**The Melody Arons Center of Preschool Research & Education**

# ABC Neuroscience Study

## Case Study 2, Methods, Findings and Conclusions

Marilyn Arons, M.S., Raymond R. Arons, Dr. P.H.

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# ABSTRACT

The ABC Neuroscience Study was conducted and funded by the Melody Arons Center for Applied Preschool Research and Education, Inc.(MAC). It examined over a ten year period whether or not and to what degree six musical elements had the potential to improve the expressive language of children who were classified pursuant to the Individuals With Disabilities Education Act. Two trials of five children each were conducted. A Down Syndrome child was included in each trial due to their right hemisphere processing of language in contrast to the typical left hemisphere processing of the other children. Both Down Syndrome children demonstrated average to borderline intelligence, with strong social skills, and severe expressive language disorders. This second case study was an exact match to the first in age, gender and initial evaluation data. A total of thirty-one video-taped one hour sessions were given once weekly from June 7, 2008 to April 17, 2009, one or both parents attending each session. One investigator was teacher and program developer, with a background in special education, music and neuroscience. The other investigator videotaped the sessions with minimal direct child involvement, with a background in scientific research, data collection and analysis. This second case study explored music and movement to theoretically examine connections between musical rhythms, specifically the stressed downbeat in music, and the accented syllables of words in spoken language. Each session explored responses to duple and triple meters in music, movement, and spoken speech patterns, air flow, and understandability. Fatigue, delayed auditory processing, vocal fry, and over dependence on the father for reassurance were unexpected variables. The degree and severity of vocal fry was not reflected in any evaluation. As a result, the child experienced extreme discomfort and frustration in efforts to sing and pitch matching. In addition, her sessions occurred after a six hour school day. Sensory integration was utilized to improve her self-regulation and arousal, her initial slow-to-warm up period often lasting 30-45 minutes of the 60 minute session. She was consistently engaged, with advanced social skills, and the ability to manipulate her environment to avoid tasks she found difficult. Both empirical and qualitative data were obtained through use of a rating chart measuring nine variables per minute for 60 minutes. The parents independently formed one data collection team, the MAC investigators the other. Qualitative data was provided through parent feedback during and after the lessons, as well as through lesson plan summaries and observations by the principle investigator and data analyst. Data revealed that when sensory integration was applied, there was no statistically significant effect in the increase of understandable language. It was, therefore, concluded that the data collection instrument used was not valid for this child due to the unexpected variables, particularly vocal fry and delayed auditory processing. Her improvement in performing motor sequences, not a data collection point, appeared to match efforts to expand her length of utterance, an observed and unexpected finding.

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## INTRODUCTION

The Melody Arons Center for Applied Preschool Research and Education, Inc. (hereafter MAC) is a non-profit organization that does research and provides direct services to at-risk or disabled infants, toddlers and preschool children, ages 0-5. It utilizes music and movement elements as primary intervention techniques and self-regulation tools.  Its director, Marilyn Arons, has been a musician and school teacher for five decades. As a special educator, she participated in the Neuroscience and Education program at Teachers College, Columbia University from 1980-1985. Raymond Arons, leading expert in the application of large-scale data sets to solve public health questions, has been a research scientist since 1963.  With degrees in mechanical engineering, in addition to his work as a rocket scientist on the lunar landing module for the Apollo Project, he is also a musician. He is a retired professor from Columbia University School of Public Health and the Baruch/Mount Sinai MBA program. He developed the data collection materials for this study and performed the data analysis. Dr. and Mrs. Arons have worked together as a research team since 2001 when they created MAC.

Based upon their professional and personal experience, Dr. and Mrs. Arons questioned why music, and particularly rhythm, often enabled children to improve their overall functioning, whether disabled or not. They recognized the difficulty of educators in comprehending the language and concepts of neuroscientists, as well as the impatience of neuroscientists with educators who attempt to apply brain sciences to their work in the classroom. Through this study, they sought to bring education and neuroscience closer together, without sacrificing the hands-on preference of one for the exactitude of the other. Their goal was to empirically measure specific observable behaviors of preschool children with disabilities in a natural setting through individually designed lesson plans implemented within a play-based environment. A long-term goal was to find new and inexpensive methods to assist in remediating disabilities of young children without the purchase of costly programs, devices or technologies.

The Alphabet Song phenomena presented a well-known behavior of many young children under age 5. The majority appear to remember the alphabet when singing its song, but have difficulty when saying it without the rhythm pattern or melodic contour. Why? No research was found to answer that question. As a result, this ABC Study was born in 2001. Six musical elements in humans were selected from the Seashore Measure of Musical Talents (1940): sense of pitch, intensity discrimination, sense of time, timbre, tonal memory, and sense of rhythm. These elements were examined in the ABC Study relative to language development in disabled children, ages 2-5.

In order to control for as many variables as possible, children with comprehensive, multidisciplinary evaluations were screened to measure IQ, language functioning, behavior, and diagnosis. Only children of borderline to average intelligence were considered, without hearing impairment or aggressive behaviors, and with enjoyment of music. Of those who initially applied, only one was accepted, a four year old girl with Down Syndrome.  During the formation of the second trial, a comparable Down Syndrome girl was required so as to match the first trial group in the study. This is the case study of that second child.

## HYPOTHESIS

The hypothesis for this study posits that specific musical elements in humans support increased expressive language through bilateral stimulation of all language systems involved, resulting in improved articulation, language production, memory and self-regulation. Those musical elements are:

SENSE OF RHYTHM

SENSE OF TIME

INTENSITY DISCRIMINATION

SENSE OF PITCH

TIMBRE

TONAL MEMORY

The hypothesis of the study was premised upon a gradient theory concerning the corpus collasum and language (Bloom & Hynd, 2005). The corpus collasum is the largest of the brain commissures, bands of fibers that connect the two cerebral hemispheres (http://medical-dictionary.thefreedictionary.com). In the developing brain, gradients are used to divide regions into distinct functional domains that do not operate in a linear way but function as a network (Sansom & Liveset, 2009). This theory accepts that the right hemisphere is the nonverbal part of the brain, specializing in visual, spatial, perceptual, and intuitive information. It processes input holistically to determine spatial relationships as they relate to the whole, specializing in complexity, ambiguity and paradox (Paivio, 1986). This study theoretically loaded the right hemisphere with intense sensory experiences through use of traditional children's songs, dance, art, poetry, and play experiences within a 60 minute period, based upon Allott's motor theory of language (1994). Activities were designed to fit the profile of the child's strengths and weaknesses. Children's songs were learned and sung, processed holistically, similar to a music jingle and without analysis of the meaning of the words (Hoffman, 2001). Songs were paired with simultaneous rhythm and movement activities. When the child was able to sing songs independently, linguistic analysis was added about the lyric by asking Who, What, When, and Where questions, thereby requiring left brain activity of the song lyrics and the theoretical crossing of the corpus collasum from right hemisphere to left. This activity recognized that left hemisphere functioning involved analytical thinking, excelled in naming and categorization, speech, reading, writing, arithmetic, and sequential reasoning. Conceptually, the loading of the right hemisphere with simultaneous rhythmic, sensory, and traditional children's songs provided a holistic language memory bank from which to draw at a later time for analytical language use, categorization and analytical thinking. Down Syndrome brains, however, commonly process language in the right hemisphere, thereby providing a control group for the majority who process language in the left hemisphere.

