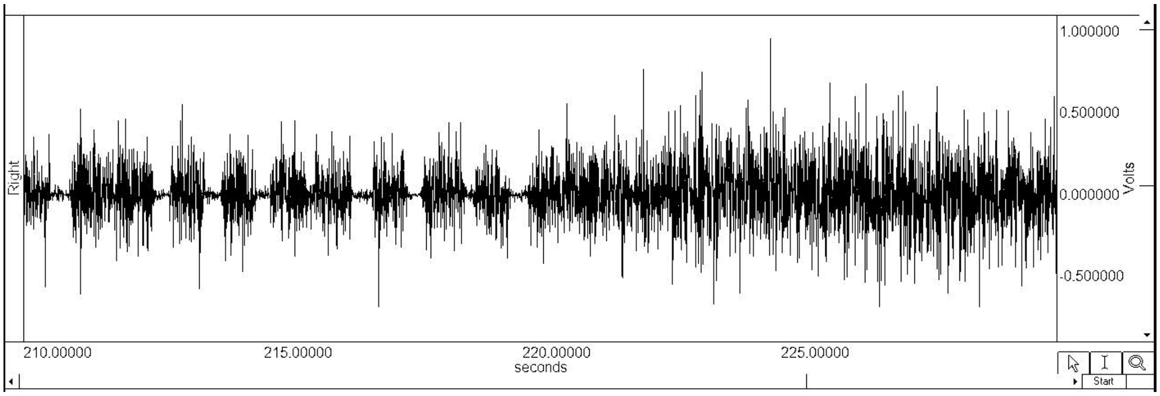

Figure 13: EMG activity of an improper staccato performance.

In the interval between 210 seconds and 220 seconds the subject allowed his embouchure to relax for a brief time between notes. The diminished EMG activity is clearly visible at regular periods during this interval. The following interval, from 220 seconds to 230 seconds, shows a more typical pattern of EMG activity which would be appropriate for sustained or staccato-style playing. Allowing a clarinetist, such as the one in this example, to view the real-time EMG while playing could be a useful pedagogical tool in identifying the inappropriate technique and correcting it.

Never allowing the embouchure to relax can also be a problem. If the clarinetist continuously maintains embouchure formation, fatigue is likely to set in more quickly than if the clarinetist allows the embouchure to relax momentarily during a breath. *Figure 14* shows a typical relaxation (reduced muscle activity) during a breath at about 275 seconds.

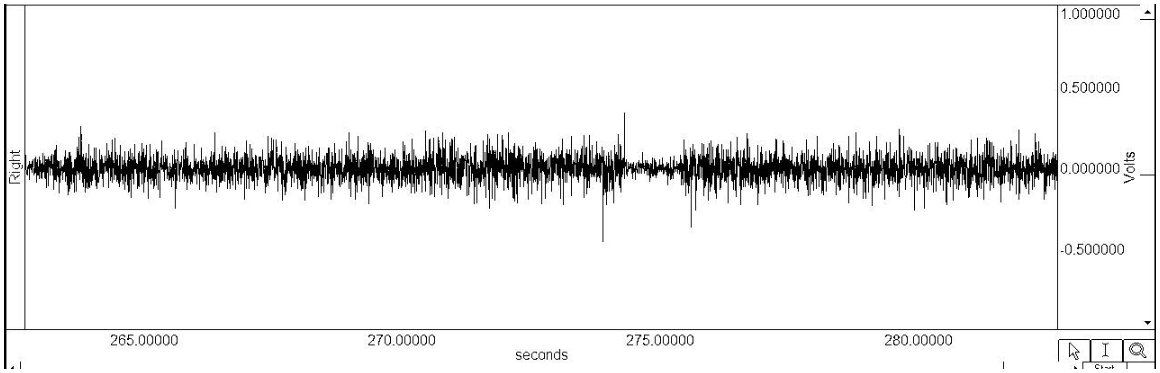

Figure 14: Breath taken at 275 seconds.

Figure 15 shows continuous muscle activity with no relaxation of the embouchure even though the subject took a breath at about 135 seconds.

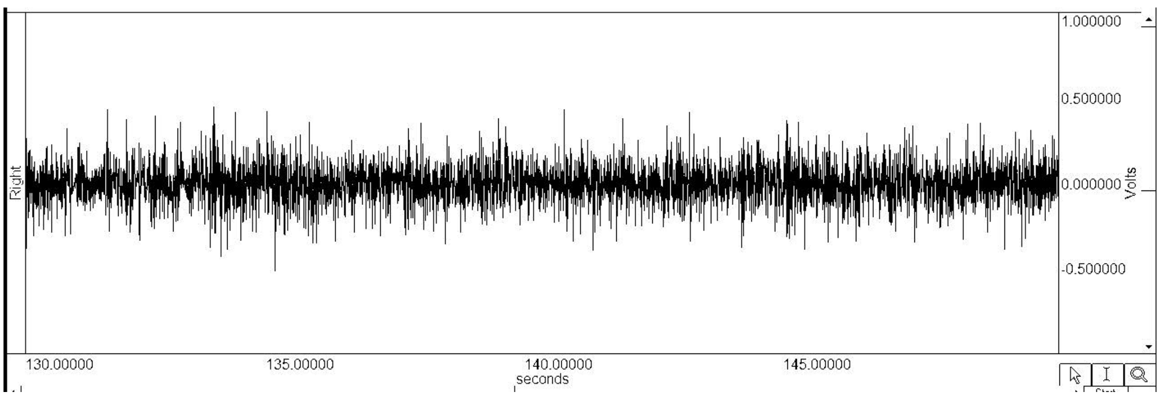

Figure 15: No breath visible.

This pattern of continuously maintaining embouchure formation could be detrimental to endurance. Real-time EMG feed-back could be used to help a clarinetist identify and correct this problem.

EMG feedback could also be pedagogically useful in correcting other difficulties such as proper embouchure adjustments for pitch correction, for tone consistency during dynamic extremes, and for eliminating extraneous jaw movement during articulation.

EMG studies could also offer valuable insight into other areas of clarinet performance not addressed by this study. The breathing apparatus, the right arm and hand which support the clarinet, and the fingers could all be studied using EMG. Such studies would be significant in advancing pedagogical approaches to improving efficiency.

BIBLIOGRAPHY

Journal Articles

Ackermann, Bronwen, Roger Adams, and Elfreda Marshall. "Strength or Endurance Training for Undergraduate Music Majors at a University?" *Medical Problems of Performing Artists* 17, no.1 (March 2002): 33-41.

Allen, Steven W. "Embouchure and Tone Production." *The Instrumentalist* 28, no. 6 (January 1974): 51-54.

Baldwin, David. "Clinic: The Seven Secrets of Endurance." *ITG Journal* 21, no. 2 (December 1996): 58.

Bengston, Keith, Ann H. Schutt, Ronald G. Swee, and Thomas H. Berquist. "Musician's Overuse Syndrome: A Pilot Study of Magnetic Resonance Imaging." *Medical Problems of Performing Artists* 8, no. 3 (September 1993): 77.

Basmajian, J. V and W. J. Newton. "Feedback Training of Parts of Buccinator Muscle in Man." *Psychophysiology* 11, no. 1 (January 1974): 92.

Basmajian, J. V. and E. R. White. "Neuromuscular Control of Trumpeters' Lip [*sic*]." *Nature* 241 (5 January 1973): 70.

Belfrage, Bengt. "Damage Due to Overstrain in Brass Players." *The Horn Call* 23, no. 2 (April 1992): 21-24.

Berque, Patrice and Heather Gray. "The Influence of Neck-Shoulder Pain on Trapezius Muscle Activity Among Professional Violin and Viola Players: An Electromyographic Study." *Medical Problems of Performing Artists* 17, no. 2 (June 2002): 68-75.

Betz, Susan. "Are You a Victim of TMJ Dysfunction?" *The Clarinet* 16, no. 2 (February/March 1989): 44-47.

Bloch, Kalman "Clarinet Intonation." *The Instrumentalist* 46, no 4 (November 1991): 42-48.

Bonetti, Ruth. "Chin Up." *Music Teacher* 80 (July 2001): 24-25.

________. Embouchure Repairs: A Saga of Crumpled Chins, Collapsed Jaws and Buckled Lips." *The Clarinet* 29, no. 2 (March 2002): 78-79.

Brandfonbrener, Alice G., Wayne A. Lee, Alexis Engel Levy, Charles E. Levy, and Joel Press. “Electromyographic Analysis of Muscular Activity in the Upper Extremity Generated by Supporting a Violin with and without a Shoulder Rest.” *Medical Problems of Performing Artists* 7, no. 4 (December 1992): 103-09.

Boeykens, Walter. “Playing the Clarinet with Finesse.” *The Instrumentalist* 42, no. 4 (November 1987): 22-30.

Brown, D. M., F. Nahai, S. Wolf, and J. V. Basmajian. “Electromyographic Biofeedback in the Reeducation of Facial Palsy.” *American Journal of Physical Medicine* 57, no. 4 (August 1978): 183-90.

Cacioppo, J. T., R. E. Petty, M. E. Losch, and H. S. Kim. “Electromyographic Activity Over Facial Muscle Regions Can Differentiate the Balance and Intensity of Affective Reactions.” *Journal of Personality and Social Psychology* 50, no. 2 (February 1986): 260-68.

Cacioppo, J. T., R. E. Petty, and B. Marshall-Goodell. “Electromyographic Specificity during Simple Physical and Attitudinal Tasks: Location and Topographical Features of Integrated EMG Responses.” *Biological Psychology* 18, no. 2 (March 1984): 85-121.

Calder, Angela. “Recovery Strategies for Sports Performance.” *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/3Sept03; Internet; accessed 29 June 2004.

Cherry, Paul Wyman. “Helpful Hints for the High Register.” *The Instrumentalist* 39, no. 6 (January 1985): 70-71.

________. “Ten Seconds to a Terrific Tone.” *The Instrumentalist* 44, no. 1 (August 1989): 58-60.

Collis, J. “Hard or Soft Clarinet Reeds.” *The Instrumentalist* 20, no 5 (December 1965): 69-70.

________. “On Clarinet Embouchures.” *The Instrumentalist* 23, no. 10 (May 1969): 58-59.

Combs, Larry. “How to Practice Effectively.” *The Instrumentalist* 39, no. 8 (March 1985): 28-30.

Combs, Larry and Victor A. Bardo. “Basics for Beginning Clarinetists.” *The Instrumentalist* 52, no. 1 (August 1997): 34.

Davies, Janet and Sandra Magion. “Predictors of Pain and Other Musculoskeletal Symptoms Among Professional Instrumental Musicians: Elucidating Specific Effects.” *Medical Problems of Performing Artists* 17, no. 4 (December 2002): 155-168.

De Villiers, Stefanus. N. “Three Control Parameters in Clarinet Tone Production.” *The Clarinet* 25, no. 3 (May/June 1998): 48-51.

Deaton, James W. “Tips for Upper Register Clarinet Playing.” *The Instrumentalist* 27, no. 6 (January 1973): 46-47.

Etheridge, David. “A Guide for Starting Beginners on the Clarinet.” *The Instrumentalist* 35, no. 10 (May 1981): 44-47.

Elving, B. Dedering and G. A. Nemeth. “Lumbar Muscle Fatigue and Recovery in Patients with Long-Term Low-Back Trouble: Electromyography and Health-Related Factors.” *Clinical Biomechanics* 18, no. 7 (August 2003): 619-630.

Fahn, Stanley, John Welsh, Steven J. Frucht, Paul E. Green, Christopher O’Brien, Michael Gelb, Daniel D. Truong, Stewart Factor, and Blair Ford. “The Natural History of Embouchure Dystonia.” *Movement Disorders* 16, no. 5 (2001): 899-906.

Fishbein, Martin and Susan E. Middlestadt. “The Prevalence of Severe Musculoskeletal Problems Among Male and Female Symphony Orchestra Players.” *Medical Problems of Performing Artists* 4, no. 1 (March 1989): 41-48.

Fishbein, Martin, Susan E. Middlestadt, Victor Ottati, Susan Straus and A. Ellis. “Medical Problems Among ICSOM Musicians: Overview of a National Survey.” *Medical Problems of Performing Artists* 3, no. 1 (March 1988): 1-8.

Foss, Ardeen and George Waln. “Teaching Techniques Used for the Clarinet.” *The Instrumentalist* 8, no. 1 (September 1953) 30-31.

