# An Investigation of Finger Motion and Hand Posture during Clarinet Performance

by

Stefanie Harger

A Research Paper Presented in Partial Fulfillment
of the Requirements for the Degree
Doctor of Musical Arts

Approved April 2011 by the
Graduate Supervisory Committee:

Robert Spring, Chair
Gary Hill
Frank Koonce
Kay Norton
Sandra Stauffer

ARIZONA STATE UNIVERSITY

May 2011

ABSTRACT

Finger motion and hand posture of six professional clarinetists (defined by entrance into or completion of a doctorate of musical arts degree in clarinet performance) were recorded using a pair of CyberGloves® in Arizona State University's Center for Cognitive Ubiquitous Computing Laboratory. Performance tasks included performing a slurred three-octave chromatic scale in sixteenth notes, at sixty quarter-note beats per minute, three times, with a metronome and a short pause between repetitions, and forming three pedagogical hand postures. Following the CyberGloves® tasks, each subject completed a questionnaire about equipment, playing history, practice routines, health practices, and hand usage during computer and sports activities.

CyberGlove® data were analyzed to find average hand/finger postures and differences for each pitch across subjects, subject variance in the performance task and differences in ascending and descending postures of the chromatic scale. The data were also analyzed to describe generalized finger posture characteristics based on hand size, whether right hand thumb position affects finger flexion, and whether professional clarinetists use similar finger/hand postures when performing on clarinet, holding a tennis ball, allowing hands to hang freely by the sides, or form a “C” shape. The findings of this study suggest an individual approach based on hand size is necessary for teaching clarinet hand posture.

ACKNOWLEDGMENTS

Sincere appreciation is due to my doctoral committee—Robert Spring, who served as Chair, Gary Hill, Frank Koonce, Kay Norton, and Sandra Stauffer. Their support and perceptive recommendations were extremely helpful in the completion of this document. I am especially indebted to Kay Norton for guiding me through the IRB approval process, acting as principle investigator, and helping design the study.

I would like to extend a warm gratitude to Robert Spring for his patience and encouragement during my musical studies. I consider myself lucky to have had such a wonderful artist and teacher to inspire my personal and artistic development. Heartfelt appreciation is due to my family for their unwavering support and encouragement throughout my life. I am indebted to my parents for the years they have invested in my musical training and education.

I would like to thank Joshua Gardner for his optimism and assurance during this process. I am appreciative of his help with the proofreading of this work and for providing me with unlimited support. A special thanks is due to Michael J. Astrauskas for his selfless attitude and countless hours spent in Arizona State University's Center for Cognitive Ubiquitous Computing laboratory working on this project with me and to Sethuraman Panchanathan for use of the laboratory. I would also like to express my gratitude to Mary Marzke for her encouragement and patience in explaining the science of the hand to this musician.

TABLE OF CONTENTS

TABLE OF CONTENTS

CHAPTER Page

TABLE OF CONTENTS

CHAPTER Page

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF TABLES

Table Page

LIST OF FIGURES

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

Figure Page

## LIST OF PHOTOGRAPHS

Photograph Page

# CHAPTER 1: INTRODUCTION

The purpose of this study is to determine the variability of finger posture and motion among professional clarinetists, and to quantify and characterize these postures and motions and promote a scientific teaching model. Three pedagogical hand postures were compared to the hand posture utilized when playing E3 (written pitch using the Acoustical Society of America's octave designation system will be used throughout this paper), a pitch engaging every finger of both hands, performed by six professional clarinetists.

## Discussion

Few hand position models exist in the clarinet pedagogical literature, and vague terms such as "natural" and "relaxed" are used to describe proper hand position. How do we know what these hand positions look like, and are these the positions professionals use? Do we use the hand postures we teach? A need for a scientific teaching model exists. Comparing the hand posture of E3 (a note engaging all of the fingers) to three common teaching models may reveal the closest model or generate a new one.

## Models for Comparison

Stein and Guy suggest that fingers should be curved as though holding a tennis ball.[1] Ridenour, Cipolla, and others suggest using a finger posture during

---

[1]Keith Stein, *The Art of Clarinet Playing*, (Miami, FL: Summy-Birchard Inc., 1958), 28-31, and Larry Guy, *Hand and Finger Development for Clarinetists*, (Stony Point, NY: Rivernote Press, 2007), 12-16.

performance similar to when hands hang down by the sides.[2] Campione and Bonade suggest clarinetists use a finger/hand posture similar to the letter "C," as in American Sign Language.[3] Quantitative research comparing finger/hand posture used during clarinet performance to these teaching models may show the effectiveness of the models. One model may prove to be the closest to actual performance, or they could all be quite different from the postures clarinetists actually use. One model may be better for a certain hand size. Studying teaching postures using a pair of CyberGloves® (instruments capable of recording 18 joint angles of each hand at over 100 samples per second) may indicate any variations between playing and teaching postures and will quantify degrees of any variance.

**Importance of this study**

Finding hand posture models that are closest to actual clarinet performance may be a valuable tool for teaching and achieving adequate technique. The clarinet is a machine, and like any other machine, when it is operated efficiently, it can run smoothly and rapidly. Moreover, Klug and other pedagogues warn that inefficient finger motion may lead to injury.[4] Examining

---

[2]Thomas Ridenour, *The Educator's Guide to the Clarinet: A Complete Guide to Teaching and Learning the Clarinet* (Denton, TX: Thomas Ridenour, 2000), 6-2, and John Cipolla, *Clarinet Basics, Foundations for Clarinet Players*, people.wku.edu/john.cipolla/ClarinetBasics.pdf (accessed October 5, 2010), 2-3.

[3]Carmine Campione, *Campione On Clarinet: A Complete Guide to Clarinet Playing and Instruction* (Fairfield: John Ten-Ten Publishing, 2001), 29, and Larry Guy, *The Daniel Bonade Workbook*, (Stony Point, NY: Larry Guy, 2004), 9.

[4]Howard Klug, *The Clarinet Doctor*, (Bloomington, IN: Woodwindiana, 1997), 60-61.

the differences in finger position during an ascending and descending chromatic scale will be useful when learning and/or teaching finger preparation and anticipation, a topic about which several pedagogues have written.[5]

Averaging multiple repetitions of professional clarinetists' hand/finger posture will create a more reliable representation for teaching clarinet hand posture. Finding the hand/finger posture differences for each pitch across all subjects may show variance of finger posture among professional clarinetists and may reveal differences in posture based on hand size and shape that can be generalized and categorized.

**Hypotheses**

Prediction: clarinetists with larger hands and longer fingers will have higher degrees of finger flexion than clarinetists with smaller hands and shorter fingers, while clarinetists with smaller hands and shorter fingers will have higher degrees of finger extension than clarinetists with larger hands and longer fingers. The position of the thumb on the thumb rest will affect the degree of flexion and extension of the fingers.

The finger motion and postures used by professional clarinetists can be quantified and characterized to form the basis of a scientific teaching model for clarinet hand and finger positions. Measurements taken using right- and left-hand CyberGloves® will reveal differences in finger motion among six professional clarinetists, the data can be generalized to estimate efficient finger motion, and

---

[5]Larry Guy, *The Daniel Bonade Workbook*, (Stony Point, NY: Larry Guy, 2004), 9.

may be categorized by hand size if clarinet hand posture and motion correlates with individual hand size and shape. Hand shape and finger motion adaptations may exist based on individualization.

**Overview**

Outlining the scope of this research is necessary for clearly defining the objectives of this document. Chapter 2 explains hand anatomy, and Chapter 3 explains hand biomechanics. Chapter 4 is a detailed literature review of the pedagogical literature on clarinet hand position, a summary of the traditional methods used to teach clarinet hand position, and a discussion addressing why a quantitative representation may be useful. Chapter 5 introduces the CyberGlove® and summarizes other studies using this tool as an effective way to measure finger motion and hand posture. Chapter 6 outlines the methods of this study, while Chapter 7 lists the results of the collected data. Chapter 8 is a discussion of the results, and Chapter 9 concludes the study.

# CHAPTER 2: ANATOMY OF THE HAND

## Planar Classification and Motion

To define joint and segment motions and to record the location in space of specific points on the body, a reference point is required. A three-dimensional rectangular coordinate system is used to describe anatomic relationships of the body. The standard anatomic body position is defined as standing erect with the head, toes, and palms of the hands facing forward and with the fingers extended away from the palms. Three imaginary planes, the sagittal, transverse, and coronal planes, are arranged perpendicular to each other through the body, with their axes intersecting at the center of gravity of the body. These planes are called the cardinal planes of the body.[6]

[6]L. K. Smith, E. L. Weiss, and L. D. Lehmkuhl, *Brunnstrom's Clinical Kinesiology*, 5th ed. (Philadelphia: F.A. Davis, 1996), 2-6.

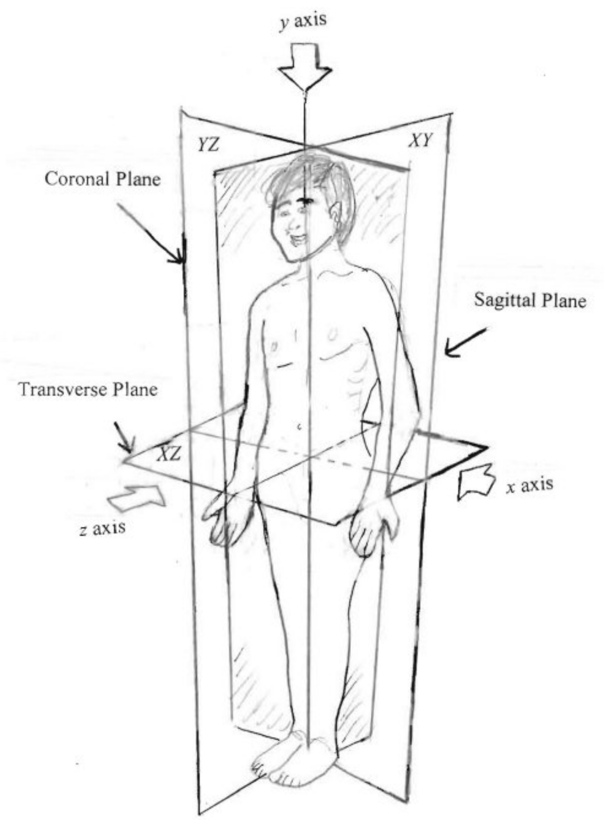



Figure 1. Planes of the body

The coronal (XY plane) is parallel to the frontal bone and divides the body into front and back parts. Motions that occur in this plane are defined as abduction (position or motion of the segment away from the midline) and adduction (position or motion toward the midline). The sagittal plane (midsagittal or YZ planes) is vertical and divides the body into right and left sides (side views). Joint motions occurring in the sagittal plane are defined as flexion (indicates that two segments approach each other) and extension (occurs when two segments move away from each other) and occur around the x axis. Hyperextension occurs if extension goes beyond the anatomic reference position. The transverse plane (XY plane) divides the body into upper and lower parts, and rotations occur in this plane around the vertical y axis. Internal rotation (inward or medial rotation) is a transverse rotation oriented to the anterior surface of the body. Pronation is the term used for internal rotation of the forearm. Supination is the external rotation (outward or lateral rotation) of the forearm in the opposite direction and is oriented to the posterior surface of the body.[7]

Defining motion of the fingers requires placing the coordinate system on the extremity. In the hand, the sagittal plane is centered through the third segment. Motion or position away from the reference segment is called “abduction,” and motion away toward the segment is called “adduction.” At the wrist, the motion of abduction is radial deviation, and the adduction is ulnar deviation. The thumb is unique because it is normally rotated 90 degrees from the plane of the hand. Thumb motions of flexion and extension occur in the frontal plane, and abduction and adduction occur in the sagittal plane.[8]

The terms “anterior” or “ventral,” and “posterior” or “dorsal” are used to indicate the relation of parts to the front or the back of the body or limbs. The terms “superior” and “inferior” to indicate the relative levels of different structures, and structures nearer to or farther from the midsagittal plane are referred to as “medial” or “lateral,” respectively. The terms “superficial” and “deep” only refer to the relative depth from the surface of various structures. In

---

[7]Ibid.

[8]Ibid.

the context of limbs, the terms “proximal” and “distal” refer to the relative distance from the attached end limb.[9]

**Hand Anatomy Overview**

The hand and wrist are comprised of 27 bones. The wrist alone contains eight small bones called carpals. These carpals join with the two forearm bones, the radius and ulna, forming the wrist joint. Further into the palm, the carpals connect to the five metacarpals, one for each finger and thumb. Small bone shafts called phalanges line up to form each finger and thumb.[10] The main knuckle joints are formed by the connections of the phalanges to the metacarpals. These joints are called the metacarpophalangeal joints (MCP joints). The MCP joints work like hinges to bend (flexion) and straighten (extension) the fingers and thumb. The three phalanges in each finger are separated by two joints, called interphalangeal joints (IP joints). The one closest to the MCP joint (knuckle) is the proximal IP joint (PIP joint). The joint near the end of the finger is the distal IP joint (DIP joint). The thumb has only one IP joint between the two thumb phalanges. The IP joints of the digits also serve as hinges for the fingers and thumb.[11]

The joints of the hand, fingers, and thumb are covered on the ends with articular cartilage, a white, shiny material with a rubbery consistency. The

---

[9]Henry Gray, *Anatomy of the Human Body* (New York: Lea and Febiger, 1918), 34.

[10]Ibid., 220-230.

[11]Ibid., 324-333.

function of articular cartilage is to absorb shock and provide an extremely smooth surface to facilitate motion. Articular cartilage may be found everywhere that two bony surfaces move against one another, or articulate.[12] The front, or palm-side, of the hand is referred to as the "palmar side." The back of the hand is called the "dorsal side."[13] The rest of this chapter will discuss bones, muscles, joints, and ligaments of the hand; the discussion of nerves, veins, arteries, and skin is beyond the scope of this paper.

**Osteology**

The skeleton of the hand is divided into three segments: wrist bones (carpus), the palm (metacarpus), and the digits (phalanges).[14] Figure 2 on page 12 is a detailed sketch displaying the bones of the hand.

*The Carpals*

The eight carpal bones are located in two rows: the proximal row, from the radial to the ulnar side, are the navicular, lunate, triangular, and pisiform, and the distal row (same order) are the greater multangular, lesser multangular, capitate, and hamate. Each bone (excluding the pisiform) has six surfaces. The volar (anterior) and the dorsal (posterior) surfaces are rough, for ligamentous attachment, while the dorsal surfaces are broader, except in the navicular and lunate. The proximal (generally convex) and distal (concave) surfaces are articular; the medial and lateral surfaces are also articular in the area of contact

---

[12]Ibid.

[13]Ibid., 31.

[14]Ibid., 221.

with neighboring bones, otherwise they are rough and tuberculated. These bones are comprised of a spongy tissue enclosed in a layer of compact bone.[15]

*The Metacarpals*

The metacarpals consist of five cylindrical bones numbered from the lateral side (ossa metacarpalia I-V); each comprise a body and two extremities. The body is prismoid-shaped and has three surfaces: dorsal, lateral, and medial. The medial and lateral surfaces are concave for the attachment of interossei, and separated by a prominent anterior ridge. The dorsal surface in its distal two-thirds, is a smooth, triangular, flattened area, covered by the tendons of the extensor muscles. This surface is bound by two lines, commencing in small tubercles on either side of the digital extremity, pass upward, converge and meet above the center of the bone and form a ridge running along the rest of the dorsal surface to the carpal extremity. The ridge separates two surfaces for the attachment of the interossei dorsales. The tubercles on the digital extremities have collateral ligaments of the metacarpophalangeal joints attached to them.[16]

The base of the metacarpal is cuboidal-shaped and articulates with the carpals and adjoining metacarpal bones. Its dorsal and volar surfaces are rough for the attachment of ligaments. The head of the metacarpal is an oblong surface, convex from before backward, less so transversely, and flattened from side to side and articulates with the proximal phalanx. The head is broader and extends farther upward on the volar than on the dorsal surface, and is longer in the antero-

---

[15]Ibid.

[16]Ibid.

posterior than in the transverse diameter. On either side of the head, a tubercle attaches the collateral ligament of the metacarpophalangeal joint. The dorsal surface (broad and flat) supports the extensor tendons; the volar surface is grooved for the flexor tendons, and marked on either side by an articular eminence continuous with the terminal articular surface.[17]

*The Phalanges*

There are fourteen phalanges in the hand, three for each finger and two for the thumb, each consisting of a body and two extremities. The body of the phalange tapers from above downward, is convex posteriorly, concave in front from above downward, and flat from side to side. The sides are rough, allowing attachment to the fibrous sheaths of the flexor tendons. The proximal extremities of the bones of the first row present concave, oval articular surfaces, while the proximal extremity of the second and third rows present a double concavity separated by a median ridge. The distal extremities are smaller than the proximal, each ending in two condyles separated by a shallow groove. The ungual phalanges are convex on their dorsal and flat on their volar surfaces, small in size, and are characterized by a roughened, elevated surface of a horseshoe shape on the volar surface of the distal extremity.[18]

Please see Appendix A for detailed tables of muscles, joints, ligaments, tendons, and other related structures of the hand.

---

[17]Ibid., 227-228.

[18]Ibid., 230.

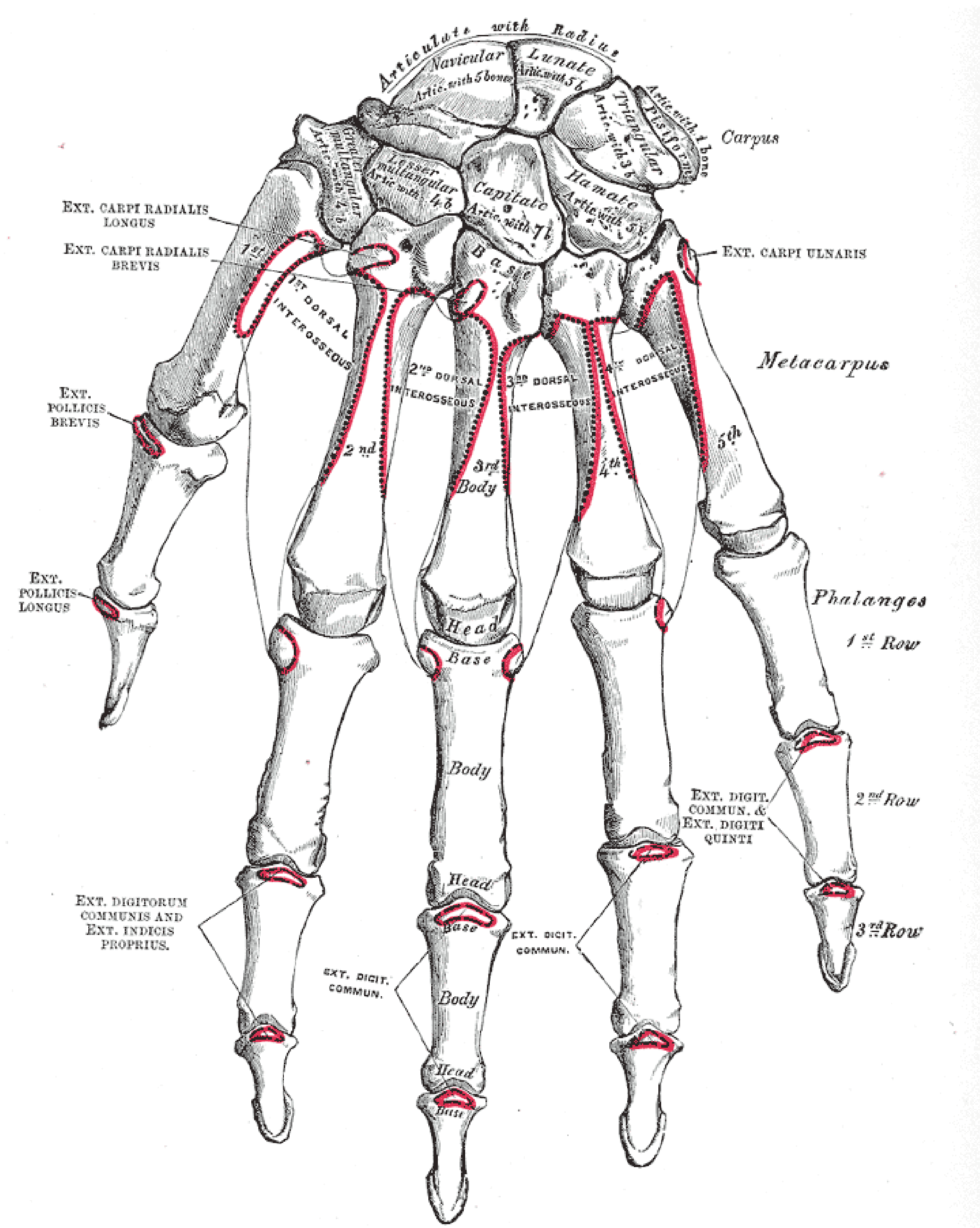



Figure 2. Bones of the hand[19]

[19]Ibid.

# CHAPTER 3: BIOMECHANICS OF THE HAND

This chapter addresses joints of the hand and wrist, mechanisms for flexion and extension, the muscles transmitting force to the extensor mechanism, arches of the hand, types of grasp, and the functional position of the hand.

## Wrist Joint

The wrist provides structural stability and mobility of the hand and is highly complex with 17 joints, 15 bones, and an extensive ligament system. The radiocarpal joint (a wrist joint) is formed by the distal end of the radius and the proximal articulating surfaces of the scaphoid and lunate bones. A triangular fibrocartilaginous disk connects to the distal end of the radius, and the styloid process of the ulna with the apex of the disk connects to the triquetrum. The disk fastens the radius and ulna together and divides the ulna and the distal radioulnar joint from the radiocarpal joint. Partial wrist motions of flexion (volar flexion), extension (hyperextension), ulnar abduction (ulnar deviation), and radial abduction (radial deviation) occur at the radiocarpal joint.[20]

The midcarpal joint is shaped by the distal and proximal carpal rows. The scaphoid articulates with the capitate, trapezium, and trapezoid; the lunate articulates with capitate, and the triquetrum with the hamate. The wrist motions of extension, flexion, and radial and ulnar abduction occur at this joint. The bases of the second to fourth metacarpals articulate with each other and with the distal row of carpal bones to form mortices. A common joint cavity occurs between the

---

[20] L. K. Smith, E. L. Weiss, and L. D. Lehmkuhl, *Brunnstrom's Clinical Kinesiology*, 5th ed. (Philadelphia: F.A. Davis, 1996), 184-189.

carpometacarpal (CMC) joint articulations, the four carpals, and into the intermetacarpal joints. The motion in the second and third CMC joints is two degrees or less, while the fourth has 10 to 15 degrees of movement, and the fifth is more flexible with 25 to 30 degrees of motion. Even though the movements at each individual joint are small, collectively, the motions provide for a large change in the shape of the transverse arch (discussed later).[21]

The CMC joint of the thumb is shaped by the trapezium and the base of the first metacarpal. Motions at the CMC joint include abduction, adduction, and opposition, the latter of which is a rotation of the first metacarpal on the trapezium to place the pad of the thumb opposite the pads of the two fingers. The laxity or looseness of this joint capsule allows 15 to 20 degrees of rotation.[22]

**Wrist Ligaments**

Ligaments cover the dorsal, radial, ulnar, and volar areas of the wrist. These ligaments stabilize joints, permit and guide motion of bones, limit joint motion, transmit forces from the hand to the forearm, and prevent dislocation of carpal bones with movement. The extrinsic ligaments connect the radius, ulna, or metacarpals to the carpal bones; intrinsic ligaments run between the carpal bones only. Short, strong, ligaments fasten the distal row of carpal bones to each other (intrinsic, short, interossei) and to the bases of the metacarpals (extrinsic, distal, CMC ligaments). The second to fourth metacarpals and the distal row of the carpal bones form a fixed unit or block without appreciable motion. Intrinsic,

---

[21]Ibid.

[22]Ibid.

medium-length ligaments connect the carpal bones, permitting more motion; most of the individual carpal (lunate, triquetrum, scaphoid, and trapezium) movements occur with these ligaments.[23]

Medial and lateral collateral ligaments and strong oblique V-shaped ligaments articulate the two rows of carpals to each other and to the radius and the ulnar fibrocartilanious disk. The extrinsic ligaments extend from the ulna and radius to converge on the lunate and the capitate. The intrinsic V ligament connects to the scaphoid and triquetrum and converges on the capitate. However, there are no ligamentous connections between the lunate and capitate, allowing considerable movement, including 2 to 3 mm of distraction (separation of joint surfaces without rupture of their binding ligaments and without displacement). The extra-articular ligamentous structures of the wrist are the extensor and flexor retinacula, which enclose the tendons running to the fingers. The flexor retinaculum includes the transverse carpal ligament, a ligament 1 to 2 mm thick and 2 to 3 cm wide, attaching to the hook of the hamate and pisiform bones and coursing to the radial side, where it attaches to the trapezium and the scaphoid. These attachments maintain the transverse carpal arch and shape a tunnel (carpal tunnel) through which the median nerve and the tendons of the flexor digitorum superficialis, flexor pollicis longus, and flexor digitorum profundus travel to the hand. Some muscle tendons have attachments on the retincula; when the muscles (flexor and extensor carpi ulnaris, extensor pollicis brevis, abductor pollicis

[23]Ibid., 184-189.

longus, palmaris longus, and thenar and hypothenar) contract, they pull on the retinacula and stabilize it (dynamic stabilization).[24]

**Wrist Motion and Axes**

Planar motions of the wrist occur at the midcarpal and the radiocarpal joints. According to Kapandji, the midcarpal joint is responsible for one-half of the motion of radial abduction and for one-third of the range of ulnar abduction with the remaining motion occurring at the radiocarpal joint.[25] These motions take place around an axis through the head of the capitate. The normal end-feel (the quality of resistance at end of range) for radial abduction is typically hard from contact of the scaphoid on the styloid process of the radius. Ulnar abduction has a firm end-feel from tension on the radial collateral ligament and provides more motion.

Kapandji states there are 50 degrees of motion at the radiocarpal joint and 35 degrees at the midcarpal joint in wrist flexion. The values reverse in full extension with 35 degrees occurring at the radiocarpal and 50 degrees at the midcarpal joint.[26] The axis of motion is also through the capitate, but migrates distally from full flexion to extension. This migration is caused by complex movements of the scaphoid and lunate, including rotational and translatory

---

[24]Ibid.

[25]IA Kapandji, *The Physiology of Joints, Vol 1, Upper Limb,* 2nd ed. (Edinburgh: Churchill Livingstone, 1970) 122-145.

[26]Ibid.

motions with change in their effective height, and these complex motions are compensatory to maintain tension of the ligaments at all times.[27]

Slight spreading of the distal radius and ulna occurs during full wrist extension. When the forearm and hand are relaxed, the wrist is unstable and permits a considerable amount of passive joint play movements. The most stable (closed-packed) position of the wrist is in full extension.[28] The normal end ranges of motion for the wrist vary between individuals and between children and adults.

Table 1. Approximate End Ranges of Motion for the Adult Wrist[29]

| Movement | Degree |
|---|---|
| Flexion | 0 to 90 degrees |
| Extension | 0 to 70 degrees |
| Ulnar abduction | 0 to 30 degrees |
| Radial abduction | 20 degrees |
| Pronation from midposition | 0 to 80 degrees |
| Supination from midposition | 0 to 90 degrees |
| Neutral when forearm and third metacarpal are in line | 0 degrees |

**Joints of the Fingers**

The metacarpophalangeal (MCP) joints of the fingers are condyloid joints with two degrees of freedom. The rounded surfaces of the metacarpal heads articulate with the concave, shallow surfaces on the bases of the proximal

[27]JN Kuhlmann and R Tubiana, Mechanism of the Normal Wrist, in JP Razemon and GR Fisk (eds): *The Wrist* (Edinburgh: Churchill Livingstone, 1982) 55-64.

[28]L. K. Smith, E. L. Weiss, and L. D. Lehmkuhl, 184-189.

[29]Ibid., 7.

phalanges. Approximately three-quarters of the circumference of the metacarpal heads are covered with articular cartilage, which extends onto the volar surface, and the articular surfaces of the base of the phalanges are extended by fibrocartilaginous volar plates. When the MCP joint is flexed, the volar plate slides proximally under the metacarpal with a folding of the membranous part. This mechanism allows a large range of motion for the small articulating surface of the phalanx. Accessory collateral ligaments manage movement of the volar plate, and the metacarpal pulley for the long flexor tendons merges with these structures.[30]

Lateral and medial collateral ligaments attach from the metacarpal heads to the bases of the phalanges. The points of attachment of these ligaments are longer when the joints are flexed than when they are extended, and abduction and adduction can occur when the joints are extended. The collateral ligaments become taut and abduction cannot be performed when the MCP joints are flexed to 90 degrees, a positioning that stabilizes the MCP joints for gripping. The deep transverse metacarpal ligament is connected to the volar plate and between the metacarpal heads to connect adjacent sides of metacarpals II to V, permitting a flexible metacarpal arch and limiting the spread of the bones.[31]

Two sesamoid bones are connected to the volar plate on its palmar surface in the thumb, and are located in the tendons of attachment of the adductor pollicis and the first dorsal interosseous ulnarly and the flexor pollicis brevis and the

---

[30]Ibid., 189-191.

[31]Ibid.

abductor pollicis brevis radially. The sesamoid bones have medial and lateral ligaments at the metacarpals and several other ligaments joining the structure to the base of the phalanx. The sesamoid mechanism allows a dynamic rotation of the thumb segment supplying precision in pinching.[32]

Each of digits II to V has two interphalangeal (IP) joints: the proximal interphalangeal (PIP) and distal interphalangeal (DIP) joints. However, the thumb has only two phalanges and consequently only one IP joint. IP joints are classified as hinge joints with one degree of freedom. The IP joints have volar plate mechanisms similar to the MCP joints with the addition of check rein ligaments preventing hyperextension. The check rein ligaments cross the joints on the volar surface on either side of the flexor tendon sheath.[33]

Finger metacarpophalangeal joints (MCP) have approximately 90 degrees of flexion; the index finger having slightly less range and the middle, ring, and little fingers having successively more range. Hyperextension is variable depending on ligamentous structure; some people may be able to extend the MCP joints to only 0 degrees while others with ligamentous laxity may be able to hyperextend up to 45 degrees. Passively, some people can hyperextend to 90 degrees. The normal end-feel is firm from restriction by the volar plate and capsule.[34] The collateral ligaments are slack and permit about 20 degrees of abduction and, if adjacent fingers are moved away, about 20 degrees of adduction

---

[32]Ibid.

[33]Ibid.

[34]Ibid.

when the MCP joint is extended. The collateral ligaments are taut and abduction or adduction is limited to a few degrees at best in 90 degrees of flexion (closed packed position of the joint).[35]

The MCP joint of the thumb is a hinge joint and has a smaller range of motion than the MCP joints of the fingers; flexion occurs from 45 to 60 degrees and hyperextension from 0 to 20 degrees. Ligaments tighten and there is little abduction or adduction in full flexion and extension. In semiflexion, 5 to 10 degrees of side-to-side motion can occur, and a dynamic rotation of the phalanx is produced by contraction of the muscles to the medial or the lateral sesamoid bone, permitting the thumb to fit precisely around objects for grasping.[36]

Distal and proximal IP joints are hinge joints with one degree of freedom. The bicondylar heads of the phalanges and greater tension of the collateral ligaments constrict abduction and adduction motion. Flexion of the PIP joints is about 120 degrees and while flexion of the DIP and IP joints is slightly less than 90 degrees. Extension of the PIP and DIP joints is to 0 degrees with the exception of individuals with ligamentous laxity where hyperextension is seen. Hyperextension of the thumb IP joint may be 5 to 10 degrees and can be more passive when pressing down with the thumb pad.[37]

---

[35]Ibid.

[36]Ibid.

[37]Ibid.

Table 2. Approximate Ranges of Motion of the Digits[38]

| Thumb: | Fingers: |
|---|---|
| CMC abduction:70 degrees | MCP flexion: 0 to 90 degrees |
| MCP flexion: 45 degrees | MCP hyperextension: 0 to 20 degrees |
| MCP abduction: negligible | MCP abduction: 0 to 20 degrees |
| MCP adduction: negligible | MCP adduction: 0 degrees |
| IP flexion: 0 to 90 degrees | Proximal IP flexion: 0 to 120 degrees |
| | Distal IP flexion: 0 to 90 degrees |
| | IP extension: 0 degrees |

**Mechanisms for Finger Flexion and Extension:**

Mechanisms for finger flexion include the flexor digitorum profundus (FDP, deep muscle) and the flexor digitorum superficialis (FDS, superficial muscle). The extensor mechanism is an expansion of the extensor digitorum comunis (EDC) tendon on the dorsum of each phalanx. The extensor indicis (EI) and the extensor digiti minimi (EDM) insert into the extensor mechanisms of the second and fifth digits, respectively. Several tendinous structures comprise the extensor mechanism; the EDC tendon attaches with a tendinous slip to the proximal phalanx and extends to the MCP joint. The central tendon attaches (dorsally) to the base of middle phalanx, and tension of this tendon extends the PIP joint. Lateral bands proceed on either side of dorsal midline and rejoin before attaching to the distal phalanx. Tension in the lateral bands extends the DIP joint. The extensor hood surrounds the MCP joint laterally, medially, and dorsally, and receives tendinous fibers from the lumbricales and interossei. Extension of the

[38]Ibid., 7.

PIP and DIP joints can occur without also extending the MCP joints, however, the PIP joint cannot extend without extending the DIP joint at the same time. Flexing only the DIP joint without also flexing the PIP joint is difficult, and full (active or passive) flexion of the PIP joint prevents active extension of the DIP joint.[39]

**Muscles Permitting Finger Motion**

Muscles transmitting force to the extensor mechanism include the dorsal interossei (DI), palmar interossei (PI), and lumbricales. The dorsal interossei attach proximally between adjacent metacarpals and distally either to bone (proximal phalanx) or to soft tissue (extensor mechanism). The dorsal interossei produce MCP abduction and, in certain instances, MCP flexion. Because they attach to the extensor mechanism, they also produce PIP and DIP extension. Abduction is stronger at the second MCP joint because most of the first DI's muscle fibers attach directly to the second proximal phalanx. Abduction of the fourth MCP joint is relatively weak since the fourth DI attaches largely to the extensor mechanism itself. Four palmar interossei attach proximally to a metacarpal, and distally to the same digit's proximal phalanx and/or its extensor mechanism. They produce MCP adduction and, in certain instances, MCP flexion. They also produce PIP and DIP extension when they introduce tension into the extensor mechanism. The four lumbricales attach proximally to the tendons of the flexor digitorum profundus, and distally to the extensor mechanism on its radial side at the level of the lateral bands. The muscles pass on the volar side of the transverse metacarpal ligament. If they act alone, they produce MCP flexion.

[39]Ibid., 180-199.

They also produce PIP and DIP extension when they introduce tension into the extensor mechanism. The lumbricals permit a dynamic interaction between flexors and extensors. Their attachments transmit their force to both the FDP tendon and the extensor mechanism. Specifically, lumbrical activity increases passive tension in the extensor mechanism and decreases passive tension in FDP tendon's distal portion.[40]

**Extensor Mechanism**

The extensor mechanism's fibers are tendinous and incapable of producing active force, but transmit force to their attachments. Many of the hand's intrinsic muscles attach to the extensor mechanism, and activity in any of these muscles produces force that the extensor mechanism communicates to its distal attachments. The extensor mechanism develops passive tension whenever it is elongated. Hand movements that passively elongate either the extensor mechanism or a structure that attaches to the extensor mechanism produce force in the extensor mechanism itself. The extensor mechanism's fibers have lines of application that are always dorsal to the lateral axes of the PIP and DIP joints. Therefore, activity in the intrinsic muscles attaching to the extensor mechanism always produces DIP and PIP extension. Passive flexion of the MCP joint elongates the extensor mechanism and extends the PIP and DIP joints. The fibrous lines of application in the hood and lateral bands pass near the MCP joint's lateral axis.

---

[40]Ibid., 200-209.

MCP flexion occurs when activity in the FDS or FDP flexes the MCP joint. The extensor mechanism is not stretchy. When the digits flex, passive tension in the lateral bands and central slip pull the hood distally. When the MCP joint is already flexed, the lines of application of the interossei fall on volar side of the MCP joint and produce MCP flexion. The distal shift in the extensor hood also increases the lumbricals' moment arm and produces a greater flexor moment at the MCP joint. In MCP extension, action in the extensor digitorum extends the MCP joint and pulls the extensor mechanism (including the hood) proximally. In this position, the interosseous muscles' lines of application are very close to the MCP joint's lateral axis.[41]

**Arches**

Three arches balance stability and mobility in the hand: the proximal transverse, distal transverse and longitudinal arch. The proximal transverse arch is a composite of two arches, the proximal and distal carpal arches according to Hertling and Kessler.[42] This arch is a stable bony arch that forms the posterior border of the carpal tunnel. The arch's integrity is maintained by a soft tissue "strut" formed by the flexor retinaculum or transverse carpal ligament. This ligamentous strut connects the scaphoid and trapezium on the arch's radial side with the hamate on its ulnar side and forms the anterior border of the carpal tunnel. The distal transverse arch is sometimes referred to as a metacarpal arch as

---

[41]Ibid.

[42]D. Hertling and Kessler, *Management of Common Musculoskeletal Disorders: Physical Therapy Principles and Methods*, 3rd ed. (Philadelphia: J.B. Lippincott, 1996), 257.

it is formed by the metacarpal heads; metacarpals two and three are stable while four and five are relatively mobile.[43] The combination of radial stability and ulnar mobility of the arch can be observed when loosely closing the fist and then squeezing more tightly, resulting in movement of the more mobile fourth and fifth metacarpals. The longitudinal arch can be observed when loosely closing a fist position. The proximal transverse arch is rigid, but the other two arches are flexible and are maintained by activity in the intrinsic muscles of the hand.[44]

**Grasp**

Two types of grasp are differentiated depending on the position and mobility of the carpometacarpal and metacarpophalangeal joints of the thumb: the power grasp and precision grasp. The power grasp involves the adductor pollicis stabilizing an object against the palm while the hand's position is static, or holding an object between the partially flexed fingers and the palm while the thumb applies counter pressure (this grip is used when full strength is needed). The power grasp includes the cylindrical grip (ex. fist grasp is a small diameter cylindrical grasp), the spherical grip, the hook grip (metacarpophalangeal extended with flattened transverse arch, sometimes includes the thumb), and the lateral prehension (this can be a power grip if the thumb is adducted, a precision grip if the thumb is abducted). The precision grasp involves an object pinched between the flexor surfaces of one or more fingers and the opposing thumb (active muscles abduct or oppose the thumb while the hand's position is dynamic)

[43]Ibid.

[44]L. K. Smith, E. L. Weiss, and L. D. Lehmkuhl, 216-219.

and includes palmar prehension (pulp-to-pulp and tripod grips), tip-to-tip (with flexor digitorum profundus active to maintain distal interphalangeal flexion), and lateral prehension (pad-to-side; key grip).[45]

The precision grasp is close to actual clarinet hand posture. However, clarinetists should not grasp or grip the clarinet while playing (technique is seriously stunted when the fingers are not allowed to move freely); only the right thumb and embouchure should support the instrument.

**Functional Position of the Hand**

The functional position of the hand and wrist is the position naturally assumed by the hand to grasp an object, or the position from which optimal function is most likely to occur. The functional position is one in which the wrist is slightly extended, the fingers are slightly flexed at all their joints, and the thumb is in midrange opposition, with the MCP joints moderately flexed and the interphalangeal joints slightly flexed. From the functional position, it is possible to grasp an object with minimal effort.[46]

This position also provides the hand and wrist with both a fixed and mobile segment. The fixed segment (stabilizing segment) consists of the distal row of carpal bones and the second and third metacarpals. There is less movement between these bones than between the bones of the mobile segments. The mobile

---

[45]Ibid., and D. Hertling and Kessler, 259-260.

[46]Ibid., 260.

segment consists of the five phalanges and the first, fourth, and fifth metacarpals. This position permits stability without rigidity.[47]

*Hand Biomechanics and Clarinet Pedagogy*

The functional position of the hand is strikingly similar to the ideal clarinet hand posture according to several pedagogical models. Various authors cited in Chapter 4 all teach naturally curved finger posture, while some pedagogues teach a “C” posture for the hands, and others suggest holding a tennis ball to find the correct arch of the palm and fingers. Clarinet tone hole and key placement permits clarinetists to use hand positions similar to the functional hand position.

The functional hand position should be used for teaching clarinet hand posture; fingers partially flexed at all joints (curved), wrists slightly extended, and finger motion executed with minimal effort. Table 3 defines approximate joint angle ranges for forming a biomechanically sound clarinet position. Joint angle ranges over these guidelines should be considered excessive and result in wasted muscle and ligament effort.

[47]Ibid.

Table 3. Approximate Joint Angles for Biomechanically Sound Clarinet Hand Posture[48]

| Location | Position |
|---|---|
| Wrist | extended 20 degrees<br>ulnarly deviated 10 degrees |
| Digits 2 through 5 | MCP joints flexed 45 degrees<br>PIP joints flexed 30-45 degrees<br>DIP joints flexed 10-20 degrees |
| Thumb | first CMC joint partially abducted and opposed<br>MCP joint flexed 10 degrees<br>IP joint flexed 5 degrees |

Figure 3. Functional position of the hand[49]

[48]C. C. Norkin and P. K. Levangie, *Joint Structure and Function*, 2nd ed. (Philadelphia: F.A. Davis, 1992), 296 and Hertling and Kessler, 260.

[49]Ibid.

# CHAPTER 4: CLARINET HAND POSITION LITERATURE REVIEW

Several pedagogues have written about clarinet hand and finger position, yet few hand and finger position models exist in the clarinet pedagogical literature. Most authors describe clarinet hand position as “natural” and “relaxed,” while others have provided concrete exercises and gestures to learn ideal clarinet hand and finger position. This chapter will briefly summarize the clarinet pedagogical literature on hand position and finger motion.

## Campione

Campione provides a detailed description of clarinet hand position.[50] He states that the left hand should be angled upward so the clarinetist can easily reach and touch the throat tone G-sharp and A keys. The right hand is also angled, but not to the same degree as the left, since the right index finger must be over the E-flat/B-flat key which is not located as far away as the G-sharp and A keys for the left hand. Campione provides a model for clarinet hand position: he explains that fingers should be slightly bent or curved in a “C” position, because, in this position, fingers are freer and are apt to move more swiftly. Straight fingers tend to be too tense and may not move as quickly as curved fingers. Even the pinkies should be slightly curved, for a straight pinky digit may adversely affect its adjacent ring finger, and these two fingers often work in together during clarinet performance.

---

[50]Carmine Campione, *Campione On Clarinet: A Complete Guide to Clarinet Playing and Instruction*, (Fairfield: John Ten-Ten Publishing, 2001), 29.

Campione argues that tone holes should be covered by the fleshy or meaty area of the fingers (pulpy pad), between the last joint (distal) of the finger and the tip of the finger. Not all fingers will cover the holes in exactly the same place on the meaty surface; some may be slightly off center to meet the essential curved posture of the hand. According to Campione, it does not matter what part of the meaty section covers the holes, as long as the player does not use the bony areas.

He also instructs that the left hand thumb is angled so it can roll from its holed key to the register key. Campione argues that there is one basic left hand thumb position—one that allows the hole to be covered while it rolls upward to press the register key. The ring finger of each hand contacts a fork key, which should be played with the bony part or fingertip rather than the meaty part (pulpy pad), since using the meaty part of the finger to touch the fork keys could lead to crowding the fingers and overlapping tone holes, affecting pitch, especially in the right hand.

Campione notes that any extraneous tension or pressure in the fingers negatively affects speed; moving fingers rapidly, he argues, requires little or no tension or pressure in the fingers. However, sometimes performance anxiety can stiffen the fingers, and the physical task of the fingers holding and stabilizing the clarinet can get in the way of light finger pressure. For these reasons, players should strive to keep fingers as tension-free as possible. Campione also stresses that the fingers should be kept close to the keys to develop good technical proficiency on the clarinet, because straying fingers take longer to return to the instrument.

**Bonade**

Bonade said, "The tone is in the fingers;"[51] he valued smooth finger motion and its effect on tonal quality. Bonade taught students to play with highly exaggerated finger motion when playing in slow passages. Raising the fingers high to bring them down slowly and gently allows the player to avoid any slamming or hitting of the keys. For very slow passages, the fingers may form a little circular motion at the top before dropping. Bonade notes that this technique ensures the fingers stay relaxed and curved. He also advocated raising and lowering the fingers from the knuckle at the base of the fingers and to keep the first and second finger joints curved. In *The Daniel Bonade Workbook*, Guy includes a "C to O" hand exercise to learn Bonade's legato finger motion. The exercise begins by forming a pair of C's with the fingers and then slowly closing the fingers down to the thumbs, making a pair of O's. Then, Guy asks the player to move the fingers slowly, as if pushing against a resistance.[52] However, this teaching concept seems as though it would produce tension in the hands. Pushing against a resistance may lead to creating tension with opposing muscles in the hands, which is an action many pedagogues say to avoid.

For faster playing, Bonade taught a finger anticipation technique, or moving the fingers toward the next key so the fingers touch the next key before depressing it. The fingers still move in a wavy motion but do not lift as high from

---

[51]Larry Guy, *The Daniel Bonade Workbook*, (Stony Point, NY: Larry Guy, 2004), 9.

[52]Ibid.

the keys as in the slow, legato technique. He advises keeping the fingers soft and using only enough pressure to activate the spring.[53]

**Ridenour**

Ridenour suggests finding a natural hand position by hanging the hands at the sides and transferring this natural, relaxed curved position to the clarinet. In this position, the tone holes are covered with the rounded area near the fingertips instead of the flatter area lower on the top finger joint.[54] To maintain curved fingers while playing, movement should occur only at the lowest finger joint (as Bonade taught). Straight fingers require excessive motion, present unnecessary tension, and seriously limit technique and technical development. Ridenour recommends practicing regularly in front of a mirror to see how the fingers move and to avoid any wasted motion, straightness of fingers, and miscoordinations.[55] He emphasizes that closure of the tone holes should be an act of controlled relaxation, not of tension, and he provides exercises to practice finger motion. Ridenour devised a "touchpoint" technique (see *The Educator's Guide to the Clarinet* for more information) as a method to learn economized finger motion through keeping the fingers close to the keys of the clarinet. He also advises that

---

[53]Ibid., 18.

[54]Thomas Ridenour, *The Educator's Guide to the Clarinet: A Complete Guide to Teaching and Learning the Clarinet*, (Denton, TX: Thomas Ridenour, 2000), 6-2.

[55]Ibid.

proper instrument maintenance will prevent squeezing and excess tension in the hands and specifies very descriptive roles for each finger of the hand.[56]

**Cipolla**

Like Ridenour and others, Cipolla suggests the position of the hands and fingers during clarinet performance should be comparable to the relaxed position of the hands when hands hang down by the sides.[57] He suggests dropping one hand to the side in a rest position with the fingers pointing downward toward the floor to find the ideal hand position. The fingers should not be extended, but should fall into their natural, slightly curved position. To transfer this hand position to the clarinet, one must bend the arm up at the elbow until the forearm is parallel with the floor, leaving the hand, wrist, and fingers in exactly the same position as when they were pointing down toward the floor. Cipolla instructs clarinetists to adapt the relaxed finger position enough so that the fingers can cover the rings and holes of the instrument, and he suggests keeping the fingers close to the relaxed position. Frequently reminding the hand muscles of this position by occasionally dropping the hands to one's side during practice will help reinforce this hand posture.[58]

---

[56]Ibid.

[57]John Cipolla, *Clarinet Basics, Foundations for Clarinet Players*, people.wku.edu/john.cipolla/ClarinetBasics.pdf (accessed October 5, 2010), 2-3.

[58]Ibid.

**Pino**

According to Pino, the player should not reach for anything in a correct clarinet hand position. Fortunately, the clarinet is built so that all the keys and holes are within reach (assuming the player does not have unusually small hands) without the player's fingers ever moving from one basic position. Pino also notes that the right thumb is the only holding support given the clarinet (no grasping or squeezing from the fingers); the embouchure only keeps it from falling off the thumb. Pino teaches hand position by describing elements of bad hand position (hooking the right index finger under the E-flat/B-flat key, having pinkies behind the clarinet to hold it, slapping the keys, etc). The wrists should be comfortable but rather low, since the right-hand pinky will barely reach the four lowest keys if the wrist is too high. Each finger should have a slight bit of rounding in its knuckle, the fingers should never straighten when playing, and tone-holes should be covered by the soft ball (pulpy pad) of the finger.[59]

Pino emphasizes that relaxed fingers maintain a slight arch in each joint. Tenseness and stiffness can creep into the fingers, and consequently the fingers start grasping at the keys and rings and even hold the clarinet, leading to technical problems. The fingers should never be pushed into place, but must be thought of as individual, relaxed, rather heavy weights that are raised and lowered solely by

---

[59]David Pino, *The Clarinet and Clarinet Playing*, (Mineola, NY: Dover, 1998), 66-68.

the joint (similar to Ridenour) attached to the palm of the hand. The outer two joints in each finger should never flex.[60]

**Stubbins**

According to Stubbins, every effort to form a comfortable and natural hand/finger position should be made; a poor hand position can be described as an unnatural use of the hands and a distortion of the natural curve and flexibility of the fingers.[61] The fingers should lay across the keys of the clarinet at approximately a 45-degree angle to the vertical axis of the instrument.

Stubbins provides descriptions of each finger's role. The left index finger should touch the G-sharp key with the second knuckle and the A natural key with the inside corner of the first knuckle of the same finger, and the tip of this finger should overlap the first tone-hole. This finger's contact with these two keys should remain undisturbed even during rapid passages. The resulting position will provide a fulcrum for the left hand and will eliminate unnecessary motion of the left wrist, consequently removing inefficient finger motion. The right index finger should be placed across the side keys of the instrument so that the second knuckle rests against the E-flat/B-flat side key. The tips of both pinkies should only touch the tips of the long lever keys. The third and fourth fingers of each hand should fall naturally in place with their position guided by the position of the index fingers and the pinkies. The left thumb is placed across the thumbhole with the

[60]Ibid.

[61]William Stubbins, *The Art of Clarinetistry*, (Ann Arbor, MI: Ann Arbor Publishers, 1965), 212-217.

inside corner of the tip resting against the register key. An angled left thumb position allows the player to depress the register key alone, cover the thumbhole without pressing the register key, and cover the thumbhole and depress the register key at the same time. To check the proper finger position of the left hand thumb and index finger, an X formation should occur when the two fingers are removed from the instrument (not a cross). Then the fingers can be returned to the instrument by opening the hand.[62]

According to Stubbins, the tone-holes should be covered with the fleshy part of the finger (pulpy pad). The fingers should not be used as plugs to stop the tone-holes. The fingers should not be flat, as the most natural position of the fingers is slightly curved and may be observed in any hand rest position. If a similar position to the natural rest position of the hand can be adapted to the clarinet, an excellent hand position will result.[63]

Many difficulties encountered in playing the clarinet can be traced to the lack of proper support. According to Stubbins, the instrument must be brought up to the player (like Pino), the embouchure formed, and the fingers of both hands allowed to play on the clarinet while it is supported with the right thumb. If any attempt is made to support the clarinet with the embouchure, good tone production is impossible, and if the fingers are required to support the instrument, then freedom of finger movement is seriously stunted. For this reason, players

---

[62]Ibid.

[63]Ibid.

often support the clarinet with their knee or neckstrap, which are not disadvantageous, provided the right thumb support is still the guiding factor.[64]

Stubbins suggests finger movement should be as conservative as possible with precise and accurate movements. Clarinet keys with pads are used to cover many of the holes, while seven other holes are covered with the pads of the fingers. The resonant sound of the fingers on the tone-holes should be balanced with the resonance produced by the closing of a key's pad. Stubbins also argues that finger motion between two notes in rapid sequence and between two notes of a slow passage is exactly the same. The only difference is that the finger action is delayed by sustaining the first of the slower notes for a longer time than the first of the rapid notes, but when the time arrives to change from one note to another, the change is instantaneous in both cases. For this reason, finger motion must be as quick and precise in a slower passage as it is in a more rapid one.[65]

**Klug**

Klug teaches that body and hand positions have an important influence over the ease with which the clarinet is played. Often young clarinetists sacrifice an ideal body posture when coping with the uncomfortable weight of the clarinet, so he suggests using a non-stretching neck strap to alleviate this problem. A neck strap will also avoid many right hand finger alignment problems that occur when the player is trying to support the weight of the instrument. Klug believes right hand position issues begin because method books start the clarinetist on left hand

[64]Ibid.

[65]Ibid.

notes, leaving the right hand nothing to do for weeks except learn a collapsed hand position to support the weight of the instrument. To avoid bad right hand position habits, Klug suggests the beginner's right hand hold the weight of the instrument by grasping the barrel, or by holding the thumb rest between the right hand thumb and index finger, or using a neckstrap.[66]

Klug also believes incorrect finger posture begins at the onset of learning the instrument and is difficult to correct. He explains that the finger holes on the clarinet are quite large, but the typical finger size of most fourth to sixth grade beginners is quite small. Even though a curved finger position is taught, young students may not be able to cover the holes with a curved finger posture, so they learn to flatten the first knuckle joint back from the fingernail to cover the holes. This flat finger posture is sufficient until the speed of the notes gets faster and until the student's hand matures into near-adult size. Flattened fingers slow the lifting process and result in numerous technical problems. By tenth or eleventh grade, the student's hand is large enough to correct, and the limitations in technique are apparent. Motivationally this problem can be a difficult habit to correct, but a curved finger posture is necessary for the student to obtain efficient finger motion.[67]

Being conscious of many musicians' "overuse" medical problems, Klug warns that flattened fingers inflict needless wear-and-tear on the body system. He

---

[66]Howard Klug, *The Clarinet Doctor*, (Bloomington, IN: Woodwindiana, 1997), p.60-61.

[67]Ibid.

compares playing a scale with flat fingers and then with curved to see the change in ligament effort of the forearms near the elbow.[68]

**Guy**

Guy teaches ten concepts for learning a hand position, permitting accuracy and ease of technical facility and efficient finger motion. The fingers should move straight up and down over the keys and rings like soft hammers or pistons, and nearly all finger motion should come from the knuckle where the fingers join the hand, acting like a hinge for the fingers and opening and closing as needed. The fingers should be curved and stay curved as they move up and down. Guy suggests clarinetists with longer fingers will have a more pronounced curve than those with short fingers. The palms should be gently arched, as if holding a tennis ball. This arch should feel "open" and comfortable as one plays.

Guy warns that the left wrist motion should be kept to a minimum at all times. He also advises using the fleshy part of the fingertip (pulpy pad) to close the tone holes and press the keys, and warns against using the absolute tip of the finger or the flatter part of the finger farther away from the tip. The fingers should touch the rings and keys with a gentle "squeeze" at all speeds, rather than hitting, banging, slamming, or grabbing. Guy teaches this gentle "squeeze" technique by placing a miniature marshmallow on the thumb and squeezing it with each curved finger one at a time. To find proper finger alignment, Guys suggests the tips of the fingers line up just past the edges of the rings, imagining a straight vertical line

[68]Ibid.

created by the position of the fingertips. The fingers should hover over or lightly touch keys without depressing or have “home bases” where they stay when not in use. The right little finger home base is the F/C key, while the left little finger home base is the E/B key. As a student of Bonade, Guy also teaches that the height of the finger motion depends upon the speed of the music: high fingers for slow legato passages and close fingers for fast technical passages.[69]

**Stein**

According to Stein, unnecessary tenseness in the body, such as hard embouchure or neck muscles, can be transmitted to the wrists, hands, and fingers, while relaxed areas influence other areas beneficially. Formation of correct or incorrect hand position is often dependent on the manner in which the weight of the clarinet is held by the right hand thumb. Stein suggests bringing a relaxed right hand thumb to the clarinet and limply hooking the thumb rest midway between the end joint and the nail to avoid tension. From the moment playing begins, the two thumb joints and the wrist joints should not stiffen along with the necessary abdominal pressure and embouchure firmness. He also warns against straightened fingers. Inability to cover tone holes completely in early stages of playing encourages the flattened fingers for better coverage, and this poor habit becomes permanently imbedded. Correctly relaxed fingers begin in the upper arms. The biceps should be relaxed and hang loosely from the shoulder joints.

---

[69]Larry Guy, *Hand and Finger Development for Clarinetists*, (Stony Point, NY: Rivernote Press, 2007), 12-16.

Stein advises allowing some “daylight” between the body and arms, keeping the inside elbow joint approximately three inches from the body.[70]

According to Stein, the secret of relaxed arms, hands, and fingers lies in the joints of the shoulders, elbows, and wrists. If the shoulders, elbows, and wrists can be moved freely while playing, it is reasonable to assume that the neighboring muscle areas are free and relaxed. To practice relaxed postures, Stein asks clarinetists to hold each arm out horizontally with the palm facing downward (without clarinet). The natural line at the wrist joint should be almost level with the forearm, rising only very slightly to the knuckles. Next, he instructs to swing the hands inward from the elbow joints to notice the natural shape of the hands and fingers as they approach the approximate positions for clarinet fingering. Facile technique, particularly in the left hand, can be realized only if an almost straight line is maintained from elbow to wrist to knuckles, and he advises clarinetists to disallow the wrists to turn inward toward the body nor outward toward the little fingers. When students are playing, the teacher can check by pressing upon their wrist joints. If they buckle elastically, the joints are properly relaxed, but if they are rigid, they need correction.

The back knuckles (metacarpophalangeal joints) must be situated at a height level with or slightly above the tone holes for best action. A hand position seated too low usually results in a distinct fingering handicap. The fingers should never be held out straight but should be curved as though holding a tennis ball so

[70]Keith Stein, *The Art of Clarinet Playing*, (Miami, FL: Summy-Birchard Inc., 1958), 28-31.

that the padded tips (pulpy pads) rest on the keys and the tone holes. A common mistake is to draw the back knuckles too far away from the clarinet making the fingers straighten out, particularly the fingers operating the third tone holes and the little finger keys of each hand.[71]

Stein describes roles for each finger. The first three left hand fingers should be positioned at almost right angles to the clarinet with a slight lean toward the A-natural and A-flat throat tone keys. The primary obligation of the left index finger is to the tone hole and a secondary one in operating the A and G-sharp throat tone keys. When playing the A key, the finger should raise just enough to allow the metal ring to rise, but still be in contact with the metal itself, hovering over the first tone hole. Depressing the A key from this point is mostly done by a rolling or leaning action sideways. The side of the joint depresses the G-sharp key. The first finger should overlap its tone hole more than the second (not more than 1/4 to 3/8 of an inch), and the second more than the third. In a correct hand position, the back knuckle of the little finger of each hand is level with the others.

The left hand thumb is positioned at an almost right angle to the clarinet with the pad of the thumb nearly covering the hole, but able to press the register key without moving from its position. Stein proposes trying to maintain the slightest arch at the last joint rather than using a tensely indented curve to achieve the correct left hand thumb position.[72] The tendency to place too much right hand thumb past the thumb rest can be remedied by frequently resetting the position

[71]Ibid.

[72]Ibid.

near the thumbnail. The right hand thumb should constantly push the clarinet into the embouchure. Some teachers allow students to rest the bell of the clarinet between the knees, relieving the right hand thumb of weight and avoiding tightening of the wrist. However, the embouchure should not become dependent on this position.

Like the left hand index finger, the right has a double task of executing the side keys in addition to its tone hole. According to Stein, the best right hand position wraps around the lower trill key, concealing it rather than deliberately coming in below it, and should stay as curved as possible when playing these right hand side keys, movement mostly originating from the back knuckle joint. If the index finger braces its second joint on the metal bar joining the tone hole rings, a crippling action will result. To avoid this pitfall, Steins advises keeping the right hand little finger on the low F key to balance the clarinet and to maintain good hand position.[73]

Finger action for most playing should be like a crisp hammer stroke, executed with as much spontaneity in the upstroke as in the downward action. Fingers should be closely observed when not in use, because they may fall out of correct position. He suggests holding inactive fingers in a hovering position over their tone holes while the others are playing. Finger height should remain within 3/8 to 5/8 of an inch from the clarinet when the finger curve is correctly

---

[73]Ibid.

maintained. Stein teaches a light finger grasp allowing the vibrations of the clarinet to be distinctly felt in the hands when playing.[74]

**Gingras**

Gingras argues that it is important to study and analyze natural hand/finger motions and adapt them to the instrument. She believes that a relaxed and natural approach will reduce the inclination to tighten the hand and arm muscles during rapid technical passages.

Gingras advocates that a natural curvature of the hands to be applied and maintained when holding the clarinet. She suggests practicing slow scales in the mirror to avoid stiff, extended, or straightened fingers and the movement of each finger should occur from the first joint (at the base of the hand) and the rest of the finger should be relaxed. This allows the first finger joint to guide the rest of the finger, and the natural weight of each finger covers the holes or closes keys and avoids excess pressure or squeezing. Retraining finger motion and posture requires slow and patient work to yield a more facile technique and perhaps to prevent injury. To integrate this technique, she suggests playing increasingly faster scales (still in front of the mirror) and varying technical patterns (such as thirds or octaves) to include lifting two, three, or more fingers simultaneously. The arms and shoulders as well as the fingers should be relaxed, and the finger joints should not cave in when covering holes or closing keys.[75]

---

[74]Ibid.

[75]Michele Gingras, *Clarinet Secrets: 52 Performance Strategies for the Advanced Clarinetist*, (Lanham, Maryland: Scarecrow Press, Inc., 2004), 36-37.

**Summary**

In summary, Bonade, Campione, Cipolla, Gingras, Guy, Klug, Pino, Ridenour, Stein, and Stubbins all recommend relaxed, soft fingers and natural, gentle, or tension-free hands as the most advantageous clarinet hand positions. Bonade, Campione, Cipolla, Gingras, Guy, Klug, Pino, Ridenour, and Stein agree that clarinet hand posture should have naturally curved fingers, while Bonade and Campione teach forming a “C” posture with the hands, and Guy and Stein suggest holding a tennis ball to find the correct arch of the fingers and palm. Campione, Guy, Pino, Ridenour, Stein, and Stubbins teach using the pulpy pad of the fingertips to close tone holes. Campione, Guy, Klug, Ridenour, Stein, and Stubbins say fingers should be kept close to the keys for efficient finger motion when playing clarinet. Bonade and Guy believe finger motion is dependent on the music; fingers should be high and away from the keys for control in legato slow passages and closer for rapid technical passages. Bonade, Gingras, Guy, Pino, Ridenour, and Stein state motion of fingers should come from the joint at the base of the fingers. Klug and Stubbins advocate use of a neckstrap to free the fingers from holding the clarinet and facilitate efficient rapid technique.

**Need for Scientific Model**

None of these authors discusses hand posture adaptations for different hand sizes (Guy briefly mentions the curvature of long fingers). Generalized hand position descriptors, categorized by hand size, may be useful when teaching efficient technique on the clarinet. Perhaps clarinetists with larger hands and longer fingers will have higher degrees of finger flexion than clarinetists with smaller hands and shorter fingers, while clarinetists with smaller hands and shorter fingers will have higher degrees of finger extension than clarinetists with larger hands and longer fingers. Research using qualitative (e.g. photographs and/or video) or quantitative analysis (ex. CyberGloves®) could show whether differences exist, and if they do, what they are.

Stein describes "correct" right hand thumb position on the thumb rest, but he does not say why it is important or describe how this position will affect the degree of flexion and extension of the fingers. Measuring the distance from the tip of the right hand thumb to the center of the thumb rest and comparing this measurement to the flexion of the fingers could show the importance of "correct" right hand thumb position. These right hand thumb measurements may reveal an important correlation: if the right hand thumb is too far past the thumb rest, then the fingers may be too curved or flexed; and if the thumb is not far enough past the thumb rest, the fingers could be too flat or extended.

After reading about these teaching models, one wonders how closely they represent actual playing posture. Quantitative research comparing finger/hand posture used during clarinet performance to holding a tennis ball as Larry Guy suggests, to hanging hands at one's sides as Thomas Ridenour, John Cipolla, and others suggest, and to forming "C" hand postures as Campione and Bonade suggest may show the relevance of these teaching models. One model may prove to be the closest to actual performance, or they could all be quite different from the postures that clarinetists actually use. One model may be best for a certain hand size. Measuring finger joint angles with CyberGloves® can make the comparisons necessary to find these differences (if any). Additionally, quantifying finger position and motion of professional clarinetists and characterizing these positions and motions may be more descriptive than the current teaching models found in the literature.

# CHAPTER 5: CYBERGLOVE® LITERATURE REVIEW

Immersion's CyberGlove® is a fully instrumented glove that provides up to 18 high-accuracy joint-angle measurements. It uses proprietary resistive bend-sensing technology to accurately transform hand and finger motions into real-time digital joint-angle data. The CyberGlove® features two bend sensors on each finger, four abduction sensors, and sensors measuring thumb crossover, palm arch, wrist flexion, and wrist abduction. Each sensor is extremely thin and flexible and virtually undetectable in the lightweight elastic glove. The CyberGlove®, known for high-performance hand measurement and real-time motion capture, has been used in a wide variety of real-world applications, including digital prototype evaluation, virtual reality biomechanics, and animation. The CyberGlove® is constructed with stretch fabric for comfort and a mesh palm for ventilation. The 18-sensor CyberGlove® includes open fingertips, which allow the user to type, write and grasp objects (or play the clarinet) while wearing the glove. The instrumentation unit provides time-stamp, CyberGlove® status, external sampling synchronization, and analog sensor outputs.[76] Tables 4 and 5 provide CyberGlove® Specifications and a detailed list of sensor locations.

---

[76]"Products: CyberGlove® II," http://www.cyberglovesystems.com/products/cyberglove-ii/overview (accessed February 7, 2011).

Table 4. CyberGlove® Specifications

| CyberGlove® Specifications[77] |
|---|
| Sensor Resolution: 0.5 degrees |
| Sensor Repeatability: 1 degree (typical standard deviation between glove wearings) |
| Sensor Linearity: 0.6% maximum nonlinearity over full joint range |
| Sensor Data Rate: 150 records/sec (unfiltered); 112 records/sec (filtered). Programmable sample period of polled I/O. (Rates listed are for 18-sensor records at 115.2 kbaud. Higher rates possible with fewer sensors enabled.) |
| Software: executable version of Immersion's VirtualHand graphic hand model display and calibration software. |
| Interface: RS-232 (115.2 kbaud max). Analog sensor outputs also provided |
| Instrumentation Unit: 10.00" x 6.25" x 2.75"; 27 oz.; 10 ft. glove cable standard (25 ft. cable optional) |

[77]Ibid.

Table 5. CyberGlove® Sensor List[78]

| Sensor# | Sensor Name |
|---|---|
| 1 | Thumb rotation/TMJ (angle of thumb rotating across palm) |
| 2 | Thumb MCP (joint where the thumb meets the palm) |
| 3 | Thumb IP (outer thumb joint) |
| 4 | Thumb abduction (angle between thumb and index finger) |
| 5 | Index MCP (joint where the index meets the palm) |
| 6 | Index IP (joint second from finger tip) |
| 7 | Middle MCP |
| 8 | Middle IP |
| 9 | Middle-index abduction (angle between middle and index fingers) |
| 10 | Ring MCP |
| 11 | Ring IP |
| 12 | Ring-middle abduction |
| 13 | Pinky MCP |
| 14 | Pinky IP |
| 15 | Pinky-ring abduction (angle between pinky and ring finger) |
| 16 | Palm arch (causes pinky to rotate across palm) |
| 17 | Wrist pitch (flexion/extension) |
| 18 | Wrist yaw (abduction/adduction) |

MCP = metacarpal phalangeal joint (inter joint), IP = interphalangeal joint (middle joint), and TMJ = trapeziometacarpal joint

## Virtual Glove Studies

Virtual gloves have been used in a wide variety of studies including stroke rehabilitation, the development of ergonomically sound laparoscopic surgery tools, studying and recording American sign language, designing hand prosthetics, creating virtual musical instruments, and in this study, analyzing clarinet finger motion and postures.

*Stroke Rehabilitation*

A virtual reality based system using a CyberGlove® and a Rutgers Master II-ND haptic glove was used to rehabilitate four post-stroke patients in the chronic phase. Each patient performed a variety of virtual reality tasks to lessen

[78]"CyberGlove v1.0 Reference Manual," Immersion Corporation, (2002).

impairments in their finger range of motion, fractionation, speed, and strength. Patients exercised for two hours per day, five days per week for three weeks. Results showed that three of the patients had gains in thumb range (50%-140%) and finger speed (10-15%) over the three-week trial.[79]

Current neuroscience has identified rehabilitation approaches with the potential to stimulate adaptive changes in the brains of persons with hemiparesis (weakness on one side of the body, common in stroke patients). These approaches include intensive task-oriented training, bimanual activities, and balancing proximal and distal upper extremity interventions to reduce competition for neural territory between these segments. The study described the design and feasibility testing of a robotic/virtual environment system designed to train the hand and arm of persons with hemiparesis. The system employed a simulated piano that presents visual, auditory, and tactile feedback comparable to that of an actual piano. Arm tracking allowed patients to train both the arm and hand as a coordinated unit, emphasizing the integration of both transport and manipulation phases. The piano trainer included songs and scales performed with one or both hands. An algorithm adjusted task difficulty in proportion to subject performance. As a group, the subjects improved in both performance time and key press accuracy. Three of the four subjects demonstrated improvements in fractionation, the ability to move each finger individually. Two subjects improved their

---

[79] R. Boian, A. Sharma, C. Han, A. Merians, G. Burdea, S. Adamovich, M. Recce, M. Tremaine, and H. Poizner, "Virtual Reality-based Post Stroke Hand Rehabilitation," in *Medicine meets virtual reality* 02/10: *Digital Upgrades, Applying Moore's Law to Heath,* ed. James Westwood (IOS Press: Lansdale, 2007), 64-70.

aggregate time on the Jebsen Test of Hand Function, and three of the four subjects improved in Wolf Motor Function Test aggregate time.[80]

*Development of Laparoscopic Surgical Tools*

Right wrist movements of surgeons were recorded with CyberGlove® during basic laparoscopic tasks. After an ergonomic assessment of wrist positions and application of biomechanics analysis techniques, specifically using rapid upper limb assessment, new use and design guidelines of the laparoscopic instruments were established in order to reduce the influence of risk factors in the wrist area, which are associated with forced positions during laparoscopic activities. The results of the study show the virtual glove is a useful and fast tool to determine the adoption of forced positions of the surgeons' wrists, and specifically those which put surgeons at high risk from muscle alterations. For this reason, setting out improvements in the use and design of the current laparoscopic instruments is considered indispensable.[81]

*Sign Language*

A CyberGlove® was used to investigate finger motion between finger spellings for more concise sign language communication. The CyberGlove®

---

[80]Sergei V Adamovich, Gerard G Fluet, Abraham Mathai, Qinyin Qiu, Jeffrey Lewis, and Alma S Merians, "Design of a complex virtual reality simulation to train finger motion for persons with hemiparesis: a proof of concept study," *Journal of NeuroEngineering and Rehabilitation* 6:28 (2009): 10.1186/1743-0003-6-28.

[81]Francisco M. Sánchez-Margallo, Juan A. Sánchez-Margallo, José B. Pagador, José L. Moyano, José Moreno and Jesús Usón, "Ergonomic Assessment of Hand Movements in Laparoscopic Surgery Using the CyberGlove®," *Computational Biomechanics for Medicine* 10:1007/978 Part 2 (2010), 121-128.

recorded the dynamic gestures corresponding to transitions between letters in order to eliminate the need for an explicit temporal segmentation step, known to be error-prone at speeds used by native signers. The study presented results recognizing 82 different words signed by a single signer, using more than an hour of training and test video. The study shows recognizing letter-to-letter transitions without temporal segmentation is feasible and results in improved performance.[82]

*Designing Functional Prosthesis for Human Hand*

By exploiting the data obtained from the CyberGlove® and surface EMG data for muscle activity, a new method for design of prosthetic and robotic hands can be developed. [83] The functional simulation in virtual reality (using a CyberGlove®) may identify the best solutions and optimize constructive solutions and use of the hand prosthesis by a human operator.[84]

*Virtual Musical Instruments*

The Cyber Composer is an interactive cyber instrument that enables both musicians and music laypersons to control the tonality and the melody of the music they generate/compose through hand motion and gestures. Cyber Composer

---

[82]Susanna Ricco and Carlo Tomasi, "Fingerspelling Recognition through Classification of Letter-to-Letter Transitions" *Lecture Notes in Computer Science* 5996/2010 (2010) 214-225.

[83]R. Vinjamuri, Zhi-Hong Mao, R. Sclabassi, and Mingui Sun, "A Novel Architecture for the Design of Prosthetic and Robotic Hands." Proceedings of the IEEE 32nd Annual Northeast Bioengineering Conference, Easton, PA (2006) 163 – 164.

[84]Cornel Brisan, Vistrian Măties, Sergiu-Dan Stan and Stelian Brad, "Main Aspects Regarding the Mechanism of the Prosthesis for Human Hand - Synthesis, Analysis, Design and Functional Simulation," *Journal Solid State Phenomena* vol. 166 – 167: Robotics and Automation Systems (2010) 383-388.

generates music according to hand motions and gestures of the users in the absence of real musical instruments. Musical expressions such as pitch, rhythm, and volume of the melody can be controlled and generated in real-time by wearing a pair of motion-sensing gloves. Central to the design of the virtual instrument is the mapping of hand motions and intuitive gestures to musical expressions, thereby requiring minimal training. Cyber Composer is expected to find applications in the fields of performance, composing, entertainment, education, and psychotherapy.[85]

*Studying Clarinet Finger Postures*

The CyberGlove® is a valuable tool for studying clarinet finger motion and posture because of its high-performance hand measurement and real-time motion capture capabilities. Lightweight stretch fabric and open fingertips (clarinetists use the pad of their fingers to cover tone holes when performing) allow the clarinetist to perform without drastically adapting finger posture and motion. With frame rates over 100 per second, the CyberGlove® can easily record rapid finger motion for every pitch and even motion between pitches. Few hand posture models exist in the current clarinet pedagogical literature and many pedagogues use the terms “natural,” “relaxed,” and/or “curved” to describe clarinet hand position. A more precise, scientific description based on the recorded postures of professional clarinetists may be a valuable tool for teaching

[85] H. Ip, K. Law, and B. Kwong, “Cyber Composer: Hand Gesture-Driven Intelligent Music Composition and Generation,” *Multi-Media Modeling Conference, International* 11th International Multimedia Modeling Conference (2005) 46-52.

clarinet hand posture. Using CyberGloves® to compare current pedagogical models to actual professional clarinet hand posture may also show one or more models to be the most accurate. Quantitative research comparing finger/hand posture used during clarinet performance to specific teaching models such as holding a tennis ball as Stein[86] and Guy[87] suggest, and hanging hands at one's sides as Ridenour,[88] Cipolla,[89] and others suggest, and forming "C" hand postures as Campione[90] and Bonade [91]suggest may show the relevance of these teaching models. One model may prove to be the closest to actual performance, or they could all be quite different from the postures that clarinetists actually use. One model might be best for a certain hand size. Measuring finger joint angles with CyberGloves® can facilitate the comparisons necessary to find these differences (if any).

---

[86]Keith Stein, *The Art of Clarinet Playing*, (Miami, FL: Summy-Birchard Inc., 1958), 28-31.

[87]Larry Guy, *Hand and Finger Development for Clarinetists*, (Stony Point, NY: Rivernote Press, 2007), 12-16.

[88]Thomas Ridenour, *The Educator's Guide to the Clarinet: A Complete Guide to Teaching and Learning the Clarinet*, (Denton, TX: Thomas Ridenour, 2000), 6-2.

[89]John Cipolla, *Clarinet Basics, Foundations for Clarinet Players*, people.wku.edu/john.cipolla/ClarinetBasics.pdf (accessed October 5, 2010), 2-3.

[90]Carmine Campione, *Campione On Clarinet: A Complete Guide to Clarinet Playing and Instruction*, (Fairfield: John Ten-Ten Publishing, 2001), 29.

[91]Larry Guy, *The Daniel Bonade Workbook*, (Stony Point, NY: Larry Guy, 2004), 9.

More research in clarinet hand mechanics, position, pedagogy, and practice will be valuable for teaching and achieving adequate technique. The clarinet is a machine. Like any other machine, when it is operated efficiently, it can run smoothly, rapidly, and accurately. The clarinet repertoire is increasingly demanding a more agile, technical capability from the player, therefore, learning more about hand mechanics and position may be useful in injury prevention. Studying injured and healthy clarinet hand positions will teach us more about which positions and postures work and do not work. Taking a detailed personal history including practice habits, computer usage, injury history, athletic activities, and other pertinent background information may also reveal more discoveries about the hands.

# CHAPTER 6: METHODS

## Subjects

Subjects were six professional clarinetists defined by entrance into or completion of a Doctorate of Musical Arts degree in clarinet performance. Four subjects were male and two female, ranging from 25-55 years of age. Subjects were recruited after the study gained IRB approval at a clarinet studio class meeting on November 15, 2010 at Arizona State University.

## Materials

Table 6. Materials

| |
|---|
| Right and left hand CyberGloves® |
| Immersion S=software for glove calibration |
| Clarinets |
| MATLAB programs for recording both CyberGloves® data simultaneously with built in metronome and applying calibration to raw sensor data |
| Desktop computer to run CyberGloves® and MATLAB programs |
| Digital caliper in millimeters |
| 2 tennis balls |
| Measuring tape in inches |
| Scale in pounds |
| Subject Measurement Form |
| Subject Measurement Analysis Form |
| Digital camera |
| Questionnaire |
| Performance exercise instructions |

Right and left hand Immersion CyberGloves® owned by the Arizona State University's Center for Cognitive Ubiquitous Computing (CUbiC) laboratory were used to record finger joint motion of six professional clarinetists. Each glove has 18 sensors featuring two bend sensors on each finger, four abduction sensors, plus sensors measuring thumb crossover, palm arch, wrist flexion, and wrist abduction. The CyberGlove® system includes open fingertips, which allows analysis of hand/finger motion during clarinet performance (clarinetists use the pad of their fingers to cover tone holes). Immersion's software, Device Configuration Utility, allows for individual hand calibration, displays a real time 3D representation of sensor data, and records data from of all 18 sensors at over 100 frames per second.

**Limitations:**

While open-fingertip CyberGloves® allow clarinetists to use the pads of their fingers to cover tone holes without drastically adapting finger posture and motion, this feature does not measure the last joint of the fingers. Measurements are recorded sequentially at a variable rate of about 100 frames per second; therefore, sensors are not measured simultaneously. This study only had a small number of subjects, so data is averaged from a small sample size. In addition, the performance task was at only one speed, and finger motion may vary according to performance speed. Data from sensor 17 of the left hand glove and sensor 12 and 15 were disregarded due to instrument malfunction.

**Tasks:**

Each subject performed a slurred three-octave chromatic scale in sixteenth notes, at sixty quarter-note beats per minute, three times, with a metronome and with a short pause between repetitions. Then, each subject was asked to form the following three pedagogical hand postures: holding a tennis ball in each hand for 7 seconds, dropping arms to subject's sides and hold for 7 seconds, and form and hold "C" posture with hands for 7 seconds. Each posture task was repeated three times. Still photos of body posture were taken during the performance and posture tasks. Following the performance tasks, each subject completed a questionnaire (see Appendix B) about equipment, playing history, practice routines, health practices, and hand usage during computer and sports activities.

**Data Collection:**

After signing an IRB approved consent form, Kay Norton (principal investigator) created the deidentified subject ID master list correlated with IDs assigned to consent forms. Stefanie Harger (SH) recorded subject hand measurements using a digital caliper, and body height with a measuring tape. Body weight and instrument case weight were measured using a scale in pounds and all measurements were recorded on appropriately coded subject measurement forms. After measurements were recorded, each subject put on the right and left hand CyberGloves® and SH calibrated each glove according to the "Calibration Guide for CyberGloves®" by Huenerfauth and Lu.[92] Separate right and left hand calibration files were saved on a password protected CUbiC laboratory computer using subject codes. The MATLAB program developed by Michael J. Astrauskas was used to record both gloves simultaneously with a built in metronome at sixty beats per minute (one click per second) synchronized with the time stamp of both CyberGloves® (sampling rate at 100 frames per second).

Next, each subject performed a slurred three-octave chromatic scale in sixteenth notes, at sixty quarter-note beats per minute, three times, with a short

[92]Matt Huenerfauth and Pengfei Lu, "Calibration Guide for CyberGlove®" The City University of New York, Version: 4.4.

pause between repetitions. At this tempo, each note of the scale task recorded approximately 25 frames of data from all 18 sensors for each hand. Then, the subject formed the following three pedagogical hand postures: holding a tennis ball in each hand for 7 seconds, dropping arms to subject's sides and holding for 7 seconds, and forming "C" posture with hands for 7 seconds. Each task was repeated three times. Still photos of body posture (omitting the face) were taken using a digital camera during performance and posture tasks. Following the performance task, each subject completed an appropriately coded questionnaire (see Appendix B) about equipment, playing history, practice routines, health practices, and hand usage during computer and sports activities in the CUbiC conference room.

**Data Analysis:**

The subject measurement analysis form (see Appendix B), completed by SH, was used to evaluate participants' gross variations from a neutral or "in between" body posture, using the still photographs taken during the performance task. Subject back posture was described as straight, in-between, or slouched. Neck posture was described by chin position: elevated, level, or tilted down. Elbow posture was evaluated for presence of marked abduction, in-between, or marked adduction. Shoulder posture descriptors were back, in-between, or slouched. Finger posture was described as curved, neutral, or flat. Finally, the angle of the instrument was described by proximity to the trunk: close to body, in-between, or away from body. The subject measurement form, subject measurement analysis form, and questionnaire data were coded and entered into a MS Excel file for direct comparison among subjects.

The CyberGloves® calibration text files were converted into a MS Excel file, so the MATLAB program developed by Michael J. Astrauskas could apply each subject's hand calibration to the recorded task data. The calibration is not automatically applied to the data when recording; the formula is Angle = Gain * (Digital_Value - Offset). Offset and gain values are set during calibration of the gloves. Offset is the difference between the minimum input of an analog input point and the actual minimum signal received from a field device. Gain is the ratio of the full-scale reading to the maximum input. (Gain * SensorValue) + Offset = AngleOnScreen. Gain and Offset per sensor are specified in each subject's calibration file, and the Digital Value is the raw sensor reading recorded in MATLAB. Raw sensor data and adjusted (calibrated) senor data were converted into MS Excel files.

After applying the calibration formula, three performance tasks were averaged to find a mean hand/finger posture for each pitch of the chromatic scale (E3 to E6). To determine whether finger position is the same or different when ascending and descending the chromatic scale, each task was averaged and the difference was calculated. Subjects were divided into small and large hand categories based on hand measurements. Data from both groups were analyzed to find similarities and differences in finger posture. Results created general characterizations about finger postures based on hand size. The right hand thumb length of each subject, and the distance of the right hand thumb placed past the center of the clarinet thumb rest were recorded, allowing the analyzers to calculate the percentage of the thumb placed past the center of the thumb rest. These thumb percentages were compared to right hand finger flexion of digits 2-5 to determine any correlation, if any (to determine whether right hand thumb position is related to finger flexion).

Averaged performance task data frames 400-425 (E3) were compared to average tennis ball postures for each subject to determine whether finger/hand posture clarinetists use during performance is similar to finger/hand posture when holding a tennis ball as Stein[93] and Guy[94] suggest. Averaged performance task data frames 400-425 (E3) were compared to average natural hand posture for each to determine whether finger/hand posture clarinetists use during performance is similar to when hands hang down at sides as Ridenour,[95] Cipolla,[96] and others suggest. Averaged performance task data frames 400-425 (E3) were compared to average "C" postures for each subject to determine whether finger/hand posture

[93]Keith Stein, *The Art of Clarinet Playing*, (Miami, FL: Summy-Birchard Inc., 1958), 28-31.

[94]Larry Guy, *Hand and Finger Development for Clarinetists*, (Stony Point, NY: Rivernote Press, 2007), 12-16.

[95]Thomas Ridenour, *The Educator's Guide to the Clarinet: A Complete Guide to Teaching and Learning the Clarinet*, (Denton, TX: Thomas Ridenour, 2000), 6-2.

[96]John Cipolla, *Clarinet Basics, Foundations for Clarinet Players*, people.wku.edu/john.cipolla/ClarinetBasics.pdf (accessed October 5, 2010), 2-3.

clarinetists use during performance is similar posture when hands form “Cs” as Campione[97] and Bonade[98] suggest.

97Carmine Campione, *Campione On Clarinet: A Complete Guide to Clarinet Playing and Instruction*, (Fairfield: John Ten-Ten Publishing, 2001), 29.

98Larry Guy, *The Daniel Bonade Workbook*, (Stony Point, NY: Larry Guy, 2004), 9.

# CHAPTER 7: RESULTS

The results of this study are presented in four parts: subject measurement data, photograph analysis, CyberGlove® data, and questionnaire data. A summary and discussion of this data is presented in the following chapter.

**Data from Subject Measurement Form**

Table 7 displays hand size data. Subjects 1, 3, and 4, with hand lengths over 189 millimeters, were binned into the large hand group. With hand lengths smaller than 189 mm, subjects 2, 5, and 6 were binned into the small hand group. The average human hand length value of 189 millimeters was used to articulate difference between small and large hands.

Table 7. Hand Length (HL), Hand Width (HW), and Wrist Width (WW) (millimeters)

| S | HL: RH | HL: LH | HW: RH | HW: LH | WW: RH | WW: LH |
|---|---|---|---|---|---|---|
| 1 | 210.99 | 216.38 | 90.22 | 89.46 | 73.55 | 70.01 |
| 2 | 189.26 | 179.91 | 81.92 | 79.93 | 67.50 | 64.20 |
| 3 | 199.31 | 200.00 | 89.27 | 84.18 | 74.49 | 68.01 |
| 4 | 199.48 | 191.51 | 89.38 | 88.49 | 70.00 | 68.73 |
| 5 | 170.65 | 172.23 | 79.54 | 78.67 | 65.05 | 65.13 |
| 6 | 171.87 | 165.74 | 81.24 | 83.23 | 66.36 | 66.99 |

**Photograph Data (**see discussion of Tasks, page 58)

Photographs 1-8 are of the performance task from various angles. The three pedagogical postures that were analyzed can be seen in photographs 9-11.

Photograph 1. Scale task: view of left thumb

Photograph 2. Scale task: view of left thumb

Photograph 3. Scale task: view of left thumb

Photograph 4. Scale task: view of right hand

Photograph 5. Scale task

Photograph 6. Scale task

Photograph 7. Scale task

Photograph 8. Scale task

Photograph 9. Natural posture

Photograph 10. Tennis ball posture

Photograph 11. “C” posture

Table 8 displays qualitative analysis of subject body posture. See pages 60 and following for discussion of protocols relating to body posture photography.

Table 8. Upper Body Posture Descriptors:

| S | Back | Neck | Elbows | Shoulders | Angle of instrument to trunk |
|---|---|---|---|---|---|
| 1 | in-between | chin tilted down | marked adduction | in-between | in-between |
| 2 | in-between | chin tilted down | marked adduction | slouched | in-between |
| 3 | in-between | chin level | in-between | slouched | in-between |
| 4 | straight | chin level | marked abduction | in-between | in-between |
| 5 | in-between | chin level | marked adduction | slouched | in-between |
| 6 | in-between | chin level | in-between | slouched | in-between |

Table 9 displays wrist posture analysis. Wrist rotation and extension were described as dorsal, volar, radial, or ulnar. From pedagogical literature, it is expected that wrists will be rotated up (radial).

Table 9. Wrist Descriptors

| S | R wrist | L wrist | R wrist rotation | L wrist rotation |
|---|---|---|---|---|
| 1 | neutral | extended | radial | radial |
| 2 | neutral | extended | radial | radial |
| 3 | neutral | extended | radial | radial |
| 4 | extended | slightly extended | radial | radial |
| 5 | extended | slightly extended | radial | radial |
| 6 | slightly extended | neutral | slightly radial | slightly radial |

In Table 10, fingers were described as curved, neutral, or flat. Digits 2-4 were curved throughout the large hand group. Subjects 4 and 5 (both in the small hand group) exhibited neutral 4 and 5 digits. All subjects had neutral digit 5 postures except for subject 3.

Table 10. Finger Posture: Curved (c), Neutral (n), or Straight (s)

| S | RH2 | RH3 | RH4 | RH5 | LH2 | LH3 | LH4 | LH5 |
|---|---|---|---|---|---|---|---|---|
| 1 | c | c | c | n | c | c | c | n |
| 2 | c | c | c | n | c | c | c | n |
| 3 | c | c | c | c | c | c | c | c |
| 4 | c | c | c | n | c | c | c | n |
| 5 | c | c | n | n | c | c | n | n |
| 6 | c | c | n | n | c | c | n | n |

**CyberGlove Data**

Finger motion was quantified during four tasks (performance and three teaching postures). Additionally, three repetitions of each task were averaged into a composite to help compensate for subject variance.

*Pedagogical Model Comparison*

Figures 4-9 show direct comparisons between the performance and teaching postures. Average performance task data frames 400-425 (E3) were compared to average tennis ball postures, to average natural hand postures, and to average “C” postures for each subject. Small and large hand groups were defined based on hand measurements taken during the experiment. Average small group teaching postures were compared to average small group E3, and average large group teaching postures were compared to average large group E3. The difference between teaching postures and E3 were calculated and plotted for all subjects and both hand size groups.