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## STUDY DESIGN

Results of the first case study found that rhythm was a primary tool in initiating both movement and expressive language, though the other five variables were also examined. Language activities alternated with rhythmic and sensory activities throughout each lesson to examine whether or not there was increased language output and improved arousal levels of the child. The study design never forced the child to do or continue an activity when there was resistance, autonomy within the session's environment demonstrating which experiences were positive and which were difficult or unpleasant for the child to do. The same protocol was followed in the second study. However, there were times when the instructor simply waited for the child to regain composure if upset, with hugs and kisses, and assurance from a parent if needed. Difficult tasks were repeated through a variety of modalities so as to increase the child's opportunity or improved processing skill level growth. Through this freedom of choice, a more accurate measurement in real time was made regarding cause and effect of improved independent expressive language, movement, sensory integration, and the use of rhythm to build understandable speech.

Sensory integration activities involving the vestibular and proprioceptive systems were found to increase arousal levels, attention, and self-regulation, developmental precursors for language output (Berger, 2002). As a result, direct sensory integration activities were juxtaposed to music and language activities throughout each session when arousal or fatigue levels were observably low. Generalization of rhythmic activities was designed to carry over into rhythms of spoken speech (prosody), articulation, movement, and breath control.

### METHODS

At the outset, investigators found no research that combined a neuroscientific construct to classroom performance that resulted in quantifiable data. Therefore, no known research methods were available for consideration when developing this study. Effort was made to provide individualized play based instruction in a manner that reflected best practice in early childhood education. This encouraged the child to lead the activity with support, scaffolding (Vygotsky, 1987), and encouragement of the teacher. Effort was made when planning individualized weekly lessons to utilize the six musical elements and facilitate observable and repeatable behaviors through environmental manipulation. All sessions but one were videotaped, a data collection sheet for minutes 1-60 of each lesson scored by two data collection teams at a later time. The independent variables categories were:

Understandable language

Non-understandable language

Sensory Integration activity

Language initiation

Rhythm activity

Volume increase

The data collection teams were the two researchers and both parents, each independently collecting the data by counting observable behaviors from the videotape. The issue of bias must be acknowledged within the methodology. The two investigators who designed and implemented the study comprised one data collection team, the parents of the child the other. The parents were trained to recognize the six elements of the study and had also participated in the weekly sessions. Therefore, their objectivity could be questioned. However, cross verification among the four data collections confirmed the reliability of the data, all having comparable measurements.

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Weekly lesson plans were based upon the diagnostic information within the evaluation data provided by the parents, the child's strengths and interests used as a springboard for remediation of deficit areas. These plans were developed prior to each session and forwarded to the parents so that they knew what to expect each week.

The analysis of the data was with SAS 9.2 which used descriptive statistics to measure variable means and frequency distributions. In addition, linear and logistic regression analyses tested understandable language and sensory integration activity as response variables.

## NEUROSCIENCE CONCEPTS CONNECTING RHYTHM, LANGUAGE, AND EVOLUTION

### Rhythm - The role of rhythm in human speech production

Humans are the only mammals with an inborn sense of rhythm, dividing time into regular divisions of even duration (Costa, 2007). The innate human response to temporal auditory sequences is to break them into patterns, commonly hearing syllables or notes in groups of 2, 3 or 4 (Montet, 2012). Some African and Caribbean languages have patterns of five and seven beat sequences, so that an inborn sense of rhythm may differ from culture to culture. A slight accent is perceived at the beginning of each group though no actual differences exist (McLaughlin, 1970).

The neutral tempo for humans is 50-95 beats per minute, or an "Andante" metronome marking (MM) (McLaughlin, 1970). This arithmetical electrical code of rhythmic impulses is the basic way the brain communicates to create associations and memory (Mehta, 2011). The zone where the judgment of time is most accurate is 0.6-0.8 seconds, or a 75MM. The primary internal human rhythms are 80 and 86 beats per minute for the heart and breath rate, respectively. All biorhythms are related to the Circadian clock and what is hypothesized as the clock gene (Vitaterna, http://pubs.niaaa.nih.gov) In musical terms, biorhythms appear to fall within the category of Andante, or the speed of walking. This commonality would support the connection between humans having two feet and the rhythms that are common to cultures across the world.

### Basal ganglia and sensory integration

Critical in the processing of music and speech rhythms is the basal ganglia and the reticular formation. The basal ganglia, a bundle of subcortical brain structures, functions like an "auto-pilot" by coordinating different motor systems, giving the pilot- the cortex- the conditions to integrate information in order to select the target for well-prepared actions (Smith, 1995). An example of such muscular movement is that involved with speech. Speech is a sensory engram associated with voluntary movement. Sensory and sensory association areas record "memories" of the different patterns of motor movements. Once learned, the memory engram for speech can be activated to perform the same sequential pattern whenever it is required. (Mallard, 2008; Lieberman, 2002). The sense of mouth movement mixes with sensory input from muscles and joints to support the synchronous development of articulators required for speech production.

Collectively, all basal ganglia parts connect to the cerebral cortex, limbic system and normal movement patterns, interacting with all areas involving cognitive functioning, executive functioning and emotion (Brown, 1997). In order to coordinate the various motor systems, the basal ganglia is a time keeping system that makes accurate decisions about the duration of time intervals (Rao, 2001). It is also extensively used in learning and memory, rhythm being a basic element in the construction of more complex human behaviors and memory (Graybiel, 1998). During learning, the medial temporal lobe and basal ganglia memory systems are activated simultaneously.

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Learned sequences are coded in the neocortex and basal ganglia (Graybiel, 1998). All parts of the cerebral cortex are connected to both the basal ganglia and to the cerebellum. The cerebellum involves the sense organs of skin, joints, muscles and tendons. Recoding and chunking gives more efficient, action oriented representation. An example of chunking is linguistic encoding. It involves motor and cognitive action repertoires of neural coding sequences in a quick and unconscious process, part of the cortico-basal ganglia loop function. The basal ganglia loops back to the motor area of the cortex through the thalamus, forming feedback loops in the cortico-spinal tract. We hear it, do it, feel it, think about it, react to it, remember it, talk about it, all actions that result from the interaction of these feedback loops. These loops form the basis for automatic movements, such as rhythm, looping allowing the brain to be "tuned" (Weinberger, 2004) on a minute-to-minute basis. There appears to be a direct correlate between the effect of these loops and sensory integration. Ayres (1979) defined sensory integration as the organization of sensory input for use, either a perception of the body, world, an adaptive response or a learning process. Methods used in this study suggest that when simple speech rhythms contain strong downbeats during instruction, they tap these feedback loops and expand the number of verbal sequences stored in memory. This activates a "store now" signal in the brain (Weinberger, 2004), rhythm providing sensory integration input that organizes brain activity generally and, some think, expressive language in particular.