Freymuth, Malva. “From the Performer’s Viewpoint: Mental Practice for Musicians: Theory and Application.” *Medical Problems of Performing Artists* 8, no. 4 (December 1993): 141.

Fridlund, A. J. and J. T. Cacioppo. “Guidelines for Human Electromyographic Research.” *Psychophysiology* 23, no. 5 (September 1986): 567-89.

Fuhrimann, Susanne, Andres Schüpbach, Urs Thüer, and Bengt Ingervall. “Natural Lip Function in Wind Instrument Players.” *European Journal of Orthodontics* 9, no. 3 (August 1987): 216-223.

Garity, L. I. “Measurement of Subvocal Speech: Correlations between Two Muscle Leads and between Two Recording Methods.” *Perceptual and Motor Skills* 40, no. 1 (30. February 1975): 327.

Gatehouse, S. and A. W. Kelman. “Comparison of the Electromyographical Activity of the Muscle Orbicularis Oris Using Different Electrode Configurations.” *Folia Phoniatrica* 28, no. 1 (1976): 52-62.

Gerbino, T. “Clarinet Embouchure Control Through Use of the Upper Lip.” *The Clarinet* 1, no. 4 (August 1974): 9-10.

Gibson, Lee. “A Handbook for Clarinetist, Part II: Embouchure and Air Column.” *The Clarinet* 4, no. 2 (Winter 1977): 10-11.

Goldsmith, W. “Recovery-Based Training: By Developing a Training Program Based on an Athlete’s Ability to Recover, Every Training Session Becomes an Opportunity to Maximize Performance Through an Individualized Training Prescription.” *Swimming Technique* 39, no. 4 (January/March 2003): 16-22.

Graulty, John Patick. “Trends in Clarinet Embouchures.” *The Instrumentalist* 44, no. 9 (April 1990): 50-56.

Hawley, C. J. and R. B. Schoene. “Overtraining Syndrome: A Guide to Diagnosis, Treatment, and Prevention.” *Physician and Sportsmedicine* 31, no. 6 (June 2003): 25-31.

Heim, Norman, M. “Clarinet Tone Production.” *The Instrumentalist* 35, no. 4 (November 1980): 50-53.

________. “The Squeak--The Clarinet Player’s Dilemma.” *The Instrumentalist* 29, no. 10 (May 1975): 49-50.

Heuser, Frank and Jill L. McNitt-Gray. “EMG Changes in a Trumpet Player Overcoming Tone Commencement Difficulties: A Case Study.” *Medical Problems of Performing Artists* 9, no. 1 (March 1994): 18-24.

Heuser, Frank and Jill L. McNitt-Gray. “EMG Patterns in Embouchure Muscles of Trumpet Players with Asymmetrical Mouthpiece Placement.” *Medical Problems of Performing Artists* 8, no. 3 (September 1993): 96.

Heuser, Frank and Jill L. McNitt Gray. “EMG Potentials Prior to Tone Commencement in Trumpet Players.” *Medical Problems of Performing Artists* 6, no. 2 (June 1991): 51-56.

Heuser, Frank and Jill L. McNitt-Gray. "Enhancing and Validating Pedagogical Practice: The Use of Electromyography during Trumpet Instruction." *Medical Problems of Performing Artists* 13, no. 4 (December 1998): 155-159.

Holton, Arthur J. "Solving Embouchure Problems." *The Instrumentalist* 43, no. 1 (September 1988): 52-61.

Hooper, Sue L., Laurel T. MacKinnon, and Alf Howard. "Physiological and Psychometric Variables for Monitoring Recovery during Tapering for Major Competition." *Medicine and Science in Sports and Exercise* 31, no. 8 (August 1999): 1205-10.

Hooper, Sue L., Laurel T. MacKinnon, Alf Howard, and D. Gordon. "Markers for Monitoring Overtraining and Recovery." *Medicine and Science in Sports and Exercise* 27, no. 1 (January 1995): 106-112.

Howard, James. A. and Anthony T. Lovrovich. "Wind Instruments: Their Interplay with Orofacial Structures." *Medical Problems of Performing Artists* 4, no. 2 (June 1989): 59-72.

Iltis, Peter W. "Excessive Practicing May Cause Muscle Tremors, Focal Dystonia." *The Instrumentalist* 57, no. 2 (September 2002): 38-40.

Isley, C. L. and J. V. Basmajian. "Electromyography of the Human Cheeks and Lips." *Anatomical Record* 176, no. 2 (June 1973): 143-47.

Jones, Marquis. E. "Dynamics and the Clarinet." *The Instrumentalist* 17, no. 8 (April 1963): 76-78.

Kirchner, Joann Marie. "A Qualitative Inquiry into Musical Performance Anxiety." *Medical Problems of Performing Artists* 18, no. 2 (June 2003): 78-82.

Kelman, A. W. and S. Gatehouse. "A Study of the Electromyographical Activity of the Musculus Orbicularis Oris." *Folia Phonaitrica* 27, no. 5 (1975): 350-63.

Kellmann, Michael. "Underrecovery and Overtraining: Different Concepts-Similar Impact?" *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/2SEPT03; Internet; accessed 29 June 2004.

Low, E. Floyd. "Keep That Pitch Up!" *The Instrumentalist* 4, no. 2 (November/December 1949): 38-41.

Lundin, P. "The Monitoring of Recovery in Endurance Athletes." *National Strength and Conditioning Association Journal* 7, no. 6 (December/January 1986): 41-42.

Ma, H. C. and J. M. Laracuente. “The Influence of Playing Musical Wind Instruments on Oral Tissues.” *General Dentistry* 27, no. 1 (January/February 1979): 46-50.

McDonald, Claudia. “Schumann’s Piano Practice: Technical Mastery and Artistic Ideal.” *Journal of Musicology* 19, no. 4 (Fall 2002): 527-63.

Moreland, Wilbur L. “Taming Clarinet High Notes.” *The Instrumentalist* 43, no. 8 (March 1989): 36-43.

Mortenson, Gary Curtiss. “Endurance in the Jazz Ensemble Trumpet Section: A Sensible Approach.” *Jazz Educators Journal* 17, no. 3 (1985): 61-63.

Murray, J. M. and A. Weber. “The Cooperative Action of Muscle Proteins.” *Scientific American* 230, no. 2 (February 1974): 58-71.

Naill, Richard and Jill L. McNitt-Gray. “Surface EMG as a Method for Observing Activation Patterns Associated with Strategies of String Depression Used by Cellists.” *Medical Problems of Performing Artists* 8, no. 1 (March 1993): 7-13.

Nesmith, David. “What Every Musician Needs to Know About the Body.” *The Horn Call* 29, no. 4 (August 1999): 71-74.

Odrich, Ronald B. “Claridontology.” *The Clarinet* 26, no.2 (March 1999): 32-33.

________. “Claridontology” *The Clarinet* 26, no. 4 (September 1999): 26.

Pearson, Lea. “Body Mapping for Flutists: What Every Flute Teacher Needs to Know About the Body.” *NACWPI Journal* 49 no. 4 (Summer 2001): 14.

Peterson, Kristen. “Athlete Overtraining and Underrecovery: Recognizing the Symptoms and Strategies for Coaches.” *Olympic Coach* 15 Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/5Sept03; Internet; accessed 29 June 2004.

Pelletier, Andrew J. “Embouchure Health and Maintenance.” *The Horn Call* 29, no. 3 (May 1999): 65-66.

Pfitzinger, P. “Your Work/Recovery Ratio: Scheduling Rest Weeks to Let Training Do Its Work.” *Running Times* 303 (January/February 2003): 47.

Pino, David James. “The Clarinet Teaching of Keith Stein, Part Two: The Embouchure.” *The Clarinet* 30, no.1 (December 2002): 82-85.

________. “The Clarinet Teaching of Keith Stein, Part Three: Random, Isolated Thoughts about Embouchure.” *The Clarinet* 30, no 3 (June 2003):36-40.

Plude, Patricia. “Creative Musical Training: Learning From the Inside Out.” *The American Music Teacher* 46, no. 2 (October/November 1996): 12-15.

Pursell, John O. “Pumping Brass: The Application of Athletic Weight Training Principles to Trumpet Embouchure Development.” *ITG Journal* 24, no. 3 (March 2000): 55-61.

Reilly, T. “Recovery from Strenuous Training and Matches.” *Sports Exercise and Injury* 4, no. 4 (November 1998): 156-158.

Ridenour, Thomas. “The Hidden Embouchure: A Monograph on Clarinet Embouchure.” *The Clarinet* 9, no. 4 (Summer 1982): 16-17.

________. “French Embouchure: A Survey” *The Clarinet* 17, no. 4 (July/August 1990): 10-15.

Riewald, Scott. “Strength Training for Young Athletes.” *Olympic Coach* 15, Winter 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/March03-5; Internet; accessed 29 June 2004.

Kellmann, Michael. “Underrecovery and Overtraining: Different Concepts-Similar Impact?” *Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/2SEPT03; Internet; accessed 29 June 2004.

Sanborn, Chase. “Brass: Endurance.” *Canadian Musician* 21 (January/February 1999): 28.

Schuele, Stephan and Richard J. Lederman. “Focal Dystonia in Woodwind Instrumentalists: Long Term Outcome.” *Medical Problems of Performing Artists* 18, no 1 (March 2003): 15-20.

Schultz, Arnold. “The Physiological Mechanics of Piano Teaching.” *The American Music Teacher* 46, no. 1 (August/September 1996): 32-35.

Snavely, Jack. “The Altissimo Clarinet Register.” *The Instrumentalist* 17, no. 6 (February 1963): 59-61.

Spahn, Claudia, Horst Hildebrandt, and Karin Seidenglanz. “Effectiveness of a Prophylactic Course to Prevent Playing-Related Health Problems of Music Students.” *Medical Problems of Performing Artists* 16, no.1 (March 2001): 24-31.

Stein, Keith. “The Stein Corner: Embouchure Discussion.” *The Clarinet* 7, no. 1 (Fall 1979): 27.

________. “The Stein Corner: Embouchure Formation” *The Clarinet* 7, no. 2 (Winter 1980): 24-25.

Stone, Michael. H. and Margaret. E. Stone. “Recovery-Adaptation: Strength and Power Sports.”*Olympic Coach* 15, Summer 2003 [journal on-line]; http://coaching.usolympicteam.com/coaching/kpub.nsf/v/4Sept03; Internet; accessed 29 June 2004.

Swift, John, Jr. “The Double Lip Clarinet Embouchure.” *The Instrumentalist* 33, no. 8 (March 1979): 36-38.

Tassinary, L. G., J. T. Cacioppo, and T. R. Green. “A Psychometric Study of Surface Electrode Placements for Facial Electromyographic Recording: I. The Brow and Cheek Muscle Regions.” *Psychophysiology* 26, no. 1 (January 1989): 1-16.

Taylor, J. “Solving the Problem of Muscle Fatigue.” *Sport-Talk* 12, no. 3 (October 1983): 1-5.

Thomas, Earl M. “Anatomical Essentials in Clarinet Embouchure.” *The Clarinet* 8, no. 2 (Winter 1981): 10-11.

Thomas, Judith. “Myofunctional Disabilities and the Flute.” *The Flutist Quarterly* 25, no. 3 (Spring 2000): 50-56.

Turner, J. and M. Byrne. “Proper Recovery – Ways to Avoid Fatigue and Overtraining.” *Performance Conditioning Soccer* 9, no. 5 (2003): 1-2.

Van Boxtel, A. “Optimal Signal Bandwidth for the Recording of Surface EMG Activity of Facial, Jaw, Oral and Neck Muscles.” *Psychophysiology* 38, no. 1 (January 2001): 22-34.

Van Boxtel, P. Goudswaard, G. M. Van Der Molen, and W. E. Bosch. “Changes in Electromyogram Power Spectra of Facial and Jaw-Elevator Muscles during Fatigue.” *Journal of Applied Physiology: Respiratory, Environmental and Exercise Physiology* 54, no. 1 (January 1983): 51-58.

Van Boxtel, A. and L. R. Schomaker. “Motor Unit Firing Rate during Static Contraction Indicated by the Surface EMG Power Spectrum.” *IEEE Transactions on Biomedical Engineering* 30, no. 9 (September 1983): 601-09.

Vax, Mike. “Endurance - - The Key to Better Playing” *Crescendo International* 18 (October 1979): 34.