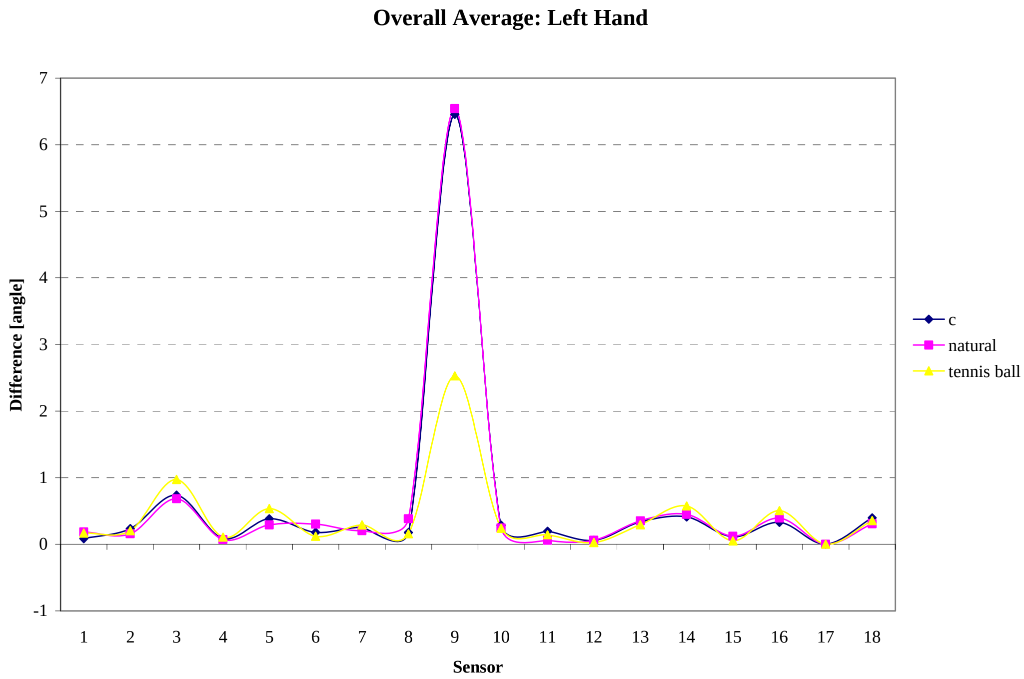



Figure 4. Difference between left hand performance and teaching postures

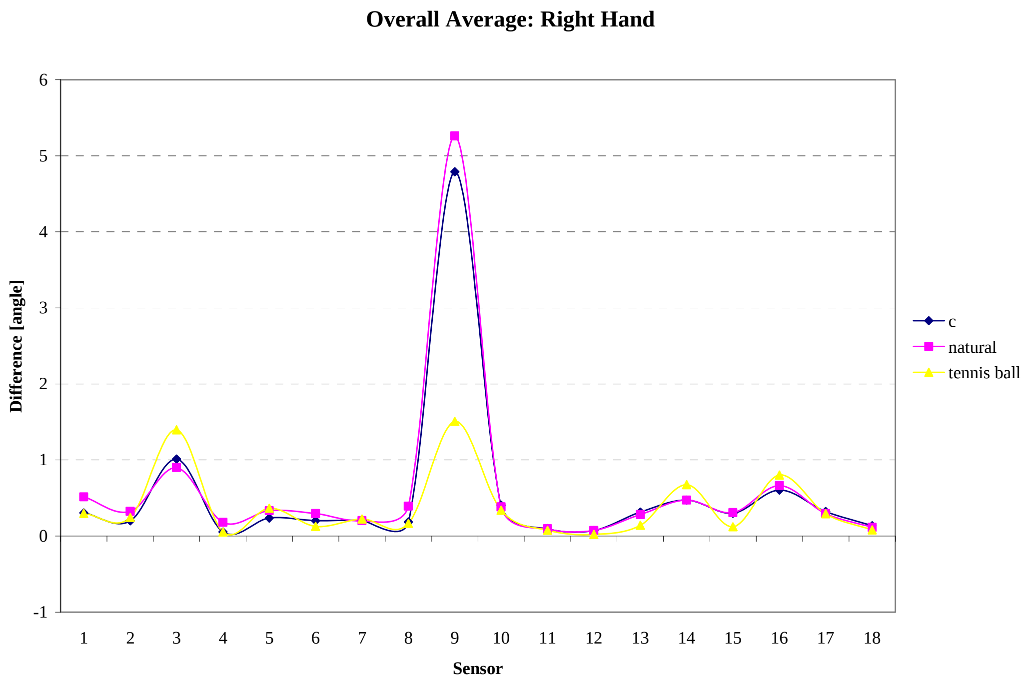



Figure 5. Difference between right hand performance and teaching postures

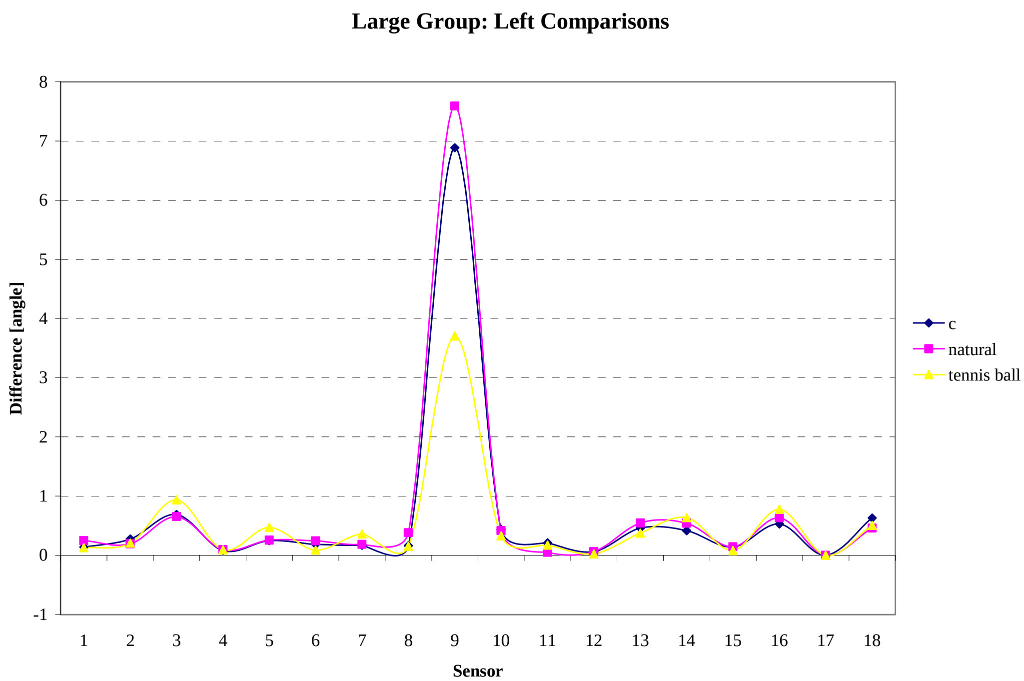



Figure 6. Difference between large group left hand performance and teaching postures

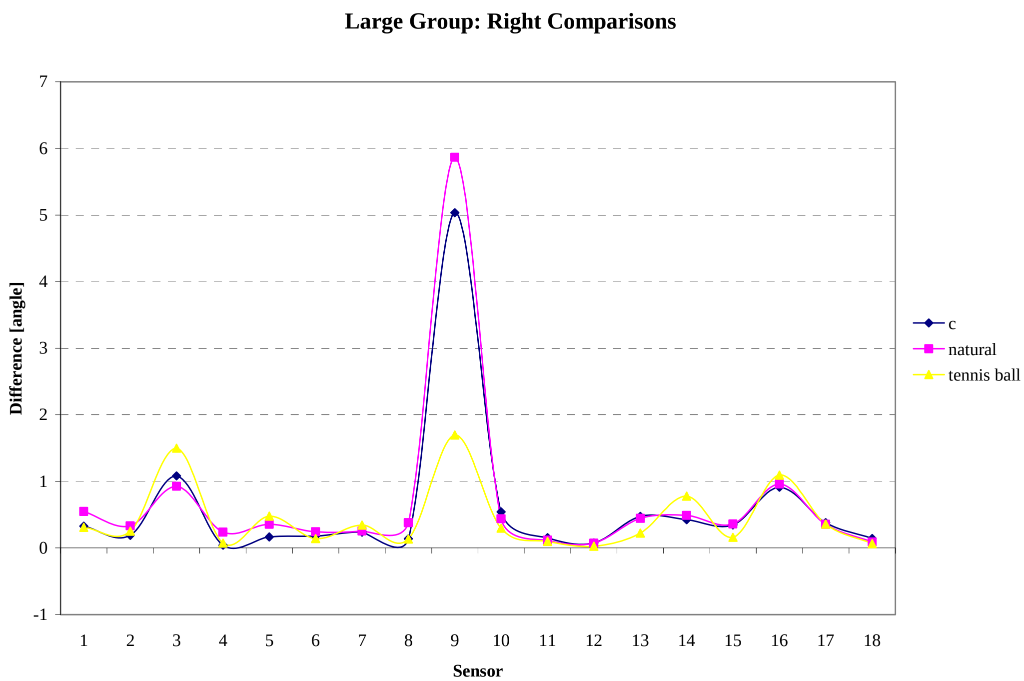



Figure 7. Difference between large group right hand performance and teaching postures

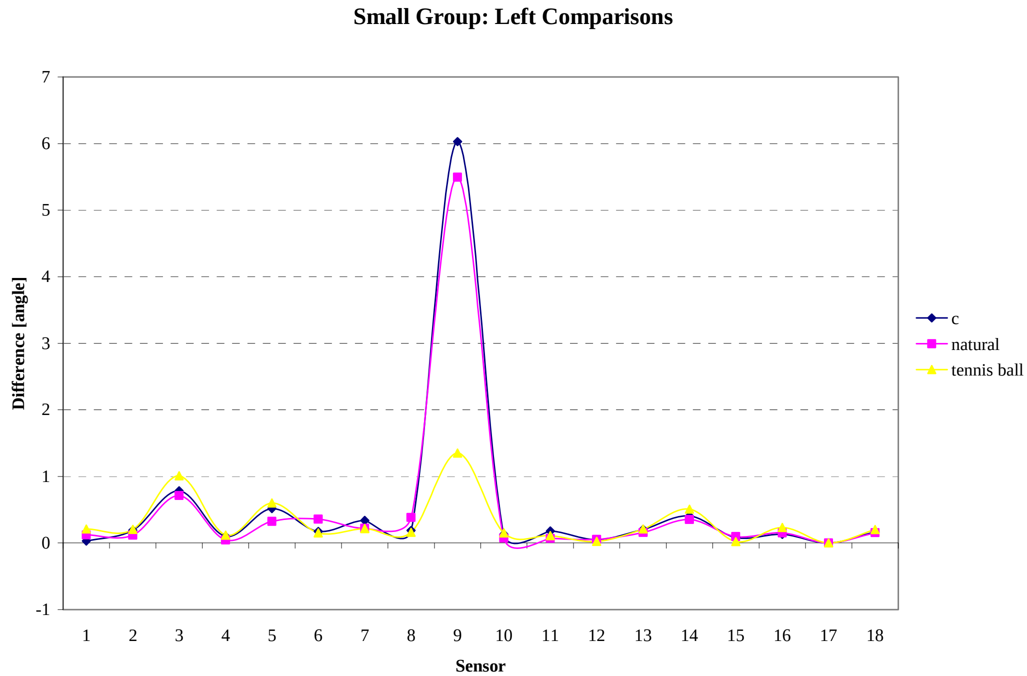



Figure 8. Difference between small group left hand performance and teaching postures

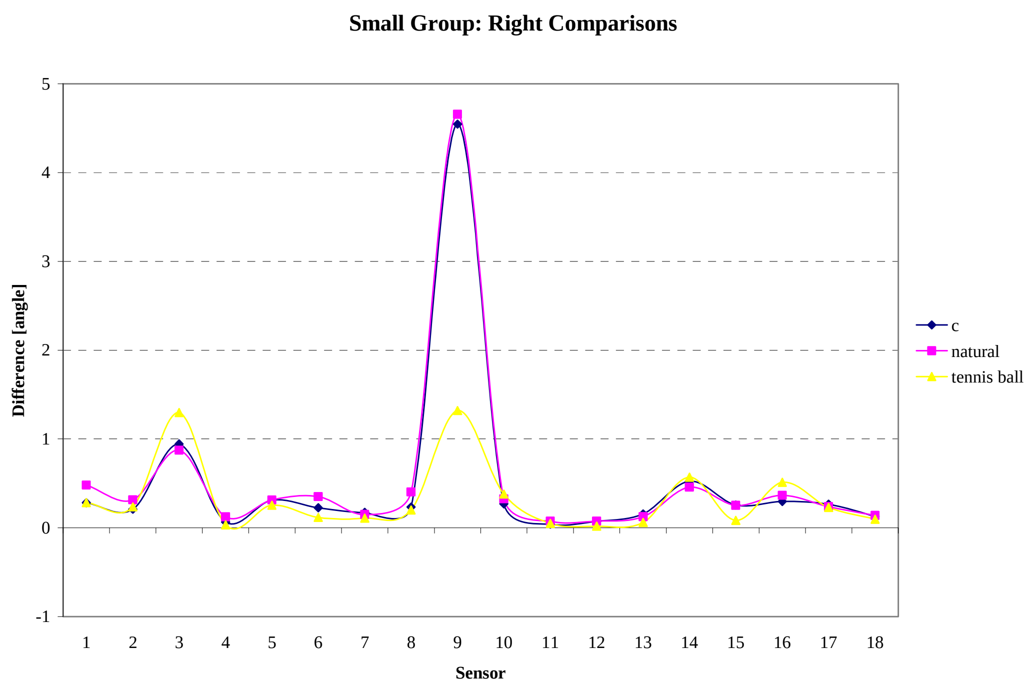



Figure 9. Difference between small group right hand performance and teaching postures

*Right Thumb Placement and Finger Flexion Correlation*

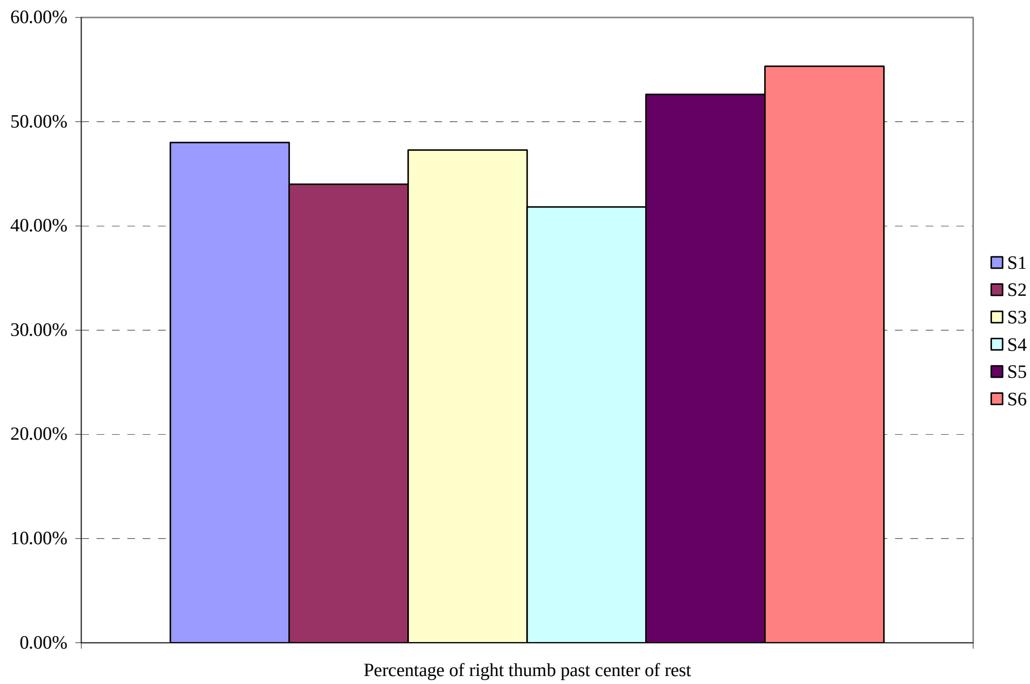



Figure 10. Right hand thumb placement past center of clarinet rest.

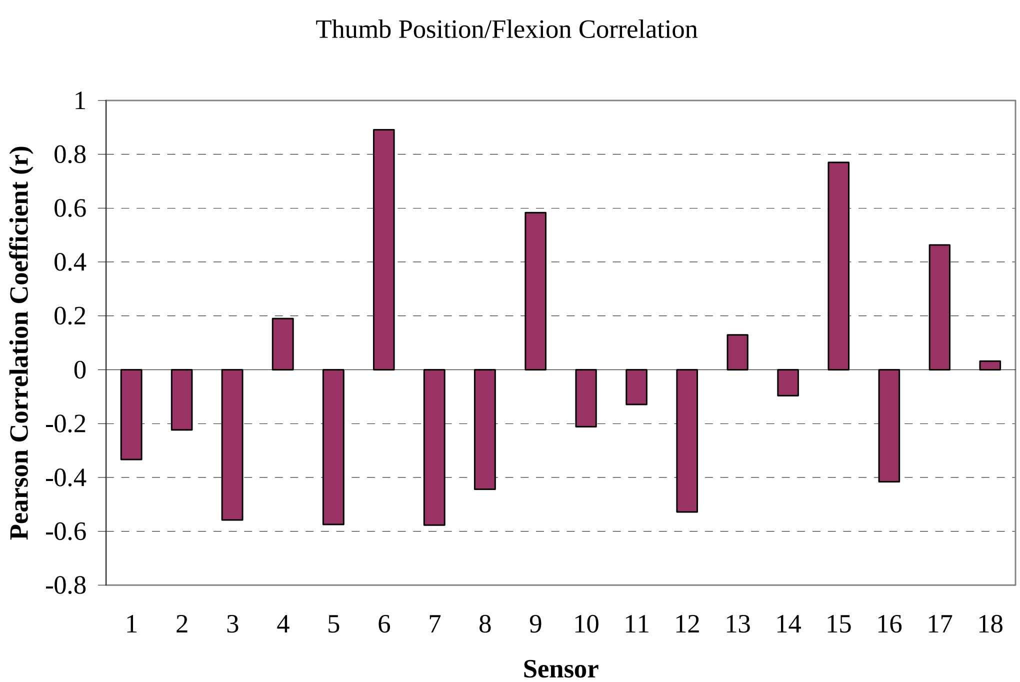



Figure 11. Thumb placement and finger flexion correlation.

Figure 10 shows the percentage of right hand thumb placed past the center of the clarinet thumb rest. Figure 11 represents a correlation analysis using right thumb percentage past the clarinet thumb rest to right hand flexion for each sensor. A positive correlation would mean that as the percentage goes up, the flexion goes up, and vice versa. A negative correlation would mean as thumb percentage goes down, flexion goes up, and vice versa.

*Finger Postures across Subjects for Each Pitch*

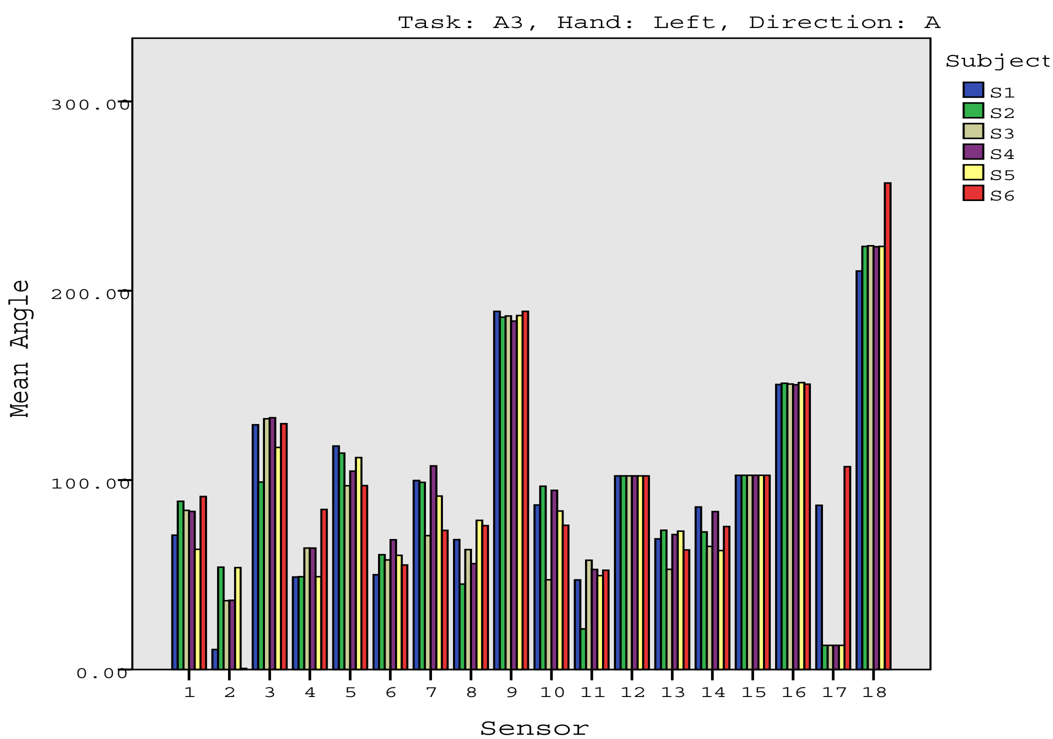



Figure 12. Left hand posture for A3 across subjects

Appendix C contains charts for each hand posture for every pitch of the performance task across all subjects. Figures 27-50, first octave ascending chromatically, beginning with E3 and, alternating left, then right hand for each;

Figures 51-74, second octave ascending; Figures 75-100, third octave ascending. Figures 101-124, first octave descending chromatically, beginning with E6 and alternating left, then right hand for each; Figures 125-148, second octave descending; Figures 149-174, third octave, descending. Data for left hand sensors 12 and 15 was disregarded due to instrument malfunction. For left hand A3, subject 6 (small hand group) shows highest mean angle flexion in sensors 1, 9, 17, and 18, while subject 1 (large hand group) shows lowest mean angle flexion in sensors 2, 4, 6, and 18.

*Performance Task Variance*

Information in tables 11 and 12 include the standard deviation (SD) for each sensor for each averaged pitch across all subjects during the performance task.

Table 11. Left Hand Standard Deviation for All Subjects

| Sensor | Standard Deviation |
|---|---|
| 1 | 22.77 |
| 2 | 14.96 |
| 3 | 6.77 |
| 4 | 19.51 |
| 5 | 13.49 |
| 6 | 4.99 |
| 7 | 7.64 |
| 8 | 2.86 |
| 9 | 7.56 |
| 10 | 9.81 |
| 11 | 10.77 |
| 12 | 2.41 |
| 13 | 11.67 |
| 14 | 8.22 |
| 15 | 5.66 |
| 16 | 1.80 |
| 17 | .15 |
| 18 | .11 |

Table 12. Right Hand Standard Deviation for All Subjects

| Sensor | Standard Deviation |
|---|---|
| 1 | 9.93 |
| 2 | 20.18 |
| 3 | 12.11 |
| 4 | 12.95 |
| 5 | 8.20 |
| 6 | 5.66 |
| 7 | 13.74 |
| 8 | 11.61 |
| 9 | 2.58 |
| 10 | 16.49 |
| 11 | 11.82 |
| 12 | .02 |
| 13 | 7.28 |
| 14 | 8.57 |
| 15 | .04 |
| 16 | .44 |
| 17 | 40.15 |
| 18 | 14.28 |

*Ascending vs. Descending Posture*

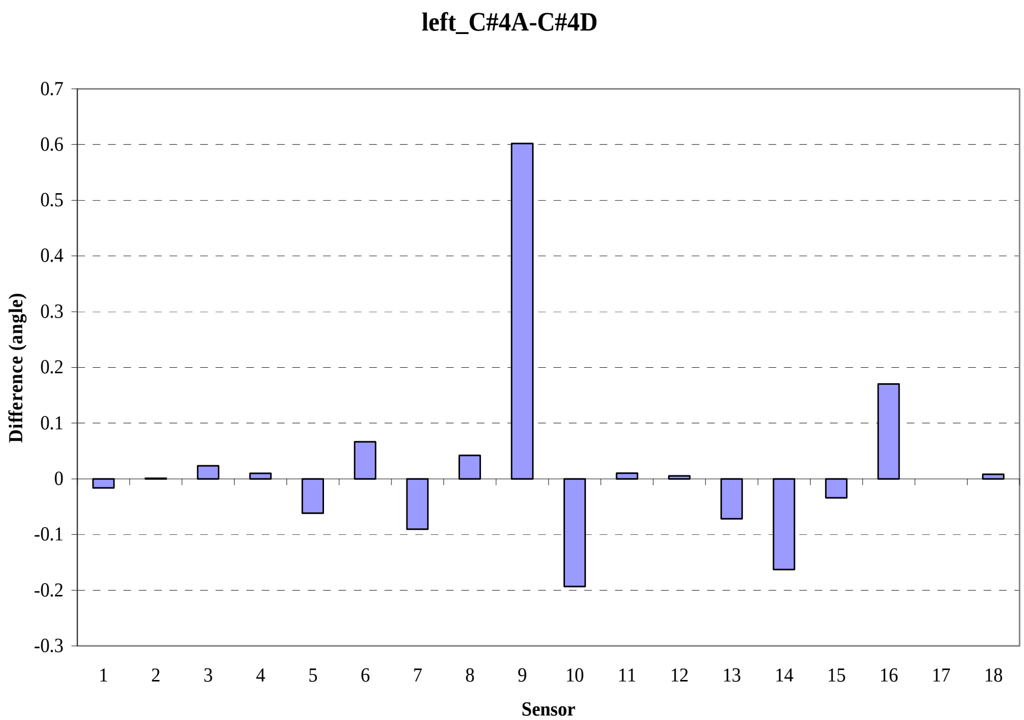



Figure 13. Ascending vs. descending C#4 left hand

Figure 13 shows the average ascending posture compared to the descending posture for left hand C#4 for all subjects. Appendix C contains average difference between ascending and descending postures for every pitch of the performance task beginning with Figure 175. Descending posture sensor data was subtracted from the ascending posture data. A positive value indicates the ascending sensor angle is greater than the sensor angle while descending, while a negative value indicates the descending sensor angle is greater than the sensor angle while ascending.

**Questionnaire Data**

Table 13 shows five out of six subjects have the same instrument set up. All subjects practice in the sitting position (subject 4 practices in both sitting and standing positions). Four out of six subjects use a neckstrap, and most have adjusted instrument spring tension.

Table 13. Subject (S) Information

| S | Age | Gender | Years playing | Modifications to clarinet | Clarinet model | Practice position |
|---|---|---|---|---|---|---|
| 1 | 26 | M | 13 | installed large rubber thumb rest | Yamaha CSV | sitting |
| 2 | 25 | F | 14 | uses neckstrap, adjustment of spring tension | Buffet R13 Greenline | sitting |
| 3 | 28 | M | 18 | uses neckstrap, adjustment of spring tension | Buffet R13 Greenline | sitting |
| 4 | 29 | M | 17 | adjustment of spring tension | Buffet R13 Greenline | sitting standing |
| 5 | 33 | F | 20 | uses neckstrap | Buffet R13 Greenline | sitting |
| 6 | 55 | M | 43 | uses neckstrap, adjustment of spring tension | Buffet R13 Greenline | sitting |

Table 14 displays each subject's playing time in minutes. Warm up/technique playing time ranged from 30 to 105 minutes a day. Repertoire varied from 60 to 270 minutes per day. Teaching and performance playing time is not consistent across subjects. Daily playing time averages ranged from 198 to 446 minutes per day.

Table 14. Subjects (S) Average Playing Time (minutes per week)

| S | Warm Up/ Technique | Repertoire Practice | Rehearsal | Teaching | Performing | Total |
|---|---|---|---|---|---|---|
| 1 | 210 | 1320 | 120 | 0 | 0 | 1650 |
| 2 | 630 | 420 | 180 | 1410 | 30 | 2670 |
| 3 | 735 | 630 | 0 | 960 | 0 | 2325 |
| 4 | 210 | 630 | 360 | 0 | 180 | 1380 |
| 5 | 420 | 840 | 0 | 630 | 0 | 1890 |
| 6 | 420 | 1260 | 0 | 1320 | 120 | 3120 |

Table 15 shows repertoire data. All subjects rated 20th century music as the genre played most frequently. The Romantic genre was rated second most frequent with an average rating of 3.33, and the Classical genre was third most frequent with an average rating of 2.83.

Table 15. Repertoire:
Subjects (S) rated the genres they play most often: 0 = never and 5 = daily

| S | Written before 1750 | Classical | Romantic | 20th century | Folk | Jazz | Rock | Other |
|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 2 | 3 | 5 | 0 | 0 | 0 | 0 |
| 2 | 0 | 3 | 4 | 5 | 0 | 0 | 2 | 0 |
| 3 | 0 | 1 | 2 | 5 | 0 | 0 | 0 | 0 |
| 4 | 0 | 5 | 5 | 5 | 0 | 0 | 0 | 0 |
| 5 | 2 | 4 | 4 | 5 | 0 | 0 | 0 | 0 |
| 6 | 1 | 2 | 2 | 5 | 0 | 0 | 0 | 0 |

Tables 16 and 17 report subject pain data. Fifty percent of subjects experience upper extremity pain during clarinet performance ranging from right-hand-specific pain to multiple-region pain of the shoulders, forearm, and wrist. However, five out of six subjects experience upper extremity pain or numbness while not playing the clarinet. Only one subject experienced clarinet related pain while not playing, while the remaining five subjects experiencing pain stated pain was aggravated by playing the instrument.

Table 16. Subject (S) Pain during Clarinet Performance

| S | Pain Present while playing | Location | Description |
|---|---|---|---|
| 1 | yes | shoulders, right forearm and wrist | pain when playing very technical/fast music with little or no breaks in finger motion |
| 2 | yes | RH ring and pinky | shooting pain |
| 3 | no | n/a | n/a |
| 4 | no | n/a | n/a |
| 5 | no | n/a | n/a |
| 6 | yes | arm | numbness |

Table 17. Subject (S) General Pain Information (not limited to playing the clarinet)

| S | Pain Present | Location | Intensity level: None 0-5 Unbearable | Description |
|---|---|---|---|---|
| 1 | yes | shoulders, right forearm and wrist | 2 | Pain is limited to one site and aggravated by playing the instrument |
| 2 | yes | RH wrist and forearm, shoulders | 2 for RH wrist and 4 for shoulders | Pain is limited to one site and aggravated by playing the instrument |
| 3 | none | none | none | none |
| 4 | yes | both forearms, wrists and hands | 3 | Pain persists away from the instrument. |
| 5 | yes | pain and occasional numbness in fingers | 3 | n/a |
| 6 | yes | left arm, forearm, wrist and hand | 2 | Pain is limited to one site and aggravated by playing the instrument. |

Table 18 represents nonmusical activity hand usage. Subjects spent an average of 13.5 hours performing computer tasks per week, which was the most common activity requiring use of the hands for this study. The second most common activity was cell phone usage (included texting, emailing, and talk time) at an average of 4.3 hours a week per subject. Average sports activities/working out activities comprised an average of 3 hours a week per subject, while weight-bearing tasks averaged 2.83 hours per week.

Table 18. Subject (S) Nonmusical Activities Requiring Use of Their Hands (average use in hours per week)

| S | Computer tasks | Weight-bearing tasks | Sports/working out | Cell phone usage | Other |
|---|---|---|---|---|---|
| 1 | 20 | 2 | 4 | 10 | 0 |
| 2 | 28 | 15 | 2 | 8 | 0 |
| 3 | 10 | 0 | 0 | 1 | 0 |
| 4 | 2 | 0 | 2 | 4 | 0 |
| 5 | 0 | 0 | 10 | 2 | 0 |
| 6 | 21 | 0 | 0 | 1 | 0 |

Table 19 includes subject wellness practices. Interestingly, subject 3 was the only subject without reported pain (clarinet related or otherwise), and this subject offered no wellness practices or coping strategies. Common wellness practices include stretching, massage therapy, and rest from playing.

Table 19. Subject (S) Wellness Practices and Coping Strategies

| S | Wellness practices/coping strategies: |
|---|---|
| 1 | Stretches, rest from playing, altered practice routine, weight-lifting/working out and maintaining overall fitness |
| 2 | Hand and arm stretches before and after playing, 5 minute breaks every hour, massage therapy, splint right hand every night, ice baths daily for 3 minutes during recital weeks, ibuprofen for hand and shoulder pain occasionally, and altered practice routine |
| 3 | None |
| 4 | Stretches, rest from playing, trigger point massage therapy, chiropractic sessions, yoga, ice and heat regiments, and pain medications |
| 5 | Stretches, rest from playing, massage therapy, and yoga |
| 6 | Massage therapy every three weeks, ice regiment after long practice sessions |

# CHAPTER 8: DISCUSSION

This study resulted in several significant findings. First, subject right hand thumb placement and hand size significantly influence variations in index finger flexion and ring-pinky abduction. Subjects in the small hand group placed a higher percentage of thumb past the center of the clarinet rest and had flatter ring and pinky fingers than the large hand group. The large hand group had lower values in right ring-pinky abduction and more pronounced curved ring and pinky finger postures. The small hand group had higher degrees of index finger flexion, resulting in a pronounced curved index finger posture, than the large hand group.

Second, the spacing between the index and middle finger, measured by sensor 9 (middle-index abduction) on the CyberGlove®, showed the greatest divergences between each of the three hand posture models and performance posture. Almost all other sensors for the three posture models were within one degree of the performance posture. While the tennis ball model diverged the least from the playing posture, these data suggest a modification of all three models is in order. Third, as the percentage of the thumb extending to the left of the clarinet rest (when looking down the instrument) decreases, the hand flattens out at the metacarpals. Conversely, as thumb percentage past the clarinet rest increases, the index finger is more curved and the pinky stretches farther to reach the pinky keys. As expected, the ascending and descending postures are significantly different. Most ascending postures have higher sensor values than the descending posture values.

The following discussion provides data from which these observations were formed.

## CyberGlove® Data

### *Finger Postures across Subjects for Each Pitch*

Appendix C contains charts for each hand posture for every pitch of the performance task across all subjects. Data for left hand sensors 12 and 15 and right hand sensor 17 were disregarded due to instrument malfunction. These charts show variability in clarinet hand position or posture differences for each pitch across subjects for notes E3-E6 (ascending and descending).

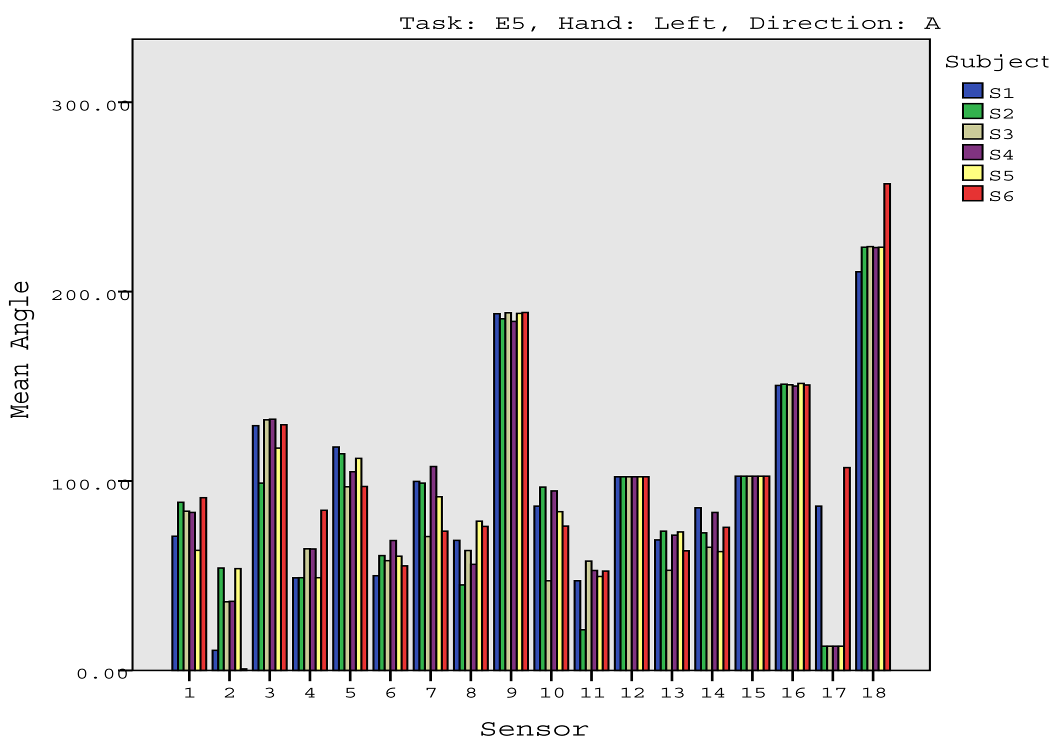



Figure 14. Left hand E5 posture across subjects

Across most pitches in the left hand, subject 6 (one of the smallest hands in either group) shows highest mean angle data in sensors 1 (angle of thumb rotating across palm), 4 (thumb abduction), 17 (wrist flexion), and 18 (wrist abduction) and lowest mean angle data in sensor 2 (thumb metacarpal phalangeal joint). Contrastingly, subject 1 (one of the largest hands in the either group) shows lowest mean angle flexion in sensors 6 (index proximal interphalangeal joint), and 18 (wrist abduction), but also has low mean angle data for sensor 2 similar to subject 6 in the small hand group. Data from sensors 9 (middle-index abduction) and 16 (palm arch) is similar across subjects. Subject 3 has low data measurements from sensors 10 (ring MCP), 13 (pinky MCP), and 14 (pinky IP), suggesting this subject keeps the left ring and pinky close to the instrument.

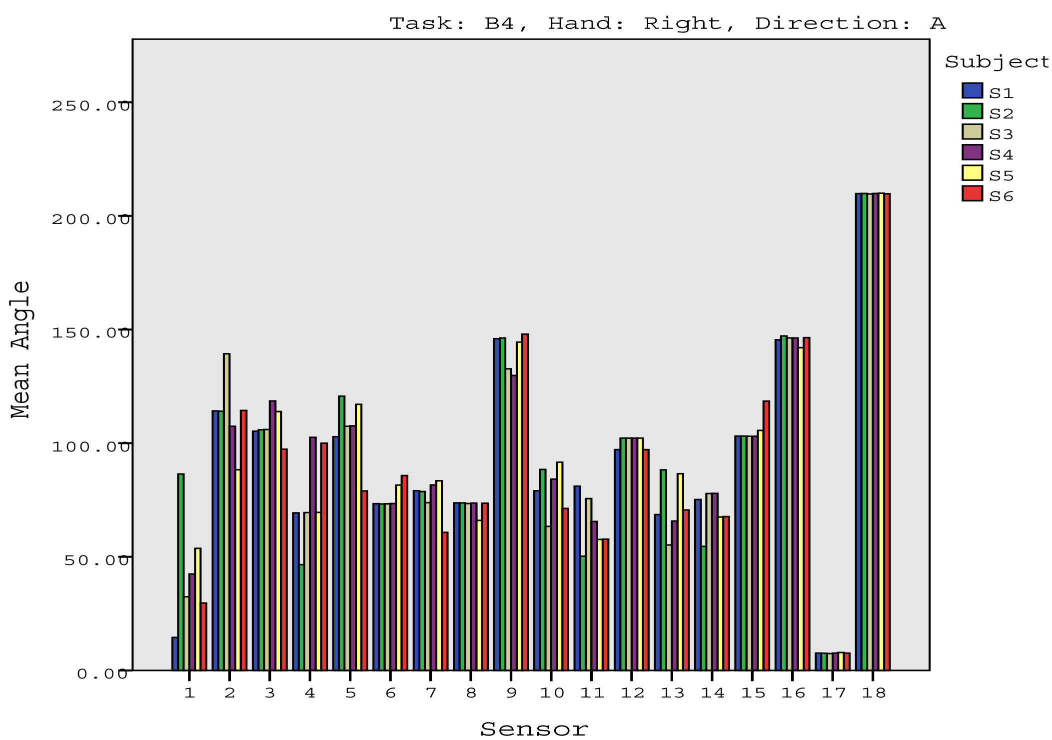



Figure 15. Right hand ascending B4 posture across subjects

Across most pitches in the right hand, subject 2 (small hand group) has higher mean angle measurements in sensors 1 (thumb rotation), 5 (index MCP), 13 (pinky MCP), and 16 (palm arch). Subject 3 has the highest joint angle measurements in sensor 2 (thumb MCP), but lowest in sensors 10 (ring MCP) and 13 (pinky MCP), suggesting s/he keeps right ring and pinky fingers close to the instrument. Sensor 14 (pinky IP) shows the large hand group (subjects 1, 3, and 4) having higher angle measurements while the small hand group (subjects 2, 5, and 6) has lower joint angle measurements. The small hand group also has higher joint angle measurements than the large hand group in sensors 13 (pinky MCP) and 15 (pinky-ring abduction), while the large hand group has higher measurements in sensors 11 (ring IP) and 14 (pinky IP). These measurements suggest the small hand group has to abduct (finger span) digits 4-5 further than the large hand group, while the large hand groups do not need to abduct as far as the small hand group. The large group also has more curved right ring and pinky fingers.

*Performance Task Variance*

The standard deviation column in table 20 shows the largest variance in sensors 1, 2, 4 (thumb joint sensors), 5 (index MCP), 11 (ring IP), and 13 (pinky MCP). Subject thumb placement and hand size are the most influential factors in these fluctuations, and both topics are discussed later in this chapter.

Table 20. Right Hand Standard Deviation for All Subjects

| Sensor | Standard Deviation |
|---|---|
| 1 | 22.77 |
| 2 | 14.96 |
| 3 | 6.77 |
| 4 | 19.51 |
| 5 | 13.49 |
| 6 | 4.99 |
| 7 | 7.64 |
| 8 | 2.86 |
| 9 | 7.56 |
| 10 | 9.81 |
| 11 | 10.77 |
| 12 | 2.41 |
| 13 | 11.67 |
| 14 | 8.22 |
| 15 | 5.66 |
| 16 | 1.80 |
| 17 | .15 |
| 18 | .11 |

The standard deviation column in table 21 shows the largest variance in sensors 2, 3, 4 (thumb joints), 7, 8 (middle finger joints) 10, 11 (ring joints), and 18 (wrist abduction). Sensor 17 was disregarded due to instrument malfunction. Similarly, subject thumb placement and hand size may be the most influential factors in these fluctuations. The fluctuation in left hand thumb joints may be related to the multiple tasks required: depress the register key alone, cover the thumbhole without pressing the register key, and cover the thumbhole and depress the register key at the same time. The large variability in thumb position may also be related to the large variability in wrist abduction as the wrist angle guides thumb placement. The left hand ring joint variability can be explained by the photographs taken during the performance task. The small hand group (except for subject 2) had flat ring finger postures while the large hand group had curved ring finger postures.

Table 21. Left Hand Standard Deviation for All Subjects

| Sensor | Standard Deviation |
|---|---|
| 1 | 9.93 |
| 2 | 20.18 |
| 3 | 12.11 |
| 4 | 12.95 |
| 5 | 8.20 |
| 6 | 5.66 |
| 7 | 13.74 |
| 8 | 11.61 |
| 9 | 2.58 |
| 10 | 16.49 |
| 11 | 11.82 |
| 12 | .02 |
| 13 | 7.28 |
| 14 | 8.57 |
| 15 | .04 |
| 16 | .44 |
| 17 | 40.15 |
| 18 | 14.28 |

*Ascending vs. Descending Posture*

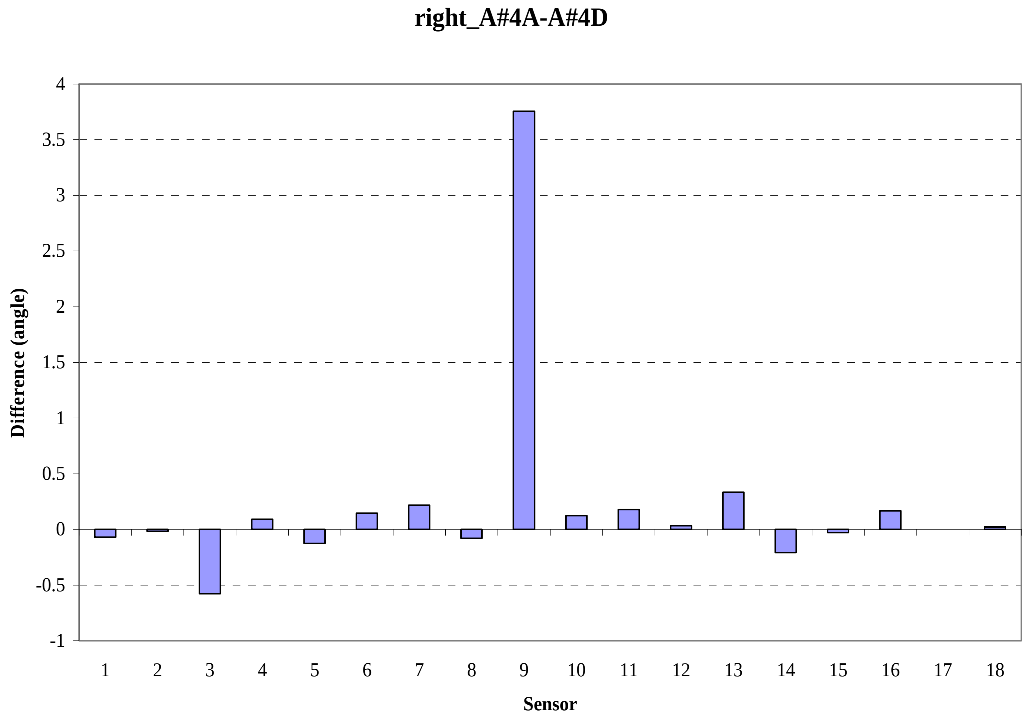



Figure 16. Ascending vs. descending A#4 right hand

Appendix C contains average difference between ascending and descending postures for every pitch of the performance task. Descending posture sensor data was subtracted from the ascending posture data. A positive value indicates the ascending sensor angle is greater, while a negative value indicates the descending sensor angle is greater. As expected, the ascending and descending postures are different.

Figure 16 contains positive values for many sensors, suggesting ascending A#4 has higher joint angle measurements than the descending A#4 for all subjects. This pitch is the last note before going over the "break" of the clarinet or the register change from the first to second registers. The ascending posture begins with only the left index and thumb pressing keys and ends with all fingers of both hands simultaneously covering tone holes or pressing keys. In the descending posture, only the left hand thumb should move.

*Pedagogical Model Comparison*

Comparing the hand posture of low E (E3, a note engaging all of the fingers) to three common teaching models may help indicate which model most closely resembles hand posture professionals use when playing. Models for comparison include holding a tennis ball, natural posture (hanging hands down alongside the body), and forming “C.”

Figures 17-22 show direct comparisons between the performance and teaching postures. Averaged performance task data frames 400-425 (E3) were compared to average tennis ball postures, to average natural hand postures, and to average “C” postures for each subject. Small and large hand groups were defined based on hand measurements taken during the experiment. Average small group teaching postures were compared to average small group E3, and average large group teaching postures were compared to average large group E3. The difference between teaching postures and E3 were calculated and plotted for all subjects and both hand size groups.

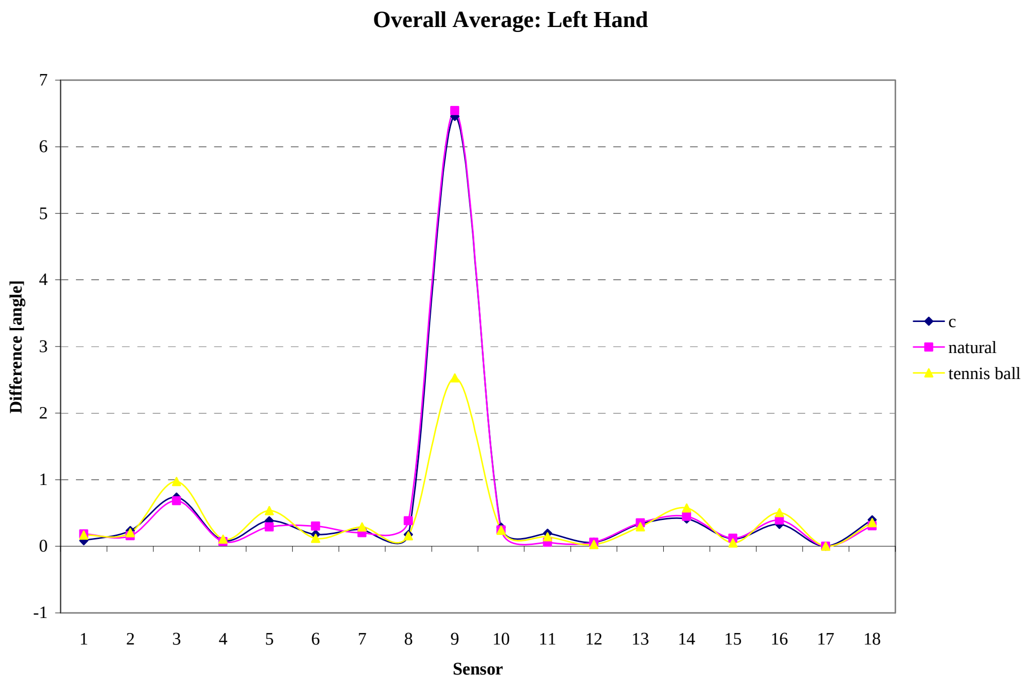



Figure 17. Difference between left hand performance and teaching postures

Sensor 9 (middle-index abduction) shows the most significant differences between teaching postures and left hand performance posture. The tennis ball is the closest for this sensor, but still differs by about 2.5 degrees. All three teaching postures are similar across the remaining sensors. Sensors 1, 4, 11, 12, 15, and 16 are almost the same as performance posture across all subjects. The tennis ball posture has the most substantive difference for sensors 3, 5, 14, and 16, while the natural posture has the largest variance for sensor 6.

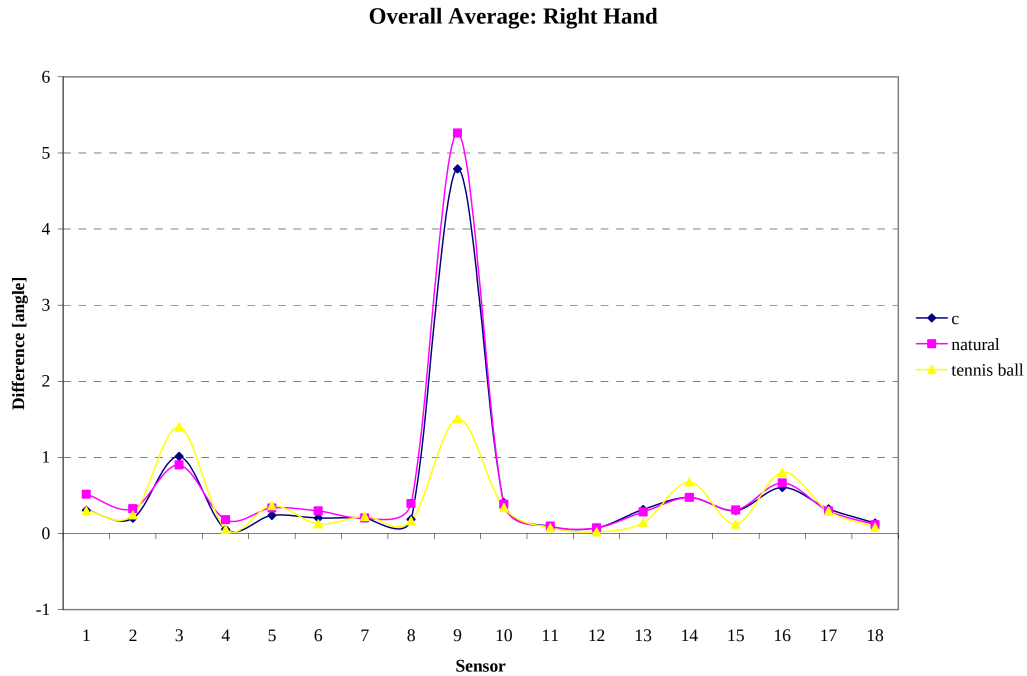



Figure 18. Difference between right hand performance and teaching postures

Sensor 9 shows the largest difference in teaching postures when compared to right hand performance posture. The tennis ball is closest for this sensor, but still differs by about 1.5 degrees. All three teaching postures are similar across the remaining sensors except for sensor 3, where the tennis ball model diverges furthest from the performance posture. Sensors 4, 11, 12, and 18 are almost the same as performance posture across all subjects. The tennis ball posture has the greatest difference for sensors 3, 14, and 16, while the natural posture has the maximum difference for sensors 1, 4, 6, and 9.

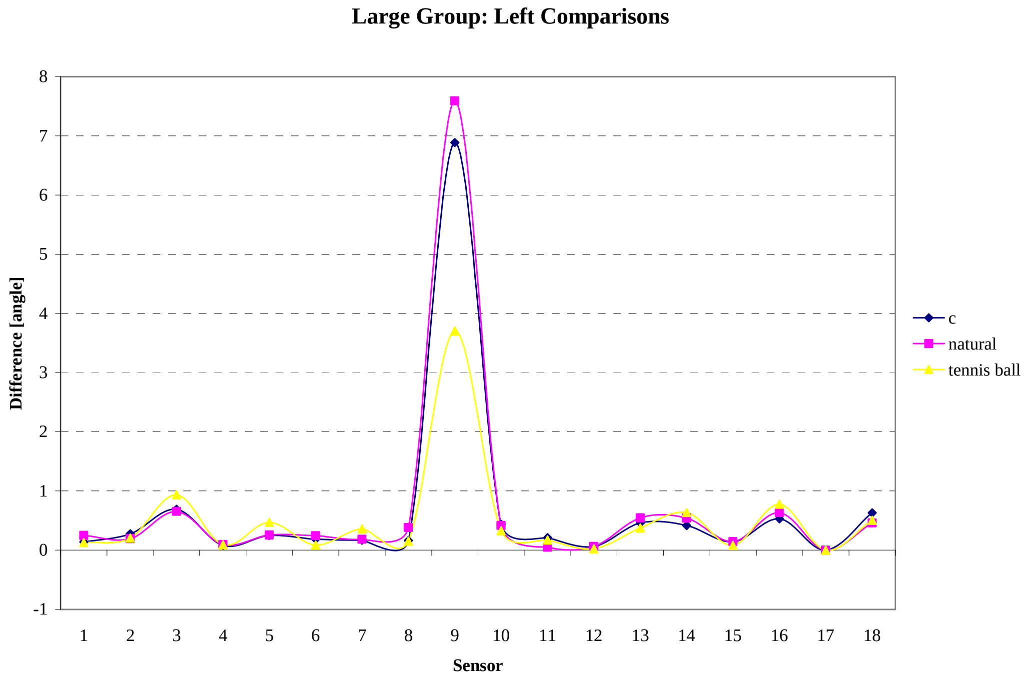



Figure 19. Difference between large group left hand performance and teaching postures

Sensor 9 shows the most substantial difference for the left hand large group in teaching postures when compared to performance posture. The tennis ball is closest for this sensor, but still differs by about 3.5 degrees. All three teaching postures are similar across the remaining sensors. Sensors 1, 2, 4, 8, 11, 12, 15, and 17 are almost the same as performance posture across large subjects. The tennis ball posture has the largest difference for sensors 3, 5, 7, 14, and 16, while the natural posture has the biggest difference for sensors 6, 9, and 13.

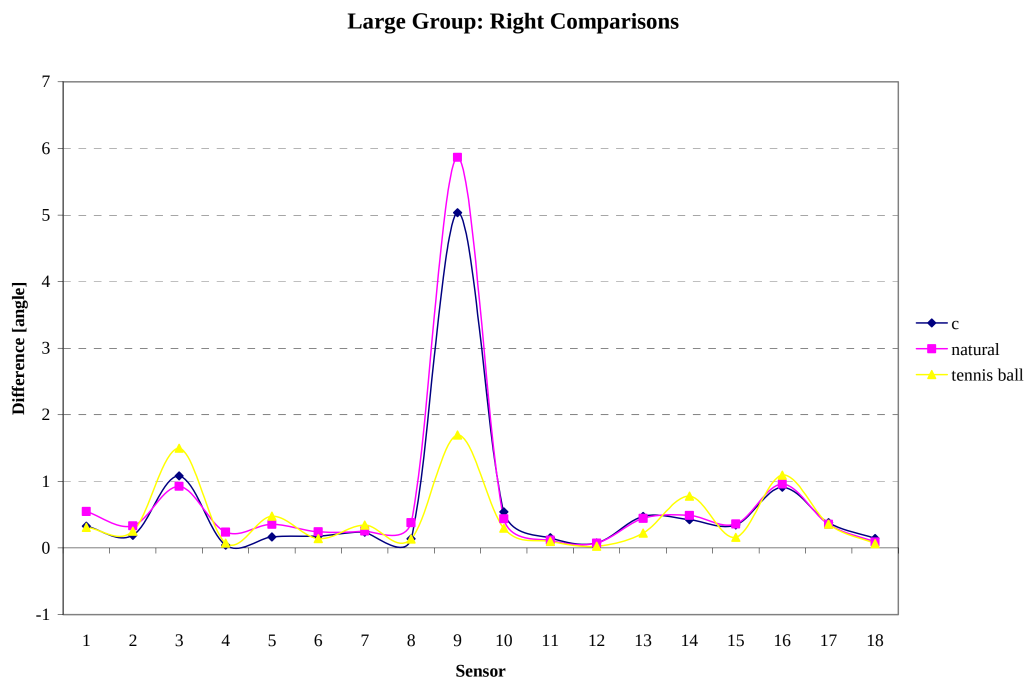



Figure 20. Difference between large group right hand performance and teaching postures

Sensor 9 shows the maximum difference for the right hand large group in teaching postures when compared to performance posture. The tennis ball is closest for this sensor, but still differs by about 1.5 degrees. All three teaching postures are similar across the remaining sensors. Sensors 11, 12, and 18 are almost the same as performance posture across large subjects. The tennis ball posture has the largest difference for sensors 3, 5, 7, 14, and 16, while the natural posture has the most substantial difference for sensors 1, 4, 6, and 9.

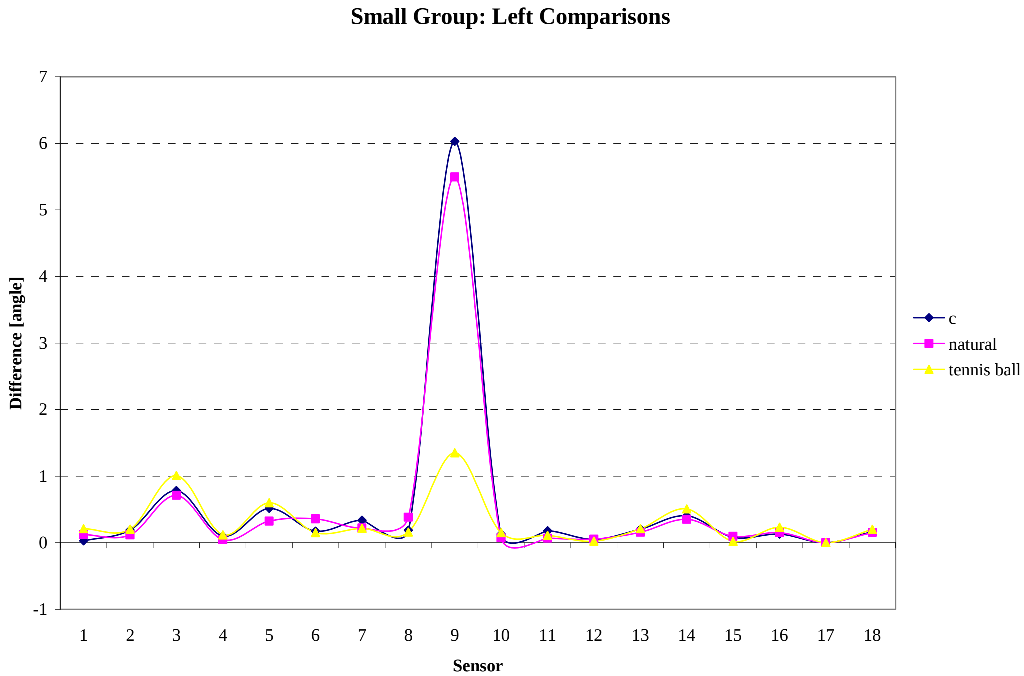



Figure 21. Difference between small group left hand performance and teaching postures

Sensor 9 shows the highest difference for the left hand small group in teaching postures when compared to performance posture. The tennis ball is closest for this sensor, but still differs by about 1.33 degrees. All three teaching postures are similar across the remaining sensors. Sensors 1, 2, 4, 10, 11, 12, 15, and 17 are almost the same as performance posture across the small group subjects. The tennis ball posture has the maximum difference for sensors 1, 3, 5, 14, and 16, while the natural posture has the largest difference for sensor 6 and the “C” posture has the greatest difference for sensor 9.

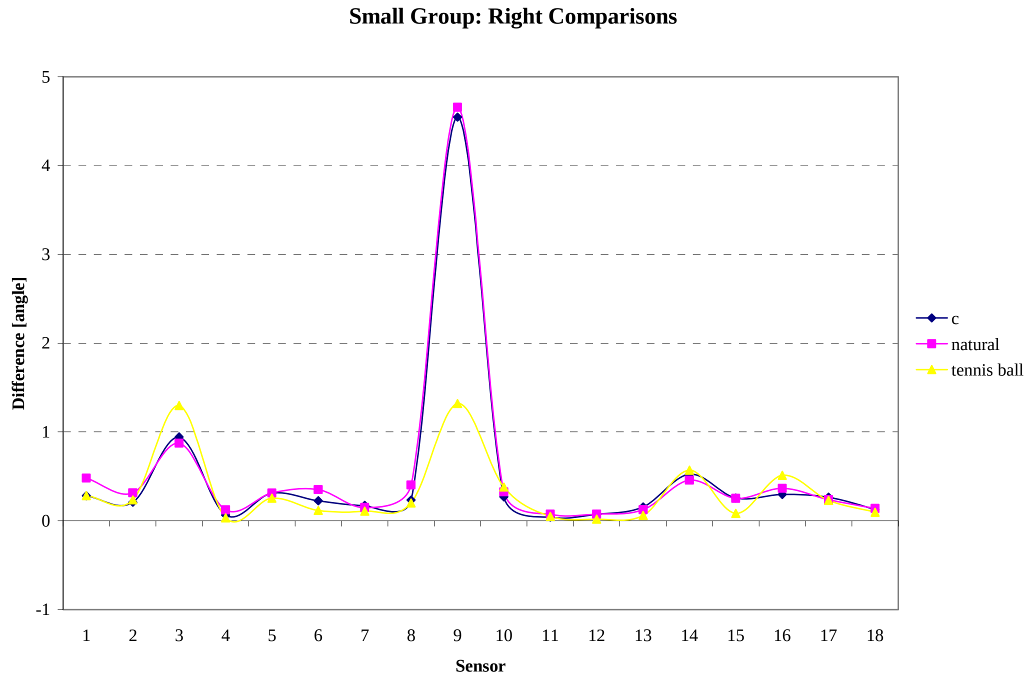



Figure 12. Difference between small group right hand performance and teaching postures

Sensor 9 shows the largest difference for the right hand small group in teaching postures when compared to performance posture. The tennis ball is closest for this sensor, but still differs by about 1.33 degrees. All three teaching postures are similar across the remaining sensors. Sensors 4, 7, 11, 12, and 18 are almost the same as performance posture across the small group subjects. The tennis ball posture has the highest difference for sensors 3, 14, and 16, while the natural posture has the largest difference for sensor 1, 6, and 9.

Overall, all of these teaching postures are very similar to actual clarinet performance. Most sensors read all postures within one degree of difference except for sensor 9, the spacing between the index and middle finger. The tennis ball posture is the closest model to this measurement, but still varies up to 3.5

degrees. However, the tennis ball is the most different for sensor 3 (thumb outer joint, but differs by about 0.5 degrees.

*Right Thumb Placement and Finger Flexion Correlation*

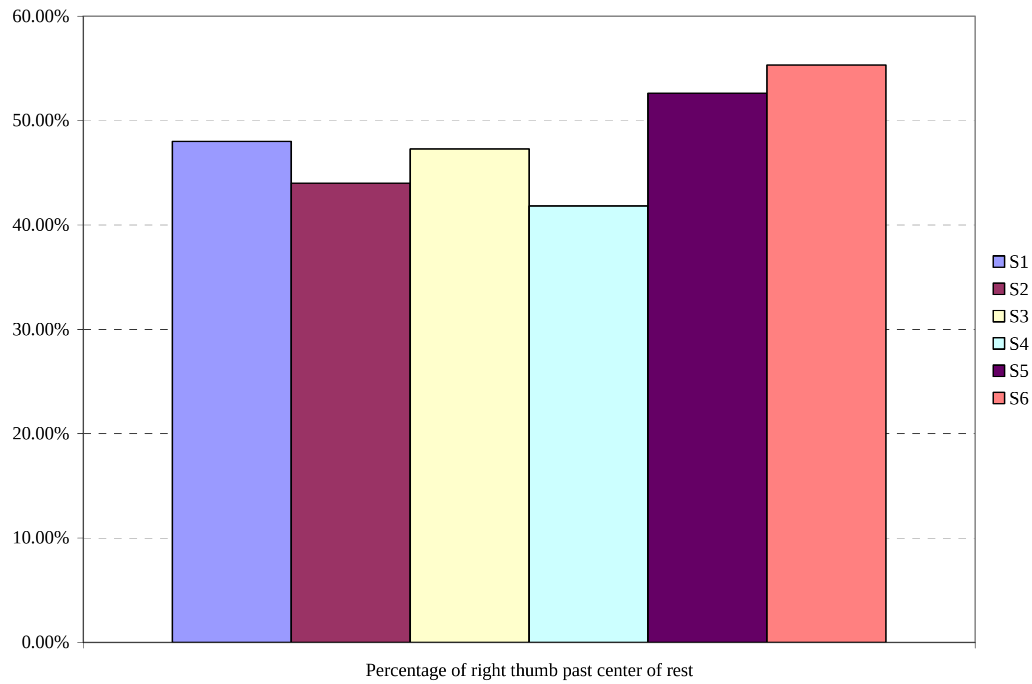



Figure 23. Right hand thumb placement past center of clarinet rest

Subjects 5 and 6, both in the small hand group, place more than 50% of the right thumb past the center of the clarinet thumb rest. Subject 2 is also in the small group and uses only 44% of the right thumb past the center of the clarinet rest; however, this subject is the largest hand of the small group. The large group (subjects 1, 3, and 4) place less than 50% of the right thumb past the center of the rest.

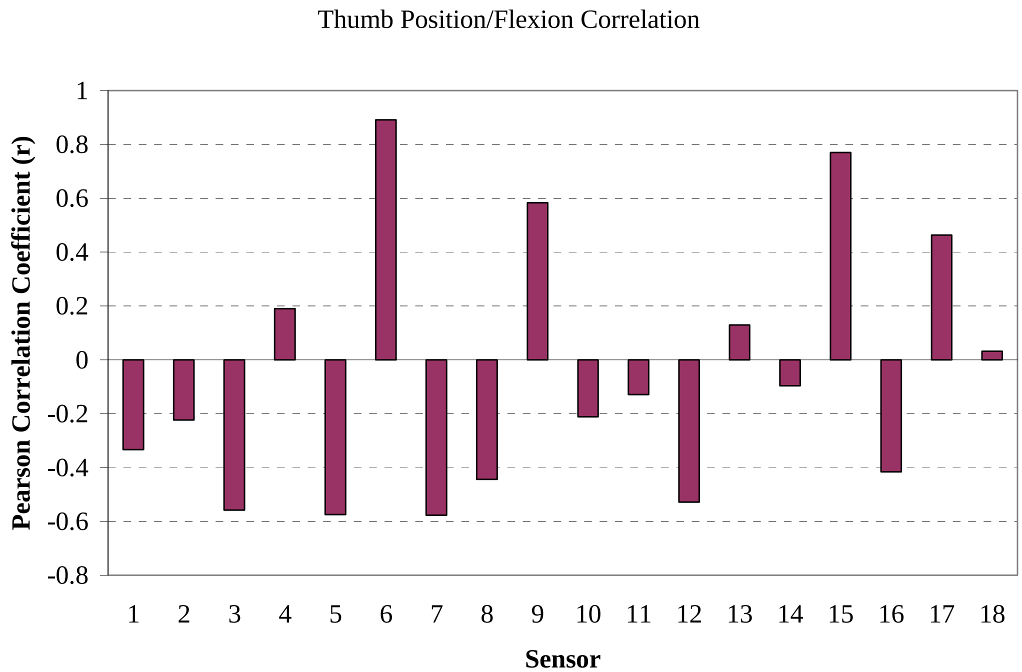



Figure 24. Thumb placement and finger flexion correlation

Figure 24 represents a correlation analysis using right thumb percentage past the clarinet thumb rest to right hand flexion for each sensor. A positive correlation indicates that as the percentage goes up, the flexion goes up, and vice versa. A negative correlation would mean as thumb percentage goes down, flexion goes up, and vice versa. Sensor 6 shows a significant positive correlation; subjects with more thumb past the center clarinet rest also have increased index IP angle measurements. Similarly, sensors 9 and 15 show a positive correlation; subjects with more thumb past the center clarinet rest also have increased index-middle and pinky-ring abduction. Sensors 3, 5, 7, and 12 have negative correlations; subjects with less thumb past the center clarinet rest have decreased thumb IP joint, index MCP, middle MCP and ring MCP angles (knuckles meeting at the palm of the hand). Overall, these correlations suggest that as the thumb percentage past the center of the clarinet rest decreases, the hand flattens out at the metacarpals, and as thumb percentage past the clarinet rest increases, the index finger is more curved and the pinky stretches farther to reach the pinky keys.

**Questionnaire Data**

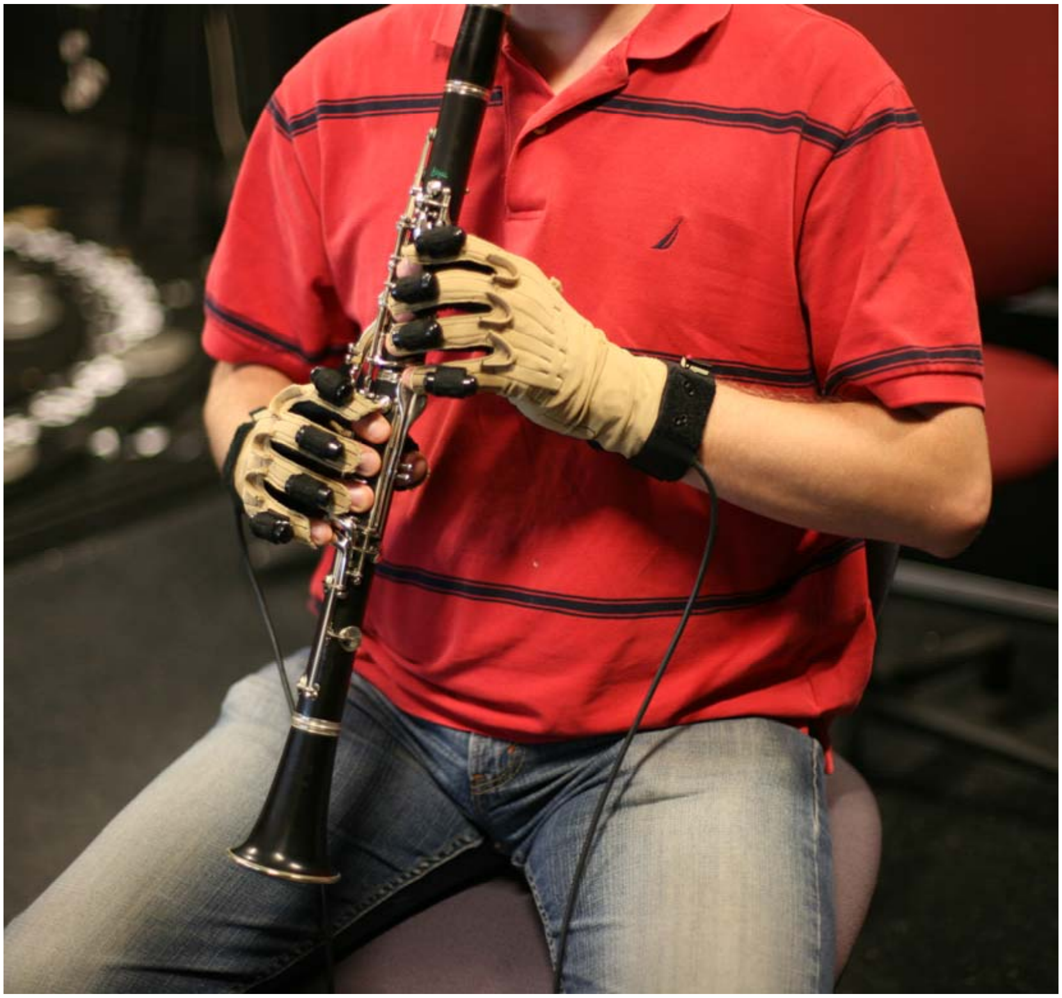
Table 22. Subject Average Playing Time (minutes per week)

| S | Warm Up/ Technique | Repertoire Practice | Rehearsal | Teaching | Performing | Total |
|---|---|---|---|---|---|---|
| 1 | 210 | 1320 | 120 | 0 | 0 | 1650 |
| 2 | 630 | 420 | 180 | 1410 | 30 | 2670 |
| 3 | 735 | 630 | 0 | 960 | 0 | 2325 |
| 4 | 210 | 630 | 360 | 0 | 180 | 1380 |
| 5 | 420 | 840 | 0 | 630 | 0 | 1890 |
| 6 | 420 | 1260 | 0 | 1320 | 120 | 3120 |

Warm up/technique playing time ranged from 30 to 105 minutes a day. Repertoire varied from 60 to 270 minutes per day. Teaching and performance playing time is not consistent across subjects. Daily playing time averages ranged from 198 to 446 minutes per day. It is interesting to note subject 3 has the longest daily warm up/technique time and experiences no pain or wellness/coping strategies (see Table 23). Subject 3 also has the lowest angle measurements for left hand ring and pinky MCP, meaning s/he keeps these fingers close to the instrument. Subject 6 plays an average of 446 minutes per day, experiences arm numbness, and has the highest right hand ring-pinky abduction. Subject 4 has the highest reported pain among all subjects in both hands, wrists, and forearms and is the only subject with both wrists extended and elbows away from the body (see Photograph 12), a posture adopted from an Alexander Technique specialist).

Table 23. Subject (S) General Pain Information (not limited to playing the clarinet)

| S | Pain Present | Location | Intensity level: None 0-5 Unbearable | Description |
|---|---|---|---|---|
| 1 | Yes | Shoulders, right forearm and wrist | 2 | Pain is limited to one site and aggravated by playing the instrument |
| 2 | Yes | RH wrist and forearm, shoulders | 2 for RH wrist and 4 for shoulders | Pain is limited to one site and aggravated by playing the instrument |
| 3 | None | None | None | none |
| 4 | Yes | Both forearms, wrists and hands | 3 | Pain persists away from the instrument. |
| 5 | Yes | Pain and occasional numbness in fingers | 3 | n/a |
| 6 | Yes | Left arm, forearm, wrist and hand | 2 | Pain is limited to one site and aggravated by playing the instrument. |



Photograph 12. Subject with abducted elbows

# CHAPTER 9: CONCLUSION

## Importance

The first goal of this study was to introduce CyberGlove® technology to the performance field, as it is viable tool for tracking finger joint angles. It is safe, non-invasive, and can be regulated to allow precise measurements of finger motion during clarinet performance.

The second goal of this study includes three parts: to record variability of finger posture during clarinet performance, to compare performance to teaching postures found in clarinet pedagogy literature, and to investigate subject hand usage (practice habits, wellness practices, hand pain history, and documentation of other activities requiring use of the hands).

The third goal of this study includes expanding resources for teaching and achieving adequate clarinet performance technique. The clarinet repertoire is increasingly demanding a more agile, technical capability from the player; therefore, learning more about hand mechanics and position may be useful in injury prevention. Klug says inefficient finger motion may lead to injury.[99]

In this study, the subjects with the greatest ring and pinky abduction had higher reported hand and arm pain than the subjects with less ring and pinky abduction values. Subjects were asked to rate pain while playing clarinet and while away from the instrument. Pain is subjective; each subject has a different pain tolerance. Subject-rated pain may or may not have included pressure,

[99]Howard Klug, *The Clarinet Doctor*, (Bloomington, IN: Woodwindiana, 1997), p.60-61.

numbness, and inflammation. The subject with elbow posture far away from the body had the greatest pain in both wrists; perhaps the weight of the clarinet is supported by the wrists and arms instead of being shared with the trunk. The author is not suggesting clarinetists should keep elbows close to the trunk; however, a neutral (not close to the body or far away) elbow posture relative to the trunk may provide a less strenuous arm/wrist posture. The clarinetist (subject 3) keeping fingers closest to the instrument with the longest warmup/technique playing time (105 minutes) reported no pain. This finding may be a coincidence, however, Klug and other pedagogues emphasize keeping the fingers close to the clarinet and warming up properly.

Drastic changes in technique, warmup, repertoire and practice time may lead to injury. The author suggests a gradual change in any of the previously stated factors. Many musicians are injured when “cramming” for an upcoming recital or recording. Instead of cramming, slowly increase practice time by 15 minutes each week when increasing endurance or total practice time, or recovering after a break from playing. The author also suggests easing into new warm up regiments, technical studies, and repertoire at slow tempi, as utilizing tension free hands may also prevent injury. Changing instruments (i.e. B-flat clarinet to E-flat clarinet) should also be gradually integrated over a long period of time. Never play through pain. The saying, “no pain, no gain,” can be detrimental to the musician’s health, well-being and ultimately, career.

**Does the Data Support the Pedagogy Literature?**

All three teaching postures were similar to actual clarinet performance posture, as measured in this study; most sensors were within one degree of difference, except for sensor 9 (index-middle abduction). The tennis ball posture was closest for this sensor overall and very similar to the natural and "C" postures for the remaining sensors with the exception of sensor 3 (thumb IP) where the natural posture was the closest to actual performance. The data suggests the area recorded by sensors 9 must be addressed for the three models to be completely effective. Applying a larger space between the index and middle fingers of both hands (approximately 1/2 inch apart at the IP joints) will help compensate for the differences between the performance and teaching postures.

The large range of variability in the left and right thumb joint motion is also supported in the pedagogical literature. Campione,[100] Stein,[101] Stubbins,[102] and others all stress the importance and responsibilities of thumb position. The right thumb must lift the clarinet's weight and influences the flexion of the index finger and the pinky's ability to reach the pinky keys. The fluctuation in left hand thumb joint values is explained by this digit's multiple responsibilities: to depress

---

[100] Carmine Campione, *Campione On Clarinet: A Complete Guide to Clarinet Playing and Instruction*, (Fairfield: John Ten-Ten Publishing, 2001), 29.

[101] Keith Stein, *The Art of Clarinet Playing*, (Miami, FL: Summy-Birchard Inc., 1958), 28-31.

[102] William Stubbins, *The Art of Clarinetistry*, (Ann Arbor, MI: Ann Arbor Publishers, 1965), 212-217.

the speaker key alone, cover the thumbhole without pressing the speaker key, and cover the thumbhole and depress the speaker key at the same time.

This study's hypothesis that clarinetists with larger hands and longer fingers will have higher degrees of finger flexion than clarinetists with smaller hands and shorter fingers, while clarinetists with smaller hands and shorter fingers will have higher degrees of finger extension than clarinetists with larger hands and longer fingers is largely correct. The large hand group generally had only curved (flexed) finger postures, while the small hand group had neutral or flat (extended) ring and pinky fingers. However, the small group had higher ring-pinky abduction values, meaning this group had to reach further for the pinky keys. Right thumb position also influenced ring-pinky abduction and index finger flexion in the right hand. Higher percentages of thumb placed past the center of the thumb rest resulted in higher ring-pinky abduction values across all subjects and increased index finger flexion values.

From these findings, the author promotes an individual approach to teaching clarinet hand posture and stresses the importance of finding a thumb position that allows easy access to the pinky keys while maintaining a slightly curved posture for all of the fingers. The thumb position of both hands is critical for finding a posture that utilizes minimal effort for the fingers, especially the ring and pinky fingers. Thumb and finger length vary drastically among clarinetists; therefore, a one-size fits all approach to forming hand posture should be reconsidered.

For the right hand, the small hand group placed a higher percentage of thumb past the center of the rest (over 50% of the thumb) and subsequently the pinky had to stretch farther to reach the pinky keys than the large hand group. For the left hand, an angled thumb position is crucial for its multiple responsibilities and for forming ring and pinky postures that can reach the keys with minimal effort. Hand size must be considered when teaching clarinet hand position. Clarinetists with large hands may have more curved finger postures than clarinets with small hands, especially the ring and pinky fingers.

The functional position of the hand (defined in Chapter 3) should be used as a guide for teaching a biomechanically sound clarinet hand posture utilizing efficient finger motion. Excess motion present in extended finger (flat) postures result in unnecessary muscle and ligament effort and are not within the ranges defined by the functional position; fingers should be partially flexed at all joints (curved), wrists slightly extended, and finger motion executed with minimal effort. Visually, the functional position of the hand (p. 29) is very similar to an ideal clarinet hand posture.

**Adjustments for Future Experiments**

The creation of 3D representations based on professional clarinet hand postures originally intended for this study could not be realized. The software program was only capable of reading the 22-sensor CyberGlove® model that measures the distal joint of each finger. This study used the 18-sensor model (open fingertip) that excluded fingertip sensor measurements, allowing clarinetists to cover tone holes.

Instrument malfunctions such as stuck sensor readings should be investigated and rectified immediately. These malfunctions were not discovered until data analysis.

## Future Research

The CyberGlove® could be used for studying finger posture during clarinet performance tasks at varying tempi. Different tasks should be investigated, including non-adjacent finger motion tasks such as arpeggios, thirds, and other leaps. Studying amateur or young students' finger postures to compare to professional finger postures may provide useful teaching information. The CyberGlove® could also be used to study finger postures used in other instruments. Studying hand strength and muscle fatigue may also reveal valuable applications for developing healthy clarinet hand posture.

## REFERENCES


Adamovich, Sergei V., Gerard G Fluet, Abraham Mathai, Qinyin Qiu, Jeffrey Lewis, and Alma S Merians. "Design of a Complex Virtual Reality Simulation to Train Finger Motion for Persons with Hemiparesis: a Proof of Concept Study." *Journal of NeuroEngineering and Rehabilitation* 6:28 (2009): 10.1186/1743-0003-6-28.

Boian, R., A. Sharma, C. Han, A. Merians, G. Burdea, S. Adamovich, M. Recce, M. Tremaine, and H. Poizner. "Virtual Reality-based Post Stroke Hand Rehabilitation." in *Medicine Meets Virtual Reality* 02/10: *Digital Upgrades, Applying Moore's Law to Heath.* ed. Westwood, James. IOS Press: Lansdale, 2007.

Brisan, Cornel. Vistrian Măties, Sergiu-Dan Stan and Stelian Brad. "Main Aspects Regarding the Mechanism of the Prosthesis for Human Hand - Synthesis, Analysis, Design and Functional Simulation." *Journal Solid State Phenomena* Vol. 166 – 167: Robotics and Automation Systems (2010) 383-388.

Campione, Carmine. *Campione On Clarinet: A Complete Guide to Clarinet Playing and Instruction*. Fairfield: John Ten-Ten Publishing, 2001.

Cipolla, John. *Clarinet Basics, Foundations for Clarinet Players*. people.wku.edu/john.cipolla/ClarinetBasics.pdf (accessed October 5, 2010).

"CyberGlove v1.0 Reference Manual." Immersion Corporation (2002).

Gest, Thomas and Jaye Schlesinger. *MedCharts: Anatomy.* New York: ILOC, 1995.

Gingras, Michele. *Clarinet Secrets: 52 Performance Strategies for the Advanced Clarinetist*, Lanham, Maryland: Scarecrow Press, Inc., 2004.

Gray, Henry. *Anatomy of the Human Body.* New York: Lea and Febiger, 1918.

Stein, Keith. *The Art of Clarinet Playing.* Miami, FL: Summy-Birchard Inc., 1958.

Guy, Larry. *The Daniel Bonade Workbook*. Stony Point, NY: Larry Guy, 2004.

Guy, Larry. *Hand and Finger Development for Clarinetists*. Stony Point, NY: Rivernote Press, 2007.

Hertling, D., and R. M. Kessler. *Management of Common Musculoskeletal Disorders: Physical Therapy Principles and Methods*. 3rd ed. Philadelphia: J.B. Lippincott, 1996.

Huenerfauth, Matt and Pengfei Lu. "Calibration Guide for CyberGlove." The City University of New York, Version: 4.4.

Ip, H., K. Law, and B. Kwong. "Cyber Composer: Hand Gesture-Driven Intelligent Music Composition and Generation." *Multi-Media Modeling Conference, International,* 11th International Multimedia Modelling Conference (2005) 46-52.

Kapandji, I.A. *The Physiology of Joints. Vol 1. Upper Limb,* 2nd ed. Edinburgh: Churchill Livingstone, 1970.

Klug, Howard. *The Clarinet Doctor*. Bloomington, IN: Woodwindiana, 1997.

Kuhlmann, J. N. and R. Tubiana. "Mechanism of the Normal Wrist." in J. P. Razemon and G. R. Fisk. eds. *The Wrist* Edinburgh: Churchill Livingstone, 1982.

Norkin, C. C. and P. K. Levangie. *Joint Structure and Function.* 2nd ed. Philadelphia: F.A. Davis, 1992.

Pino, David. *The Clarinet and Clarinet Playing*. Mineola, NY: Dover, 1998.

"Products: CyberGlove II." http://www.cyberglovesystems.com/products/cyberglove-ii/overview (accessed February 7, 2011).

Ricco, Susanna and Carlo Tomasi. "Fingerspelling Recognition through Classification of Letter-to-Letter Transitions." *Lecture Notes in Computer Science,* 5996/2010 (2010) 214-225.

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

Sánchez-Margallo, Francisco M., Juan A. Sánchez-Margallo, José B. Pagador, José L. Moyano, José Moreno and Jesús Usón, "Ergonomic Assessment of Hand Movements in Laparoscopic Surgery Using the CyberGlove." *Computational Biomechanics for Medicine* 10:1007/978 Part 2 (2010), 121-128.

Smith, L. K., Weiss, E. L., and L. D. Lehmkuhl. *Brunnstrom's Clinical Kinesiology*. 5th ed. Philadelphia: F.A. Davis, 1996.

Stubbins, William. *The Art of Clarinetistry*. Ann Arbor, MI: Ann Arbor Publishers, 1965).

Tank, Patrick, and Thomas Gest. *Atlas of Anatomy*. Philadelphia: Lippincott Williams and Wilkins, 2009.

Vinjamuri, R., Zhi-Hong Mao, R. Sclabassi, and Mingui Sun. “A Novel Architecture for the Design of Prosthetic and Robotic Hands.” Proceedings of the IEEE 32nd Annual Northeast Bioengineering Conference, Easton, PA (2006) 163-164.

# APPENDIX A

# MUSCLES, JOINTS, LIGAMENTS, TENDONS, AND RELATED STRUCTURES OF THE HAND

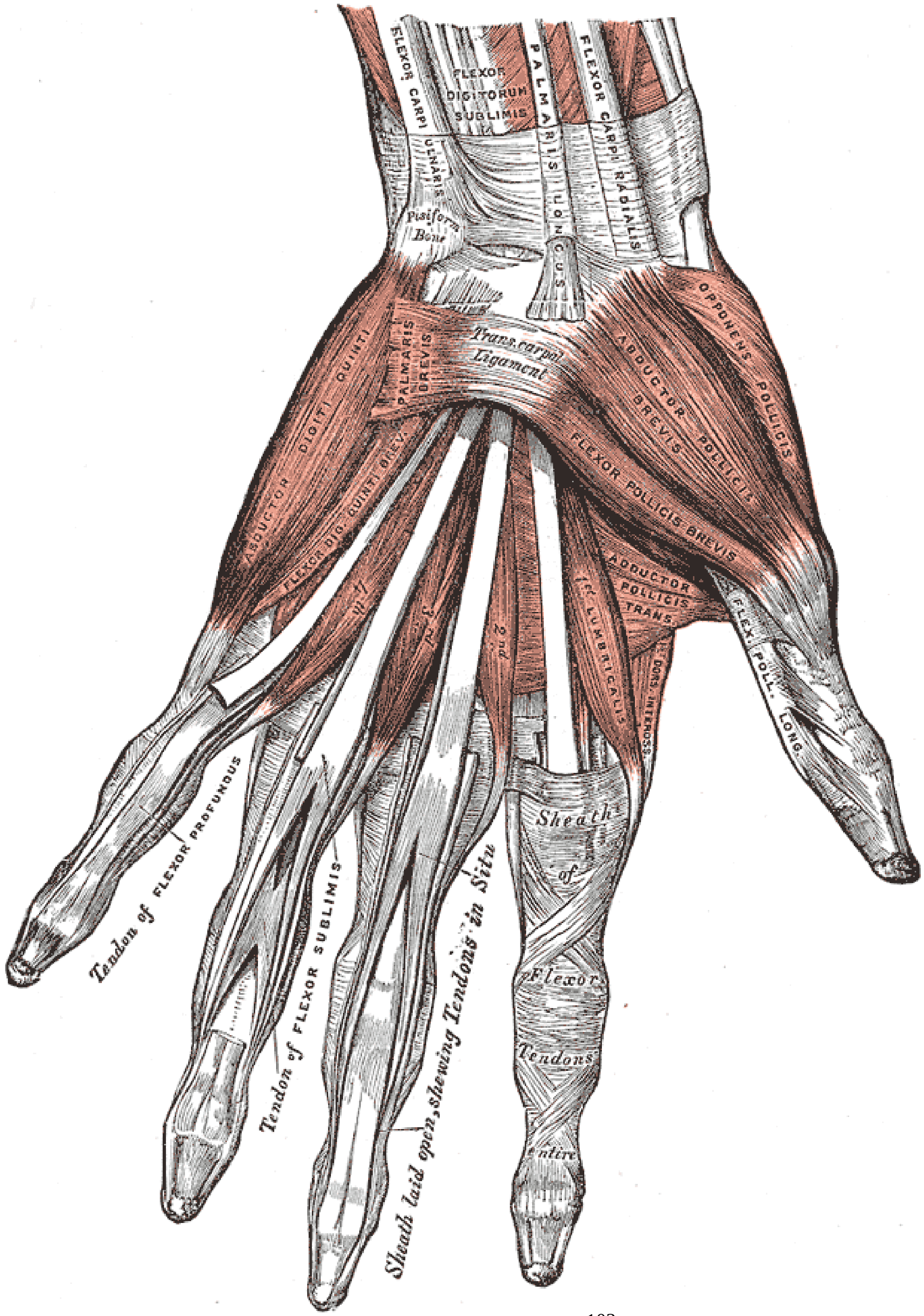



Figure 25. Muscles of the left hand (palmar surface)[103]

[103]Henry Gray, *Anatomy of the Human Body* (New York: Lea and Febiger, 1918), 463.

Table 24. Muscles of the Hand[104]

| Muscle | Origin | Insertion | Action |
|---|---|---|---|
| abductor digiti minimi (hypothenar muscle) | pisiform | base of proximal phalanx of little finger | abducts little finger |
| abductor pollicis brevis (thenar muscle) | flexor retinaculum of wrist, scaphoid and trapezium | base of proximal phalanx of thumb | abducts thumb |
| abductor pollicis longus | posterior surface of ulnar, middle aspect of radius | base of first metacarpal | abducts thumb |
| adductor pollicis | capitate second and third metacarpals | proximal phalanx of thumb | adducts thumb |
| brachioradialis | lateral supracondylar ridge of humerus | styloid process of radius | flexes forearm and supinates hand |
| extensor carpi radialis brevis | lateral epicondyle of humerus | base of fifth metacarpal | extends and adducts hand |
| extensor carpi radialis longus | lateral supracondylar ridge of humerus | base of second metacarpal | extends and abducts wrist |

[104]Gray, 445-465, Patrick W. Tank and Thomas R. Gest, *Atlas of Anatomy*, (Philadelphia: Lippincott Williams and Wilkins, 2009), 50-73, and Thomas R. Gest and Jaye Schlesinger, *MedCharts: Anatomy*, (New York: ILOC, 1995), 65-115.

| Muscle | Origin | Insertion | Action |
| --- | --- | --- | --- |
| extensor carpi ulnaris | lateral epicondyle of humerus, posterior border of ulna | base of fifth metacarpal | extends and adducts hand |
| extensor digiti minimi | lateral epicondyle of humerus | extensor expansion of little finger | extends little finger |
| extensor digitorum | lateral epicondyle of humerus | extensor expansion over fingers | extends fingers, hand and forearm |
| extensor indicis | posterior surface of ulna | extensor expansion of index finger | extends index finger |
| extensor pollicis brevis | middle 1/3 of radius | base of proximal phalanx of thumb | extends thumb |
| extensor pollicis longus | middle third ulna and interosseous membrane | base of distal phalanx of thumb | extends thumb |
| flexor carpi radialis | medial epicondyle of humerus | bases of second and third metacarpal bones | flexion and abduction of wrist |
| flexor carpi ulnaris | medial epicondyle | pisiform | flexion and adduction of wrist |
| flexor digiti minimi brevis (hypothenar muscle) | flexor retinaculum hook of hamate | proximal phalanx of little finger | flexes little finger |

| Muscle | Origin | Insertion | Action |
| --- | --- | --- | --- |
| flexor digitorum profundus | upper 3/4 of the volar and medial surfaces of the body of the ulna, interosseous membrane and deep fascia of the forearm | base of the distal phalanges of the fingers | flexes the fingers |
| flexor digitorum superficialis | medial epicondyle of the humerus and parts of the radius and ulna | anterior margins on the bases of the middle phalanges of the four fingers | flexor of fingers (proximal interphalangeal joints) |
| flexor pollicis brevis (thenar muscle) | flexor retinaculum trapezium | proximal phalanx of thumb | flexes thumb |
| flexor pollicis longus | mid volar surface of radius and adjacent interosseus membrane | base of the distal phalanx of the thumb | flexes thumb |
| interosseous, dorsal | four muscles from two adjacent metacarpal shafts | base of the proximal phalanx and the extensor expansion on lateral side of the second digit, lateral and medial sides of the digit 3, and medial side of digit 4 | flex the metacarpophalangeal joint, extend the proximal and distal interphalangeal joints of digits 2-4, abduct digits 2-4 |

| Muscle | Origin | Insertion | Action |
|---|---|---|---|
| interosseous, palmar | three (or four) muscles from the palmar surface of the shafts of metacarpals 1, 2, 4, and 5 | base of the proximal phalanx and extensor expansion of the medial side of digits 1 and 2, and lateral side of digits 4 and 5 | flexes the metacarpophalangeal, extends proximal and distal interphalangeal joints and adducts digits 1, 2, 4, and 5 |
| lumbricals I and II | tendons of flexor digitorum superficialis | lateral aspect of extensor expansion | flex metacarpophalangeal joint and extend interphalangeal joints |
| lumbricals III and IV | tendons of flexor digitorum superficialis | lateral aspect of extensor expansion | flex metacarpophalangeal joint and extend interphalangeal joints |
| opponens digiti minimi (hypothenar muscle) | flexor retinaculum hook of hamate | 5th metacarpal | opposes little finger to other digits |
| opponens pollicis (thenar muscle) | trapezium and flexor retinaculum | lateral border of first metacarpal | opposes thumb to other digits |
| palmaris brevis | flexor retinaculum and palmar aponeurosis | skin of palm into dermis | steadies skin of palm to help with grip |
| palmaris longus | medial epicondyle and antebrachial fascia | central portion of the flexor retinaculum and superficial portion of the palmar aponeurosis | flexes the hand |

| Muscle | Origin | Insertion | Action |
| --- | --- | --- | --- |
| pronator quadratus | distal 1/4 anteriomedial surface of ulna | distal 1/4 anteriolateral surface of radius | pronates the forearm and hand |
| pronator teres | medial epicondyle of humerus and coronoid process of ulna | mid lateral surface of the body of the radius | pronation of forearm, flexes elbow |
| supinator | lateral epicondyle of humerus crest of ulna | upper 1/3 of radius | supinates hand |

Table 15. Joints, Ligaments, Tendons, and Related Structures of the Hand[105]

| Joint or Structure | Description | Function |
|---|---|---|
| adductor-interosseous compartment | deepest compartment of the palmar surface of the hand | contains the adductor pollicis, three palmar interossei, four dorsal interossei, deep palmar arterial arch, and deep branch of the ulnar nerve |
| articular disk, distal radio-ulnar articulation | triangular in shape, attached by its apex to a depression between the styloid process and the head of the ulna; and by its base, which is thin, to the prominent edge of the radius; united to the ligaments of the wrist-joint | binds the lower ends of the ulna and radius together; upper surface articulates with the head of the ulna, forming an arthrodial joint; under surface articulates with the triquetral bone and medial part of the lunate |
| carpal tunnel | formed by the carpal bones and the flexor retinaculum | transmits the flexor pollicis longus, flexor digitorum superficialis and profundus, and median nerve |
| carpometacarpal ligament, dorsal | strongest and most distinct carpometacarpal ligaments | connects the carpal and metacarpal bones on their dorsal surfaces |
| carpometacarpal joint, finger | the articulation between the distal carpal bones and the proximal ends of the metacarpal bones | a synovial plane joint; limited motion is possible; reinforced by dorsal and palmar ligaments |

[105]Tank and Gest, 50-73 and Gray, 323-332.

| Joint or Structure | Description | Function |
|---|---|---|
| carpometacarpal ligament, palmar | fibrous bands | connect the palmar surfaces of the carpal and metacarpal bones |
| carpometacarpal joint, thumb | the articulation between the trapezium and the proximal end of the metacarpal bone of the thumb | permits flexion/extension and abduction/adduction which may be combined to produce circumduction |
| central compartment | central compartment of the palmar surface of the hand | contains the flexor tendons, lumbricals, superficial palmar arterial arch, and common palmar digital branches of the median and ulnar nerves |
| extensor retinaculum | strong, fibrous band, extending obliquely downward and medialward across the back of the wrist, contains part of the deep fascia of the back of the forearm | holds the tendons of the extensor muscles in place |
| fibrous flexor digital sheaths | fibrous tunnels formed on the palmar surfaces of the phalanges | transmits the flexor tendons |
| flexor retinaculum | a ligament stretching from the scaphoid and trapezeum to the hamate and pisiform, deep and slightly distal to the palmar carpal ligament | forms the carpal tunnel |
| hypothenar compartment | medial compartment of the palmar surface of the hand | contains the abductor digiti minimi, flexor digiti minimi brevis, and opponens digiti minimi |

| Joint or Structure | Description | Function |
|---|---|---|
| interosseous membrane, forearm | connects the interosseous borders located on the shafts of the radius and the ulna | a syndesmosis; proximally directed forces from the hand pass through the radius and are transferred to the ulna |
| intercarpal ligaments: dorsal, interosseous, and palmar | short fibrous bands | connect the adjacent surfaces of the various carpal bones |
| intermetacarpal joint | the articulation between the adjacent sides of the proximal ends of metacarpal bones 2-5 | a synovial plane joint; limited motion is possible |
| interphalangeal joints, collateral and palmar | the articulations between the proximal and middle phalanges or the middle and distal phalanges | a synovial hinge joint; strengthened by medial and lateral collateral ligaments |
| interosseous metacarpal ligaments | fibrous bands extending between dorsal and palmar metacarpal ligaments | connects the bases of metacarpals two to five |
| metacarpophalangeal joint | the articulation between the head of a metacarpal and the base of a proximal phalanx | a synovial condyloid joint; strengthened by medial and lateral collateral ligaments; permits flexion/extension and abduction/adduction which may be combined to yield circumduction |
| midcarpal joint | connects the proximal and distal rows of carpal bones | synovial plane joints; limited ranges of motion permitted; reinforced by numerous ligaments |

| Joint or Structure | Description | Function |
|---|---|---|
| palmar aponeurosis | a thick aponeurotic layer overlying the central compartment of the palm | palmaris longus inserts into the palmar aponeurosis |
| pisiform joint | synovial joint between the pisiform and triquetrum | includes the pisohamate ligament and pisometacarpal ligament |
| pisohamate ligament | small rectangular band; prolongation of the tendon of the flexor carpi ulnaris. | volar ligament that connects the pisiform to the hamate; serves as part of the origin for the abductor digiti minimi |
| pisometacarpal ligament | a fibrous band from the distal surface of the pisiform bone | joins the pisiform to the base of the fifth metacarpal bone |
| radial bursa | the synovial sheath enveloping the tendon of the flexor pollicis longus through the carpal canal | continuous with the digital sheath of the thumb |
| radial collateral ligament, wrist | connects the styloid process of the radius with the scaphoid and trapezium | reinforces the articular capsule on the lateral side of the wrist |
| radiate carpal ligament | attaches to the head of the capitate bone and diverges on the palmar surface of the carpal bones | unites the carpal bones |

| Joint or Structure | Description | Function |
|---|---|---|
| radiocarpal (wrist) joint | synovial joint, the radius articulates with the articular disk which articulates with the proximal row of carpals | characterized by an intracapsular articular disk; permits abduction/adduction and flexion/extension that when combined produce circumduction |
| radiocarpal ligament, dorsal | attached, above, to the posterior border of the lower end of the radius; below, to the dorsal surfaces of the scaphoid, lunate, and triangular | continuous with the dorsal intercarpal ligament, strengthens the radiocarpal joint |
| radiocarpal ligament, volar | broad membranous band, attached above to the anterior margin of the lower end of the radius, to its styloid process, and to the front of the lower end of the ulna; its fibers pass downward and medialward to be inserted into the volar surfaces of the scaphoid, lunate, and triangular bones, some continue to the capitate | strengthens the radiocarpal joint |
| radioulnar ligament, dorsal | extends between corresponding surfaces on the dorsal aspect of the distal radioulnar articulation | provide stability for the distal radio-ulnar joint |

| Joint or Structure | Description | Function |
|---|---|---|
| radioulnar ligament, volar | narrow band of fibers extending from the anterior margin of the ulnar notch of the radius to the front of the head of the ulna | provide stability for the distal radio-ulnar joint |
| scapholunate ligament | an intraarticular ligament binding the scaphoid and lunate bones of the wrist together | main stabilizer of the scaphoid |
| superficial flexor retinaculum | consists of transverse oriented fibrous bands in the fascia of the anterior antebrachium over the tendons of the superficial flexor muscles of this region | covers the flexor carpi ulnaris, palmaris longus, and flexor carpi radialis tendons as they pass into the wrist |
| tendon sheaths | abductor pollicis longus and extensor pollicis brevis, extensor carpi radialis longus, extensor carpi ulnaris, extensor digiti minimi, extensor digitorum and extensor indicis, extensor pollicis longus, flexor carpi radialis, flexor pollicis longus | wraps around tendons to protect it from friction on all sides |
| thenar compartment | lateral compartment of the palmar surface of the hand | contains the abductor pollicis brevis laterally, flexor pollicis brevis medially, and opponens pollicis deeply |

| Joint or Structure | Description | Function |
|---|---|---|
| transverse metacarpal ligament, deep | a ligament that connects the metacarpophalangeal joints 2-5 on their palmar surface | limits motion between the distal ends of adjacent metacarpal bones; forms a solid foundation for finger movements |
| transverse metacarpal ligament, superficial | a ligament beneath the deep transverse metacarpal ligament; a thin band of transverse fasciculi; stretches across the roots of the four fingers, and is closely attached to the skin of the clefts, and medially to the fifth metacarpal bone | the digital vessels and nerves pass beneath it |
| ulnar bursa | synovial sheath surrounding tendons of flexor digitorum superficialis and profundus | extends into the fibrous flexor sheath of the 5th digit |
| ulnar canal | space at the wrist between the pisiform bone and the hamate bone | where the ulnar artery and the ulnar nerve travel into the hand |
| ulnar collateral ligament, wrist | connects the styloid process of the ulna to the pisiform and triquetrum | reinforces the articular capsule on the medial side of the wrist |
| ulnocarpal, dorsal | fibrous band from the styloid process of the ulnar styloid process to the dorsal aspect of the carpal bones | helps stabilize the distal radioulnar joint |
| ulnocarpal, palmar | cord-like ligament attaches the styloid process of the ulna to the lunate and triquetral bones | strengthens the wrist joint and prevents displacement of the head of ulna |

| Joint or Structure | Description | Function |
| --- | --- | --- |
| vincula | slips of synovial membrane extending between phalanges and flexor tendons | vincula conduct neurovascular bundles to the flexor tendons |

# APPENDIX B

# EXPERIMENT FORMS AND IRB APPROVAL DOCUMENT

Arizona State University
Herberger Institute for Design and the Arts
School of Music
Investigation of Finger Motion and Hand Posture during Clarinet Performance
Stefanie Harger

Subject Measurements Form (SMF)

Height: ____________

Weight: ____________

Instrument case weight: ___________

1. Finger measurements (in millimeters):

Length of fingers

RH 1: ________________LH 1: __________________

RH 2: ________________LH 2: __________________

RH 3: ________________LH 3: __________________

RH 4: ________________LH 4: __________________

RH 5: ________________LH 5: __________________

Pad size

Measure crease to distal end

RH 1: ______________LH 1: ______________

RH 2: ______________LH 2: ______________

RH 3: ______________LH 3: ______________

RH 4: ______________LH 4: ______________

RH 5: ______________LH 5: ______________

Width of pulpy pad (midway between crease and fingertip)

RH 1: _____________LH 1: _____________

RH 2: _____________LH 2: _____________

RH 3: _____________LH 3: _____________

RH 4: _____________LH 4: _____________

RH 5: _____________LH 5: _____________

Finger span:

RH 4-5:__________________LH 4-5:__________________

2. Hand measurements:

Hand length (wrist crease to tip of middle finger):

RH: _______________LH: _______________

Hand width at the level of the metacarpal heads (2-5):

RH: _______________LH: _______________

Wrist width (at the base of the full thumb):

RH: _______________LH: ______________

3. Still photos: during performance recording without face

player's left side while playing without face

player's right side while playing without face

behind player to capture thumbs

4. Clarinet specific measurements:

Distance from tip of R thumb to thumb rest center: _______

Distance of RH thumb rest to top of bottom joint: ________

Distance from top of first-finger hole to top of bottom joint: ______

Arizona State University
Herberger Institute for Design and the Arts
School of Music
Investigation of Finger Motion and Hand Posture during Clarinet Performance
Performance and Posture Tasks

Please play the following exercise at **sixty beats per minute** three times with at least ten seconds between repetitions. Each repetition should begin after four clicks sound from the computer's metronome.