The basal ganglia also appear to play a part in the prosody of language (Sidtis, 2005; St. Clair, 2004). As a result of its looping system, it promotes motor strategies that bind syllables and sequences together for faster and smoother speech. In stress-timed languages, such as English, it marks boundaries by pausing, changing pitch, resetting the phrase and syllable lengthening. It is planned and programmed, favoring assembly of smaller into larger units.

**Reticular formation and speech disorders**

The reticular system regulates cortical electrical rhythms (www.medscape.org) . There are many shared pathways between the reticular and auditory systems. The reticular system, however, amplifies the auditory input with connections that impact on the entire cortex, as well as on large subcortical areas. Disturbances in recognizing rhythm and executing patterns is often associated with apraxia disorders.

There are two pathways from the ear into the brain. The non-primary pathway for auditory messages is also called the reticular sensory pathway. When sound enters the ear it hits the cochlear nuclei where it connects with the reticular formation. That message joins all other sensory messages. The main function of the reticular system is to select the type of message the brain should treat first. It is unknown as to whether or not rhythmic patterns are selected for action first. The data from this study suggests that this may be the case relative to movement.

**Motor theories of speech**

There are several motor theories of speech perception, one of the most complete developed by Robin Allott (www.percepp.com). He explained a cross modal paradigm that is supported by the multiple and simultaneous functions of the cortico-basal ganglia loops referenced above. He describes speech as neural motor programs of specific positions and movements of the articulatory system, producing specific patterns of sound in time. He views speech as the logical evolution of sounds evolved from innate motor programs controlling bodily actions, with a direct neural link between the complex motor system and the articulatory structure permitting speech. All words have a motor basis.

A cross-modal transformation, auditory to motor, occurs that also involve mirror neurons. Mirror neurons form the substrate for understanding motor actions in others. There are an increased number of mirror neurons in the sensory motor, emotional and language centers. It is, therefore, suggested that their existence was a pre-adaptive condition for language development in humans (Rizzolatti & Sinigaglia, 2006). They fire when an individual performs an action with a goal in mind, or when watching another perform that same action, such as a baby watching its parent speak. Mirror neurons create a template for

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anticipating what will happen next. They kick in at birth and work best in real life, providing a direct link to the sharing of cultures, emotions, and language (www.sciencedaily.com, 2007).

Two other theories appear to relate to the concepts of the ABC Study. First is the Dual Coding Theory of Allan Paivio (1986). He assumed two cognitive subsystems, with equal importance given to both verbal and non-verbal (visual) processing. These systems constituted a person's perceptual, affective and behavioral knowledge with origins in perceptual, motor and effective experience. These two independent memory codes, either of which can result in recall, provide a better chance of remembering than a single code (Reed, 2006) Norman Weinberger is a pioneer in researching learning and memory in the auditory system. He discovered that the more intense the stimulation to the auditory cortex, the higher level of acetycholine release, and the improvement of memory recall (2006). He concluded that there was a need to describe the factors and forms of sensory plasticity so that there is improved understanding of when a memory is not formed, as well as when it is (Bieszczad & Weinberger, 2012). .Collectively, the theories of Allott, Paivio, and Weinberger appear to agree on the motor, or sensory base, that underlies memory and movement. Paivio provides a verbal, non-verbal model built upon basic sensory input, while Weinberger provides an auditory model of memory which connects with sensory input.

**Babies**

Babies are born with sensitivity to highly specific rhythmic patterns naturally found in languages (Costa, 2007). Hearing is the first sense to develop in the fetus at about 16 weeks. Therefore, rhythms heard in utero appear to provide the foundation for prosody, defined as tempo, rhythm and duration of phonetic speech segments. It may be that the baby's perception of linguistic rhythms is a key mechanism that launches the process of human language acquisition, humans the only mammals capable of keeping time and moving rhythmically together. There is a universal "motherese" in which parents in all cultures use short, simple sentences, repeated over and over again, to speak to their babies. Such rhythmic repetition may "tune" the baby's auditory and motor systems to the native rhythms of all of the countries on the planet. Dissanayake (2001) postulated five reasons that music is an evolved human propensity for adaptation and survival. They are:

1. Universality- Music exists in every social group known over time across the globe;
2. Costliness- Societies give large amounts of time, energy, and material resources to music and music-related events;
3. Pleasure- Music is emotionally highly positive and rewarding;
4. Predisposition- Young humans willingly and spontaneously move and even vocalize to music;
5. Cultural importance- Music is an integral part of most culturally important events.

She theorizes that ritualized sounds and movements create an emotional bonding between mother and infant with common sounds and rhythms used for social affiliation and coordination.

The initial task a baby has of finding words is a difficult one. Fluent speech does not contain pauses or other consistent acoustic cues marking word boundaries. However, babies can infer meter from rhythmic patterns, using that metrical structure to secure their knowledge acquisition. The first brain imaging study that compared the brains of young children discriminating between simple rhythms and melodies found that different aspects of rhythm were processed in different brain regions in both hemispheres, though there was some specialization in the left hemisphere. There is currently no agreement as to whether or not and to what degree rhythm is hard wired or culturally based.

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It is generally agreed that the right hemisphere is organized principally to process novel challenge and perceives input holistically. The left has a more linear organization dealing with familiar routines in an analytical, efficient and established manner. For people who are musically untrained, music is processed in the right hemisphere. As input becomes more familiar, neural processing transfers to the left hemisphere. For trained musicians, music is also processed in the left. The right to left shift that occurs with increasing musical competence requires further analysis as to specific elements of the music being processed, and whether or not the person is untrained or a trained musician. This phenomenon, sometimes referred to as the gradient theory, may have significance for improving language functioning if the mechanisms were better understood. It could be that the rhythmic flow of language, such as that heard in the inflected babbling and jargon of infants and toddlers, is the place for neuroscientists to begin that inquiry.

It is commonly accepted that children under the age of eight do not integrate information from their senses. Research suggests that perceptual systems of developing children may require constant recalibration by using one sense to fine tune the other, either vision or touch dominating, though this may also reflect the limitations of a still developing brain. There is fundamental agreement that human development between ages 0-5 is based upon sensory motor movement, experience and social connectedness (Piaget, 1973).