Vitti, M. and J. V. Basmajian. “Integrated Actions of Masticatory Muscles: Simultaneous EMG from Eight Intramuscular Electrodes.” *Anatomical Record* 187, no. 2 (February 1977): 173-89.

Waln, George. “Clarinet Teaching Tips for Better Fundamentals.” *The Instrumentalist* 11, no. 1 (September 1956): 36-41.

________. “A Teacher’s Guide for Building Clarinet Fundamentals.” *The Instrumentalist* 15, no. 2 (October, 1960): 82-84.

________. “A Weak Fundamental in Clarinet Playing.” *The Instrumentalist* 26, no. 3 (October, 1971): 49-50.

Waterink, W. and A. Van Boxtel. “Facial and Jaw-Elevator EMG Activity in Relation to Changes in Performance Level during a Sustained Information Processing Task.” *Biological Psychology* 38, no. 3 (July 1994): 183-98.

Webster, Michael Fanning. “Teaching Clarinet: Gaining Speed (A New Kind of Interval Training.)” *The Clarinet* 29, no. 4 (September 2002): 12-16.

White, Elmer R. and John V. Basmajian. “Electromyographic Analysis of Embouchure Muscle Function in Trumpet Playing.” *Journal of Research in Music Education* 22 no. 4 (Winter 1974): 292-304.

________. “Electromyography of Lip Muscles and Their Role in Trumpet Playing.” *Journal of Applied Physiology* 35, no. 6 (December 1973): 892-97.

Wilson, Heston L. “The Embouchure.” *The Clarinet* 22, no. 2 (February/March 1995): 54-55.

________. “Lips.” *The Clarinet* 27, no. 4 (September 2000): 38-39.

Books

Barrett, Richard H. *Oral Myofunctional Disorders*, 2d ed. Saint Louis: Mosby, 1978.

Basmajian, John V. and Carlo J. De Luca. *Muscles Alive: Their Functions Revealed by Electromyography*, 5th ed. Baltimore: Williams and Wilkins, 1985.

Battinelli, Thomas. *Physique, Fitness, and Performance.* Boca Raton, Florida: CRC Press, 2000.

Berger, Richard A. *Applied Exercise Physiology*. Philadelphia: Lea and Febiger, 1982.

Bradley, Robert M. *Essentials of Oral Physiology*. St. Louis: Mosby, 1995.

Broer, Marion Ruth. *An Introduction to Kinesiology*. Englewood Cliffs, New Jersey: Prentice-Hall, 1968.

Brown, Joseph F. *Dictionary of Speech and Hearing Anatomy and Physiology*. n.p.: 1975.

Brymer, Jack. *Clarinet*. New York: Schirmer Books, 1977.

Burba, Malte. *Brass Master-Class: Method for Brass Players: The Logical Way to Attain Unlimited Control, Endurance and Range,* Mainz: Schott, 1997.

Camaione, David N. *Fitness Management*. Dubuque, Iowa: Brown and Benchmark, 1993.

Carlson, Francis D. *Muscle Physiology*. Englewood Cliffs, New Jersey: Prentice-Hall, 1974.

Clark, Henry Harrison. *Muscular Strength and Endurance in Man*. Englewood Cliffs, New Jersey: Prentice Hall, 1966.

Cureton, Thomas Kirk. *The Physiological Effects of Exercise Programs on Adults*. Springfield, Illinois: Thomas, 1969.

Davies, John and Paul Harris. *Essential Clarinet Technique: Tone · Intonation Articulation · Finger Technique*. London: Faber Music Limited, 1985.

DeVries, Herbert A. *Physiology of Exercise for Physical Education and Athletics*, 4th ed. Dubuque, Iowa: W. C. Brown Company, 1986.

Donnelly, Joseph E. *Living Anatomy*, 2d ed. Champaign, Illinois: Human Kinetics Books, 1990.

Ernst, Jokl. *Physiology of Exercise*. Springfield, Illinois: Thomas, 1964.

Freymuth, Malva. *Mental Practice and Imagery for Musicians: A Practical Guide for Optimizing Practice Time, Enhancing Performance and Preventing Injury*. Boulder, Colorado: Integrated Musician's Press, 1999.

Fridlund, Alan J. *Human Facial Expression: An Evolutionary View*. San Diego: Academic Press, 1994.

Gilbert, Linda M. *The Practice Handbook: A Musician's Guide to Positive Results in the Practice Room*. Redondo Beach, California: Damore Publications, 1993.

Green, Barry with W. Timothy Gallwey. *The Inner Game of Music*. New York: Doubleday, 1986.

Guy, Larry. *Embouchure Building for Clarinetists*, 2d ed. Sony Point, New York: Rivernote Press, 2000.

Herzog, Walter, ed. *Skeletal Muscle Mechanics: from Mechanisms to Function*. Chinchester, New York: John Wiley and Sons, 2000.

Hinson, Marilyn M. *Kinesiology,* 2d ed. Dubuque, Iowa: Wm. C. Brown Publishers, 1981.

Housh, Terry J., Dona J. Housh, and Herbert A. deVries. *Applied Exercise and Sport Physiology*. Scottsdale, Arizona: Holcomb Hathaway, 2003.

Horvath, Steven M. and Elizabeth C. Horvath. *The Harvard Fatigue Laboratory: Its History and Contribution*. Englewood Cliffs, New Jersey: Prentice-Hall, 1973.

Jensen, Clayne R. *Applied Kinesiology: The Scientific Study of Human Performance*. New York: McGraw-Hill, 1970.

Johnson, Arthur T. *Biomechanics and Exercise Physiology*. New York: J. Wiley and Sons, 1991.

Kaplan, Andrew, S. and Gray Williams. *TheTMJ Book.* New York: Pharos Books, 1988.

Kellmann, M., ed. *Enhancing Recovery: Preventing Underperformance in Athletes*. Champaign, Illinois: Human Kinetics, 2002.

Kaplan, Harold Morris. *Anatomy and Physiology of Speech,* 2d ed. New York: McGraw-Hill, 1971.

Lenman, J. A. R. and Anthony Elliot Ritchie. *Clinical Electromyography,* 4th ed. Edinburgh, New York: Churchill Livingstone, 1987.

Loeb, Gerald E. and Carl Gans. *Electromyography for Experimentalist*. Chicago: University of Chicago Press, 1986.

Lockhart, Robert Douglas. *Living Anatomy: A Photographic Atlas of Muscles in Action and Surface Contours*. London: Faber and Faber, 1963.

Marieb, Elaine. *Human Anatomy & Physiology,* 5th ed. San Francisco: Benjamin Cummings an Imprint of Addison Wesley Longman, Incorporated, 2001.

Matthews, Donald K. *Physiology of Muscular Activity and Exercise*. New York: Ronald Press Company, 1964.

Maughan, Ron J., Michael Gleeson, and Paul L. Greenhaff. *Biochemistry of Exercise and Training*. New York: Oxford University Press, 1997.

McArdle, William D., Frank I. Katch, and Victor L. Katch. *Exercise Physiology: Energy, Nutrition, and Human Performance*, 4th ed. Baltimore: Williams and Wilkins, 1996.

Moore, E. C. *The Clarinet and its Daily Routine*. Kenosha, Wisconsin: Leblanc Publications, 1962.

Morehouse, Laurence Englemohr and Augustus T. Miller, Jr. *Physiology of Exercise,* 6th ed. Saint Louis, Missouri: C. V. Mosby Company, 1971.

Nigg, Benno Maurus. *Biomechanics of the Musculo-Skeletal System,* 2d ed. Chichester, New York: Wiley, 1999.

Norris, Richard. *The Musician's Survival Manual: A Guide to Preventing and Treating Injuries in Instrumentalists*. St. Louis, Missouri: MMB Music, 1993.

Pino, David. *The Clarinet and Clarinet Playing*. New York: Charles Scribner's Sons, 1983. Reprint, Mineola, New York: Dover Publications, Incorporated, 1998.

Ridenour, Thomas. *The Educator's Guide to the Clarinet: A Complete Guide to Teaching and Learning the Clarinet*. Denton, Texas: Thomas Ridenour, 2000.

Sataloff, Robert Thayer, Alice G. Brandfonbrener, and Richard J. Lederman, eds. *Performing Arts Medicine*, 2d ed. San Diego, California: Singular Publishing Group, Inc., 1998.

Saxon, Keith G. and Carole M. Schneider. *Vocal Exercise Physiology*. San Diego, California: Singular Publishing Group, Incorperated, 1995.

Schlossberg, Max. *Daily Drills and Technical Studies for Trumpet*. New York: M. Baron Company, 1941.

Schneck, Daniel J. *Mechanics of Muscle*, 2d ed. New York: New York University Press, 1992.

Shearer. William M. *Illustrated Speech Anatomy*, 2d ed. Springfield, Illinois: C. C. Thomas, 1968.

Shephard, Roy J. *Alive Man! The Physiology of Physical Activity*. Springfield, Illinois: Thomas, 1972.

________. *Endurance Fitness*, 2d ed. Toronto: University of Toronto Press, 1977.

________. *Exercise Physiology*. Philadelphia: B. C. Decker, 1987.

________. *Physiology and Biochemistry of Exercise*. New York: Prager, 1982.

Sherman, Roger. *The Trumpeter's Handbook: A Comprehensive Guide to Playing and Teaching the Trumpet*. Athens, Ohio: Accura Music, 1979.

Snitkin, Harvey R. *Practicing for Young Musicians: You are Your Own Teacher*, Revised and expanded edition. Niantic, Connecticut: HMS Publications, 1997.

Snyder, Conrad Wesley Jr. and Bruce Abernethy, eds. *The Creative Side of Experimentation: Personal Perspectives from Leading Researchers in Motor Control, Motor Development, and Sport Psychology*. Champaign, Illinois: Human Kinetics Publishers, 1992.

Spaulding, Roger W. *Double High C in 37 Weeks*. Hollywood, California: High Note Studios, Inc., 1963.

Stallman, Robert. *Flute Workout: 14 Melodic Exercises for Technical Mastery*. New York: International Music Company, 1995.

Stauffer, Donald W. *Mind, Muscle and Motion: Studies of Instrumental Performing and Conducting*. Birmingham, Alabama: Stauffer Press, 1988.

Stein, Keith. *The Art of Clarinet Playing*. Princeton, New Jersey: Summy-Birchard, 1958.

Stegemann, Jürgen. *Exercise Physiology: Physiologic Bases of Work and Sport*. Translated by James S. Skinner. Chicago: Year Book Medical Publishers, 1981.

Stiévenard, Émile. *Practical Study of the Scales for the Clarinet*. Milwaukee, Wisconsin: G. Schirmer, 1922.

Teal, Larry. *The Art of Saxophone Playing*. Secaucus, New Jersey: Summy-Bichard, 1963.

Tipton, Charles M., ed. *Exercise Physiology: People and Ideas.* New York: Oxford University Press, 2003.

Unger, Renate. *Die Querflöte: Ein Lehr-und Übungsbuch 1* [*The Flute: A Tutor and Study Book 1*.] Wisbaden: Breitkopf and Härtel, 1988.

Van Cleave, Mark. *Maximizing Practice* Bloomington, Indiana: D'note, 1993.

Whipp, B. J. and A. J. Sargeant, eds. *Physiological Determinants of Exercise Tolerance in Humans*. Princeton, New Jersey: Princeton University Press, 1999.

Westcott, Wayne L. *Strength Fitness: Physiological Principles and Training Techniques*, 2d expended ed. Boston: Allyn and Bacon, 1987.

Whitfield, Philip. *The Human Body Explained: A Guide to Understanding the Incredible Living Machine*. New York: H. Holt, 1995.

Wilmore, Jack H. and David L. Costill. *Physiology of Sport and Exercise*. Champaign, Illinois: Human Kinetics, 1994.

Wye, Trevor. *Trevor Wye Practice Books for the Flute*, Omnibus ed. London: Novello, 1999.

Congress Reports

An, Kai-Nan, B. M. Hillberry, Jaiyoung Ryu, and Fadi J. Bejjani. "Upper Extremity Biomechanics in Musicians." In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine*, edited by Fadi J. Bejjani, 139-146. Pennington, New Jersey: A cappella Books, 1993.

Anand, L. and H. Stoboy, eds. *Advances in Exercise Physiology: Symposium Held in Conjunction with the 26th International Congress of Physiological Sciences, New Delhi, October 1974*. New York: Karger, 1976.