After the three repetitions of the chromatic scale, Stefanie will ask you to

1. hold a tennis ball in each hand for 7 seconds
2. drop your arms to your sides and hold for 7 seconds
3. form and hold "C" postures with your hands for 7 seconds

Between tasks please place hands flat on the table.

Arizona State University
Herberger Institute for Design and the Arts
School of Music
Investigation of Clarinetists' Finger Motion
Stefanie Harger
Subject Questionnaire

Age: ________________________________

Gender:______________________________

1. What is your primary instrument *(circle one)*?
    a. B-flat Clarinet
    b. E-flat Clarinet
    c. Bass Clarinet
    d. Other *(please describe)* _________________

2. How many years have you been playing your primary instrument? _______

3. Which of the following instruments do you play at least two days a week *(circle all that apply)*?
    a. B-flat clarinet
    b. E-flat clarinet
    c. Bass clarinet
    d. C clarinet
    e. Alto clarinet
    f. Bass clarinet
    g. Contra-Alto/Bass clarinet
    h. Other *(please describe)* _________________

4. How many years ago did you begin playing a musical instrument? _______ _________________________

5. Which instrument did you first study? _________________

6. Please circle any of the following adjustments or modifications you have made to your primary instrument
    a. Use of a neckstrap
    b. Relocation of thumb rest
    c. Plateau key(s) *(Please list keys)* ________________
    d. Relocation of key(s) *(Please list keys)* ___________
    e. Adjustment of spring tension
    f. Other *(please describe)* ________________
    g. None

7. What is the make and/or model of your primary clarinet? ______________ _________________________

8. Are you right- or left-handed? Right Left

9. Have you switched make and/or model of clarinet within the last year?
   Yes or No
   If yes, please list old instrument:

______________________________________________________________

10. What type of clarinet case do you use (circle one)?
    a. Single case
    b. Double case
    c. Triple case
    d. Quad case
    e. Other *(please describe)* _______________

11. How do you usually carry your case (*circle one*)?
    a. By hand
    b. Over the shoulder with a single strap
    c. With two straps over both shoulders (like a backpack)
    d. Using a luggage cart on wheels
    e. Other *(please describe)* _______________

12. In which position do you typically practice (circle one)?
    a. Sitting
    b. Standing

13. Please estimate how much time you spend daily on each of the following tasks in minutes:

| Playing Task | Mon. | Tues. | Wed. | Thurs. | Fri. | Sat. | Sun. |
|---|---|---|---|---|---|---|---|
| Warm up/technique | | | | | | | |
| My own repertoire | | | | | | | |
| Rehearsal | | | | | | | |
| Teaching | | | | | | | |
| Performance | | | | | | | |

14. Circle and briefly explain any changes in the following over the last year:
    a. Practice habits
    b. Technique
    c. Teachers
    d. Repertoire

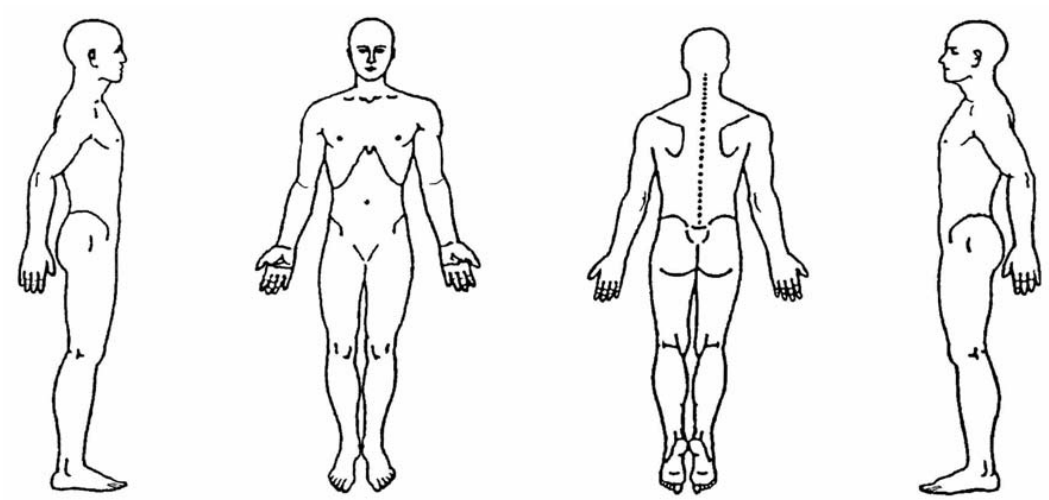
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

15. Please rate the genres of music that you play, where 0 = never and 5 = daily
    a. Music written before 1750 ______
    b. Classical era (ca 1750-1810) ______
    c. Romantic era (ca 1810-1900) ______
    d. 20th century to present ______
    e. Folk ______
    f. Jazz ______
    g. Rock ______
    h. Other *(please describe)* ________________

16. Do you feel physical pain when playing certain pieces? Yes or No
If yes, please describe pain on the lines below, indicate the locations of pain on the following diagrams, and indicate the intensity of pain as described below.

____________________________________________________
____________________________________________________
____________________________________________________

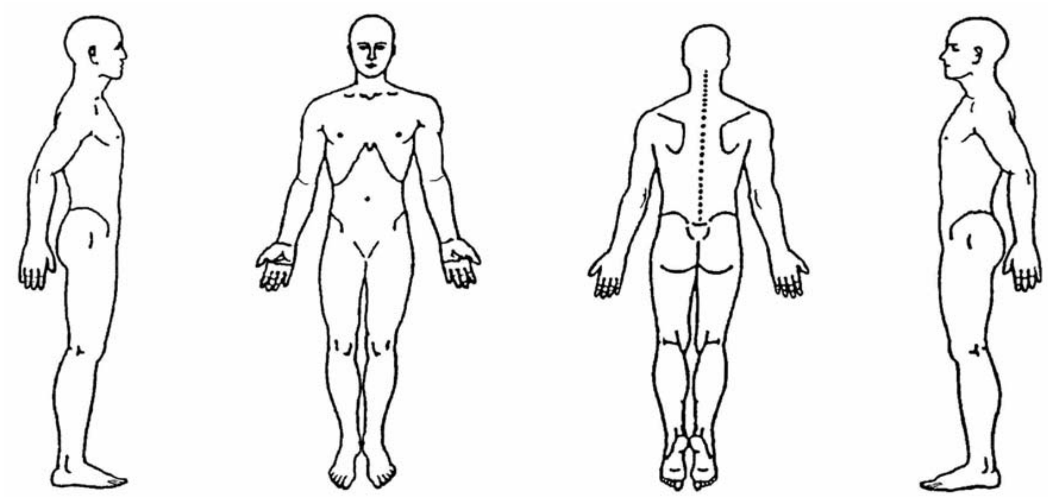
Example:



None 0 1 2 3 4 5 Unbearable

17. Shade in the anatomic areas on the pictures below where you have symptoms of pain, numbness, tingling, or tightness, and draw arrows to indicate intensity of pain.

Your Body:



None 0 1 2 3 4 5 Unbearable

18. Please circle the selection that best describes you.

0 I experience no pain while playing the instrument.

1 Pain is limited to one site and aggravated by playing the instrument.

2 Pain occurs in two or more sites during a high workload and possibly involves some loss of coordination. Physical signs may be present; however, there is no interference with other uses of the hand.

3 Pain persists away from the instrument. A possible loss of coordination or strength exists in other uses of the hand (ex. difficulty fastening buttons or opening a jar). Physical findings include persistent tenderness of the upper limb structures. I have difficulty maintaining a high workload.

4 Pain persists at rest, at night, or both. I have pain with most uses of the hand, including activities of daily living. A normal workload is challenging.

5 I have no functional use of the hand. My musical career is seriously threatened.

19. Please rate your sources of stress: None 0 1 2 3 4 5 Unbearable
    a. Work environment ______
    b. Personal (relationships, etc.) ______
    c. Finances ______
    d. Health ______
    e. Playing environment ______
       (hot/cold temperture, lighting, furniture)
    f. Performance/lesson anxiety ______
    g. Other *(please describe)* _________________
20. Please circle any of the following nonmusical activities that require use of your hands. Please provide average weekly activity time in hours.
    a. Computer tasks ______
    b. Weight-bearing tasks ______
    c. Sports/working out ______
    d. Cell phone usage (texting and holding the phone)_________
    e. Other *(please describe)* _________________
21. If you have seen a medical specialist for any hand-related injuries, please indicate the diagnosis and the recommended course of treatment:

_________________________________________________________________

_________________________________________________________________

_________________________________________________________________

22. Please circle the following wellness practices/coping strategies that you use to stay healthy and describe them in the space below.
    a. Stretches
    b. Rest from playing
    c. Massage therapy
    d. Chiropractic sessions
    e. Splinting
    f. Yoga sessions
    g. Ice Regiments
    h. Heat Regiments
    i. Pain medications
    j. Herbal Supplements
    k. Altered Practice Routine
    l. Other (please describe)

**CONSENT FORM**

An Investigation of Finger Motion and Hand Posture during Clarinet Performance

**INTRODUCTION**

The purposes of this form are to provide you (as a prospective research study participant) information that may affect your decision as to whether or not to participate in this research and to record the consent of those who agree to be involved in the study.

**RESEARCHERS**

Dr. Kay Norton, Associate Professor of Music History, Herberger Institute of Design and the Arts, Michael Astrauskas, and Stefanie Harger have invited your participation in a research study.

**STUDY PURPOSE**

The purpose of the research is to investigate finger motion during clarinet performance.

**DESCRIPTION OF RESEARCH STUDY**

You must be at least 21 years of age or older to participate. Your participation would involve playing a slurred three-octave chromatic scale in sixteenth-notes at sixty quarter note beats per minute, and making three shapes with your hands while wearing Cybergloves on both hands. The scale pattern will be repeated three times consecutively, with no breaks, and with a metronome. During the performance task, you will be photographed, but your face will not be shown. Following the performance task, you will also be asked to complete questionnaire in which you may skip questions. Prior to the performance task, you will be weighed and measured for height and length of fingers.

If you say YES, then your participation will last for approximately 120 minutes at the Arizona State University CUBIC Laboratory on December 10, 2010. Approximately 5 subjects will be participating in this study.

**RISKS**

There are no known risks for this study, but there is some possibility that you may be subject to risks that have not yet been identified.

**BENEFITS**

Although there may be no direct benefits to you, one possible benefit of your participation in the research is helping to further the knowledge base of clarinet pedagogy for clarinet teachers.

**NEW INFORMATION**
If the researchers find new information during the study that would reasonably change your decision about participating, then they will provide this information to you.

**CONFIDENTIALITY**
All information obtained in this study is strictly confidential unless disclosure is required by law. The results of this research study may be used in reports, presentations, and publications, but the researchers will not identify you. In order to maintain confidentiality of your records, Michael Astrauskas will randomly deidentify all collected subject information by assigning subject code numbers. Information linking the data to the subject's identity will be kept on a password-protected computer in the ASU CUBIC Laboratory. Only laboratory staff and researchers will have access to this information. The researchers believe that excluding the face in photos will protect the subjects' identities. Signed consent forms will be kept in a secure location in Dr. Kay Norton's office in the ASU School of Music (W206).

**WITHDRAWAL PRIVILEGE**
It is ok for you to say no. Even if you say yes now, you are free to say no later, and withdraw from the study at any time. Withdrawal from the study will not affect your grade or treatment in class in any way.

**COSTS AND PAYMENTS**
There is no payment for your participation in the study.

**COMPENSATION FOR ILLNESS AND INJURY**
If you agree to participate in the study, then your consent does not waive any of your legal rights. However, no funds have been set aside to compensate you in the event of injury.

**VOLUNTARY CONSENT**
Any questions you have concerning the research study or your participation in the study, before or after your consent, will be answered by:

Dr. Kay Norton
School of Music
Herberger Institute for Design and the Arts
PO Box 872102
Tempe, AZ 85287-2102
480.727.7051

If you have questions about your rights as a subject/participant in this research, or if you feel you have been placed at risk; you can contact the Chair of the Human

Subjects Institutional Review Board, through the ASU Office of Research Integrity and Assurance, at 480-965 6788.

This form explains the nature, demands, benefits and any risk of the project. By signing this form you agree knowingly to assume any risks involved. Remember, your participation is voluntary. You may choose not to participate or to withdraw your consent and discontinue participation at any time without penalty or loss of benefit. In signing this consent form, you are not waiving any legal claims, rights, or remedies. A copy of this consent form will be given (offered) to you.

Your signature below indicates that you consent to participate in the above study. By signing below, you are granting to the researchers the right to use your photos (excluding your face) for presenting or publishing this research.

_____________________ ________________________________________________

Subject's Signature Printed Name Date

**INVESTIGATOR'S STATEMENT**

"I certify that I have explained to the above individual the nature and purpose, the potential benefits and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature. These elements of Informed Consent conform to the Assurance given by Arizona State University to the Office for Human Research Protections to protect the rights of human subjects. I have provided (offered) the subject/participant a copy of this signed consent document."

______________________________________________________________________

Signature of Investigator Date

Arizona State University
Herberger Institute for Design and the Arts
School of Music
Investigation of Finger Motion and Hand Posture during Clarinet Performance
Recruitment Script

Robert Spring, Professor of Clarinet at ASU, will provide the researchers an opportunity to present material on the study to his clarinet studio class. Neither Spring nor Norton (PI) will remain in the room for this presentation so that student confidentiality will be maintained. Stefanie will read the recruitment script, answer any questions that arise, hand out the consent forms, and make available the sign-up sheet for the December 10, 2010 data collection times. Stefanie will leave the room and Michael (who has no face recognition of the clarinet students) will receive any consent forms of students willing to participate in the study. Michael will ask students willing to participate to sign up for a data collection time on Dec. 10. Michael will then leave with the consent forms and the sign-up sheet, and will subsequently assign subject code numbers to each participant. These codes will be used for the duration of the study. Consent forms and code chart will be stored in Norton's ASU office, Music W 206, in a sealed envelope, beginning no later than one hour after the recruitment meeting.

Stefanie Harger's Script:

Dr. Norton, Michael Astrauskas, and I are all researchers in a study entitled, "Investigation of Clarinetists' Finger Motion." We invite you to participate in this study. Your participation would involve playing a slurred three-octave chromatic scale in sixteenth-notes at sixty quarter note beats per minute, and making three shapes with your hands (I will demonstrate the three shapes) while wearing Cybergloves on both hands. The scale pattern will be repeated three times consecutively, with no breaks, and with a metronome. During the performance task, you will be photographed with your face excluded to protect your identity. Following the performance task, you will also be asked to complete a questionnaire. Prior to the performance task, you will be weighed and measured for height and length of fingers. This procedure will take approximately 120 minutes and will take place at the Arizona State University CUBIC Laboratory located in the Brickyard Engineering Building, 699 S. Mill Ave., Suite 380 on December 10, 2010. Your participation in this research project is voluntary and your participation and resulting data will be kept confidential. The data and still images collected will be retained indefinitely for archival purposes. The results of the research study may be published, but the participants' identities will not be used. You may choose not to participate in the study at any time. Withdrawal will not affect your grade or treatment in class in any way. Although there may be no direct benefit to you, one possible benefit of your participation is helping to further the knowledge base of clarinet pedagogy for clarinet teachers.

Arizona State University
Herberger Institute for Design and the Arts
School of Music
Investigation of Clarinetists' Finger Motion
Stefanie Harger
Subject Sign Up Form

**CUBIC Lab Schedule 12/10/10**

8:00am ____________________________________

10:00am ___________________________________

1:00pm ____________________________________

3:00pm ____________________________________

5:00pm ____________________________________

7:00pm ____________________________________

Arizona State University
Herberger Institute for Design and the Arts
School of Music
Investigation of Finger Motion and Hand Posture during Clarinet Performance
Stefanie Harger
Subject Measurement Analysis Form (SMAF)

Data from SMF
Finger Measurement Analysis:
Length difference between the thumb and third finger:

RH: ________LH:_________(measured from base of metacarpals)

Length difference between the fifth finger and third finger:

RH: ________LH:_________

Data from photographs
Body Posture (circle one):

| | | | |
|---|---|---|---|
| Back Posture: | straight | in-between | slouched |
| Neck Posture: | chin elevated | chin level | chin tilted down |
| Elbows: | marked abduction | in-between | marked adduction |
| Shoulders: | back | in-between | slouched |
| Angle of instrument to trunk: | close to body | in-between | away from body |

Wrist measurement analysis: (from still photographs)

Wrist: extended, neutral or flexed:

RH: ________LH: ________

Wrist rotation (up/down) radial, neutral or ulnar:

RH: ________ LH: ________

Finger posture (photograph): curved, flat, or neutral

RH 1: _______LH 1: _______

RH 2: _______LH 2: _______

RH 3: _______LH 3: _______

RH 4: _______LH 4: _______

RH 5: _______LH 5: _______

ASU Knowledge Enterprise Development

Office of Research Integrity and Assurance

| | |
|---|---|
| **To:** | Kay Norton<br>MUSIC BUIL |
| **From:** | Carol Johnston, Chair<br>Biosci IRB |
| **Date:** | 10/29/2010 |
| **Committee Action:** | **Expedited Approval** |
| **Approval Date:** | 10/29/2010 |
| **Review Type:** | Expedited F4 F7 |
| **IRB Protocol #:** | 1010005615 |
| **Study Title:** | An Investigation of Finger Motion during Clarinet Performance |
| **Expiration Date:** | 10/28/2011 |

The above-referenced protocol was approved following expedited review by the Institutional Review Board.

It is the Principal Investigator's responsibility to obtain review and continued approval before the expiration date. You may not continue any research activity beyond the expiration date without approval by the Institutional Review Board.

Adverse Reactions: If any untoward incidents or severe reactions should develop as a result of this study, you are required to notify the Biosci IRB immediately. If necessary a member of the IRB will be assigned to look into the matter. If the problem is serious, approval may be withdrawn pending IRB review.

Amendments: If you wish to change any aspect of this study, such as the procedures, the consent forms, or the investigators, please communicate your requested changes to the Biosci IRB. The new procedure is not to be initiated until the IRB approval has been given.

Please retain a copy of this letter with your approved protocol.

Figure 26. IRB approval page

APPENDIX C

DATA REPORTS

Table 26. Subject (S) Height, Weight, Case Weight, and Hand Size Classification

| S | Height | Weight (lbs) | Case Weight (lbs) | Hand Size Classification |
|---|---|---|---|---|
| 1 | 6' | 209 | 16 | Large |
| 2 | 5' 7.5" | 155 | 12.5 | Small |
| 3 | 5' 11" | 192 | 13 | Large |
| 4 | 6' 1" | 194 | 12 | Large |
| 5 | 5' 6" | 125 | 6 | Small |
| 6 | 5' 8.625" | 175 | 13 | Small |

Table 27. Finger Length (millimeters)

| S | RH1 | RH2 | RH3 | RH4 | RH5 | LH1 | LH2 | LH3 | LH4 | LH5 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 72.75 | 80.42 | 91.01 | 81.73 | 68.67 | 77.33 | 82.86 | 91.67 | 84.00 | 68.97 |
| 2 | 64.56 | 73.25 | 80.42 | 71.68 | 59.07 | 61.95 | 70.96 | 77.53 | 74.87 | 63.81 |
| 3 | 69.40 | 81.28 | 87.87 | 77.63 | 64.61 | 75.13 | 83.66 | 88.46 | 79.73 | 67.24 |
| 4 | 70.65 | 80.07 | 86.40 | 77.53 | 62.39 | 72.36 | 76.20 | 82.28 | 76.21 | 62.69 |
| 5 | 57.19 | 70.59 | 75.43 | 72.07 | 58.19 | 63.24 | 69.29 | 75.05 | 73.11 | 60.54 |
| 6 | 50.71 | 65.74 | 67.46 | 62.14 | 53.83 | 52.99 | 67.59 | 68.53 | 62.26 | 55.71 |

Table 28. Pad Length (millimeters)

| S | RH1 | RH2 | RH3 | RH4 | RH5 | LH1 | LH2 | LH3 | LH4 | LH5 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 38.68 | 28.59 | 30.36 | 27.68 | 26.55 | 41.22 | 29.03 | 30.49 | 26.98 | 24.68 |
| 2 | 29.76 | 26.69 | 28.00 | 26.02 | 24.82 | 31.28 | 25.15 | 26.51 | 25.40 | 23.25 |
| 3 | 37.85 | 31.13 | 30.90 | 30.94 | 25.81 | 36.40 | 30.31 | 30.63 | 28.71 | 25.72 |
| 4 | 38.05 | 28.98 | 31.55 | 30.29 | 27.98 | 39.32 | 27.12 | 28.66 | 30.75 | 27.71 |
| 5 | 36.19 | 26.84 | 28.42 | 28.62 | 24.52 | 35.46 | 25.25 | 28.59 | 26.16 | 24.79 |
| 6 | 35.83 | 25.44 | 26.14 | 24.83 | 23.45 | 36.27 | 25.98 | 25.89 | 25.29 | 24.49 |

Table 29. Pad Width (millimeters)

| S | RH1 | RH2 | RH3 | RH4 | RH5 | LH1 | LH2 | LH3 | LH4 | LH5 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 21.83 | 18.76 | 15.75 | 16.05 | 15.16 | 23.16 | 16.99 | 17.35 | 15.57 | 13.45 |
| 2 | 18.41 | 14.14 | 14.07 | 14.26 | 13.30 | 18.01 | 13.98 | 13.75 | 12.51 | 11.46 |
| 3 | 25.15 | 17.81 | 17.42 | 17.08 | 15.48 | 23.32 | 17.56 | 15.75 | 15.98 | 14.08 |
| 4 | 23.58 | 18.38 | 17.49 | 17.22 | 15.67 | 23.41 | 18.87 | 17.06 | 16.43 | 14.84 |
| 5 | 20.03 | 15.17 | 14.85 | 14.35 | 12.17 | 17.89 | 14.39 | 14.50 | 13.28 | 12.34 |
| 6 | 23.89 | 18.83 | 17.26 | 15.86 | 15.88 | 23.35 | 19.24 | 18.08 | 16.41 | 14.77 |

Table 30. Other Measurements (millimeters)

| S | Finger Span 4-5: RH | Finger Span 4-5: LH | R1 tip to thumb rest center | thumb rest to top of bottom joint | first ring to top of bottom joint | R1 tip to thumb rest center | thumb rest to top of bottom joint | first ring to top of bottom joint |
|---|---|---|---|---|---|---|---|---|
| 1 | 73.23 | 73.29 | 34.92 | 55.47 | 32.69 | 34.92 | 55.47 | 32.69 |
| 2 | 69.42 | 70.69 | 28.41 | 47.47 | 32.80 | 28.41 | 47.47 | 32.80 |
| 3 | 65.65 | 63.20 | 32.83 | 48.77 | 32.23 | 32.83 | 48.77 | 32.23 |
| 4 | 76.73 | 77.15 | 29.55 | 53.62 | 32.82 | 29.55 | 53.62 | 32.82 |
| 5 | 66.11 | 74.35 | 30.10 | 57.30 | 32.63 | 30.10 | 57.30 | 32.63 |
| 6 | 69.61 | 68.81 | 28.05 | 55.15 | 33.68 | 28.05 | 55.15 | 33.68 |