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## LANGUAGE PROCESSING IN DOWN SYNDROME

The central nervous system differs in those with Down Syndrome. There is reduced brain size and weight, smaller and fewer sulci, a narrower temporal gyrus, fewer cortical neurons, decreased neuronal density, delayed neuronal myelination, and often mild to moderate hearing loss (Lubec, 2002). The muscular system has both absent and extra muscles in the facial region, with a large, muscular tongue. There are abnormal dendrite structures and altered cellular membranes. These differences are associated with difficulties in the accuracy, speed, consistency, and economy of speech movements. Variations in speech and language skills are attributed to their speech motor abilities which relate to their anatomical and physiological characteristics. People with Down Syndrome usually display an atypical left ear, right hemisphere advantage for speech sounds, with movement organized in their left hemisphere. Their cerebral organization processes language and movement in a reversed cerebral specialization from the rest of the population for speech perception (Chua, 1996). This creates problems due to Down Syndrome right hemisphere specialization for speech production, but left hemisphere specialization for the organization and control of movement. This causes a disconnection between speech perception and movement production, including production of speech movements. As a result of this brain organization, problems occur in integrating perception and action (i.e., speech perception and movement production).

An in-depth biochemical study of Down Syndrome brains found that the anterior commissure in adults was reduced in size, but no consistent picture of their “wiring” has emerged, the extra chromosome not explaining their dysmorphic features. The only areas affected by the extra gene were the frontal and temporal lobes, involved with self-regulation and language (Gardiner, 2010). Other research confirmed the basic premise of neuroscience- the operation of circuits determines all brain function. Therefore, any changes in brain functioning must be linked to changes in circuit functioning. When these circuits do not fire as actively as they should, learning and memory are impaired.

Given these unknowns, as well as the high functioning of some with Down Syndrome, consideration of the parietal lobe and its functioning should be made, including exploration into a kind of back-up system for forms of language processing. The parietal lobe is found behind the frontal lobes and above the temporal lobes at the top back of the brain. They are involved with the processing of nerve impulses related to the senses, such as touch, pain, taste, pressure and temperature, in addition to language functioning. This area integrates information from different modalities, in particular spatial sense and navigation. Near the juncture between the two lobes in the parietal lobe is the precuneus. It is involved in episodic memory, visual-spatial abilities, motor activity coordination strategies, self-perception, and executive and working memory (Cavanna, 2007). Dancing activates the precuneus (Brown, 2008). It is the seat of self-awareness and is responsible for allowing people to self-evaluate, and compare self and others to inform social behavior. Because of strength in social skills, empathy, and courtesies in many with Down Syndrome, these regions may provide an alternate pathway for input and techniques to improve expressive language.

Mirror neuron differences between those with Down Syndrome and the rest of the population are considered an important finding. In 2010, it was discovered that there was little activity in a key part of the brain’s mirror neuron system when the Down Syndrome person observed actions. There was very little activity in the movement related areas of the brain, and brain activity was much more scattered and less organized than in those without Down Syndrome. This is thought to play a critical role in their understanding of the emotions of others and in the acquisition of language (Hayden, 2010).

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## DEFINITION OF TERMS

### Sensory Integration

This theory is based on senses normally below the level of our awareness. Input comes from the environment, synthesizing sensory information so as to make proper responses to stimuli. The seven sensory systems are: visual, auditory, smell, taste, and touch. Balance and movement are controlled by the inner ear, while body position is controlled by muscles and joints. (www.ehow.com/about_5098852_definition-sensory-integration.html)

### Vestibular system

Housed in the cochlea of the ear, it detects motion, gravity, and provides the sense of balance. Multiple connections with the rest of the brain influences auditory processing and language, muscle tone, fine and gross motor coordination, oral motor coordination, and supports the ability of the body to use both sides in a coordinated way. (www.medterms.com)

### Proprioceptive system

This system provides information about the internal position of body parts, such as muscles, tendons, ligaments, joints, and equilibrium. (www.medterms.com)

### Scaffolding

This instructional method offers a support structure to the child in order to accomplish a task slightly beyond current ability. As performance improves, the scaffolding is gradually withdrawn. (Linder, 1993)

### Consolidation

This is the process of having information in short term memory placed into long term memory through spaced repetition. (www.human-memory.net/processes_consolidation.html)

### Low tone

Also called hypotonia, muscles resist movement, feeling soft and doughy. Symptoms include shallow breathing, feeding problems, failure to develop motor milestones, delayed speech and lethargy. (http://paulahenry1.hubpages.com)

### Self-regulation

This refers to the ability to alter behaviors in accordance to either internal needs or society's expectations. It requires a child to adapt, demonstrate flexibility, and inhibit impulses to do what is requested rather than what they want to do. (http://cehs.unl.edu/csi/self.shtml)

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## INTRODUCING JENNY

Jenny began her participation in the study on 5/1/08 when she was four years, seven months of age. She was diagnosed with Down Syndrome and was a classified student attending a local public school in an inclusion preschool. She was completely independent in all life skills, strengths shown in vocabulary, turn-taking, listening skills, pretend play, telling stories about pictures, and matching colors. Strong interests were shown in sensory games. She was a self-confident, highly social youngster from an in tact family who was devoted to meeting her needs, as well as including her in all family experiences (Dyches, 2012). Deficits were in attention, fine motor, and expressive language at the $18^{th}$ percentile. Oral motor activities were difficult with low tone in her oral facial region. She participated in 31 videotaped sessions, the last one on 4/17/09. In addition to her public school program, she received private occupational therapy once per week throughout 2008-2009. Her data is presented here for the first 14-15 sessions so as to match the data from the first case study. One session in this case study was not videotaped, but the lesson plan is included or review, totaling 15 sessions, only 14 videotaped. The remaining sessions and data will be reviewed at a later time and have particular relevance for examining delayed auditory processing, consolidation, and the unexpected improvement in motor performance and dance sequences that appear to relate to work in expanding length of utterance in expressive language.

Jenny was a secure child from a highly enriched environment. She was strongly bonded with both parents, particularly her father. She demonstrated extremely slow auditory processing, often missing the first syllable of the word. Her motor responses were significantly better so that she learned basic dance movements easily. She retreated to ritualized doll play when language demands were made, saying “I can’t” or crying for “Daddy”. As her sensory needs were increasingly met, she showed more willingness to participate in activities she viewed as difficult or frustrating. She had an unusual ability to self-calm, sitting cross legged in a chair without any movement, a slight smile on her face, until she was ready to continue.

Jenny was an extremely charming and beautiful child who was accustomed to manipulating the adults around her in order to get out of doing an activity or get an activity she had been denied. She had a large repertoire of behaviors and responses to get out of doing an activity she did not want to do. Due to her sweet demeanor and advanced social skills, she was accustomed to being able to control the activities in an instructional setting. These assets, combined with her small size, led some prior instructors and therapists not to push her beyond her comfort zone. Only her parents scaffolded her development, constantly pushing her beyond where she was performing to the next level of development. During the sessions, it became clear that she could do far more than her school testing showed. Her simultaneous struggles with hypotonia, weak facial muscles, language difficulties, and a very competitive personality often led to shut downs, unless care was taken to juxtapose what she could do with what was difficult to do. Collectively, Jenny’s deficits frequently resulted in exhaustion because she tried so hard to keep up.