Balser, Dietrich. "Role of the Larynx in Instrumental Music Performance" In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine,* edited by Fadi J. Bejjani, 163-66. Pennington, New Jersey: A cappella Books, 1993.

Bejjani, Faddi J. and Michelle Chin. "Effect of Strap Design on Back Muscle Activity in Guitarists." In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine*, edited by Fadi J. Bejjani, 173-75. Pennington, New Jersey: A cappella Books, 1993.

Bouchard, Claude, ed. *Physical Activity, Fitness, and Health: International Proceedings and Consensus Statement of the International Conference on Physical Activity, Fitness, and Health, Held in Toronto in May 1992*. Champaign, Illinois: Human Kinetics Publishers, 1994.

Dai, Kerong, Chris J. Snijders, and Hideo Yano. "Quantative Analysis of the Motion and Balance Function of Artists." In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine*, edited by Fadi J. Bejjani, 147-149. Pennington, New Jersey: A cappella Books, 1993.

Dawson, William J. "Hand and Upper Extremity Injuries in Instrumentalists: Epidemiology and Outcome." In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine,* edited by Fadi J. Bejjani, 311-14. Pennington, New Jersey: A cappella Books, 1993.

Komi, Paavo V., ed. *Proceedings of the International Symposium on Sport Biology Held at the Finnish Sports Institute, Vierumaki, Finland in October, 1979*. Champaign, Illinois: Human Kinetics Publishers, 1982.

Steinacker, Jürgen M. and Susan Ward, eds. *The Physiology and Pathophysiology of Exercise Tolerance: Proceedings of the International Symposium on the Physiology and Pathophysiology of Exercise Held September 21-24 in Ulm, Germany*. New York: Plenum Press, 1996.

Tamanaga, Dwight M. and Julie A Plezbert. "Preventive Home Conditioning for Muscians." In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine*, edited by Fadi J. Bejjani, 353-56. Pennington, New Jersey: A cappella Books, 1993.

van Eijsden-Besseling, M. D. F. and E. Terpstra-Lindeman. "What Can Happen to Muscians?" In *Current Research in Arts Medicine: A Compendium of the MedArt International 1992 World Congress on Arts Medicine*, edited by Fadi J. Bejjani, 343-45. Pennington, New Jersey: A cappella Books, 1993.

Dissertations

Broida, J. M. *Time for Recovery from Successive Bouts of Exercise as Measured by Changes in the Anaerobic Threshold: A Comparison of Recovery Intervals of 24 and 48 Hours*. Ed. d. thesis. University of Northern Colorado, 1979; Eugene, Oregon, Microform Publications, International Institute for Sport and Human Performance, 1981.

Campbell, Bonnie Heather. *An Exploratory Study of the Functioning of Selected Masticatory Muscles during Clarinet Playing as Observed Through Electromyography.* D. M. diss. Indiana University, 1999; Ann Arbor, Michigan, University Microfilms, 2000.

Engelhart, Robert James. *An Electromyographic Study of Preparatory Set in Singing as Influencd by the Alexander Technique*. Ph.D. diss. Ohio State University, 1989.

Felix, S. D. *Swimming Performance Following Different Recovery Protocols.* M.S. thesis. Springfield College, 1996; Eugene, Oregon, Microform Publications, International Institute for Sport and Human Performance, 1997.

Garrison, Thomas Edwin. *The Effect of Electromyographic Biofeedback Training on Singers with Tension Problems in the Laryngeal Musculature*. D. A. diss. Ball State University, 1978; Ann Arbor Michigan, University Microfilms, 1978.

Gossett, Claude Washington, Jr. *A Spectrographic and Electromyographic Investigation of the Relationship of the Effects of Selected Parameters upon Concurrent Study of Voice and Oboe.* Ph.D. diss. University of Southern Mississippi, 1977; Ann Arbor, Michigan, University Microfilms, 1977.

Graulty, John Patrick. *The Status of Double-Lip Clarinet Embouchure in Present-Day Pedagogy and Performance: A Study of College Clarinet Instructors and Symphony Orchestra Clarinetists.* Ed.D. diss. Columbia University Teacher's College, 1989; Ann Arbor, Michigan, University Microfilms, 1994.

Hendrickson, W. R. *The Effects of Recovery Time on Throwing Velocity and Accuracy of College Baseball Pitchers*. M.S. thesis. Salt Lake City, Utah, Brigham Young University, 1993; Eugene, Oregon, Microform Publications, International Institute for Sport and Human Performance, 1995.

Heuser, Frank. *Embouchure Muscle Activity Prior to Tone Commencement in Trumpet Players.* D.M.A. diss. University of Southern California, 1991; Los Angeles, California, University of Southern California, University Library Micrographics and Reprographics, 1992.

Johnson, Todd Alan. *An Electromyographic Examination of Wrist Motion While Executing Selected Drumstick Techniques with Matched Grip*. D.M.A. diss. The University of Oklahoma, 1999.

Knasko, Susan Carolyn. *Music's Effect on Running Performance, Pulse Rate and Emotional State (Arousal, Gross Motor Task, Perceived Control, Dominance, Attitude.)* Ph.D. diss. Pennsylvania State University, 1985; Ann Arbor Michigan, University Microfilms, 1989.

Kjelland, James Martin. *The Effects of Electromyographic Biofeedback Training on Violoncello Performance: Tone Quality and Muscle Tension*. Ph.D. diss. The University of Texas at Austin, 1985; Ann Arbor, Michigan, University Microfilms, 1987.

Lewis, Pamela. *The Alexander Technique: Its Relevance for Singers and Teachers of Singing*. D.A. diss. Carnegie-Mellon University, 1980; Ann Arbor, Michigan, University Microfilms, 1982.

Newton, William Jackson. *The Activity of Certain Facial Muscles in the B-Flat Soprano Clarinet Embouchure: An Exploratory Study Utilizing Electromyography*. Ed.D. diss. University of North Texas, 1972; Ann Arbor Michigan, University Microfilms, 1972.

Peterson, Ken Doty. *Electromyographic Investigation of Abdominal Musculature during Measured Active Expiration*. D.A. diss. University of Northern Colorado, 2001.

Post, Nora. *The Development of Contemporary Oboe Technique*. Ph.D. diss. New York University, 1979; Ann Arbor, Michigan, University Microfilms, 1985.

Sieber, Richard Earl. *Contraction-Movement Patterns of Violin Performance*. D.M.E. diss. Indiana University, 1969; Ann Arbor, Michigan, University Microfilms, 1970.

Smith, Ethel Closson. *An Electromyographic Investigation of the Relationship Between Abdominal Muscular Effort and Rate of Vocal Vibrato*. D.M. diss. Indiana University, 1967; Ann Arbor Michigan, University Microfilms, 1969.

Teirila, Marjatta. *Physiology of Wind Instrument Playing and the Implications for Pedagogy*. Ph.D. diss. University of Jyväskylä, 1998.

Weber, Matthew Joseph. *An Investigation of Selected Muscle Potential Activity in Violin/Viola Vibrato*. Ph.D. diss. University of North Texas, 1995; Ann Arbor, Michigan, University Microfilms, 1995.

Consultants

Bemben, Michael, Ph.D. Professor, Health and Sport Sciences, The University of Oklahoma.

Braun, Elie. Application Specialist, BIOPAC Systems, Incorporated.

Green, Joey. Health Care Professional and Personal Trainer, Henslee Therapy Associates, Wichita Falls, Texas.

Hartman, Michael. Graduate Assistant, Health and Sport Sciences, The University of Oklahoma.

Stolt, Genevieve. Graduate Assistant, Health and Sport Sciences, The University of Oklahoma.

Electronic Media

Biopac Systems, Incorporated. Homepage for Biopac Systems, Incorporated. Available at http://biopac.com/. Accessed 7 March 2004.

RSI Clinic. Homepage for the RSI Clinic. Available at http://www.rsiclinic.com/index.html. Accessed 7 March 2004.

Wilson, Frank R. "Current Controversies on the Origin, Diagnosis, and Management of Focal Dystonia in Musicians," in *International Dystonia On-line Support Group Website:* available at http://www.dystonia-support.org/LA-Focal%20Dystonia%20in%20Musicians.htm, Accessed 13 September 2004.

APPENDIX I

Informed Consent Form

INFORMED CONSENT FORM FOR RESEARCH BEING CONDUCTED UNDER THE AUSPICES OF THE UNIVERSITY OF OKLAHOMA-NORMAN CAMPUS

INTRODUCTION: This study is entitled: "Fatigue and Recovery Patterns in the Mouth Muscles Used to Play the Clarinet." The persons directing this project are David Belcher – DMA Candidate and Dr. David Etheridge – Professor of Clarinet, The University of Oklahoma. This document defines the terms and conditions for consenting to participate in this study.

DESCRIPTION OF THE STUDY: This study involves the measurement of muscle activity in the mouth muscles used while playing the clarinet and the fatigue and recovery of those muscles. Muscle activity will be measured through the use of small, surface electrodes placed over the appropriate mouth muscles so that EMG data can be recorded. Participants will be asked to come to the neuromuscular lab in the Huston Huffman Center on the campus of The University of Oklahoma for three testing sessions lasting no more than forty-five minutes each. During each session the participant will be provided with the sheet music for a musical exercise and be asked to play for thirty minutes, (No preparation time will be required.) The participant will be asked to return the following day for a similar session. After the second day of testing, the participant will be asked to not play the clarinet for two days. After this two-day rest period, the participant will be asked to return for the final day of testing.

RISKS AND BENEFITS: The risk of participation in this study is limited to some mild discomfort associated with intense, fatiguing performance. The benefits include a contribution to clarinet pedagogy which would allow for the development of more refined practice routines, increased gains in endurance and a reduction of overuse injuries.

CONDITIONS OF PARTICIPATION: Participation is voluntary. Refusal to participate will involve no penalty or loss of benefits to which the subject is otherwise entitled. Furthermore, the participant may discontinue participation at any time without penalty or loss of benefits to which the participant is otherwise entitled.

CONFIDENTIALITY: Findings will be presented in aggregate form with no identifying information to ensure confidentiality.

AUDIO TAPING OF STUDY ACTIVITIES: To assist analysis of data, your musical performance may be recorded on an audio recording device. Interview/discussion will not be recorded. Participants have the right to refuse to allow such recording without penalty. Please select one of the following options.

[ ] I consent to the use of audio recording.
[ ] I do not consent to the use of audio recording.

CONTACTS FOR QUESTIONS ABOUT THE STUDY: Participants may contact David Belcher: <david.e.belcher-1@ou.edu> 940-696-3137 or Dr. David Etheridge: <david-etheridge@ou.edu> 405-325-4372 with questions about the study.

For inquires about rights as a research participant, contact the University of Oklahoma-Norman Campus Institutional Review Board (OU-NC IRB) at 405/325-8110 or irb@ou.edu.

PARTICIPANT ASSURANCE: I have read and understand the terms and conditions of this study and I hereby agree to participate in the above-described research study. I understand my participation is voluntary and that I may withdraw at any time without penalty.

______________________________	______________________
Signature of Participant	Date
______________________________	______________________
Printed Name of Participant	Researcher Signature

APPENDIX II

Questionnaire

Date:____________

Subject #: ________

Fatigue Patterns in the Mouth Muscles Used to Play the Clarinet

Questionnaire

The purpose of this questionnaire is to gather general information about you and your playing habits. Please be assured that your identity will be kept confidential and nothing will be written that could link you to your answers. You may either bring your completed questionnaire to the first test session or, if you prefer, it will be completed by the investigator during your test session.

Please answer the following questions as precisely as possible. If you need more space, feel free to attach extra pages.

Age: _________ Sex:_________ Height:_________ Weight:_________

How long have you been playing the clarinet?

Do you play with a single-lipped embouchure or a double-lipped embouchure? If both, what percentage of your playing time is spent with each?

On average, on how many **days** each week do you play the clarinet? (Include individual practice, rehearsals and performance – everything.)

On average, how many **hours** per week do you play the clarinet? (Again, include all practice, rehearsal and performance.)

In the few weeks prior to an important performance do you find that the time you spend playing:
(Circle one)

Increases Decreases Stays about the same

Do you ever experience fatigue (muscle “burn” or loss of strength) in your embouchure while you play the clarinet? If yes, please explain.

Is endurance ever a problem for you during public performance?
If yes, please explain.

Many performers take a short break (a few days perhaps) from playing following an important performance for which they have prepared especially intensely. Is this something that you do?

Please comment on why or why not.