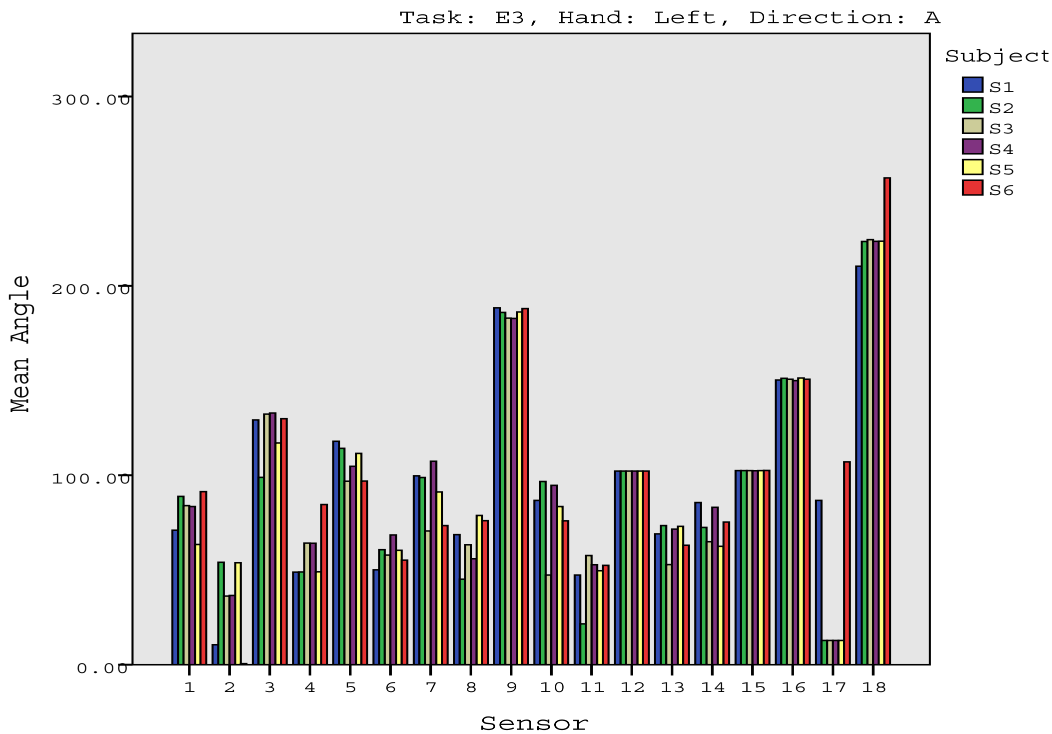



Figure 27. Ascending E3 left hand

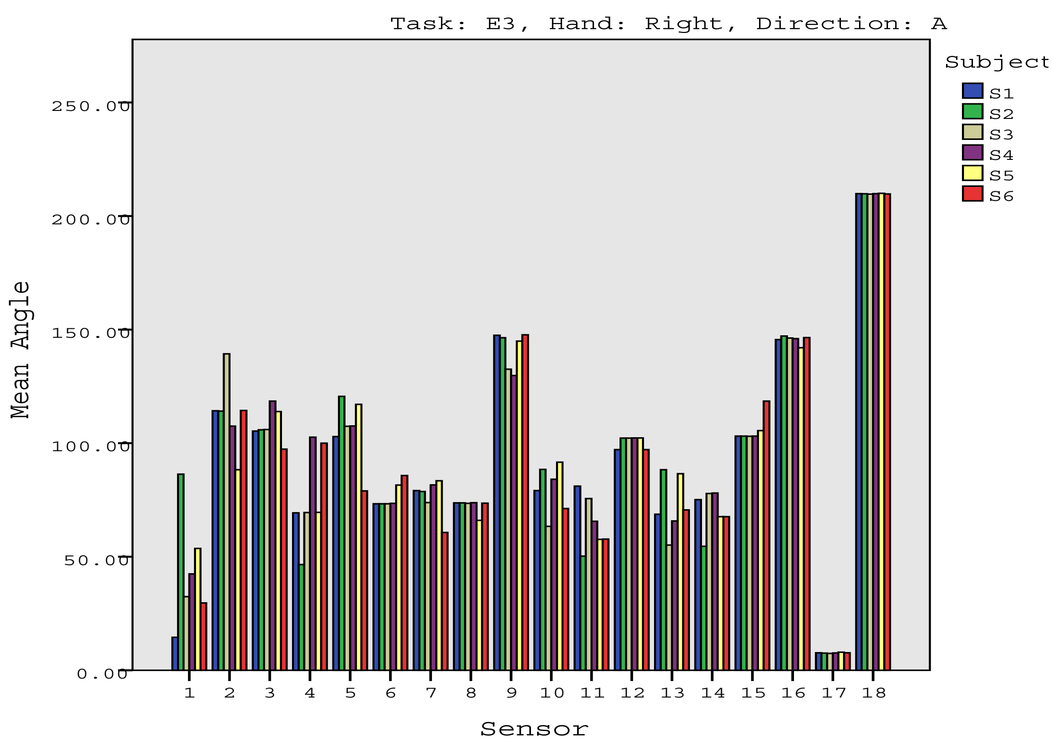



Figure 28. Ascending E3 right hand

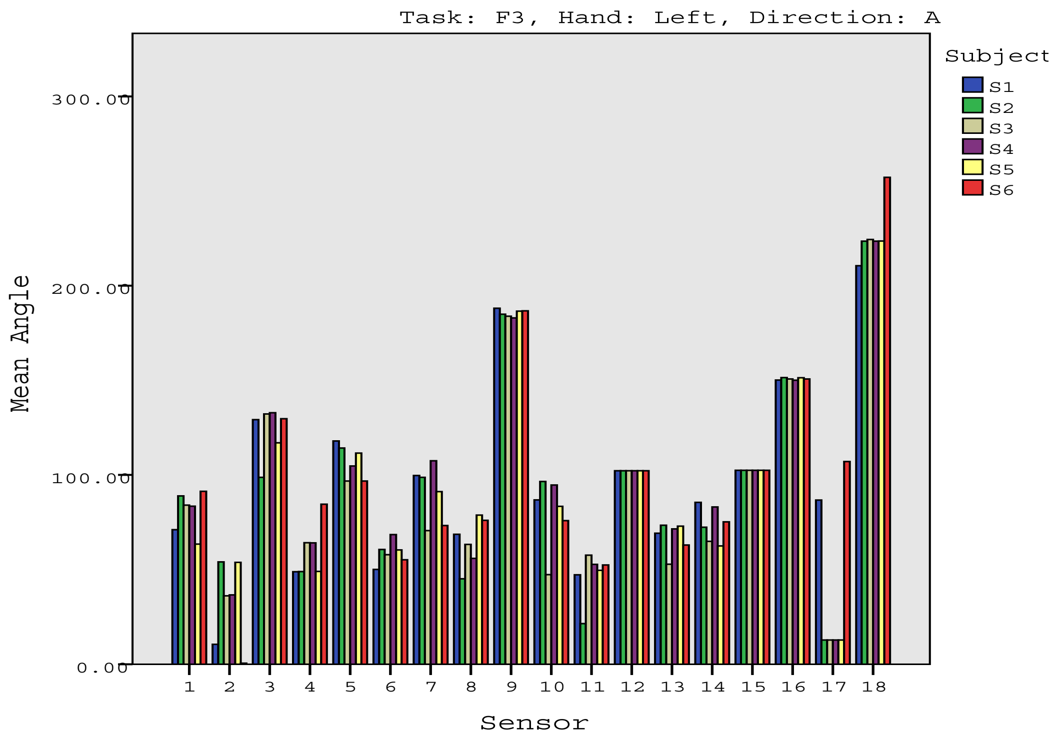



Figure 29. Ascending F3 left hand

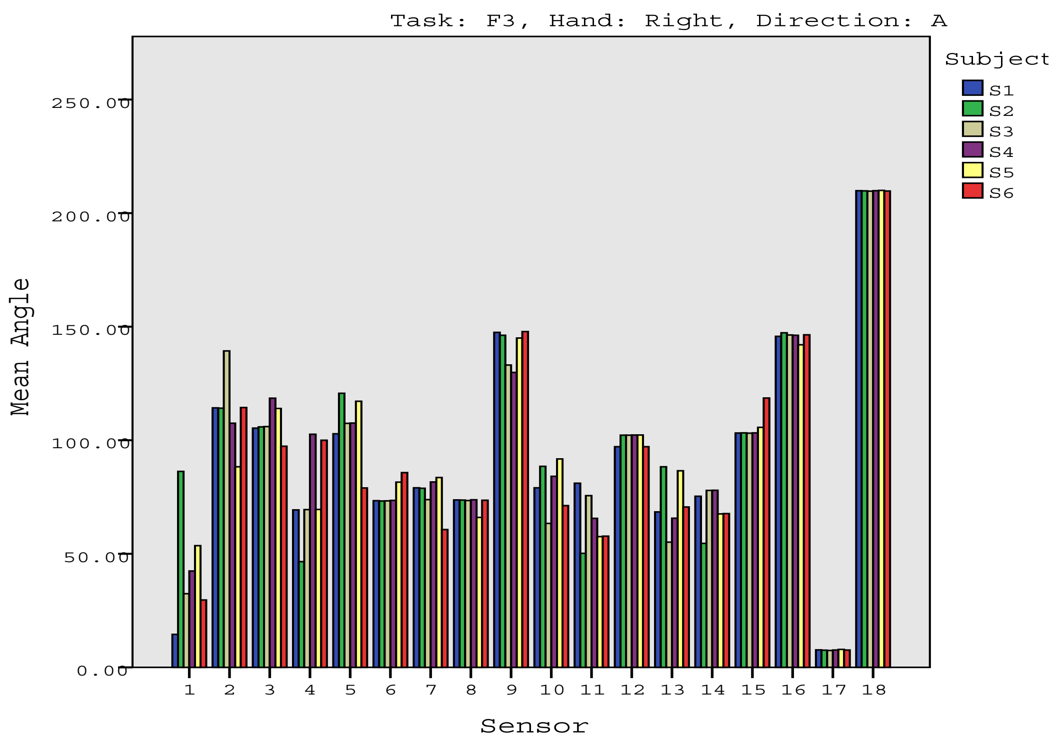



Figure 30. Ascending F3 right hand

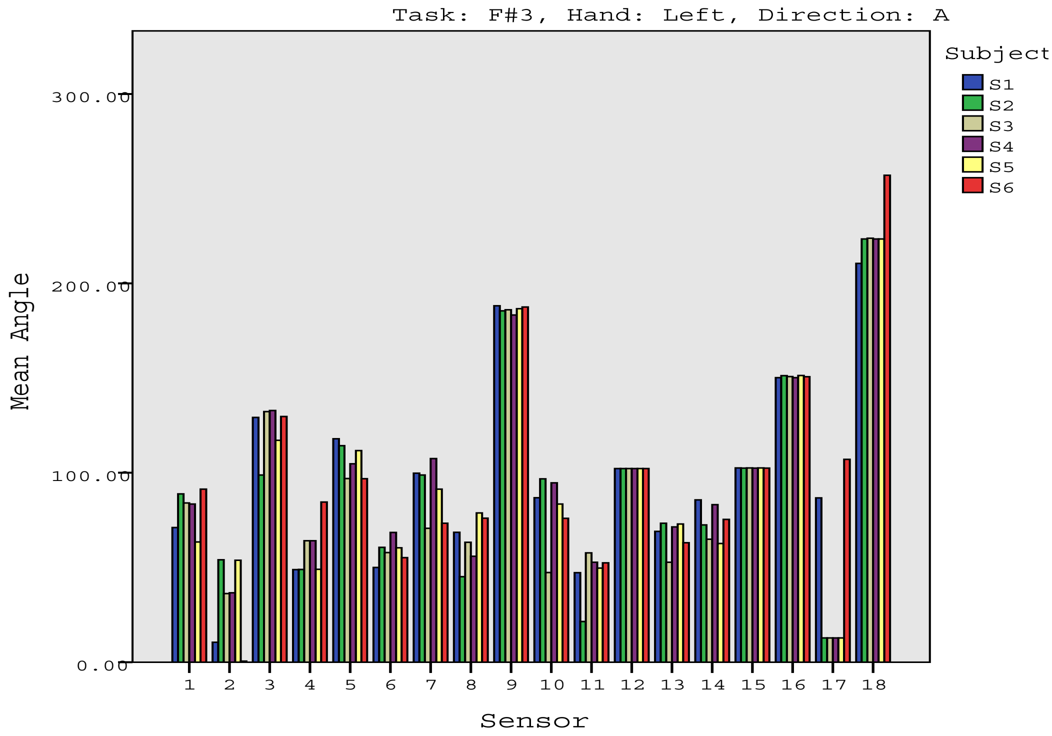



Figure 31. Ascending F#3 left hand

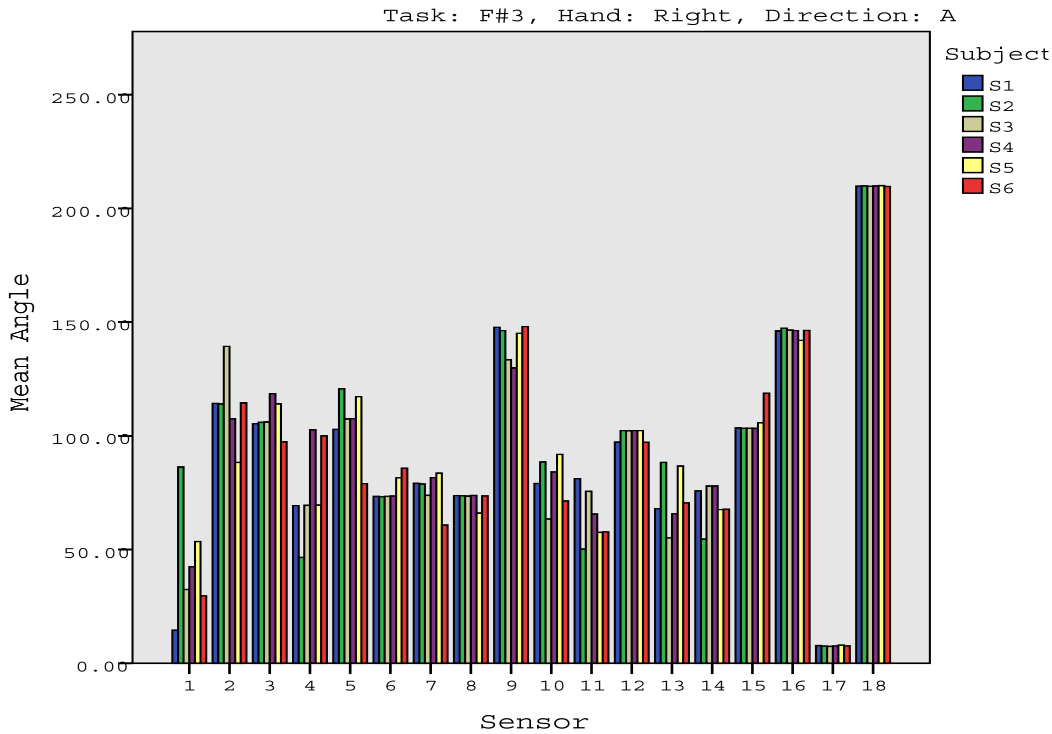



Figure 32. Ascending F#3 right hand

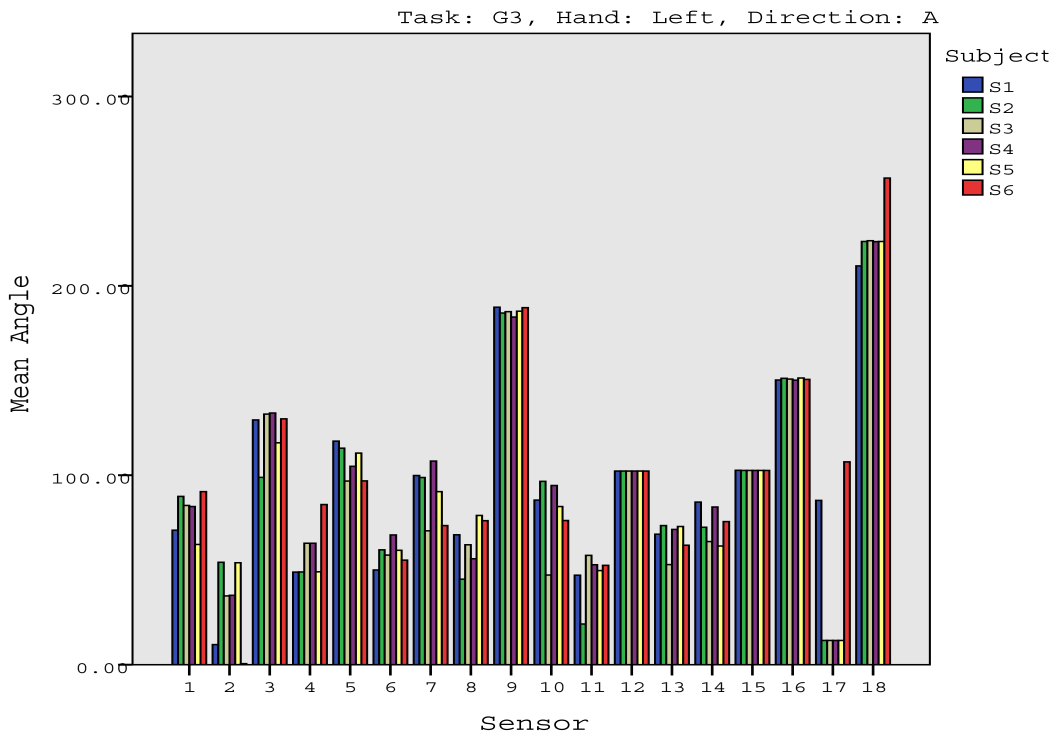



Figure 33. Ascending G3 left hand

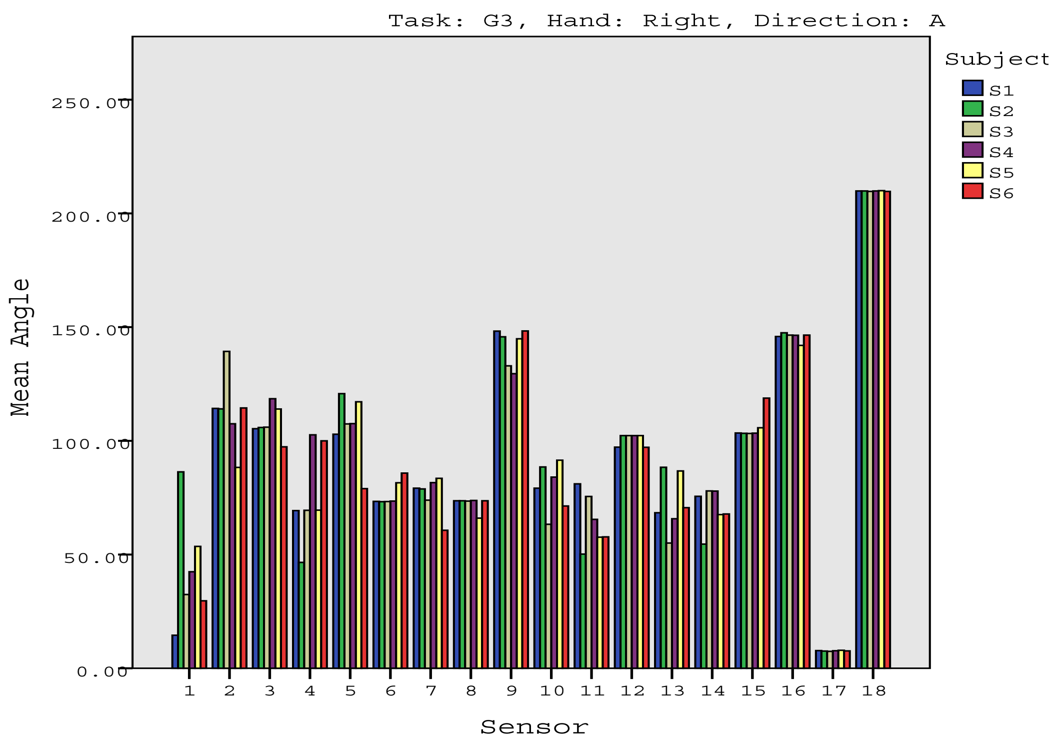



Figure 34. Ascending G3 right hand

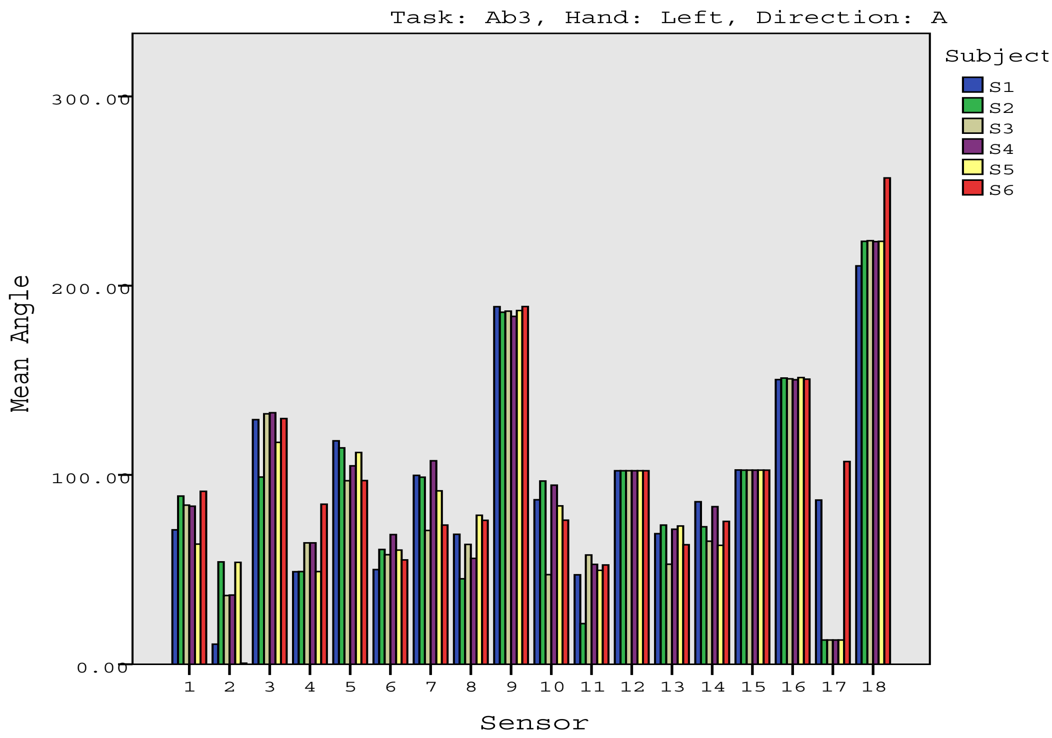



Figure 35. Ascending Ab3 left hand

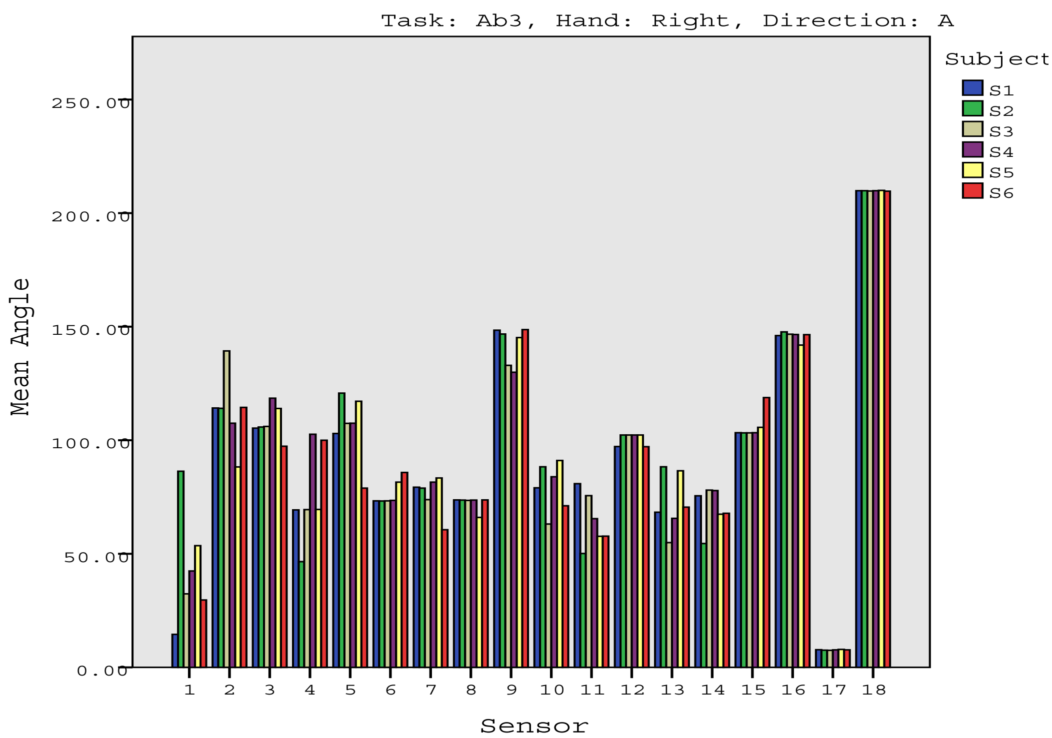



Figure 36. Ascending Ab3 right hand

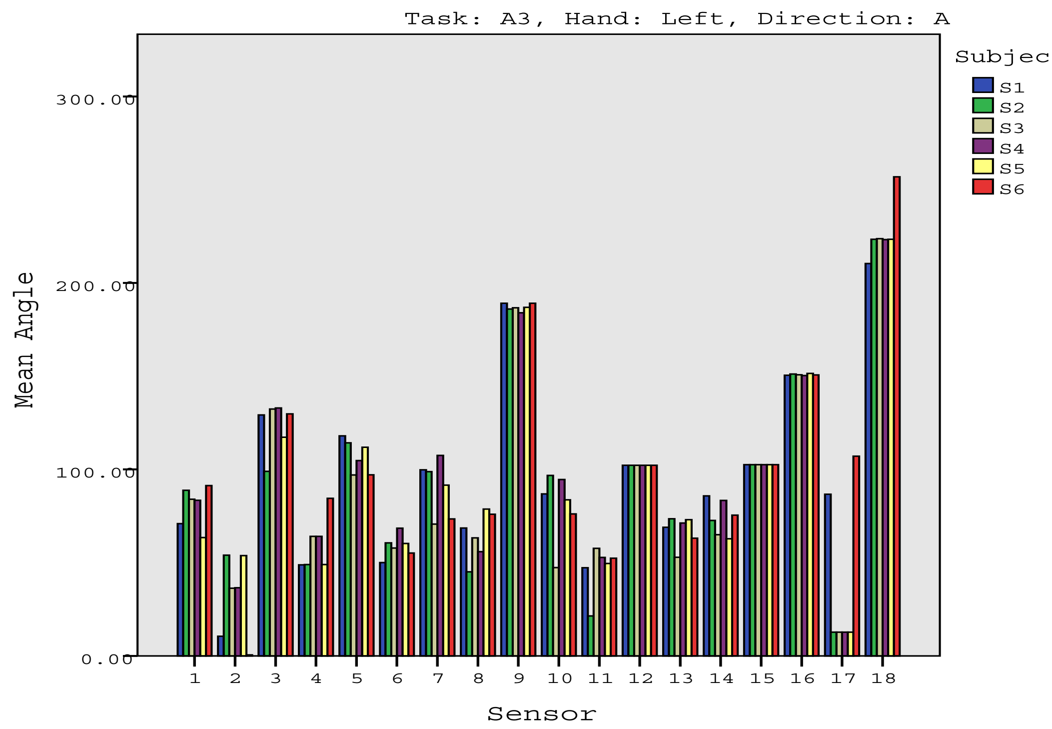



Figure 37. Ascending A3 left hand

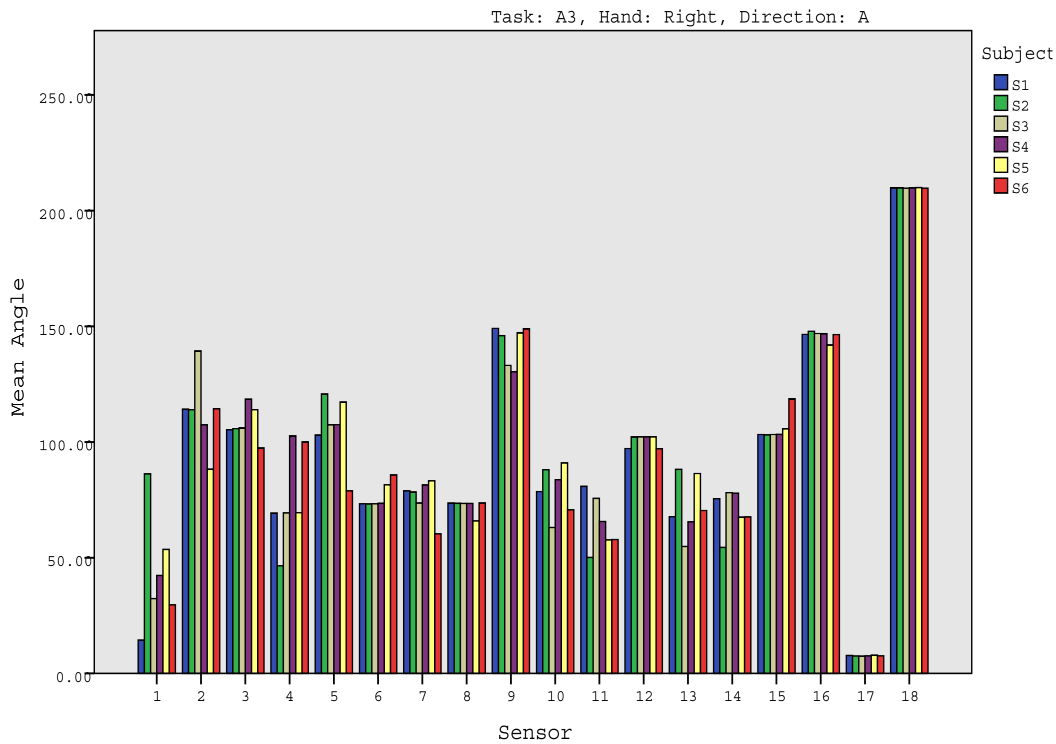



Figure 38. Ascending A3 right hand

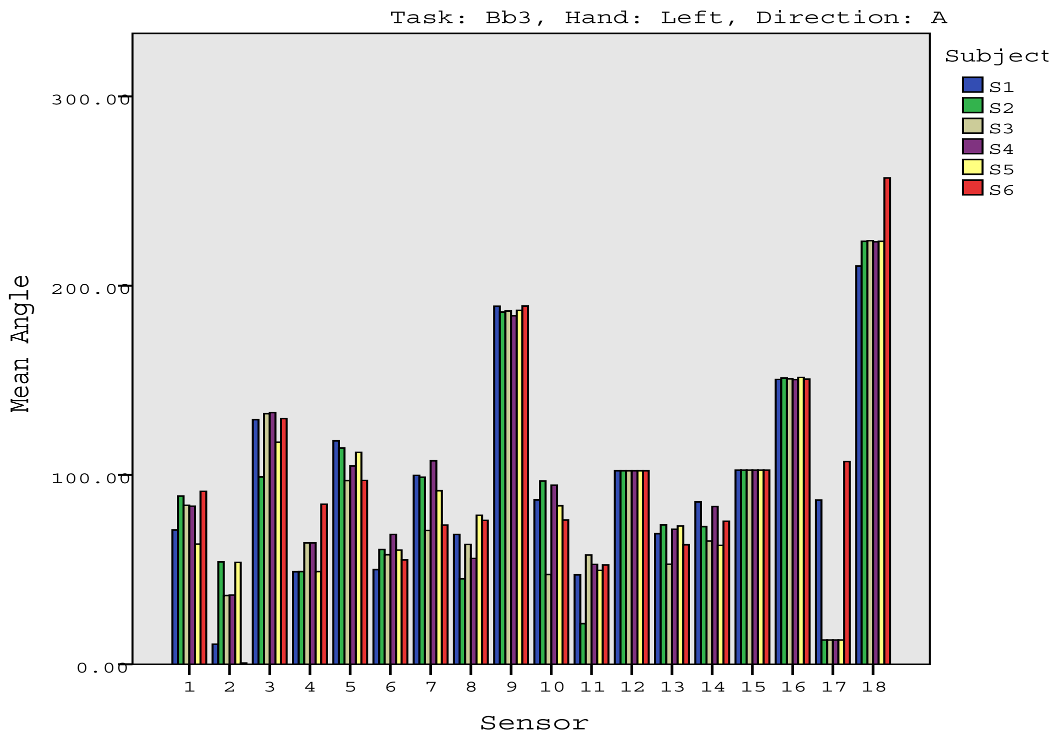



Figure 39. Ascending Bb3 left hand

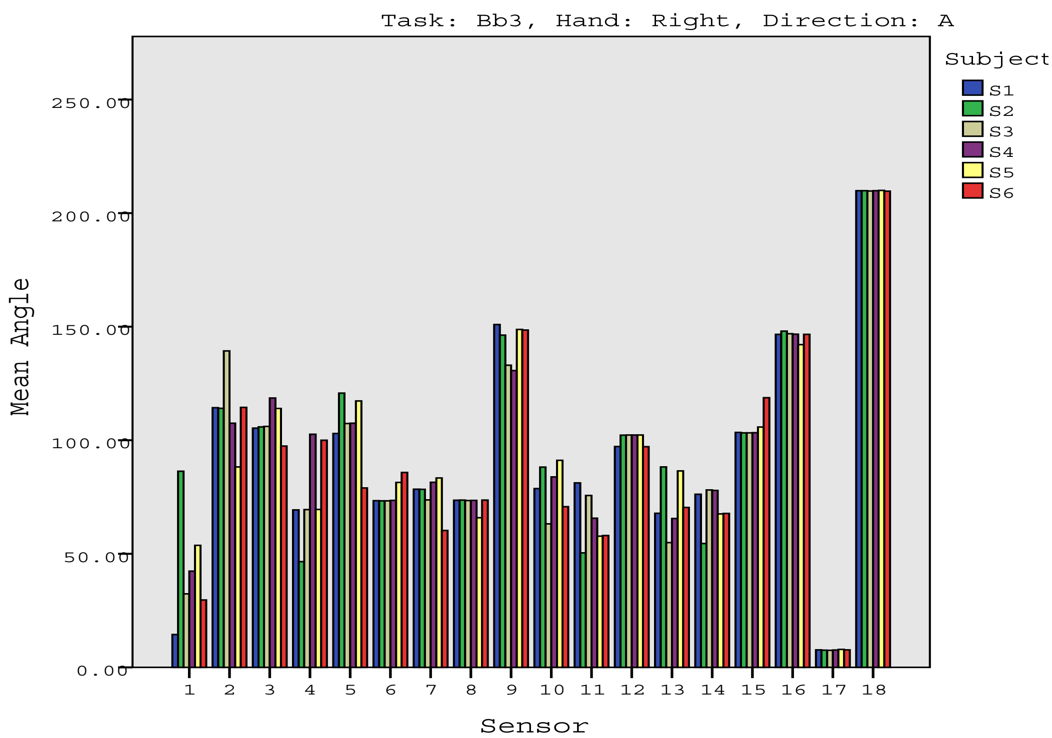



Figure 40. Ascending Bb3 right hand

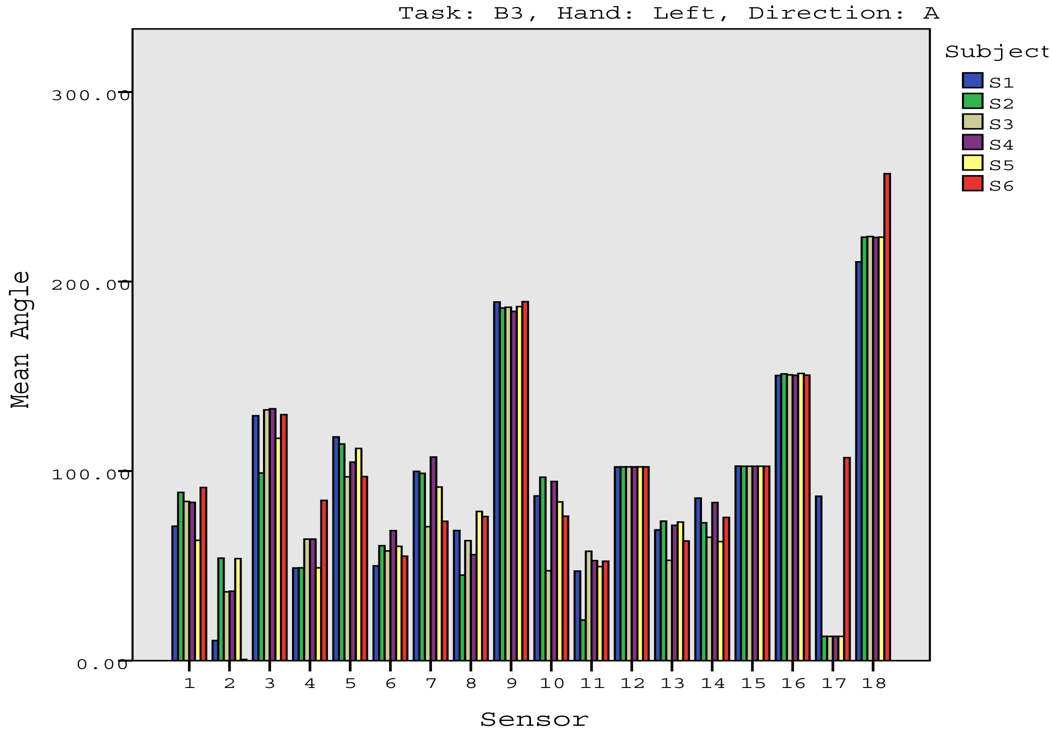



Figure 41. Ascending B3 left hand

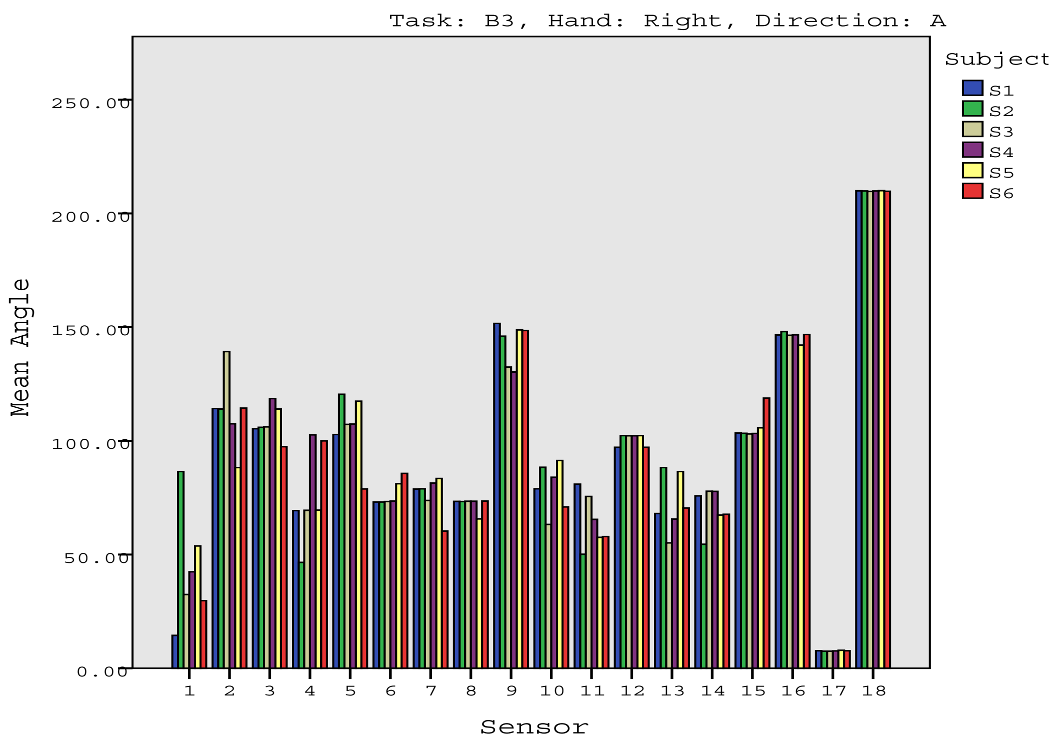



Figure 42. Ascending B3 right hand

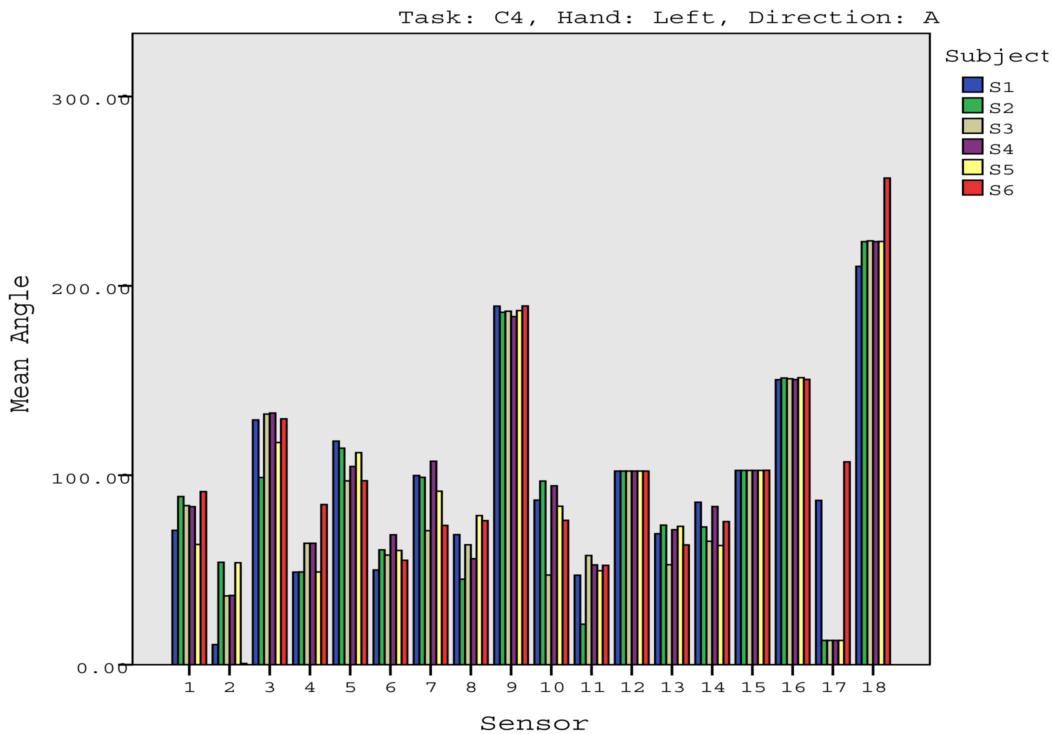



Figure 43. Ascending C4 left hand

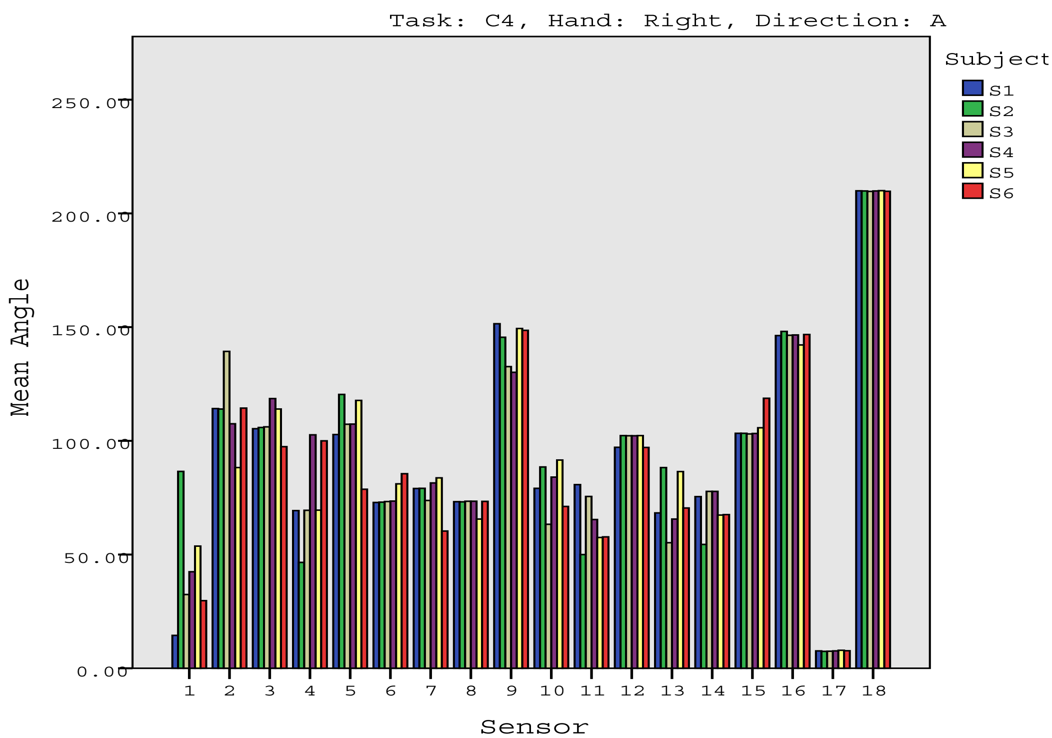



Figure 44. Ascending C4 right hand

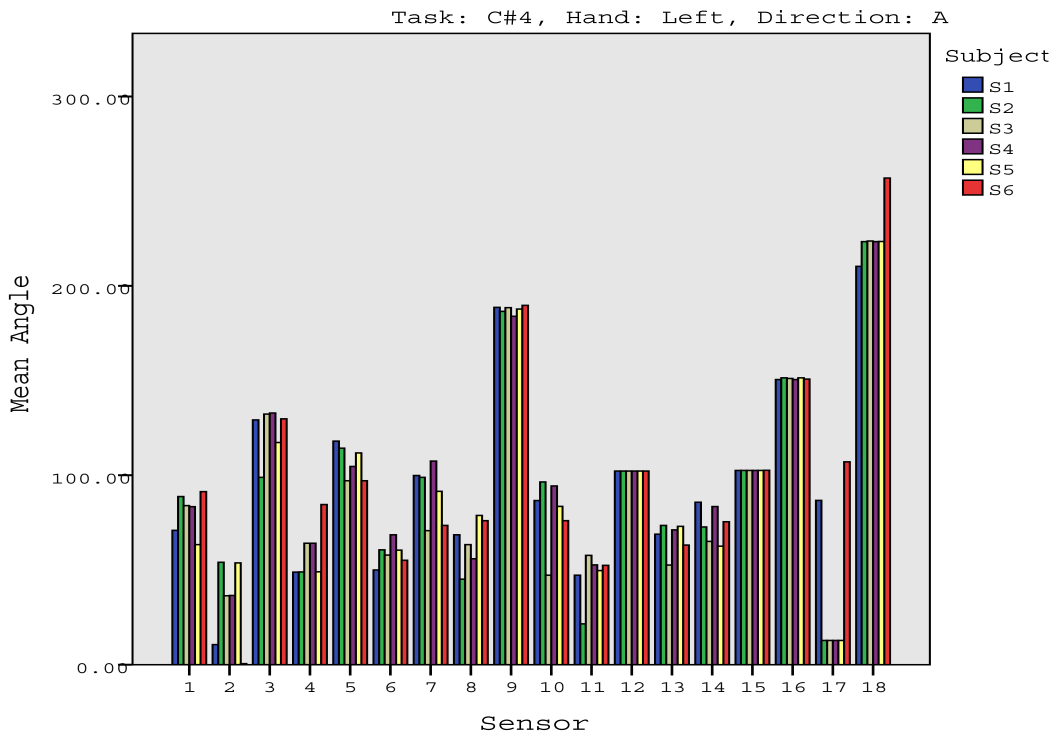



Figure 45. Ascending C#4 left hand

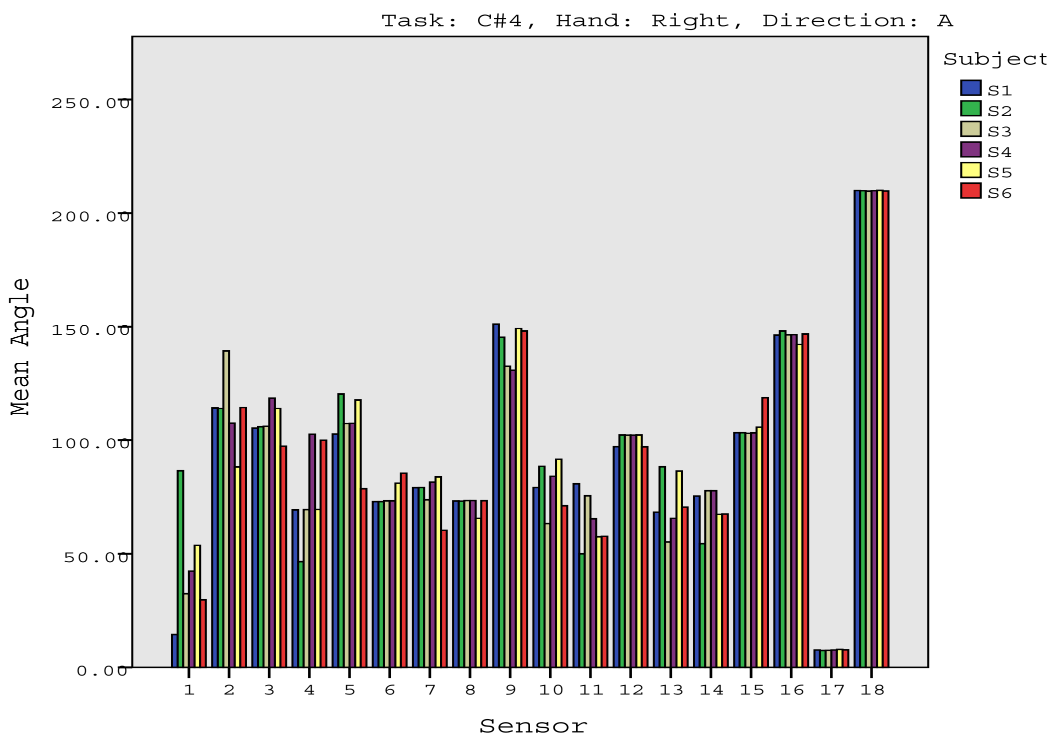



Figure 46. Ascending C#4 right hand

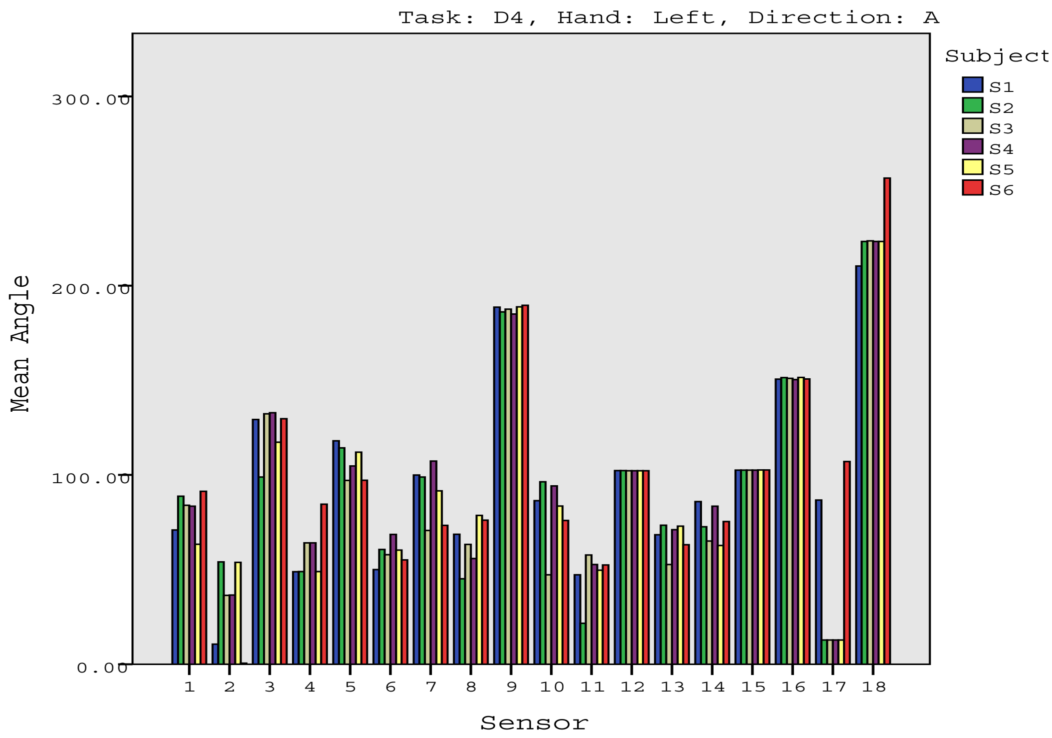



Figure 47. Ascending D4 left hand

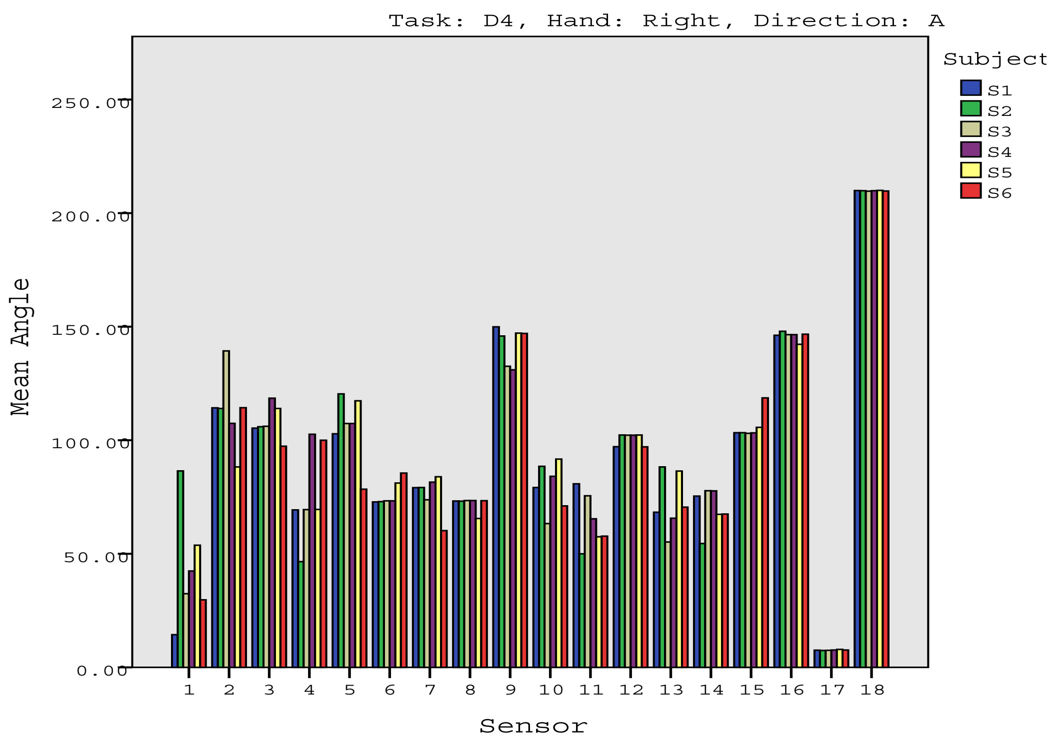



Figure 48. Ascending D4 right hand

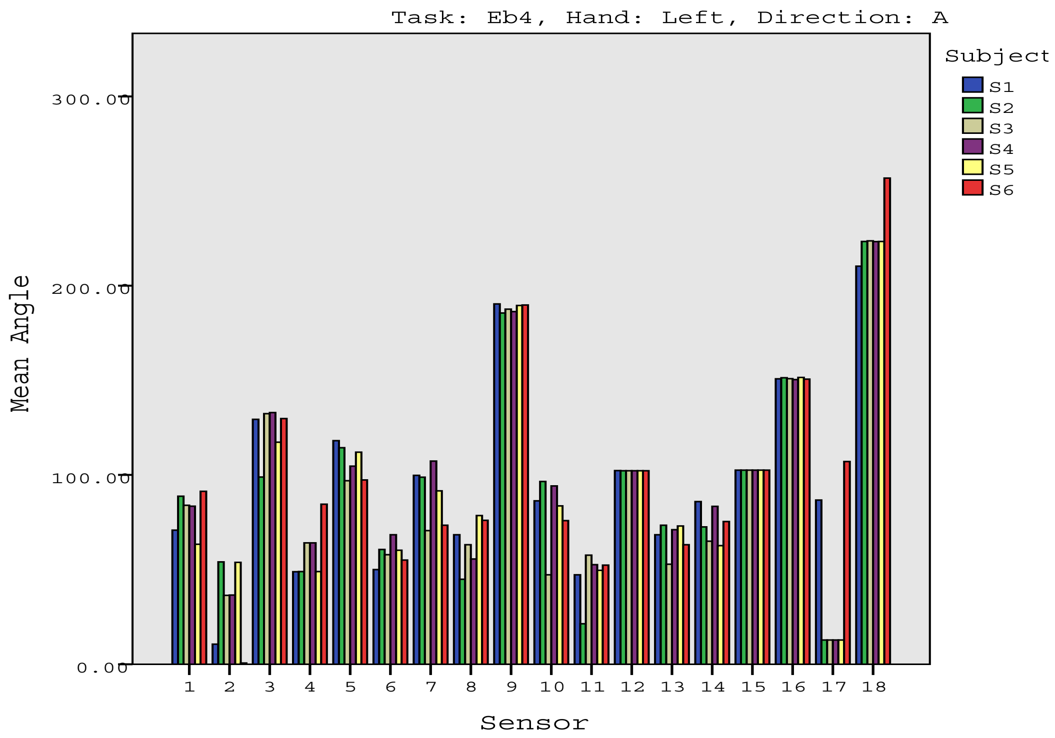



Figure 49. Ascending Eb4 left hand

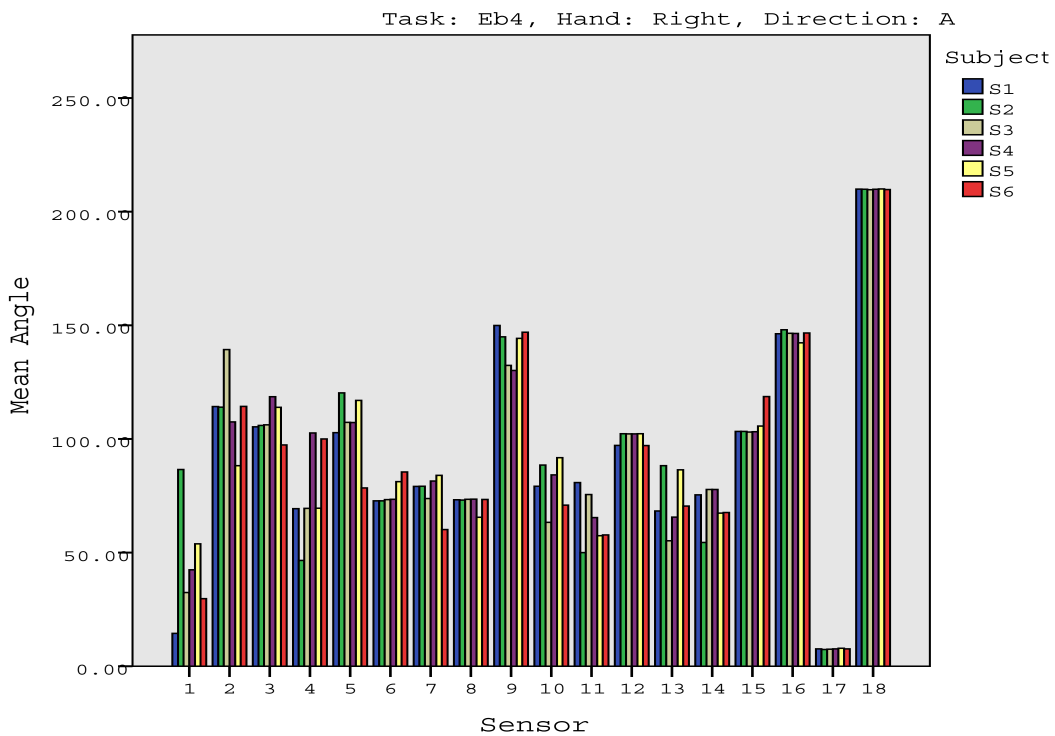



Figure 50. Ascending Eb4 right hand

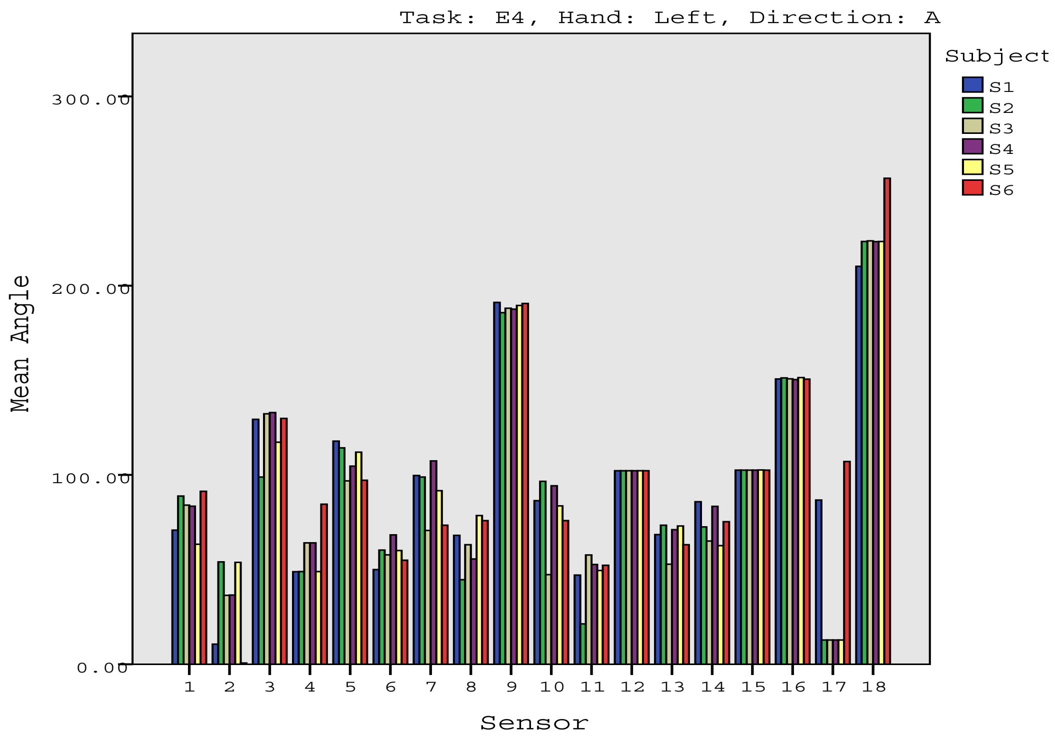



Figure 51. Ascending E4 left hand

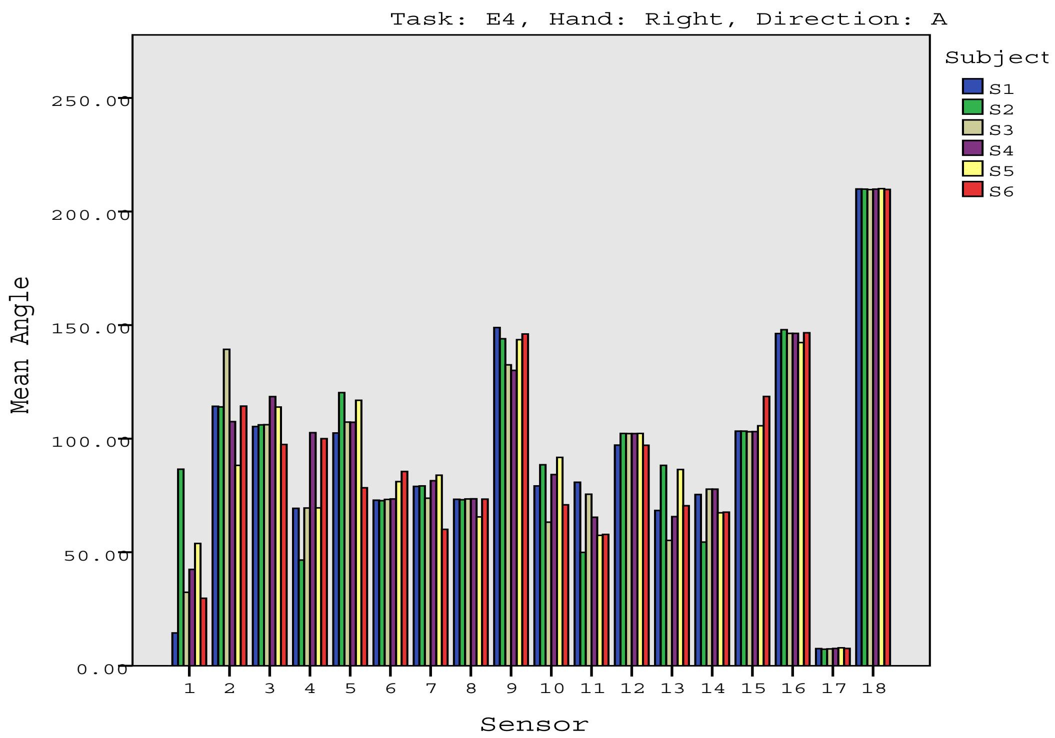



Figure 52. Ascending E4 right hand

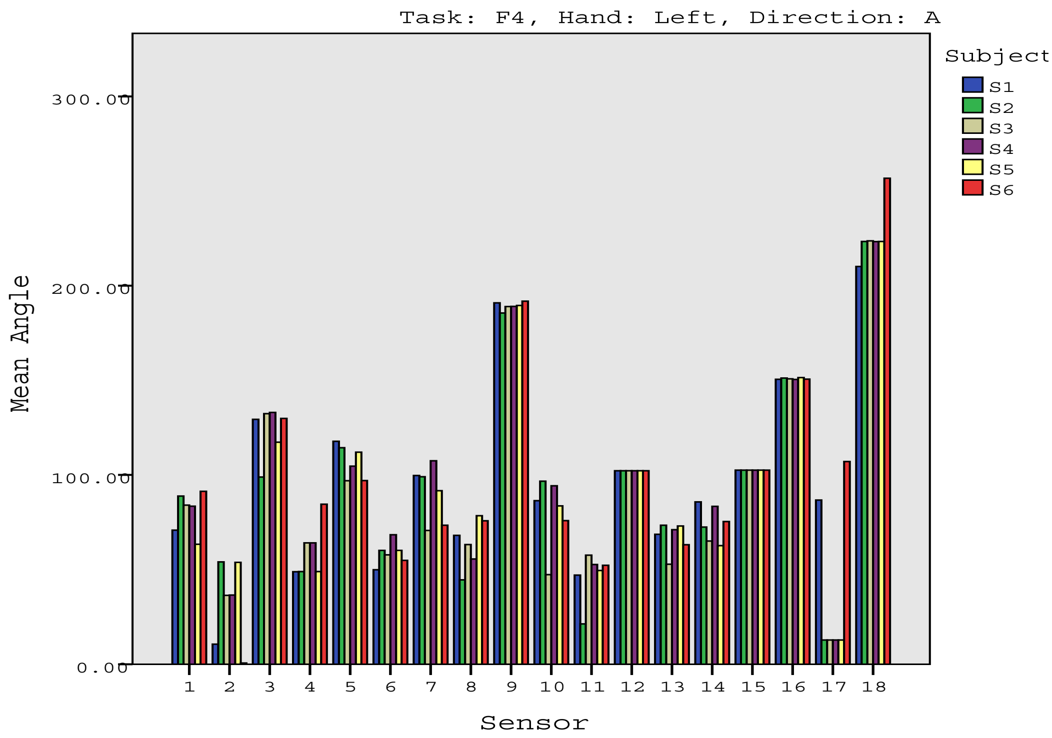



Figure 53. Ascending F4 left hand

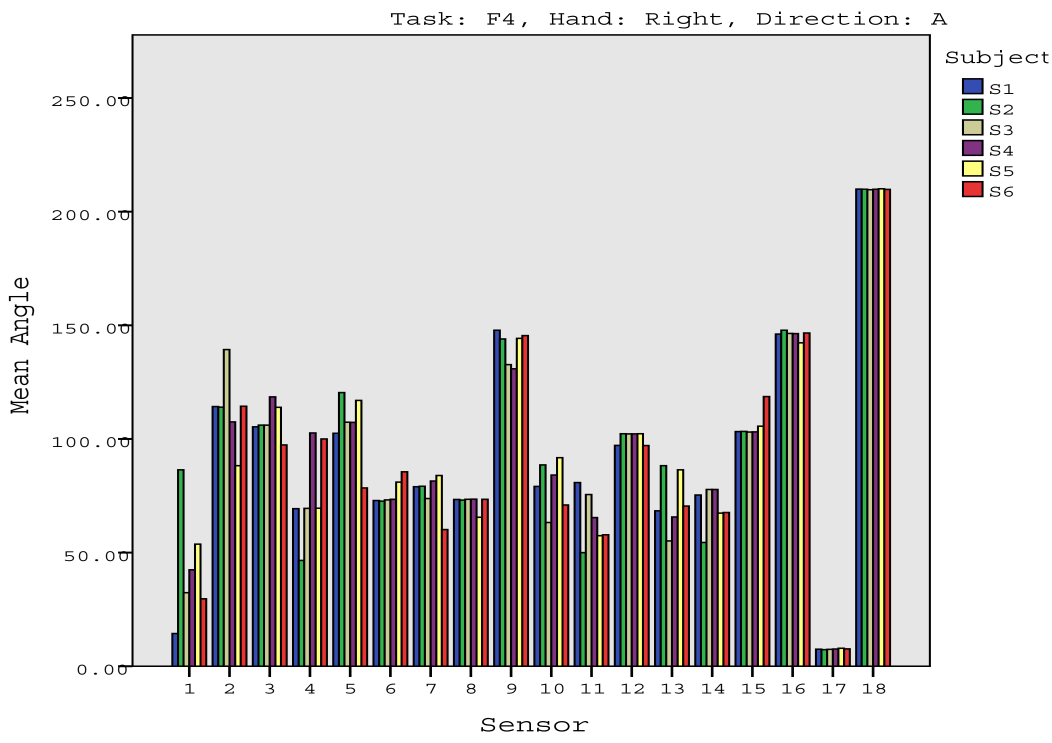



Figure 54. Ascending F4 right hand

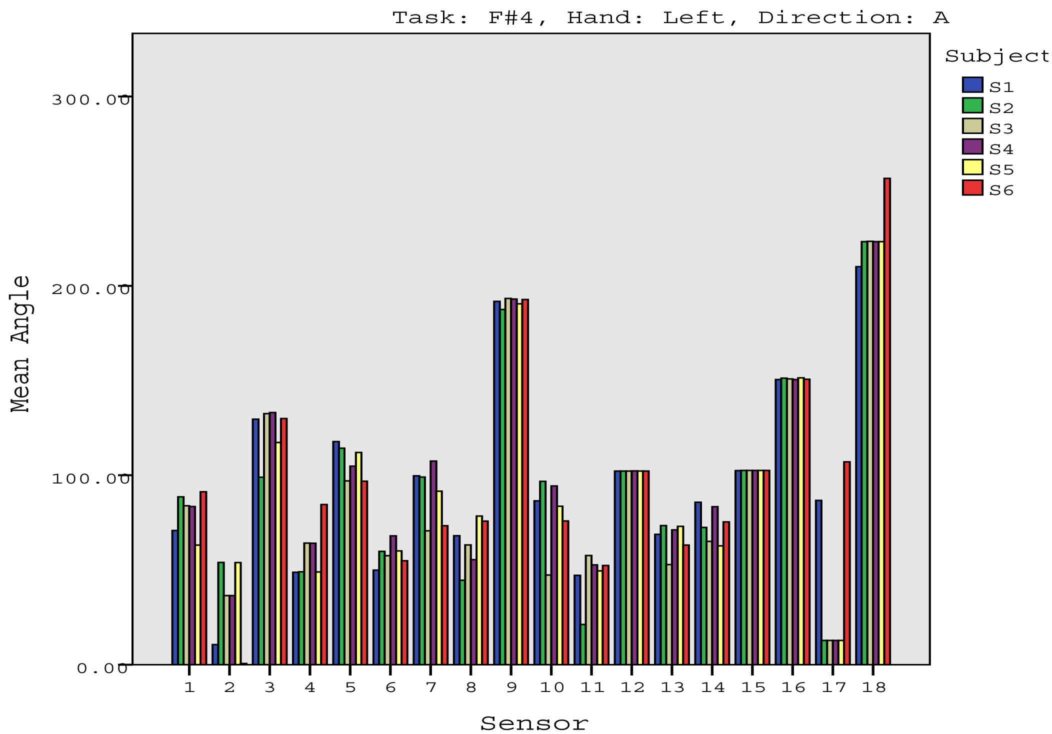



Figure 55. Ascending F#4 left hand

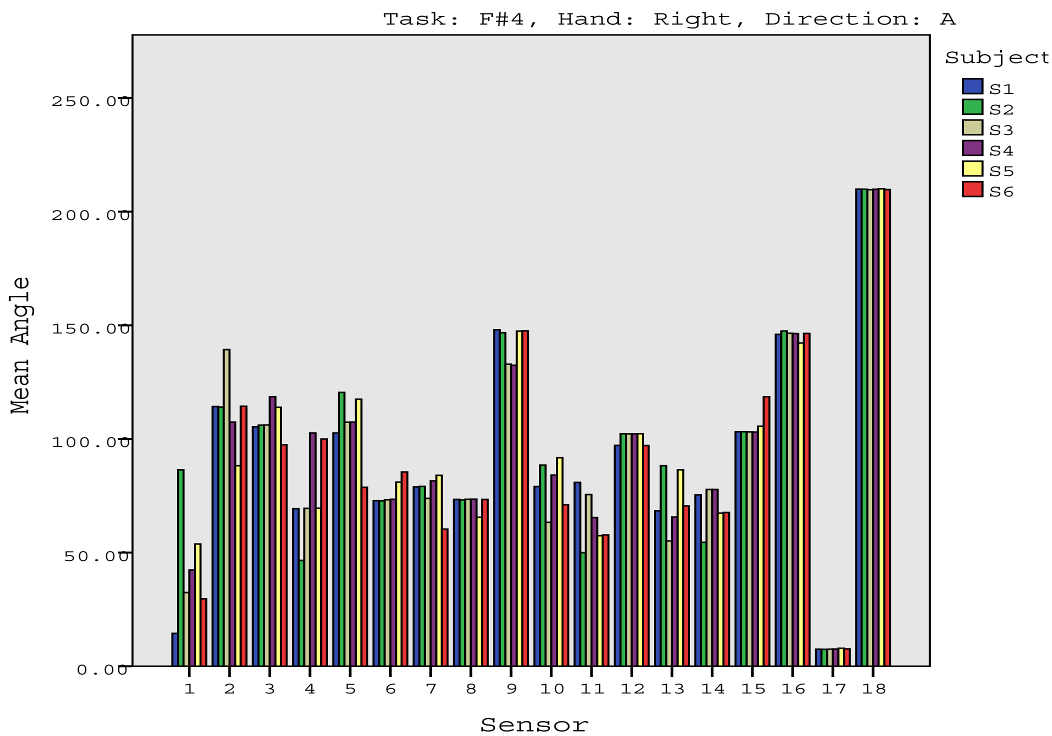



Figure 56. Ascending F#4 right hand

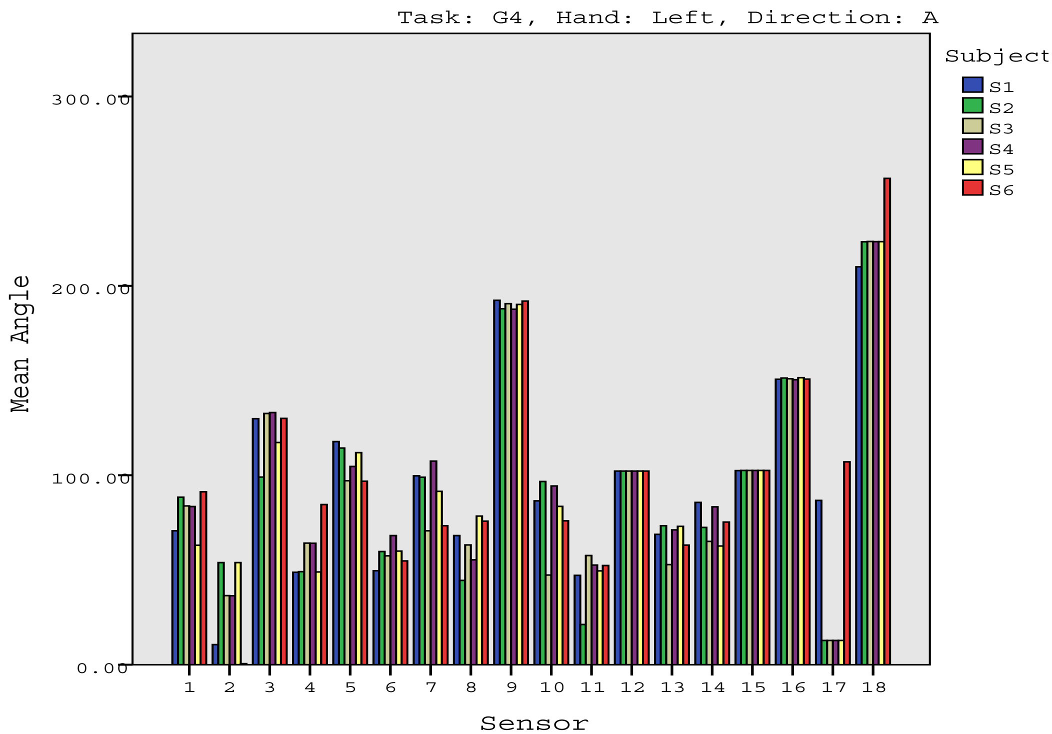



Figure 57. Ascending G4 left hand

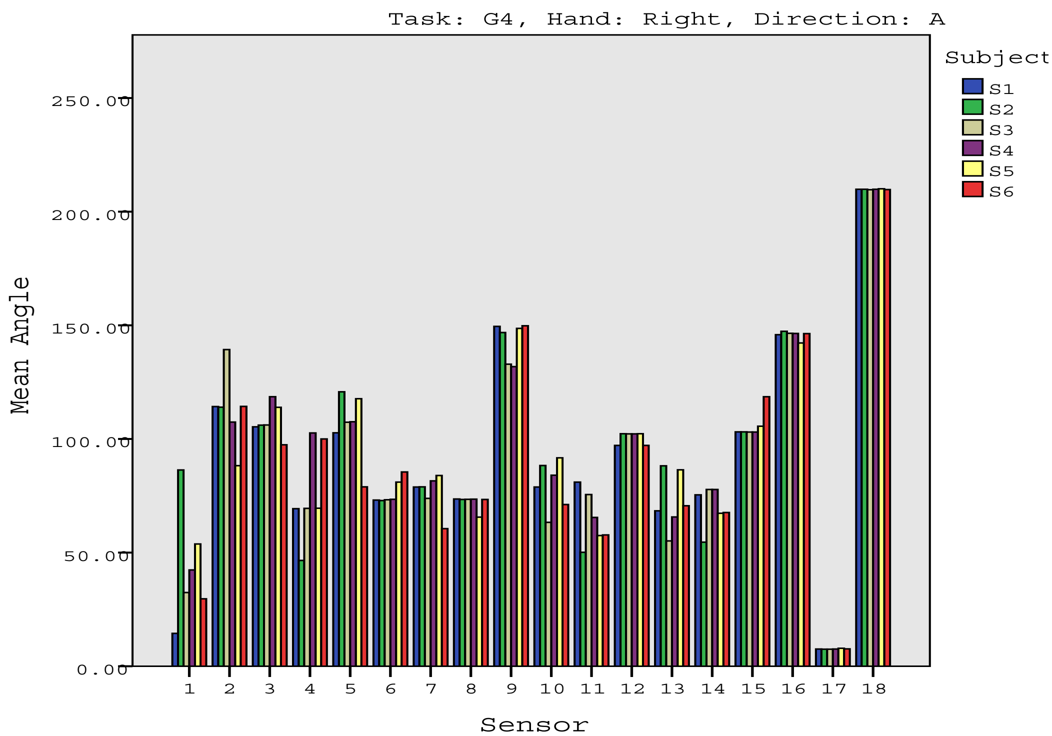



Figure 58. Ascending G4 left hand

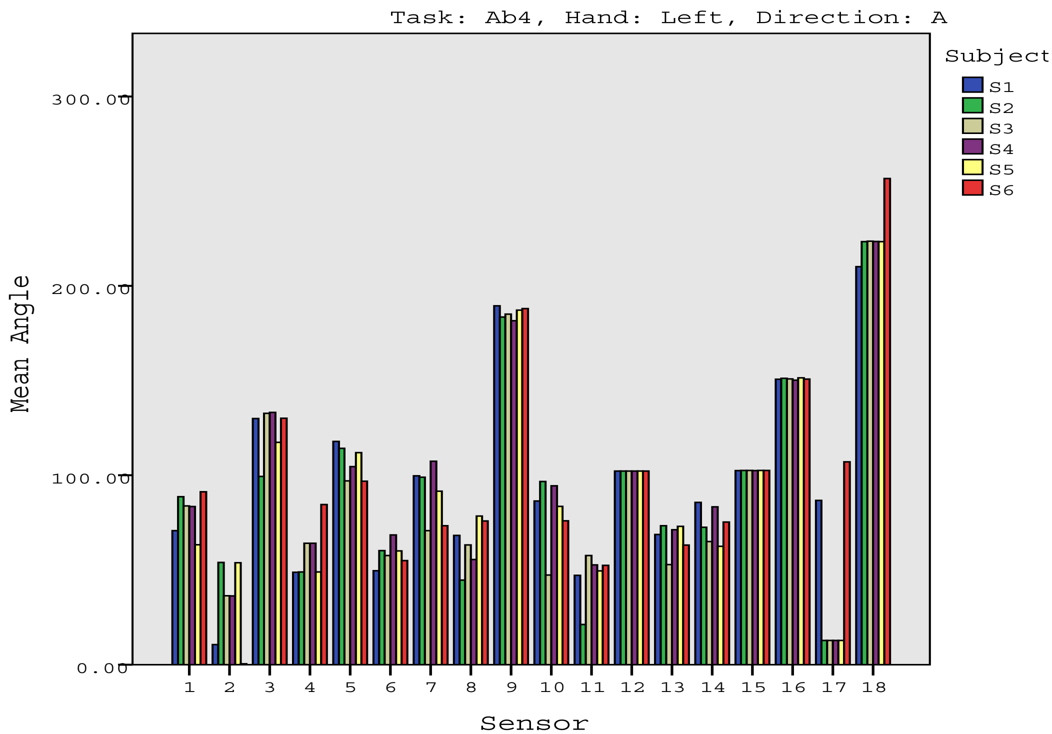



Figure 59. Ascending Ab4 left hand

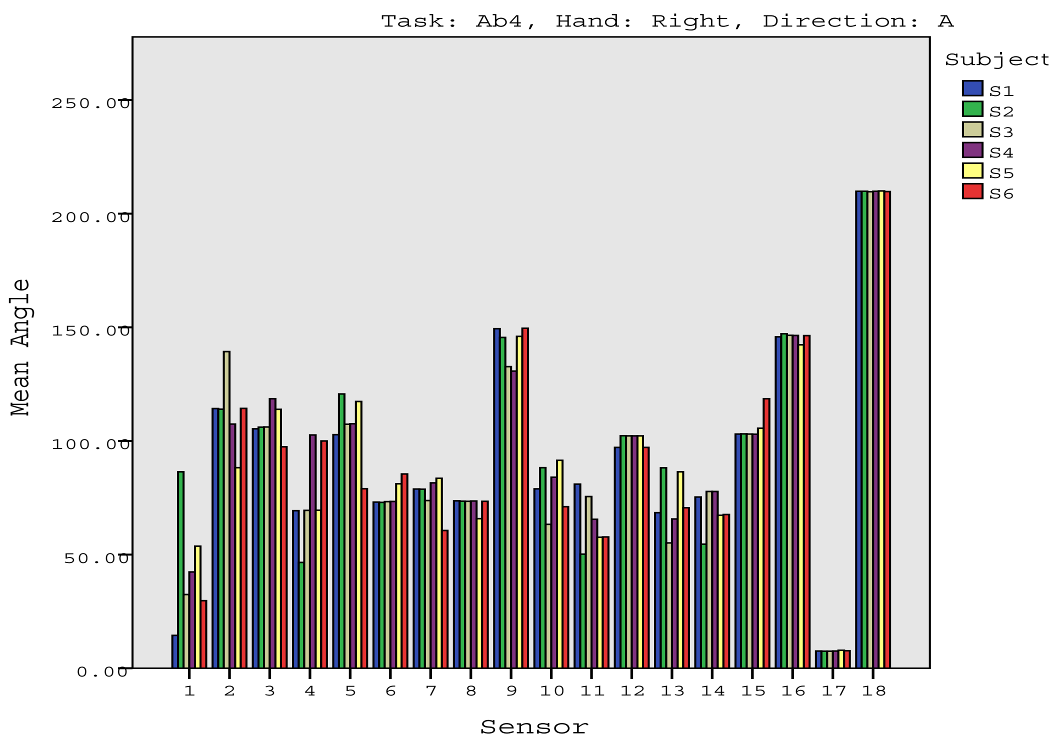



Figure 60. Ascending Ab4 left hand

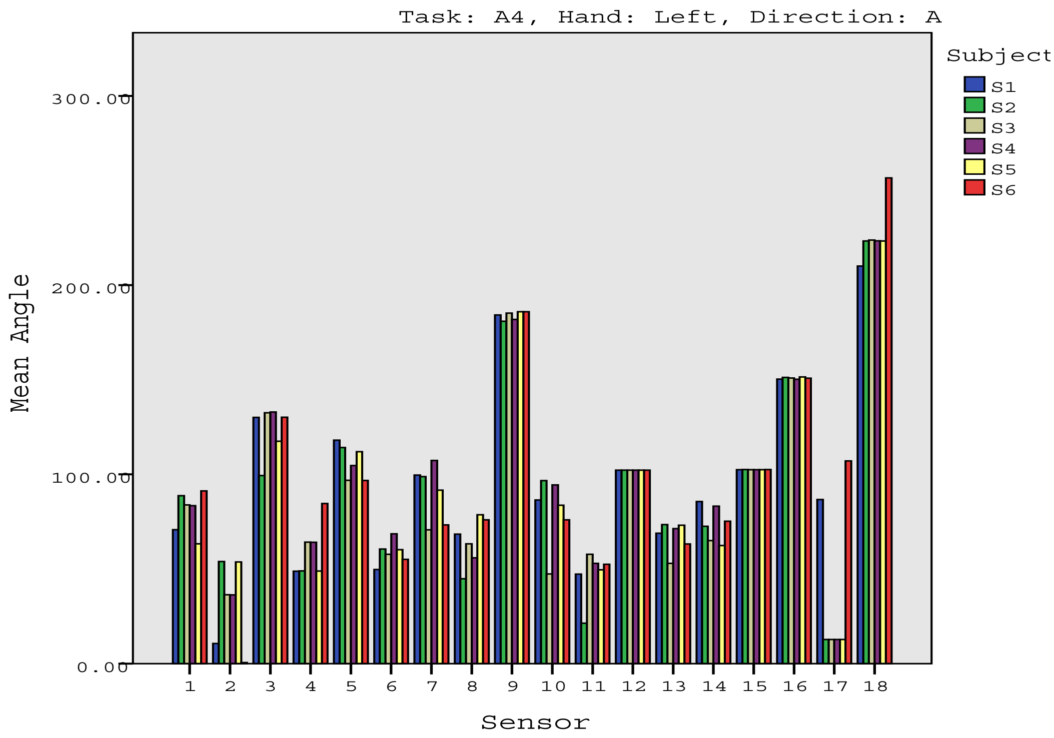



Figure 61. Ascending A4 left hand

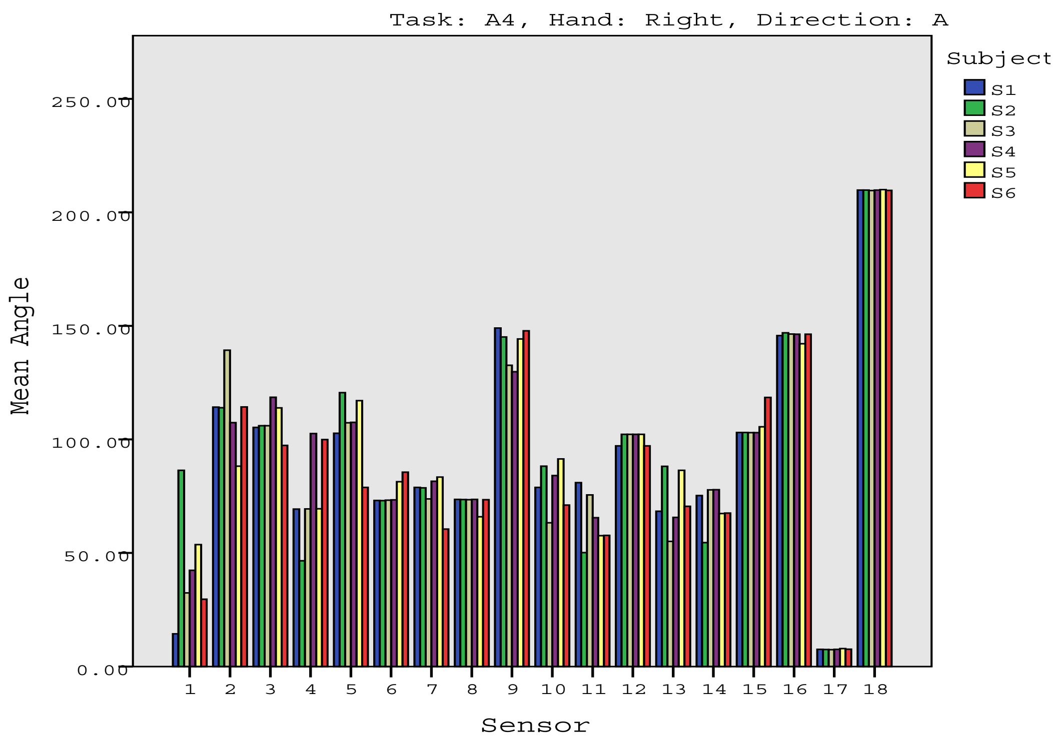



Figure 62. Ascending A4 right hand

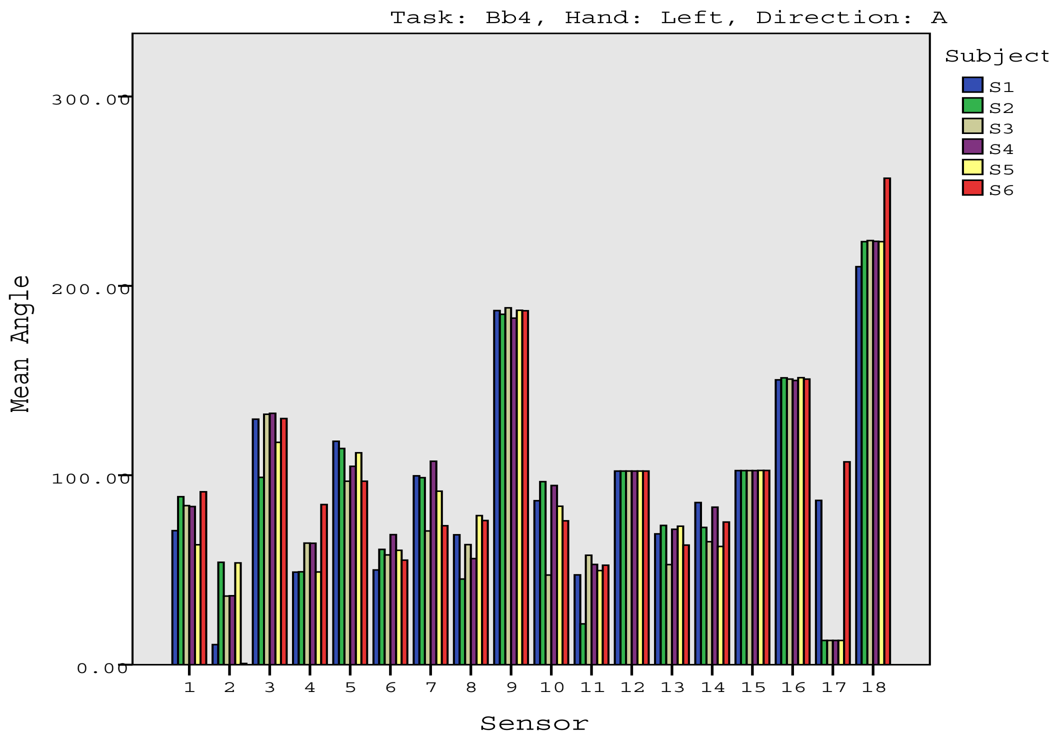



Figure 63. Ascending Bb4 left hand

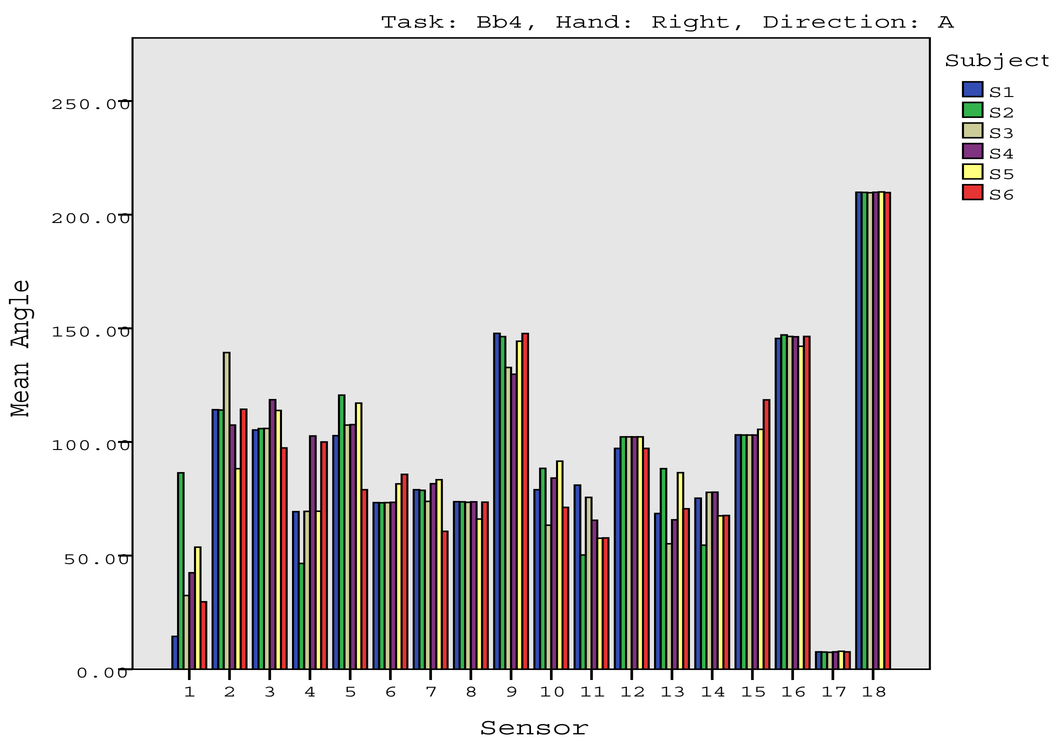



Figure 64. Ascending Bb4 right hand

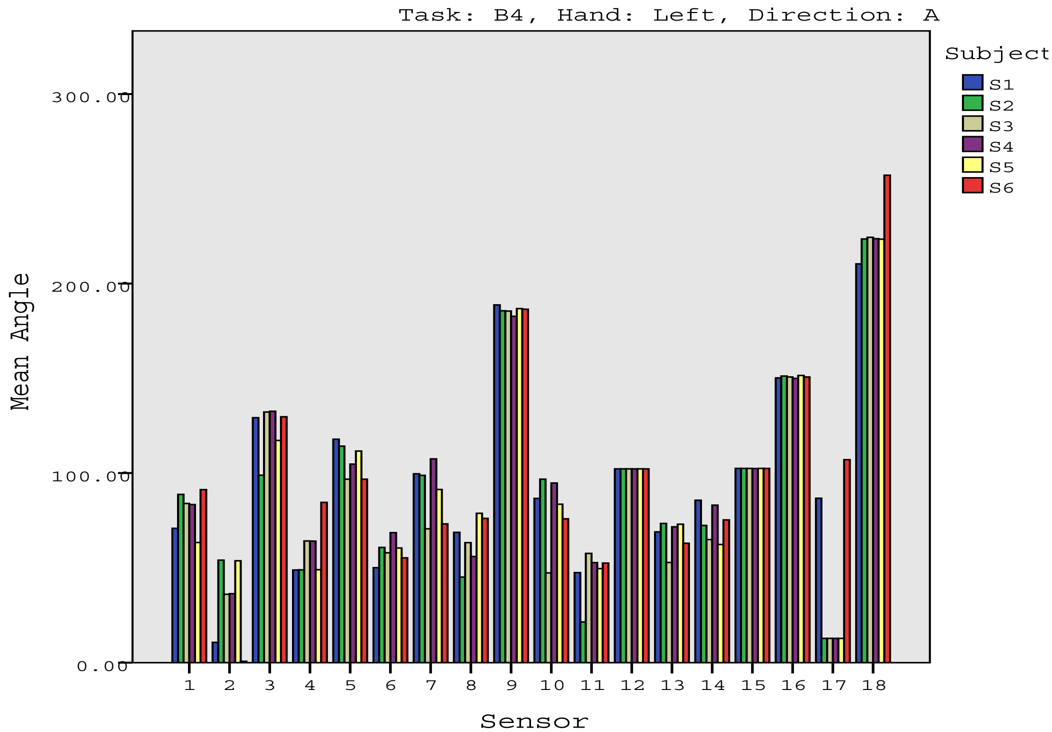



Figure 65. Ascending B4 left hand

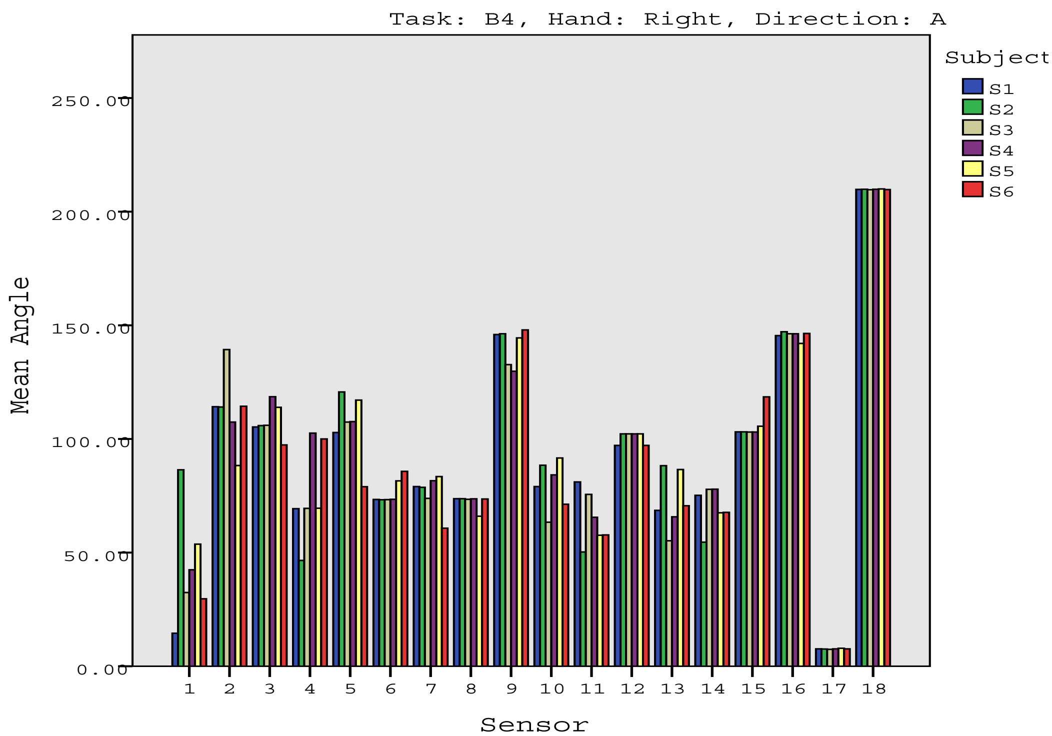



Figure 66. Ascending B4 left hand

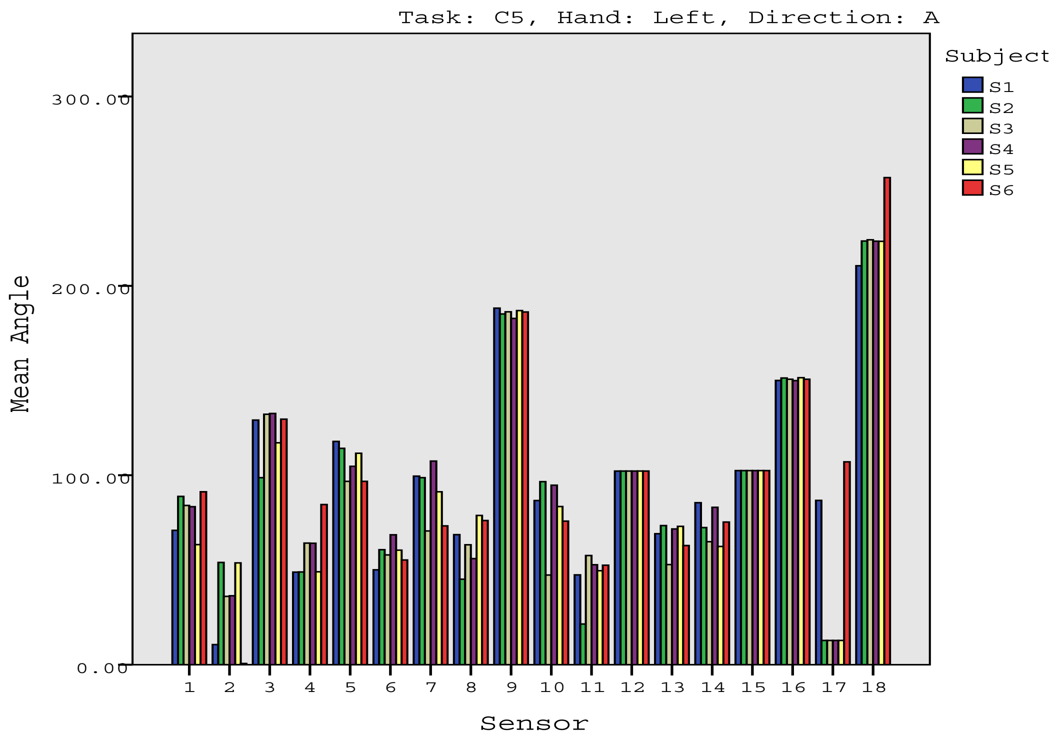



Figure 67. Ascending C5 left hand

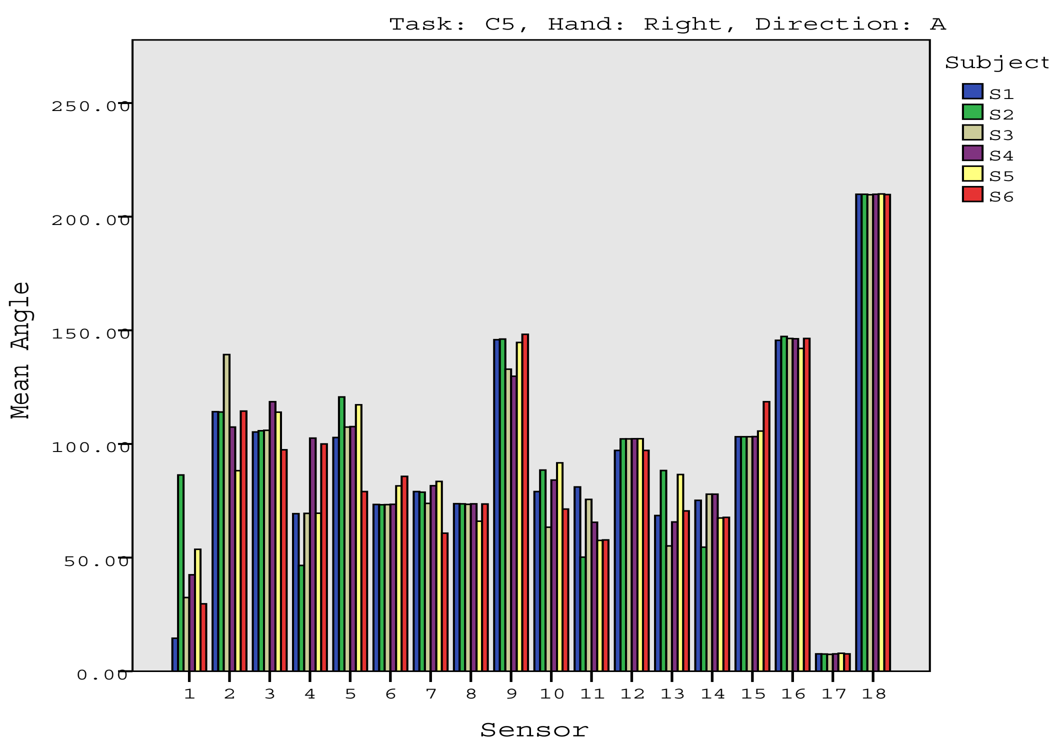



Figure 68. Ascending C5 left hand

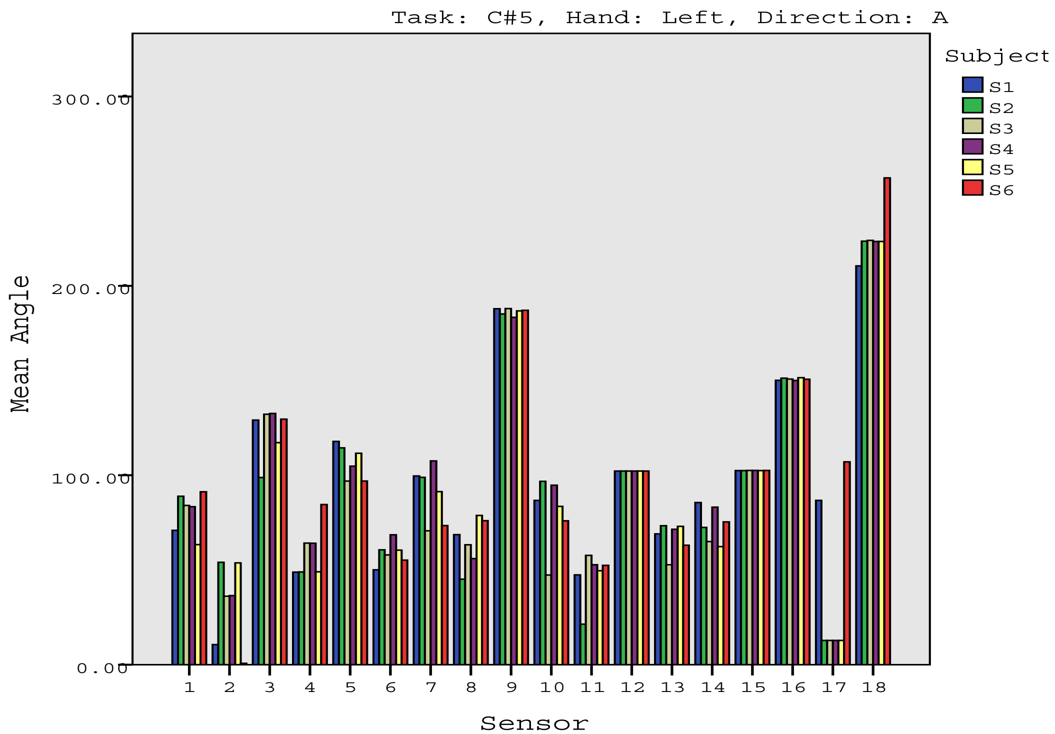



Figure 69. Ascending C#5 left hand

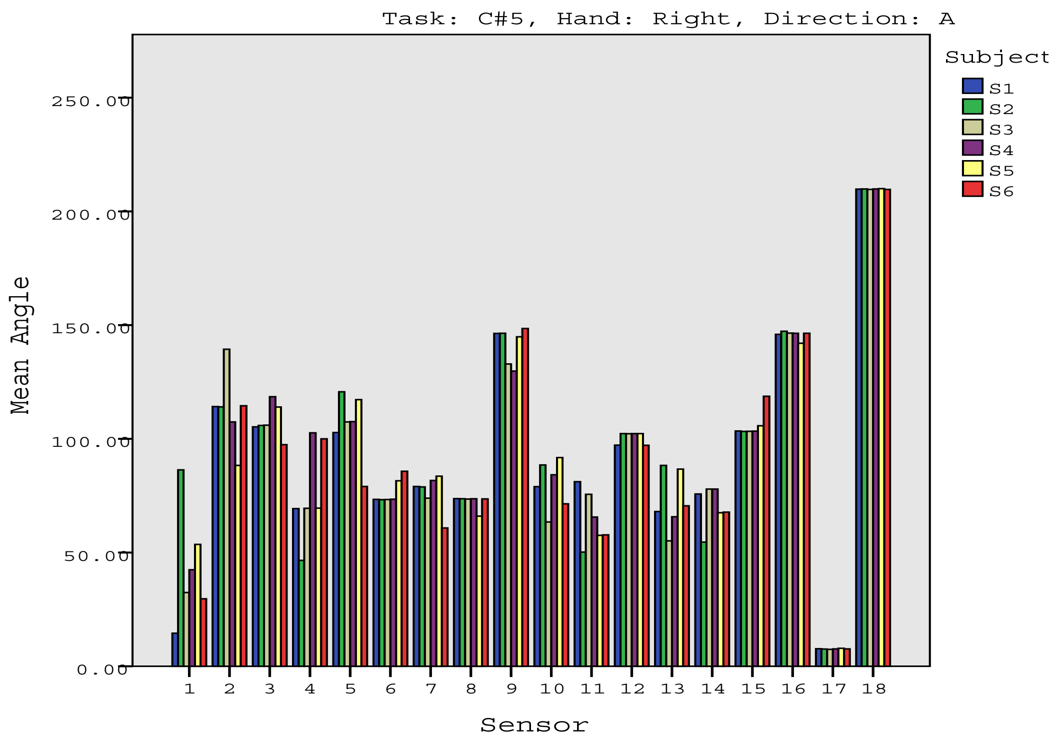



Figure 70. Ascending C#5 right hand

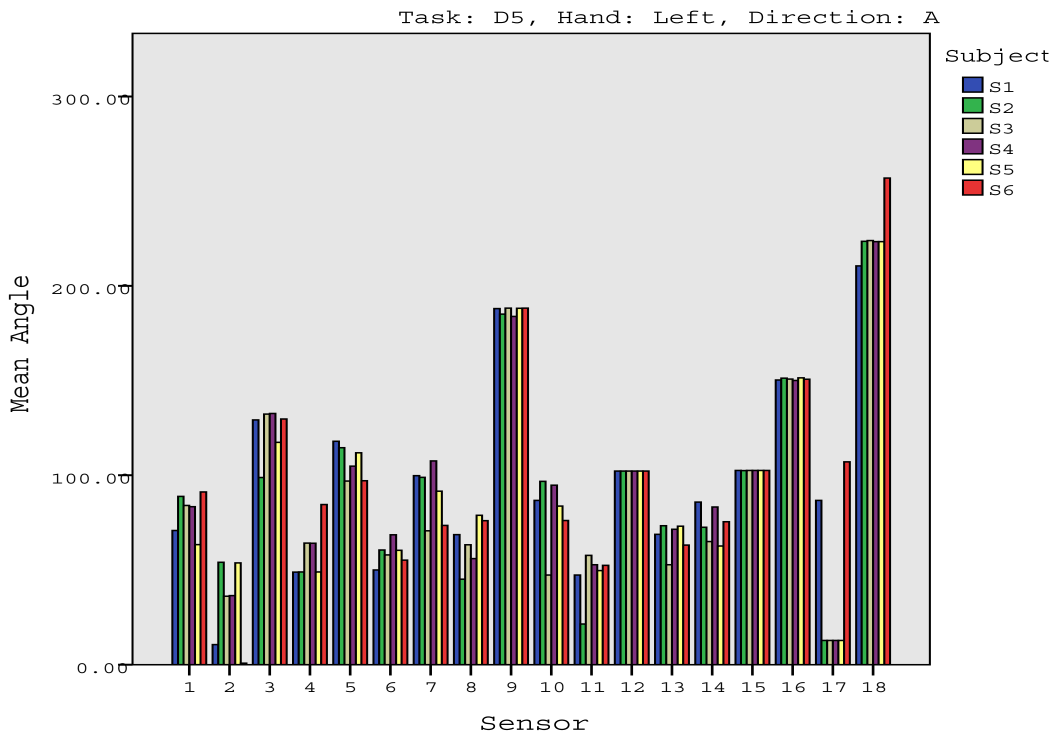



Figure 71. Ascending D5 left hand

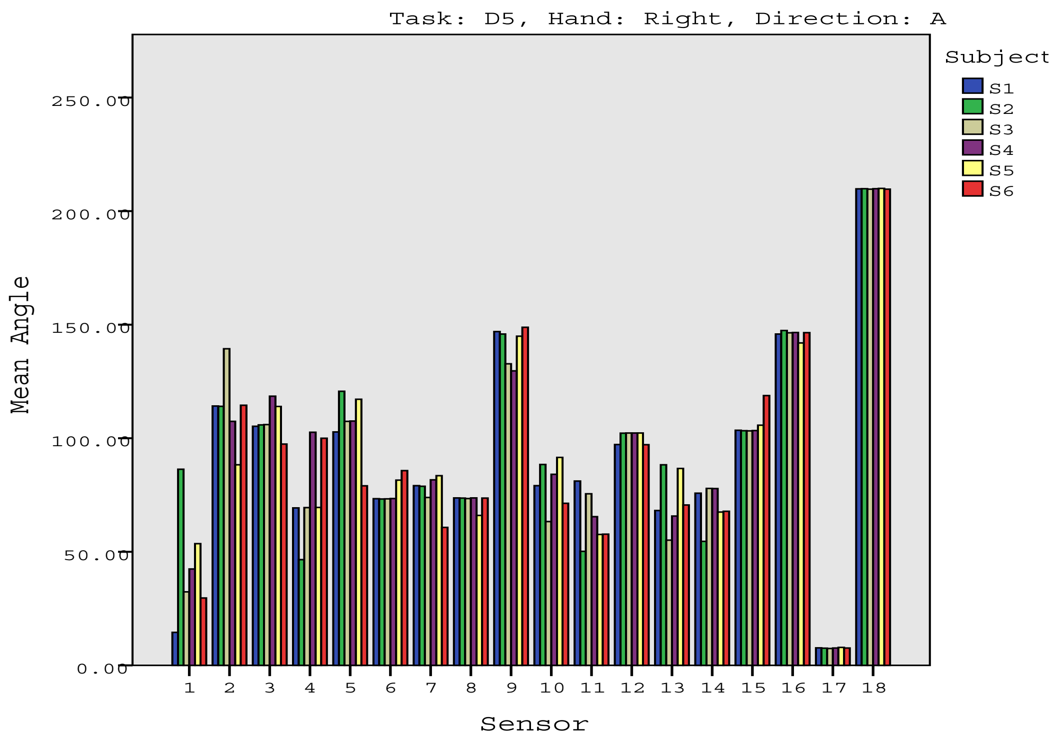



Figure 72. Ascending D5 right hand

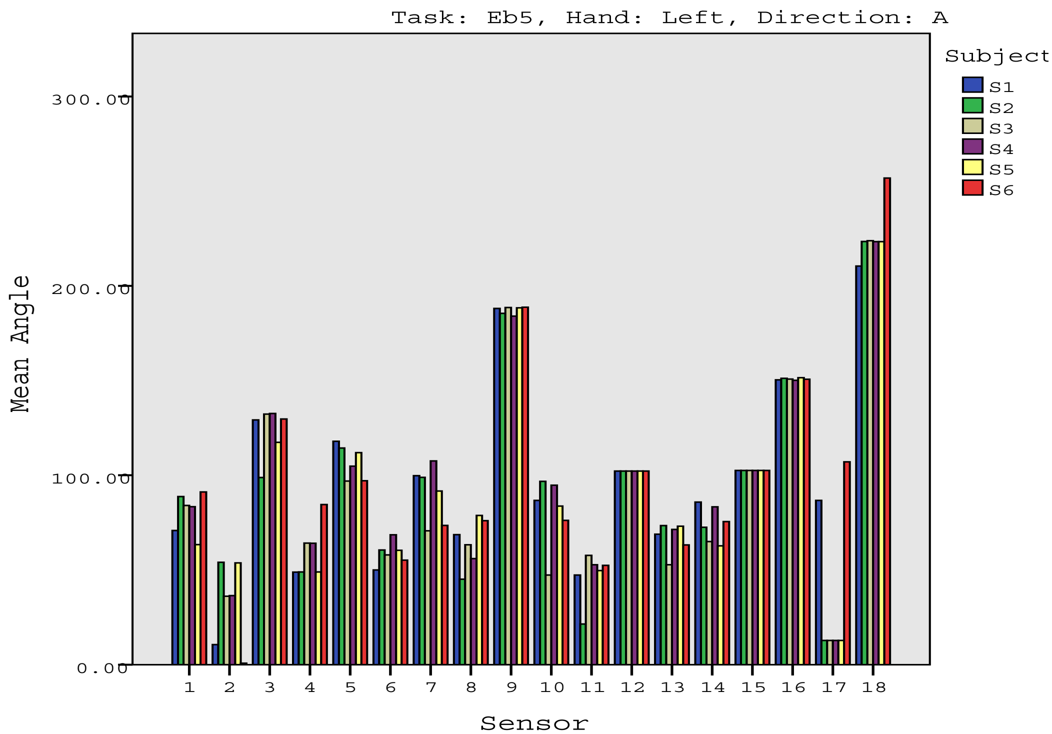



Figure 73. Ascending Eb5 left hand

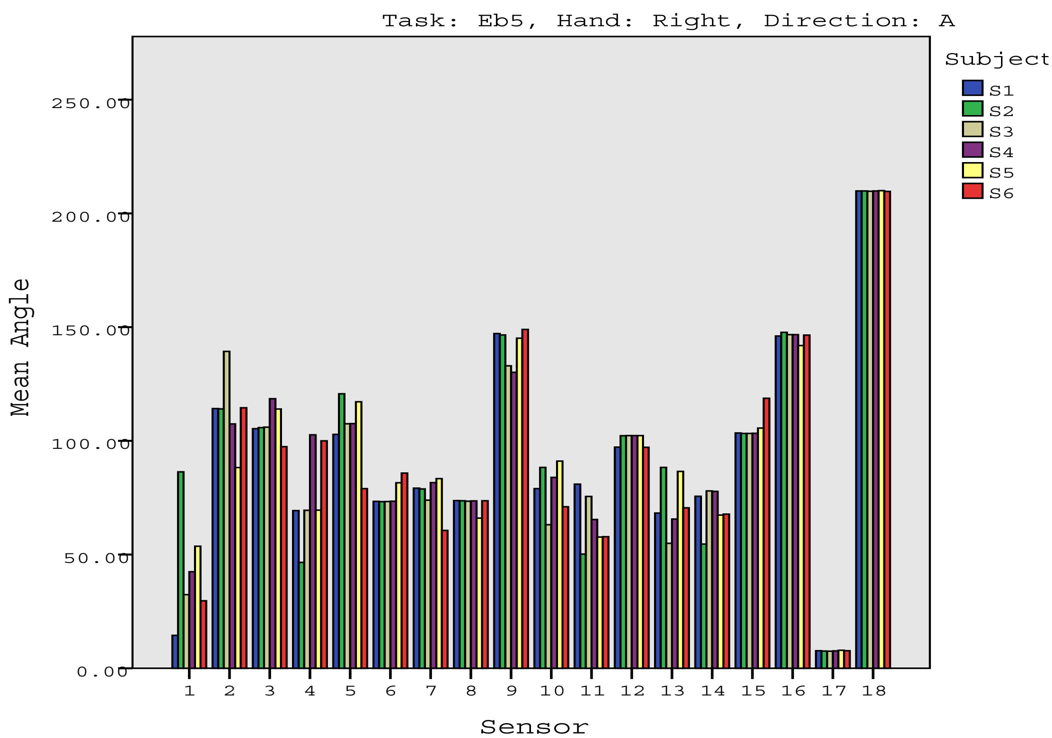



Figure 74. Ascending Eb5 right hand

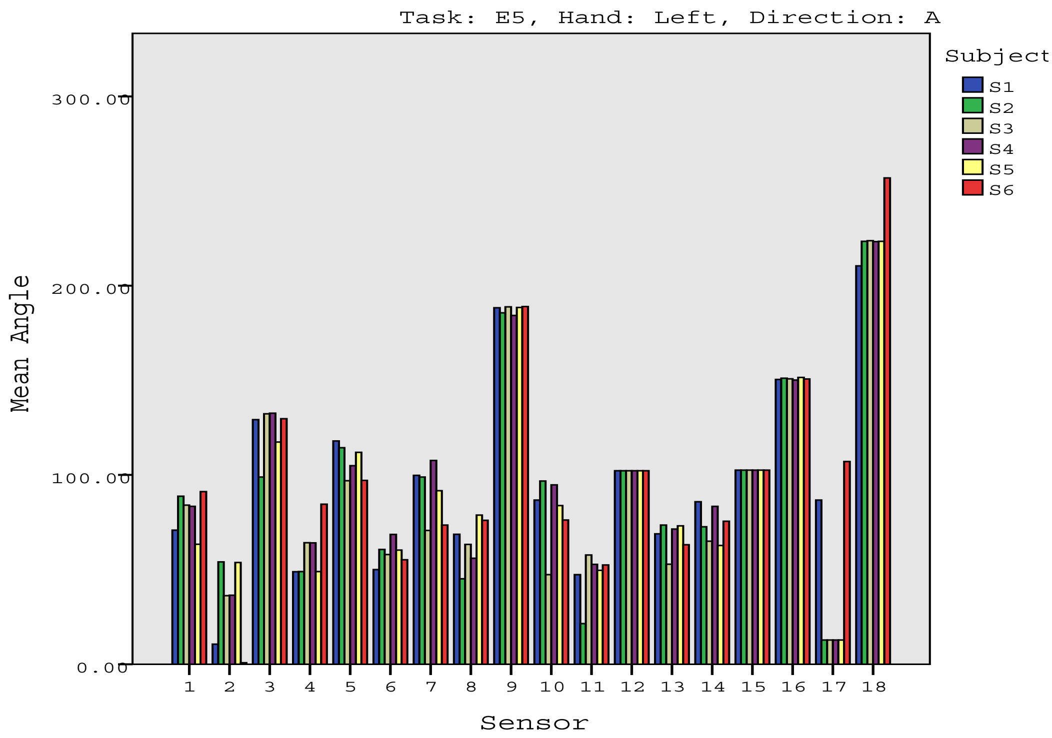



Figure 75. Ascending E5 left hand

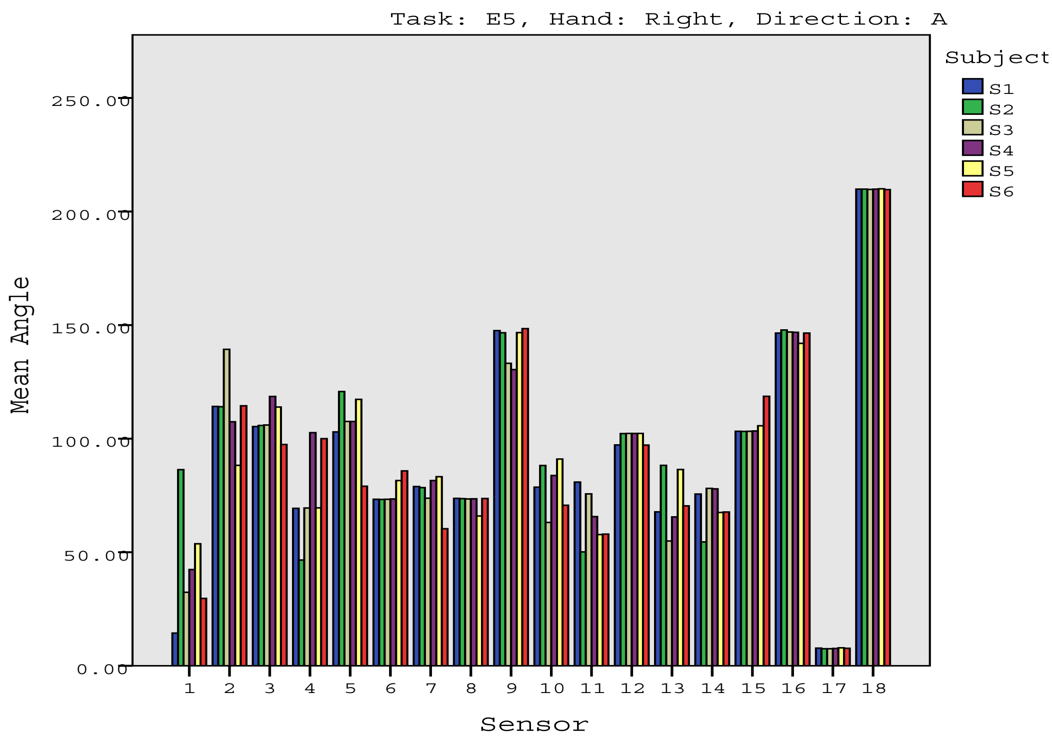



Figure 76. Ascending E5 right hand

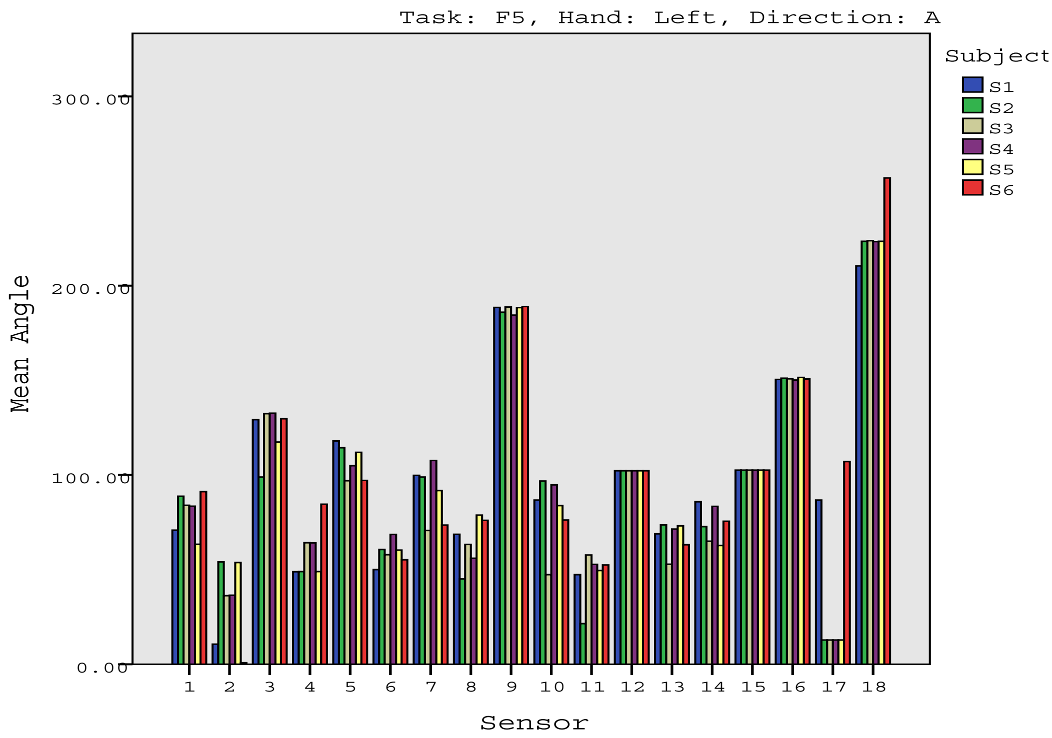