Her parents’ use of humor and silliness helped her through these times. Eventually, parental intervention was decreased as Jenny gained confidence in her new abilities. A key factor in her improved motor output was development of a rhythmic sense and the ability to coordinate a rhythm with a movement. Her vocal fry caused great frustration in that she had the language, but her vocal cords would not sustain the volume or the pitches of spoken language. After she completed 14 sessions, her parents requested that she continue because of the progress they had seen. During the additional six months of intervention, totaling 31 sessions, Jenny’s vocal fry improved modestly, and her articulation was more understandable. The use of anti-gravity activities and other sensory activities was observed to be an important component of her improvement.

Nine documents were reviewed prior to her participation in the study. They were an educational summary, physical therapy report, school progress report, speech and language evaluation, social history, psychological evaluation and the 2007-2008 individualized education plan (IEP). Deficits across all

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disciplines were noted. Articulation difficulties documented sound substitutions, omissions, an interdental "s" distortion, and a tongue thrust reverse swallow pattern, in addition to overall hypotonia and low oral and facial tone. Her receptive language was at the 14$^{th}$ %ile, and expressive language at the 18$^{th}$ %ile. Hopping, jumping, alternating feet, kicking a rolling ball, and washing her hands in sequence were also noted as weaknesses. There was no IQ measurement in the psychological assessment, data confirming problems in fine motor and visual spatial perception. Upon interview and a play-based assessment, she demonstrated creativity, self-confidence, and no cognitive deficits. The social history referred to her strong musical interests and her ability to sing along with all school songs, hand motions better than her nondisabled peers. She had two brothers, one a year younger, the other six years older. The younger brother was developmentally advanced and was both a playmate and role model for Jenny.

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## DESCRIPTIVE STATISTICS

All data was analyzed using SAS 9.2. Table 1 below is a summary table where data was acquired each minute for nine (9) variables measured over the fourteen sessions. They began on June 7, 2008 and ended on October 31, 2008, with 797 data points (N) collected. The variables included: date, session, understandable language, non-understand language, circles of communication, length of utterance, sensory integration, language initiation, rhythm activity, and volume increase. These videotaped sessions on average were 60 minutes, plus or minus 2 minutes, with the exception of session three which had 16 minutes due to camera malfunction. There was a mean of 2.4 understandable words per minute over the 797 minutes occurring in the 14 sessions, ranging from a minimum of zero to a maximum of fifteen. This equaled 1,916 understandable words, ranging from none to a maximum of 15 per minute. As shown, there were 264 non-understandable words ranging from zero to seven per minute. There were 918 circles of communication with as few as zero and as many as seven. The lengths of utterances observed equaled 2,372 with a range of zero to a maximum of 30. Language initiation occurred 661 times with a minimum of zero and a maximum of 12 in a minute totaling 661. Lastly, sensory integration was applied 60.8 percent of the time with rhythm activity and volume increases observed 37.0% and 10.4% respectively.

**Table 1**

The SAS System

The MEANS Procedure

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Session | 797 | 7.6976161 | 1.0000000 | 14.0000000 | 6135.00 | 4.0172563 |
| Understand | 797 | 2.4040151 | 0 | 15.0000000 | 1916.00 | 2.2422135 |
| Non-under | 797 | 0.3312422 | 0 | 7.0000000 | 264.0000000 | 0.8970583 |
| Circle | 797 | 1.1518193 | 0 | 7.0000000 | 918.0000000 | 1.1960098 |
| Length | 797 | 2.9761606 | 0 | 30.0000000 | 2372.00 | 3.2222037 |
| Sensory In. | 797 | 0.6085320 | 0 | 1.0000000 | 485.0000000 | 0.4883852 |
| Lang In. | 797 | 0.8293601 | 0 | 12.0000000 | 661.0000000 | 1.1145413 |
| Rhythm Act | 797 | 0.3701380 | 0 | 7.0000000 | 295.0000000 | 0.6177944 |
| Vol. In | 797 | 0.1041405 | 0 | 3.0000000 | 83.0000000 | 0.3216562 |

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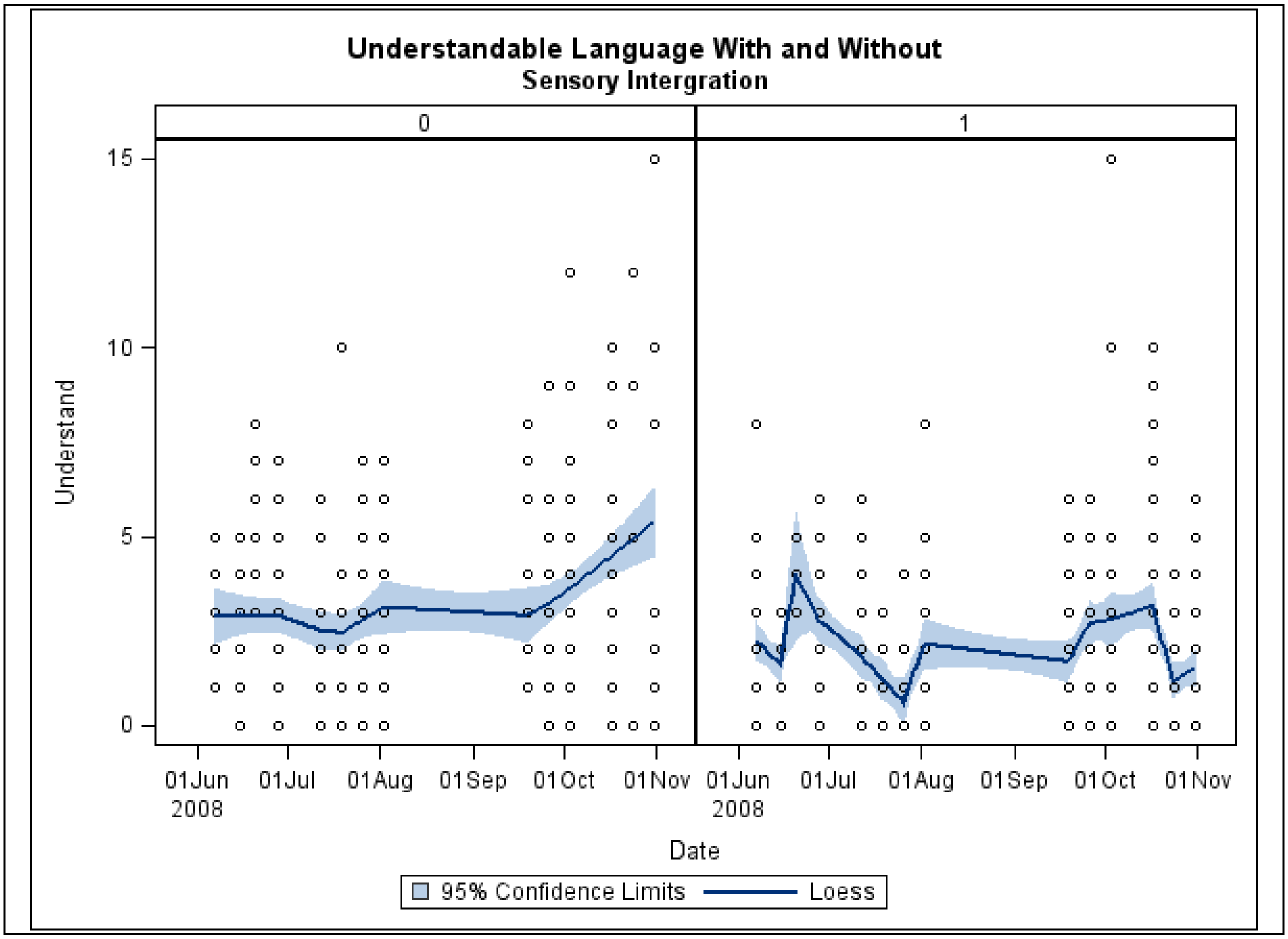
Figure 1 shows that when sensory integration was applied, understandable language was reduced throughout Jenny's sessions. A one (1) means there is sensory integration (SI) while a zero (0) means there was no sensory integration occurring simultaneously with understandable language production. This will be discussed further in the multivariate section.