If you do take a break after one of these important performances how do you feel with respect to endurance after you resume your normal playing routine?

Has it ever been suggested to you by a music educator (private instructor, band director, conductor, method book author, etc) that you should play every day?

If yes, please explain.

Do you have a specific individual practice schedule?

If yes, please describe.

If you have a specific practice schedule does it ever change?

If yes, please describe the factors which affect a change in this schedule.

What types of performance tasks do you find particularly fatiguing?

Date:____________

Subject #: ________

After First Day of Testing:

How do you feel with respect to embouchure fatigue now? Circle one.
(1 = not fatigued at all. 10 = completely fatigued)

1 2 3 4 5 6 7 8 9 10

Estimate at what point your embouchure began to feel tired? Circle one.

Began to feel tired…

Within the first five minutes of testing

After 5 minutes of testing

After10 minutes of testing

After 15 minutes of testing

After 20 minutes of testing

Did not experience any fatigue

How much do you feel that your tone quality deteriorated during this test session? Circle one. (1=tone improved or there was no change. 10 = tone deteriorated to your worst possible sound.)

1 2 3 4 5 6 7 8 9 10

Date:____________

Subject #: ________

After Second Day of Testing:

How do you feel with respect to embouchure fatigue now? Circle one.
(1 = not fatigued at all. 10 = completely fatigued)

1 2 3 4 5 6 7 8 9 10

Estimate at what point your embouchure began to feel tired? Circle one.

Began to feel tired…

Within the first 5 minutes of testing

After 5 minutes of testing

After10 minutes of testing

After 15 minutes of testing

After 20 minutes of testing

Did not experience any fatigue

How much do you feel that your tone quality deteriorated during this test session? Circle one. (1=tone improved or there was no change. 10 = tone deteriorated to your worst possible sound.)

1 2 3 4 5 6 7 8 9 10

Date:____________

Subject #: ________

To be completed by the researcher at the beginning of the third test session.

Have you played the clarinet since the last testing session?

If no: Testing continues

If yes: How long did you play and when?

If less than an hour: Testing continues

If more than an hour: Testing ends and data discarded

If playing occurred on the day of the third day of testing: Testing ends and data discarded.

Date:____________

Subject #: ________

After Third Day of Testing:

How do you feel with respect to embouchure fatigue now? Circle one.
(1 = not fatigued at all. 10 = completely fatigued)

1 2 3 4 5 6 7 8 9 10

Estimate at what point your embouchure began to feel tired? Circle one.

Began to feel tired…

Within the first 5 minutes of testing

After 5 minutes of testing

After10 minutes of testing

After 15 minutes of testing

After 20 minutes of testing

Did not experience any fatigue

How much do you feel that your tone quality deteriorated during this test session? Circle one. (1=tone improved or there was no change. 10 = tone deteriorated to your worst possible sound.)

1 2 3 4 5 6 7 8 9 10

APPENDIX III

Raw Data

The following section contains the raw right-side data values for: IEMG (volts), amplitude (μv), frequency (Hz), subject information, subject perceived fatigue level, subject perceived beginning of fatigue, subject perceived depreciation of tone, percent decline in IEMG, percent decline in amplitude, and percent decline in frequency.

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 1 trial 1 IEMG (v)	0.01957	0.01917	0.01096	0.01198	0.00668	0.02584	0.01772	0.01772	0.02884
day 1 trial 1 IEMG (v)	0.01882	0.01663	0.00839	0.00909	0.00698	0.02183	0.01238	0.01301	0.02556
day 1 trial 3 IEMG (v)	0.0168	0.01207	0.00856	0.00993	0.00667	0.01493	0.01512	0.01207	0.01628
day 1 trial 4 IEMG (v)	0.01439	0.01322	0.01092	0.00936	0.00705	0.01507	0.01077	0.01101	0.01453
day 1 trial 5 IEMG (v)	0.01159	0.01226	0.01025	0.00836	0.00706	0.01149	0.01166	0.01151	0.01699
day 1 trial 6 IEMG (v)	0.01771	0.0151	0.01054	0.00902	0.00772	0.01425	0.01446	0.0116	0.01931
day 1 trial 7 IEMG (v)	0.01309	0.01275	0.01121	0.00832	0.00817	0.01538	0.0121	0.01365	0.01821
day 1 trial 8 IEMG (v)	0.01262	0.01482	0.00778	0.00912	0.00827	0.013	0.01181	0.01099	0.01803
day 1 trial 9 IEMG (v)	0.00781	0.01257	0.01045	0.00828	0.00711	0.0152	0.01029	0.01411	0.01639
day 1 trial 10 IEMG (v)	0.01254	0.01297	0.0116	0.00659	0.00853	0.01518	0.00934	0.01105	0.01816
day 1 trial 11 IEMG (v)	0.01777	0.01174	0.01007	0.00745	0.00944	0.00638	0.00799	0.013	0.01928
day 1 trial 12 IEMG (v)	0.01453	0.01088	0.01039	0.00672	0.00853	0.01634	0.00921	0.01271	0.01971
day 1 trial 13 IEMG (v)	0.0166	0.01382	0.01008	0.00611	0.00926	0.01576	0.01361	0.01152	0.0172
day 1 trial 14 IEMG (v)	0.01466	0.0118	0.01034	0.0062	0.00879	0.00918	0.01274	0.01192	0.01443
day 1 trial 15 IEMG (v)	0.01447	0.01394	0.01016	0.0056	0.00894	0.01256	0.01346	0.01087	0.01399
day 1 trial 16 IEMG (v)	0.01086	0.01231	0.0101	0.00601	0.00822	0.01489	0.01125	0.01064	0.01599
day 1 trial 17 IEMG (v)	0.01446	0.01429	0.01038	0.0059	0.00877	0.01416	0.00896	0.01157	0.01255
day 1 trial 18 IEMG (v)	0.00968	0.01347	0.00976	0.00531	0.00771	0.01178	0.00972	0.01189	0.01189
day 1 trial 19 IEMG (v)	0.01284	0.01143	0.00985	0.00573	0.00653	0.01257	0.01333	0.01088	0.01109
day 1 trial 20 IEMG (v)	0.01064	0.01295	0.00962	0.00488	0.00617	0.01169	0.01241	0.01212	0.01003
day 1 trial 21 IEMG (v)	0.00514	0.01251	0.00891	0.00553	0.00638	0.01329	0.0091	0.00988	0.0085
day 1 trial 22 IEMG (v)	0.01025	0.01068	0.00792	0.00487	0.00588	0.01436	0.00879	0.01221	0.00893
day 1 trial 23 IEMG (v)	0.0094	0.0121	0.0093	0.00549	0.00672	0.01307	0.01521	0.00987	0.00671
day 1 trial 24 IEMG (v)	0.01232	0.01208	0.00937	0.00501	0.00526	0.01126	0.01089	0.0119	0.00661
day 1 trial 25 IEMG (v)	0.00909	0.01091	0.00923	0.00464	0.00567	0.01248	0.00662	0.01029	0.00628
day 1 trial 26 IEMG (v)	0.01296	0.01118	0.00826	0.00509	0.00496	0.01179	0.0097	0.00944	0.00573
day 1 trial 27 IEMG (v)	0.01207	0.01136	0.00848	0.00522	0.00512	0.01192	0.00889	0.00956	0.0059
day 1 trial 28 IEMG (v)	0.01318	0.01069	0.00821	0.00516	0.00582	0.01122	0.00848	0.00959	0.00474
day 1 trial 29 IEMG (v)	0.01212	0.00982	0.00713	0.00563	0.00561	0.01313	0.00561	0.00918	0.00515

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 1 trial 30 IEMG (v)	0.01132	0.00954	0.00844	0.0058	0.00463	0.01072	0.00863	0.0097	0.00491
day 2 trial 1 IEMG (v)	0.01844	0.01762	0.01237	0.01335	0.0079	0.02221	0.01375	0.01436	0.02685
day 2 trial 2 IEMG (v)	0.01674	0.01435	0.00991	0.01104	0.00704	0.01422	0.00995	0.01092	0.0253
day 2 trial 3 IEMG (v)	0.016	0.0109	0.00957	0.01138	0.00742	0.00898	0.01486	0.0105	0.02271
day 2 trial 4 IEMG (v)	0.01376	0.01405	0.00989	0.01101	0.00755	0.01488	0.01024	0.01077	0.01663
day 2 trial 5 IEMG (v)	0.0137	0.01052	0.01026	0.01122	0.00889	0.01277	0.01116	0.0118	0.02015
day 2 trial 6 IEMG (v)	0.01562	0.01208	0.00971	0.0117	0.00698	0.01253	0.00817	0.0116	0.02083
day 2 trial 7 IEMG (v)	0.01546	0.01105	0.01059	0.01166	0.00796	0.01318	0.01144	0.00868	0.01496
day 2 trial 8 IEMG (v)	0.01398	0.01178	0.00997	0.01092	0.00771	0.01021	0.01253	0.01064	0.01924
day 2 trial 9 IEMG (v)	0.00779	0.00904	0.0087	0.01186	0.00708	0.01283	0.01264	0.00752	0.01843
day 2 trial 10 IEMG (v)	0.01356	0.00886	0.01036	0.01165	0.00731	0.01634	0.01056	0.0088	0.01785
day 2 trial 11 IEMG (v)	0.01411	0.0081	0.01076	0.01174	0.00695	0.01276	0.01222	0.01035	0.02028
day 2 trial 12 IEMG (v)	0.01131	0.00852	0.00906	0.01017	0.00685	0.01411	0.00973	0.01285	0.01668
day 2 trial 13 IEMG (v)	0.01314	0.01224	0.01095	0.0113	0.0053	0.01228	0.00747	0.01004	0.01979
day 2 trial 14 IEMG (v)	0.00955	0.01258	0.00885	0.01129	0.00441	0.01236	0.01017	0.01062	0.0169
day 2 trial 15 IEMG (v)	0.01503	0.01487	0.00877	0.01099	0.00416	0.00856	0.01011	0.00912	0.021
day 2 trial 16 IEMG (v)	0.01207	0.00963	0.00804	0.01062	0.0035	0.01165	0.01062	0.01092	0.01931
day 2 trial 17 IEMG (v)	0.00916	0.01253	0.00763	0.01037	0.00334	0.01204	0.00888	0.01152	0.01664
day 2 trial 18 IEMG (v)	0.01134	0.0105	0.00779	0.01053	0.00313	0.01097	0.01335	0.01164	0.01987
day 2 trial 19 IEMG (v)	0.00978	0.01031	0.00661	0.00966	0.00278	0.01371	0.01664	0.00987	0.01761
day 2 trial 20 IEMG (v)	0.00996	0.00744	0.00665	0.01002	0.00269	0.01141	0.01	0.00819	0.01624
day 2 trial 21 IEMG (v)	0.01131	0.0119	0.0063	0.00903	0.00271	0.01204	0.01078	0.01057	0.01653
day 2 trial 22 IEMG (v)	0.00871	0.01164	0.00585	0.00959	0.00177	0.00585	0.00734	0.01229	0.01682
day 2 trial 23 IEMG (v)	0.00963	0.01024	0.00576	0.00997	0.00225	0.00972	0.00831	0.0106	0.01425
day 2 trial 24 IEMG (v)	0.01043	0.00912	0.00583	0.00975	0.00211	0.01046	0.01457	0.0112	0.01536
day 2 trial 25 IEMG (v)	0.01173	0.01011	0.00597	0.00897	0.00229	0.01138	0.00956	0.00998	0.01406
day 2 trial 26 IEMG (v)	0.01134	0.00808	0.00571	0.00903	0.00197	0.01149	0.00895	0.01017	0.01198
day 2 trial 27 IEMG (v)	0.0113	0.01171	0.00562	0.00886	0.00214	0.011	0.00816	0.00985	0.0132
day 2 trial 28 IEMG (v)	0.01068	0.01035	0.00497	0.00872	0.00204	0.00943	0.00833	0.00988	0.01597
day 2 trial 29 IEMG (v)	0.01079	0.0086	0.00497	0.00921	0.00208	0.00748	0.00858	0.00844	0.01587