Figure 77. Ascending F5 left hand

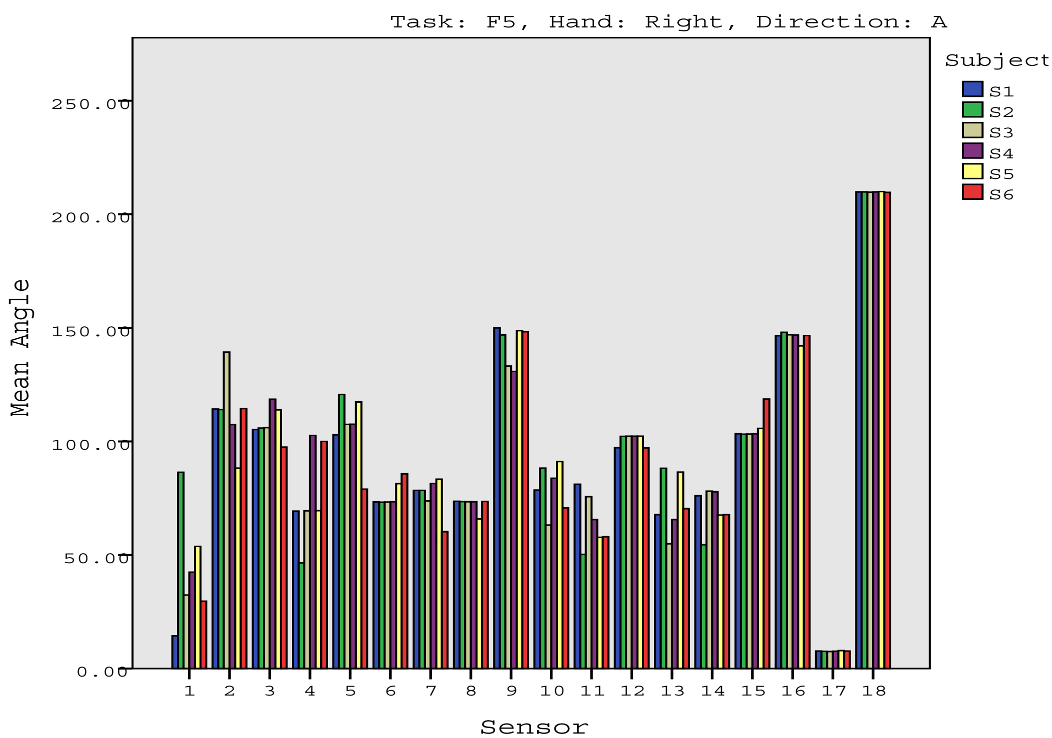



Figure 78. Ascending F5 right hand

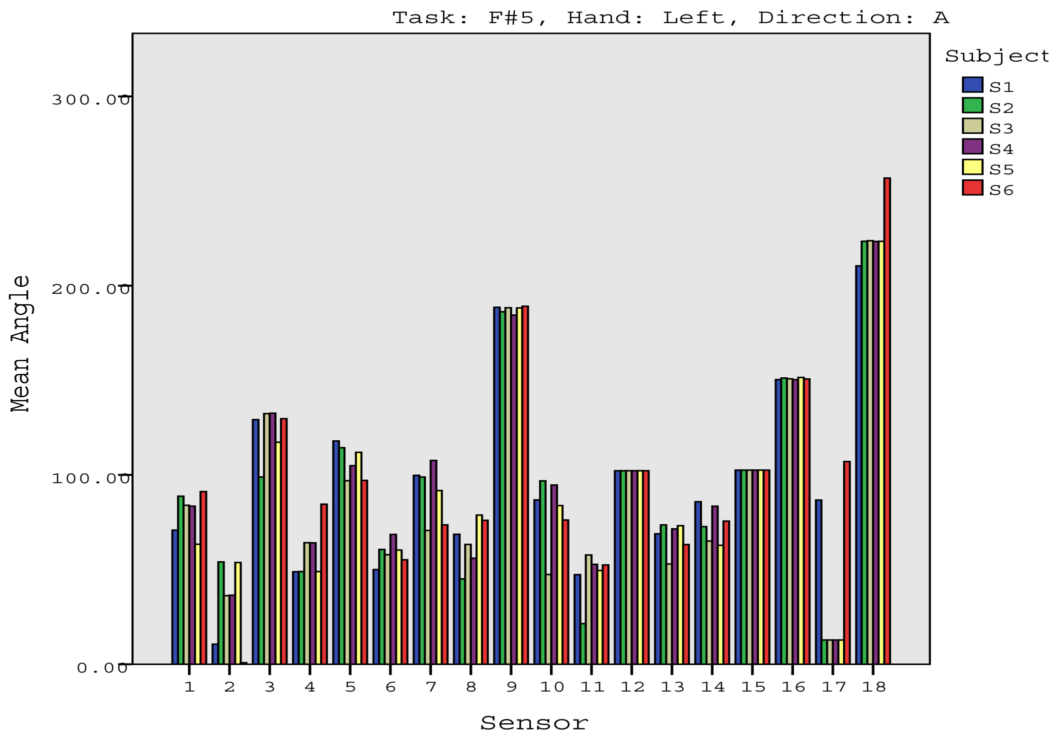



Figure 79. Ascending F#5

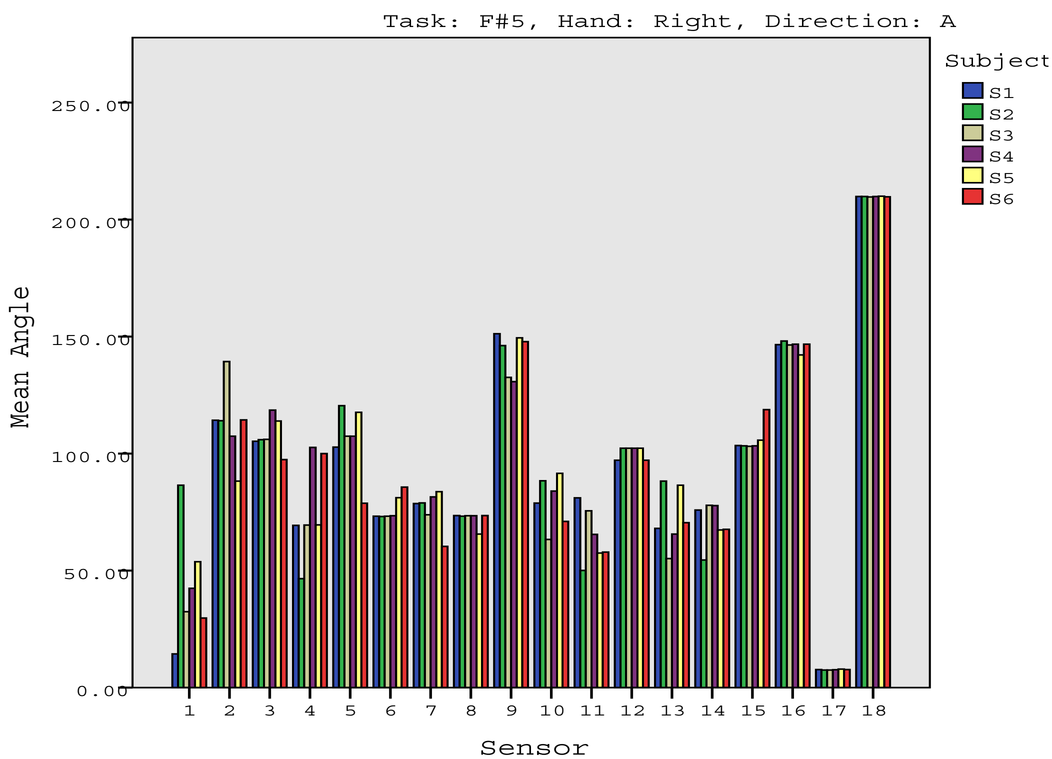



Figure 80. Ascending F#5 right hand

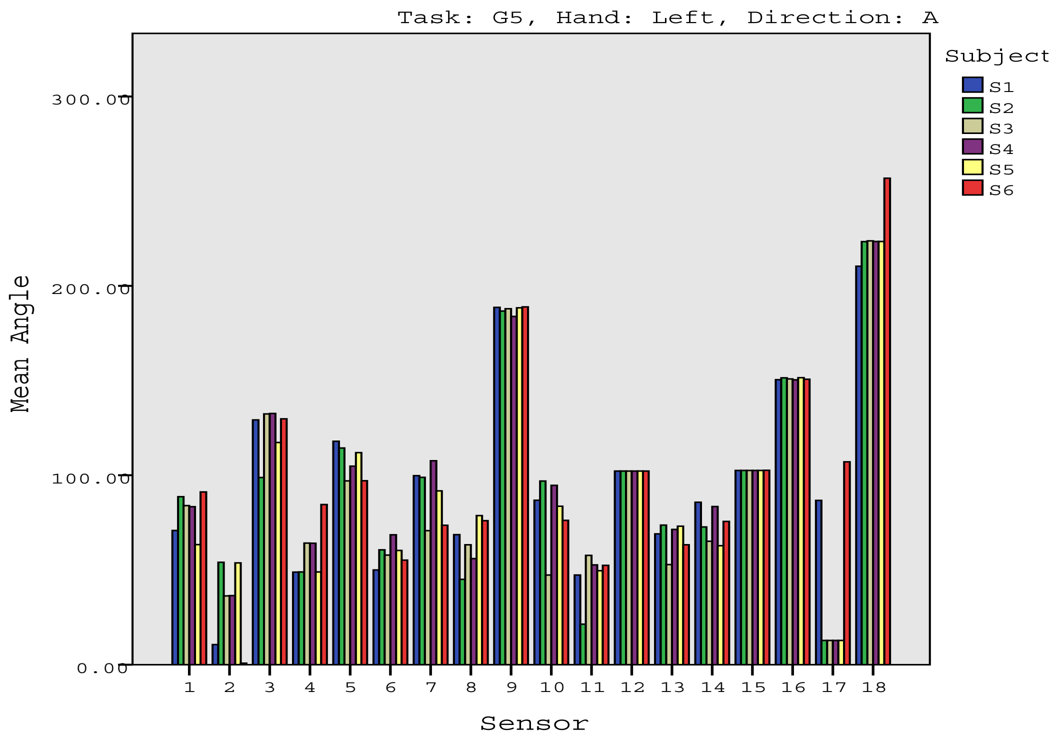



Figure 81. Ascending G5 left hand

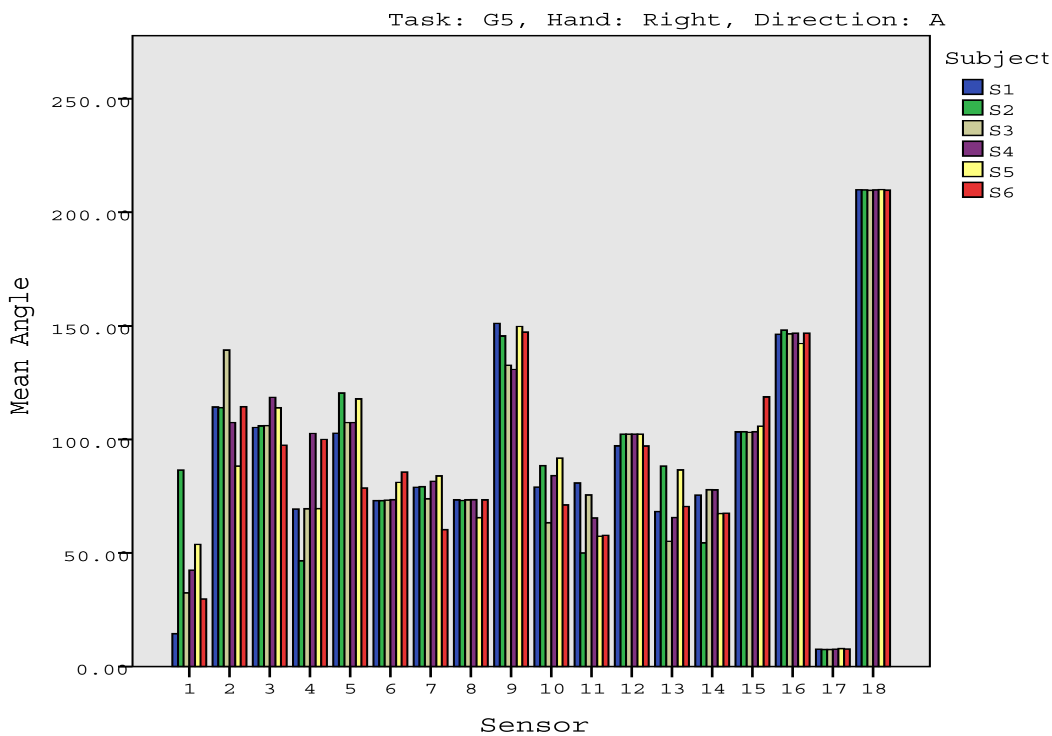



Figure 82. Ascending G5 right hand

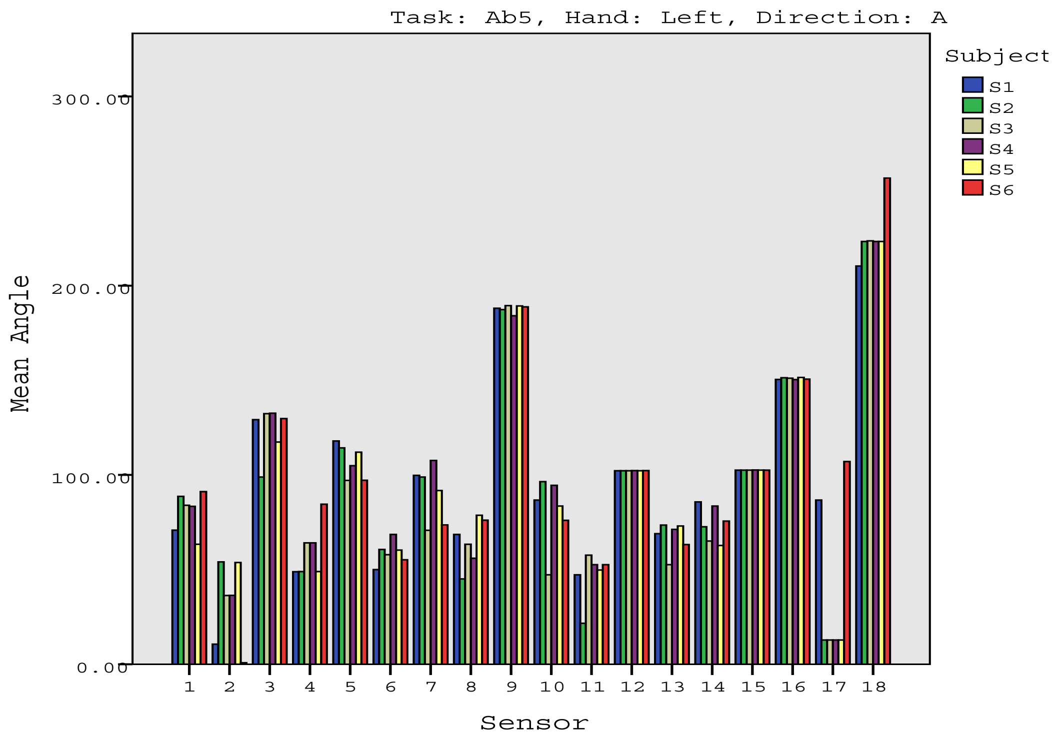



Figure 83. Ascending Ab5 left hand

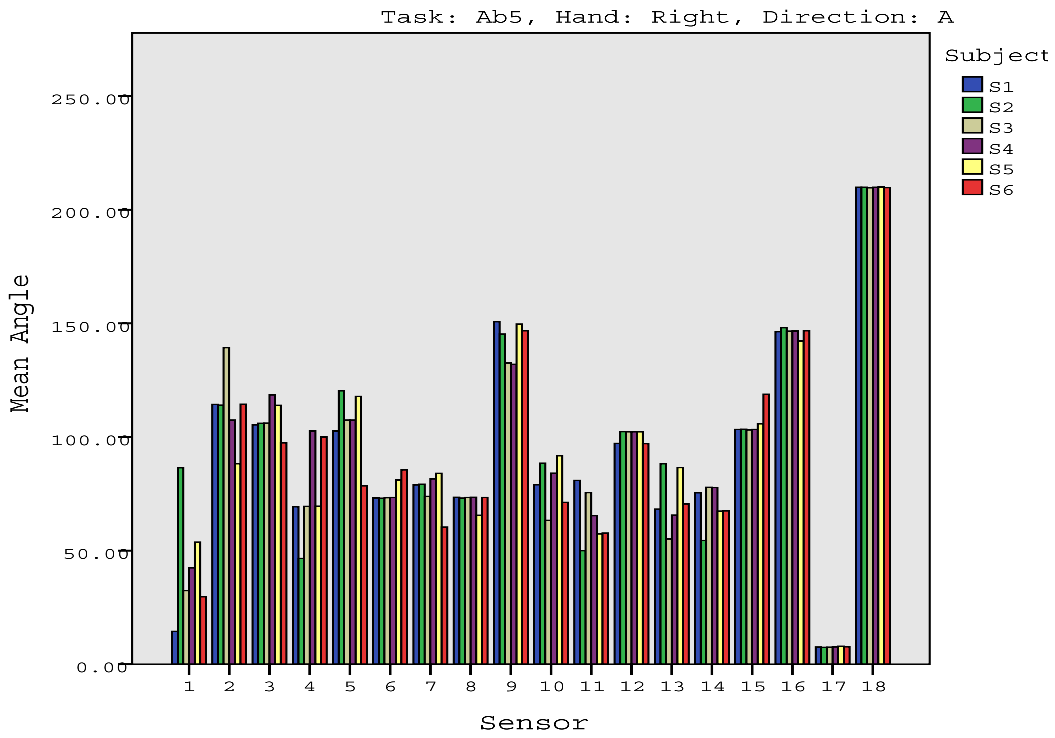



Figure 84. Ascending Ab5 right hand

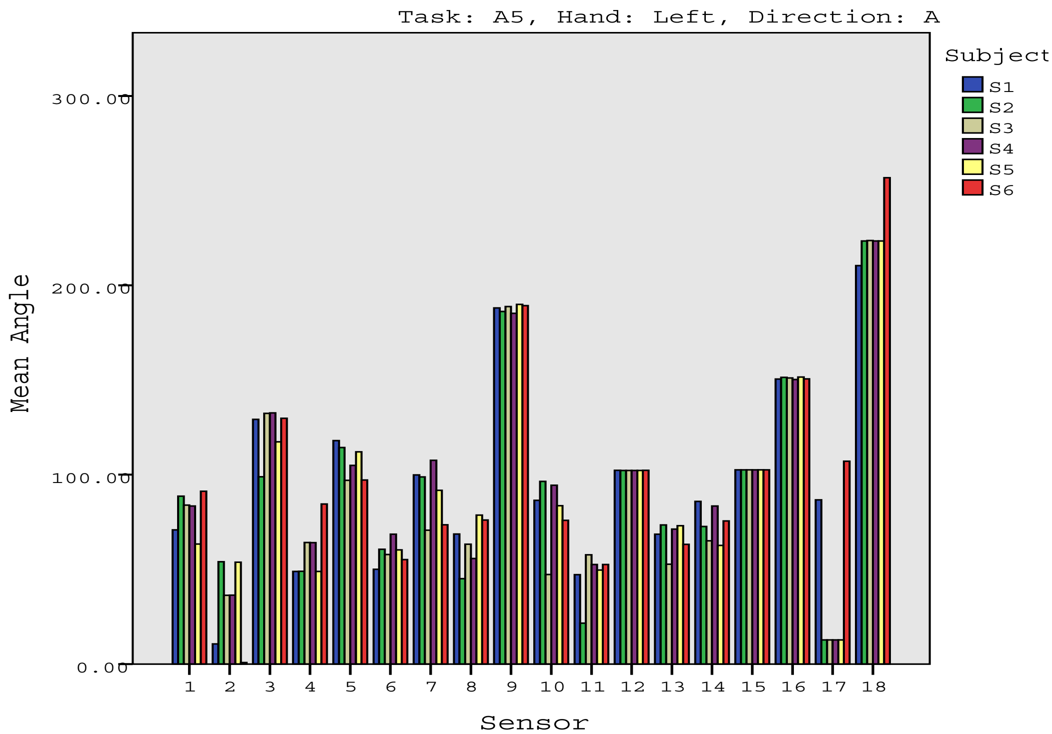



Figure 85. Ascending A5 left hand

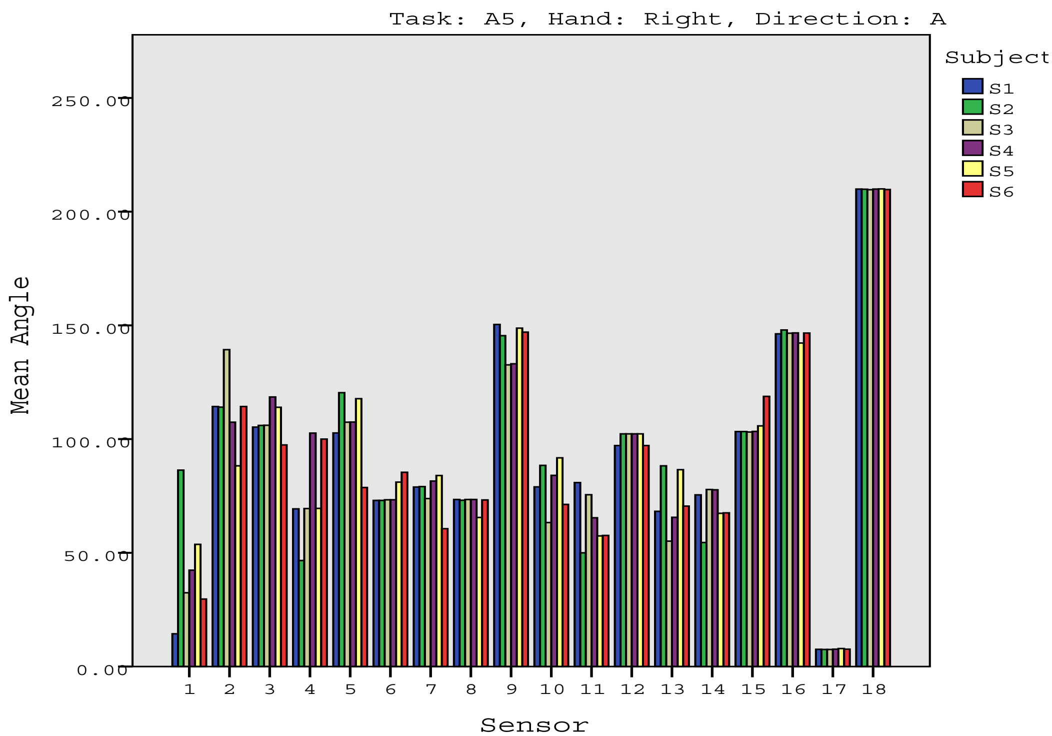



Figure 86. Ascending A5 right hand

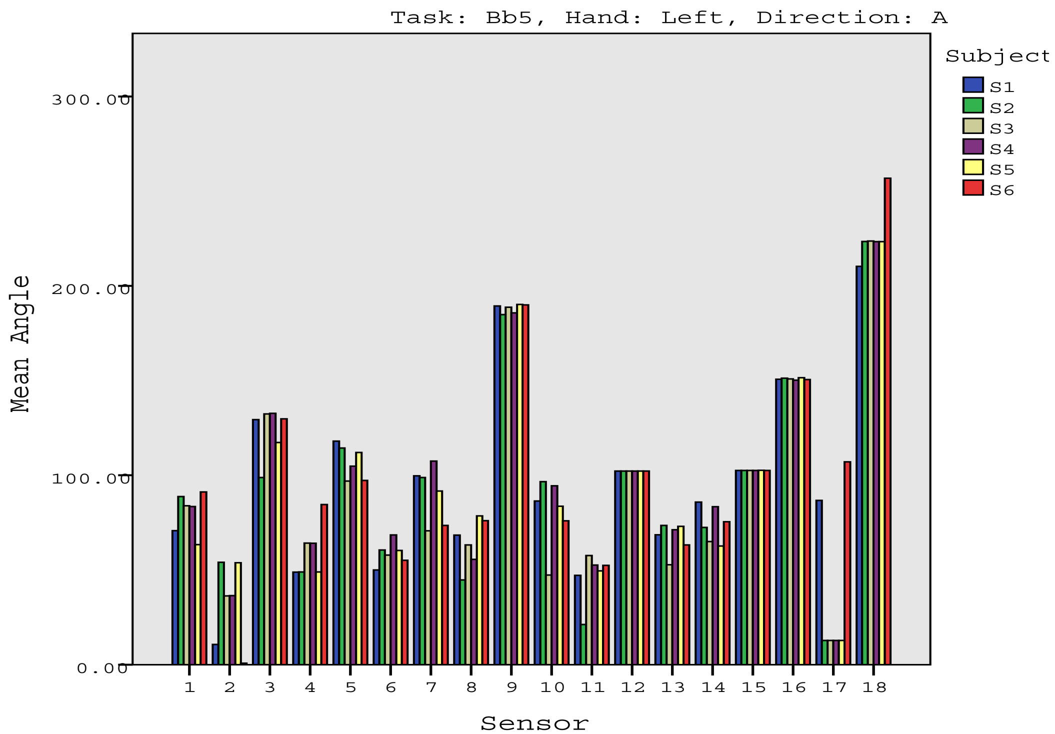



Figure 87. Ascending Bb5 left hand

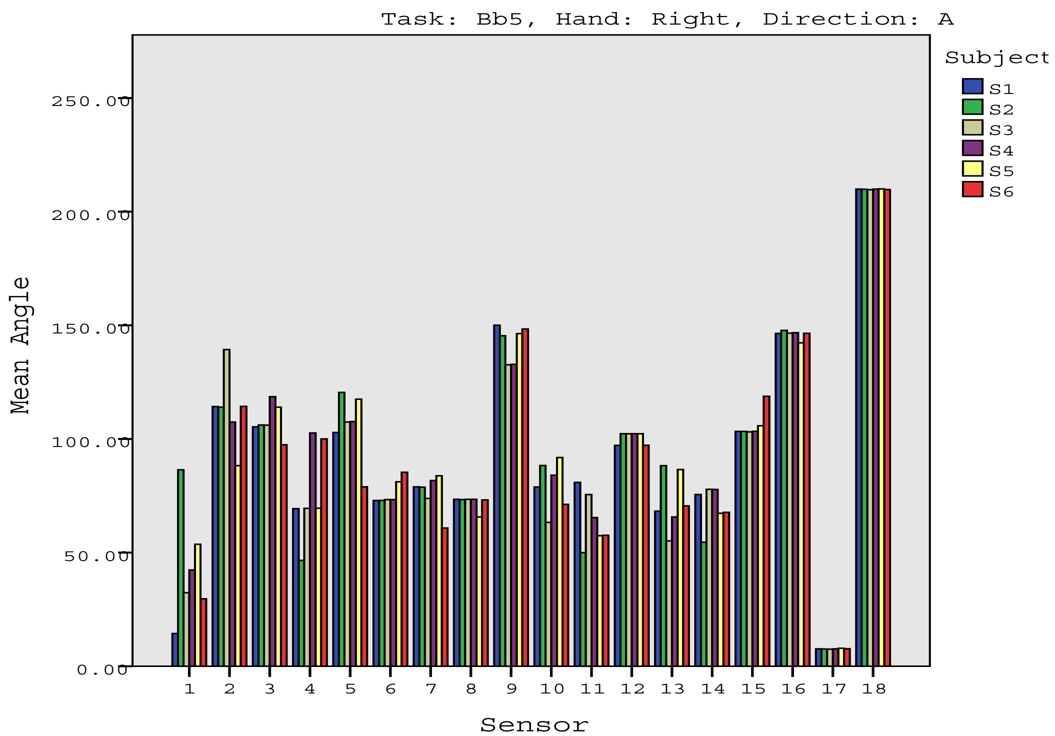



Figure 88. Ascending Bb5 right hand

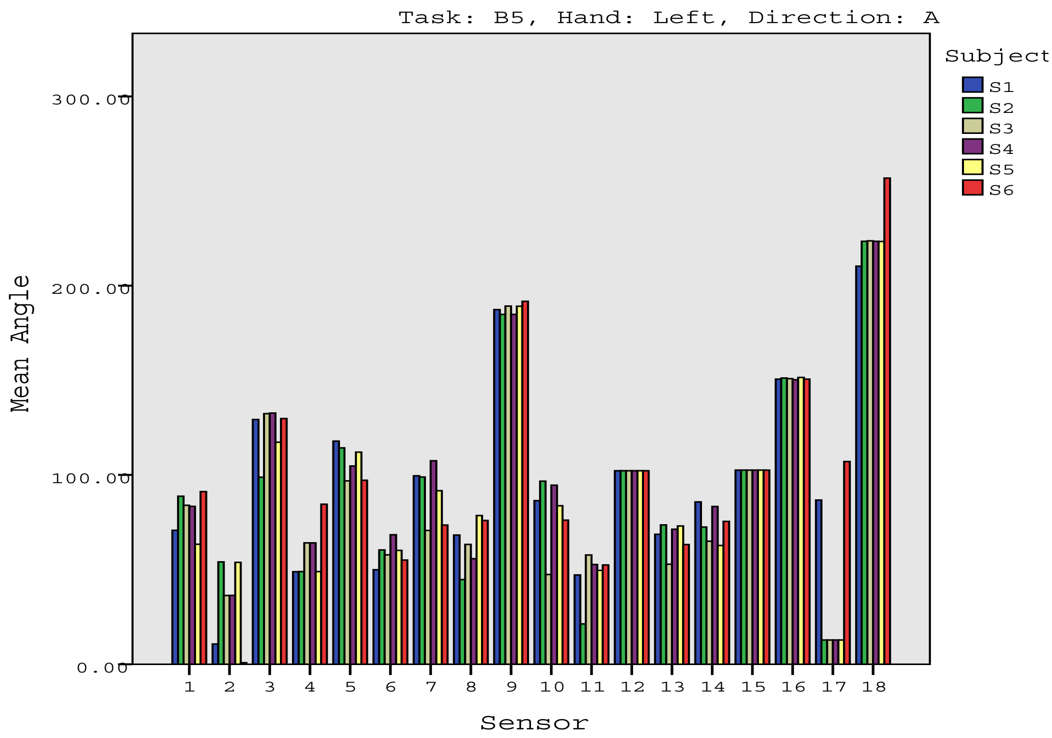



Figure 89. Ascending B5 left hand

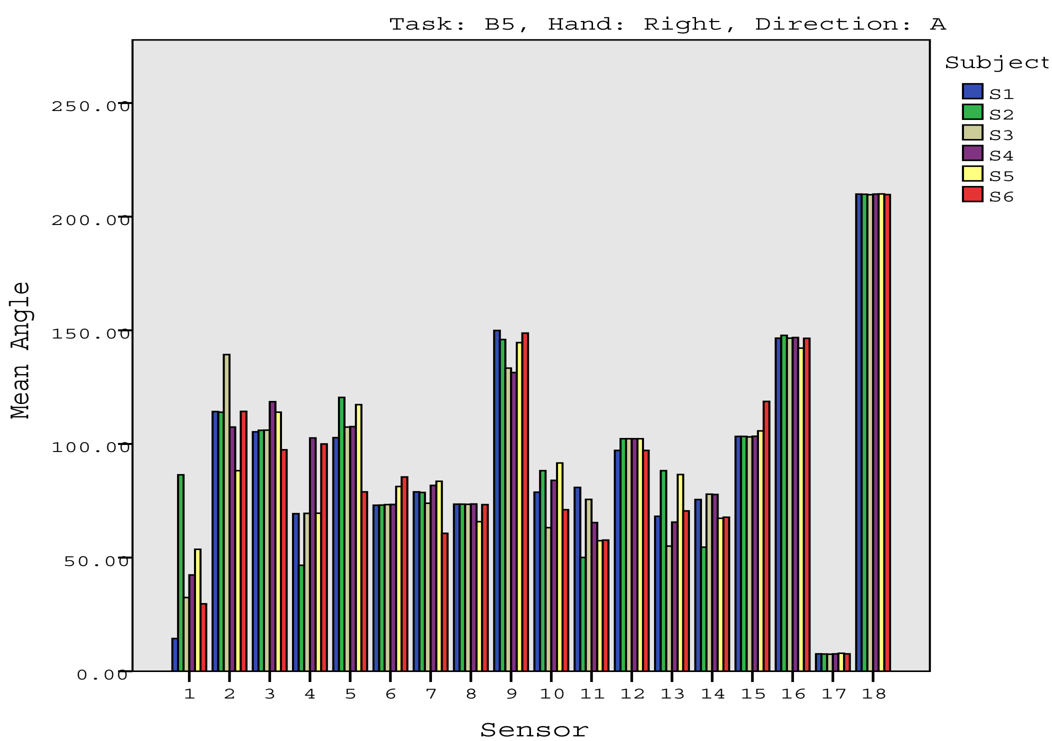



Figure 90. Ascending B5 right hand

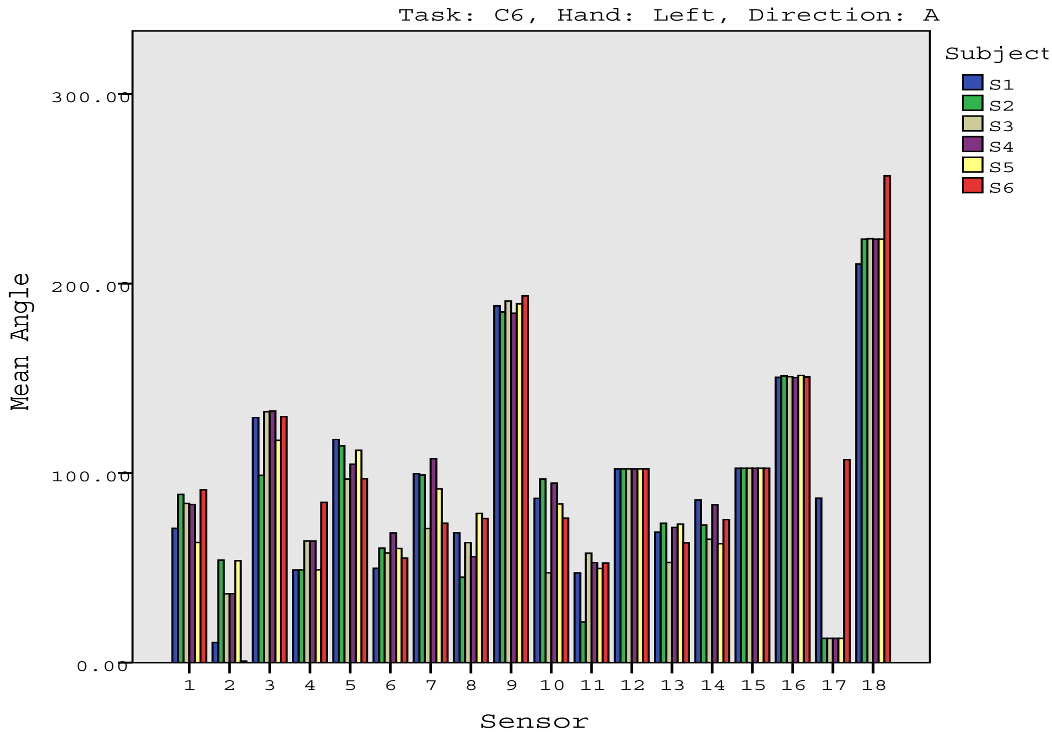



Figure 91. Ascending C6 right hand

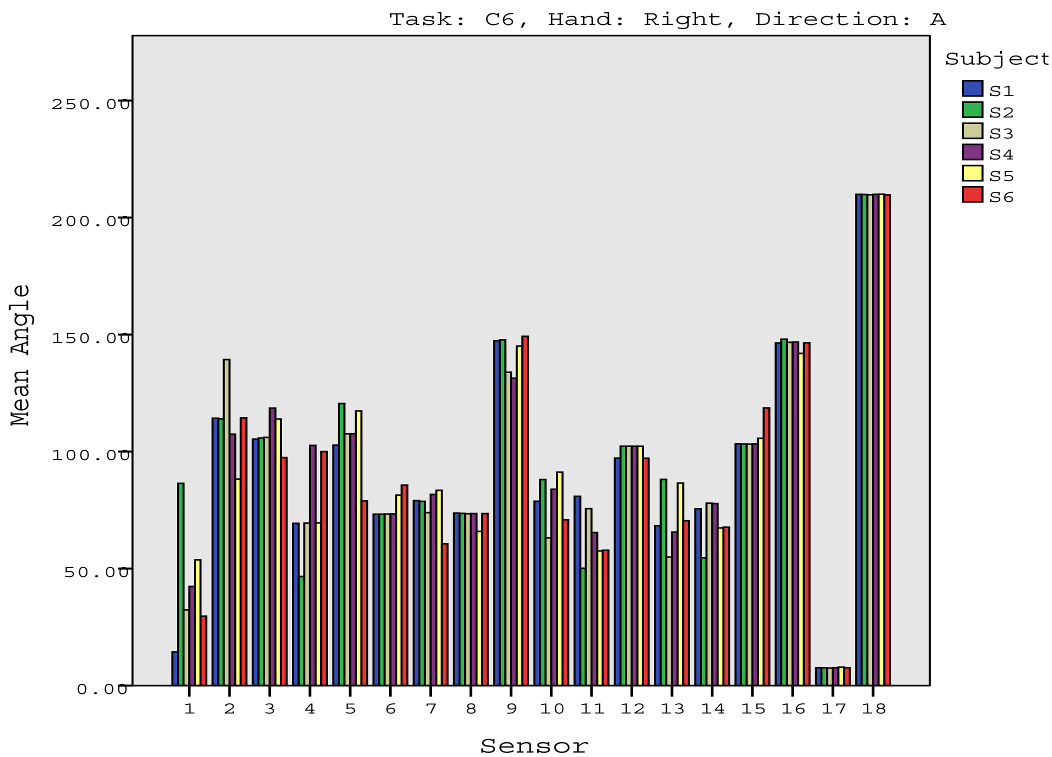



Figure 92. Ascending C6 right hand

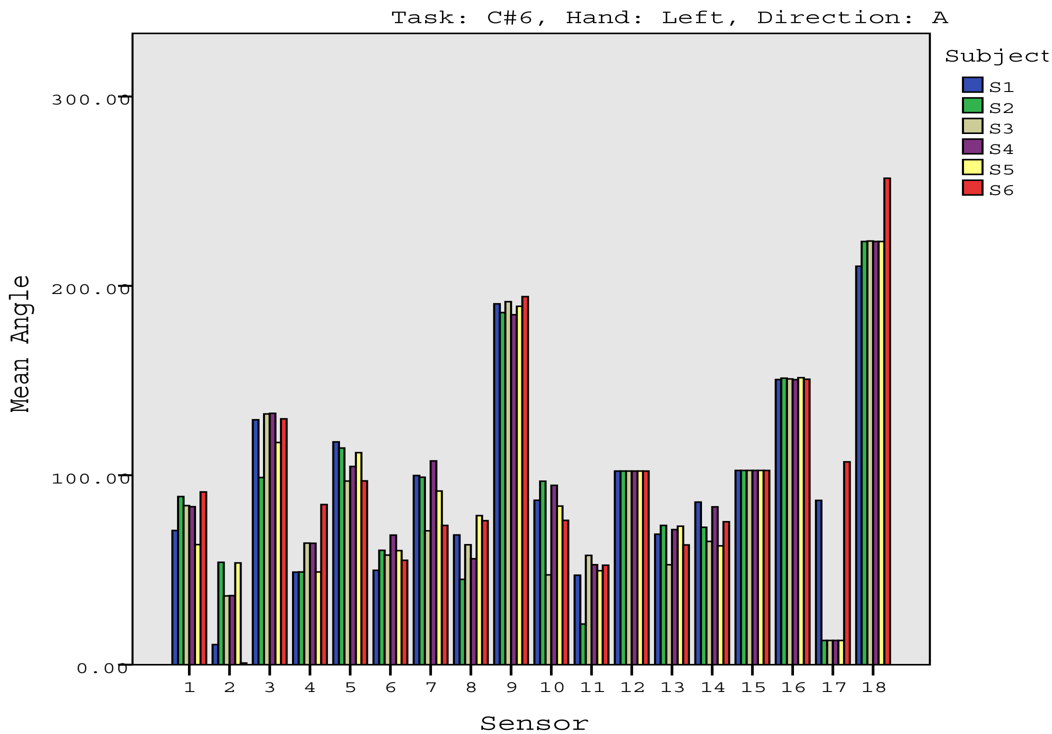



Figure 93. Ascending C#6 left hand

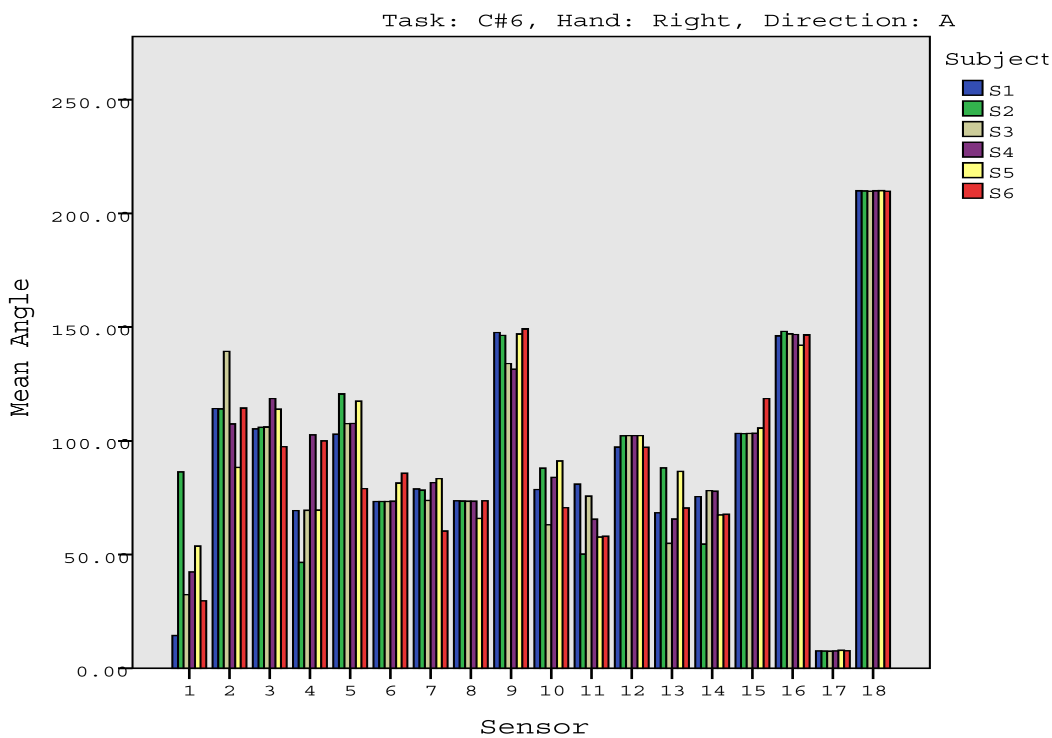



Figure 94. Ascending C#6 right hand

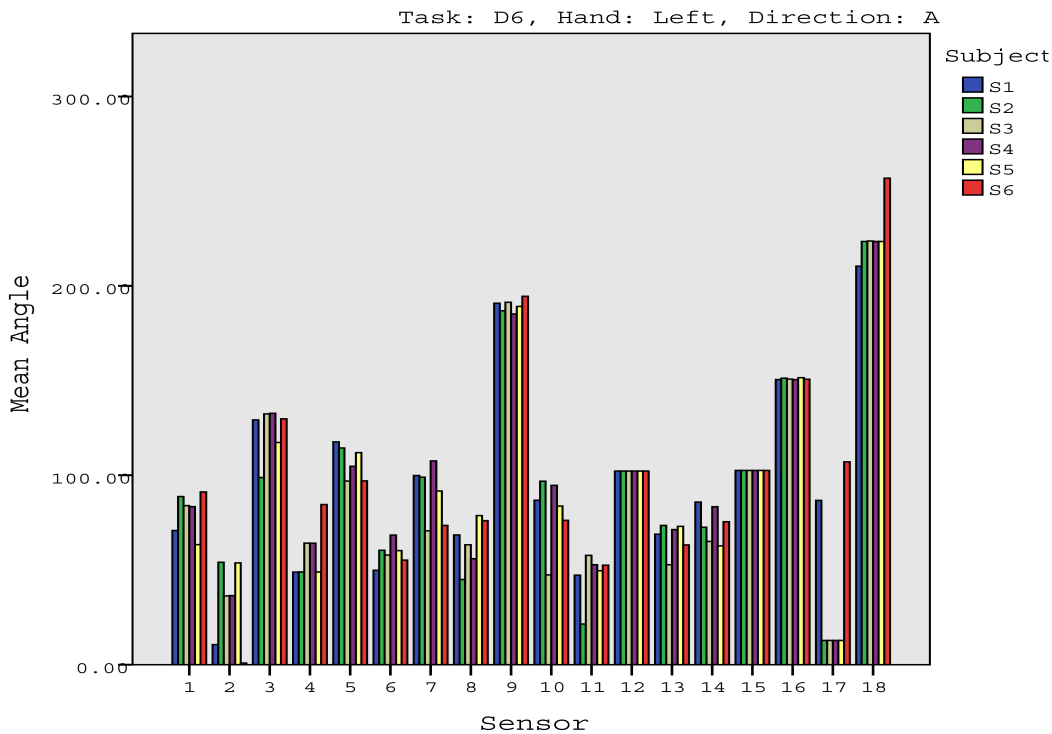



Figure 95. Ascending D6 left hand

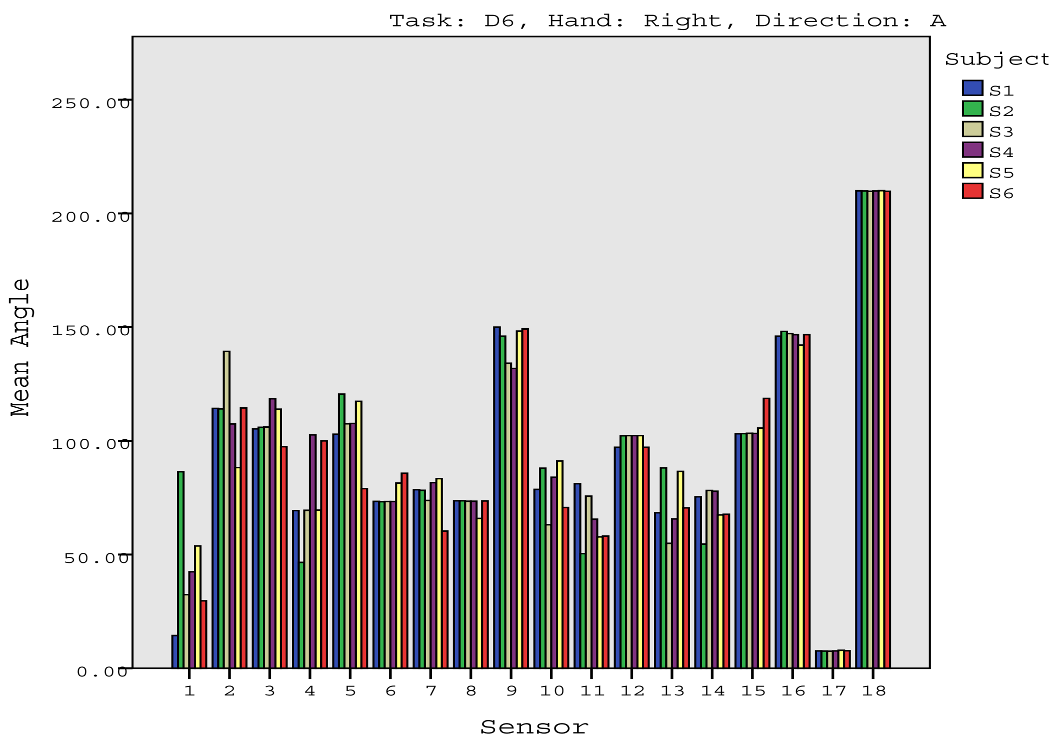



Figure 96. Ascending D6 right hand

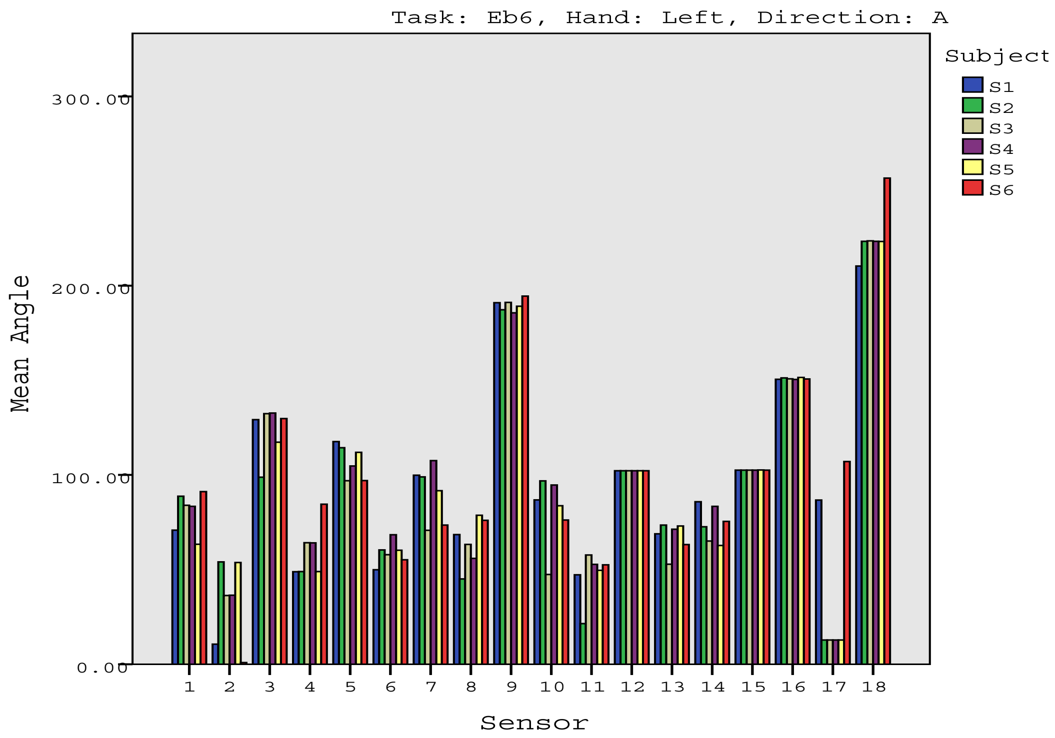



Figure 97. Ascending Eb6 left hand

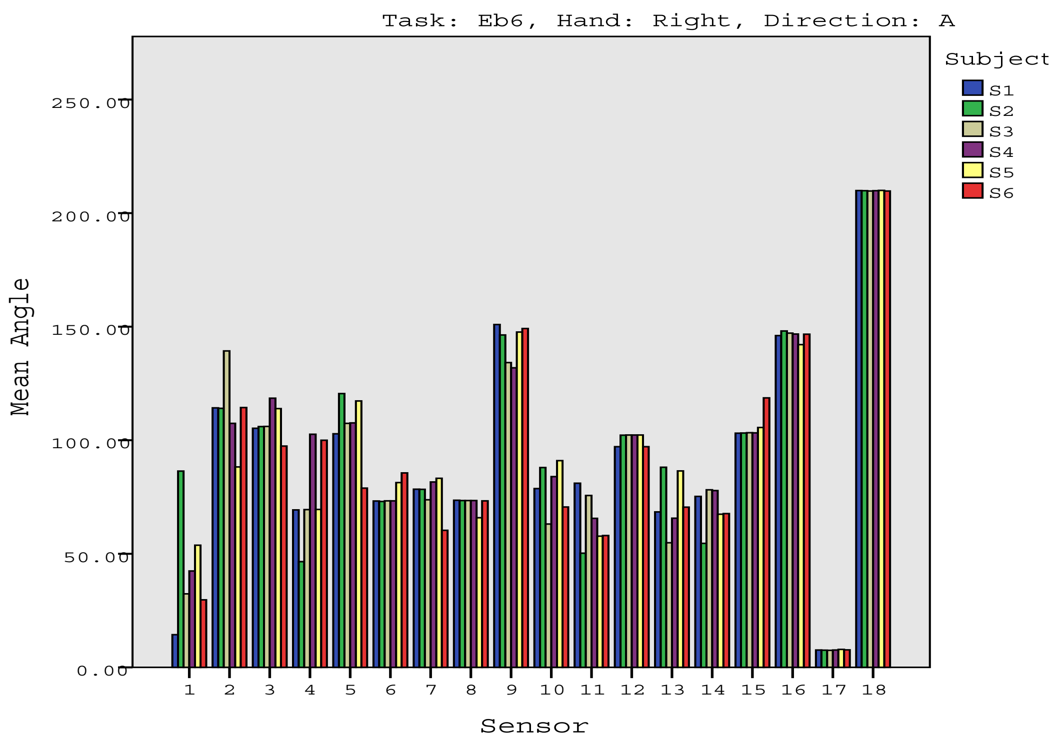



Figure 98. Ascending Eb6 right hand

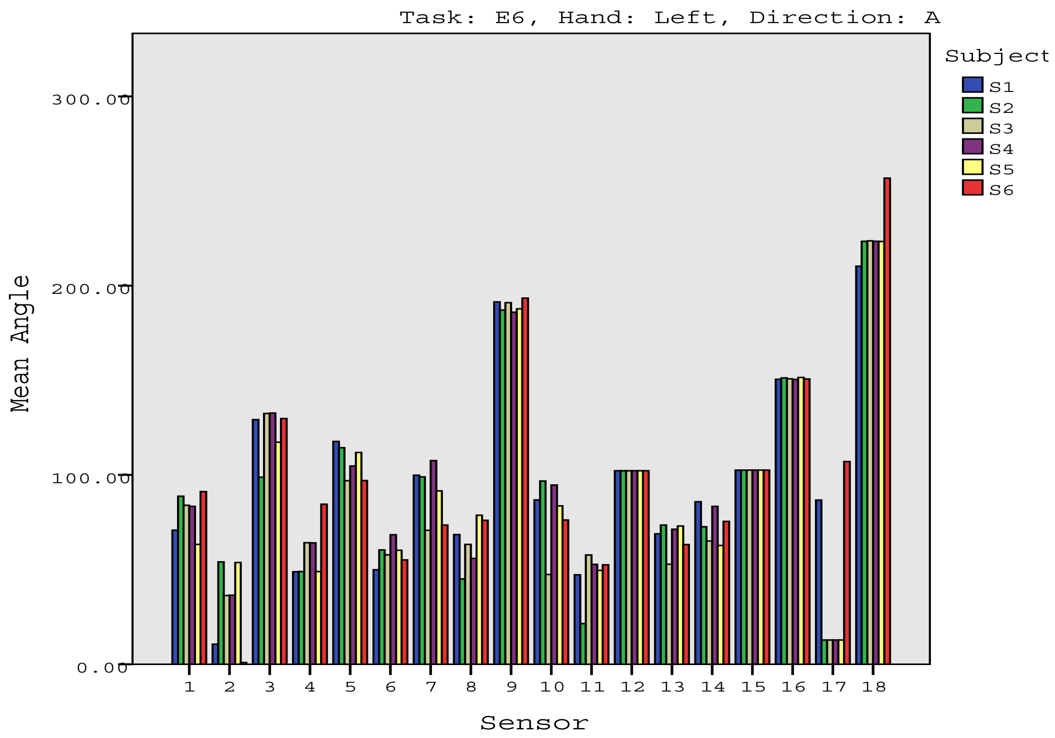



Figure 99. Ascending E6 left hand

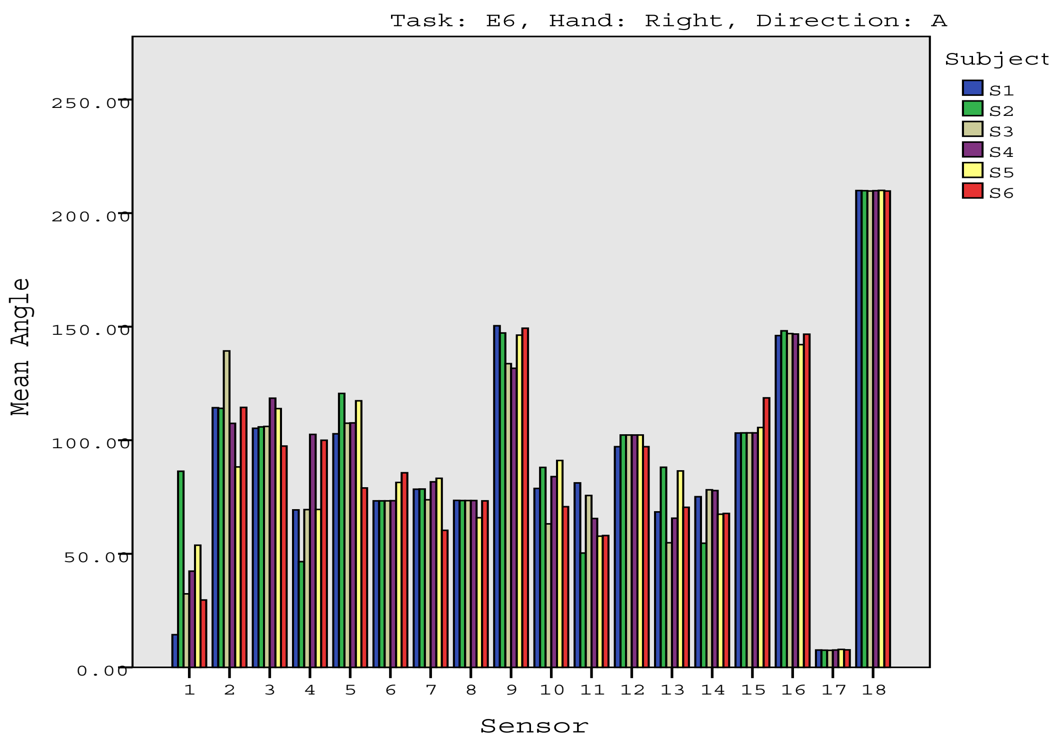



Figure 100. Ascending E6 right hand

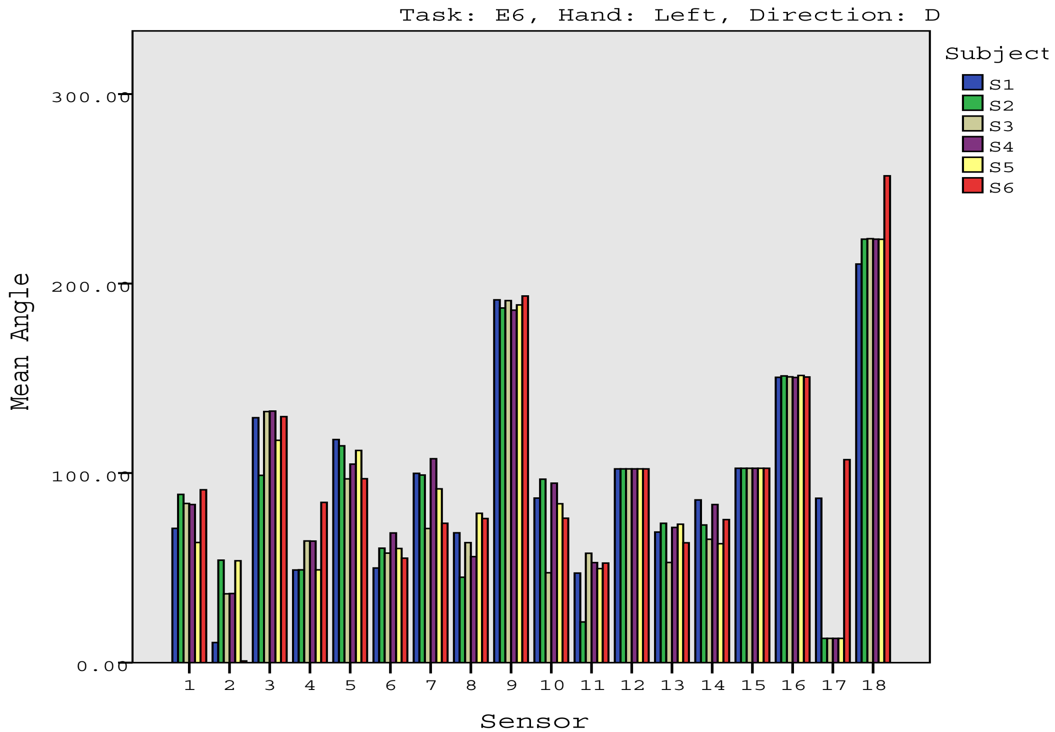



Figure 101. Descending E6 left hand

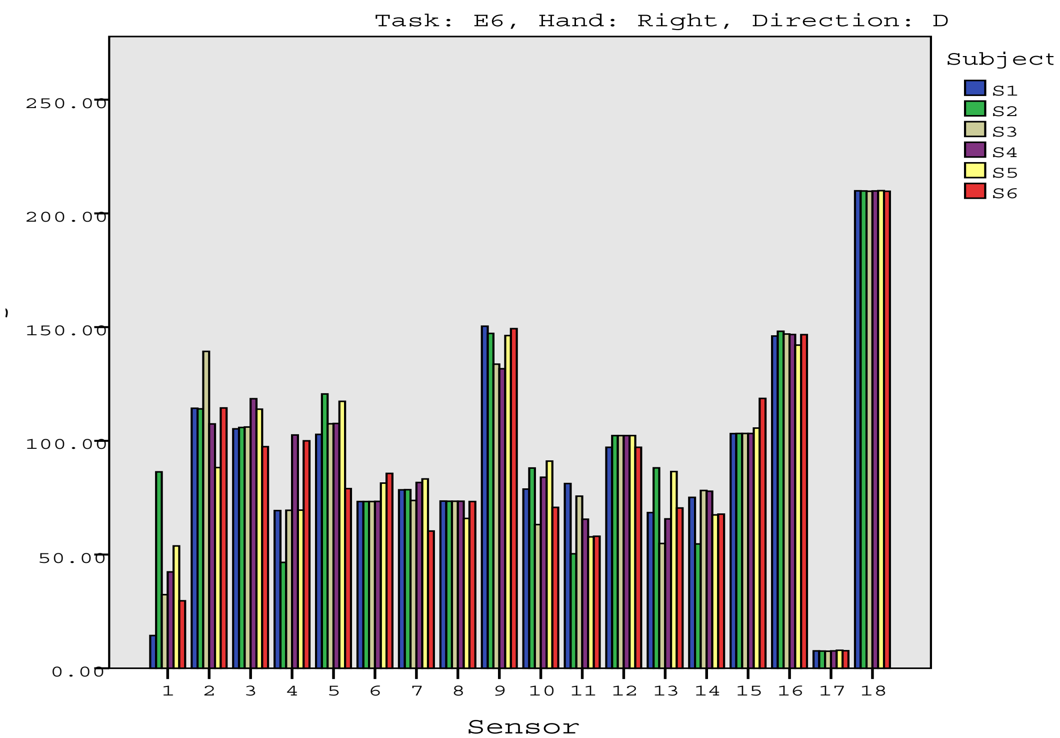



Figure 102. Descending E6 right hand

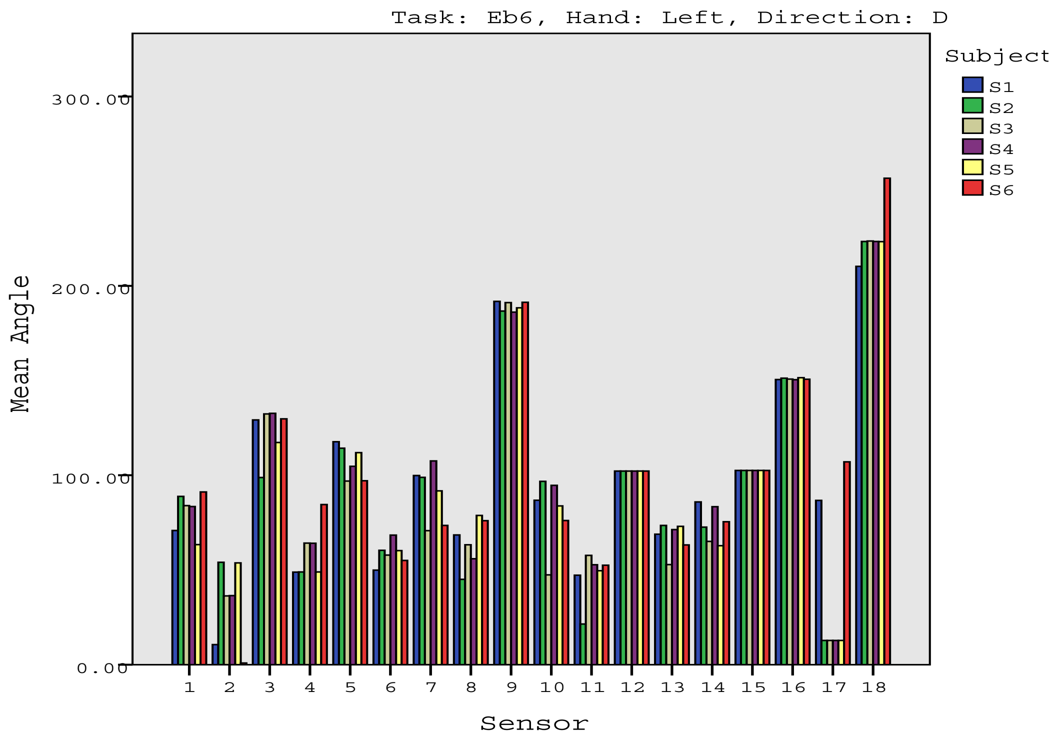



Figure 103. Descending Eb6 left hand

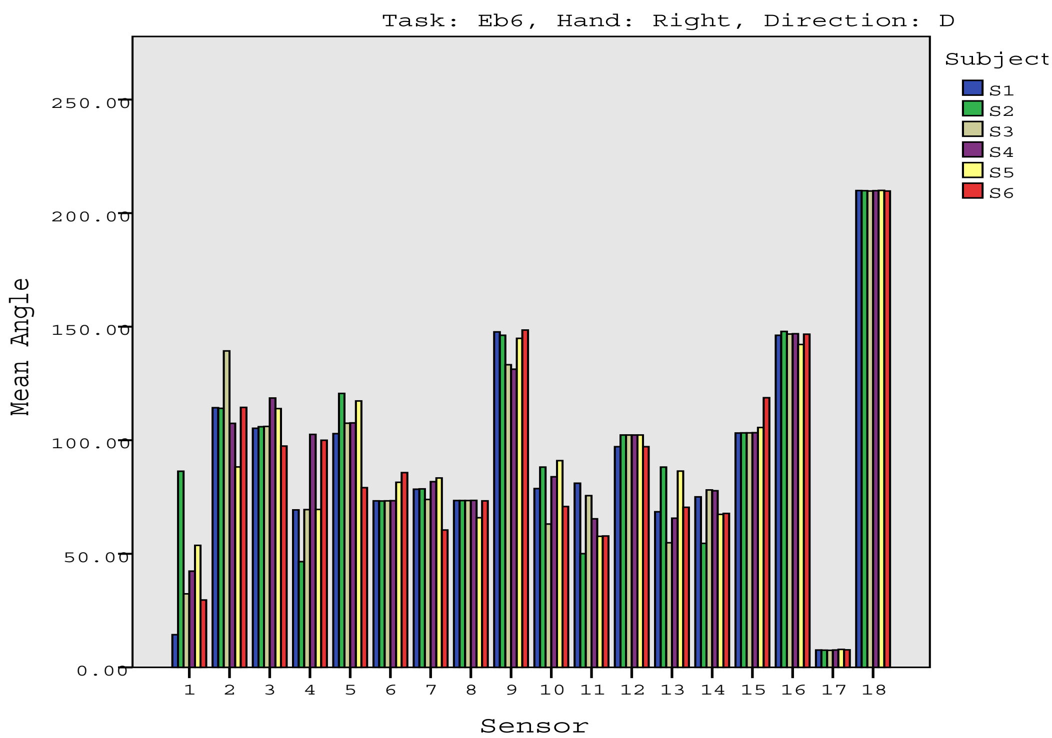



Figure 104. Descending Eb6 right hand

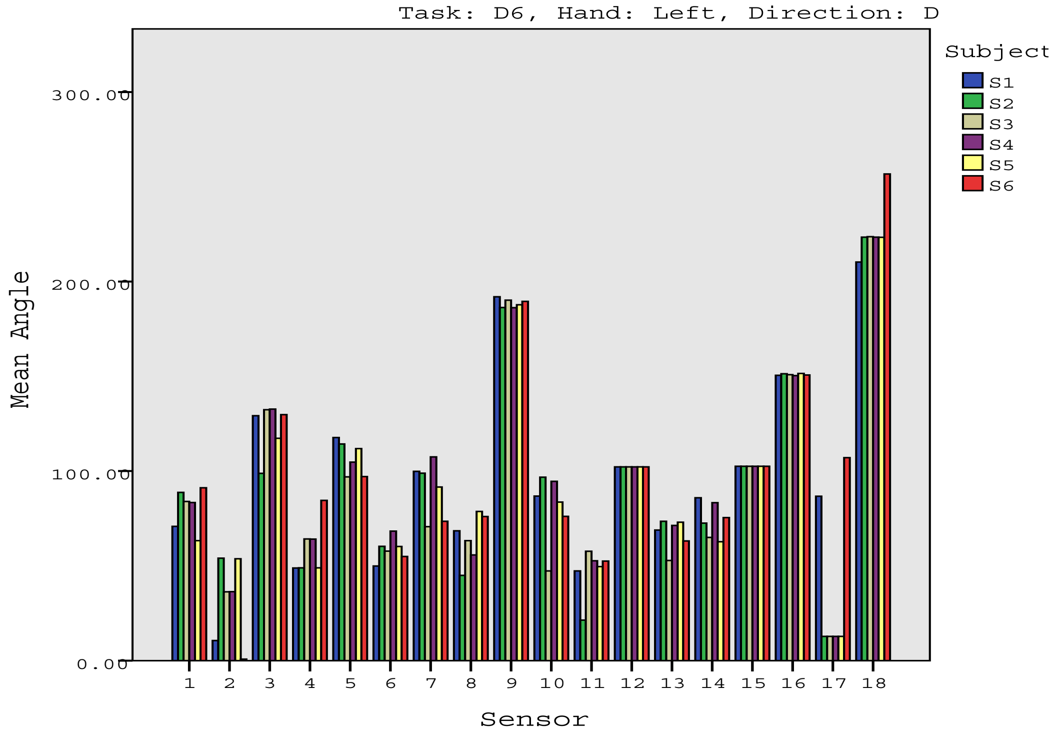



Figure 105. Descending D6 left hand

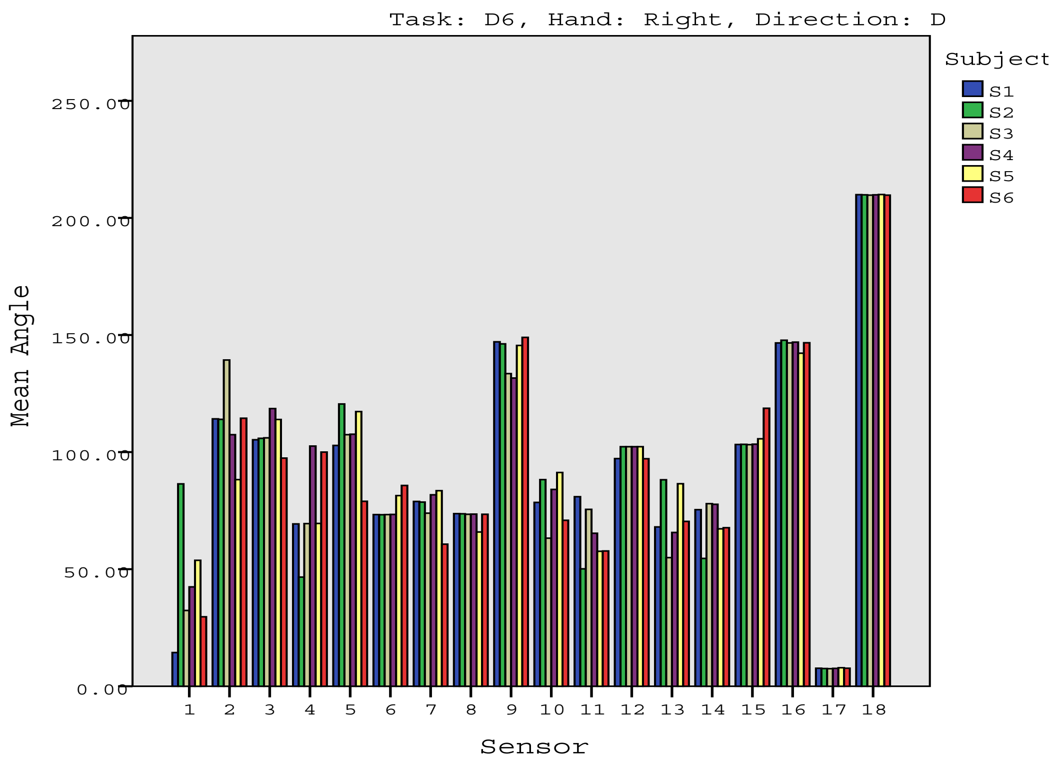



Figure 106. Descending D6 right hand

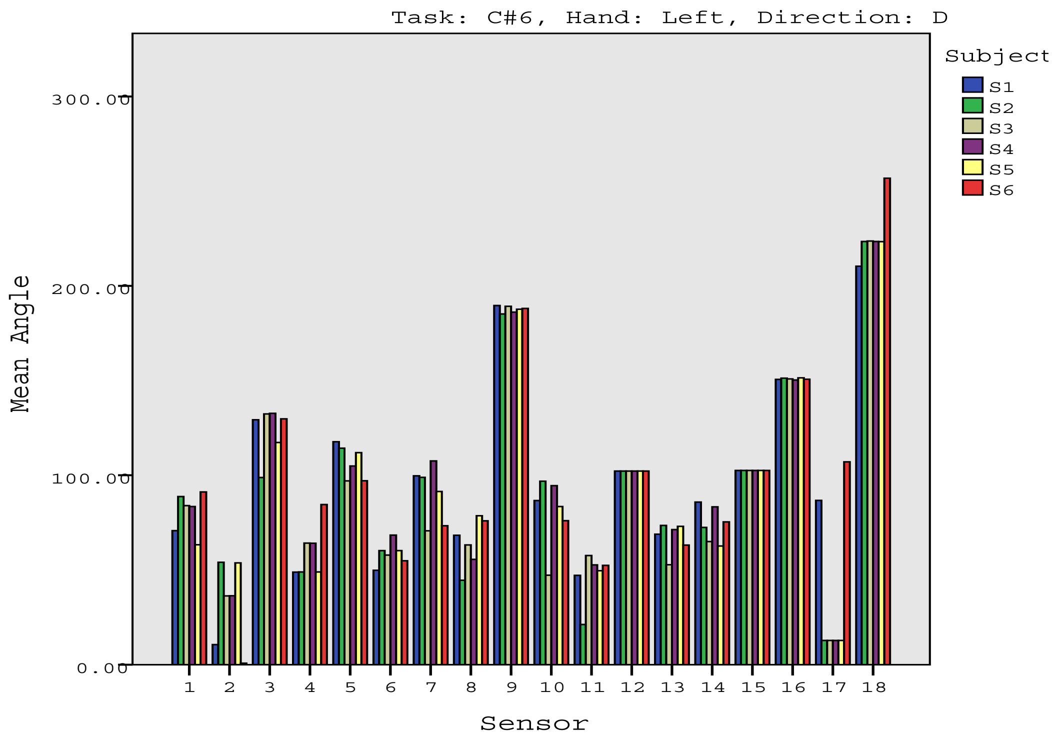



Figure 107. Descending C#6 left hand

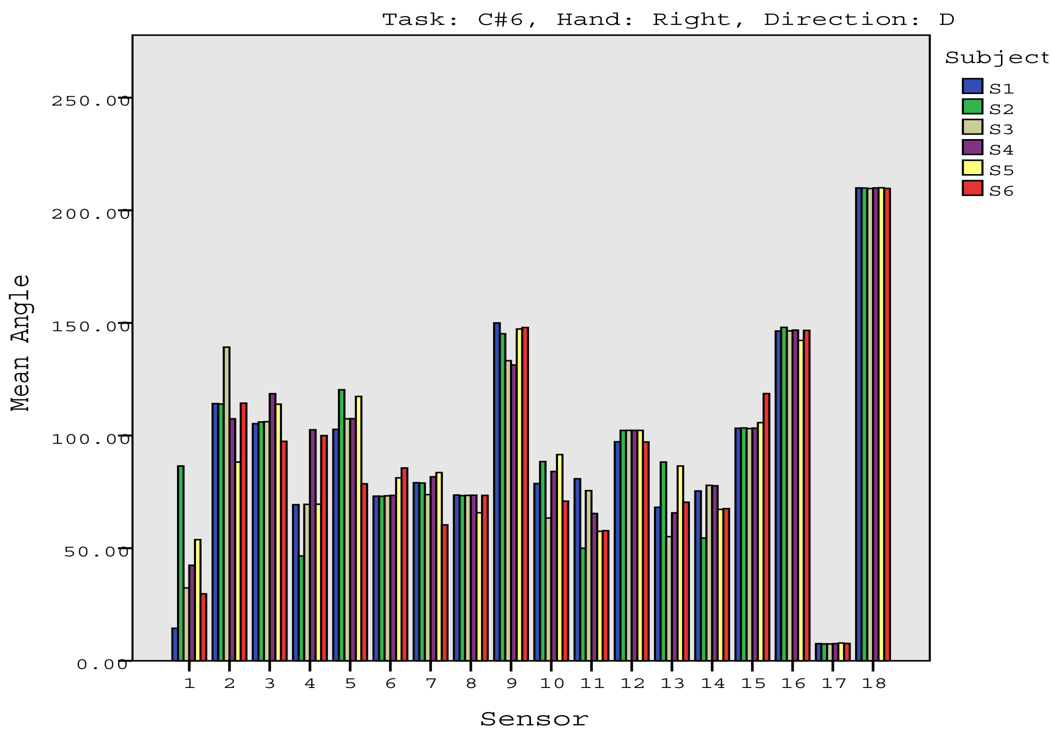



Figure 108. Descending C#6 right hand

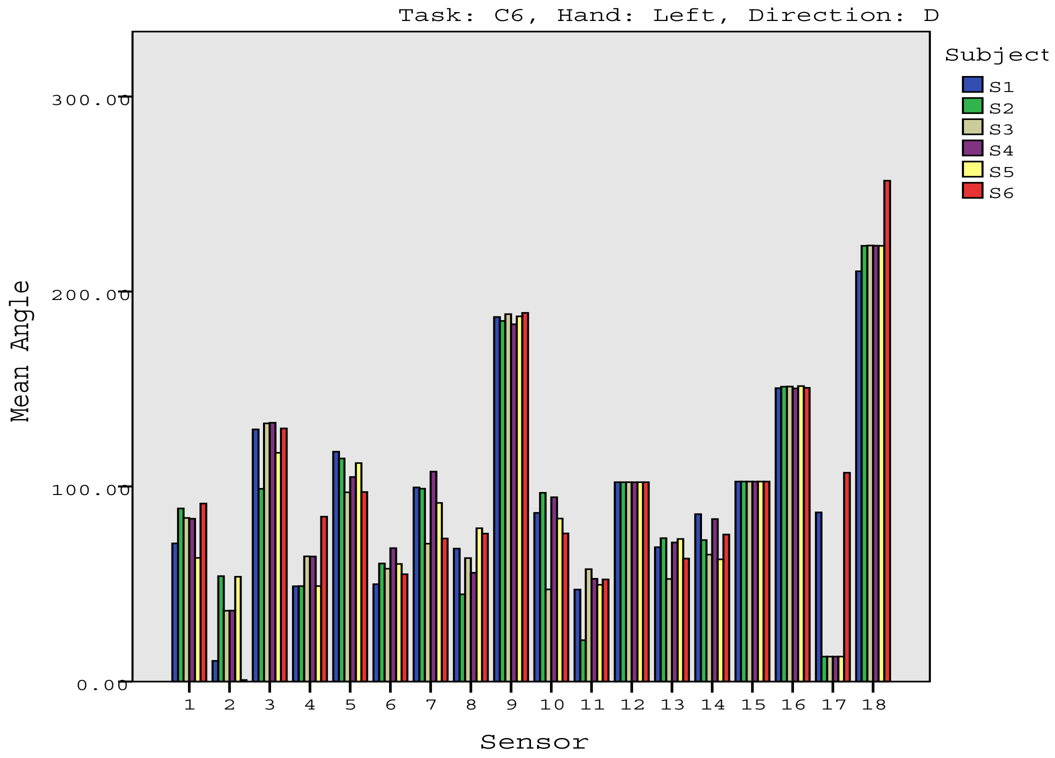



Figure 109. Descending C6 left hand

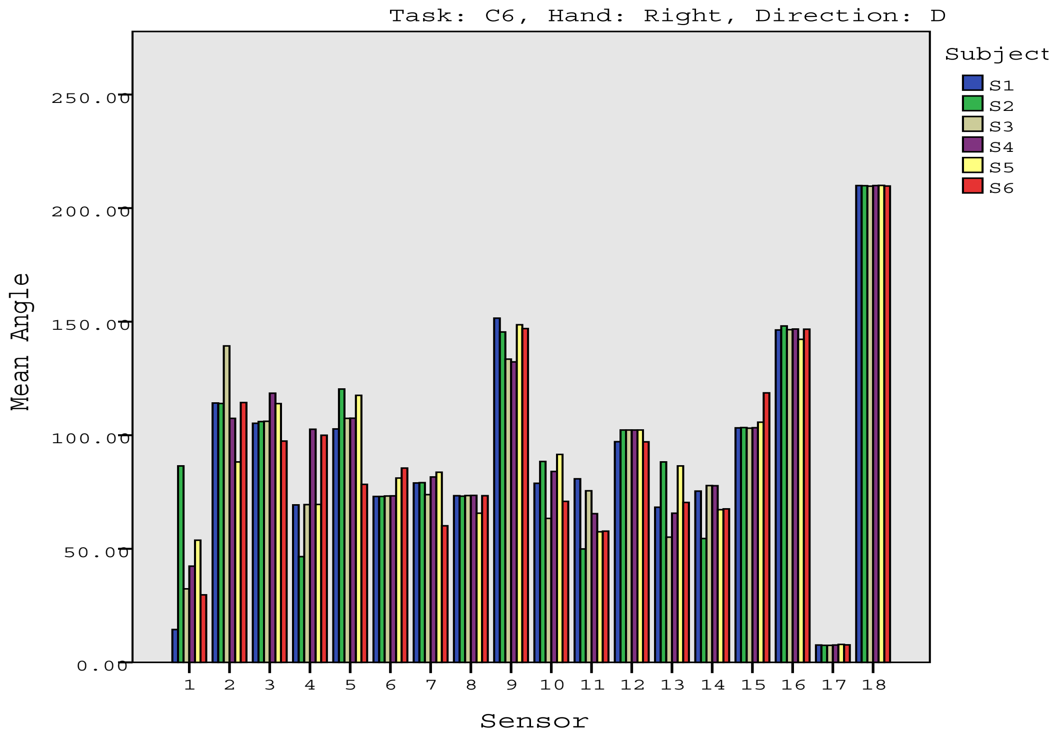



Figure 110. Descending C6 right hand

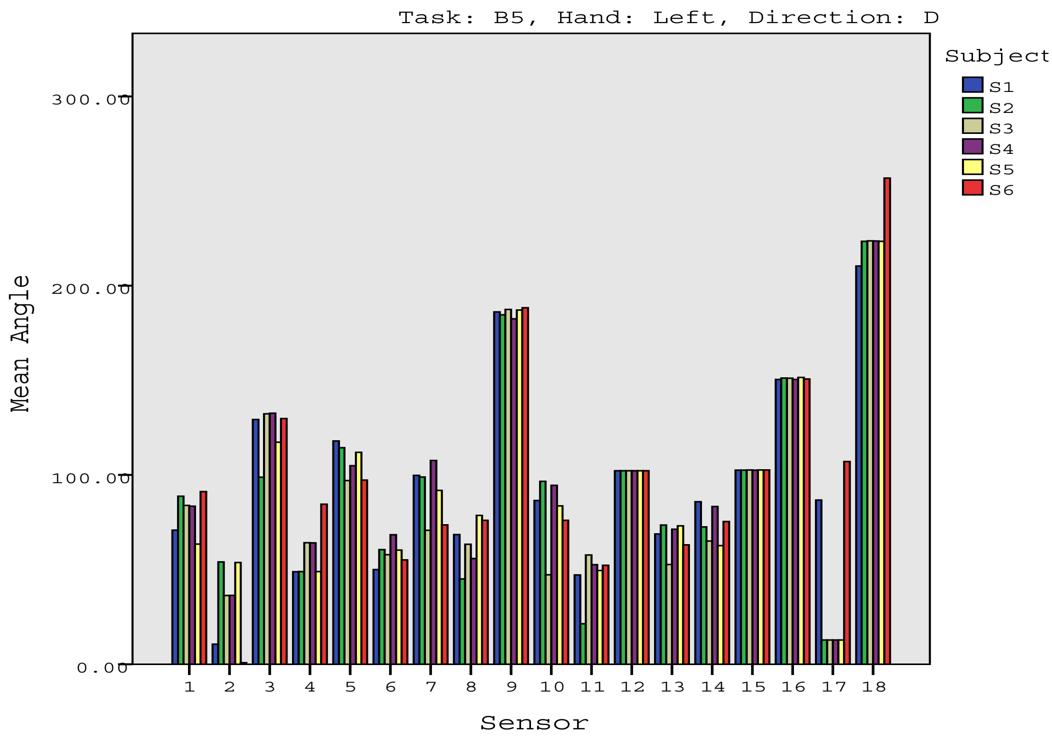



Figure 111. Descending B5 left hand

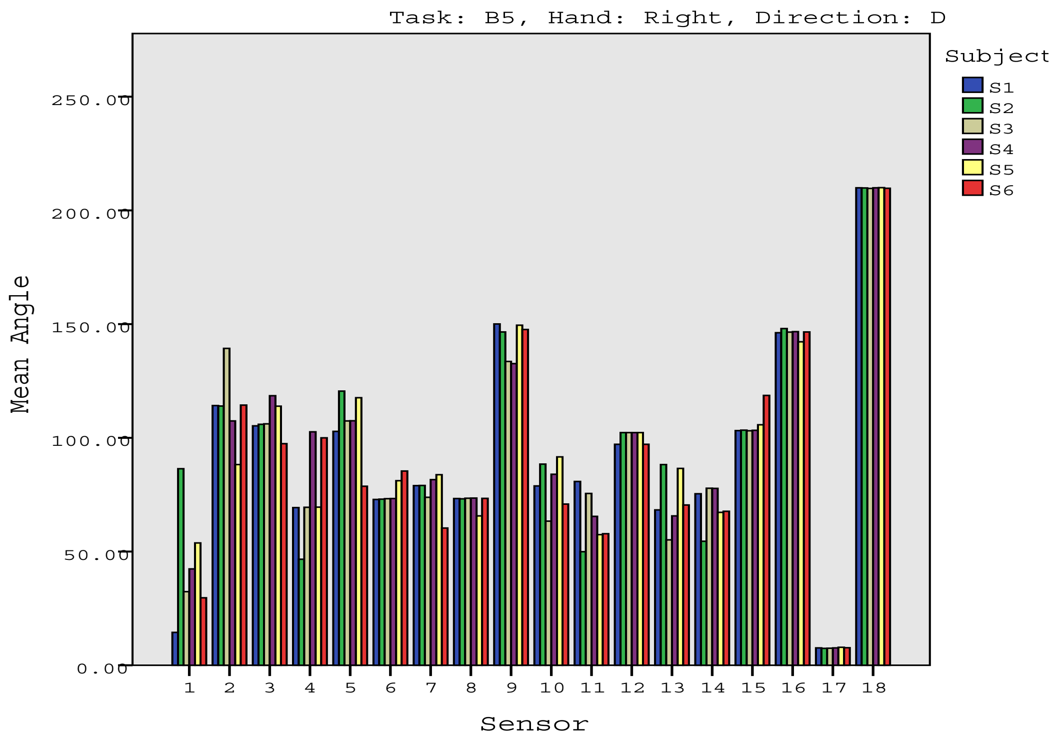



Figure 112. Descending B5 right hand

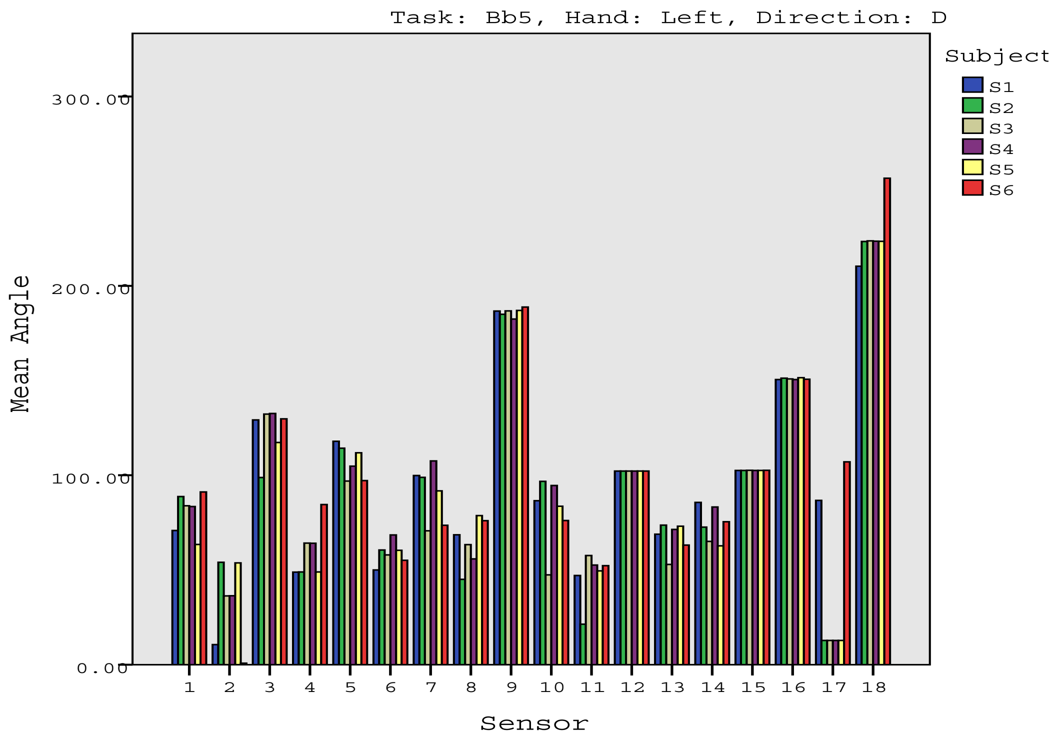



Figure 113. Descending Bb5 left hand

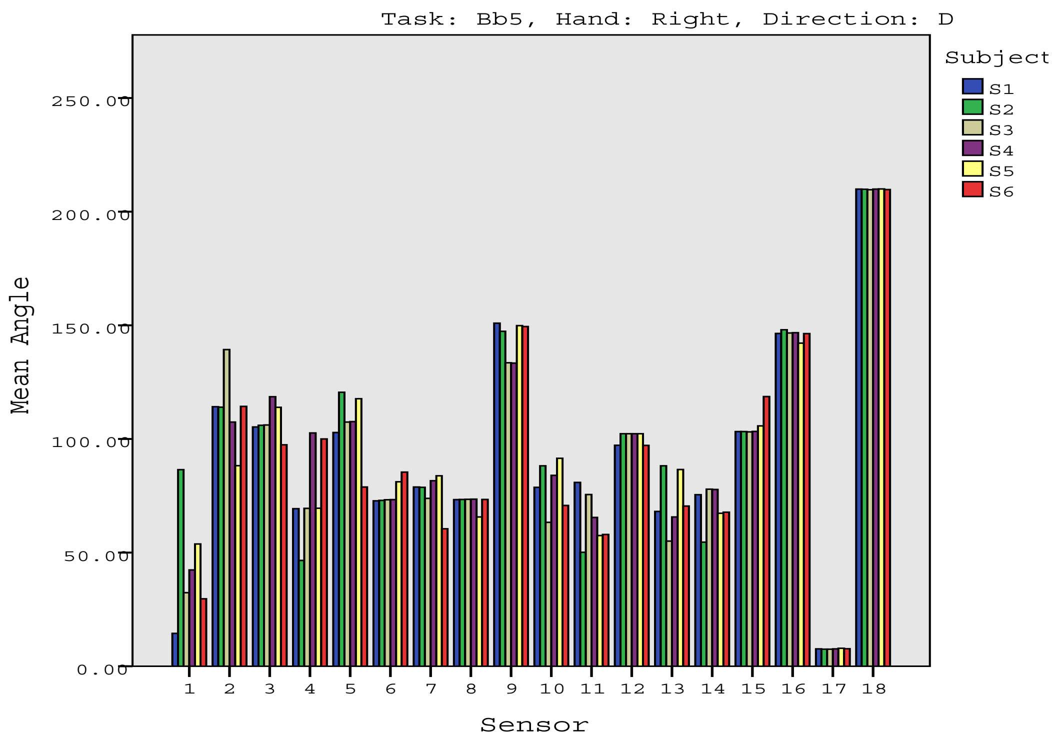



Figure 114. Descending Bb5 right hand

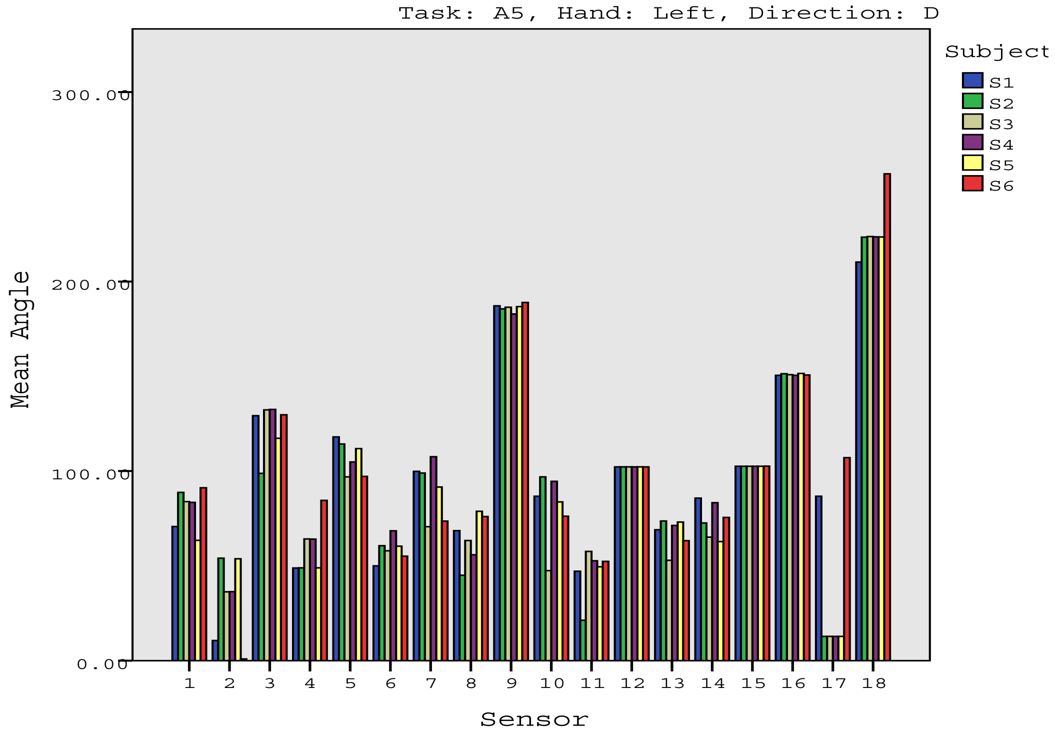



Figure 115. Descending A5 left hand

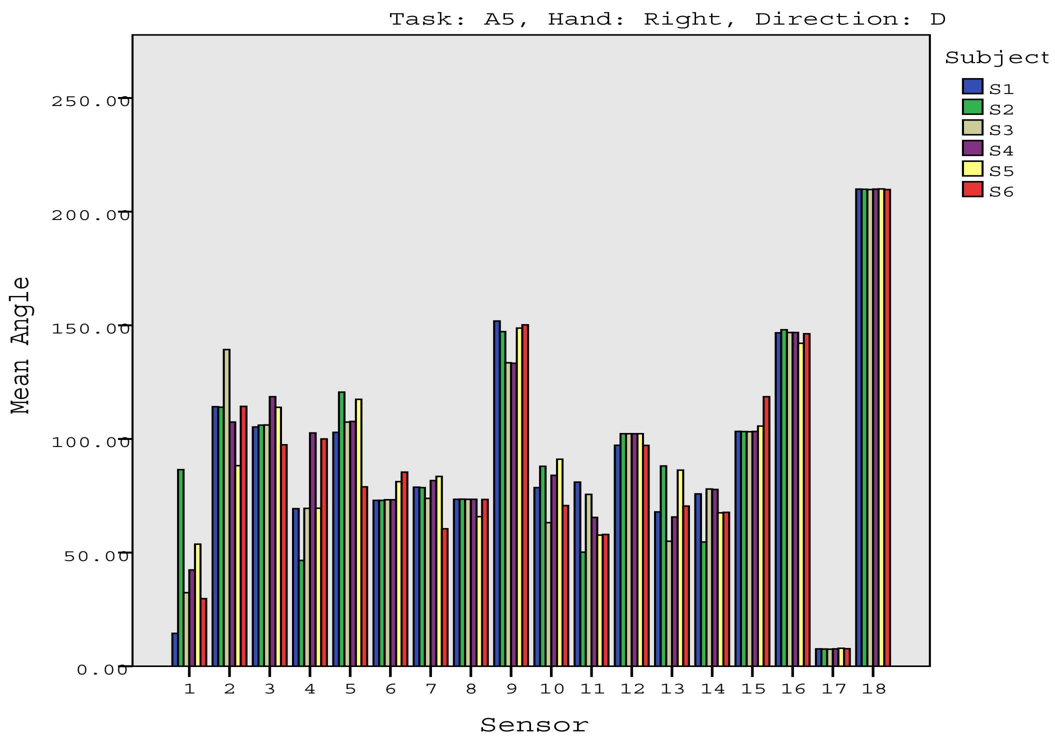



Figure 116. Descending A5 right hand

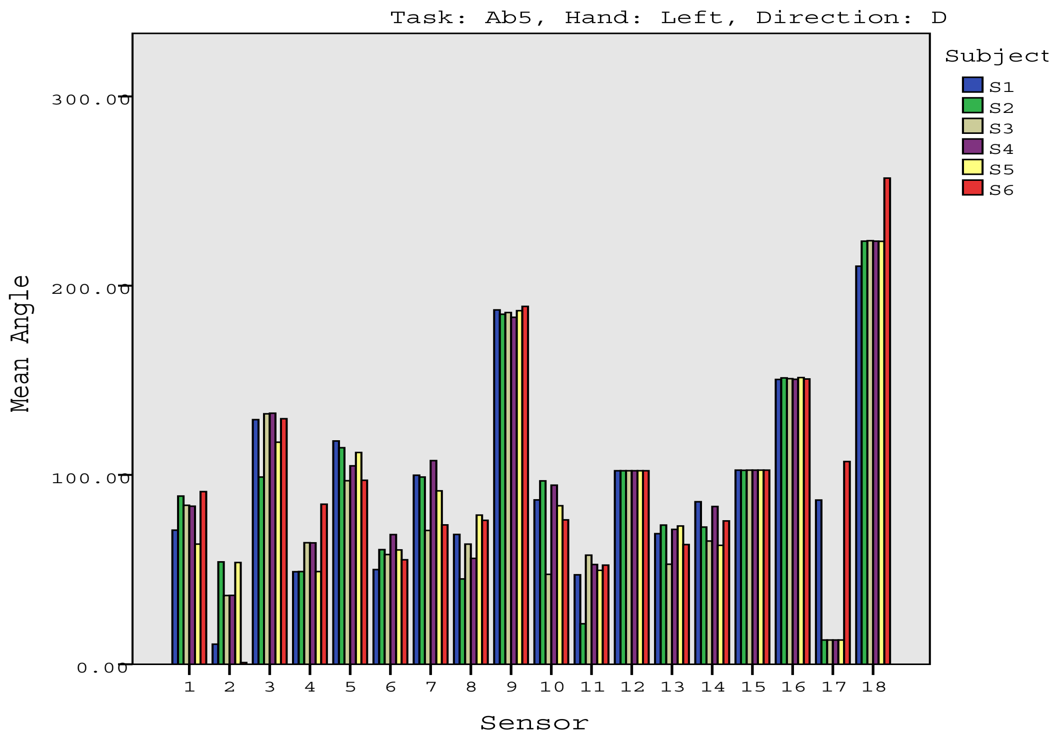



Figure 117. Descending Ab5 left hand

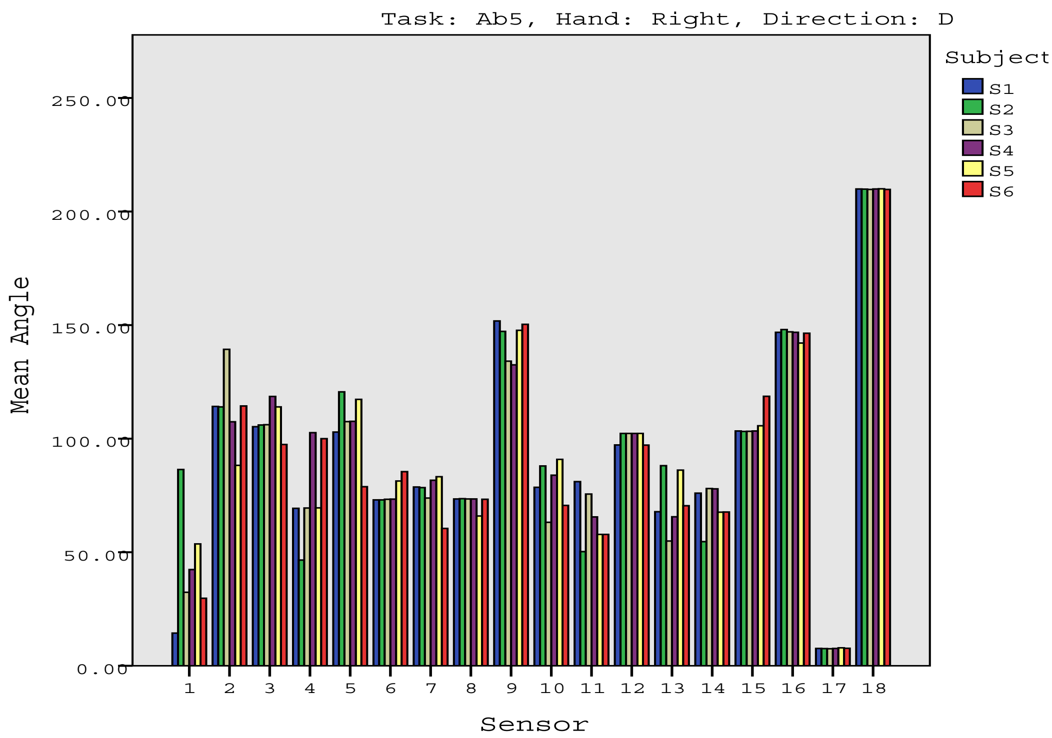



Figure 118. Descending Ab5 right hand

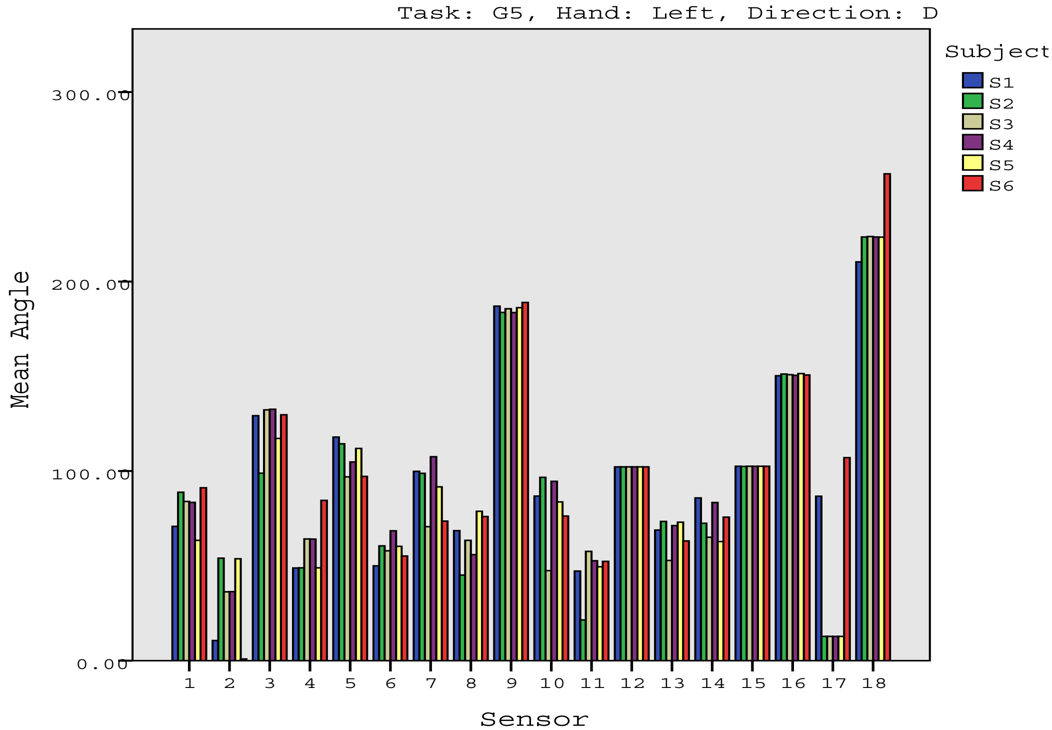



Figure 119. Descending G5 left hand

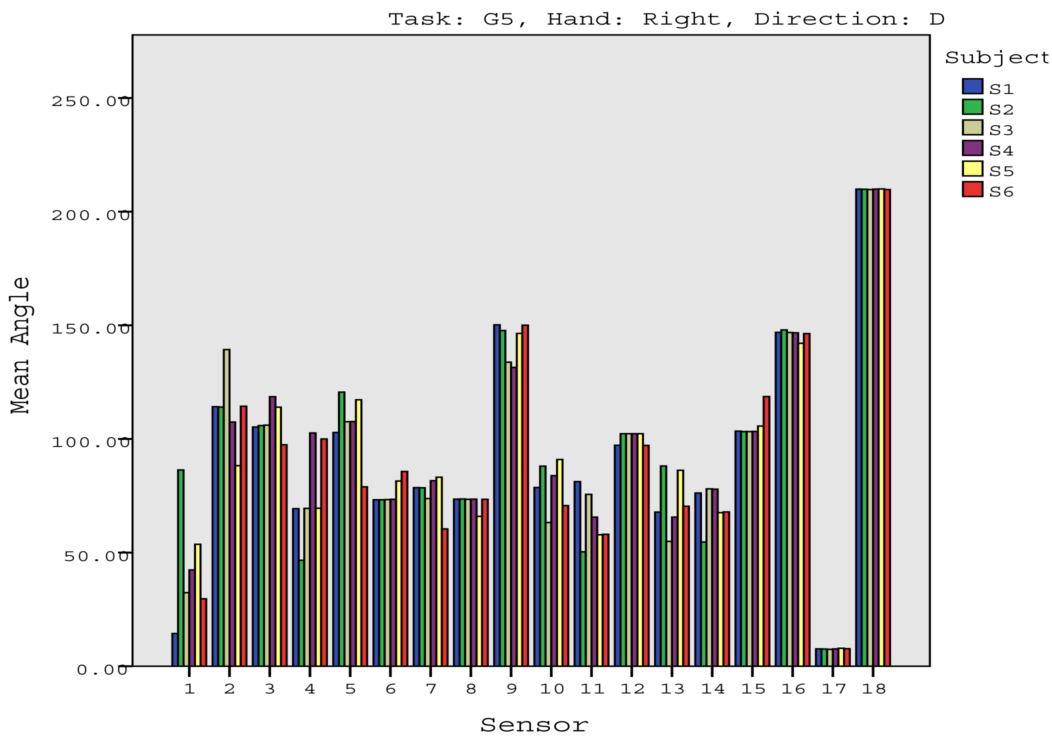



Figure 120. Descending G5 right hand

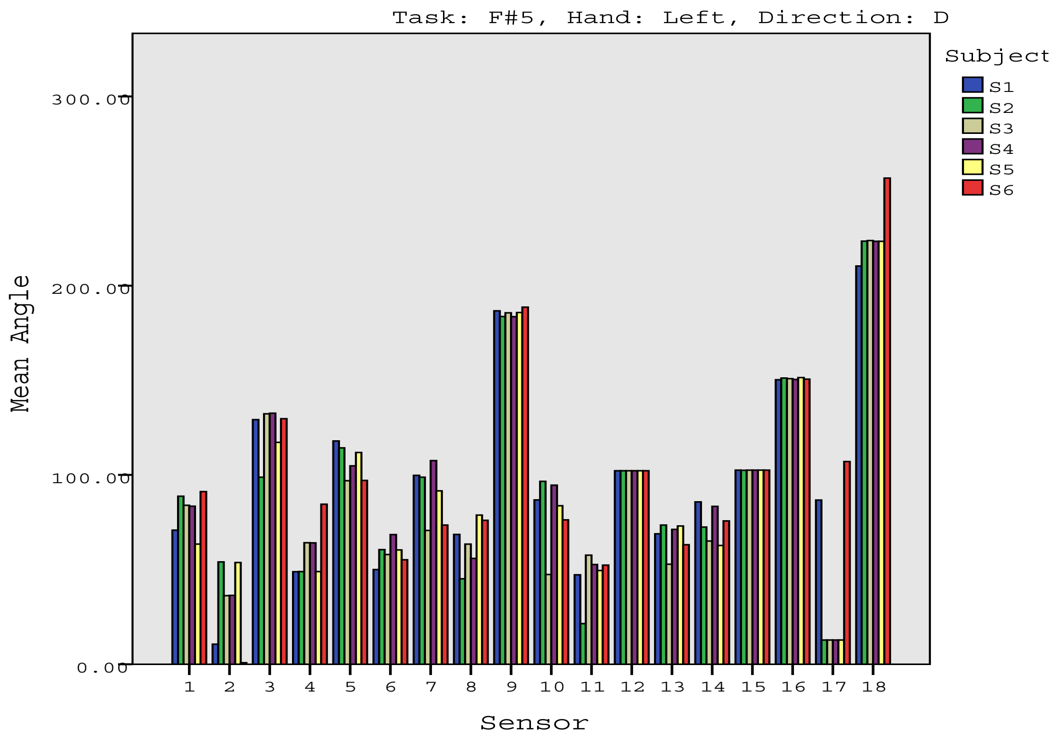



Figure 121. Descending F#5 left hand

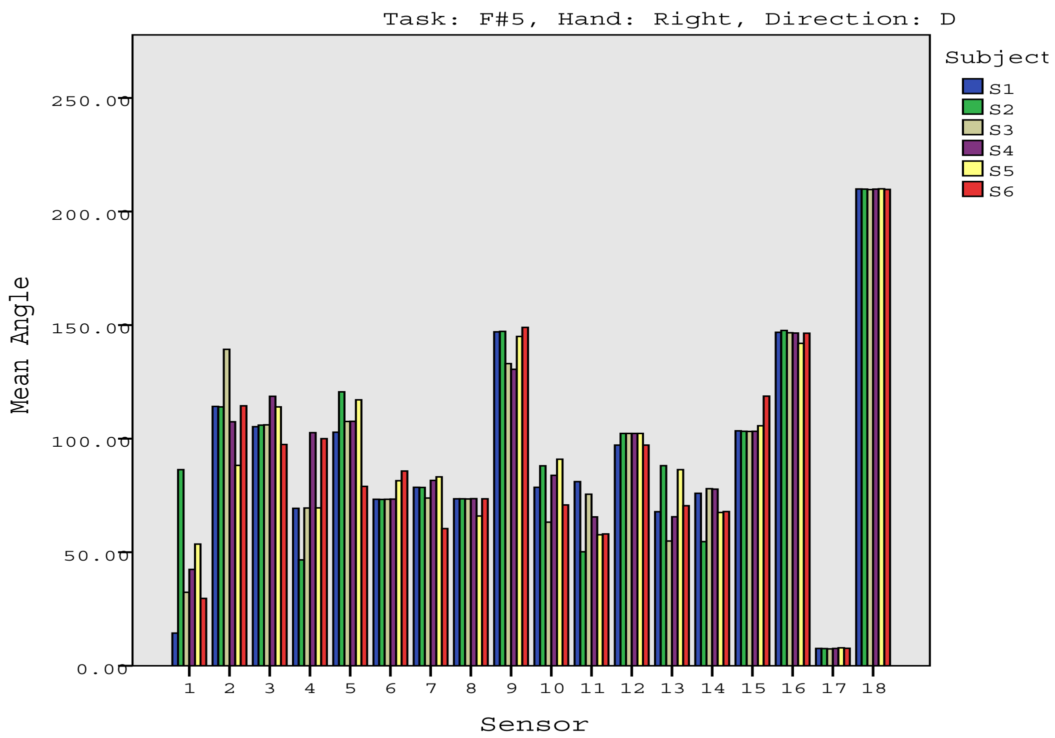



Figure 122. Descending F#5 right hand

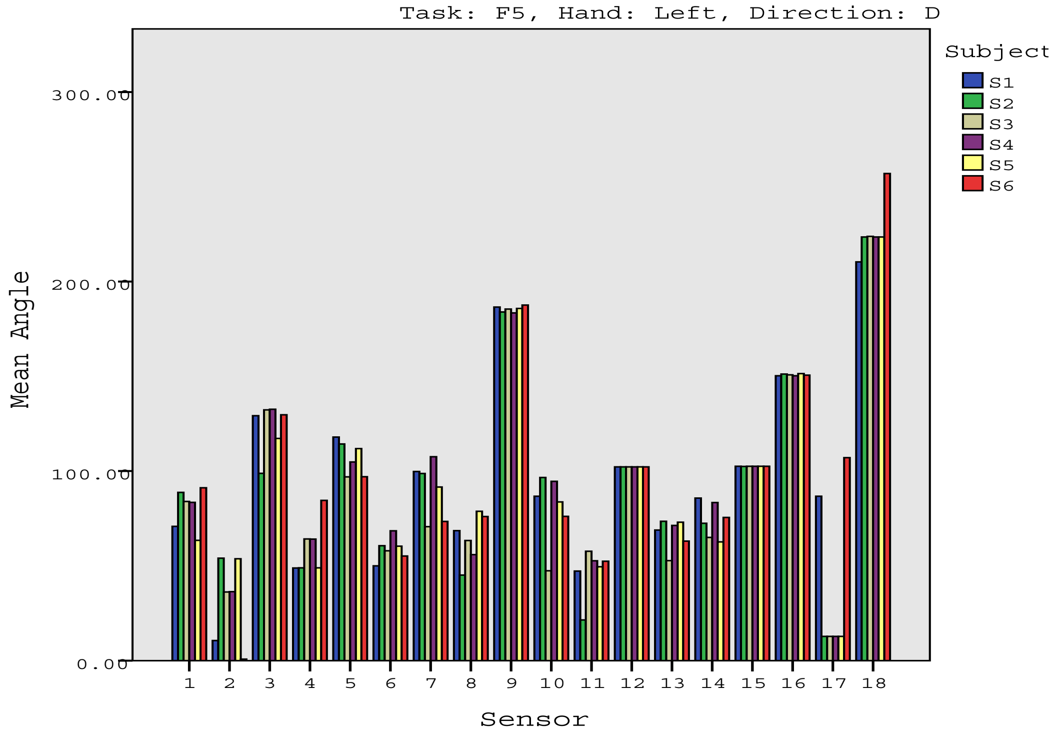



Figure 123. Descending F5 left hand

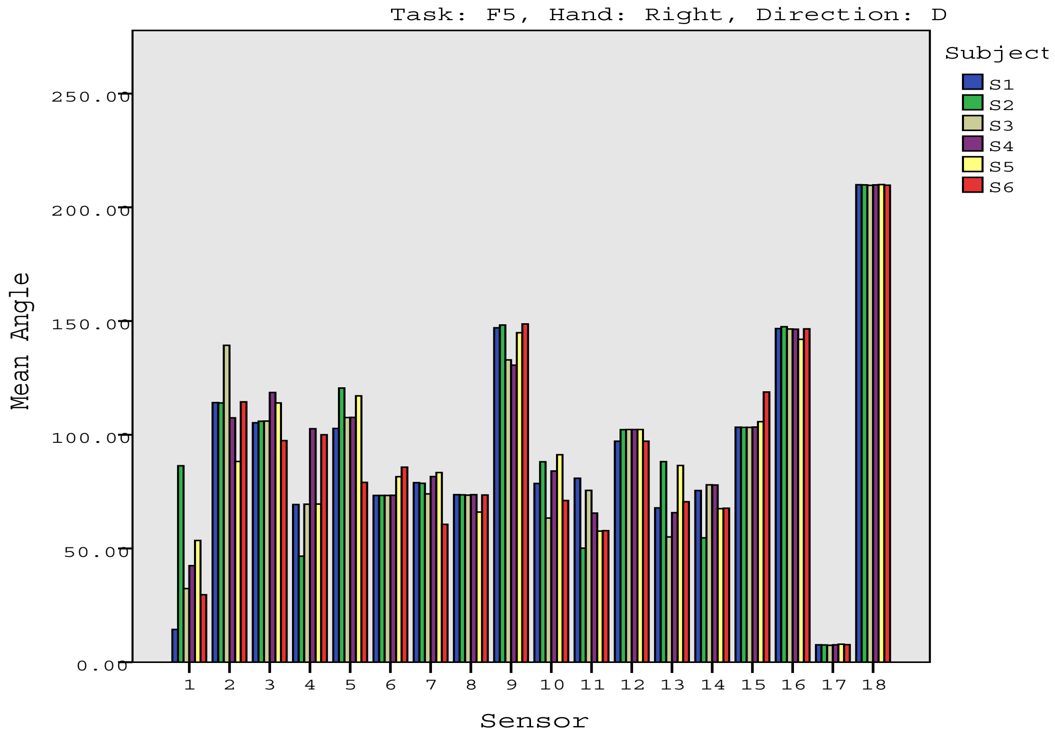



Figure 124. Descending F5 right hand

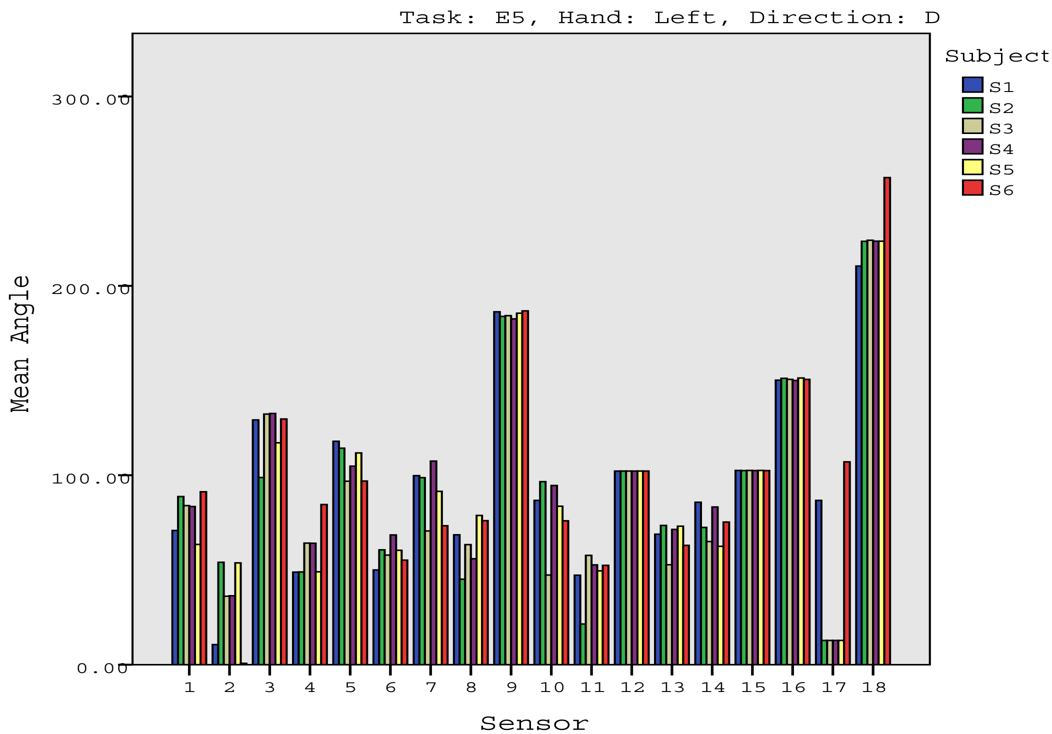



Figure 125. Descending E5 left hand

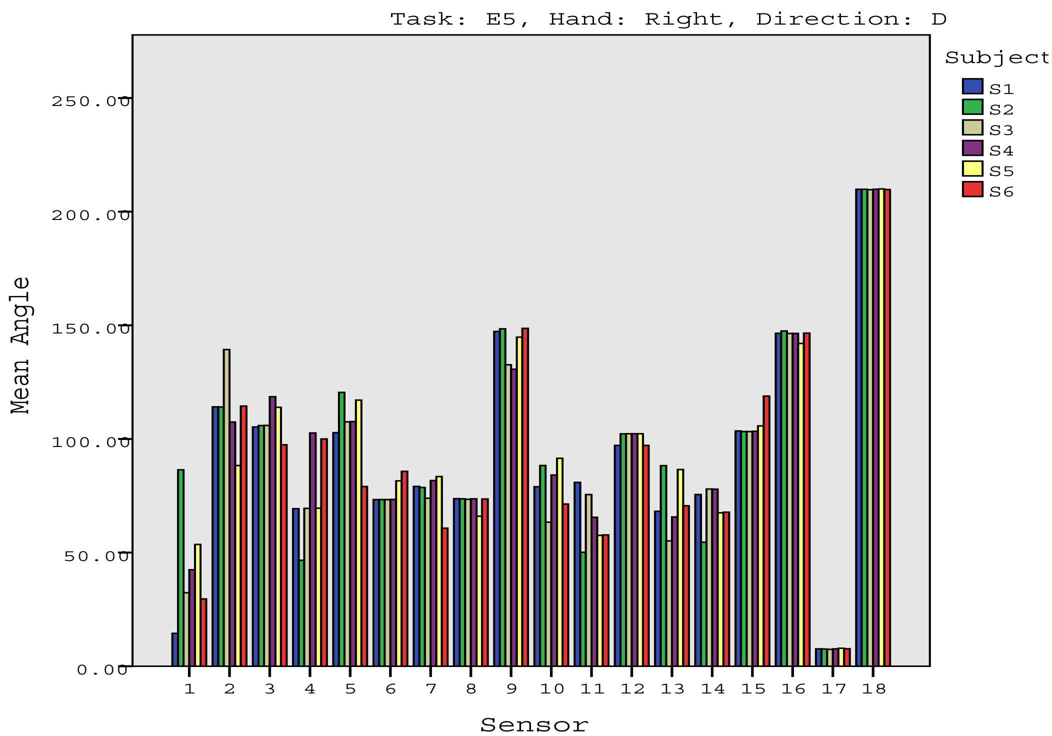



Figure 126. Descending E5 right hand

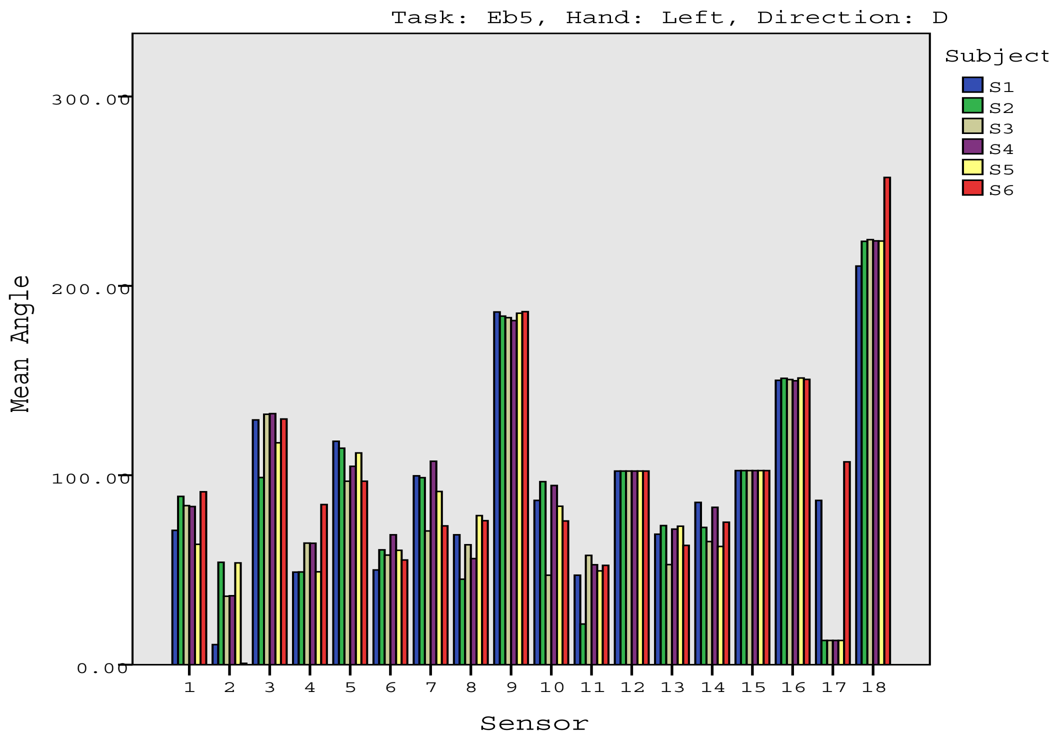