**Figure 1 - Understandable Language With and Without Sensory Integration**

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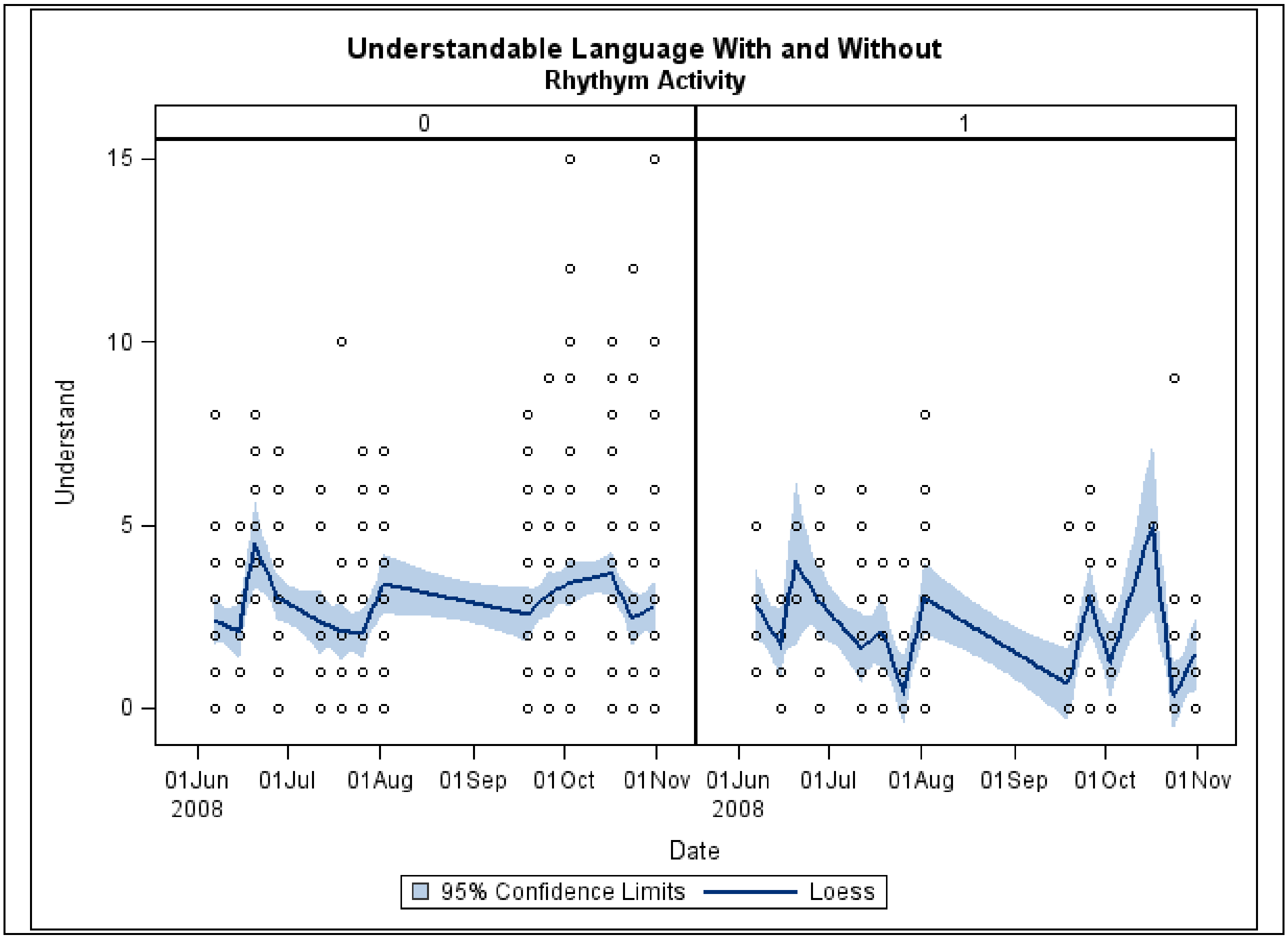
As demonstrated in Figure 2, understandable language was reduced with a rhythm activity. A one (1) means there is rhythm activity (RA) while a zero (0) means there is no rhythm activity (RA) occurring simultaneously with understandable language production. This will be discussed in the multivariate section.