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 2 trial 30 IEMG (v)	0.00638	0.00912	0.00476	0.00895	0.00168	0.00805	0.01044	0.00946	0.01467
day 3 trial 1 IEMG (v)	0.01959	0.01266	0.01003	0.01555	0.00904	0.01986	0.01341	0.01565	0.01853
day 3 trial 2 IEMG (v)	0.01701	0.01014	0.00848	0.01248	0.00785	0.01356	0.01093	0.01242	0.01665
day 3 trial 3 IEMG (v)	0.01668	0.00836	0.00802	0.01256	0.00958	0.00954	0.01234	0.01208	0.01363
day 3 trial 4 IEMG (v)	0.01344	0.01027	0.00882	0.01221	0.0073	0.01215	0.01363	0.01266	0.01158
day 3 trial 5 IEMG (v)	0.01615	0.00985	0.00862	0.01246	0.00832	0.0124	0.012	0.01349	0.01345
day 3 trial 6 IEMG (v)	0.01204	0.00828	0.00928	0.01248	0.00838	0.01146	0.01158	0.01226	0.01417
day 3 trial 7 IEMG (v)	0.01204	0.00795	0.00961	0.01289	0.00831	0.01235	0.01264	0.01221	0.0128
day 3 trial 8 IEMG (v)	0.01419	0.0087	0.00999	0.01334	0.00705	0.0129	0.00913	0.01322	0.0141
day 3 trial 9 IEMG (v)	0.01536	0.00952	0.00918	0.01266	0.00729	0.01225	0.00869	0.01285	0.01358
day 3 trial 10 IEMG (v)	0.01479	0.00768	0.00887	0.01289	0.00858	0.01252	0.01602	0.01203	0.01281
day 3 trial 11 IEMG (v)	0.01421	0.00939	0.00817	0.01305	0.00939	0.01177	0.01326	0.01226	0.01482
day 3 trial 12 IEMG (v)	0.01419	0.00667	0.00909	0.01085	0.00797	0.01291	0.01285	0.01077	0.01319
day 3 trial 13 IEMG (v)	0.01253	0.00761	0.00902	0.01198	0.00737	0.01125	0.01034	0.01184	0.01444
day 3 trial 14 IEMG (v)	0.01353	0.00872	0.00895	0.01207	0.00711	0.01414	0.01146	0.01132	0.01279
day 3 trial 15 IEMG (v)	0.01202	0.00902	0.00946	0.01152	0.00779	0.01017	0.01147	0.01004	0.01405
day 3 trial 16 IEMG (v)	0.01014	0.01118	0.00853	0.01112	0.00752	0.00953	0.00814	0.01108	0.01395
day 3 trial 17 IEMG (v)	0.00936	0.00911	0.00689	0.01299	0.00706	0.01125	0.01538	0.0108	0.01249
day 3 trial 18 IEMG (v)	0.01446	0.01202	0.00843	0.01119	0.00669	0.01103	0.01427	0.0103	0.01379
day 3 trial 19 IEMG (v)	0.01057	0.0119	0.00839	0.01127	0.00632	0.0104	0.01233	0.00944	0.01183
day 3 trial 20 IEMG (v)	0.00978	0.00788	0.00791	0.01009	0.00651	0.01173	0.00683	0.00994	0.01187
day 3 trial 21 IEMG (v)	0.01039	0.01126	0.0079	0.01003	0.00668	0.01142	0.00882	0.01078	0.01119
day 3 trial 22 IEMG (v)	0.01069	0.0088	0.00816	0.00931	0.00533	0.01091	0.01044	0.01064	0.01195
day 3 trial 23 IEMG (v)	0.01168	0.00869	0.00829	0.00881	0.00813	0.00994	0.01315	0.00965	0.01139
day 3 trial 24 IEMG (v)	0.0104	0.00928	0.00766	0.00839	0.00649	0.00999	0.00923	0.01048	0.01155
day 3 trial 25 IEMG (v)	0.01038	0.0104	0.008	0.00779	0.00694	0.0102	0.0134	0.00871	0.01075
day 3 trial 26 IEMG (v)	0.01106	0.00979	0.00738	0.00835	0.0065	0.0084	0.01519	0.00976	0.01116
day 3 trial 27 IEMG (v)	0.00963	0.00652	0.00779	0.00851	0.00657	0.00843	0.01551	0.00949	0.01014
day 3 trial 28 IEMG (v)	0.01051	0.01083	0.00704	0.00825	0.00575	0.01132	0.01527	0.00787	0.01029
day 3 trial 29 IEMG (v)	0.00819	0.00877	0.00755	0.0073	0.00533	0.01075	0.00792	0.009	0.00986

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 3 trial 30 IEMG (v)	0.00879	0.01032	0.00635	0.0071	0.00593	0.00842	0.00882	0.00895	0.01072
day 1 trial 1 amplitude (µv)	2.86715	2.57474	1.79966	1.79717	1.05448	3.73087	2.79011	2.5052	4.58113
day 1 trial 2 amplitude (µv)	2.83711	2.68891	1.39145	1.71652	1.18331	3.37017	2.08761	2.11926	3.7296
day 1 trial 3 amplitude (µv)	3.07806	2.34215	1.72819	1.84139	1.01189	2.77492	3.58764	2.00166	2.34788
day 1 trial 4 amplitude (µv)	2.57232	2.46598	1.98652	1.66053	1.2314	2.59859	1.82823	1.86162	2.30125
day 1 trial 5 amplitude (µv)	2.986	2.0959	1.68954	1.5682	1.10376	2.18806	2.57857	1.97823	2.96984
day 1 trial 6 amplitude (µv)	2.9789	2.35621	1.91456	1.51885	1.21348	2.42798	2.71269	1.95708	3.08723
day 1 trial 7 amplitude (µv)	2.33978	2.43108	2.04726	1.68174	1.37446	2.72879	2.45138	2.04628	3.03826
day 1 trial 8 amplitude (µv)	2.01781	2.4558	1.7821	1.63918	1.47378	2.15428	2.39589	1.92545	3.15633
day 1 trial 9 amplitude (µv)	1.8545	2.39732	2.11967	1.68108	1.20906	2.97663	1.69131	2.38255	3.13093
day 1 trial 10 amplitude (µv)	2.331	2.94624	1.986	1.11378	1.32851	2.68366	1.84628	2.14514	3.20143
day 1 trial 11 amplitude (µv)	3.10693	2.33721	1.8321	1.54281	1.41786	1.70019	1.76567	2.3333	3.5163
day 1 trial 12 amplitude (µv)	2.47256	2.06308	1.75151	1.13311	1.60848	2.40228	2.17105	1.98323	2.99996
day 1 trial 13 amplitude (µv)	2.99351	2.13906	1.84117	1.04906	1.40836	2.50463	2.62146	2.02198	2.88706
day 1 trial 14 amplitude (µv)	2.84695	2.37218	1.62965	1.17701	1.58599	2.30599	2.03873	2.00556	2.32706
day 1 trial 15 amplitude (µv)	2.55184	2.37559	1.94277	1.04749	1.52875	2.18053	2.46909	1.98501	2.38471
day 1 trial 16 amplitude (µv)	2.35034	2.09076	1.99722	1.01609	1.5279	2.70998	2.30105	1.7837	2.90739
day 1 trial 17 amplitude (µv)	2.43267	2.6318	1.78496	1.08019	1.41753	2.34865	1.86855	1.90915	2.2897
day 1 trial 18 amplitude (µv)	2.05993	2.58526	1.68077	0.92968	1.3737	2.13744	1.80267	1.75839	2.0706
day 1 trial 19 amplitude (µv)	2.37258	2.17575	1.76483	1.01011	1.11518	2.14713	2.77135	1.89904	1.95142
day 1 trial 20 amplitude (µv)	1.99084	2.43187	1.73502	0.79012	1.02153	2.0549	2.37726	1.92415	1.68063
day 1 trial 21 amplitude (µv)	1.51334	2.26023	1.47599	0.93697	0.92273	2.48482	1.74274	1.51967	1.37005
day 1 trial 22 amplitude (µv)	41.0155	2.22123	1.45031	0.91896	1.02438	2.31886	2.03353	2.2506	1.46199
day 1 trial 23 amplitude (µv)	1.67614	2.0433	1.73453	0.89643	1.01237	2.30405	2.73062	1.99685	1.2098
day 1 trial 24 amplitude (µv)	2.05733	2.5672	1.46624	0.89516	0.90588	2.01743	1.85494	1.97393	1.11172
day 1 trial 25 amplitude (µv)	1.81368	2.19074	1.5334	0.96303	0.98042	2.29089	1.52401	1.67623	1.04358
day 1 trial 26 amplitude (µv)	2.21086	2.00681	1.3283	0.81894	0.8415	1.9267	2.03867	1.45126	1.01476
day 1 trial 27 amplitude (µv)	2.05133	2.0193	1.45657	0.93294	0.80673	1.86813	1.48503	1.68087	1.03414
day 1 trial 28 amplitude (µv)	2.01799	1.72972	1.51741	0.82468	0.99405	1.9321	1.41572	1.63028	0.8059
day 1 trial 29 amplitude (µv)	2.50348	1.85534	1.22676	0.96558	0.93646	2.44234	1.2034	1.60648	1.00014

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 1 trial 30 amplitude (µv)	1.94706	1.95689	1.25584	0.94889	0.87093	1.9082	1.86612	1.75344	0.87639
day 2 trial 1 amplitude (µv)	2.33911	3.32153	1.9047	2.00448	1.15403	3.49485	1.94708	2.22545	4.0576
day 2 trial 2 amplitude (µv)	2.59546	2.84112	1.82792	2.04578	1.11145	2.69207	1.6087	1.95798	4.18118
day 2 trial 3 amplitude (µv)	2.56099	2.2409	1.67393	2.03258	1.2368	1.91859	2.63509	1.82092	3.83726
day 2 trial 4 amplitude (µv)	2.48855	2.46886	1.45331	1.94179	1.20223	2.53403	1.82624	1.59619	2.69177
day 2 trial 5 amplitude (µv)	2.22017	2.27047	1.74334	2.12694	1.38812	2.28281	2.28865	2.0148	3.70059
day 2 trial 6 amplitude (µv)	2.7334	2.27492	1.52555	2.06787	1.0869	2.39887	1.69562	1.98808	3.63728
day 2 trial 7 amplitude (µv)	2.56313	2.03956	1.78152	1.91382	1.19696	2.18236	1.97979	1.71457	3.40466
day 2 trial 8 amplitude (µv)	2.2555	2.29875	1.73753	1.79541	1.17612	2.04971	2.01093	1.78572	3.40466
day 2 trial 9 amplitude (µv)	1.90211	2.07809	1.91413	1.9693	1.25053	2.24355	1.98007	1.85987	3.18028
day 2 trial 10 amplitude (µv)	2.398	1.70382	1.69341	2.10036	1.03984	2.94611	2.41571	1.55953	3.14405
day 2 trial 11 amplitude (µv)	2.48321	1.62589	1.71757	2.27935	1.23341	2.31943	1.95356	1.99263	3.21284
day 2 trial 12 amplitude (µv)	2.46609	1.64188	1.72984	1.87534	1.08116	2.32925	1.91014	2.43113	2.96977
day 2 trial 13 amplitude (µv)	2.32824	2.23974	1.71536	1.78548	0.90706	2.21718	1.44869	1.89675	3.15319
day 2 trial 14 amplitude (µv)	2.30281	2.23048	1.61234	1.97119	0.77007	2.18151	2.03776	1.72209	2.56224
day 2 trial 15 amplitude (µv)	2.52903	2.63051	1.31677	1.80439	0.71777	1.69081	1.77498	1.70124	4.39498
day 2 trial 16 amplitude (µv)	2.19002	2.0716	1.34022	1.85416	0.59106	2.06212	1.83438	1.89074	3.13248
day 2 trial 17 amplitude (µv)	1.76534	2.22783	1.25913	1.81823	0.54339	2.06539	1.84194	1.79895	3.03207
day 2 trial 18 amplitude (µv)	2.06472	1.89139	1.23573	1.82983	0.49971	1.92414	2.63618	1.97139	2.9863
day 2 trial 19 amplitude (µv)	1.91224	1.78149	1.09564	1.81327	0.52205	2.28462	2.96425	1.68453	3.00931
day 2 trial 20 amplitude (µv)	1.84829	1.56693	1.16977	1.6909	0.49044	1.9177	2.24075	1.5577	2.60141
day 2 trial 21 amplitude (µv)	1.93463	2.10944	1.05157	1.6313	0.42755	2.13015	1.86605	1.74759	2.75667
day 2 trial 22 amplitude (µv)	1.85904	2.08889	0.99253	1.81979	0.2601	1.39326	1.45277	1.92119	3.14055
day 2 trial 23 amplitude (µv)	2.09355	1.66979	0.99075	1.60446	0.3217	1.73199	1.75886	1.92598	2.4413
day 2 trial 24 amplitude (µv)	1.81223	1.66401	0.99422	1.83823	0.3823	1.87134	2.57712	1.8878	2.43268
day 2 trial 25 amplitude (µv)	2.17484	1.73226	0.98909	1.54051	0.37338	1.84885	1.89768	1.58409	2.6631
day 2 trial 26 amplitude (µv)	2.06542	1.49626	0.92715	1.52009	0.32111	1.89212	1.45622	1.72853	2.01316
day 2 trial 27 amplitude (µv)	1.83963	2.15904	0.8938	1.42965	0.32455	1.90846	1.7257	1.73643	2.1926
day 2 trial 28 amplitude (µv)	1.83478	1.6784	0.79368	1.37027	0.34445	1.59867	1.59749	1.41282	2.45335
day 2 trial 29 amplitude (µv)	1.66372	1.39071	0.87011	1.59687	0.36779	1.25754	1.66843	1.42644	2.59239