Figure 127. Descending Eb5 left hand

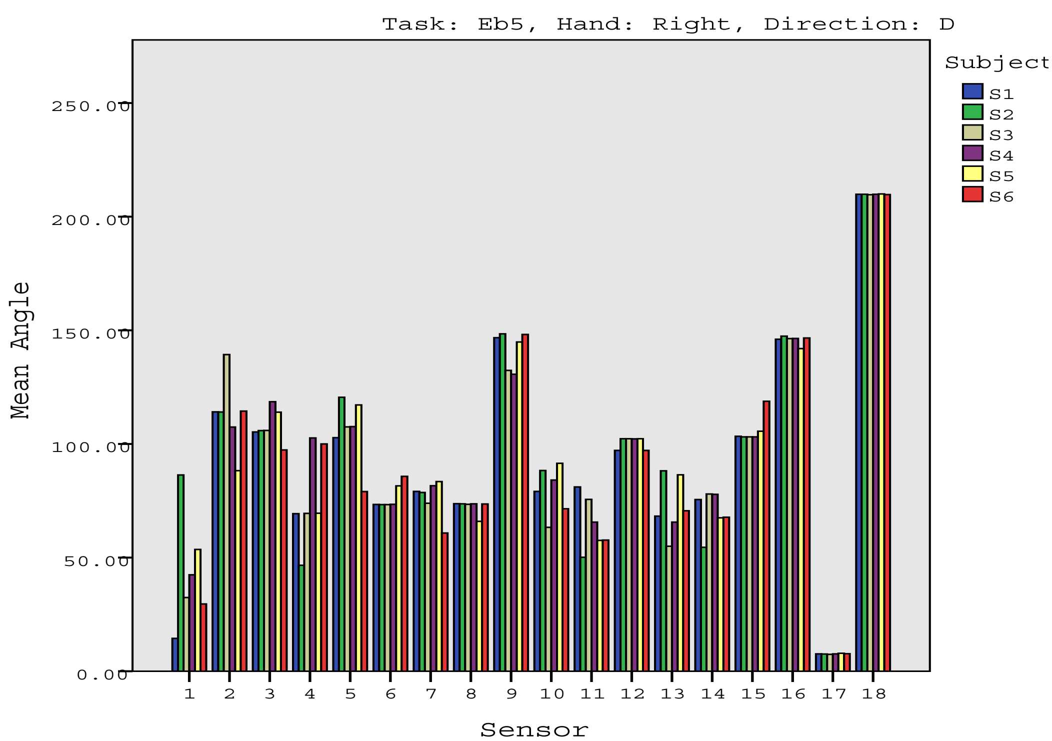



Figure 128. Descending Eb5 right hand

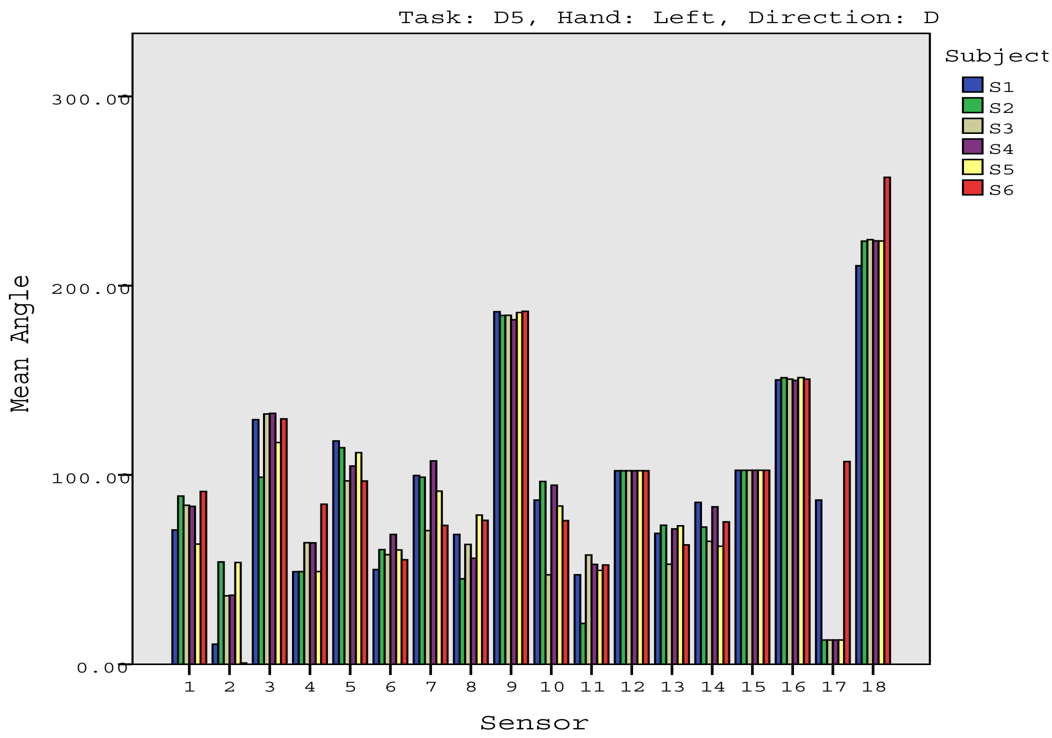



Figure 128. Descending D5 left hand

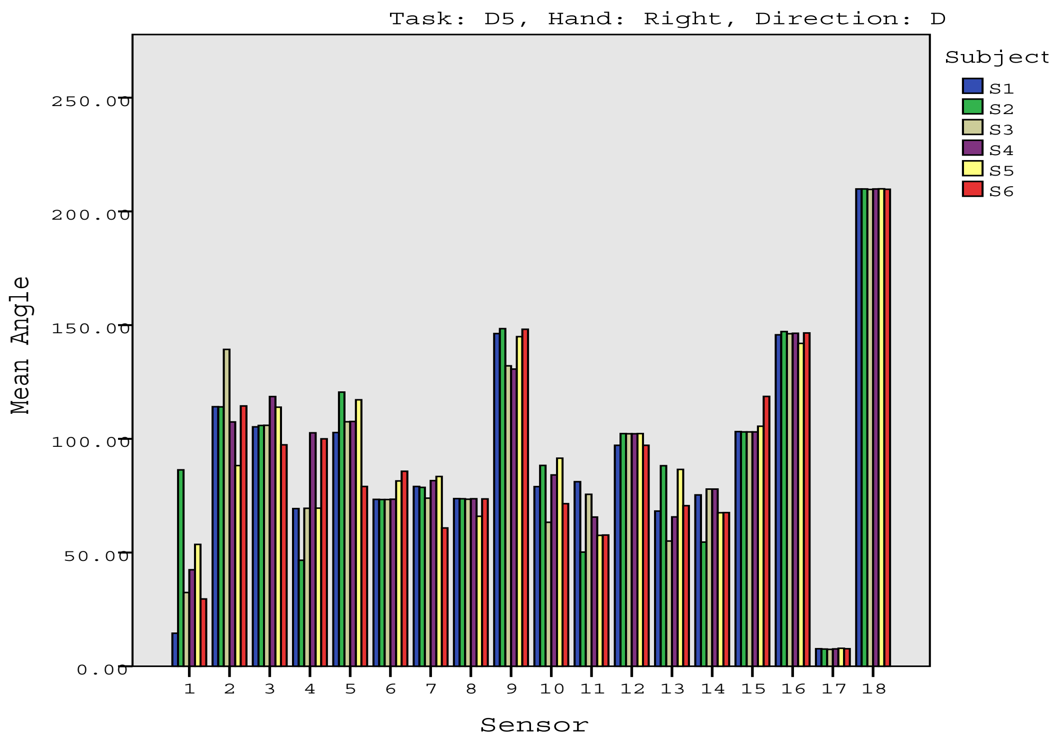



Figure 129. Descending D5 right hand

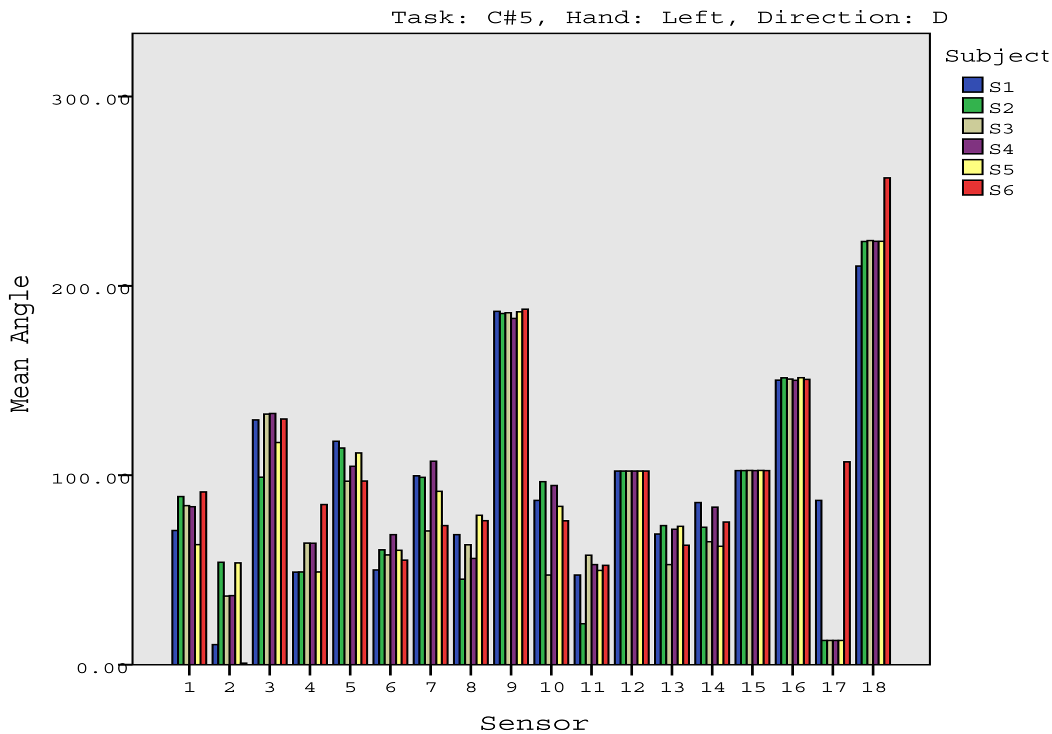



Figure 130. Descending C#5 left hand

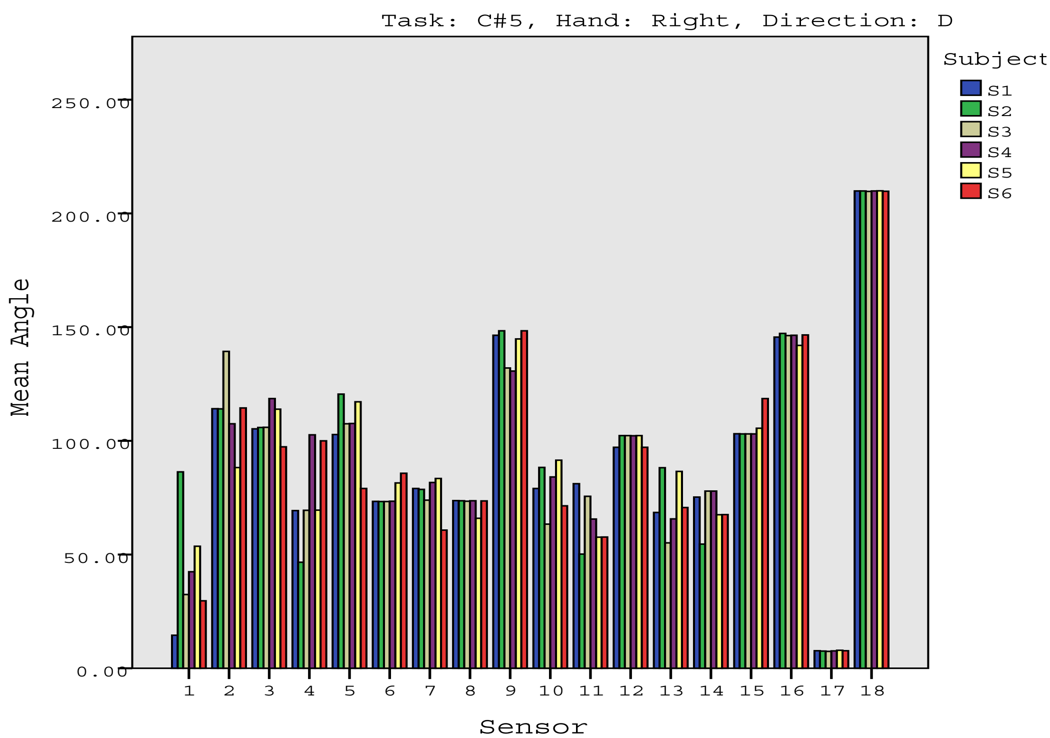



Figure 131. Descending C#5 right hand

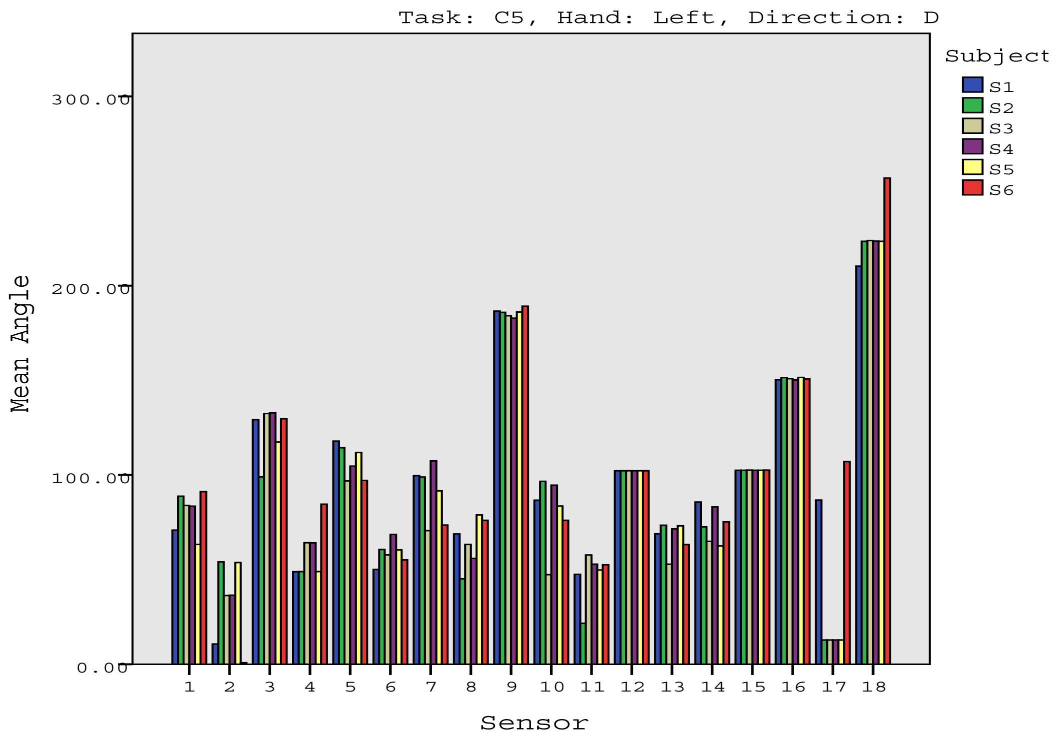



Figure 132. Descending C5 left hand

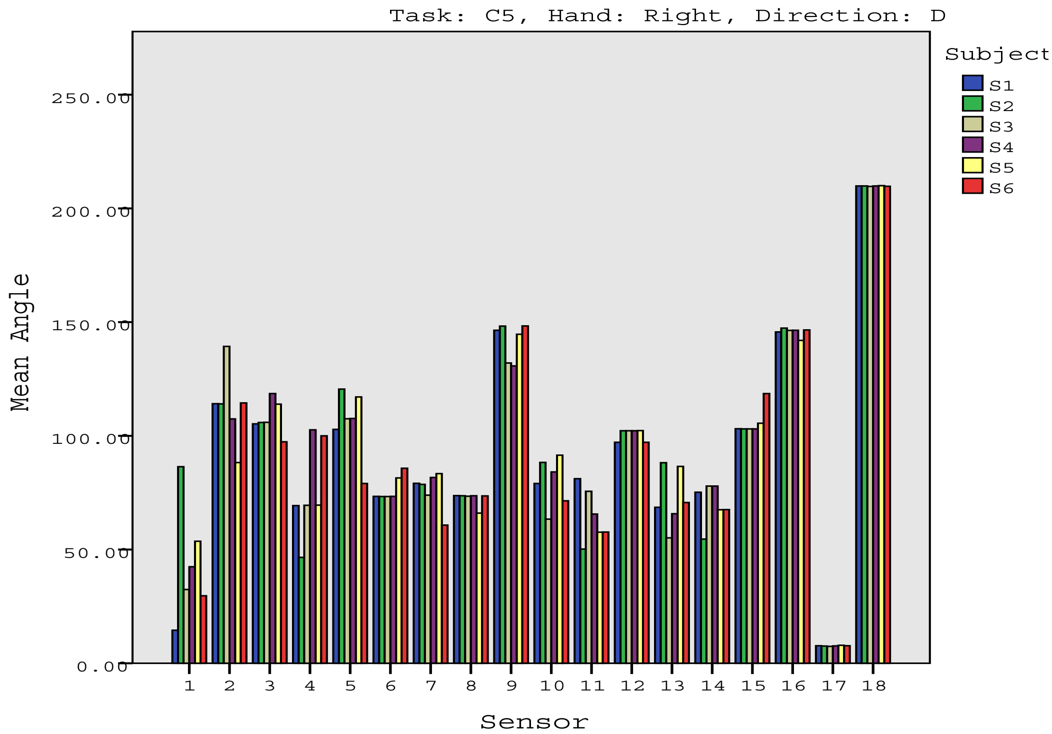



Figure 133. Descending C5 right hand

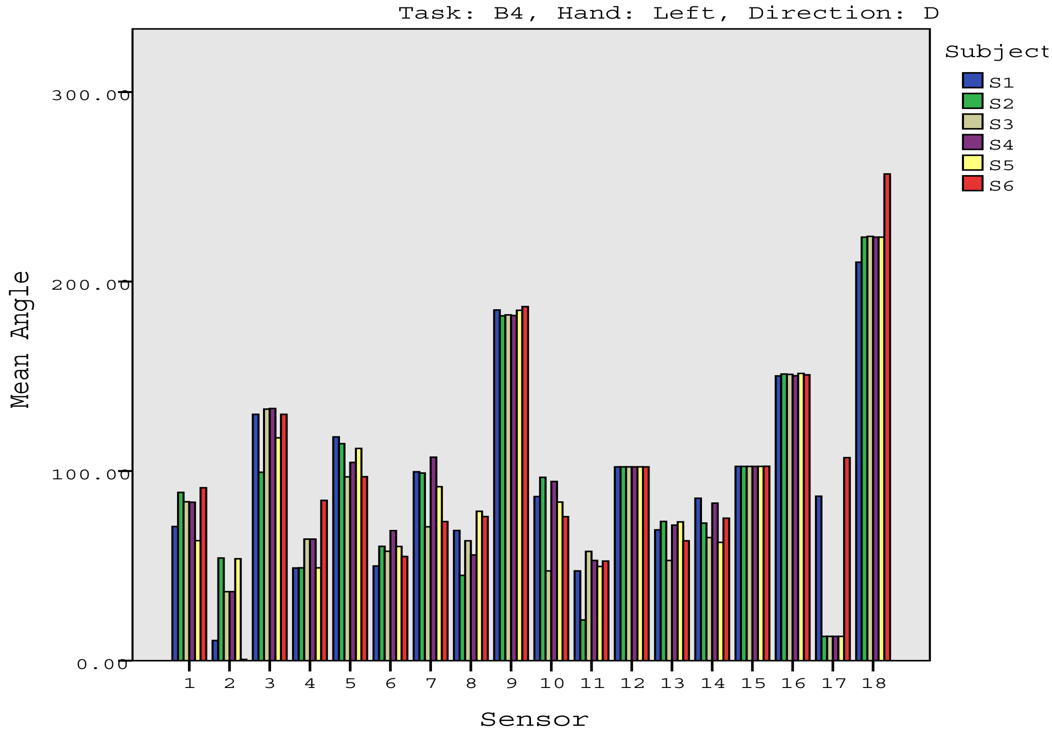



Figure 134. Descending B4 left hand

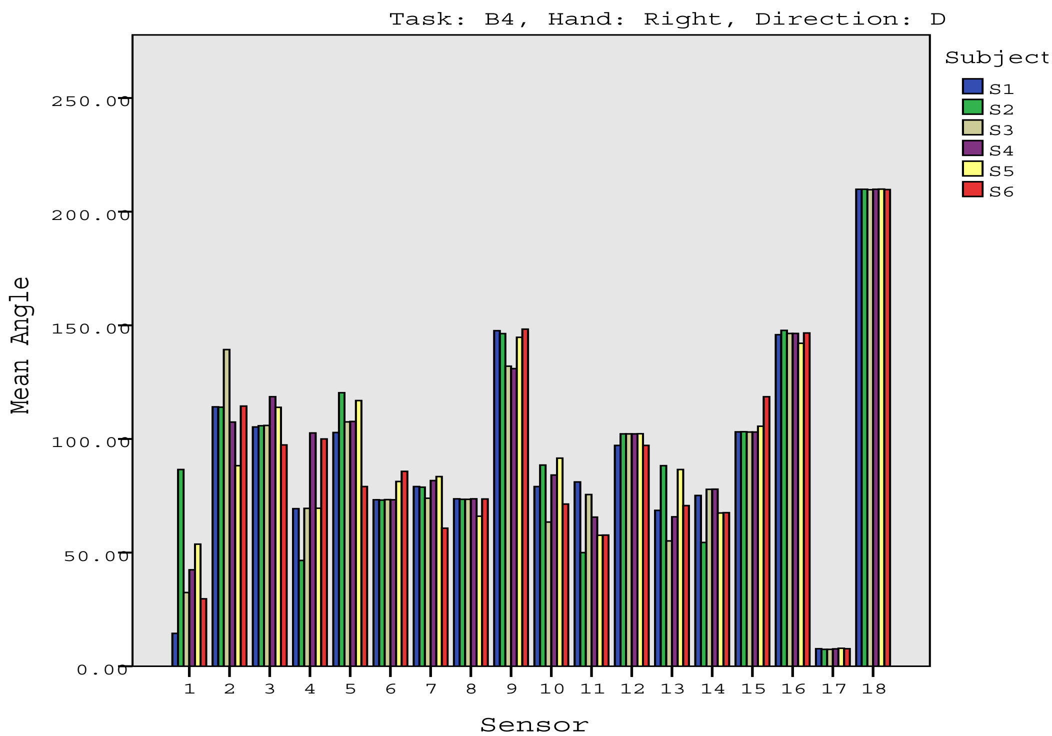



Figure 135. Descending B4 right hand

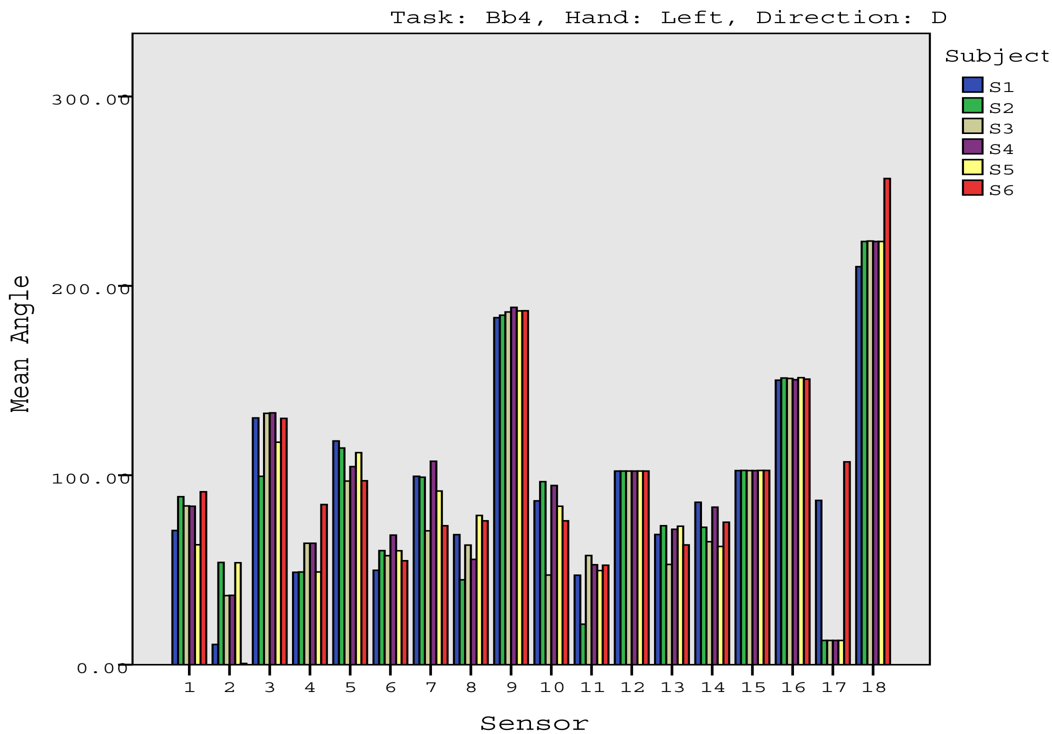



Figure 137. Descending Bb4 left hand

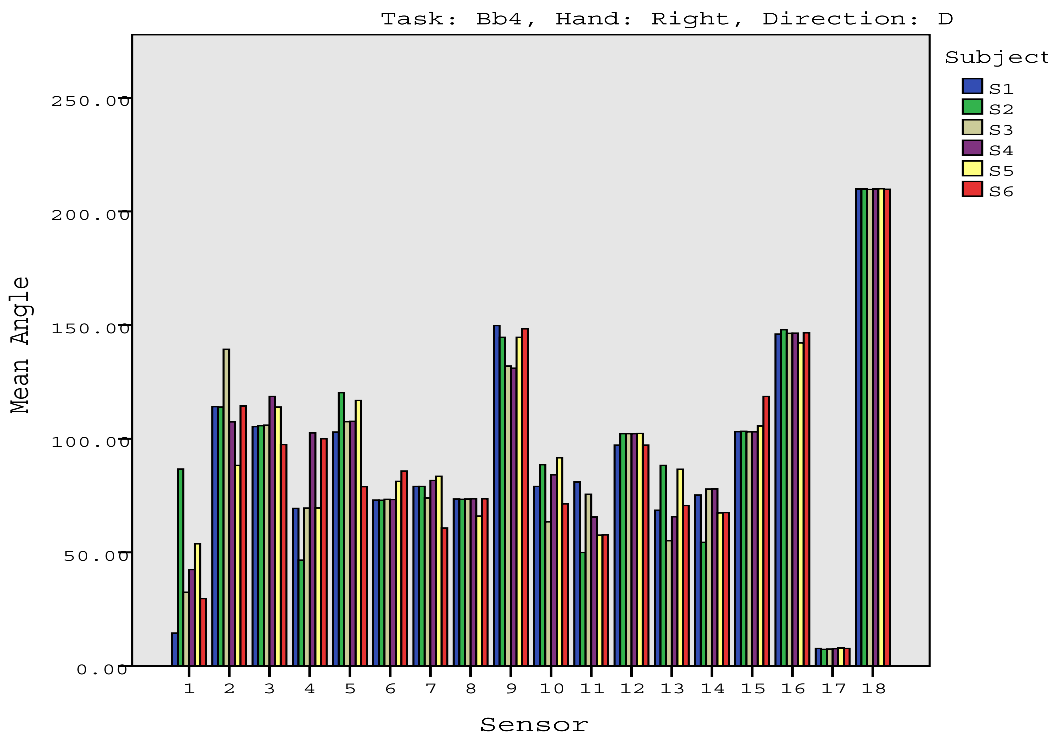



Figure 138. Descending Bb4 right hand

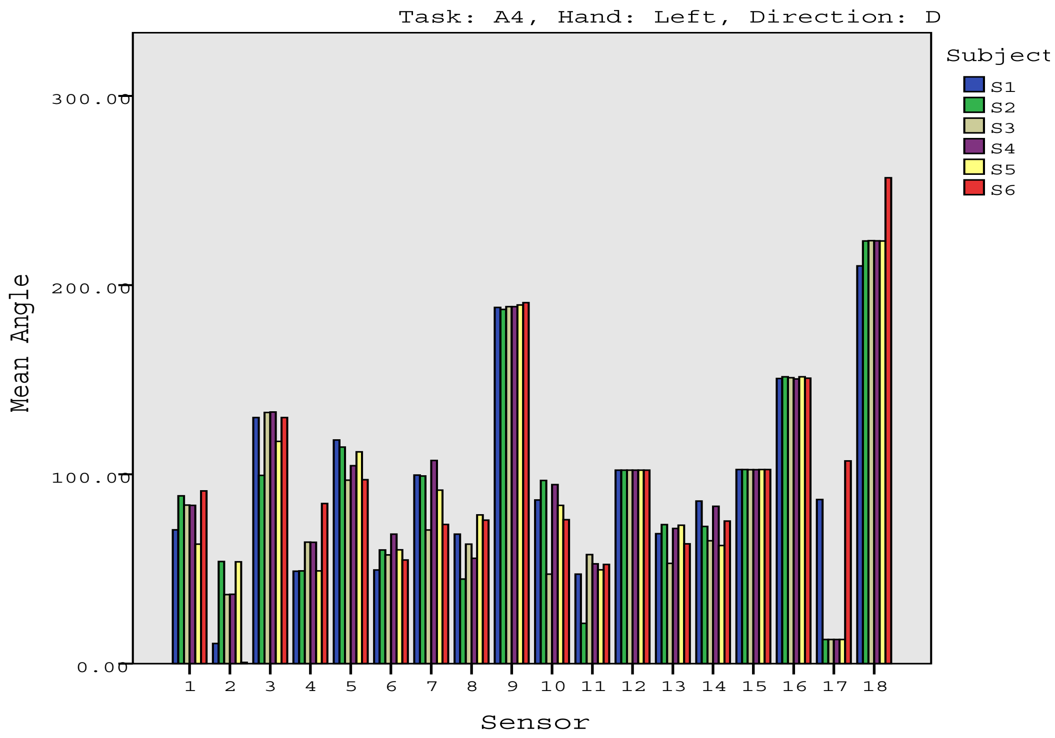



Figure 139. Descending A4 left hand

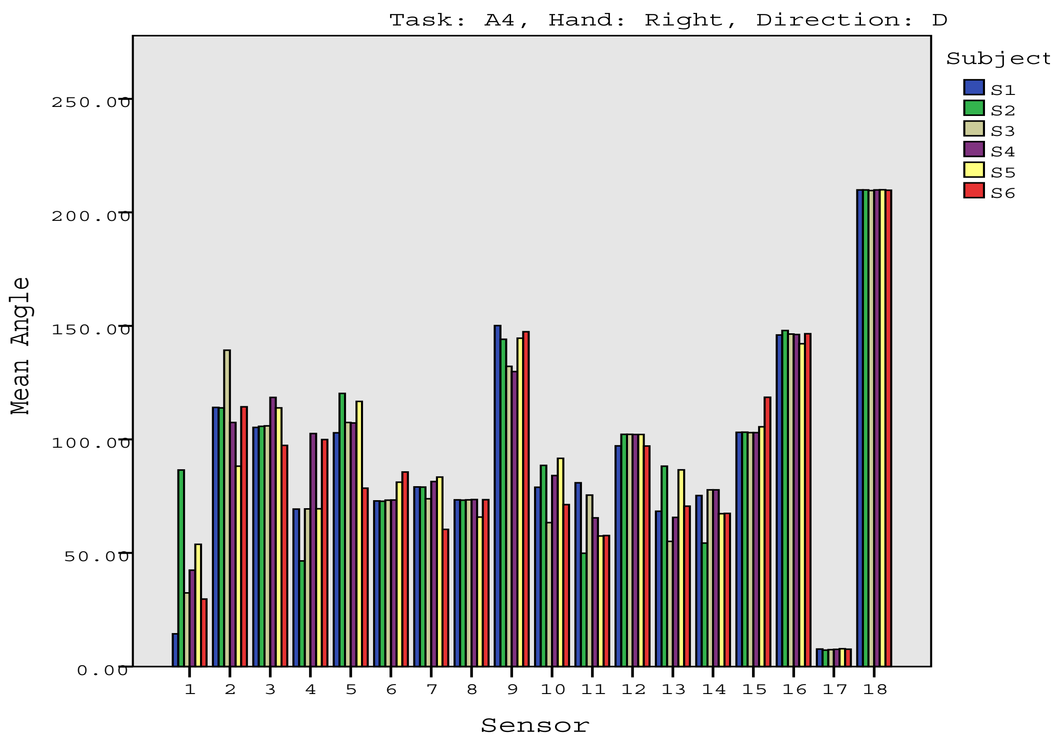



Figure 140. Descending A4 right hand

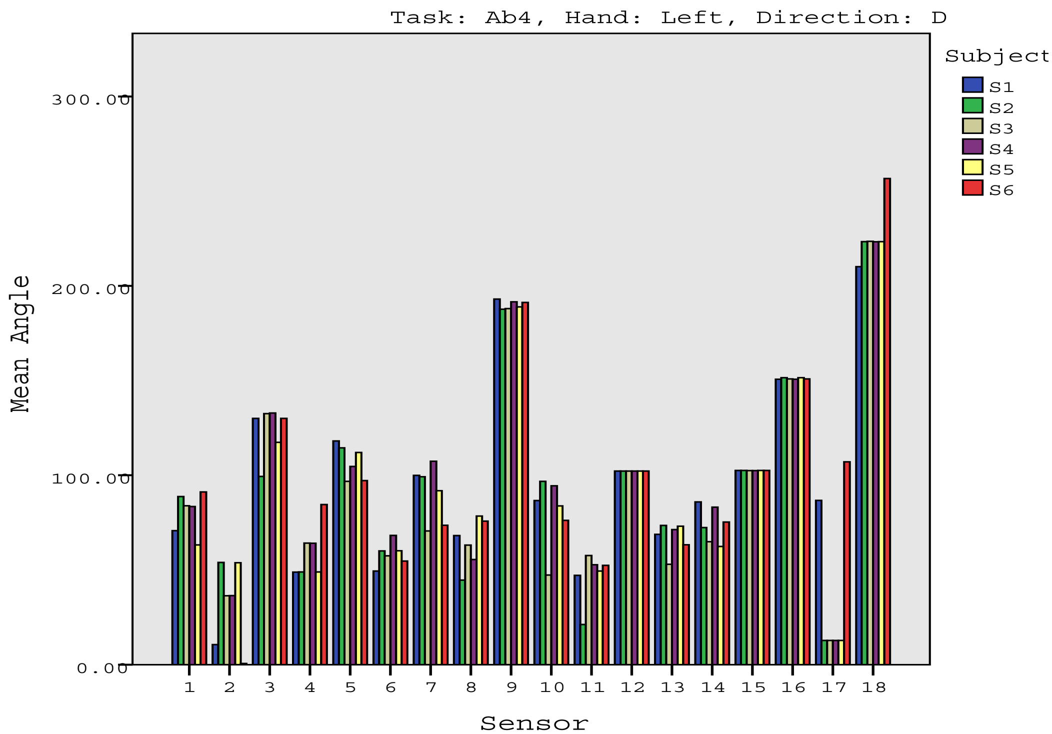



Figure 141. Descending Ab4 left hand

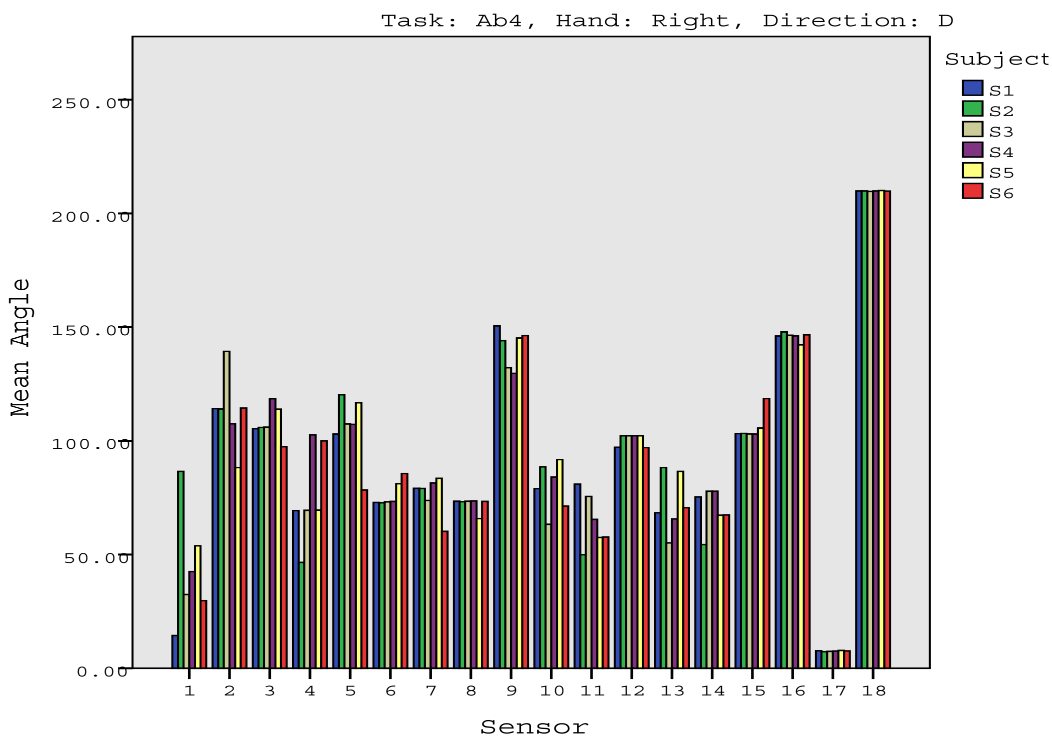



Figure 142. Descending Ab4 right hand

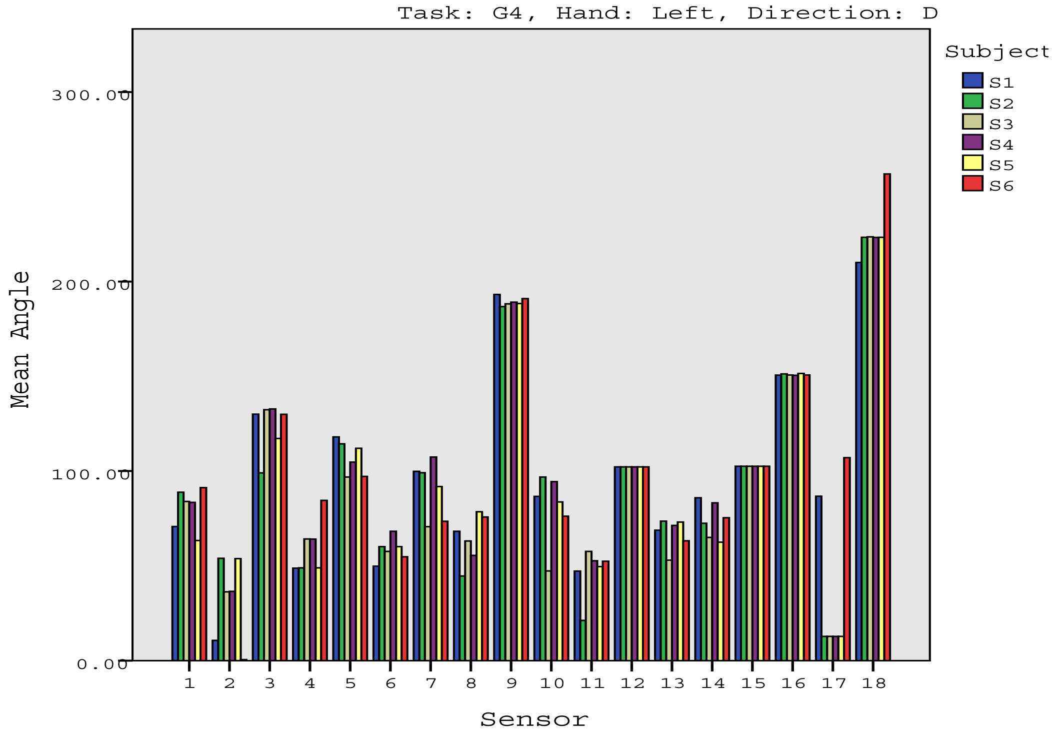



Figure 143. Descending G4 left hand

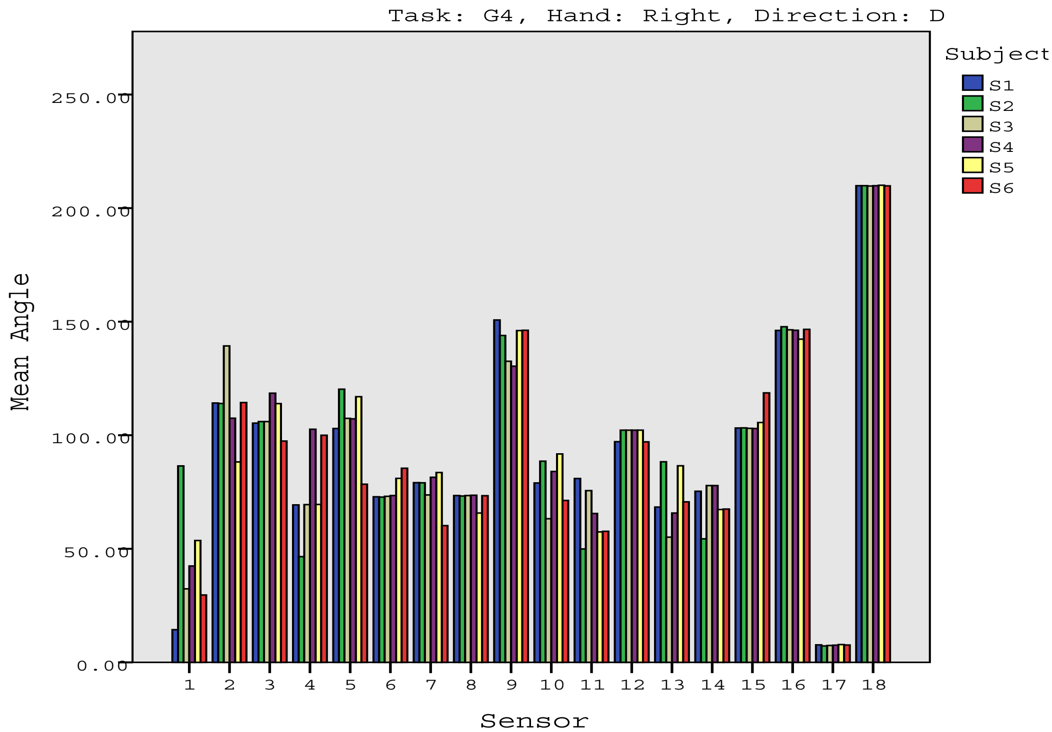



Figure 144. Descending G4 right hand

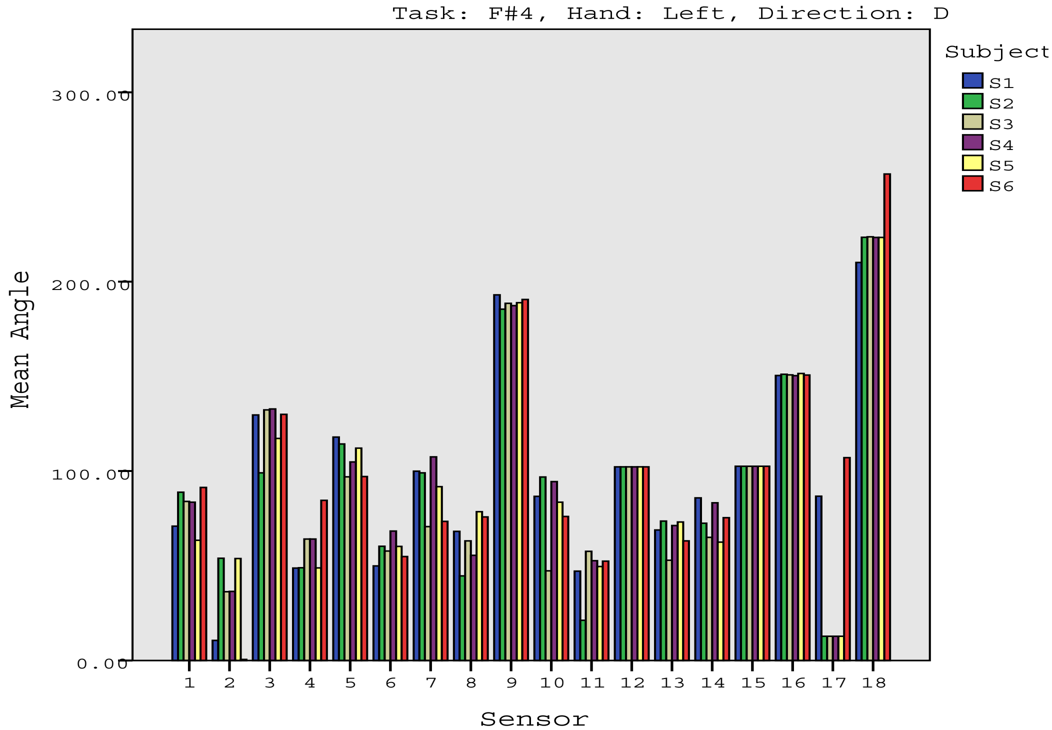



Figure 145. Descending F#4 left hand

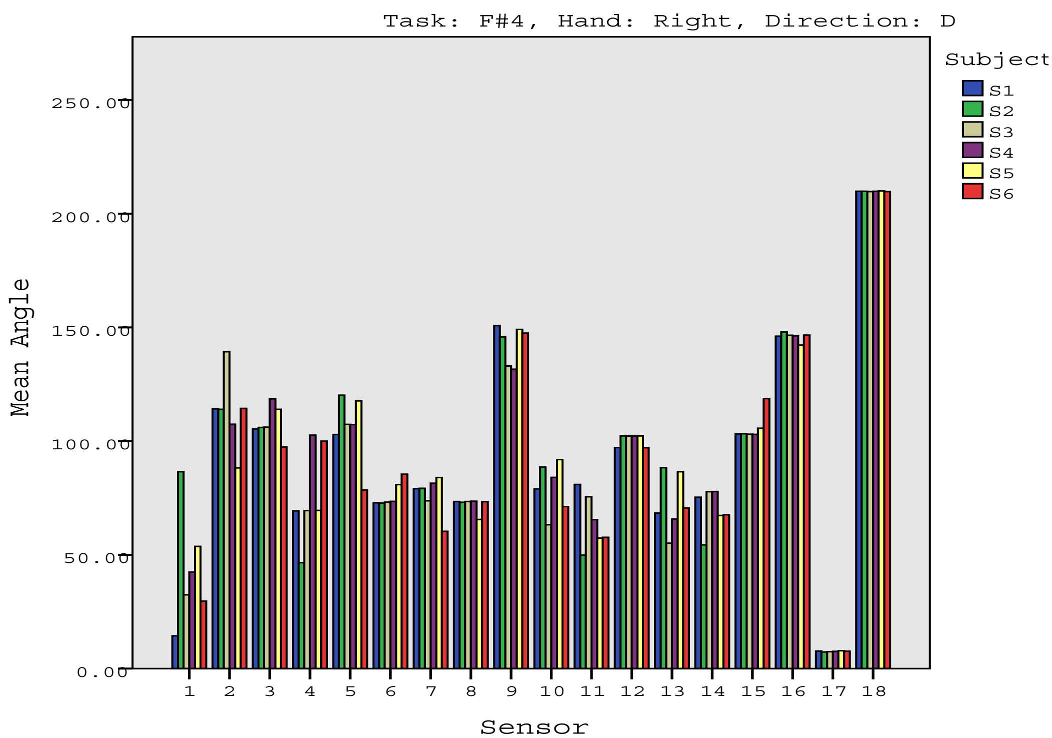



Figure 146. Descending F#4 right hand

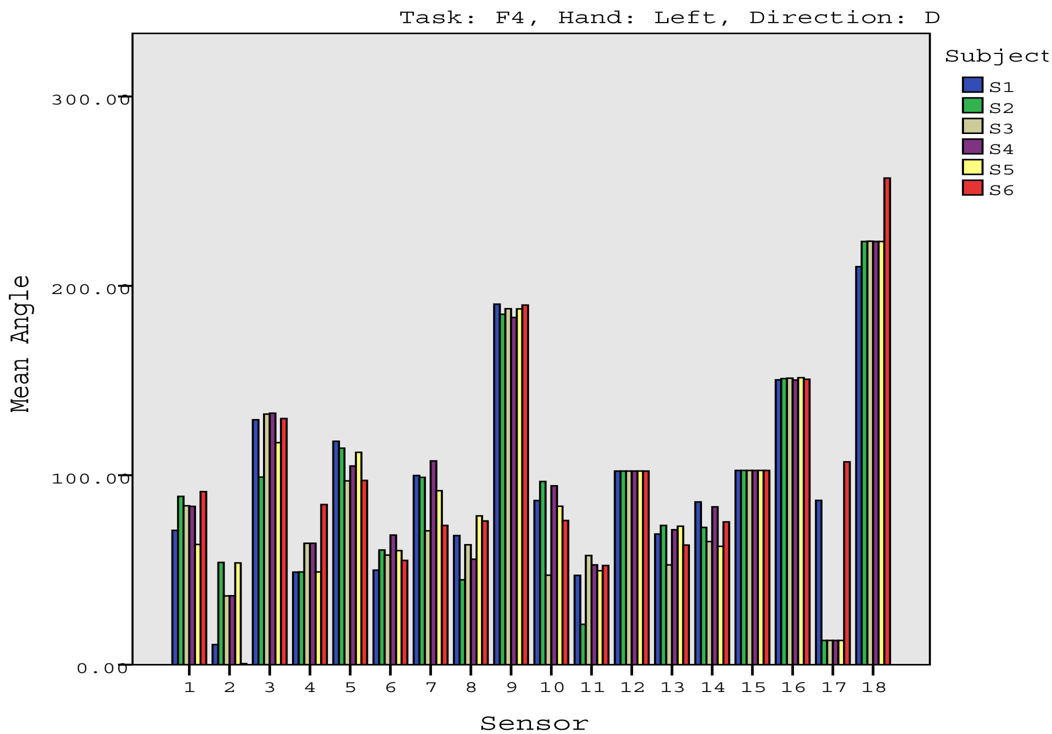



Figure 147. Descending F4 left hand

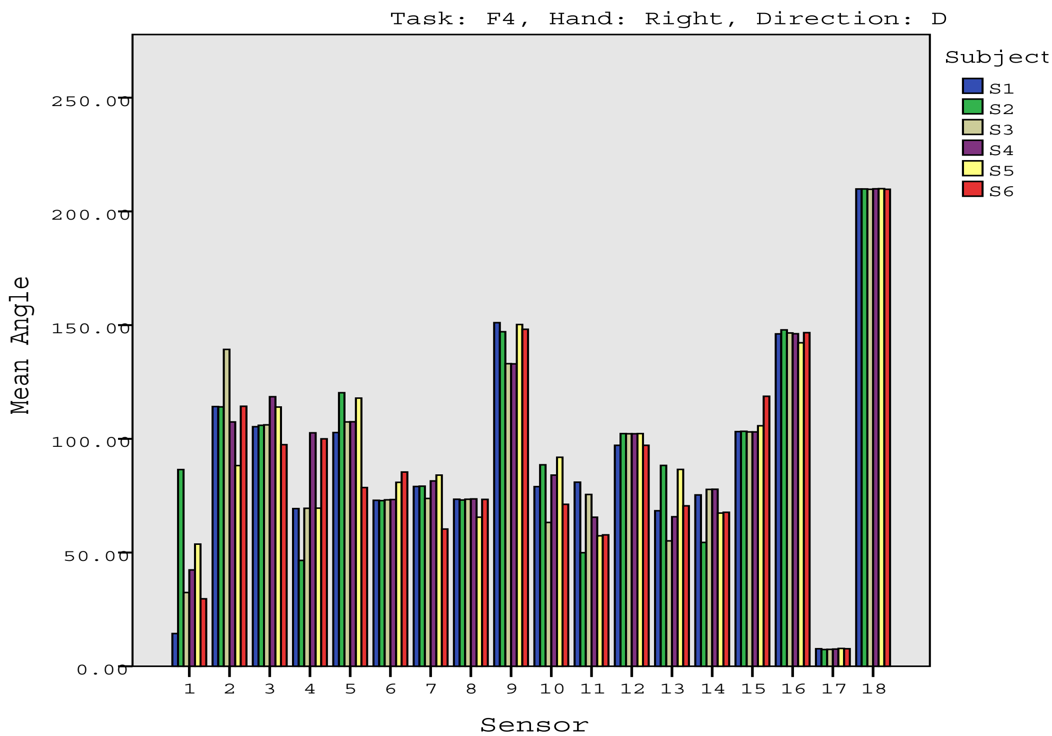



Figure 148. Descending F4 right hand

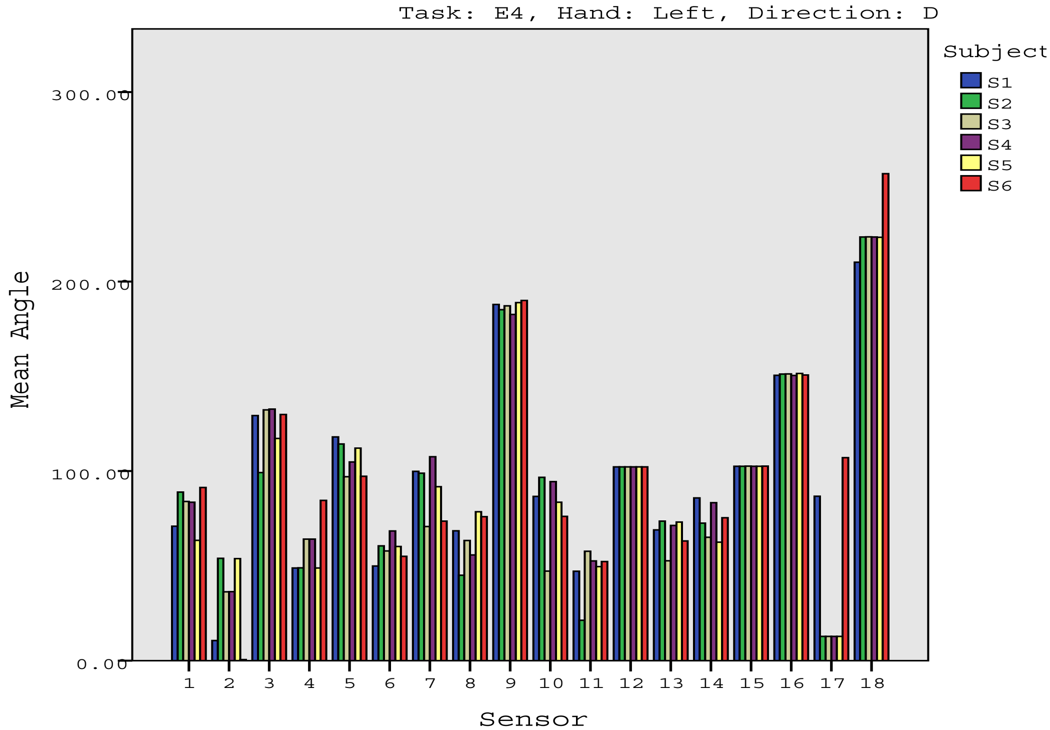



Figure 149. Descending E4 left hand

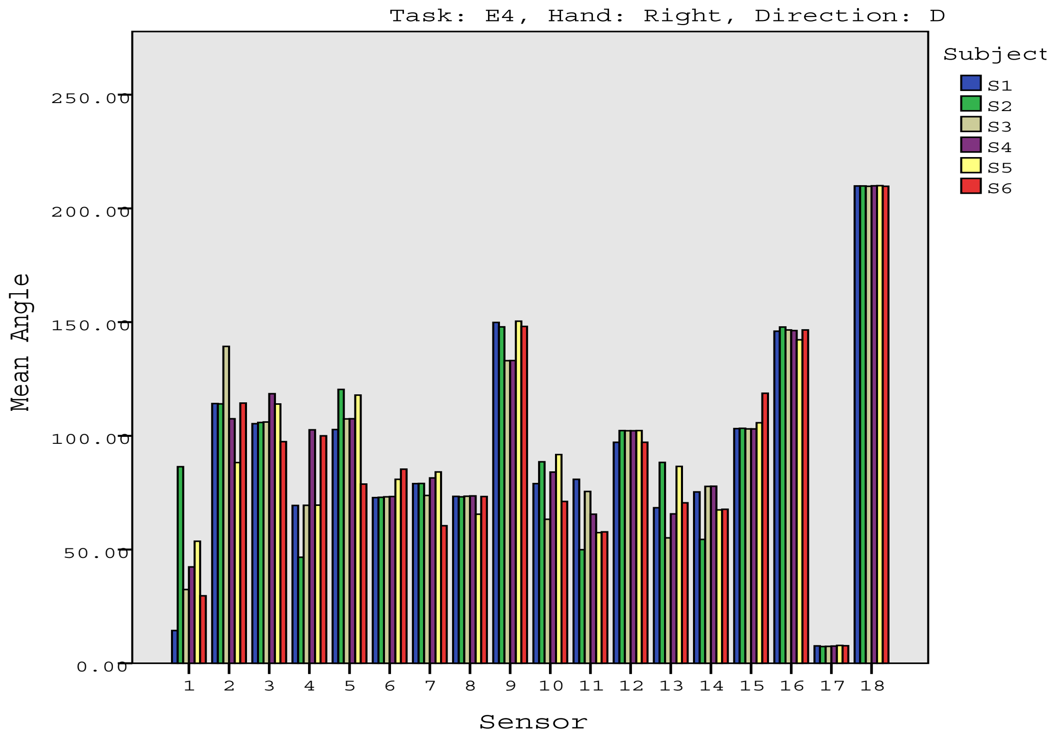



Figure 150. Descending E4 right hand

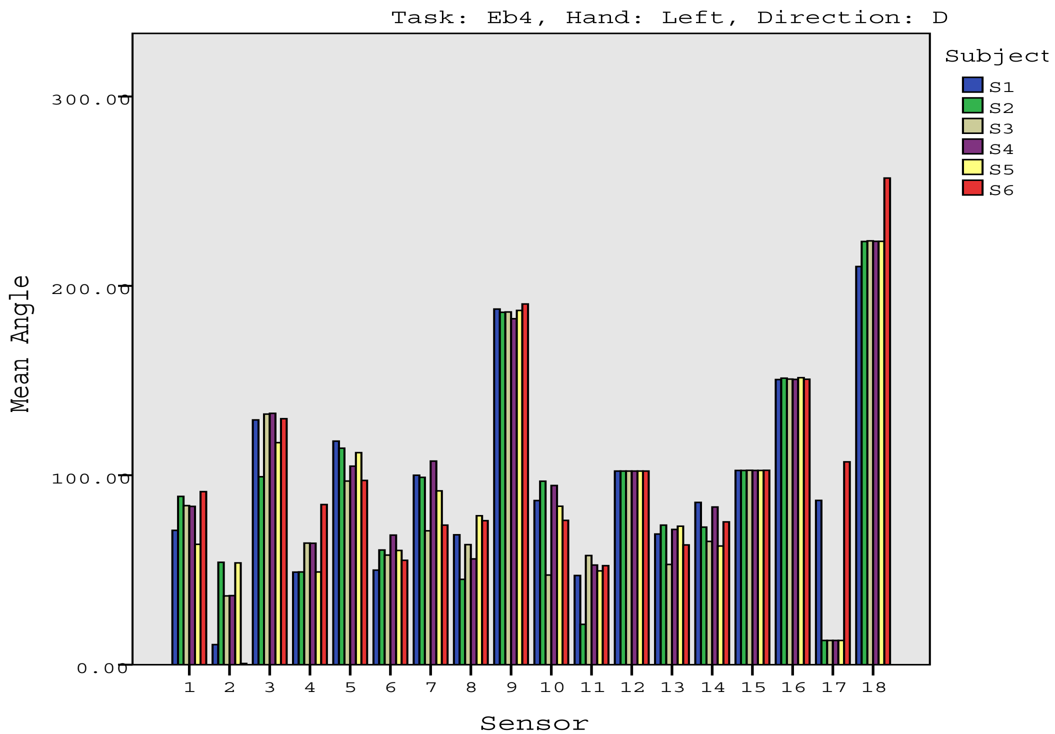



Figure 151. Descending Eb4 left hand

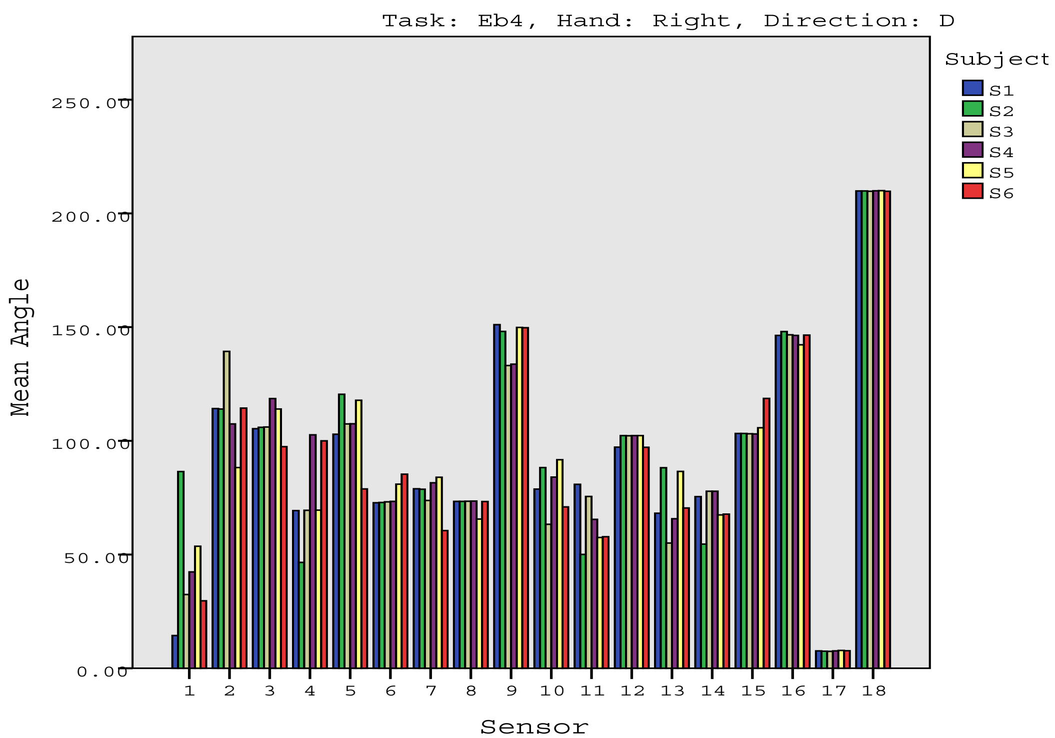



Figure 152. Descending Eb4 right hand

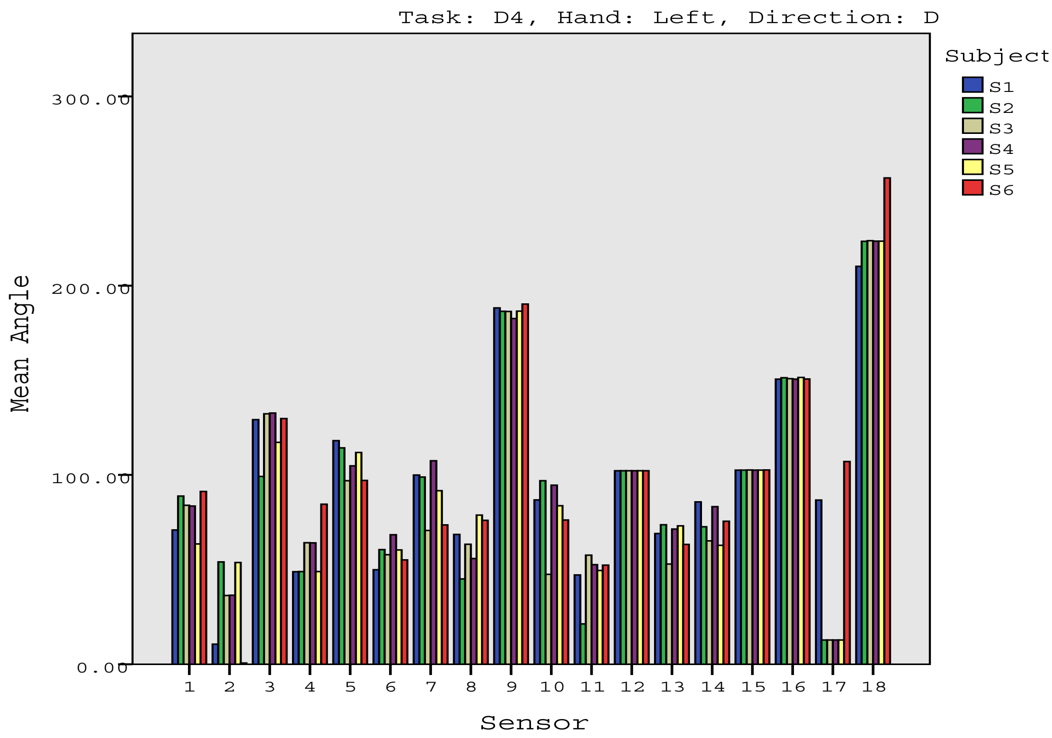



Figure 153. Descending D4 left hand

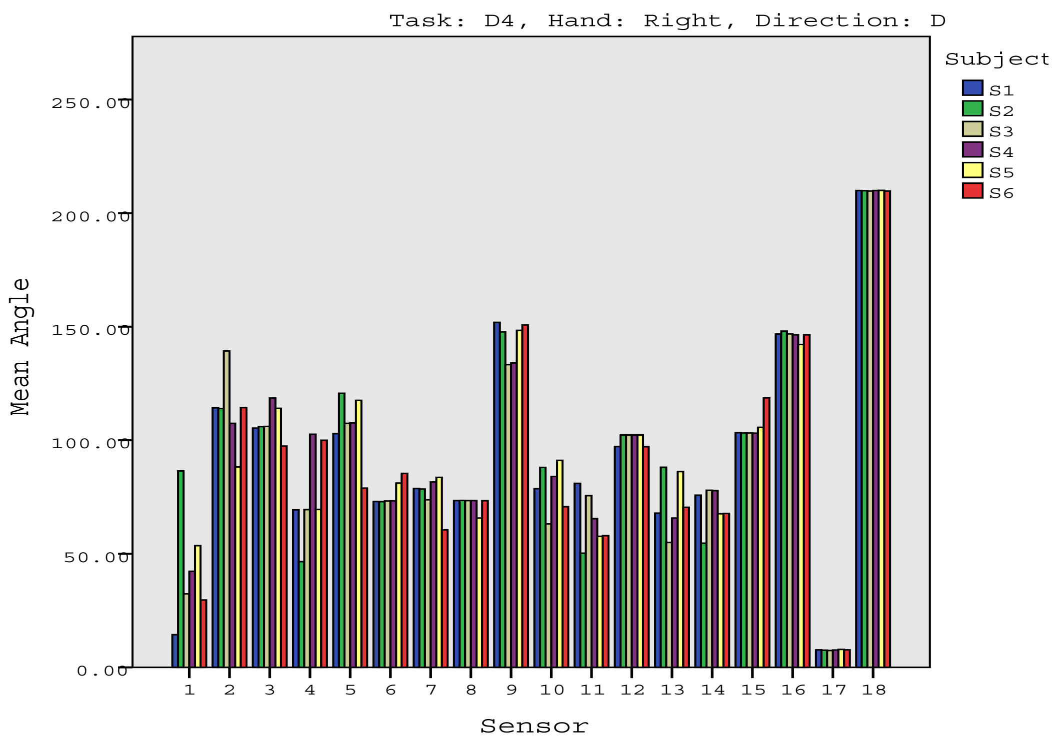



Figure 154. Descending D4 right hand

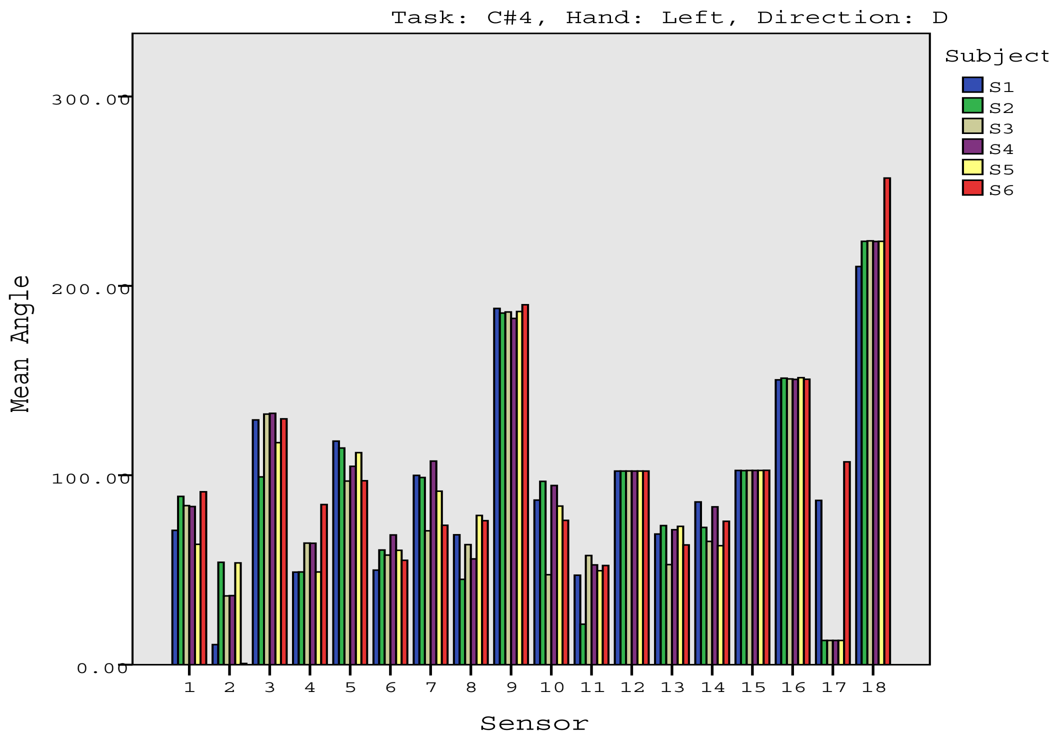


Figure 155. Descending C#4 right hand

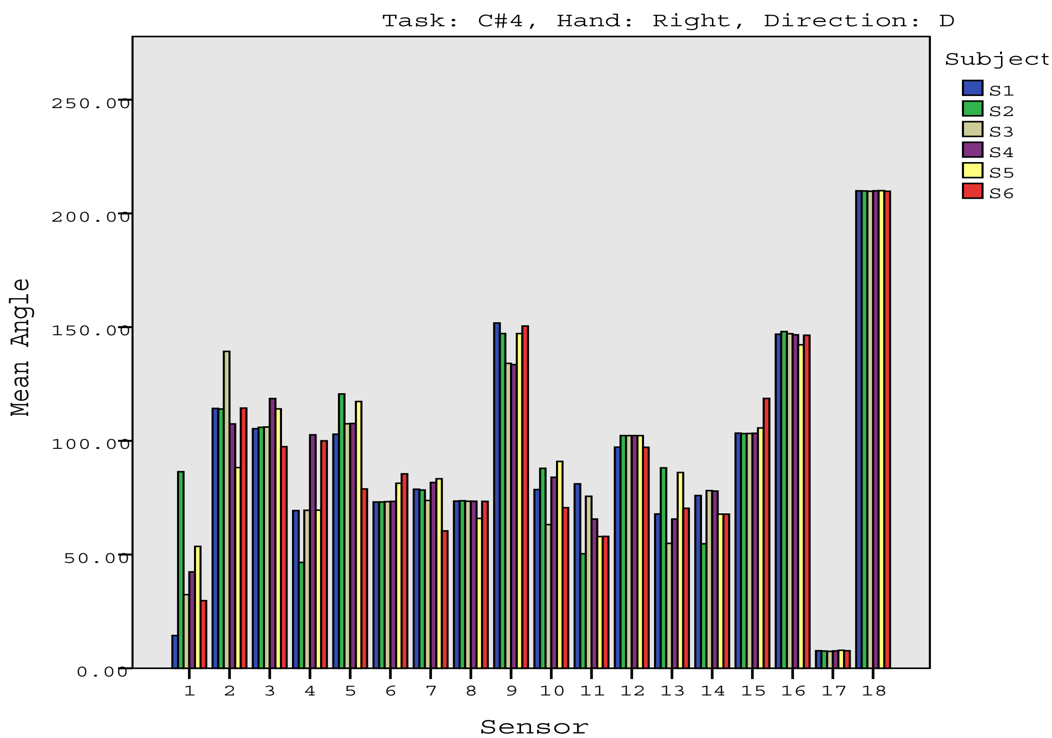


Figure 156. Descending C#4 left hand

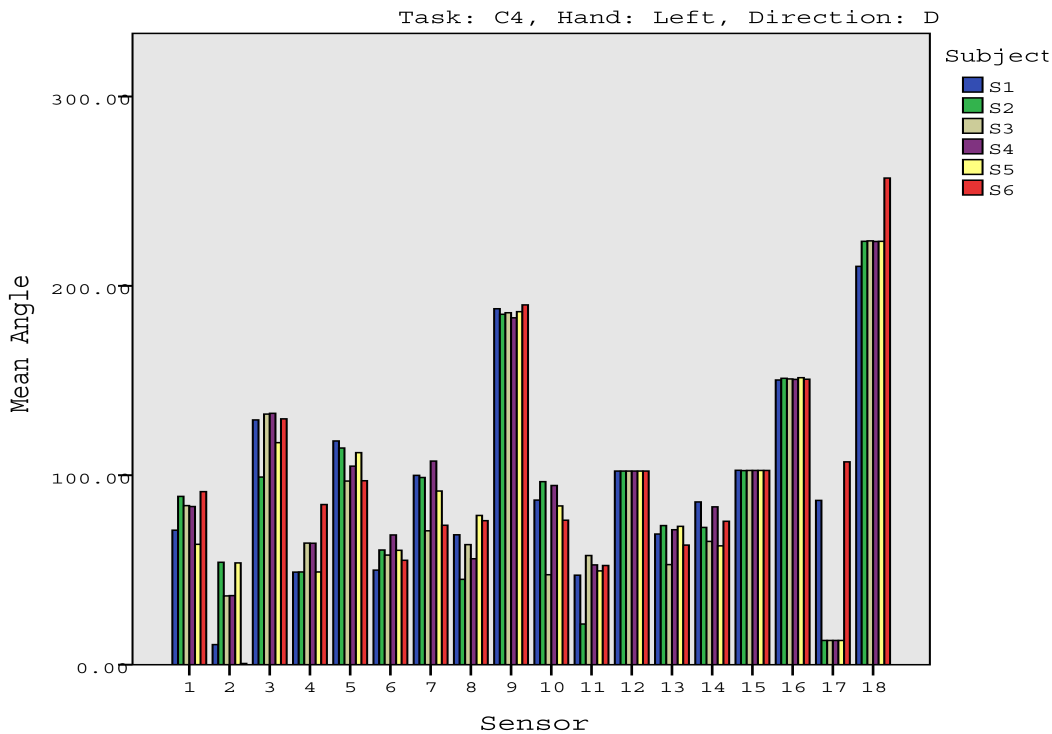



Figure 157. Descending C4 left hand

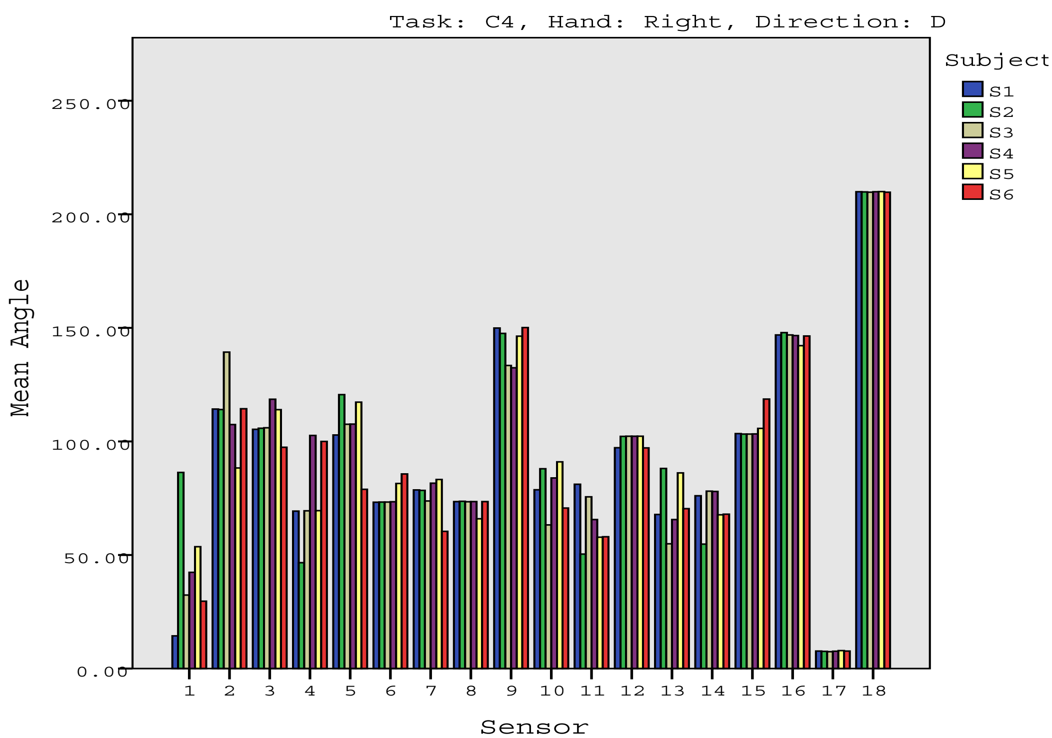



Figure 158. Descending C4 right hand

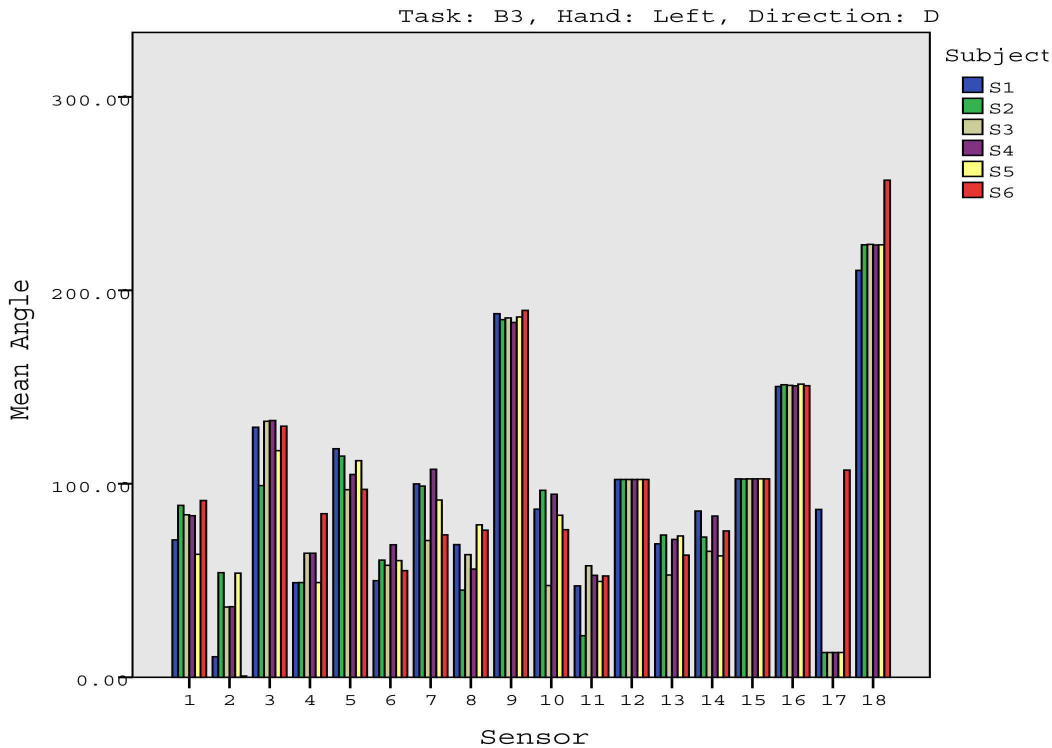



Figure 159. Descending B3 left hand

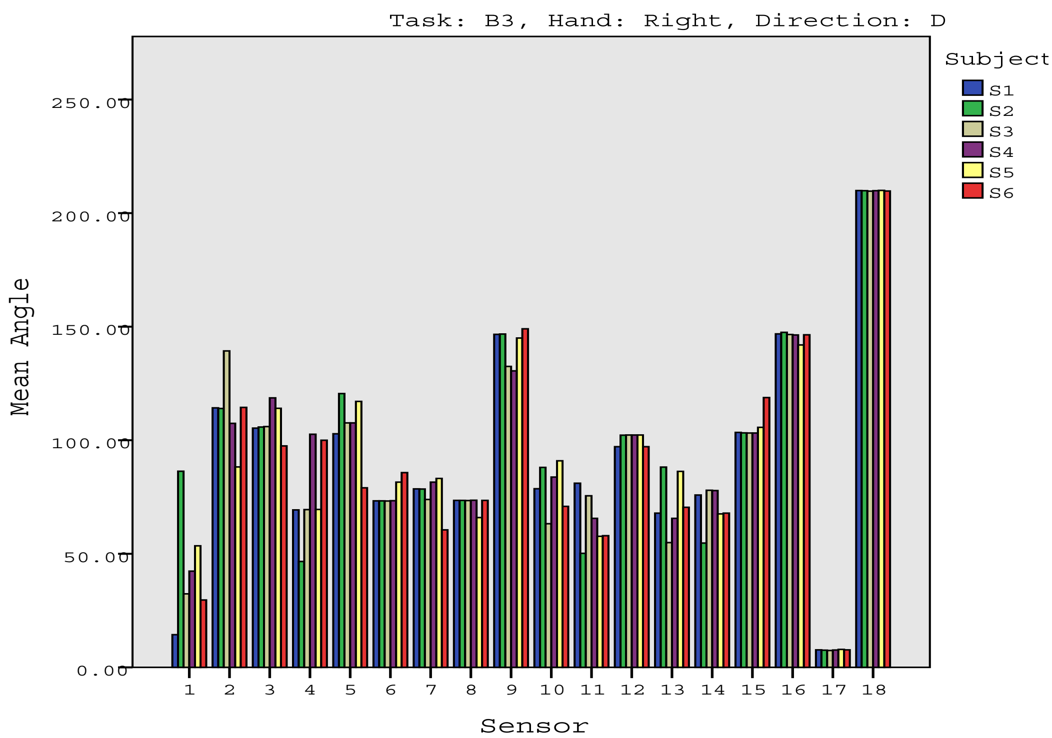



Figure 160. Descending B3 right hand

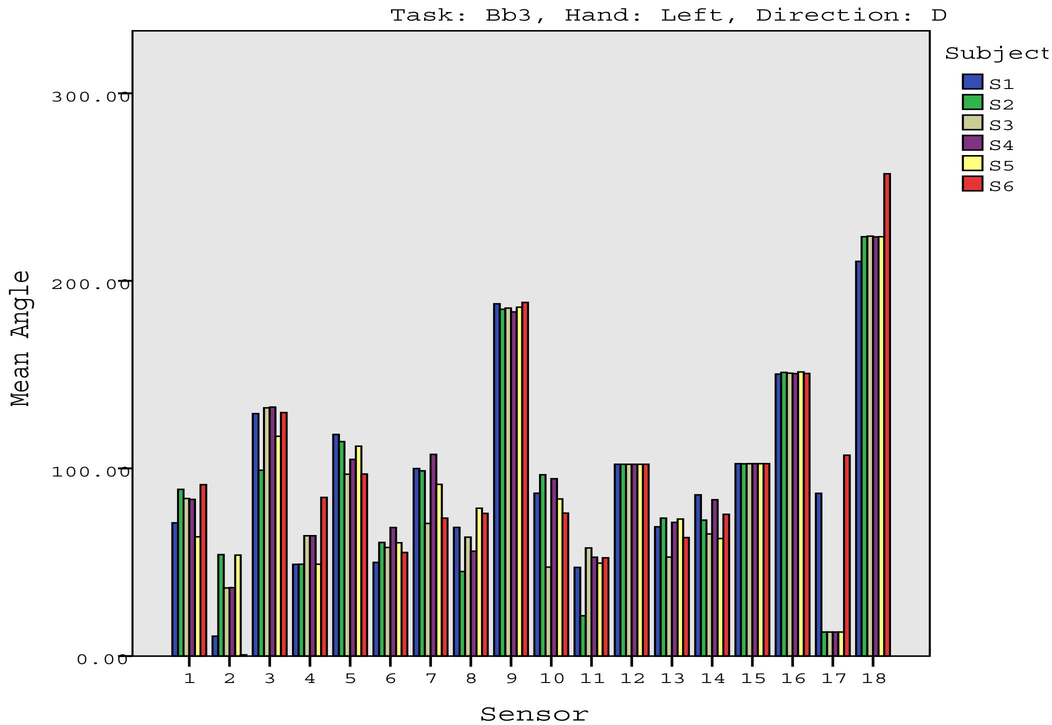



Figure 161. Descending Bb3 left hand

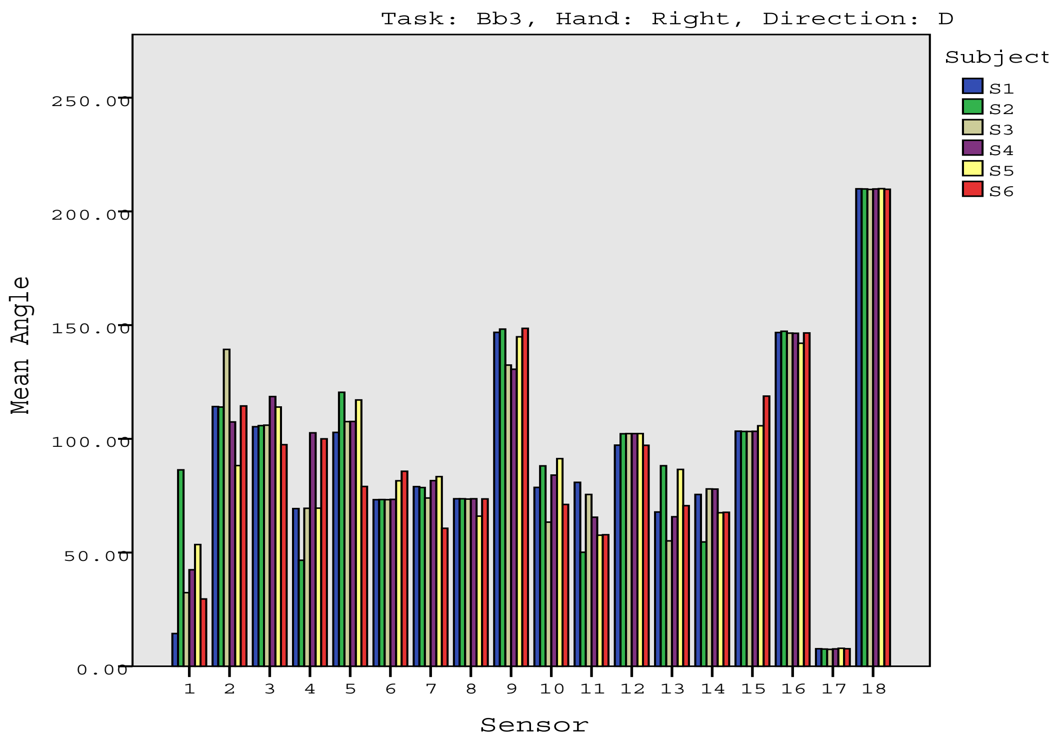



Figure 162. Descending Bb3 right hand

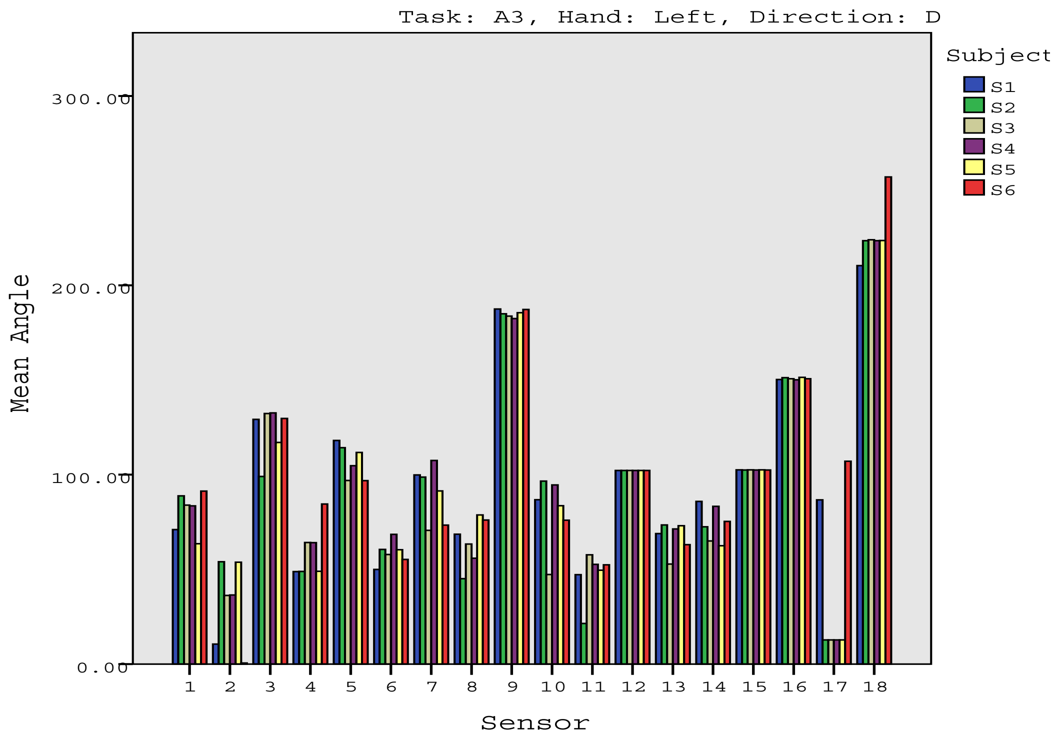



Figure 163. Descending A3 left hand

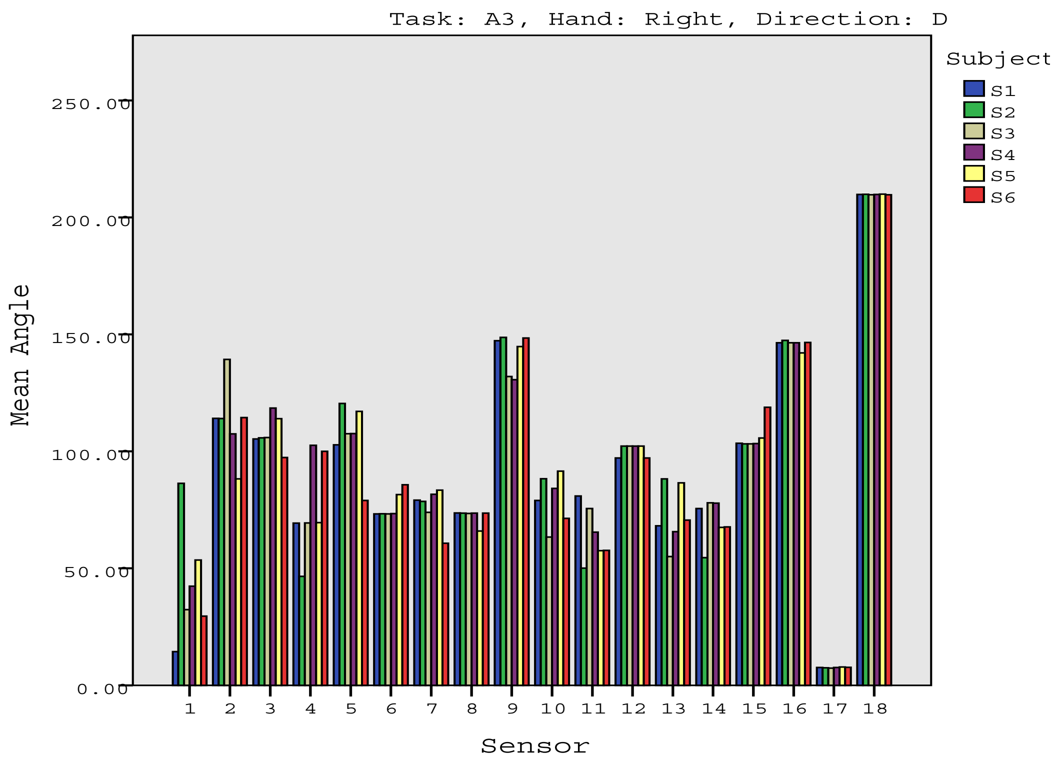



Figure 164. Descending A3 right hand

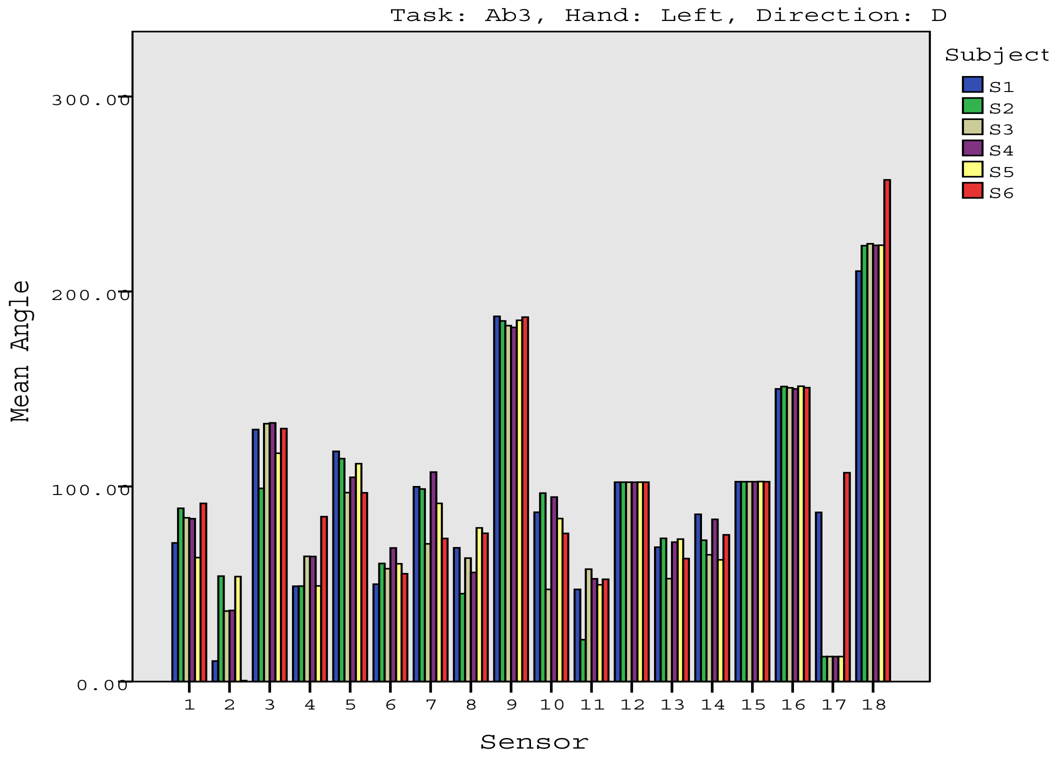



Figure 165. Descending Ab3 left hand

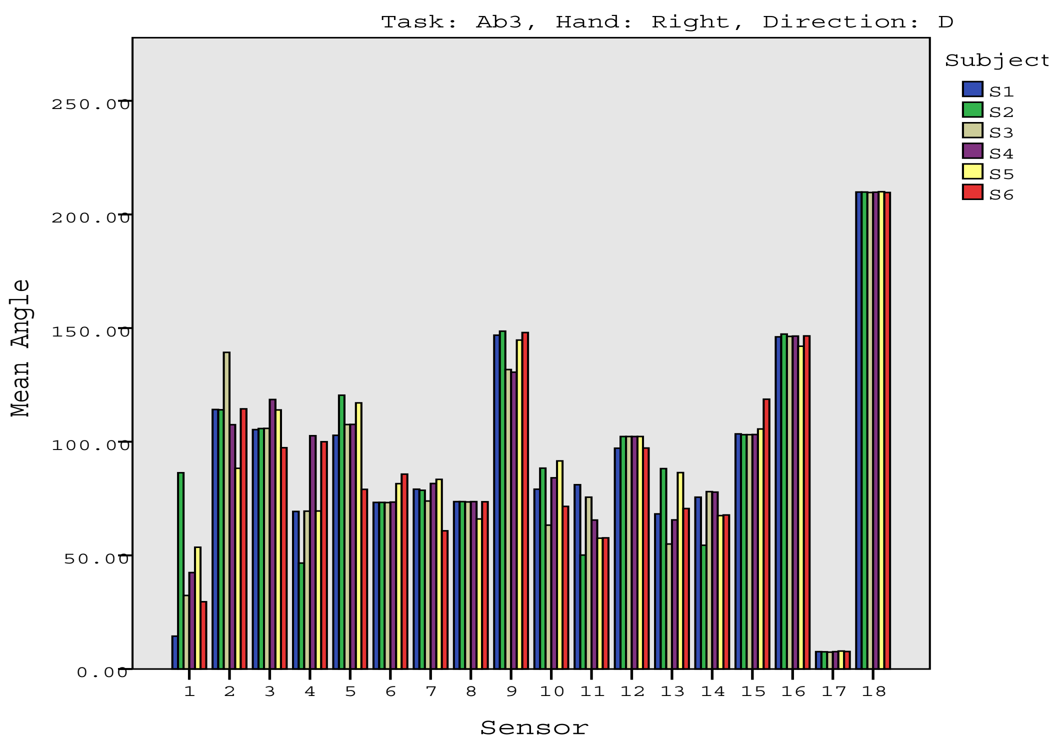



Figure 166. Descending A3 right hand

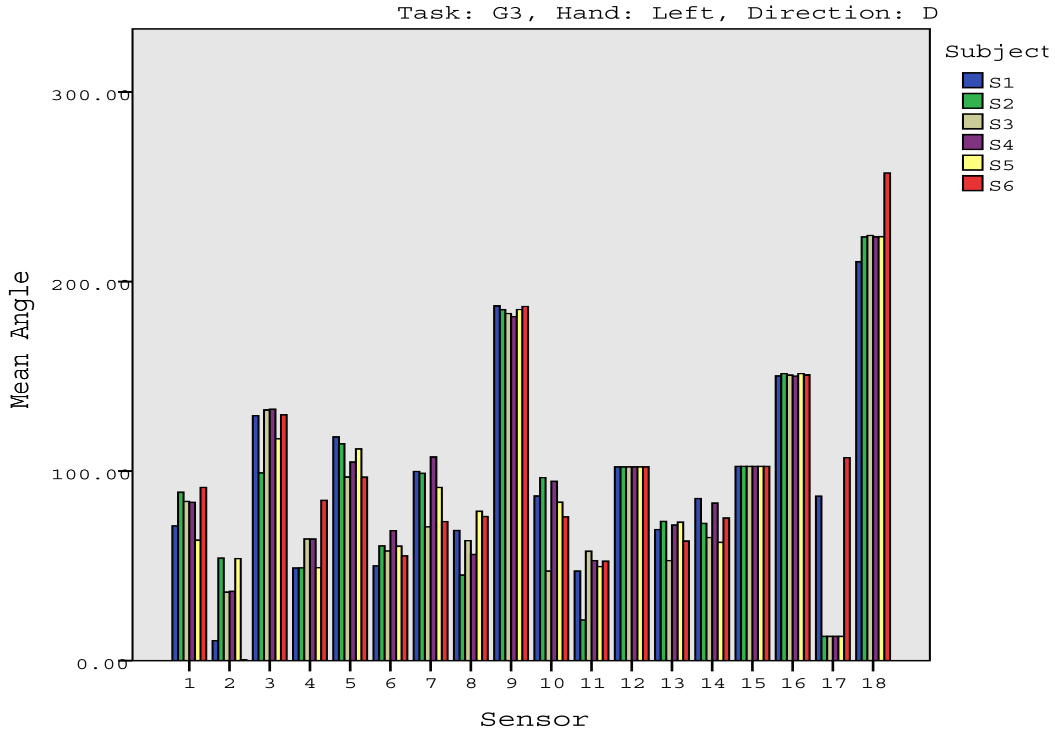



Figure 167. Descending G3 left hand

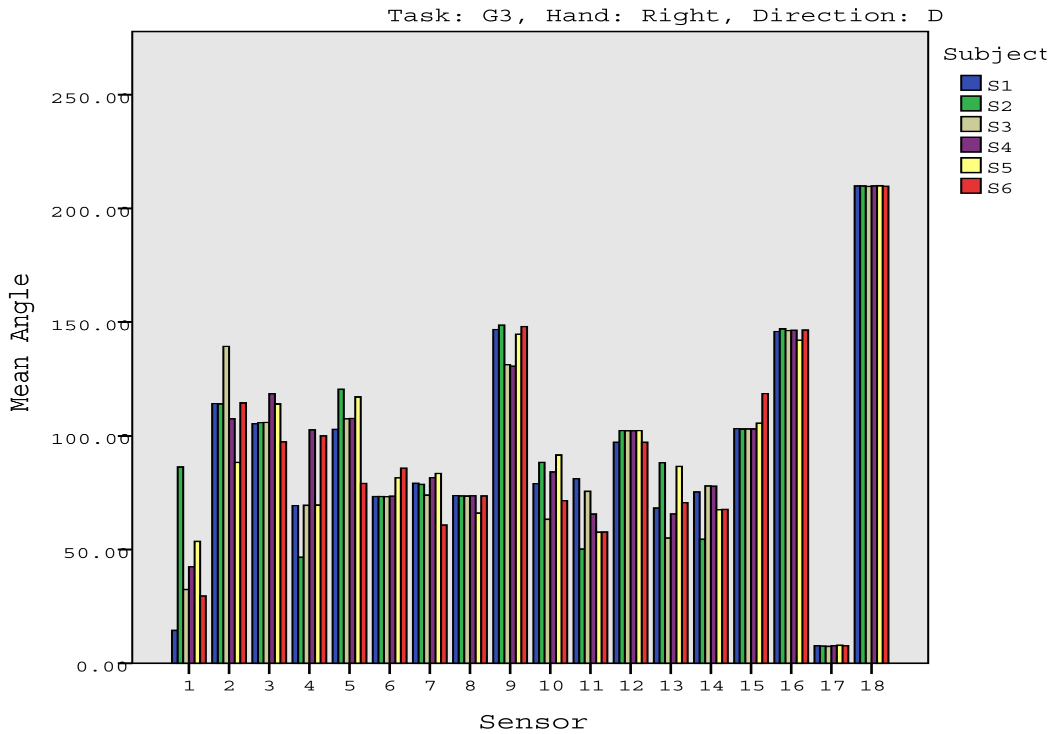



Figure 168. Descending G3 right hand

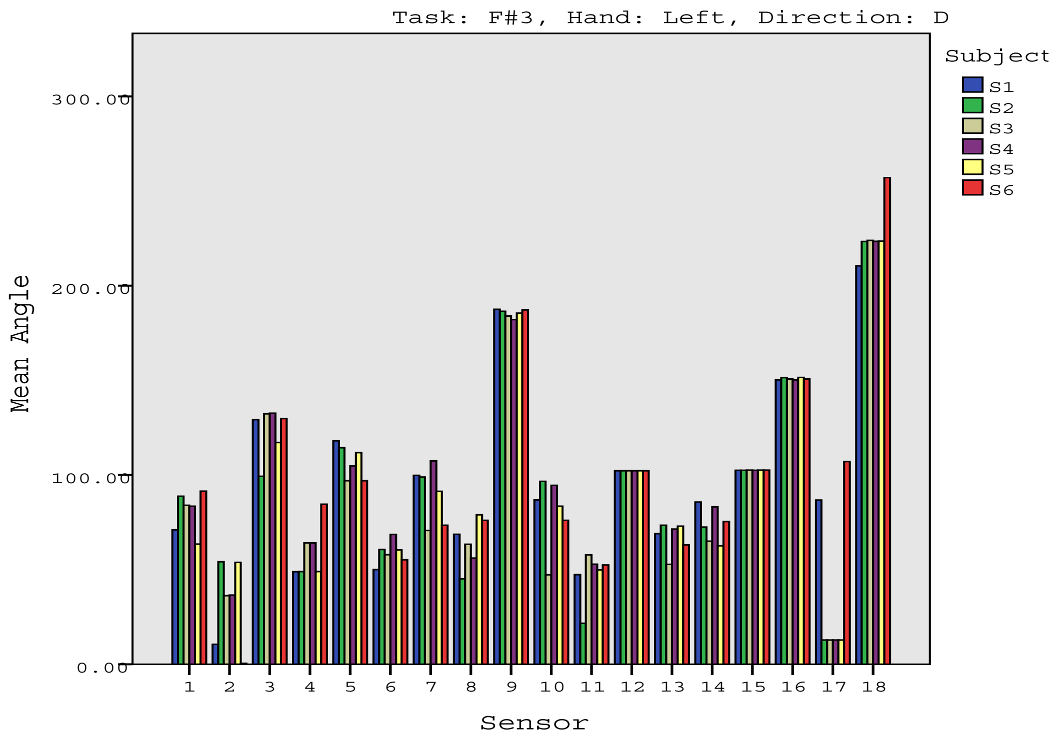



Figure 169. Descending F#3 left hand

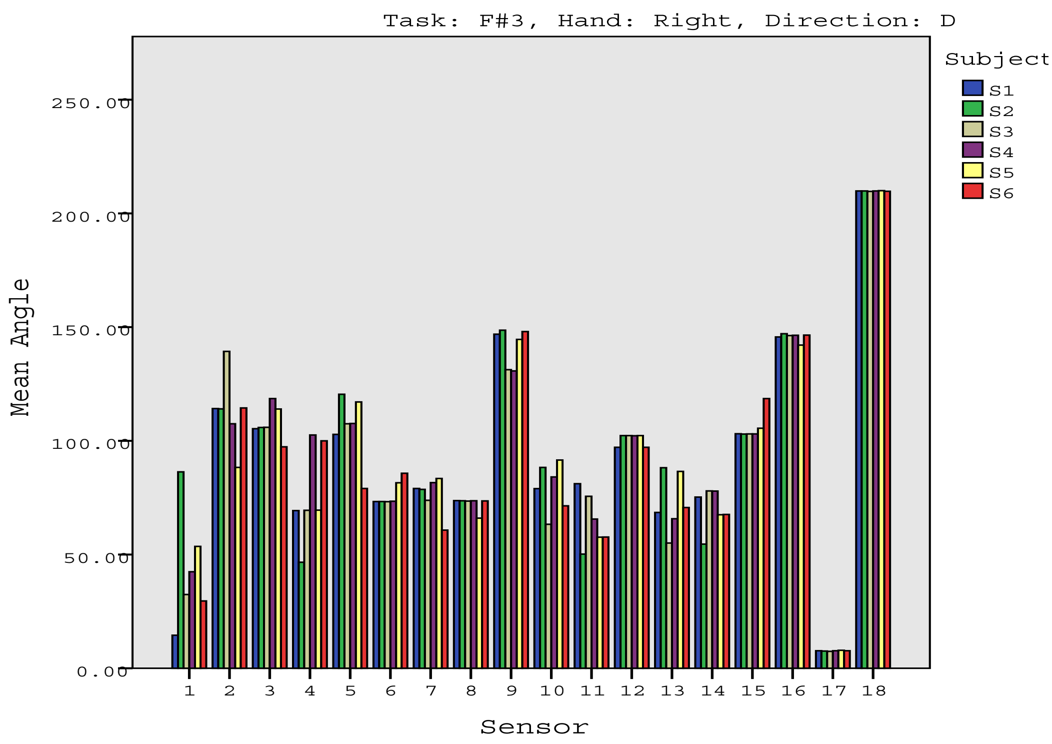



Figure 170. Descending F#3 right hand

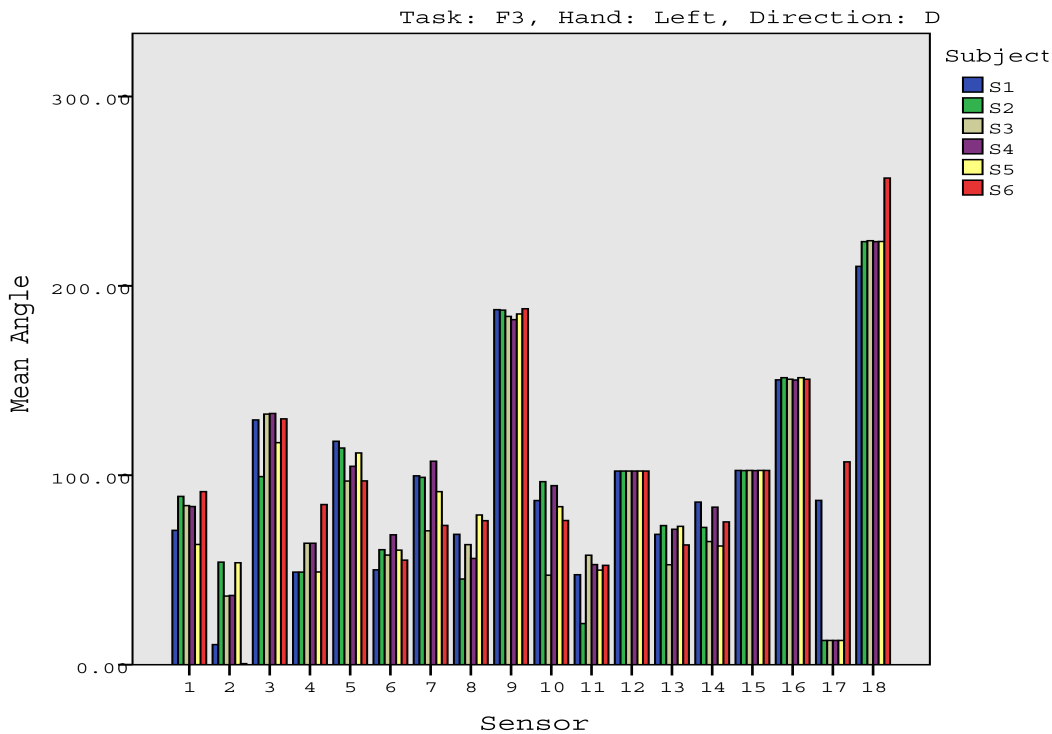



Figure 171. Descending F3 left hand

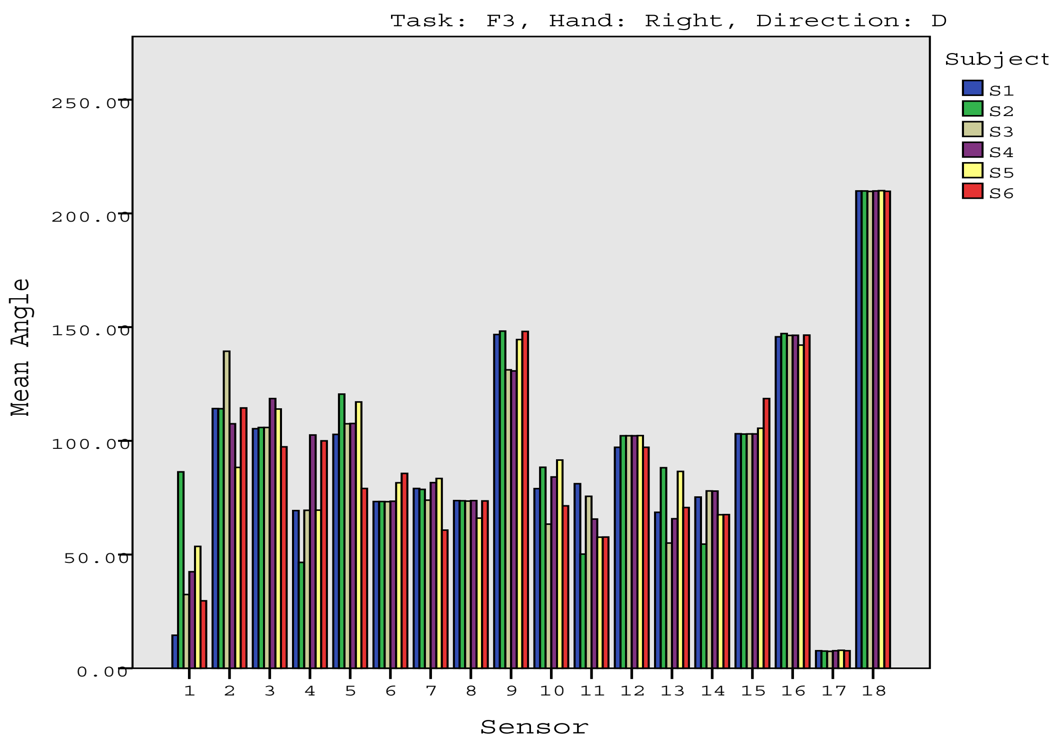



Figure 172. Descending F3 right hand

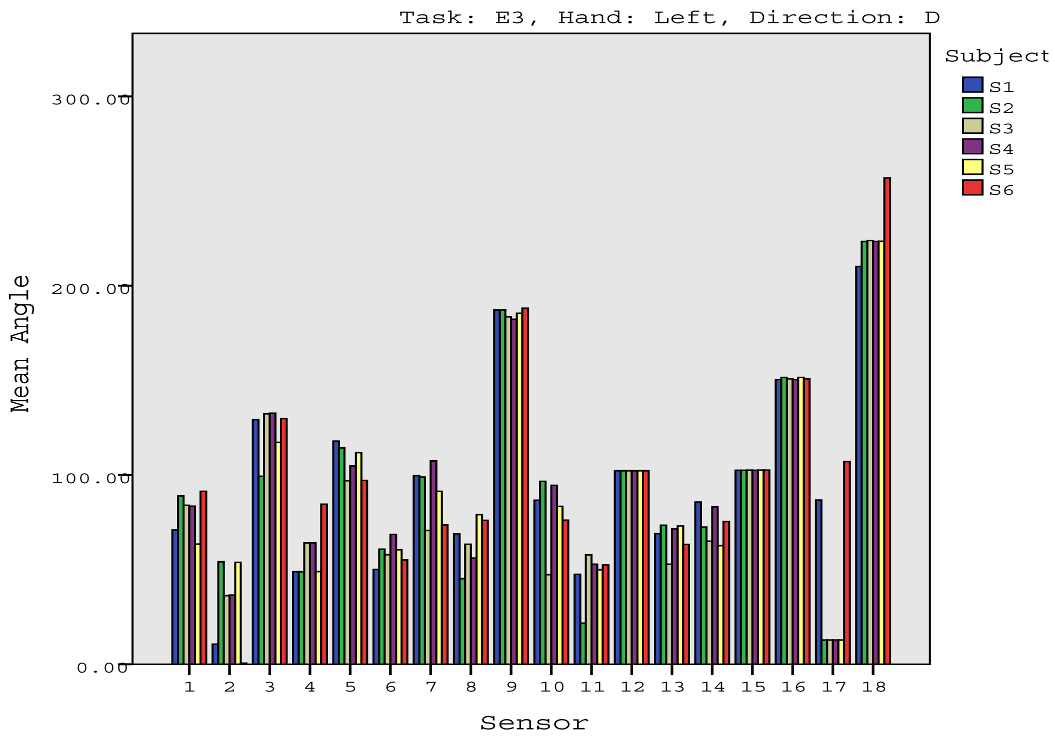



Figure 173. Descending E3 left hand

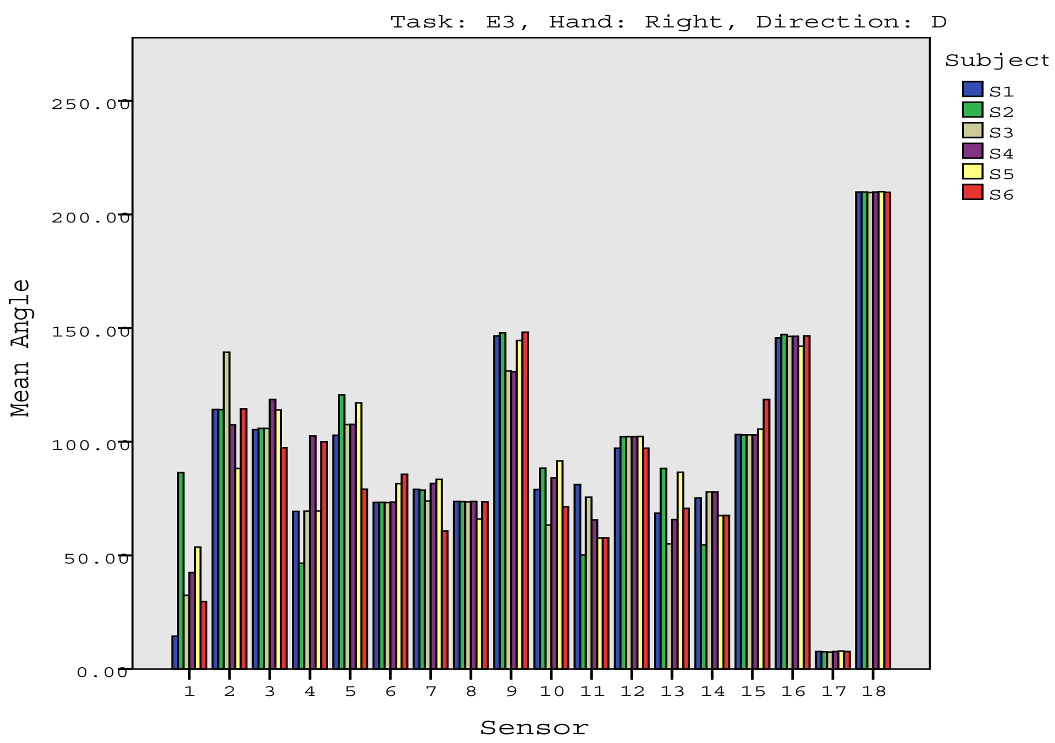



Figure 174. Descending E3 right hand

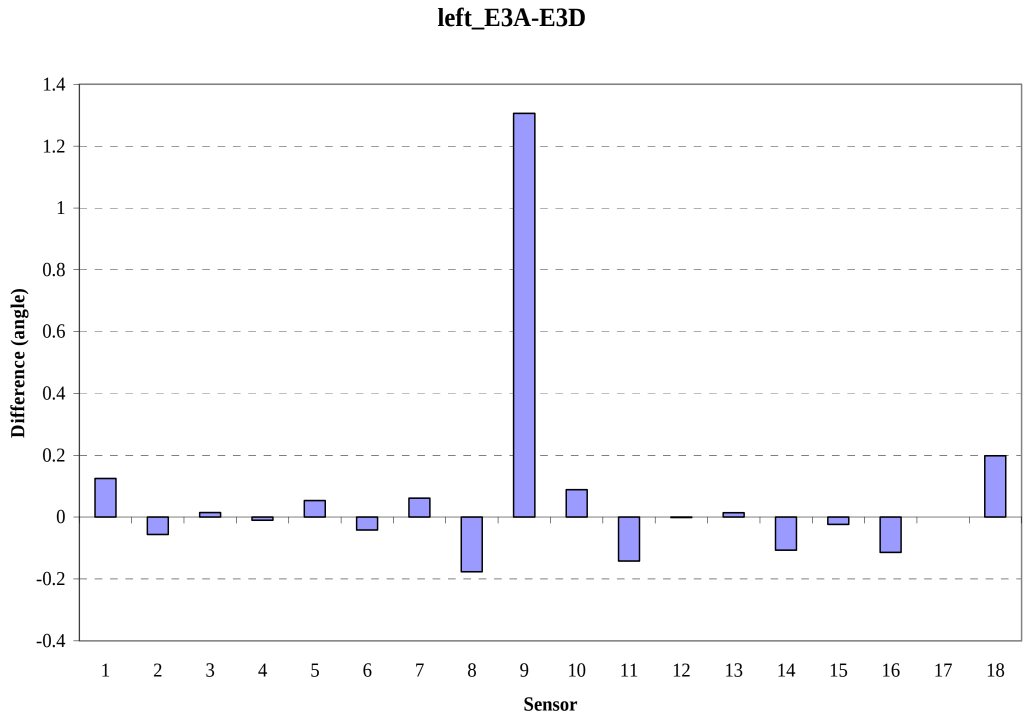



Figure 175. Ascending vs. descending E3 left hand

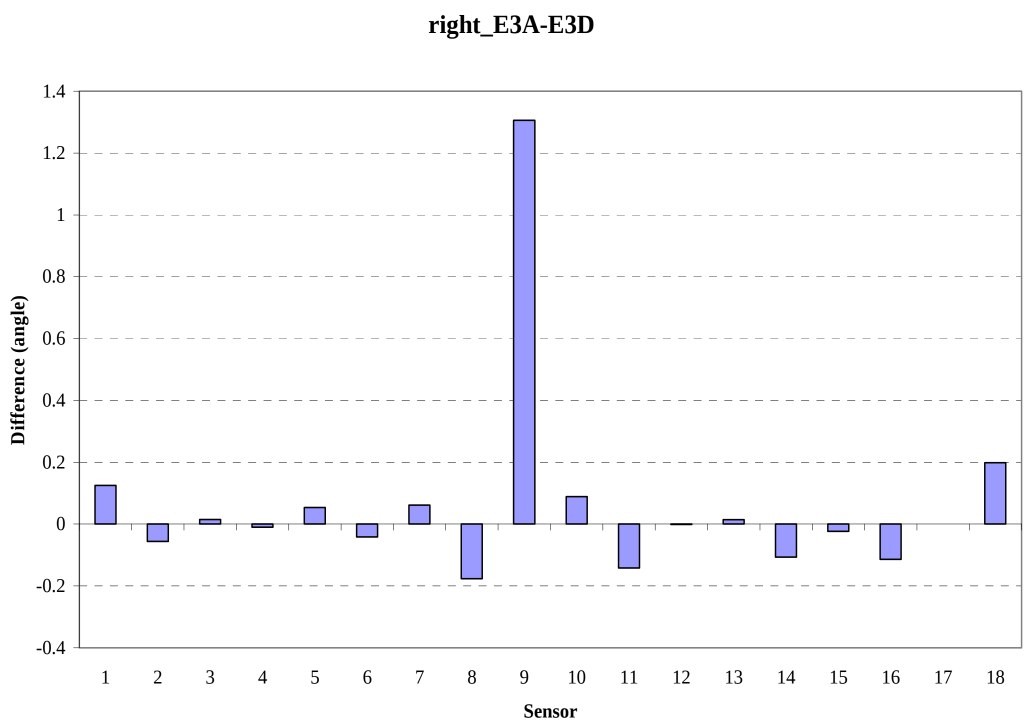