## Figure 2 - Understandable Language With and Without Rhythm Activity

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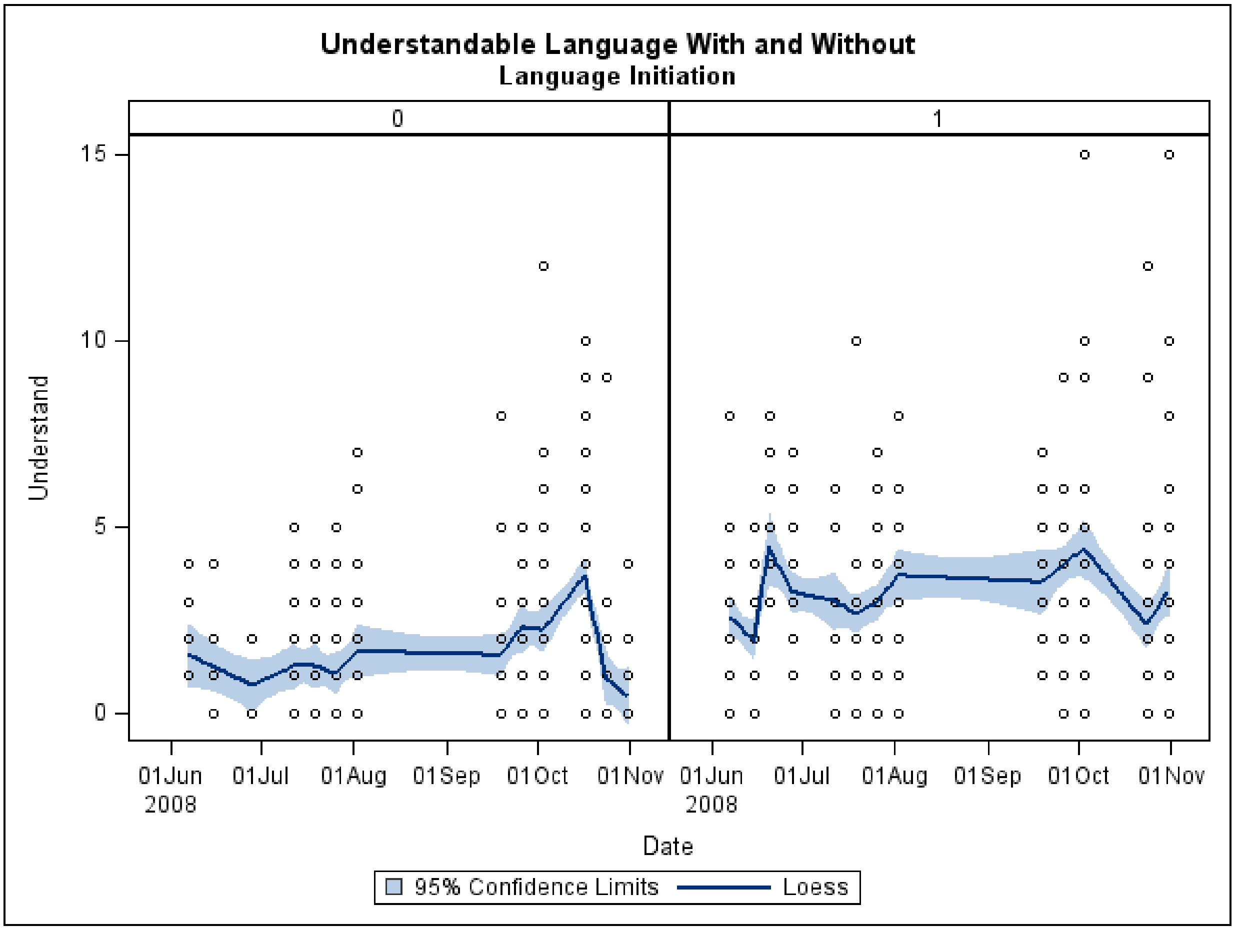
As shown in Figure 3, understandable language increased slightly with Jenny showed language initiation (LI). A one (1) means there is language initiation (LI) while a zero (0) means there is no language initiation (LI) occurring simultaneously with understandable language production. This will be discussed in the multivariate section.

**Figure 3 - Understandable Language With and Without Language Initiation**

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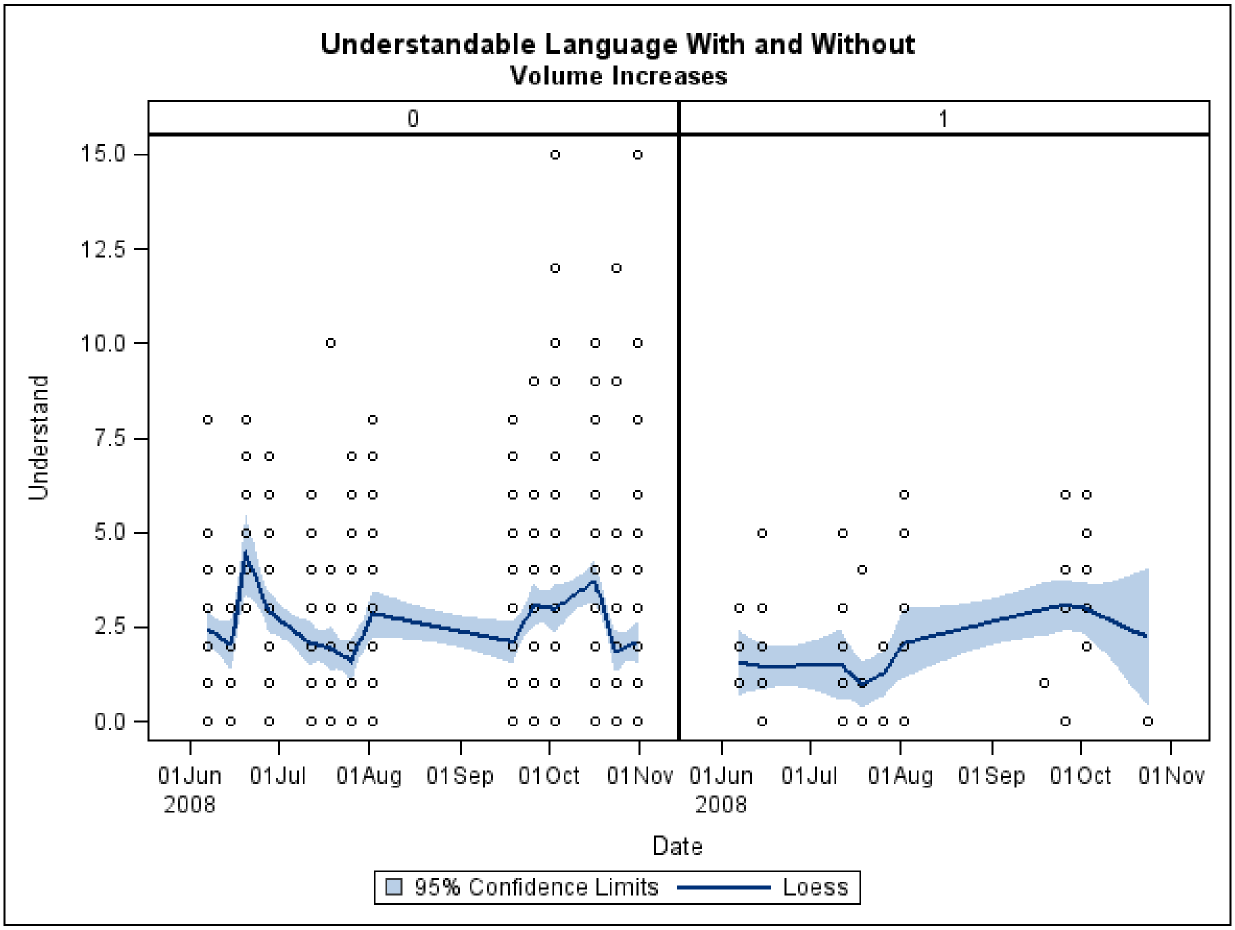
As observed in Figure 4, understandable language was reduced with increases in voice volume (IVV). A one (1) means there is an increase in voice volume (IVV) while a zero (0) means there is no increase in voice volume (IVV) occurring simultaneously with understandable language production. Again, this will be further reviewed in the multivariate section.