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 2 trial 30 amplitude (µv)	1.29827	1.65292	0.81827	1.44008	0.28627	1.3826	1.77204	1.69022	2.1944
day 3 trial 1 amplitude (µv)	2.85697	2.38724	1.6278	2.65244	1.45037	3.06581	2.13835	2.40998	2.5351
day 3 trial 2 amplitude (µv)	2.97178	1.69075	1.36005	2.06061	1.37264	2.33677	1.88144	2.03412	2.22023
day 3 trial 3 amplitude (µv)	3.13681	1.56042	1.39551	2.15698	1.78336	1.81794	2.1521	2.01442	1.9801
day 3 trial 4 amplitude (µv)	2.48246	1.67582	1.45745	2.09053	1.16794	2.17867	1.98926	2.07654	1.74707
day 3 trial 5 amplitude (µv)	2.99166	1.96681	1.47289	2.13678	1.34764	2.17451	2.32226	2.06542	2.13137
day 3 trial 6 amplitude (µv)	2.2272	1.6208	1.38226	2.29031	1.36228	2.24411	1.70859	2.00286	2.17147
day 3 trial 7 amplitude (µv)	1.89579	1.36128	1.46859	2.31323	1.33211	1.89123	2.45406	2.01553	1.74991
day 3 trial 8 amplitude (µv)	2.17131	1.56342	1.58574	2.22582	1.21203	2.27307	1.98706	2.2929	2.34135
day 3 trial 9 amplitude (µv)	2.41543	1.71944	1.52928	2.4731	1.29755	2.49168	1.88224	1.95293	2.19067
day 3 trial 10 amplitude (µv)	2.74192	1.58207	1.78234	2.47631	1.38376	2.31639	2.88606	2.22971	1.99191
day 3 trial 11 amplitude (µv)	2.52763	1.64092	1.36481	2.18033	1.42407	2.30067	2.37256	1.87597	2.46194
day 3 trial 12 amplitude (µv)	2.82144	1.5657	1.89886	1.96928	1.38085	2.05639	2.40121	1.75527	2.28113
day 3 trial 13 amplitude (µv)	2.12252	1.40444	1.34532	2.19788	1.18258	1.85883	2.02711	1.84946	2.06866
day 3 trial 14 amplitude (µv)	2.62786	1.36919	1.72582	2.03646	1.26935	2.25075	2.1325	1.70505	1.94396
day 3 trial 15 amplitude (µv)	2.01722	1.72101	1.57065	2.40362	1.38233	1.72662	2.02792	1.6225	2.04774
day 3 trial 16 amplitude (µv)	1.97202	2.14454	1.50821	2.00679	1.18763	1.85382	1.75599	1.7391	2.22708
day 3 trial 17 amplitude (µv)	2.48464	1.55628	1.30754	2.24179	1.21553	2.01903	2.80381	1.94627	2.07095
day 3 trial 18 amplitude (µv)	2.44604	2.03219	1.3504	2.21823	1.11746	2.0626	2.34998	1.81736	2.00609
day 3 trial 19 amplitude (µv)	1.99091	1.76493	1.49704	2.01697	0.99556	2.00655	2.06826	1.50824	2.00185
day 3 trial 20 amplitude (µv)	1.92059	1.56039	1.36688	1.95816	1.23528	2.01884	1.60459	1.61897	2.03816
day 3 trial 21 amplitude (µv)	2.0775	1.8539	1.46246	1.89529	1.23912	1.93194	1.80112	1.49291	1.67706
day 3 trial 22 amplitude (µv)	1.78102	1.96655	1.34041	1.50574	0.84851	1.82211	2.0213	1.48552	2.17482
day 3 trial 23 amplitude (µv)	2.29735	1.58587	1.60471	1.61735	1.26911	1.75997	2.63828	1.5198	1.85068
day 3 trial 24 amplitude (µv)	2.28431	1.56554	1.36364	1.49957	1.08683	1.66723	1.67026	1.60154	1.826
day 3 trial 25 amplitude (µv)	2.28687	1.91631	1.32745	1.52761	1.10923	1.93537	2.7039	1.51534	1.82847
day 3 trial 26 amplitude (µv)	1.85531	1.93401	1.3702	1.42758	1.12852	1.66157	2.66525	1.76075	1.51676
day 3 trial 27 amplitude (µv)	1.89443	1.12781	1.44028	1.43677	1.04013	1.41615	2.84704	1.4981	1.68129
day 3 trial 28 amplitude (µv)	1.82131	1.94311	1.12897	1.34151	0.87191	1.95648	2.84704	1.65696	1.54475
day 3 trial 29 amplitude (µv)	1.58342	1.59669	1.27924	1.31947	0.83922	1.85507	1.33567	1.27148	1.83641

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 3 trial 30 amplitude (µv)	1.61356	1.928	1.21054	1.33423	1.18489	1.57544	1.52091	1.45332	1.77851
day 1 trial 1 frequency (Hz)	47.6334	45.1333	36.6058	40.8617	44.6247	40.0715	38.1099	42.2068	43.2396
day 1 trial 2 frequency (Hz)	42.2531	42.6084	40.9164	35.4727	36.0188	46.7515	33.8918	40.061	42.2228
day 1 trial 3 frequency (Hz)	36.6317	44.5931	31.9813	35.0183	42.9087	34.3952	23.2489	36.5532	40.3341
day 1 trial 4 frequency (Hz)	36.9033	39.5467	38.0618	27.593	35.5664	43.5617	35.9922	36.8977	36.0838
day 1 trial 5 frequency (Hz)	27.7574	39.3496	37.4377	42.1937	38.2005	34.892	31.171	37.6275	34.8823
day 1 trial 6 frequency (Hz)	39.4097	49.4169	31.3424	42.3402	39.7069	42.5686	30.6066	36.7427	38.0025
day 1 trial 7 frequency (Hz)	2.33978	45.6138	36.8143	28.9741	38.7956	41.4652	38.7407	38.4672	40.1905
day 1 trial 8 frequency (Hz)	44.8223	43.5432	21.7754	34.5837	39.3003	42.8503	29.3528	29.0556	30.8269
day 1 trial 9 frequency (Hz)	34.0235	41.126	31.1839	40.063	46.6476	46.0506	42.2273	40.3153	40.5217
day 1 trial 10 frequency (Hz)	41.5166	34.2265	40.7314	39.7825	36.2867	35.8544	32.5202	35.9037	36.7534
day 1 trial 11 frequency (Hz)	39.0134	38.4104	33.8769	30.7406	38.0938	23.7103	39.0356	39.1314	40.5057
day 1 trial 12 frequency (Hz)	43.0904	37.3019	41.7866	41.5683	31.2566	42.2897	29.2909	45.1078	39.7187
day 1 trial 13 frequency (Hz)	36.664	44.4751	38.2941	35.4813	39.3281	38.373	30.8356	37.2653	37.9862
day 1 trial 14 frequency (Hz)	34.8033	41.1568	38.8778	32.4711	36.6957	36.0857	42.9365	35.6468	37.8918
day 1 trial 15 frequency (Hz)	34.9208	39.2415	34.3372	32.2952	33.2372	36.1883	34.5929	33.5194	35.0182
day 1 trial 16 frequency (Hz)	33.9914	44.3177	36.4804	40.7303	33.0085	34.4928	33.6727	40.276	31.0744
day 1 trial 17 frequency (Hz)	36.4173	37.8981	35.8113	32.6452	36.6404	38.6871	43.0167	41.6153	35.2206
day 1 trial 18 frequency (Hz)	24.5834	30.3663	38.9543	36.3833	35.2927	33.0866	29.4374	45.0417	36.0679
day 1 trial 19 frequency (Hz)	31.3885	38.0587	38.3568	39.0594	47.3523	40.7629	25.3329	40.8238	36.4832
day 1 trial 20 frequency (Hz)	31.8814	41.8925	33.7519	40.1851	45.5699	39.0339	35.9526	38.2358	39.482
day 1 trial 21 frequency (Hz)	41.0155	38.0055	39.7038	41.2606	41.9803	41.9625	32.2222	39.7846	41.148
day 1 trial 22 frequency (Hz)	41.0155	37.5303	33.2786	40.1357	34.1718	41.1965	26.1589	31.6755	33.1106
day 1 trial 23 frequency (Hz)	39.0057	44.8422	33.6112	36.9848	43.3828	35.4386	33.2779	34.9705	37.2291
day 1 trial 24 frequency (Hz)	37.6227	31.1113	42.0885	37.1055	38.1971	41.6034	41.7042	39.5673	37.234
day 1 trial 25 frequency (Hz)	32.5579	38.8406	39.5577	36.3473	35.8113	38.6894	27.8663	37.8967	37.5195
day 1 trial 26 frequency (Hz)	41.6733	40.3707	40.4228	37.881	34.785	37.9877	29.0167	41.1316	30.9642
day 1 trial 27 frequency (Hz)	36.8261	41.4405	36.8804	37.9132	44.1704	44.5274	35.9962	34.9744	38.1669
day 1 trial 28 frequency (Hz)	33.1561	42.9066	32.0037	42.719	36.6217	37.3439	41.1074	35.8818	38.3144
day 1 trial 29 frequency (Hz)	27.1007	37.5249	34.5952	36.5829	34.4516	39.6205	37.3675	33.907	29.2822