Figure 176. Ascending vs. descending E3 right hand

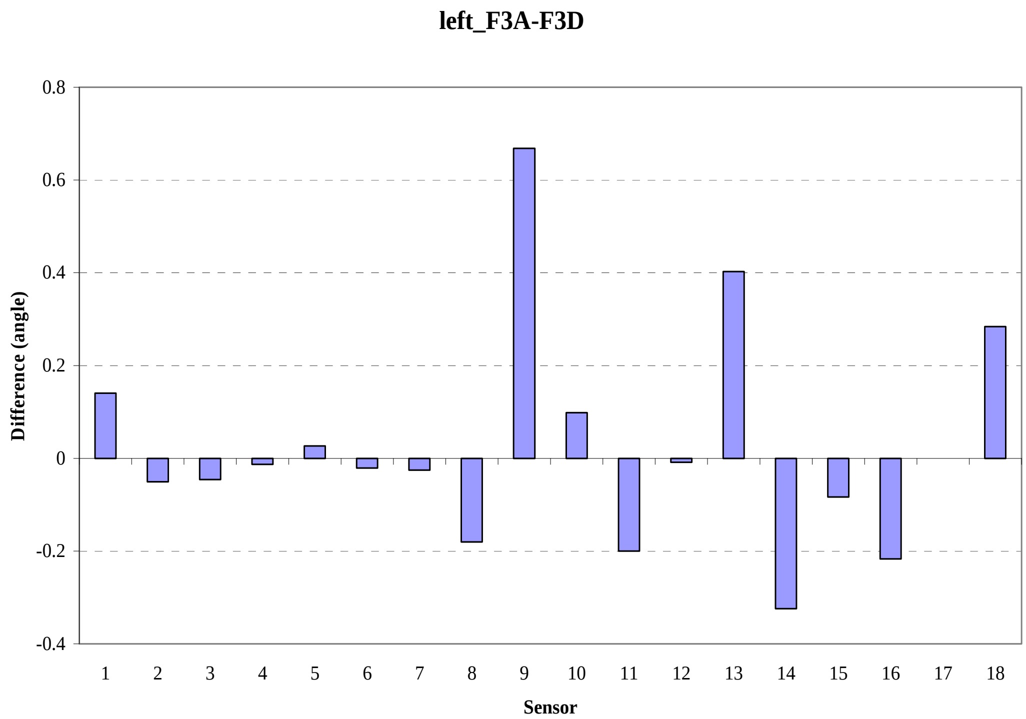



Figure 177. Ascending vs. descending F3 left hand

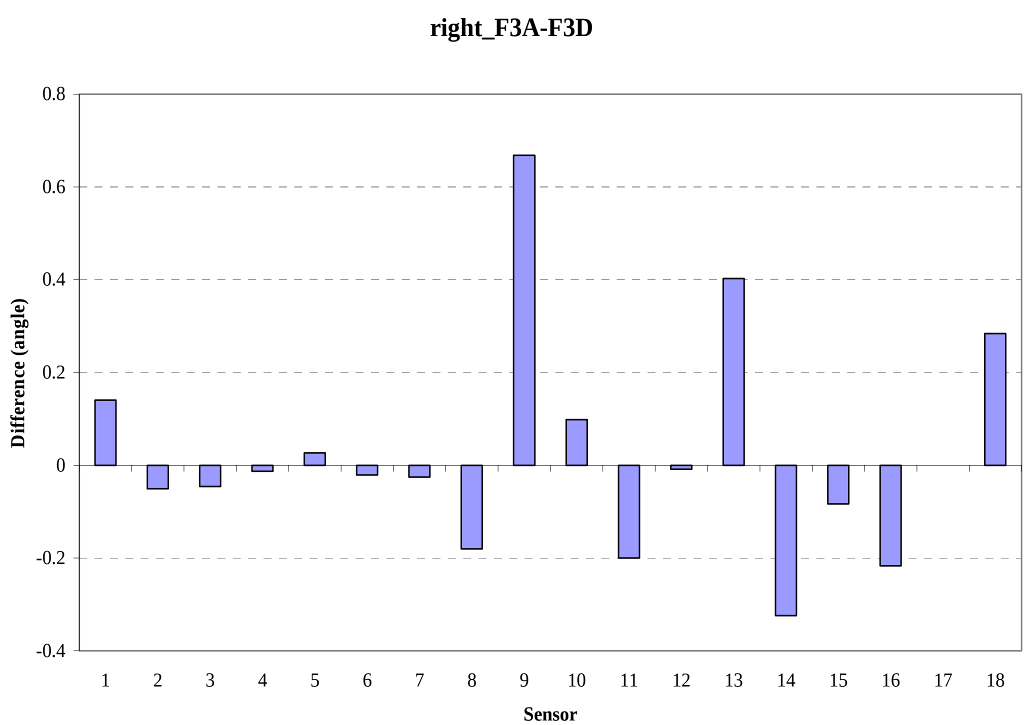



Figure 178. Ascending vs. descending F3 right hand

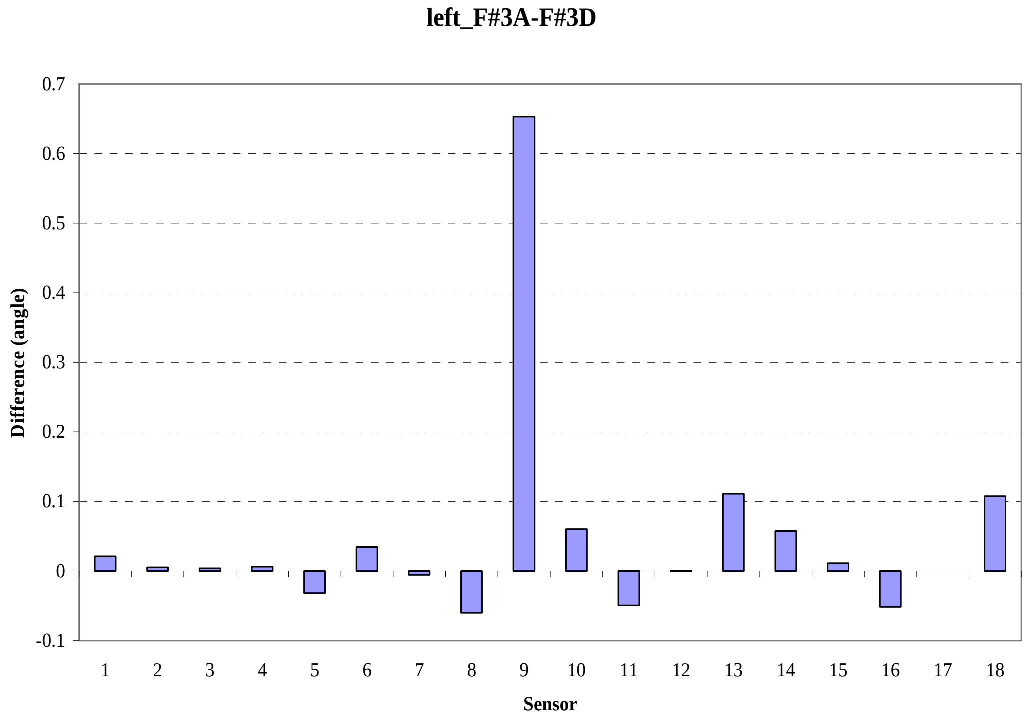



Figure 179. Ascending vs. descending F#3 left hand

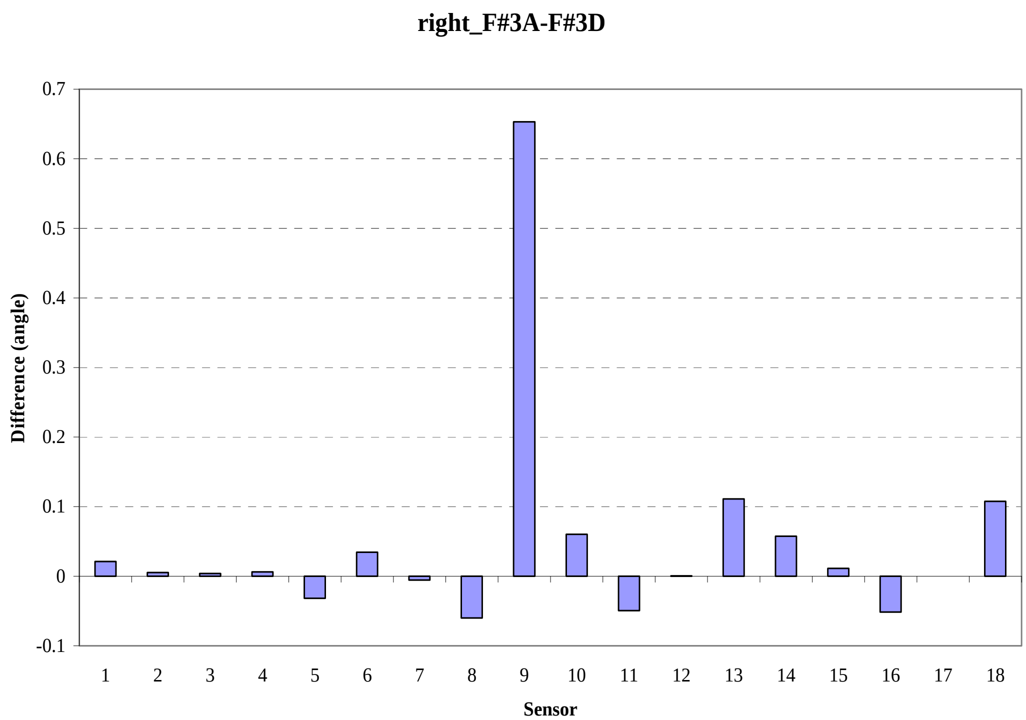



Figure 180. Ascending vs. descending F#3 right hand

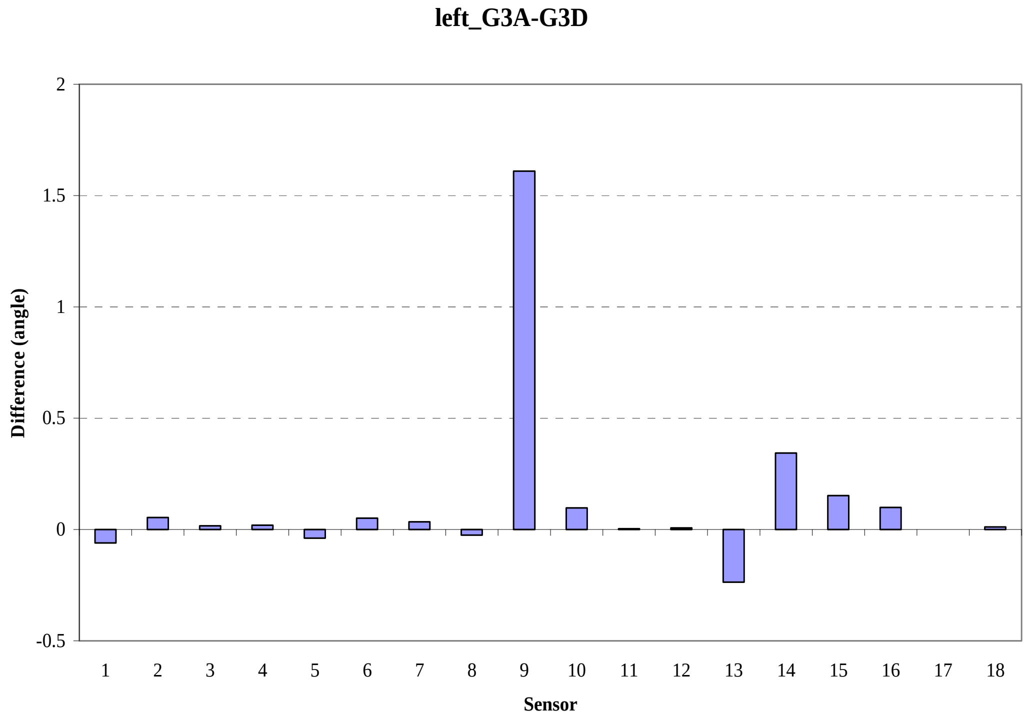



Figure 181. Ascending vs. descending G3 left hand

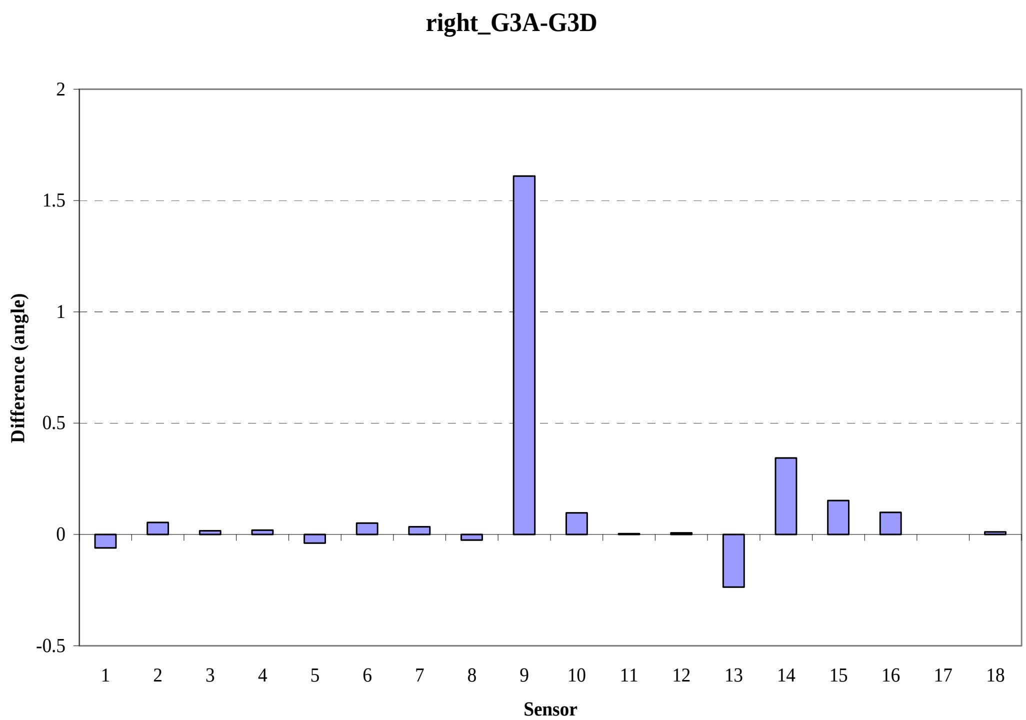



Figure 182. Ascending vs. descending G3 right hand

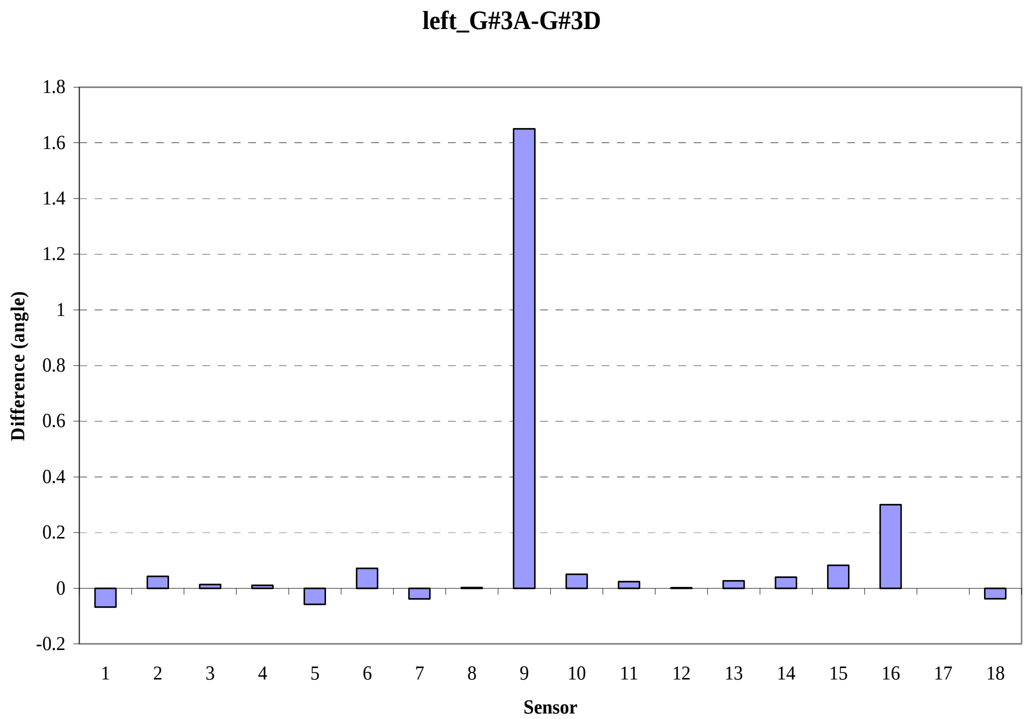



Figure 183. Ascending vs. descending G#3 left hand

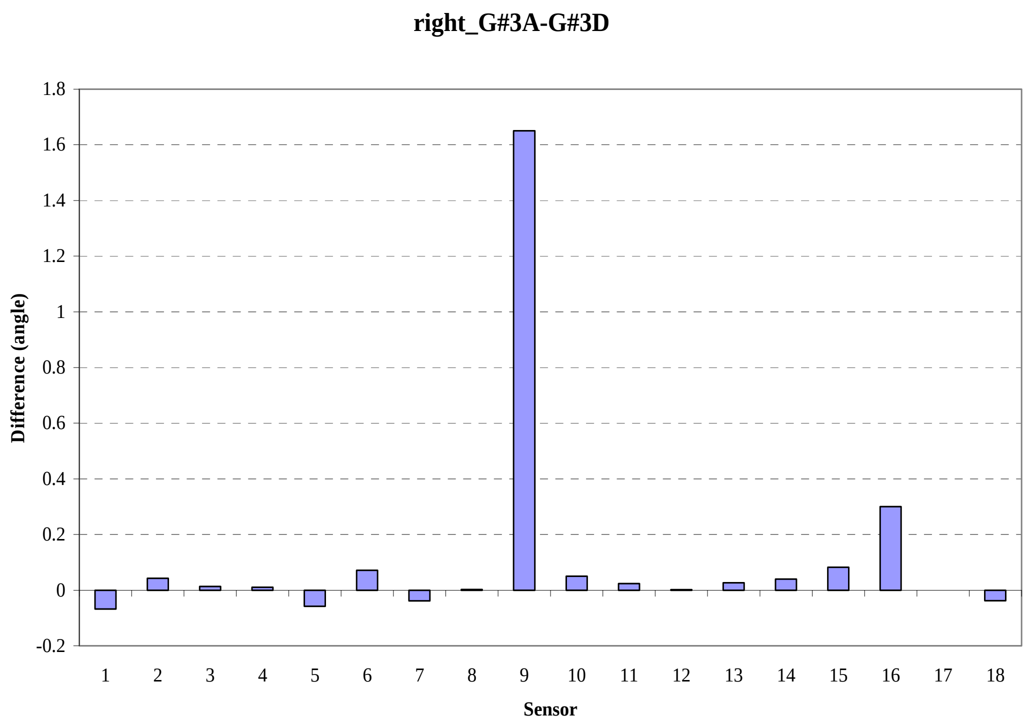



Figure 184. Ascending vs. descending G#3 right hand

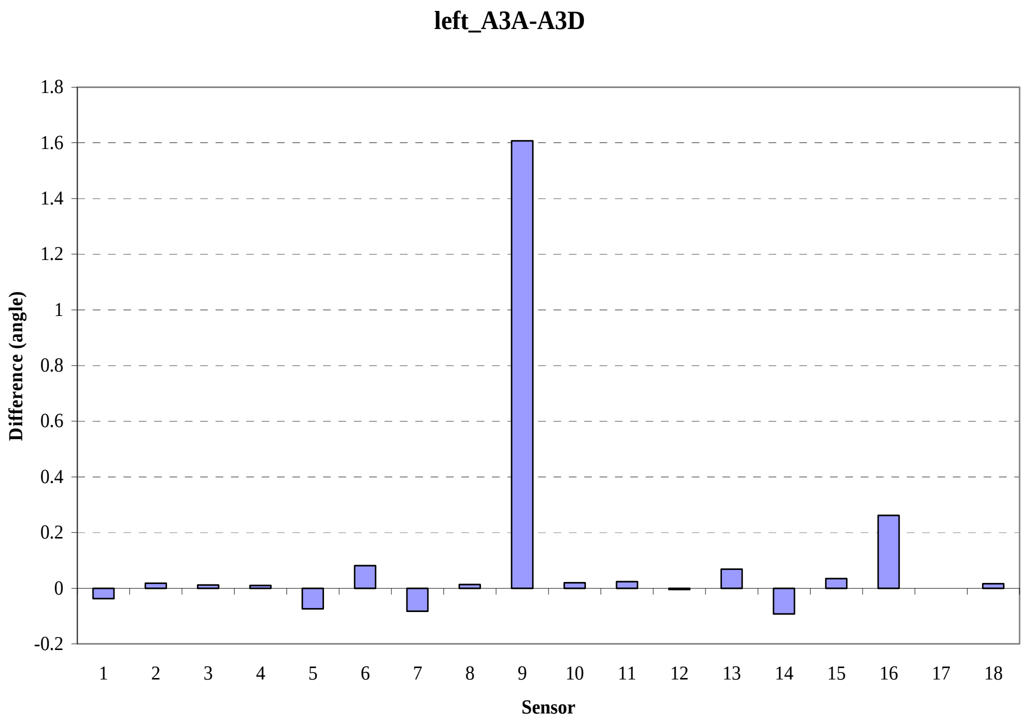



Figure 185. Ascending vs. descending A3 left hand

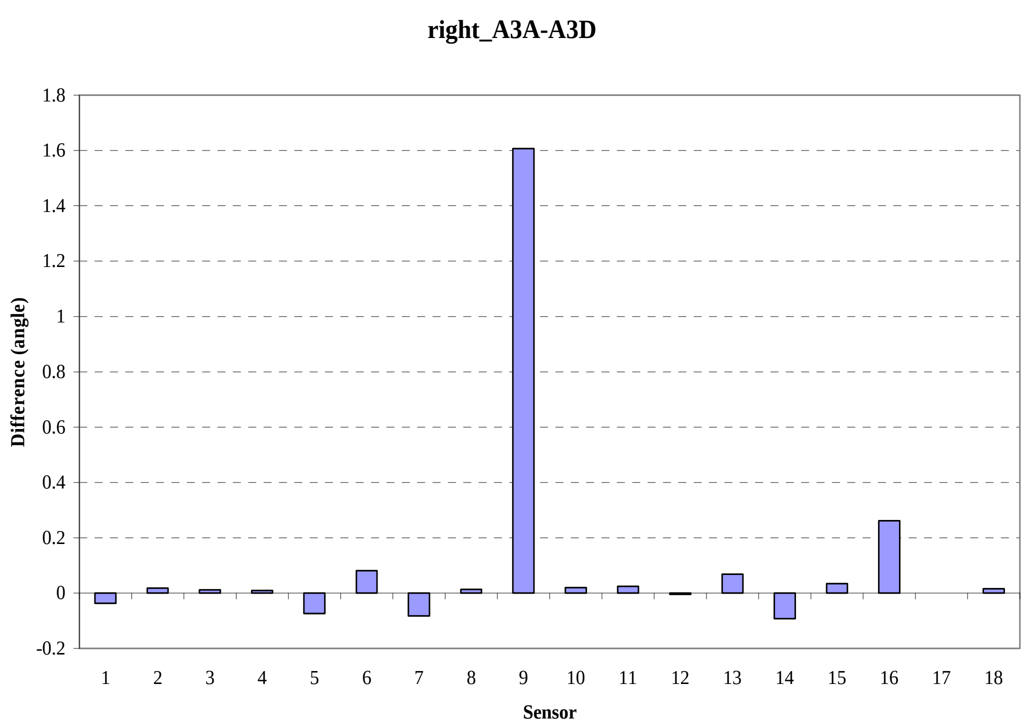



Figure 188. Ascending vs. descending A3 right hand

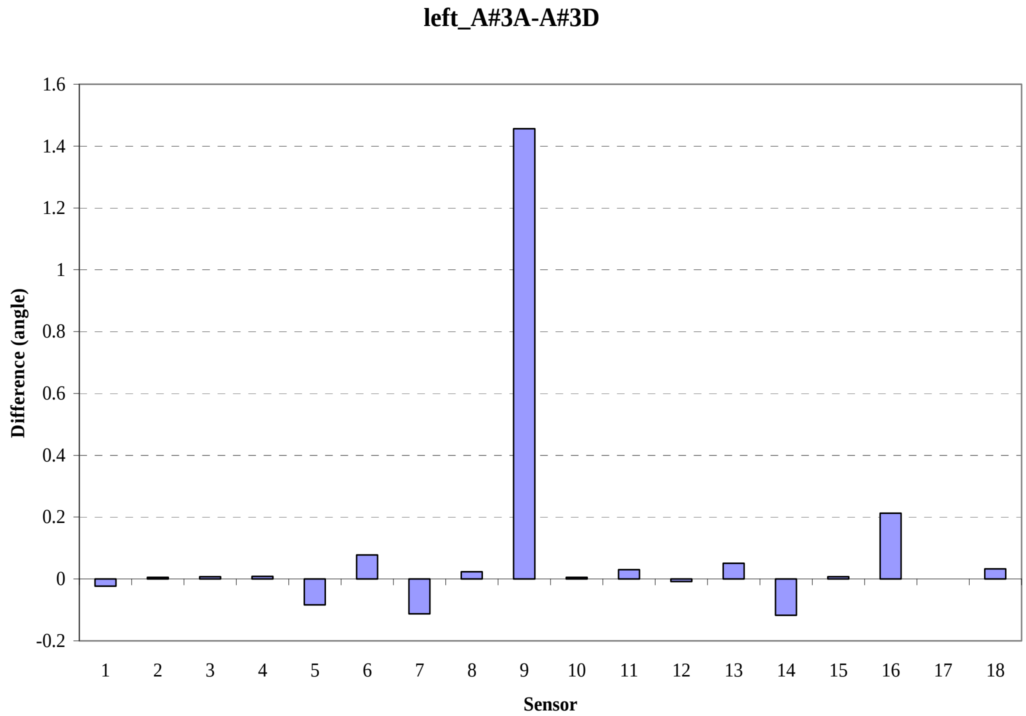



Figure 188. Ascending vs. descending A#3 left hand

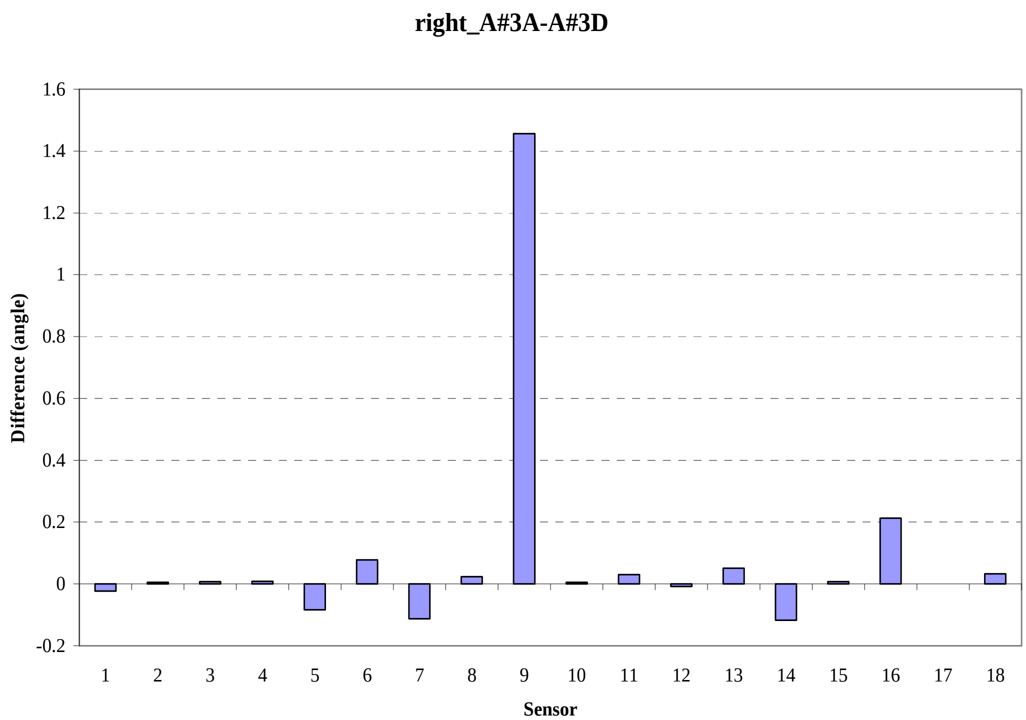



Figure 189. Ascending vs. descending A#3 right hand

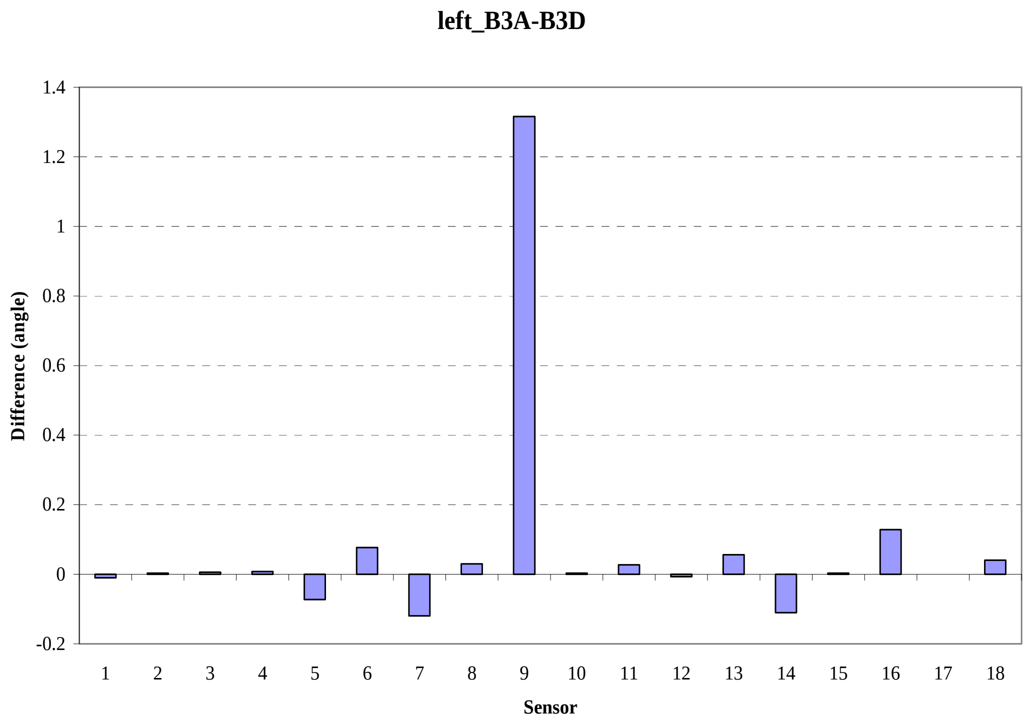



Figure 189. Ascending vs. descending B3 left hand

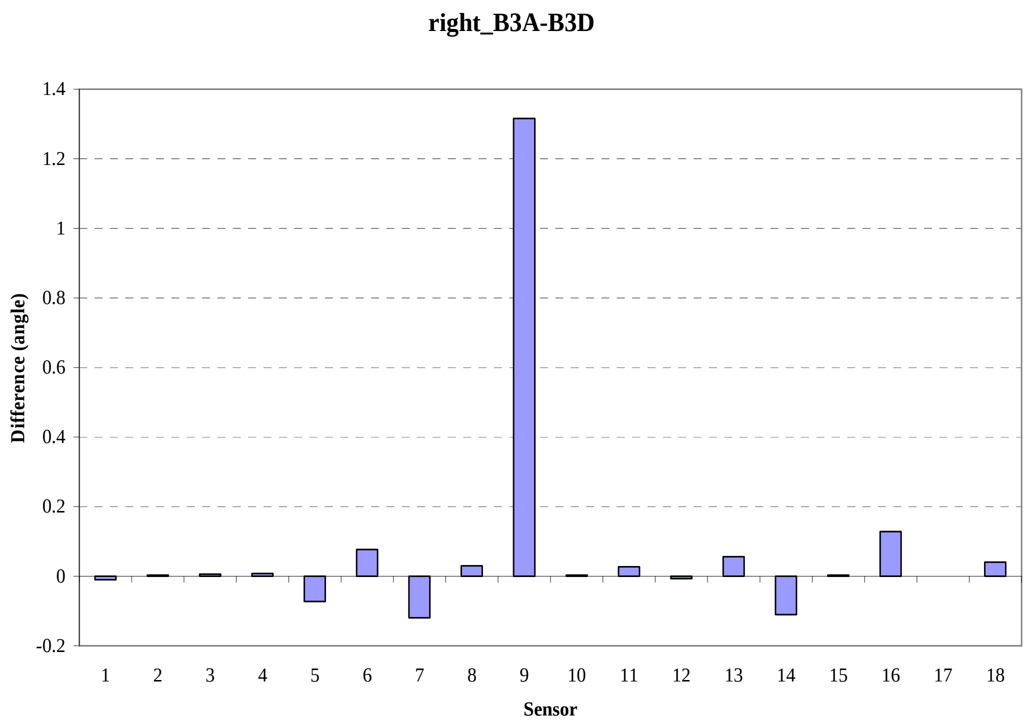



Figure 190. Ascending vs. descending B3 right hand

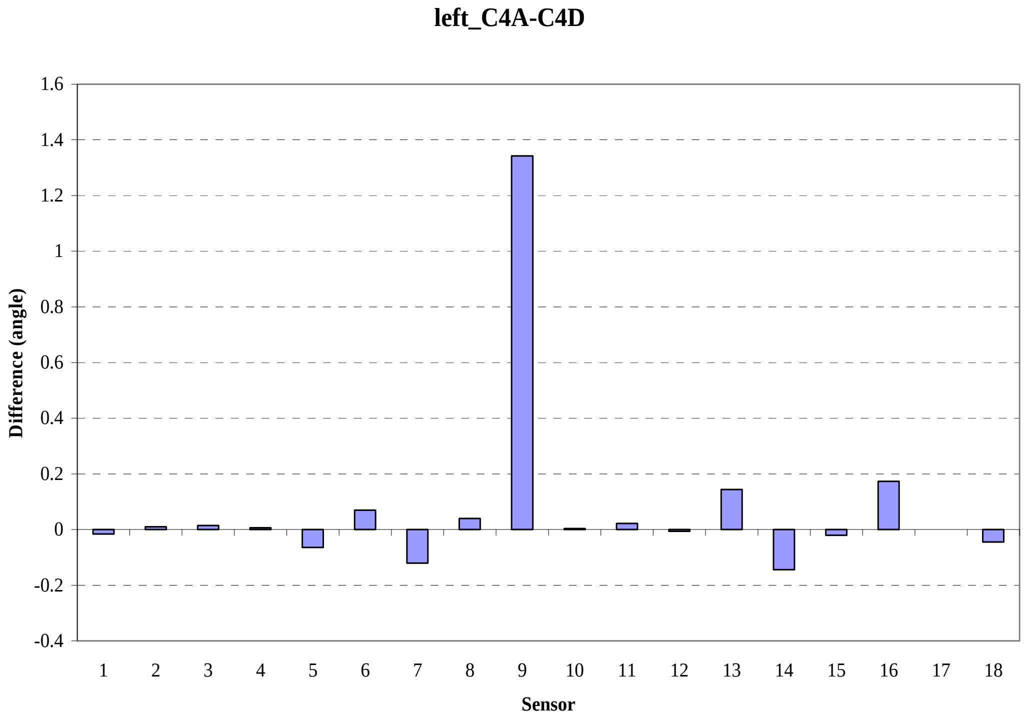



Figure 191. Ascending vs. descending C4 left hand

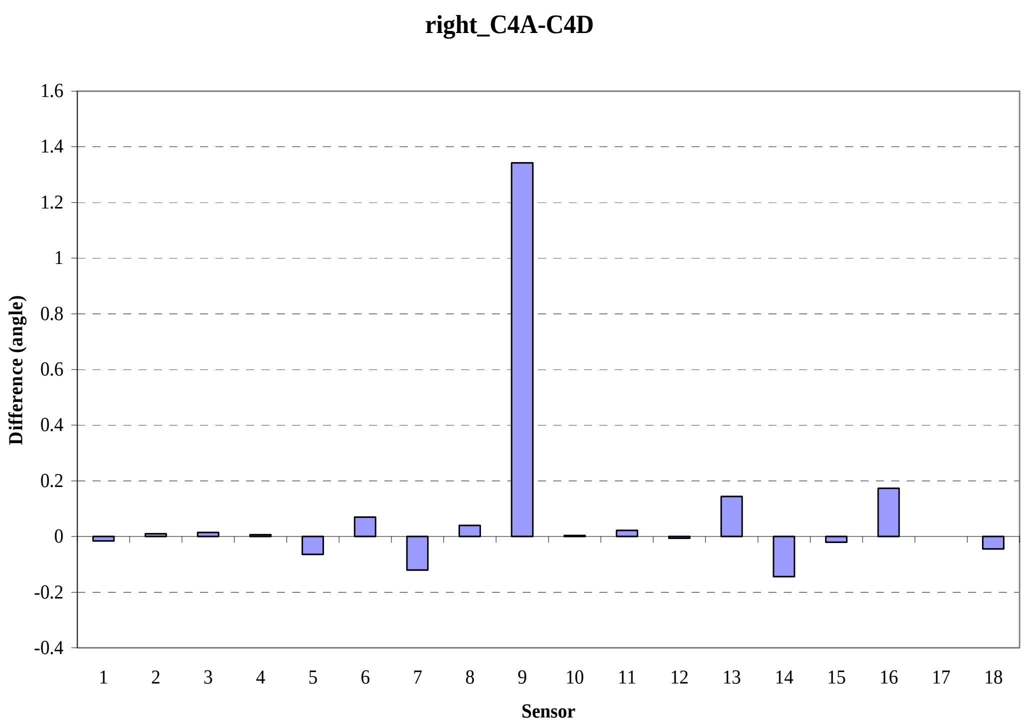



Figure 192. Ascending vs. descending C4 right hand

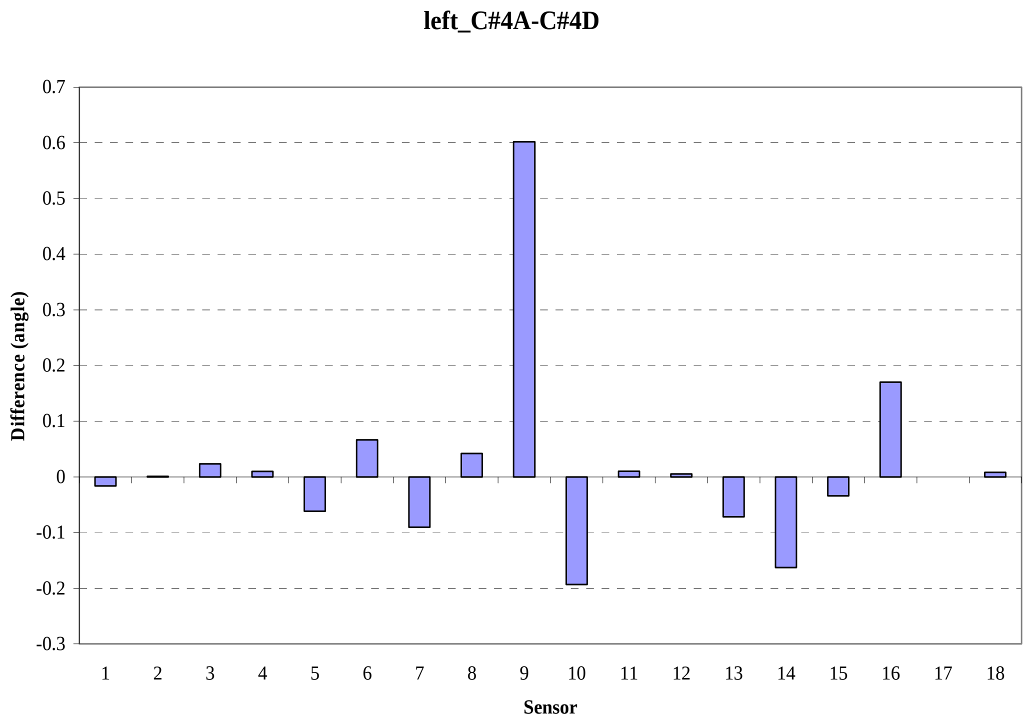



Figure 193. Ascending vs. descending C#4 left hand

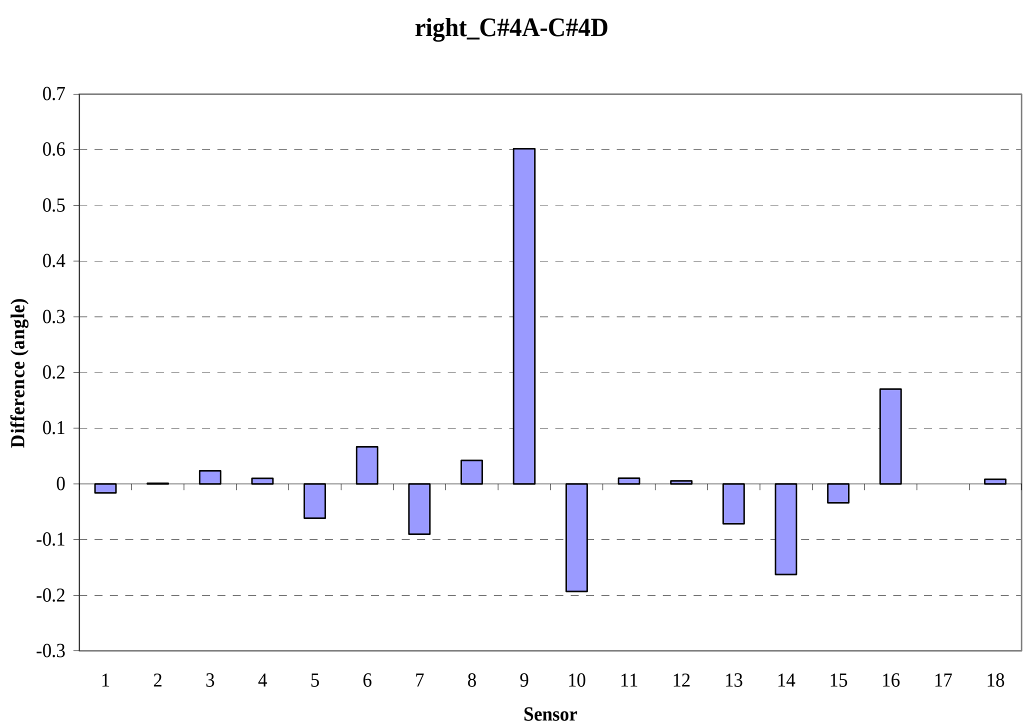



Figure 194. Ascending vs. descending C#4 right hand

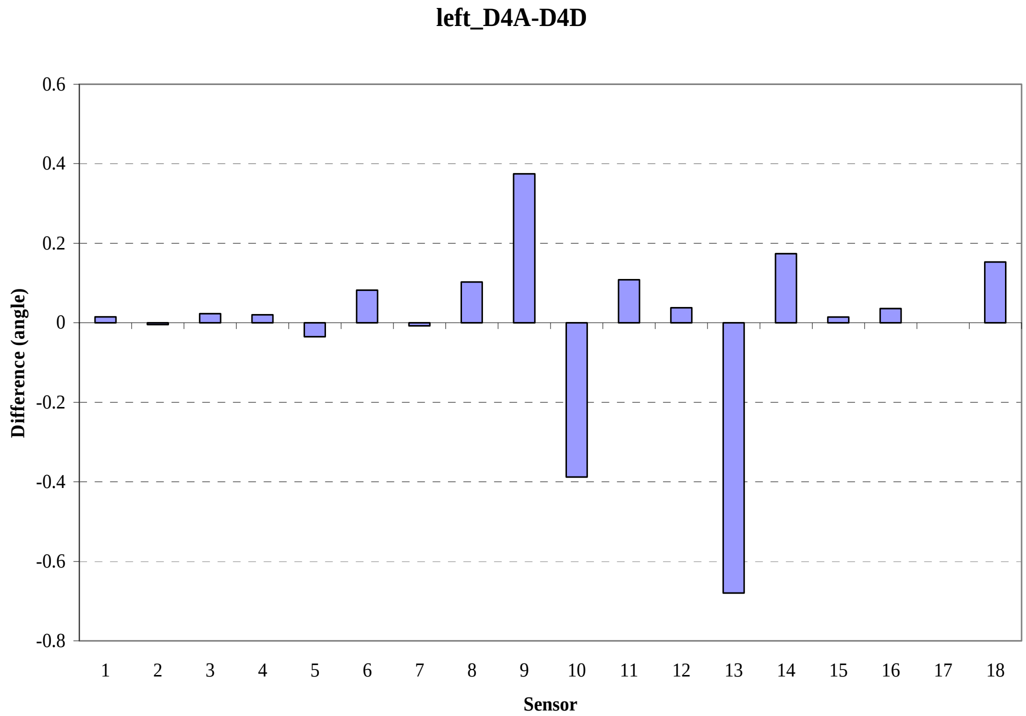



Figure 195. Ascending vs. descending D4 left hand

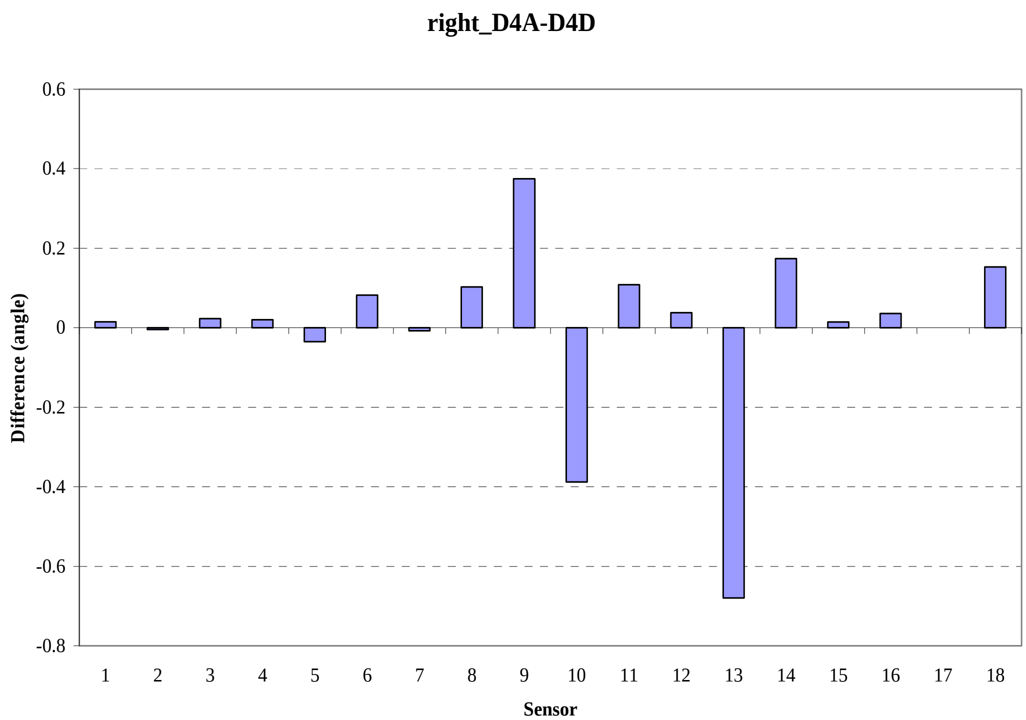



Figure 196. Ascending vs. descending D4 right hand

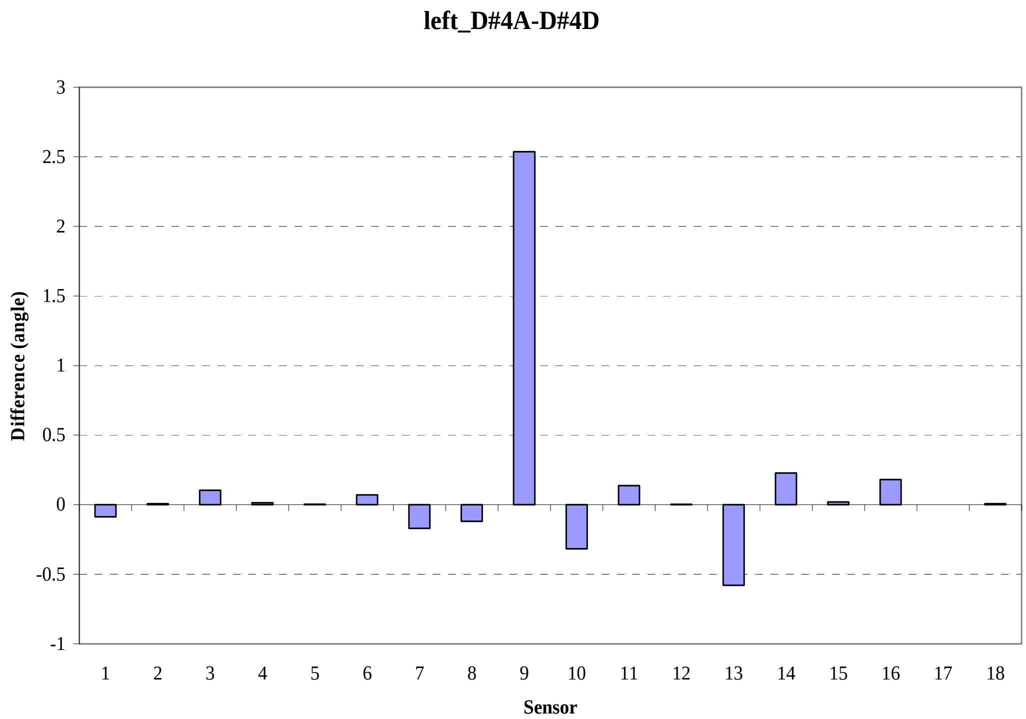



Figure 197. Ascending vs. descending D#4 left hand

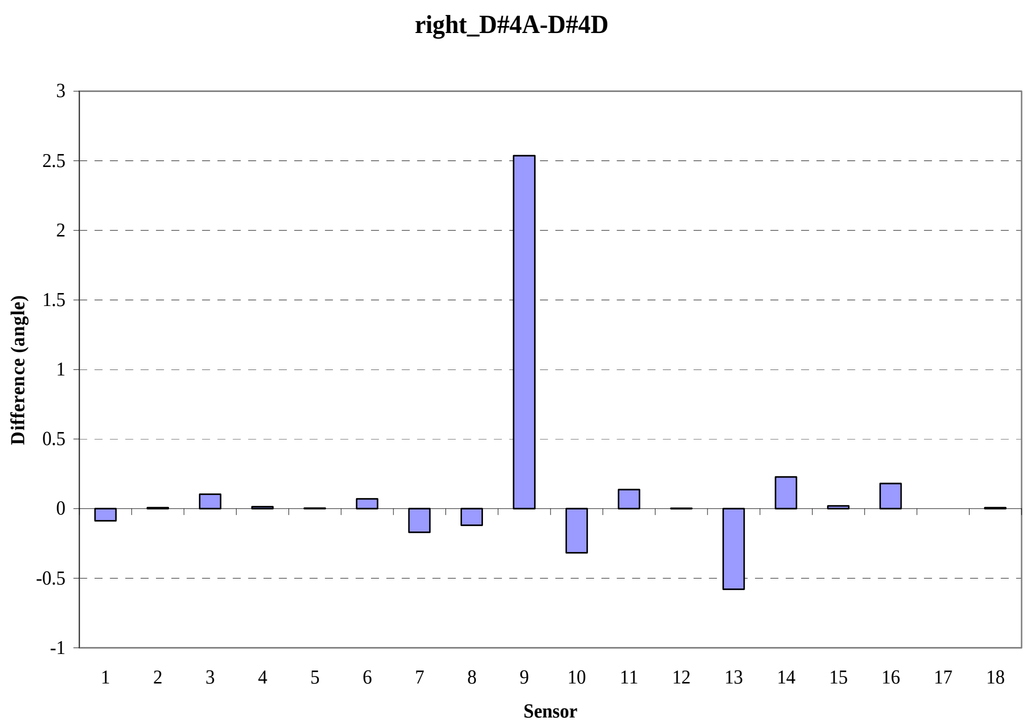



Figure 198. Ascending vs. descending D#4 right hand

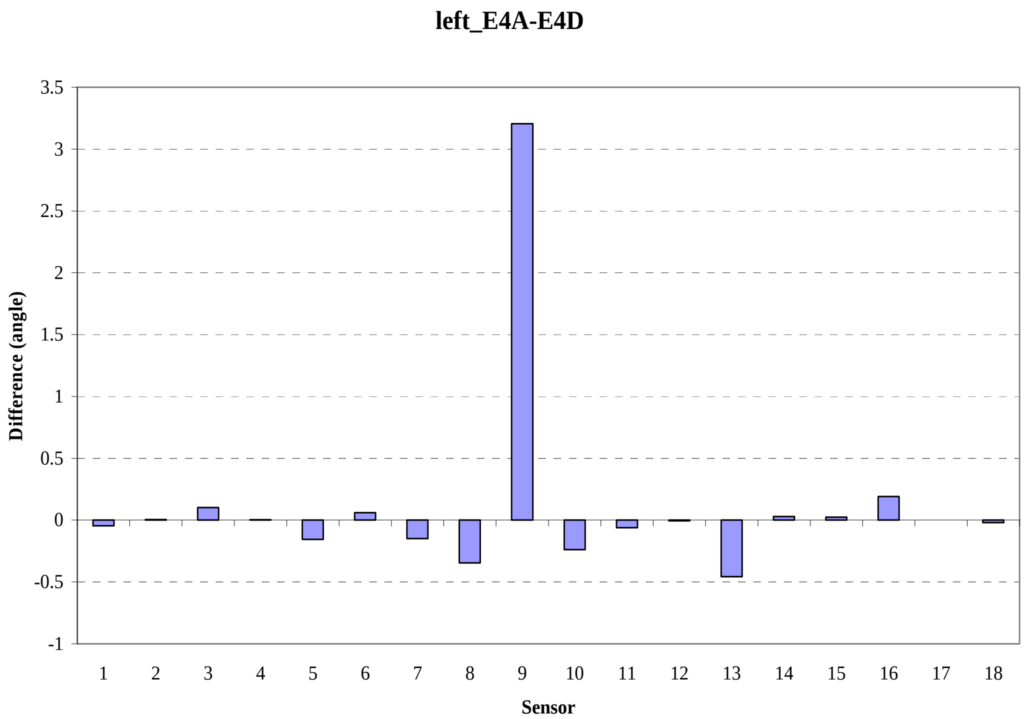



Figure 199. Ascending vs. descending E4 left hand

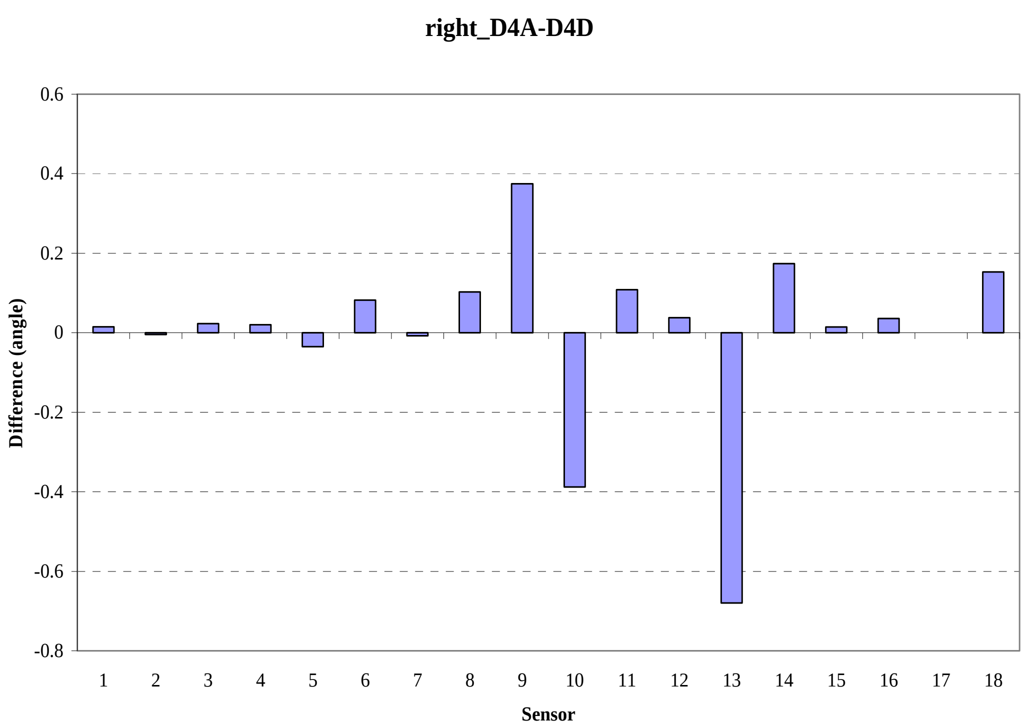



Figure 200. Ascending vs. descending E4 right hand

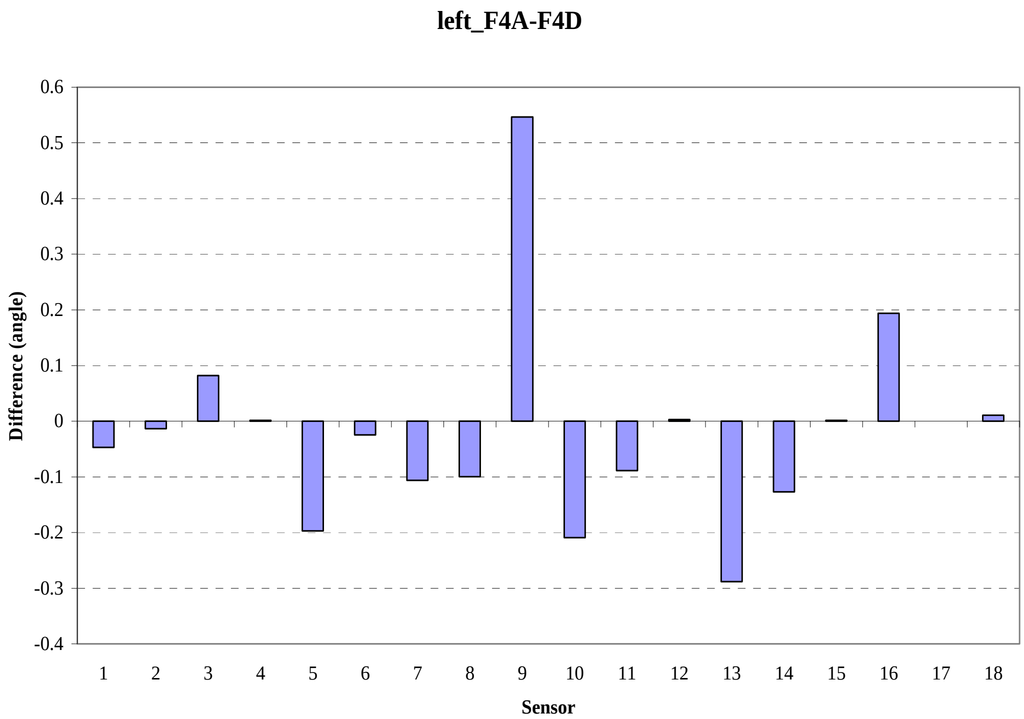



Figure 201. Ascending vs. descending F4 left hand

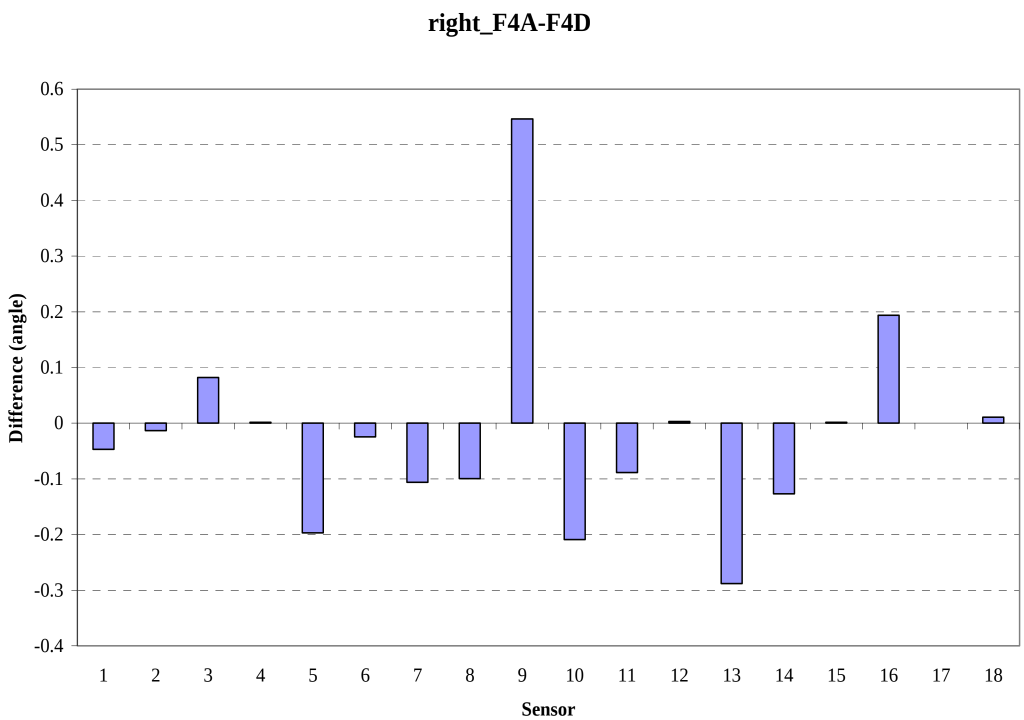



Figure 202. Ascending vs. descending F4 right hand

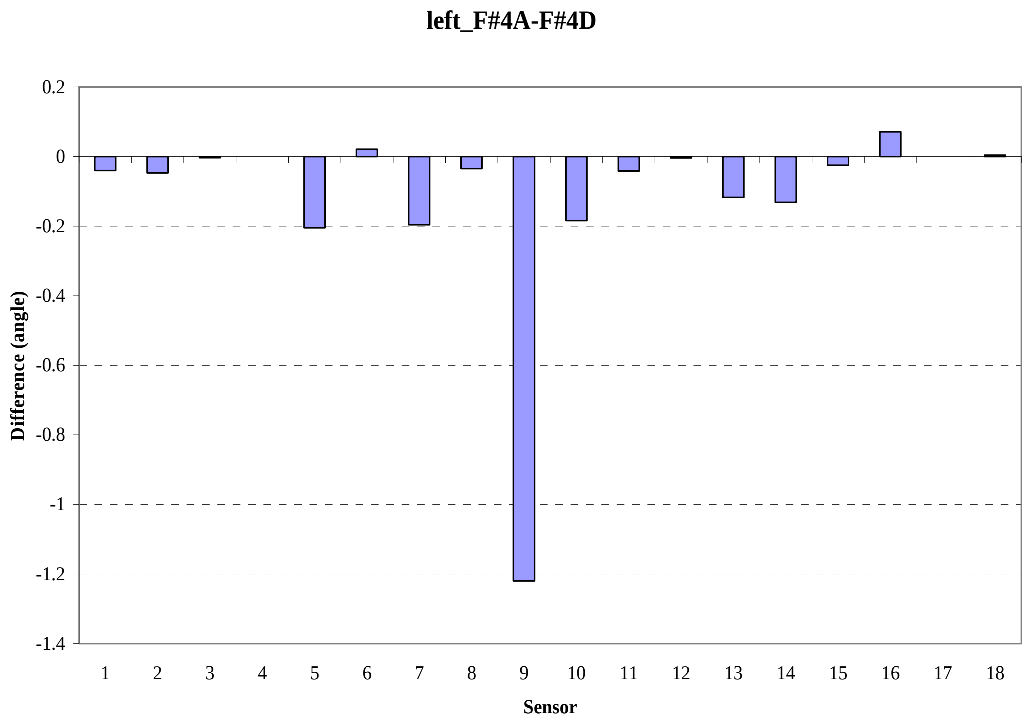



Figure 203. Ascending vs. descending F#4 left hand

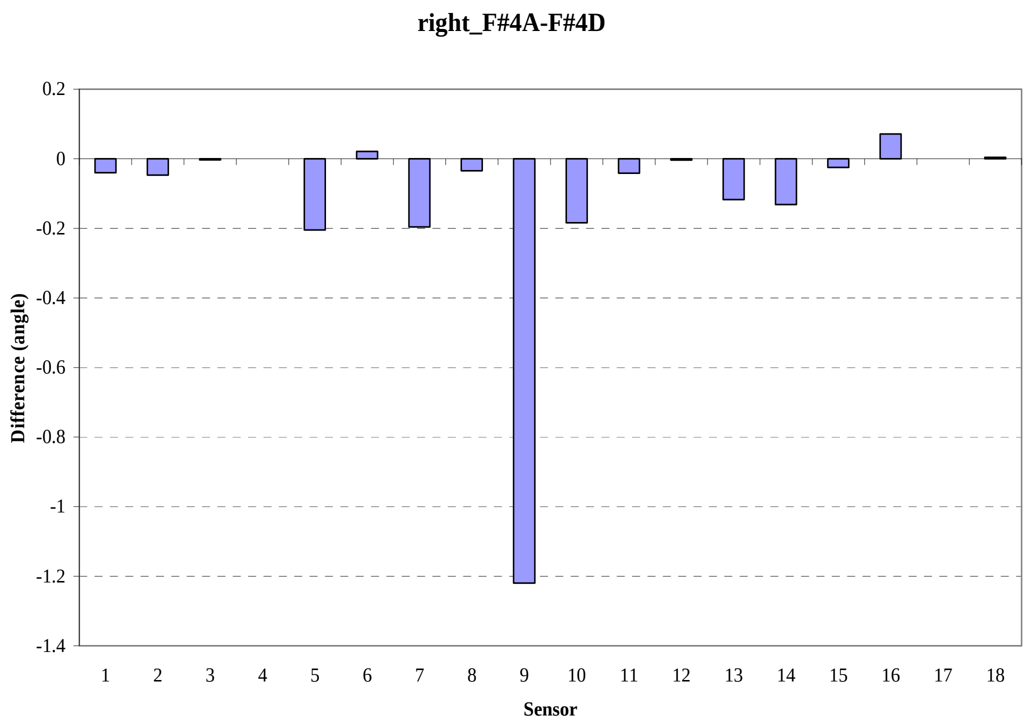



Figure 204. Ascending vs. descending F#4 right hand

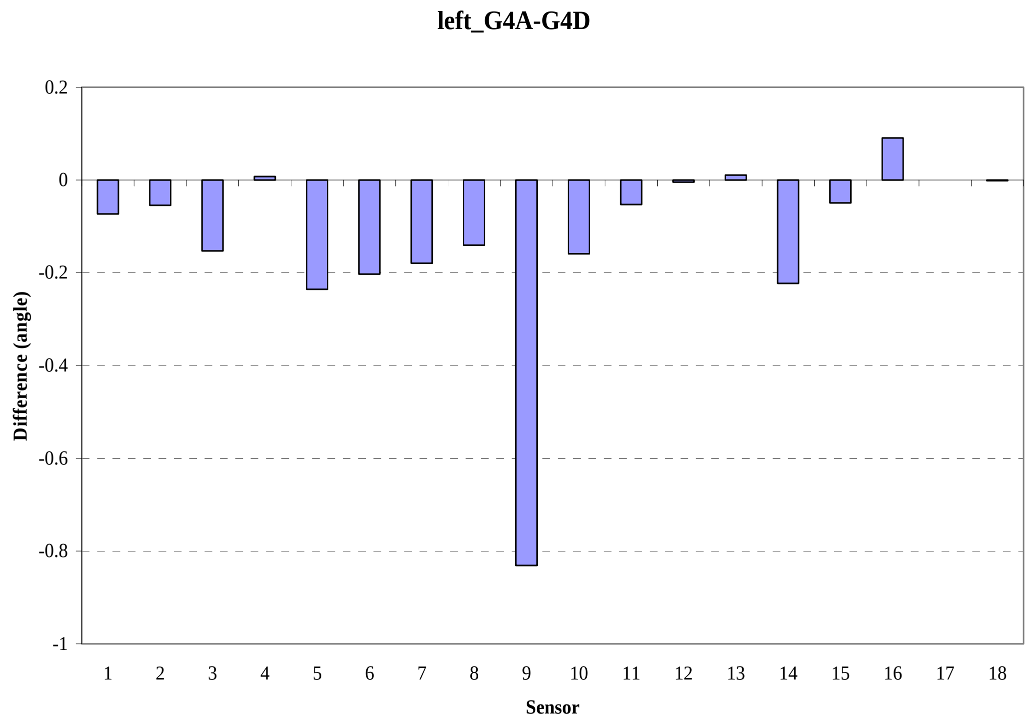



Figure 205. Ascending vs. descending G4 left hand

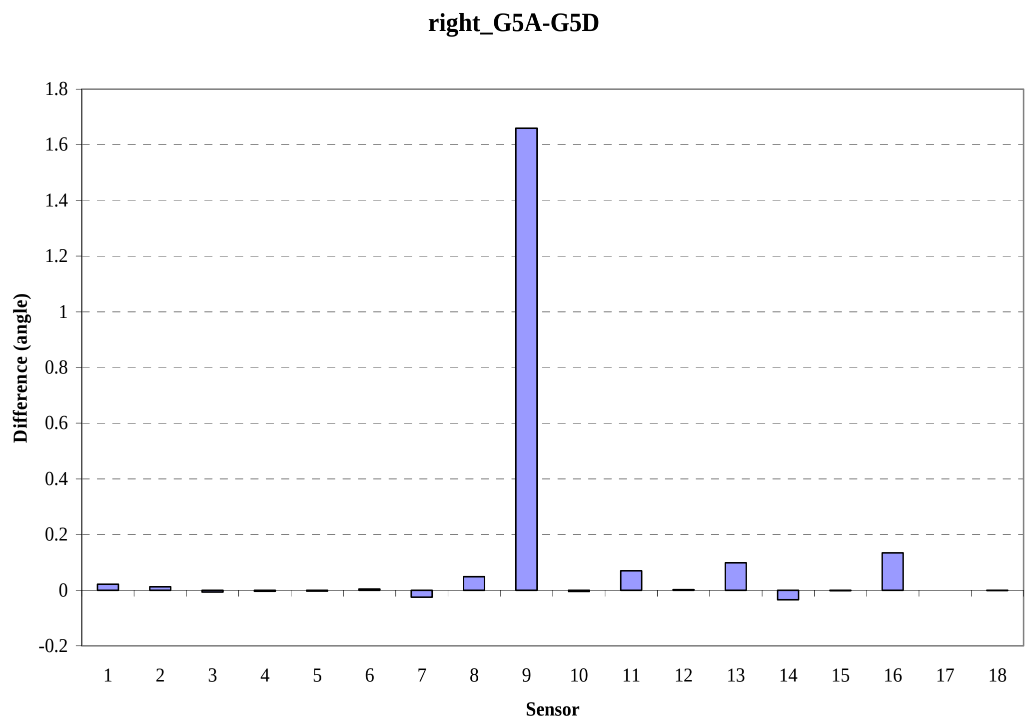



Figure 206. Ascending vs. descending G4 right hand

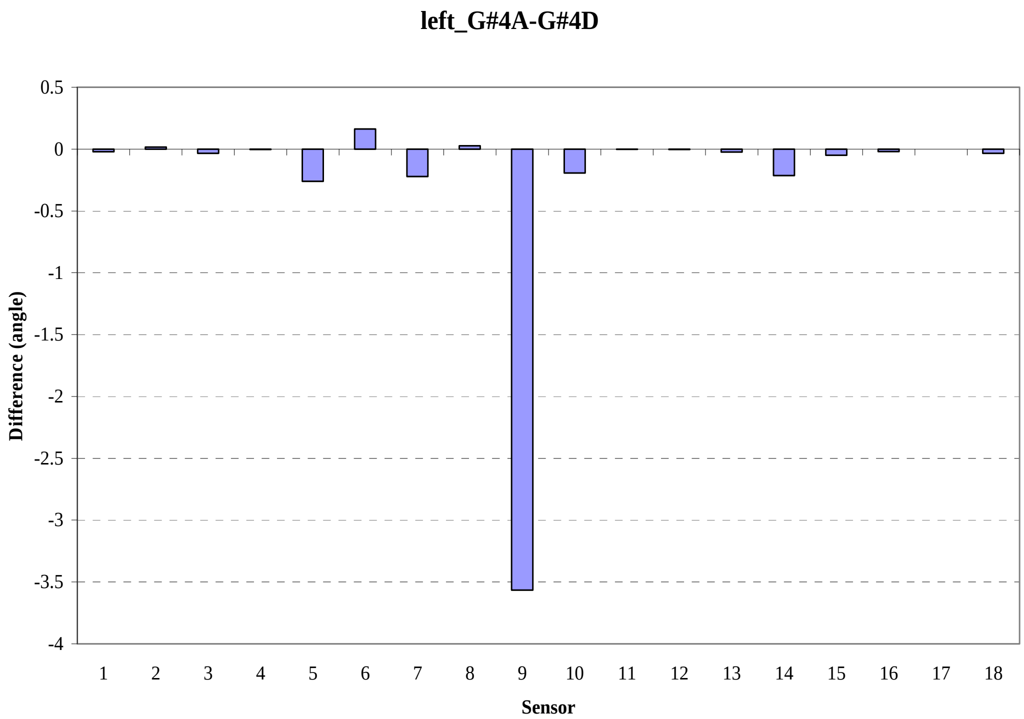



Figure 207. Ascending vs. descending G#4 left hand

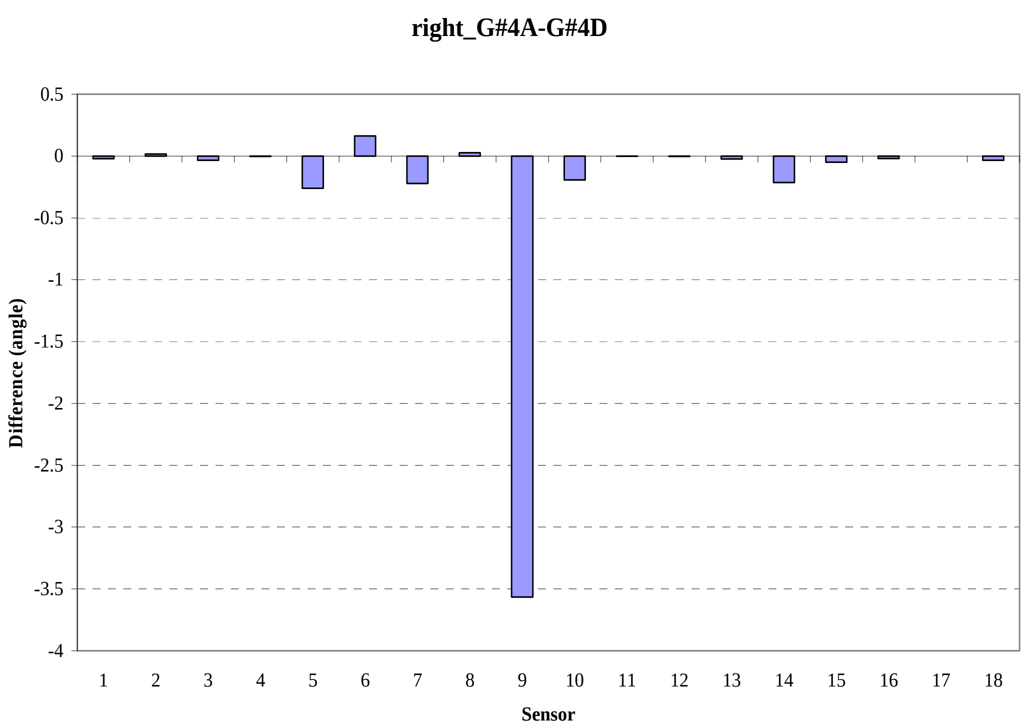



Figure 208. Ascending vs. descending G#4 right hand

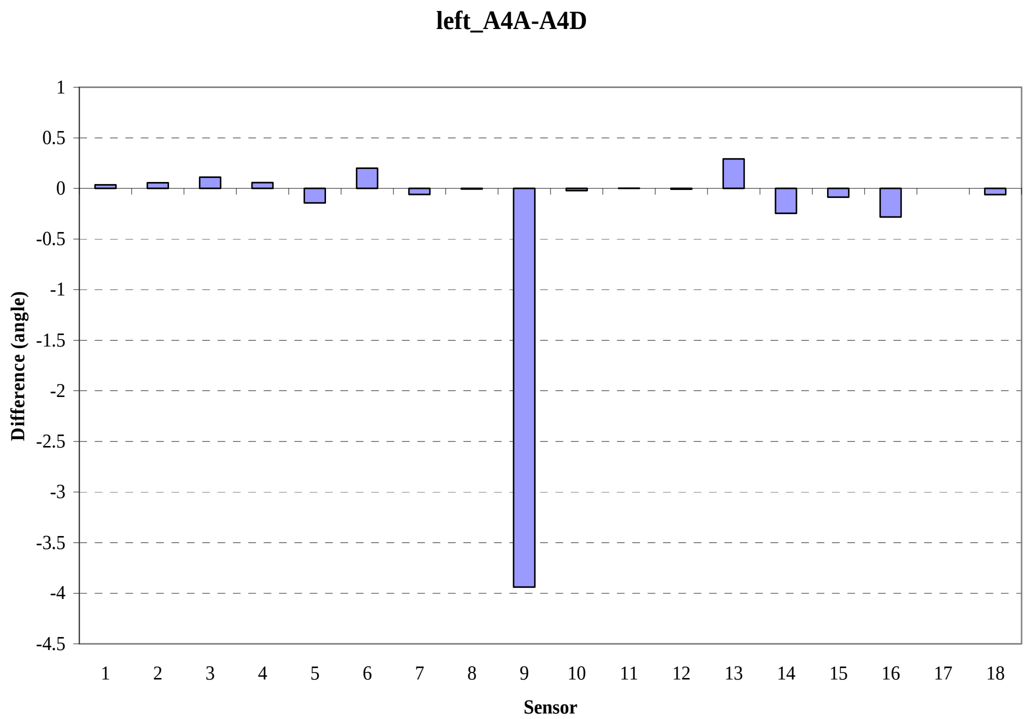



Figure 209. Ascending vs. descending A4 left hand

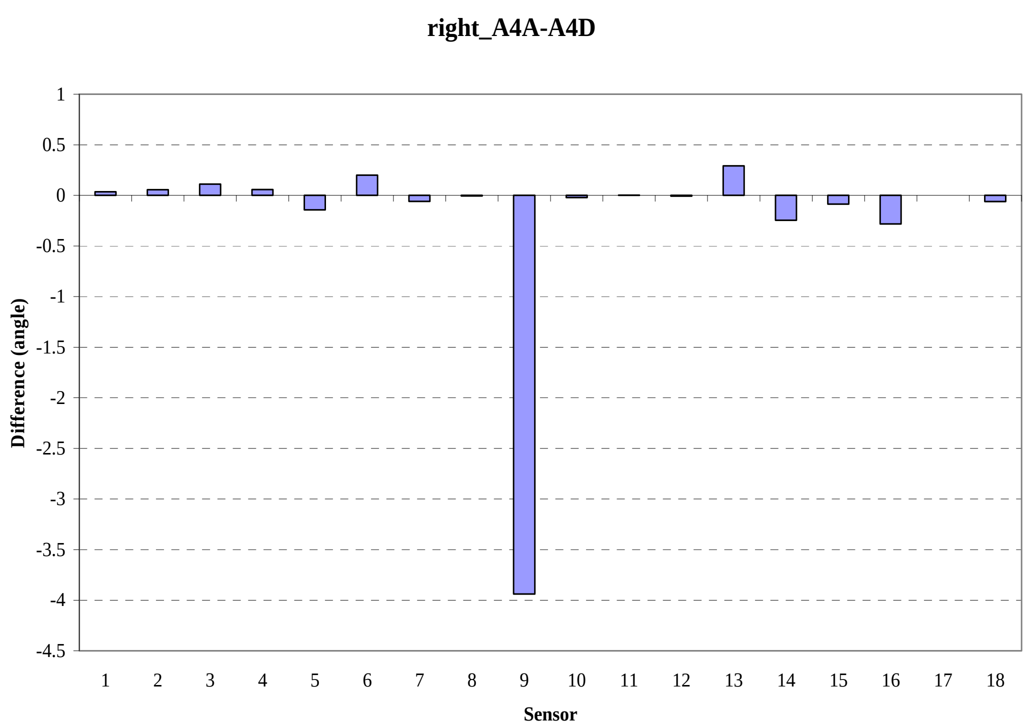



Figure 210. Ascending vs. descending A4 right hand

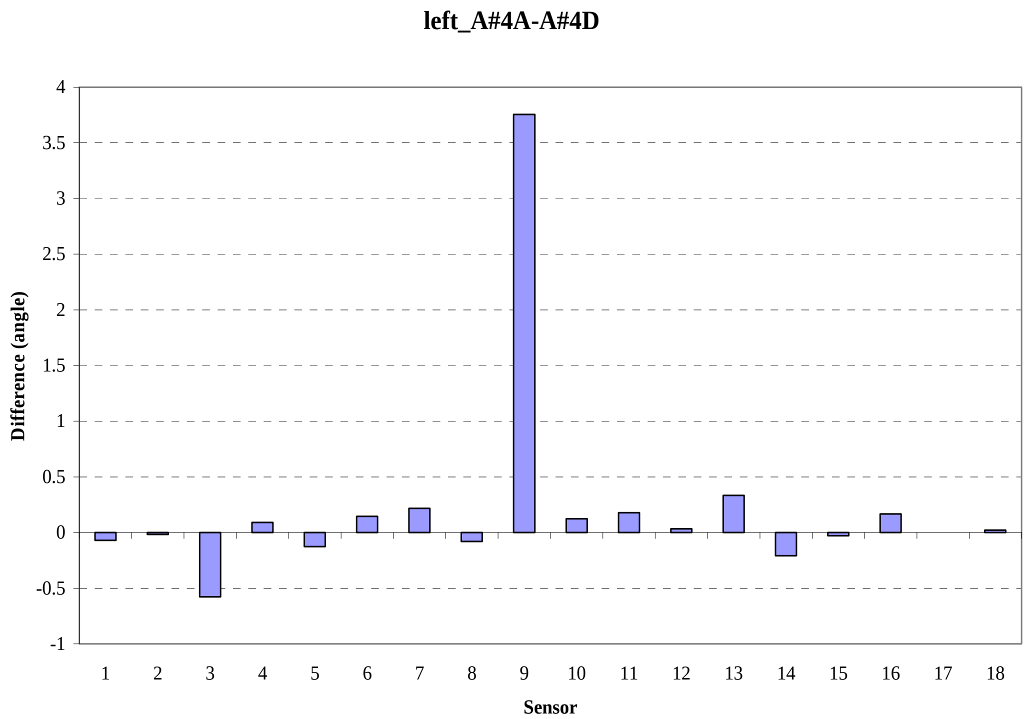



Figure 211. Ascending vs. descending A#4 left hand

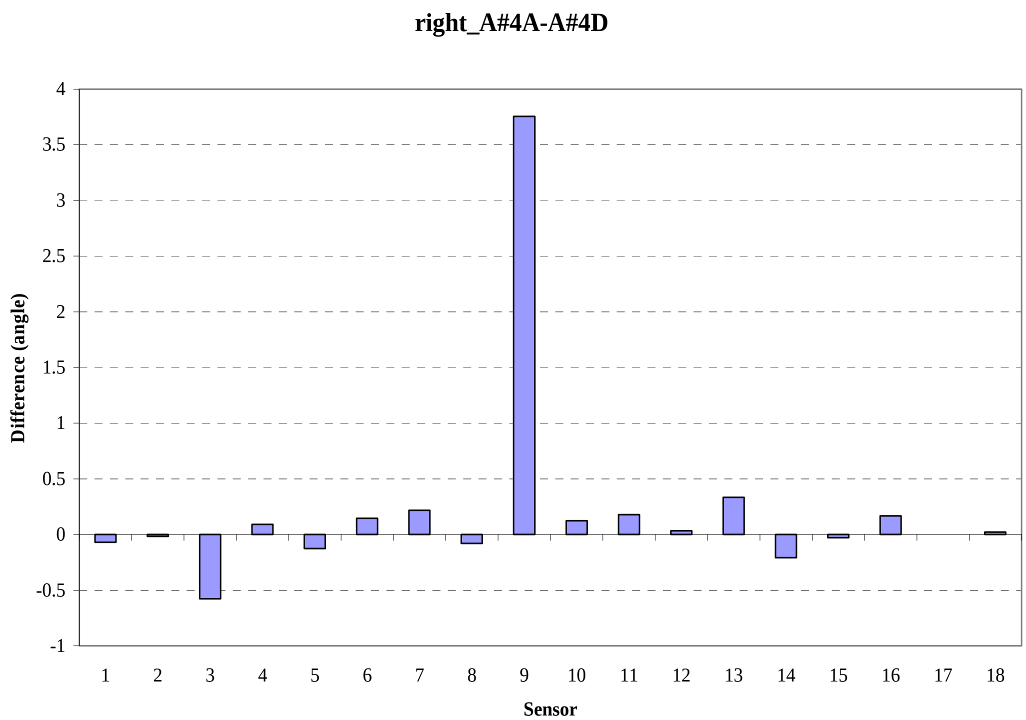



Figure 212. Ascending vs. descending A#4 right hand

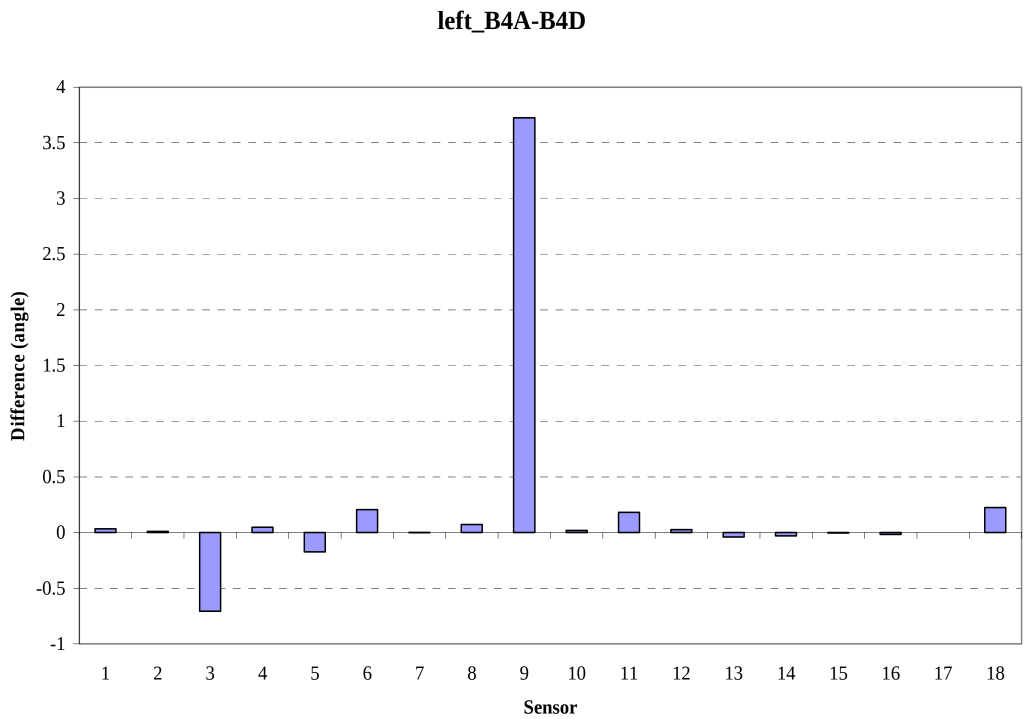



Figure 213. Ascending vs. descending B4 left hand

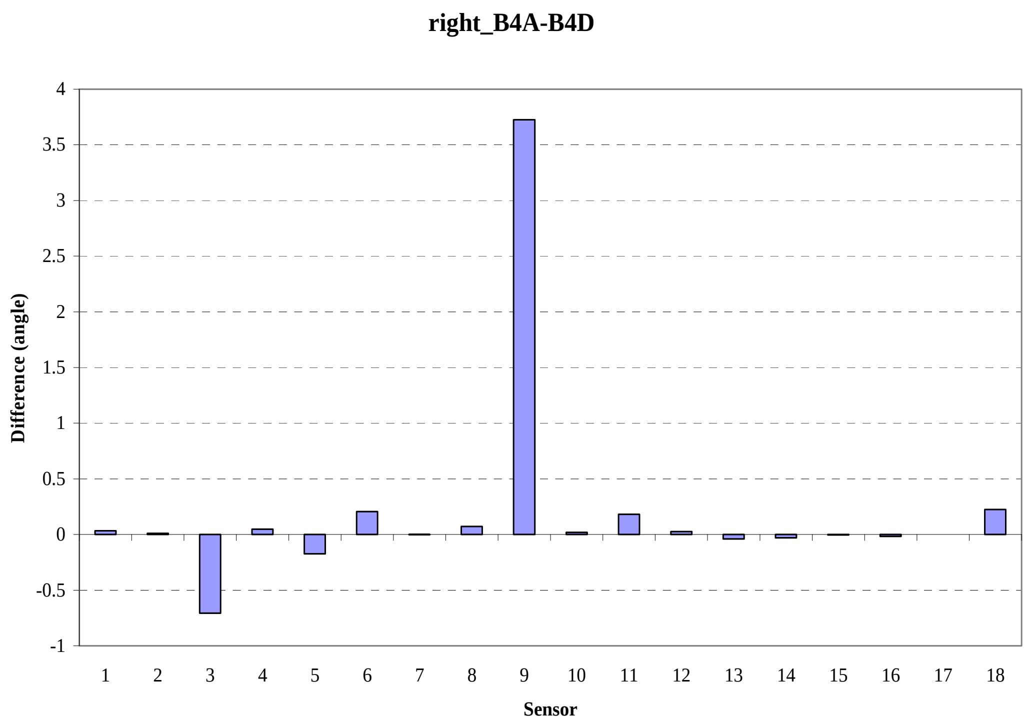



Figure 214. Ascending vs. descending B4 right hand

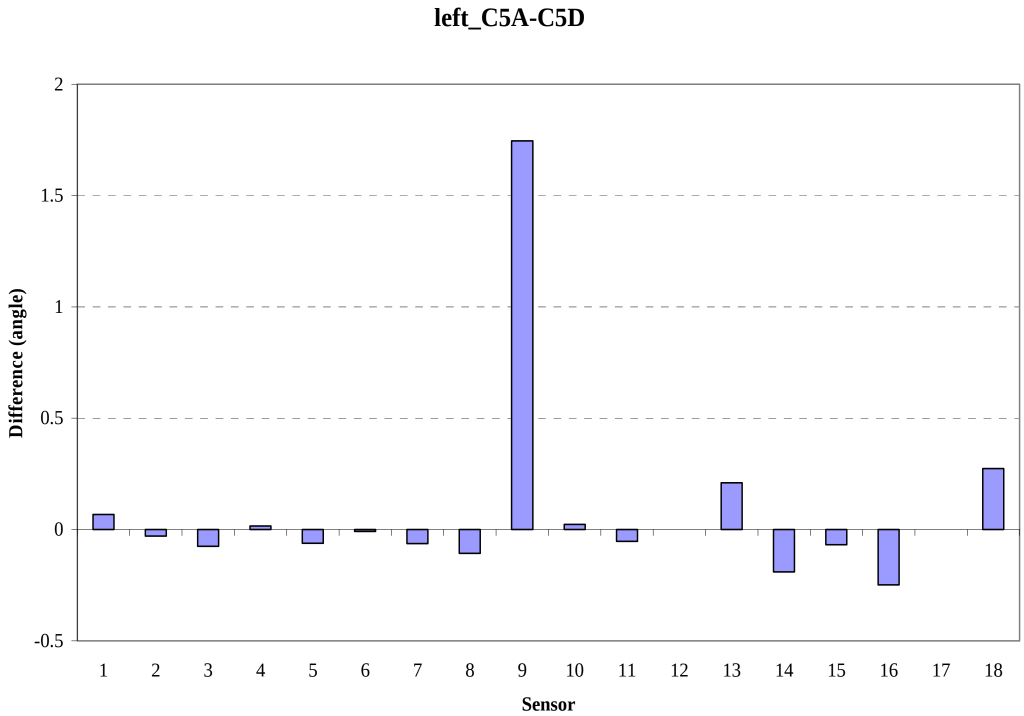



Figure 215. Ascending vs. descending C5 left hand

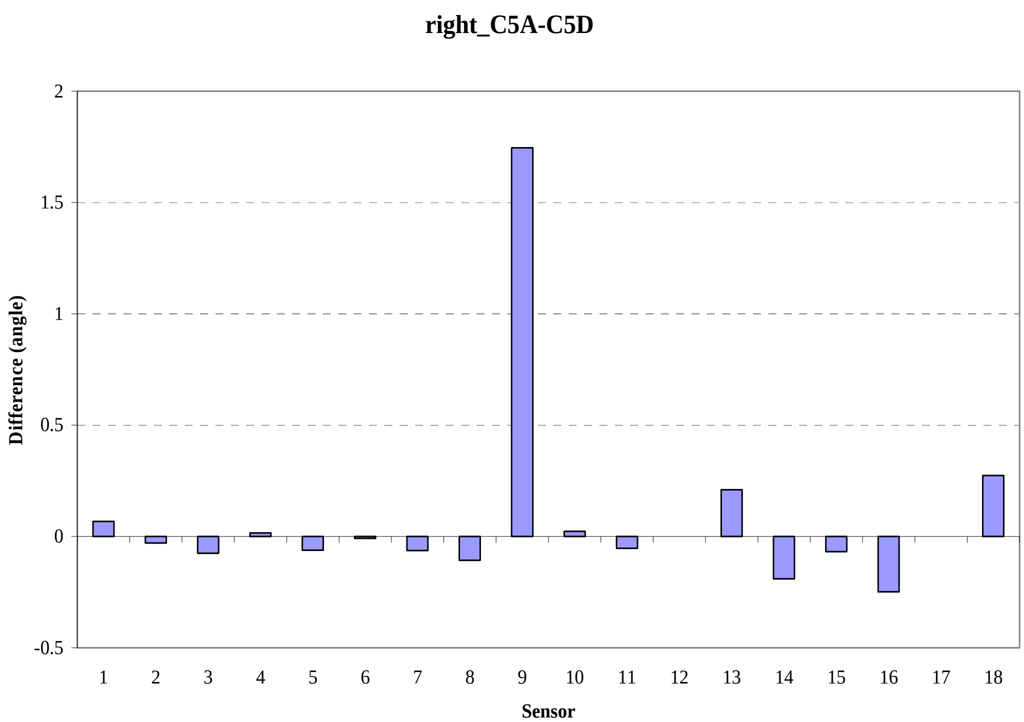



Figure 216. Ascending vs. descending C5 right hand

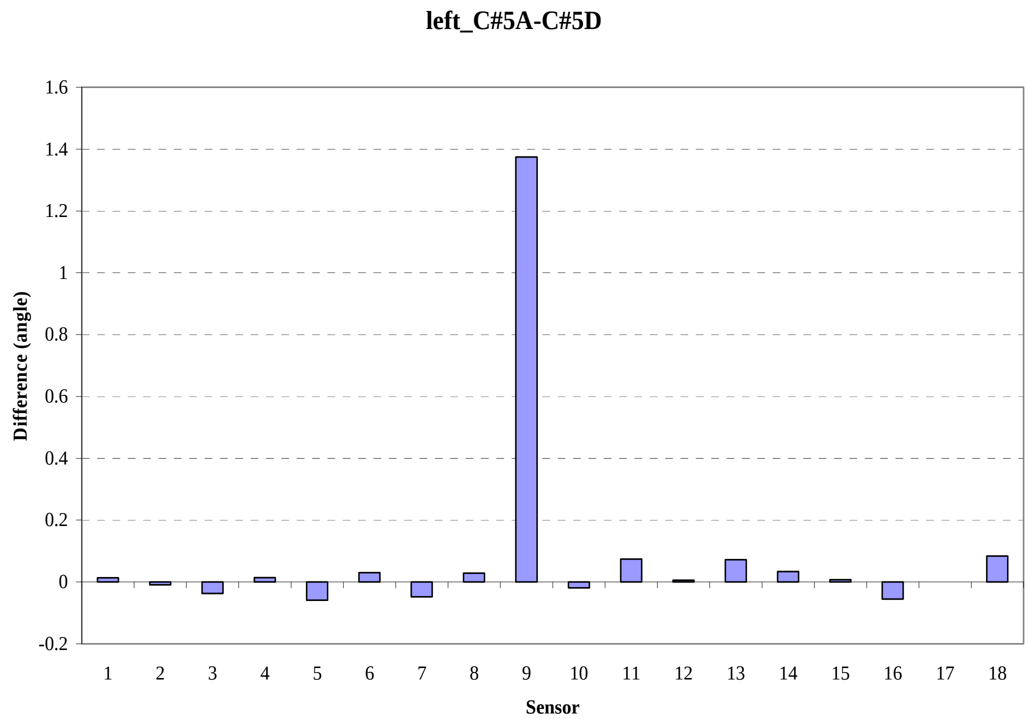



Figure 217. Ascending vs. descending C#5 left hand

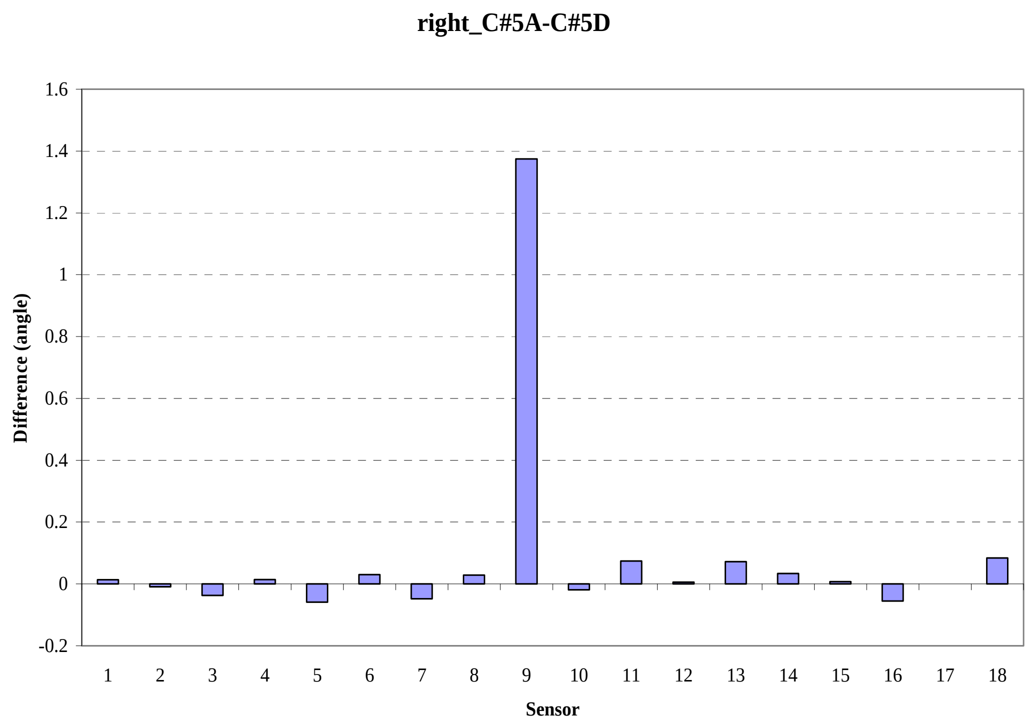