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 1 trial 30 frequency (Hz)	33.598	34.0209	41.1495	45.5123	37.6247	34.8533	25.7998	36.1582	30.198
day 2 trial 1 frequency (Hz)	43.5707	34.9183	37.5018	45.1589	41.7803	39.5039	41.2279	32.046	41.6971
day 2 trial 2 frequency (Hz)	39.56	39.5512	31.1096	34.7077	44.2717	34.2403	31.8282	34.9471	42.6024
day 2 trial 3 frequency (Hz)	39.1616	27.7928	39.7811	33.5629	37.8996	37.5422	29.0264	35.8218	38.2189
day 2 trial 4 frequency (Hz)	37.4697	41.2741	40.7312	38.836	39.5348	41.081	32.8371	43.8447	39.041
day 2 trial 5 frequency (Hz)	38.33	32.3964	33.1602	34.7276	38.4094	34.769	33.8525	37.9039	35.4366
day 2 trial 6 frequency (Hz)	39.822	33.729	42.3034	43.9118	37.4913	32.6542	33.9263	35.54	41.2446
day 2 trial 7 frequency (Hz)	42.919	43.4165	40.8395	34.7402	39.8981	42.113	40.9043	33.9933	37.0679
day 2 trial 8 frequency (Hz)	39.9518	38.8193	40.8894	34.4516	39.0185	42.2373	39.6564	43.3221	37.0679
day 2 trial 9 frequency (Hz)	43.1417	39.7805	32.1542	43.2566	35.0857	34.8067	40.2669	26.0814	33.9956
day 2 trial 10 frequency (Hz)	48.6314	40.9972	39.2737	38.3426	44.8258	36.2727	29.338	30.0811	40.3323
day 2 trial 11 frequency (Hz)	38.6072	33.5535	41.4276	36.2537	35.3327	35.8104	38.2299	41.1895	39.1865
day 2 trial 12 frequency (Hz)	33.5372	37.8834	30.7899	34.039	37.5687	40.5735	41.2316	36.9232	45.0727
day 2 trial 13 frequency (Hz)	36.3582	37.3244	46.085	38.9838	36.4835	42.2708	37.133	39.0352	46.7291
day 2 trial 14 frequency (Hz)	37.6197	40.1826	37.7416	38.2589	35.5958	38.5203	32.5703	37.6337	46.8043
day 2 trial 15 frequency (Hz)	39.6231	35.7146	45.5418	37.0799	36.5548	38.6473	39.2124	40.471	31.8487
day 2 trial 16 frequency (Hz)	40.3327	39.5902	34.4099	34.947	44.5844	36.2336	41.1173	36.5555	37.461
day 2 trial 17 frequency (Hz)	31.7018	38.4945	41.8021	32.2876	45.8694	35.9735	29.3896	34.7461	33.853
day 2 trial 18 frequency (Hz)	34.0544	43.4556	44.4851	41.6372	37.026	40.2814	26.8437	40.3113	38.7978
day 2 trial 19 frequency (Hz)	43.7704	37.863	39.1912	36.8142	29.9363	41.76	32.5504	36.289	37.6254
day 2 trial 20 frequency (Hz)	33.1119	35.4109	38.1996	38.2768	36.9359	38.5001	36.3061	37.3218	37.7276
day 2 trial 21 frequency (Hz)	33.0022	45.7059	35.4939	39.24	38.8554	34.9124	39.7694	39.8168	36.9927
day 2 trial 22 frequency (Hz)	35.8088	36.5219	35.0019	38.8413	37.5492	32.1427	31.0493	45.3717	34.8134
day 2 trial 23 frequency (Hz)	32.4942	46.7029	36.035	42.6042	48.8803	38.9572	30.6415	33.0367	36.8732
day 2 trial 24 frequency (Hz)	36.8069	45.5617	35.3385	35.9519	36.4029	34.6054	31.1929	34.3598	43.9929
day 2 trial 25 frequency (Hz)	37.1019	40.1905	37.886	38.9435	37.1868	36.2832	44.5732	38.7121	31.6949
day 2 trial 26 frequency (Hz)	37.2498	37.8509	41.4633	34.6675	37.1845	36.2385	34.6667	38.6698	40.8774
day 2 trial 27 frequency (Hz)	39.1503	35.7985	40.7079	43.2028	40.5132	38.8708	33.3134	30.6864	34.7263
day 2 trial 28 frequency (Hz)	33.4351	39.9947	44.3931	42.5854	35.216	38.7028	32.1399	40.5511	36.9287
day 2 trial 29 frequency (Hz)	45.8794	43.4006	38.485	39.105	36.4318	37.2081	34.1674	38.2536	36.6262

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 2 trial 30 frequency (Hz)	43.24	34.7385	36.0088	43.3974	36.3282	38.7625	37.297	29.2735	39.6155
day 3 trial 1 frequency (Hz)	38.8841	36.2577	34.2813	37.8873	37.0585	43.4588	36.1063	37.4354	42.0927
day 3 trial 2 frequency (Hz)	40.9562	40.2591	35.6883	33.3532	40.0355	33.7143	30.563	40.1801	47.8968
day 3 trial 3 frequency (Hz)	3.13681	45.7531	41.8816	32.4852	37.2558	35.0528	34.5068	38.9638	39.7701
day 3 trial 4 frequency (Hz)	34.4888	38.5375	42.37	35.7459	41.7334	35.5006	44.1027	36.1611	45.3741
day 3 trial 5 frequency (Hz)	34.3329	30.708	37.431	41.884	38.0505	33.2284	27.347	40.8151	38.7001
day 3 trial 6 frequency (Hz)	41.0509	35.8495	43.3748	35.9938	40.2677	37.0824	43.5037	37.1315	42.8654
day 3 trial 7 frequency (Hz)	38.6142	41.0122	39.3285	35.687	37.7459	48.0427	33.939	32.1011	42.9902
day 3 trial 8 frequency (Hz)	39.486	36.5138	47.5014	42.8565	38.9126	40.8776	31.4165	37.4551	37.0539
day 3 trial 9 frequency (Hz)	37.0355	49.2277	42.2447	36.189	34.7407	33.4659	42.2951	39.9478	32.7454
day 3 trial 10 frequency (Hz)	33.9465	30.0422	37.9024	33.6194	40.0812	35.4546	36.361	31.946	41.1322
day 3 trial 11 frequency (Hz)	39.6804	37.9902	42.4972	40.9576	43.7695	33.8173	31.0721	38.0343	42.4686
day 3 trial 12 frequency (Hz)	34.5261	34.4945	32.2684	38.955	36.4877	44.2278	36.0662	38.1514	39.1611
day 3 trial 13 frequency (Hz)	44.9444	35.0844	39.2508	33.2816	42.7762	41.2869	39.0983	39.9542	42.3873
day 3 trial 14 frequency (Hz)	30.2113	40.706	35.2979	40.7684	35.4254	41.0801	39.8124	39.3923	46.3327
day 3 trial 15 frequency (Hz)	43.6834	32.7889	38.712	34.2707	39.5043	40.4615	39.8838	37.7694	47.5375
day 3 trial 16 frequency (Hz)	40.4457	32.1136	35.301	34.6994	40.8897	40.944	31.3502	36.6959	35.1286
day 3 trial 17 frequency (Hz)	25.0279	37.6151	35.0634	35.9841	40.613	37.6231	36.9487	40.1779	44.066
day 3 trial 18 frequency (Hz)	40.3096	45.3358	37.95	39.7697	37.7404	41.2277	33.0131	38.171	40.5525
day 3 trial 19 frequency (Hz)	30.6341	45.764	35.3485	34.675	42.9706	33.0034	36.231	32.4426	35.7172
day 3 trial 20 frequency (Hz)	36.1514	39.173	42.3354	35.8336	33.8014	42.2838	31.5546	37.7018	35.1384
day 3 trial 21 frequency (Hz)	38.1382	37.3018	34.3537	41.8354	37.3444	47.8648	25.5669	44.1764	39.2283
day 3 trial 22 frequency (Hz)	39.5773	26.5723	40.973	42.8868	44.7503	35.5843	31.5146	47.0584	33.018
day 3 trial 23 frequency (Hz)	31.8153	36.2497	37.0434	37.6702	48.7482	35.2594	36.0076	42.3962	35.747
day 3 trial 24 frequency (Hz)	30.12	40.3909	40.2038	39.8624	35.8711	43.312	36.2684	37.6891	43.7592
day 3 trial 25 frequency (Hz)	33.2293	33.8404	42.6754	35.7933	45.9083	39.7229	32.9286	37.5022	36.7623
day 3 trial 26 frequency (Hz)	40.3952	35.1337	37.6256	39.5482	33.9696	38.3463	34.1816	35.1657	46.4254
day 3 trial 27 frequency (Hz)	32.8167	44.4287	40.1518	40.9819	37.1837	37.8753	41.8196	36.092	38.0395
day 3 trial 28 frequency (Hz)	38.9962	34.9462	47.4565	41.9217	48.8179	32.5639	41.8196	31.4299	44.9521
day 3 trial 29 frequency (Hz)	37.0701	38.679	34.5361	34.9641	37.4908	41.4627	44.4279	44.8504	32.2013

variable	subject 1	subject 2	subject 3	subject 4	subject 5	subject 6	subject 7	subject 8	subject 9
day 3 trial 30 frequency (Hz)	40.2809	38.4872	35.2203	36.0125	39.1369	37.9093	33.8671	34.7207	32.3583
subject age	19	19	21	21	22	28	22	36	24
subject height in inches	64	67	70	69	68	71	68	72	66
subject's weight in pounds	130	198	155	150	235	165	185	200	150
yeas subject has played clarinet	8	9	8	9	10	17	10	24	14
days each week subject plays	5	7	6	6	5	7	6	5	6
hours spent playing each week	8.5	28	9	14	9	30	24	10	22
perceived fatigue level, day 1	7	2	9.5	7	8	7	3	7	8
perceived fatigue level, day 2	8	3.5	8	6	10	7	2	8	6
perceived fatigue level, day 3	5.5	2	6.5	5	8	9	2	6	4
perceived beginning of fatigue minutes, day 1	5	25	1	1	15	1	10	5	15
perceived beginning of fatigue minutes, day 2	1	15	1	1	1	1	15	1	5
perceived beginning of fatigue minutes, day 3	1	15	5	5	1	1	20	15	5
perceived depreciation of tone, day 1	9	1	10	7	6	3	7	6	8
perceived depreciation of tone, day 2	8	5	8	8	8	4	4	8	6
perceived depreciation of tone, day 3	8	3.5	6	8	7	1	2	5	3
percent decline in IEMG for day 1	38.94	45.92	19.53	45.75	25.04	49.97	52.69	38.56	81.51
percent decline in IEMG day 2	51.19	44.57	56.33	25.54	74.83	57.37	19.75	29.19	41.44
percent decline in IEMG for day 3	53.61	16.27	24.91	48.63	33.33	42.64	31.22	36.05	41.5
percent decline in amplitude for day 1	21.98	27.57	22.2	45.51	19.23	38.73	37.07	27.34	77.42
percent decline in amplitude for day 2	39.97	50.61	54.77	25.02	71.13	57.33	3.24	25.5	41.9
percent decline in amplitude for day 3	45.15	13.57	16.67	43.69	28.3	36.5	28.94	38.69	23.98
percent decline in frequency for day 1	32.47	18.46	2.29	-7.55	10.62	14.22	12.27	14.83	30.4
percent decline in frequency for day 2	-7.2	-4.93	-8.57	-3.3	15.45	-3.02	2.18	-0.8	9.56
percent decline in frequency for day 3	3.12	-0.85	0.3	0.37	0.6	-2.85	-17.44	-2.52	28.26

APPENDIX IV

Approval for the Use of Human Subjects by the Institutional Review Board

The University of Oklahoma

OFFICE OF HUMAN RESEARCH PARTICIPANT PROTECTION

April 6, 2004

Mr. David Belcher
School of Music
CMC 138
CAMPUS MAIL

Dear Mr. Belcher:

The Institutional Review Board-Norman campus has reviewed your proposal, "Fatigue and Recovery Patterns in the Mouth Muscles Used to Play the Clarinet," under the University's expedited review procedures. The Board found that this research would not constitute a risk to participants beyond those of normal, everyday life, except in the area of privacy, which is adequately protected by the confidentiality procedures. Therefore, the Board has approved the use of human subjects in this research.

This approval is for a period of twelve months from April 6, 2004, provided that the research procedures are not changed from those described in your approved protocol and attachments. Should you wish to deviate from the described subject protocol, you must notify this office, in writing, noting any changes or revisions in the protocol and/or informed consent document and obtain prior approval from the Board for the changes. A copy of the approved informed consent document is attached for your use.

At the end of the research, you must submit a short report describing your use of human subjects in the research and the results obtained. Should the research extend beyond 12 months, a progress report must be submitted with the request for continuation, and a final report must be submitted at the end of the research.

If data are still being collected after five years, resubmission of the protocol is required.

Should you have any questions, please contact me at 325-8110 or irb@ou.edu.

Cordially,

E. Laurette Taylor, Ph.D.
Chair
Institutional Review Board-Norman Campus (FWA #00003191)

FY2004-280

Cc: Dr. David Etheridge, Music

APPENDIX V

Permission to Use Copyrighted Material

David Belcher
6003 Sandy Hill Blvd.
Wichita Falls, TX
76310
(940) 696-3137
david.e.belcher-1@ou.edu

RECEIVED
SEP 30 2004

September 28, 2004

Dear Ms. Wollar

I am requesting permission to use material from *Human Anatomy & Physiology*, 5th edition, by Elaine N. Marieb (ISBN: 0-8053-4989-8). The information would be used in a dissertation (titled Fatigue and Recovery Patterns of the Mouth Muscles Used to Play the Clarinet) required for the degree of Doctor of Musical Arts at the University of Oklahoma. The information of interest is several diagrams and text limited to the accompanying labels. The diagrams will be scanned into the document and will be rendered in black and white (grayscale). The diagrams that I would like to use are:

Diagrams from "Table 9.1 Structure and Organizational Levels of Skeletal Muscle" p. 282.

Figure 9.7 Sequence of events involved in the sliding of the actin filaments during contraction. p. 287.

Figure 10.6 Lateral view of muscles of the scalp, face, and neck. p. 335.

Thank you for your consideration.

Sincerely,

David Belcher

David Belcher

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Fee: $ Gratis
Date: 9/30/04 Beth Wollar
Beth Wollar