Figure 218. Ascending vs. descending C#5 right hand

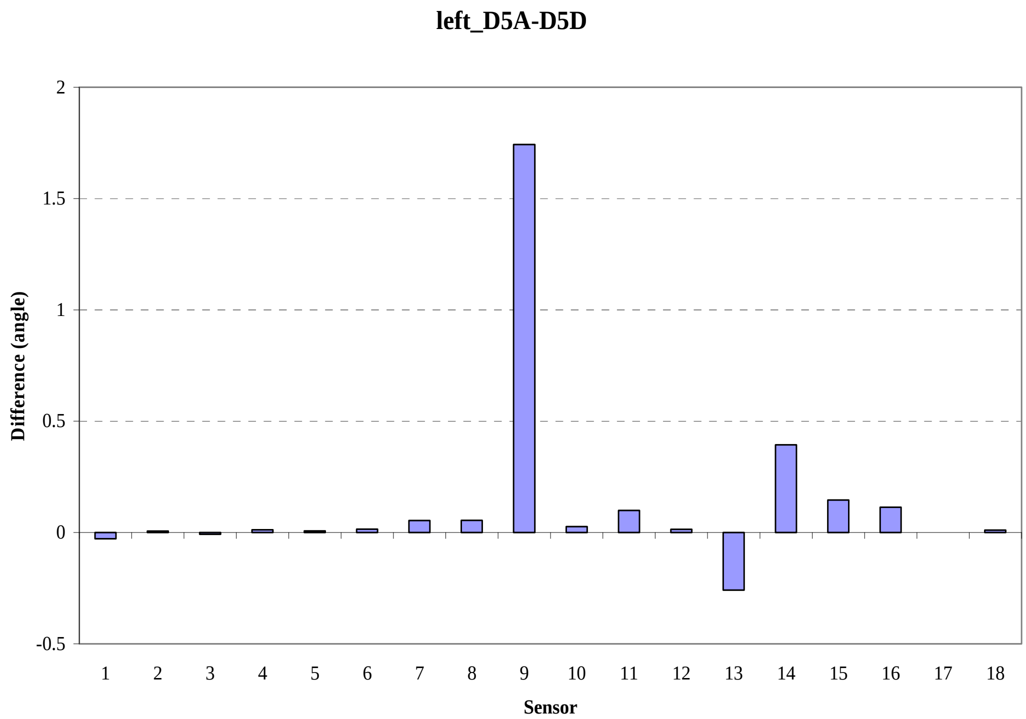



Figure 219. Ascending vs. descending D5 left hand

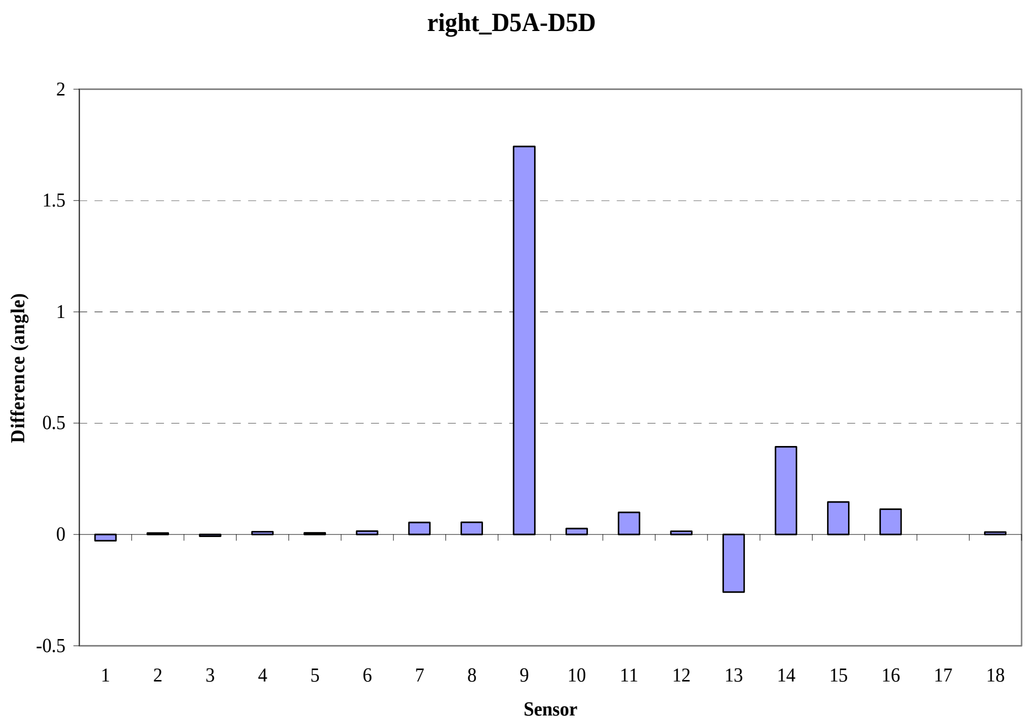



Figure 220. Ascending vs. descending D5 right hand

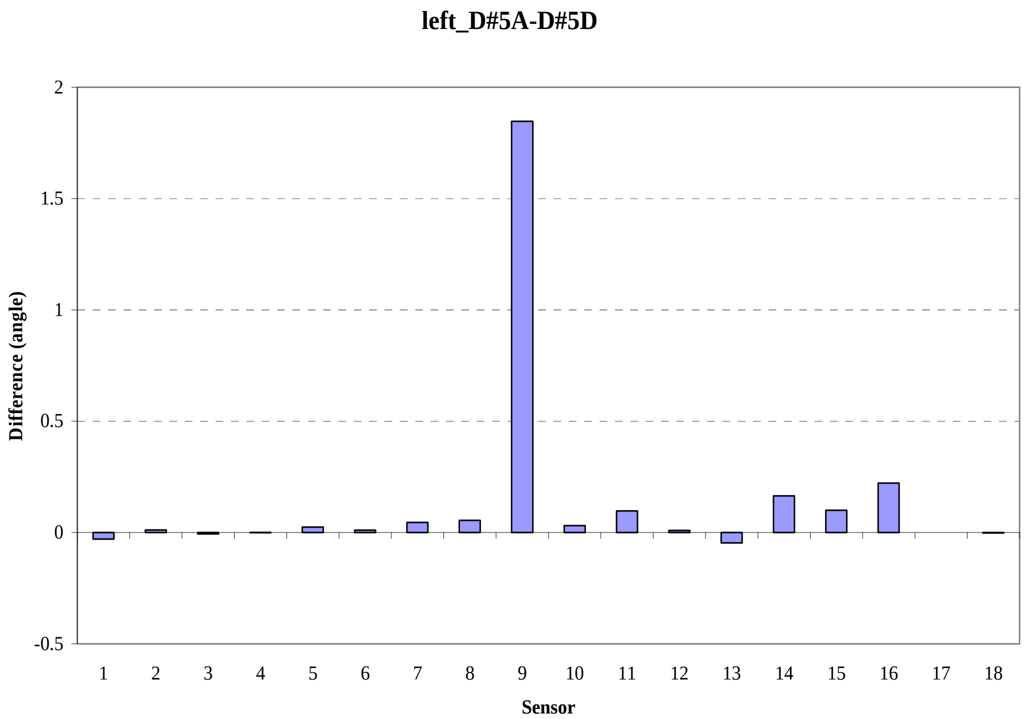



Figure 221. Ascending vs. descending D#5 left hand

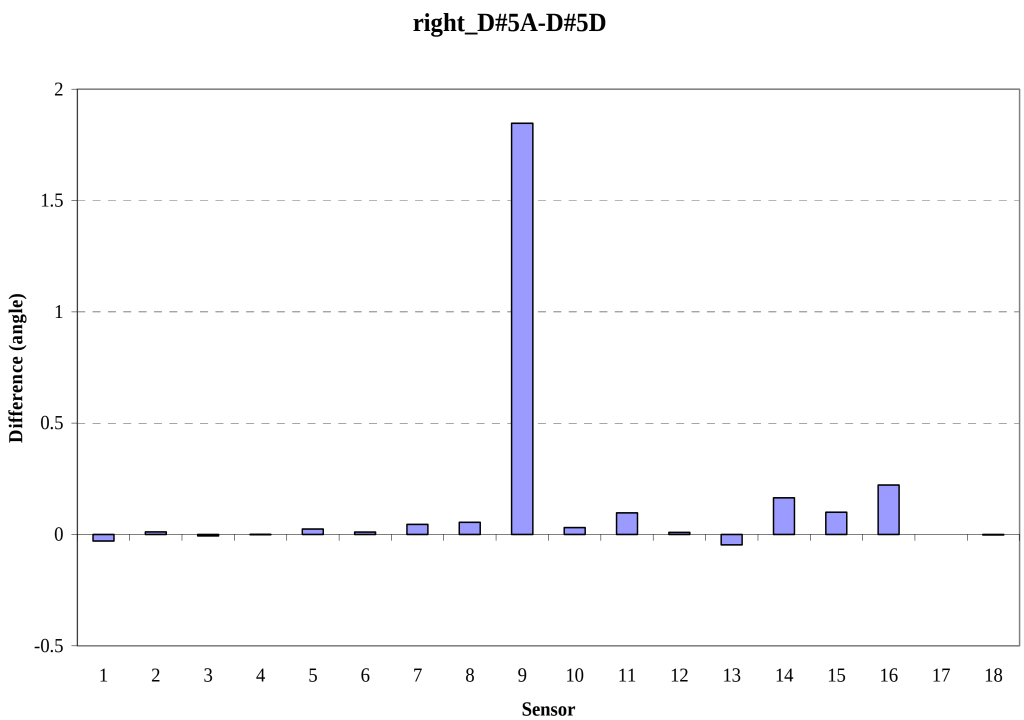



Figure 222. Ascending vs. descending D#5 right hand

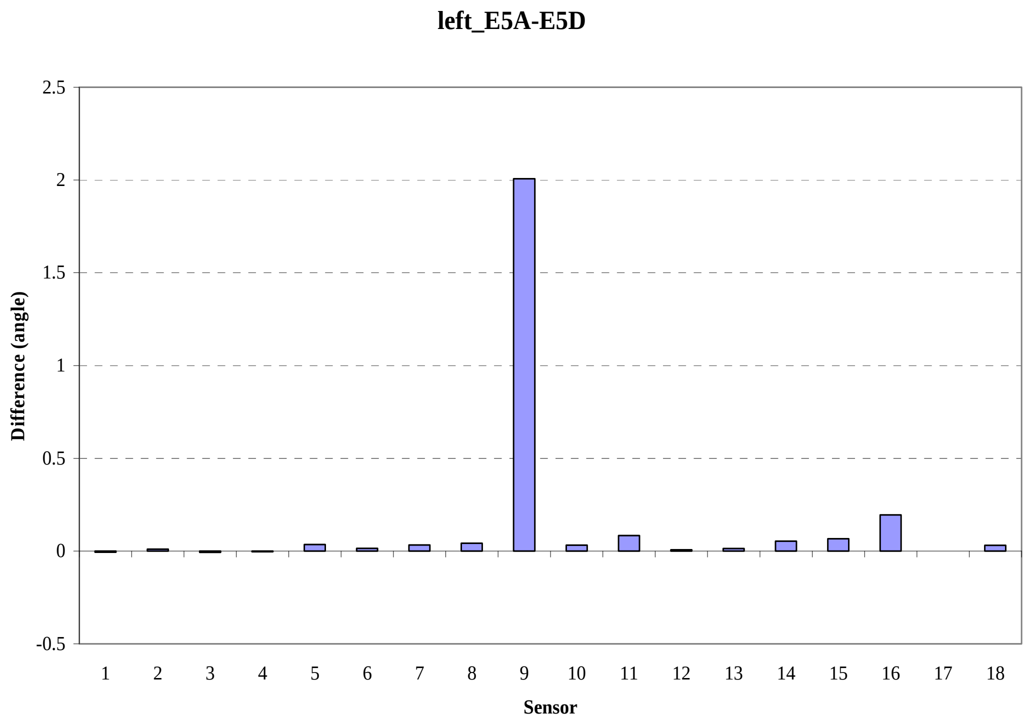



Figure 223. Ascending vs. descending E5 left hand

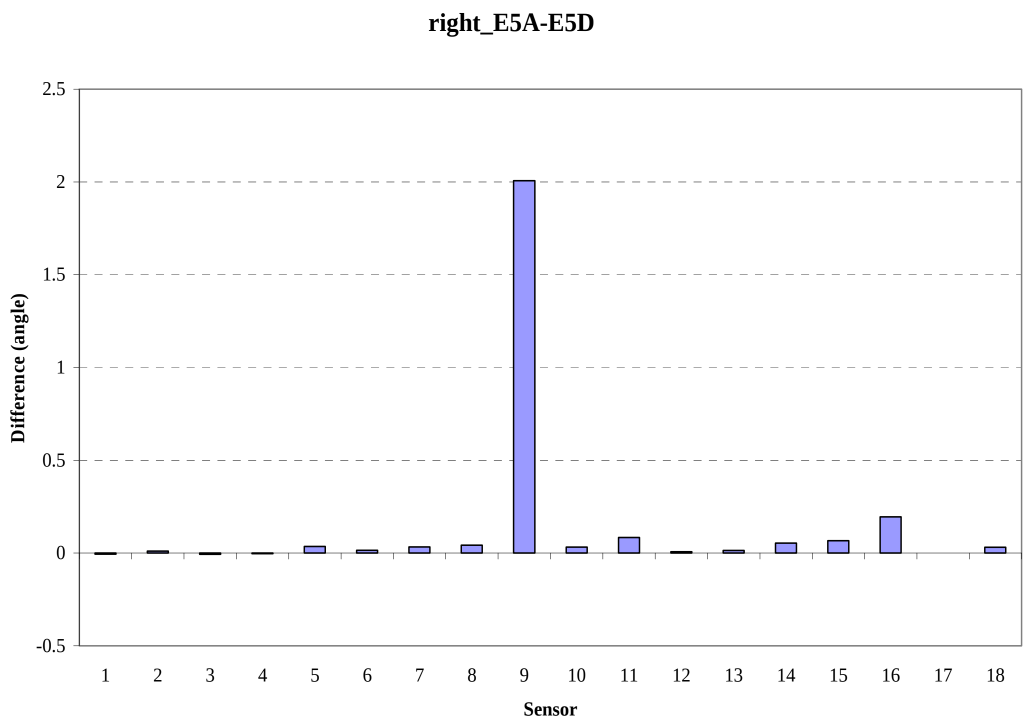



Figure 224. Ascending vs. descending E5 right hand

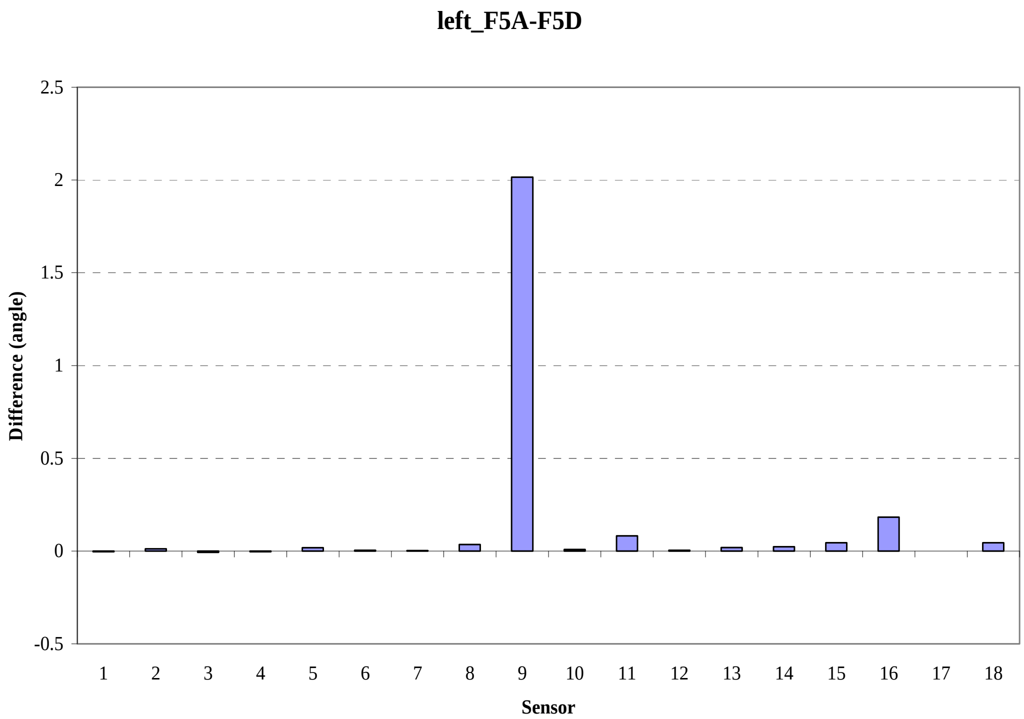



Figure 225. Ascending vs. descending F5 left hand

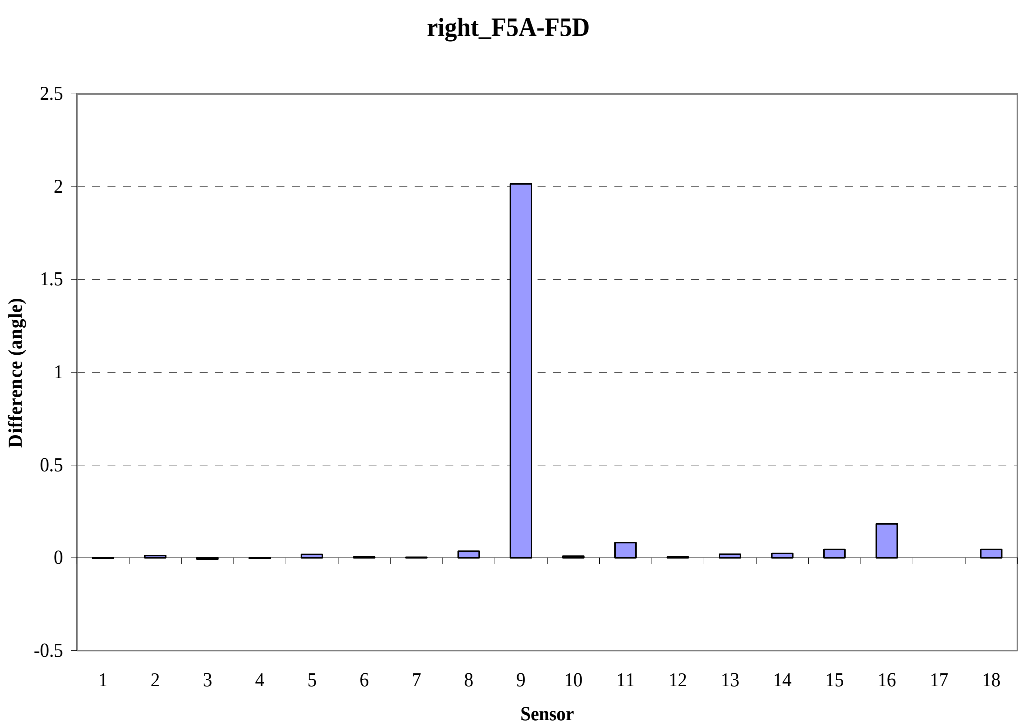



Figure 226. Ascending vs. descending F5 right hand

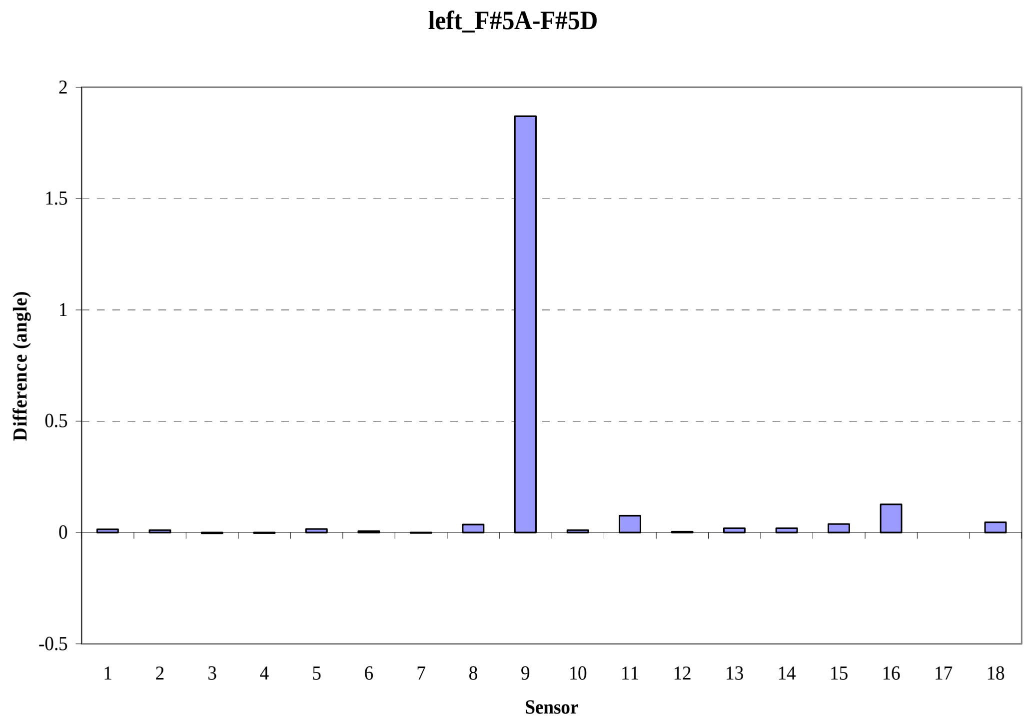



Figure 227. Ascending vs. descending F#5 left hand

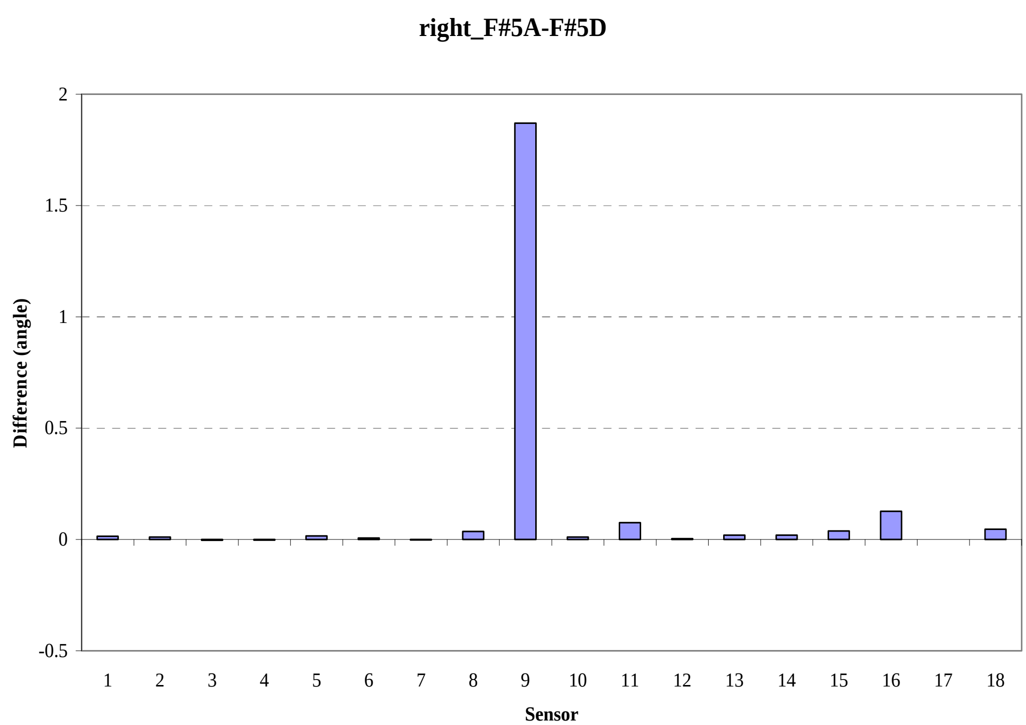



Figure 228. Ascending vs. descending F#5 right hand

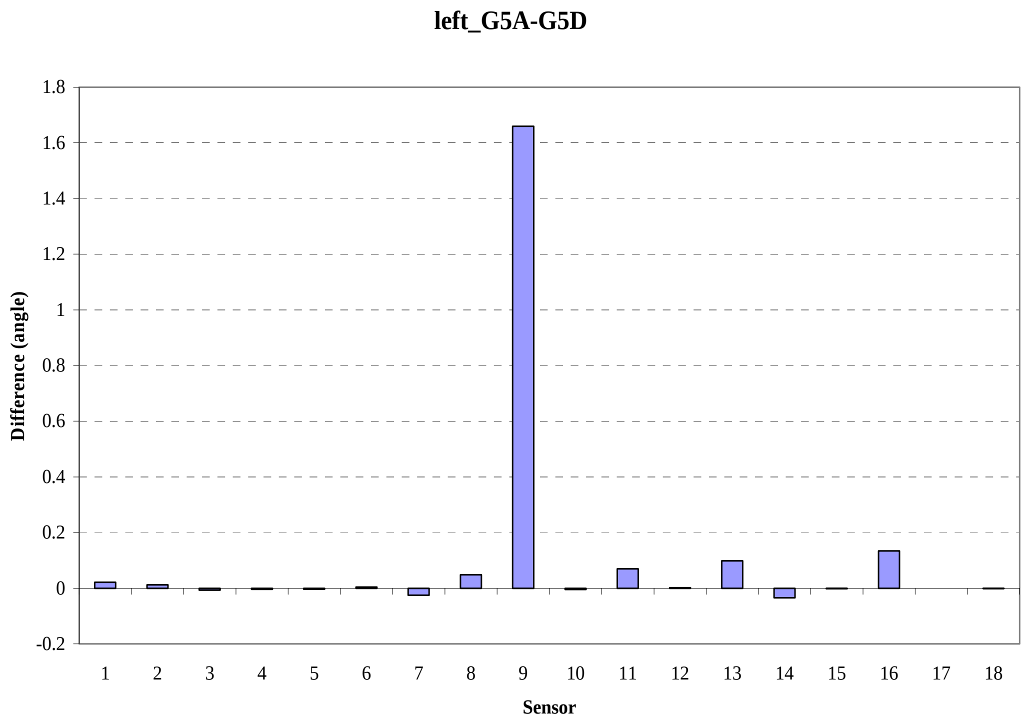



Figure 229. Ascending vs. descending G5 left hand

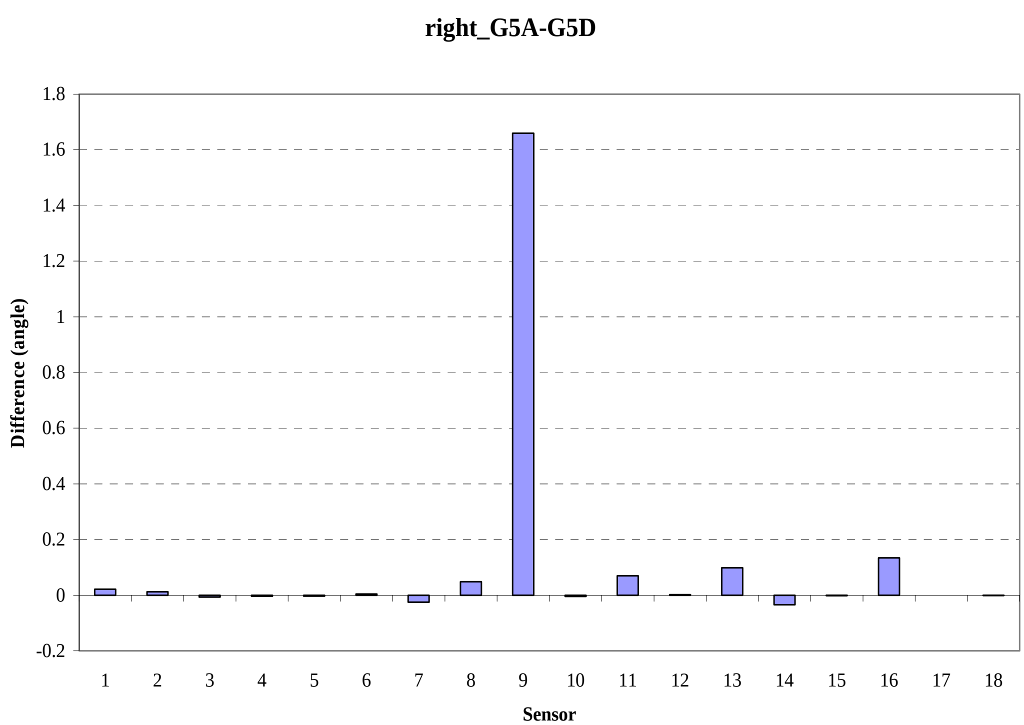



Figure 230. Ascending vs. descending G5 right hand

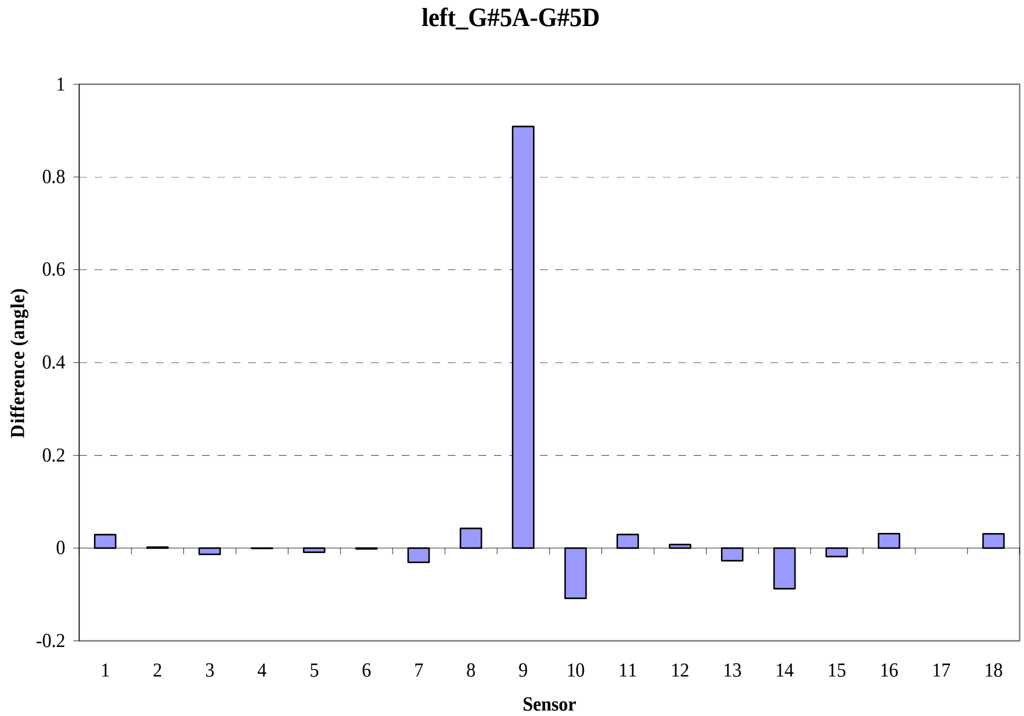



Figure 231. Ascending vs. descending G#5 left hand

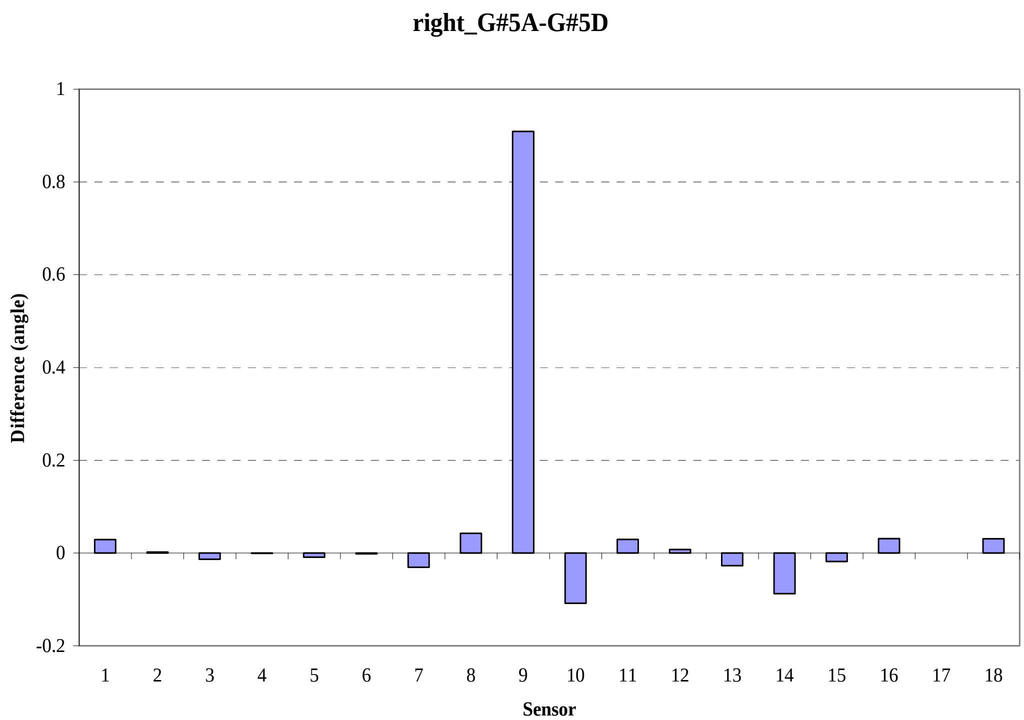



Figure 232. Ascending vs. descending G#5 right hand

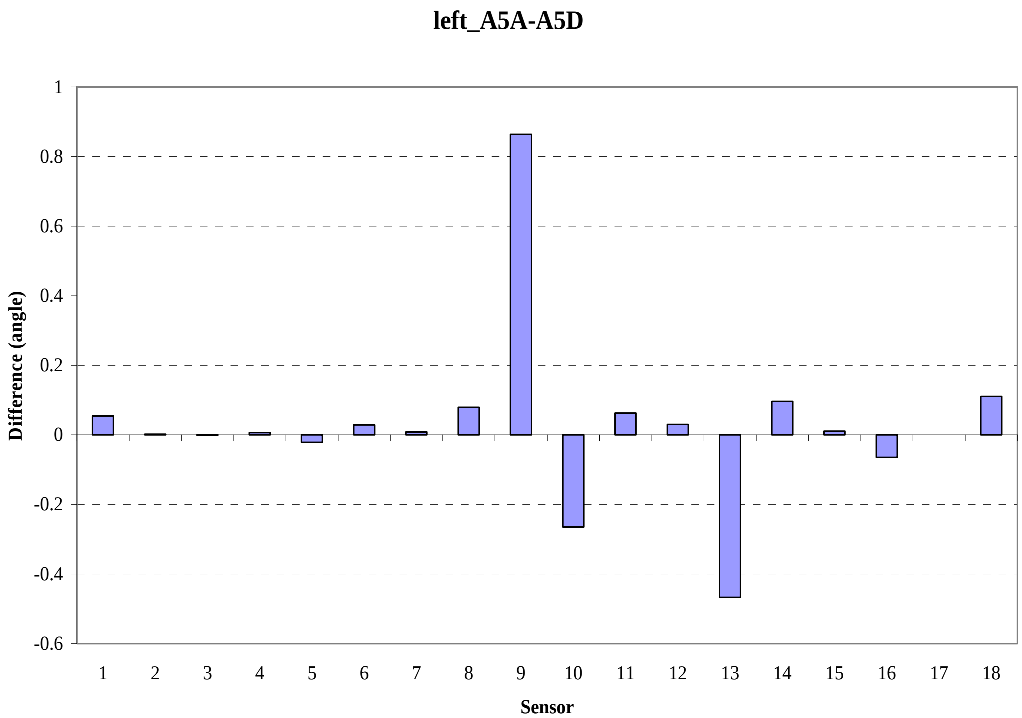



Figure 233. Ascending vs. descending A5 left hand

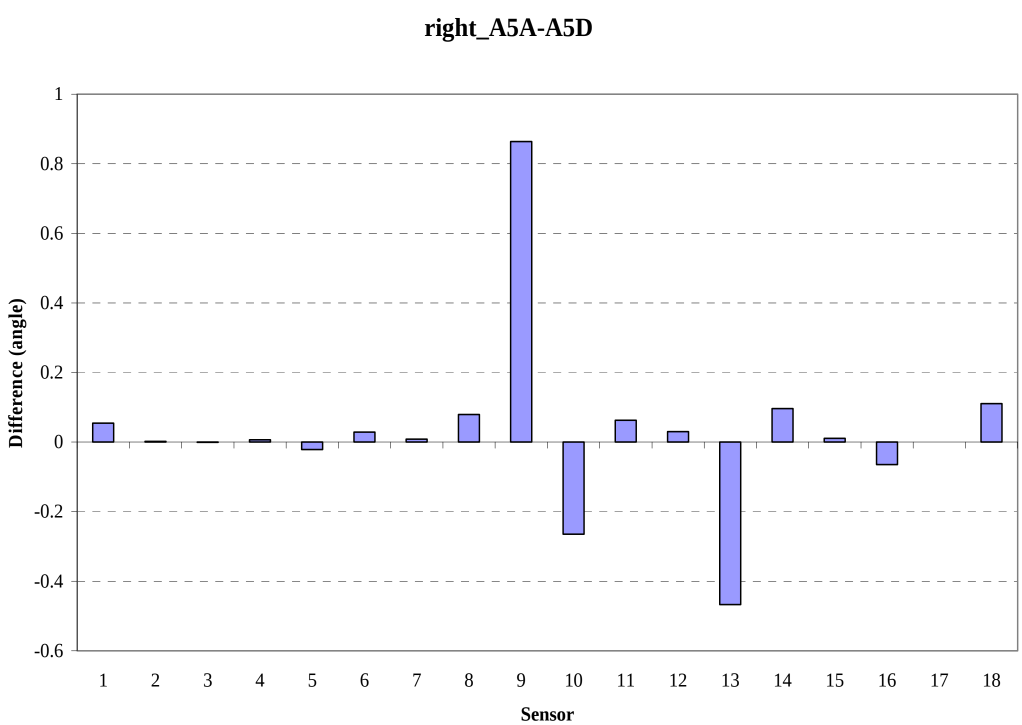



Figure 234. Ascending vs. descending A5 right hand

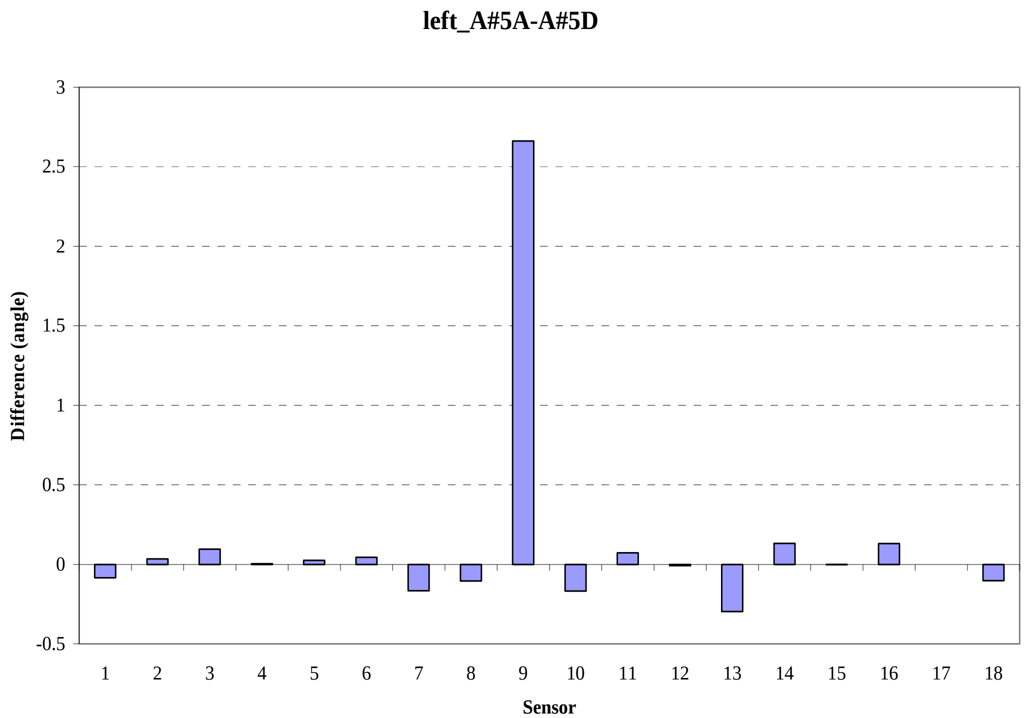



Figure 235. Ascending vs. descending A#5 left hand

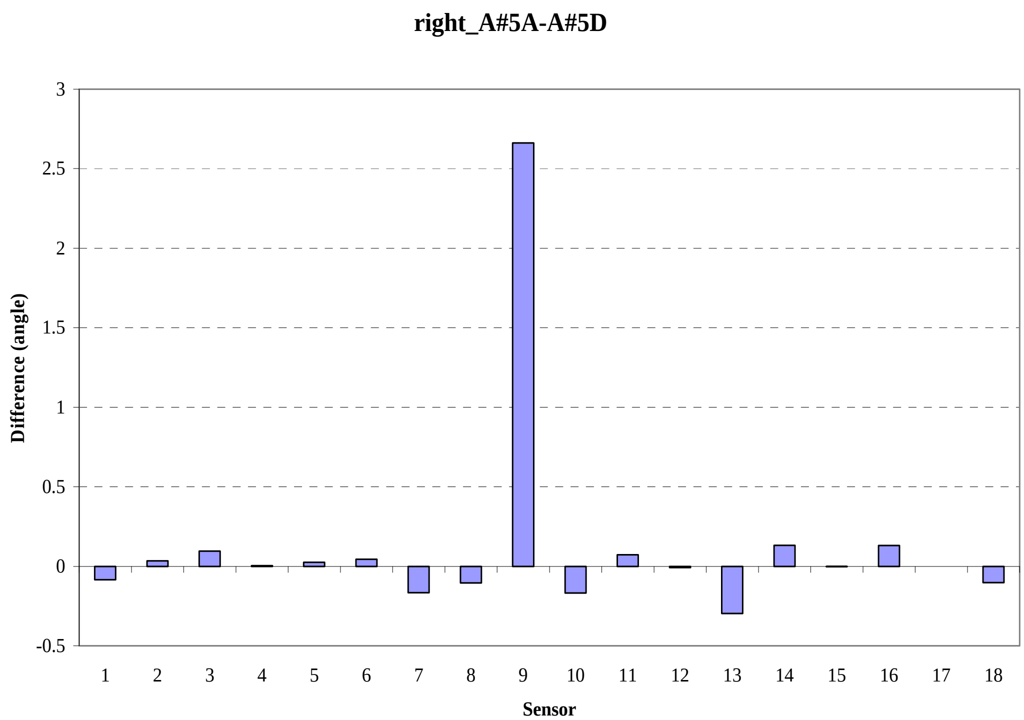



Figure 236. Ascending vs. descending A#5 right hand

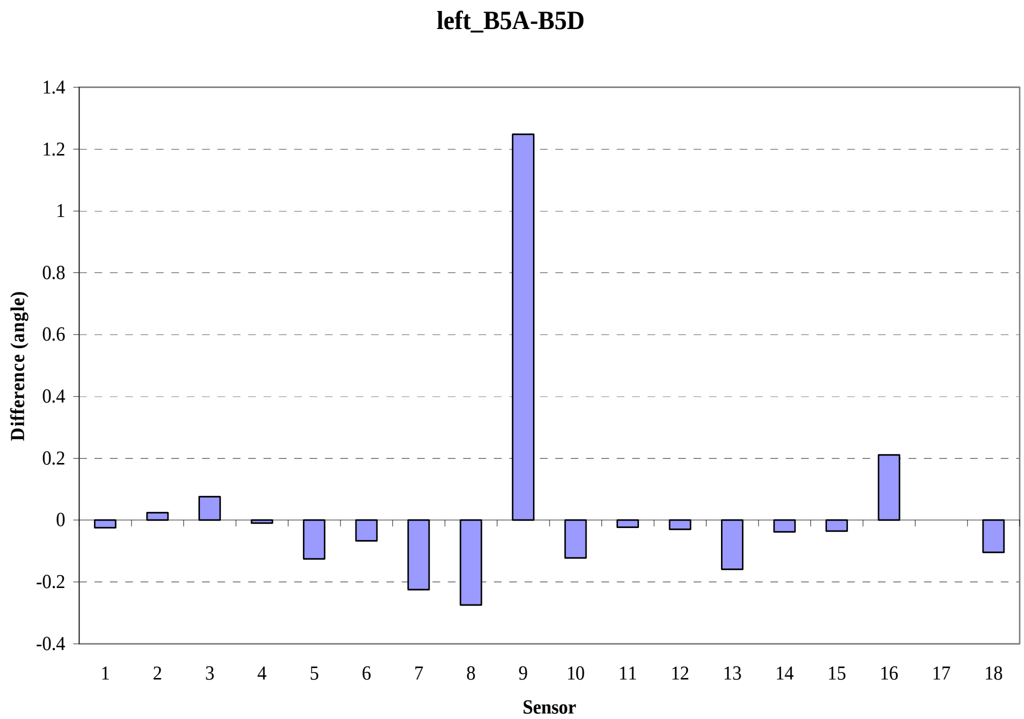



Figure 237. Ascending vs. descending B5 left hand

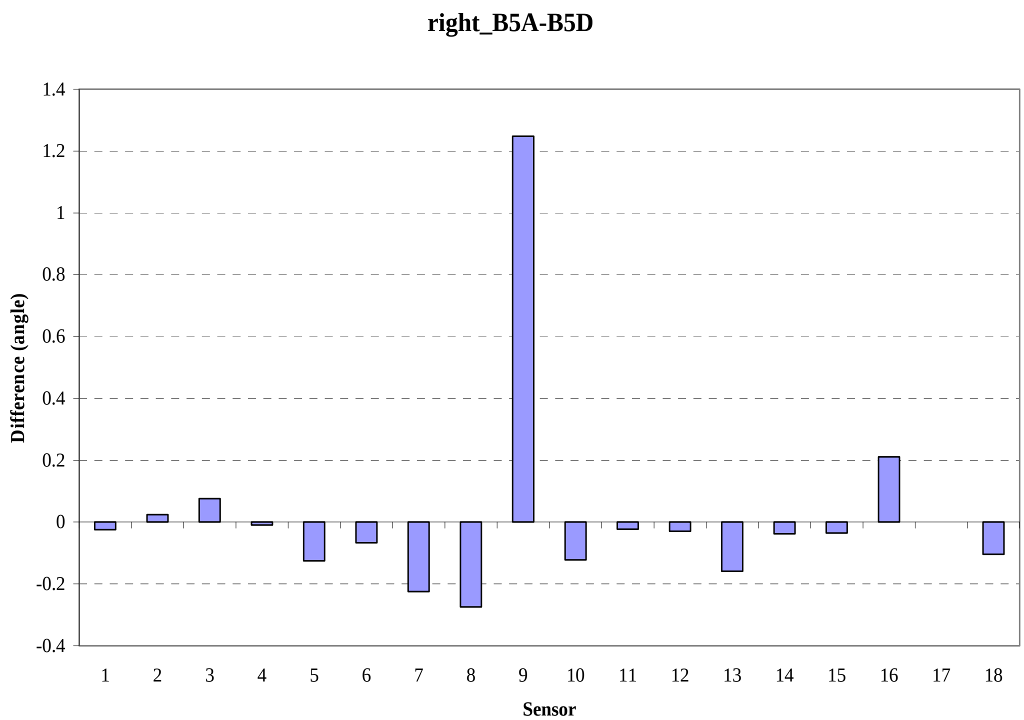



Figure 238. Ascending vs. descending B5 right hand

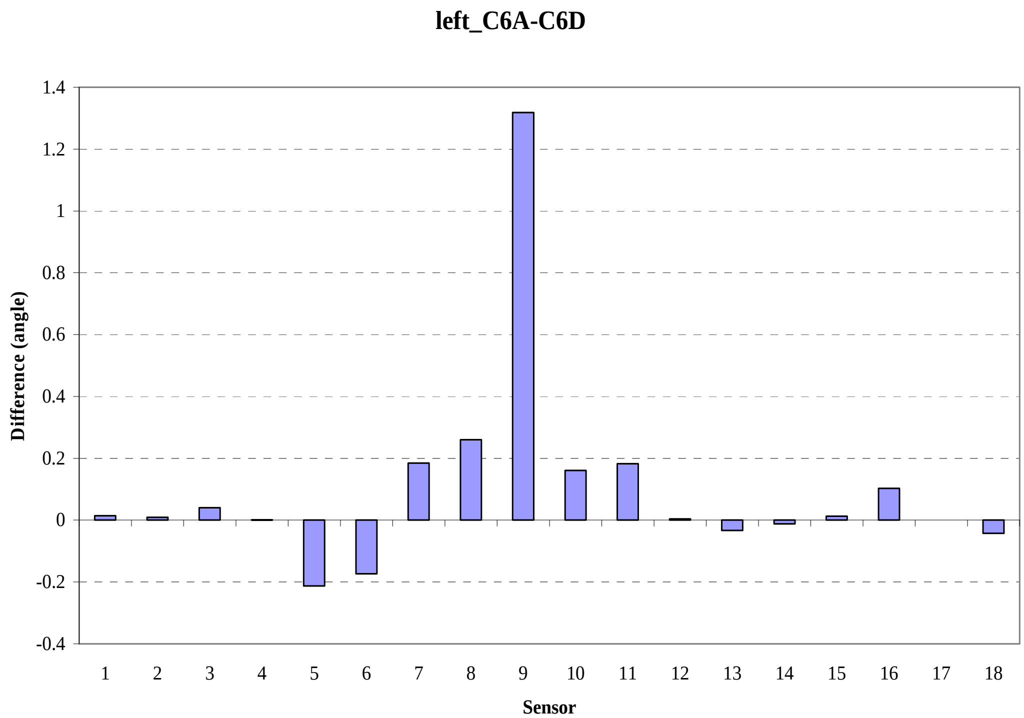



Figure 239. Ascending vs. descending C6 left hand

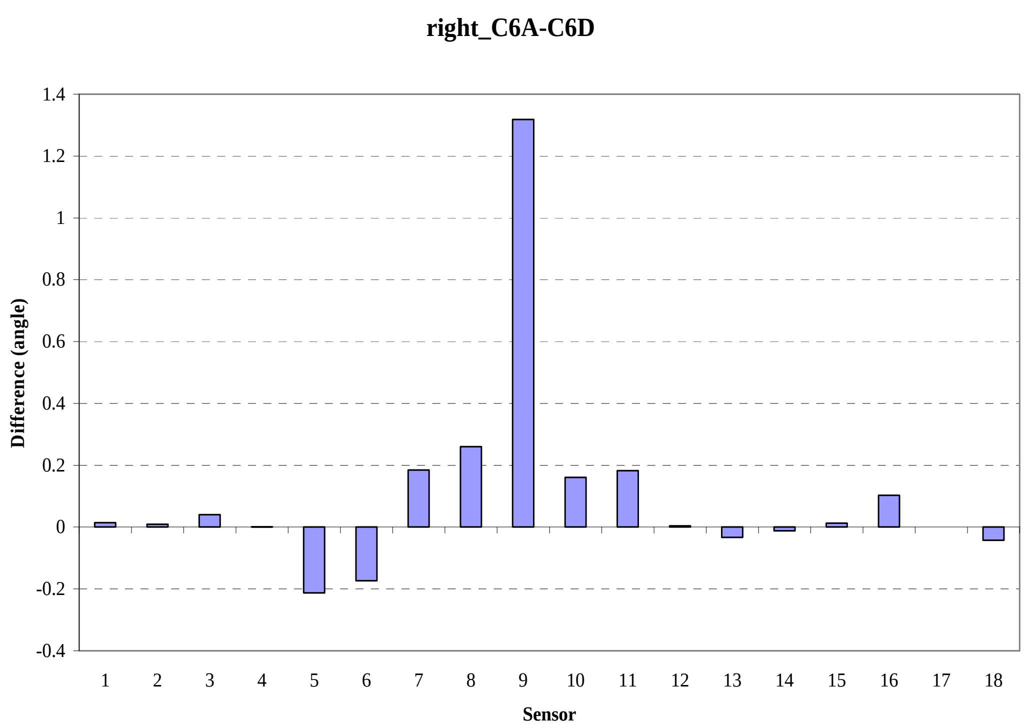



Figure 240. Ascending vs. descending C6 right hand

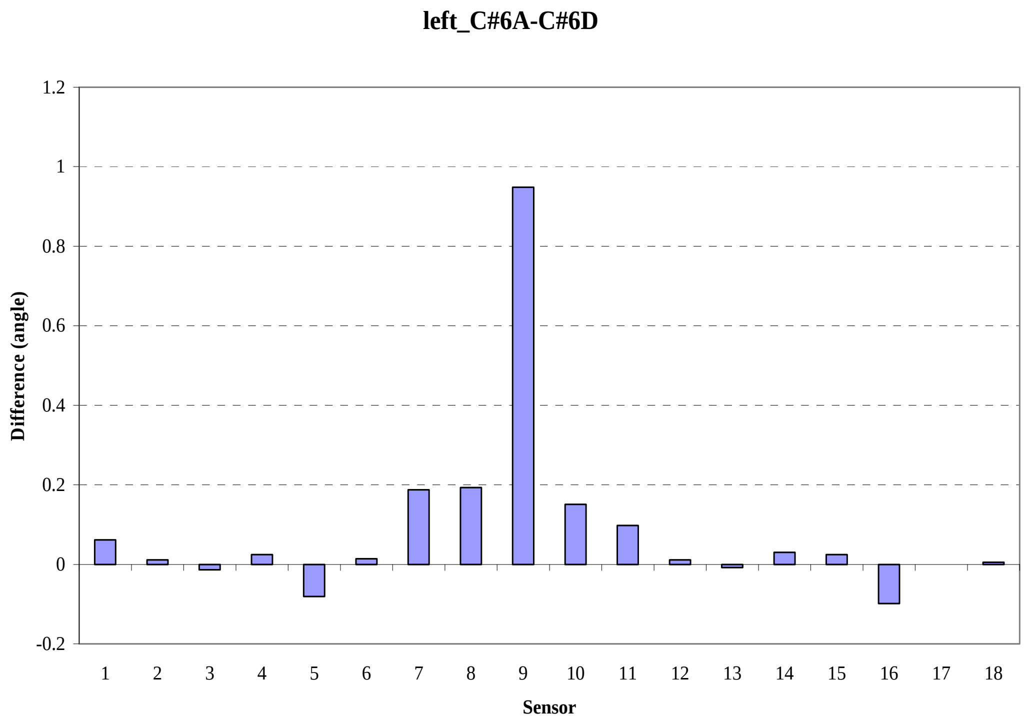



Figure 241. Ascending vs. descending C#6 left hand

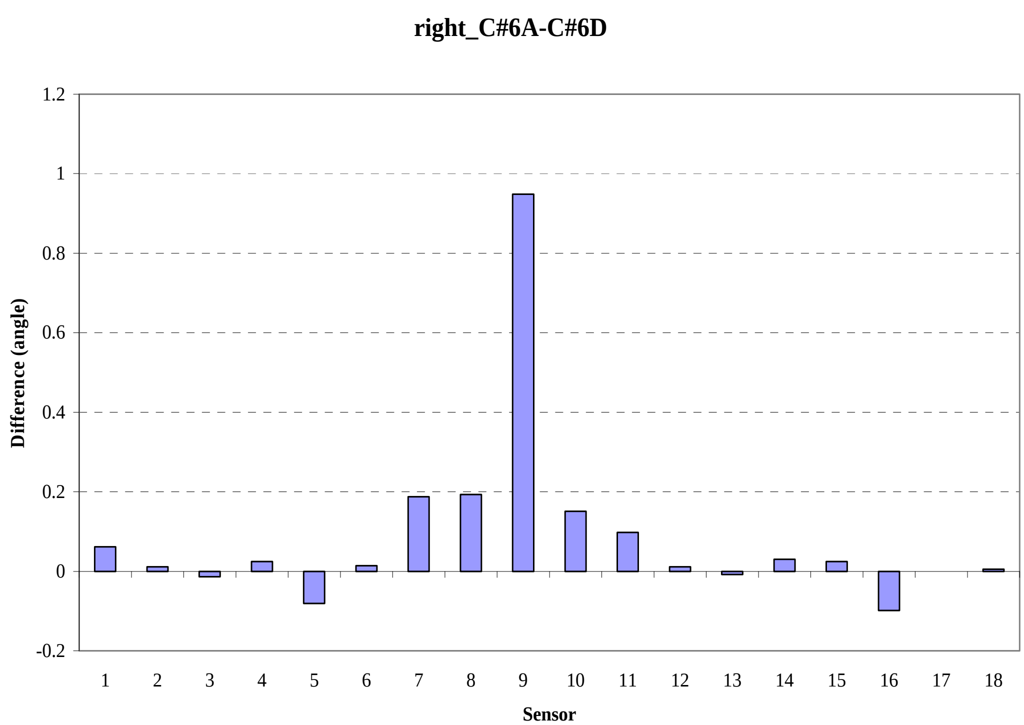



Figure 242. Ascending vs. descending C#6 right hand

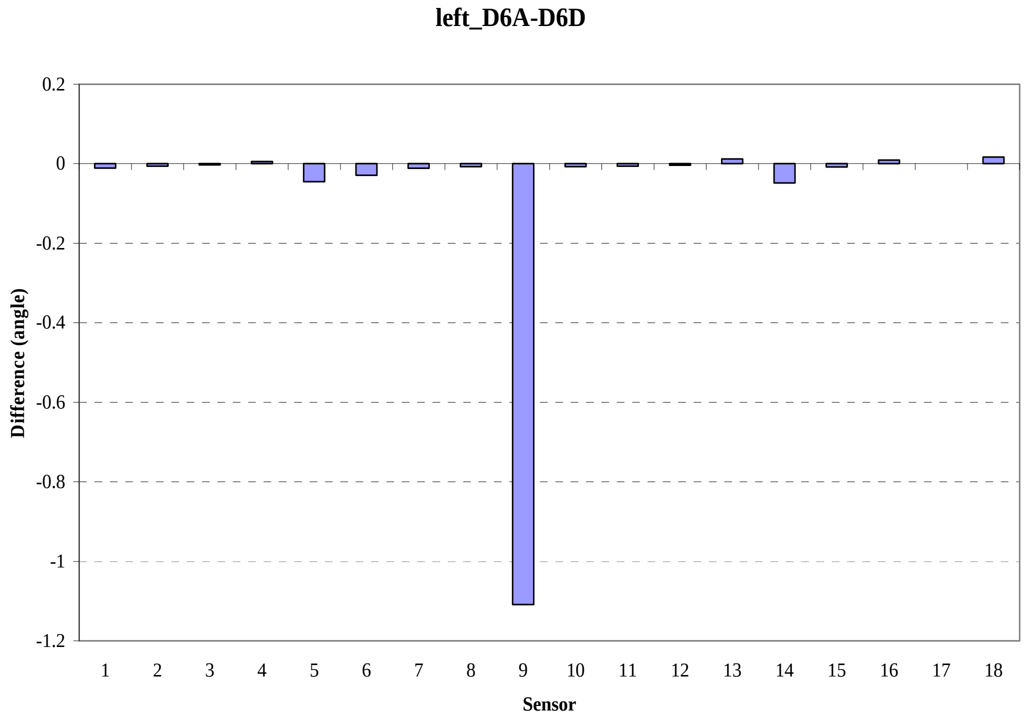



Figure 243. Ascending vs. descending D6 left hand

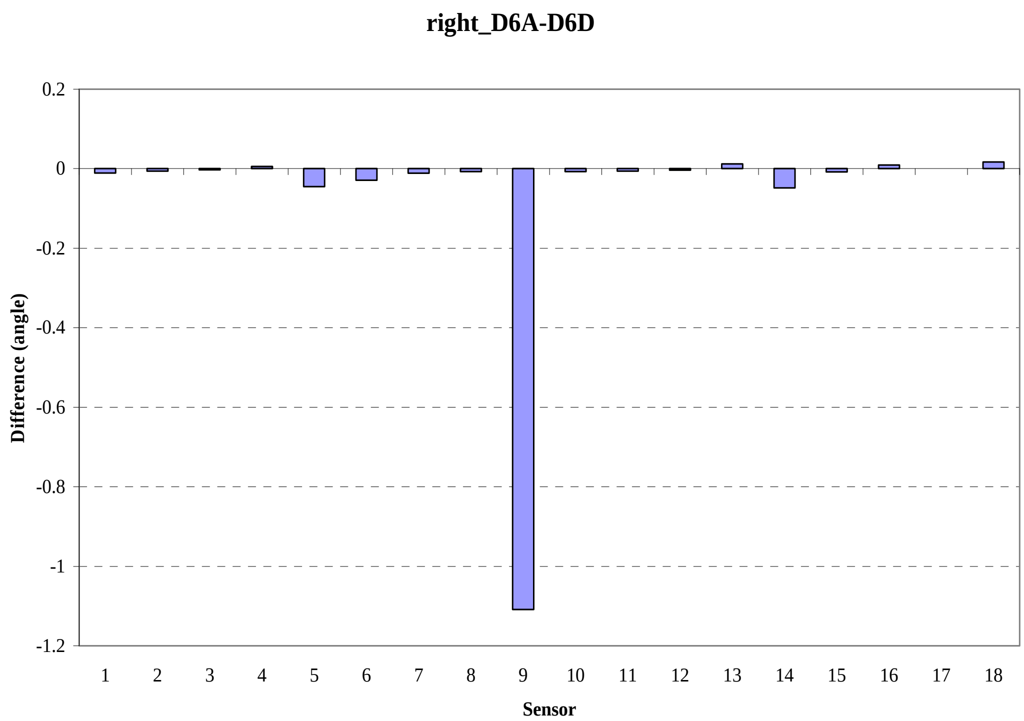



Figure 244. Ascending vs. descending D6 right hand

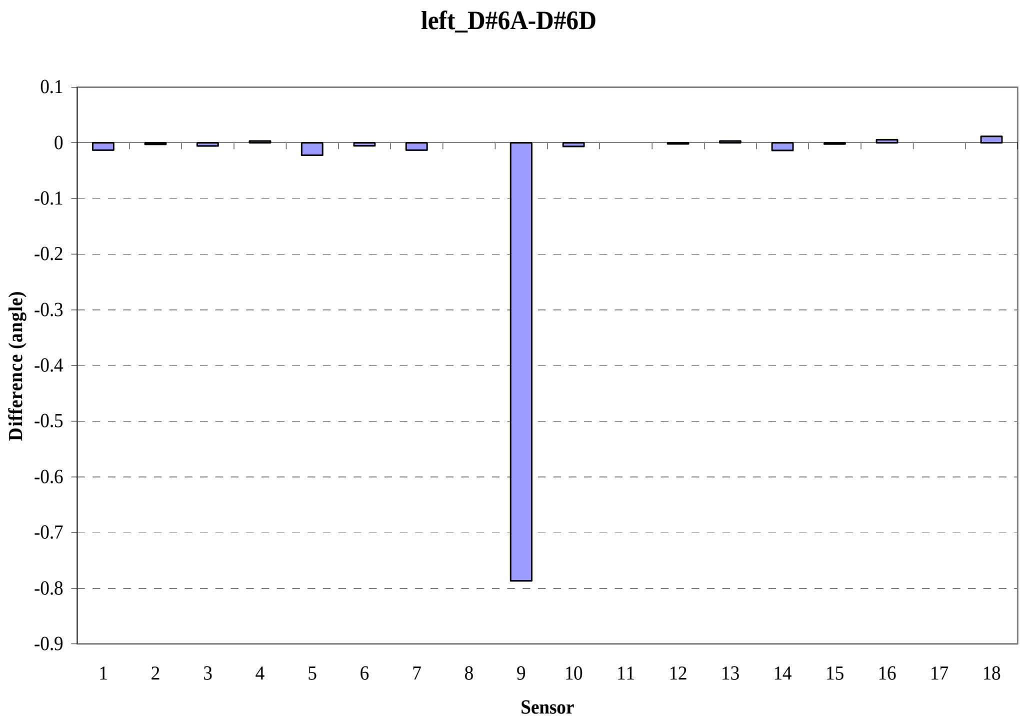



Figure 245. Ascending vs. descending D#6 left hand

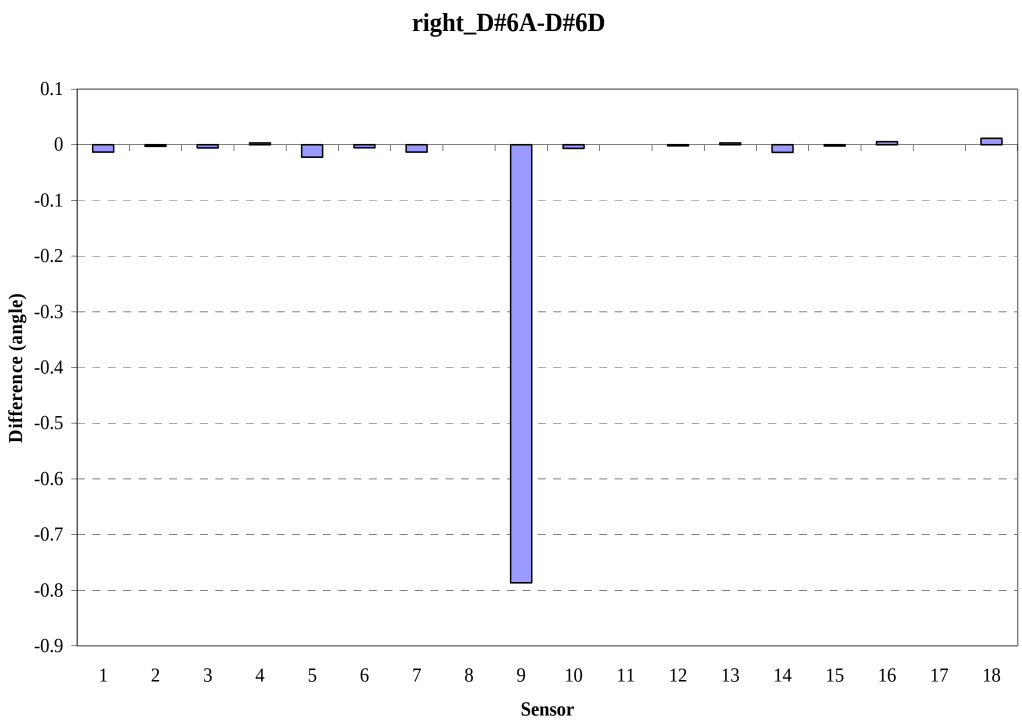



Figure 246. Ascending vs. descending D#6 right hand

## BIOGRAPHICAL SKETCH

Stefanie Harger is a candidate for the degree Doctor of Musical Arts in Clarinet Performance and a student of Robert Spring. She has performed in a wide variety of ensembles including ASU's Chamber Players, Symphony Orchestra, Wind Symphony, Clarinet Choir, and several chamber ensembles. Harger won the 2007 Concerto Competition at ASU and was a finalist in 2006, and has been featured as soloist with many community bands in the Southern United States. She is a member of Trio de Café and has performed with several Phoenix area organizations including Arizona Opera, Symphony of the Southwest, Mill Avenue Chamber Players, and the Fountain Hills Chamber Players. Harger maintains a large private studio in the Phoenix area. Many of her students have participated in Regional and All-State honor ensembles, won chamber and concerto competitions, and received music scholarships at prestigious music schools. Harger was awarded a teaching assistantship by the Music History and Literature area in the ASU School of Music during the academic years 2008-2010 and also was Manager of lnstrumental Ensembles. Harger guest lectured for Hadassah (the Women's Zionist Organization of America) and ASU's CUbiC department. You may contact her at stefanie.gardner@hotmail.com.