## Figure 4- Understandable Language With and Without Volume Increases

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## Means Values across Variables

Table 2 in the appendix contains a breakdown of each of the 14 sessions presenting the values of the nine measured variables. For example in session one (1), 62 minutes long, there were 150 understandable words, 34 non-understandable, 159 lengths of utterances, 61.2 percent application of sensory integration, 67 language initiations, 24% applications of rhythm activity and 4.8 percent of youngster's voice volume increases.

Session five (5) lasted 62 minutes. There were 123 understandable words, 29 non-understandable, 15 lengths of utterances, 59.6 percent where sensory integration was applied, 47 language initiations, 80.6% rhythm activity and 14.5 percent voice volume increases.

In comparison to session one (1), session fourteen lasted 60 minutes. There were 125 understandable words, 17 non-understandable, 246 lengths of utterances, 86.6 percent application of sensory integration, 70 language initiations, 35% applications of rhythm activity and zero percent of youngster's voice volume increases.

## Frequency Distribution across Variables

Table 3 presents the frequency distribution for the ten (10) variables captured during each session. Shown are the data ranges and their distributions. For example, the session **date** variable presents the individual durations of each session and the 797 cumulative minutes obtained in the 14 sessions. Most of the sessions ranged from 59 to 62 minutes with the exception of June 20, 2008 which was 16 minutes.

Looking at the **understandable word** variable, central to our study, there were zero understandable words observed over 179 minutes or 22.46 percent of the study duration. Similarly, there were 146 single understandable words equal to 18.32 percent. On the other end of the spectrum 15 understandable words were heard twice over a two minutes period.

82.94 percent or 661 seconds of the study, there were zero **non-understandable words**. In 8.66 percent of the study there were 69 non-understandable words, followed by 32 minutes when at least two non-understandable words were observed. The extreme case was 2 minutes in which15 non-understandable words were recorded.

Zero **circles of communications** occurred 252 times or 31.6 percent of study duration. This was followed by 342 single or 42.91 percent circles of communication. Lastly, there was one instance in which over a one minute period there was seven circles of communication.

**Length of utterance** (LOU) ranged from zero to thirty. The largest proportion was zero occurring 33.12 percent of the time for 264 minutes. The second highest was 3 equal to 13.30 percent. As observed the distribution had a long tail where in one instance Jenny was observed in one minute to have had a length of utterance of 30 or 0.13 percent of the study.

Due to Jenny's full engagement, the variable of **time on task** did not apply; hence its value was 99.6 percent of the entire study.

**Sensory integration** (SI) is the response variable that was tested to measure the influence of a range of indicator variables that had the potential to predict its application. Since it is binary, logistic regression was selected to measure the significance. As shown 61 percent of the time, SI was applied as a means by which to illicit understandable language and 39.15 percent it was not.

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For almost half of the study, (49.44 percent) **language initiation** (LI) did not occur. The range of language initiations were 0 to 12 and 30.24 percent of the time a single LI occurred. LI occurred twice 99 times, followed by 47 instances when three LIs occurred. On one occasion 12 LIs occurred. Since it is a linear measurement, regression analysis was selected to measure the significance that it may have on language production.

**Rhythm activity** (RA), is a binary response variable that was tested to measure its potential to predict understandable language. As shown 66.88 percent of the time there was no RA applied versus 31.4 percent when it was.

**Volume increase** (VI) generated by Jenny is also a binary variable. Volume increase as an indicator variable was tested to measure its potential to predict understandable language. As shown 89.96 percent of the time there was no volume increase observed versus 9.70 percent when it occurred.

## MULTIVARIATE ANALYSIS

## LINEAR REGRESSION

As shown in Table 4 of the Appendix, the regression analysis output model uses the number of understandable language as the response variable with the predictor variables being session, circles of communications, length of utterance, application of sensory integration, language initiation, and rhythm activity. All else being equal:

1. The increased number of sessions had no statistical influence on the number of understandable language (p=0.1761)
2. Circles of communications had no statistical influence on the number of understandable language (p=0.4387)
3. Length of utterances had no statistical influence on the number of understandable language (p=0.5488)
4. The application sensory integration reduces understandable language by 0.2 words. (p=0.0024)
5. Language initiation had no statistical influence on the number of understandable language (p=0.4915) and
6. Rhythm activity had no statistical influence on the number of understandable language (p=0.1951)

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## LOGISTIC REGRESSION

As shown in Table 5 of the Appendix, the logistic regression analysis model uses application of sensory integration as the response variable with the seven predictor variables being: understandable language, non-understandable language, number session, circles of communications, length of utterance, application of sensory integration, language initiation, and rhythm activity. All else being equal:

1. Understandable language is 17 percent less likely to occur with sensor integration. p=0.0001 [CI 0.765, 0.915]
2. Non-Understandable language is 22 percent less likely to occur with sensor integration. p=0.0046 [CI 0.656, 0.926 ]
3. Increases in sessions results in a 5.7 percent increase in the use of sensor integration. p=0.0056 [CI 1.016 1.100]
4. Circles of communication are not statistically predators of sensory integration. p=0.4595 [CI 0.797, 1.108]
5. Length of utterance is 10 percent less likely to occur with sensor integration. p=0.0107 [CI 0.830, 0.976]
6. Language initiation is not statistically predators of sensory integration. p=0.0621 [CI 0.992, 1.386] and
7. Rhythm activity was 1.982 to be a predictor of the use of sensor integration. p=0.0001 [CI 1.450, 2.708]

SUMMARY

In summary the key findings of both regression models showed that the application of sensory integration had a negative effect upon the production of understandable language.

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## OBSERVATIONAL AND QUALITATIVE DATA

Observations follow for each videotaped lesson, 1-15. Lesson plans were developed in advance of the session and forwarded to the parents for their records. All activities were known by the family prior to the session. Lesson plans are found in the appendix at the end of this case study.

**Lesson 1, 6/7/08**

Jenny was introduced to the routine of the lesson. She walked downstairs to the “Here We Go Down the Stairs” song, connecting movement from one step to the next with the downbeat of the song. Attendance pictures were taken, to be used for language and pre-reading activities in each subsequent lesson. Activities assessed her social skills, initiation, articulation, language, fine and gross motor co-ordination, sensory-integration, rhythmic reactions, and her developmental level of free play. From the outset, she was an extremely social, courteous child, with extensive vocal fry. No mention was made about vocal fry or its severity in any report. She was on task at all times, exploring beating a drum, sand play, and pretend play with dolls. Doll play elicited the most spontaneous language, much of it appearing to be scripted and ritualistic. She had excellent ball skills, both in catching and in kicking. She enjoyed playing with live rabbits, always showing gentleness and affection. A new activity, as well as transitions generally, caused her to automatically say “I can’t”. She relied on her father for regulation and support, seeking him out to rescue her from an activity she did not want to do, or when she was tired. She showed a strong positive response to all music activities, articulation improving with song lyrics as opposed to spoken language. She had no natural rhythmic responses, unable to establish or model a beat.

**Lesson 2, 6/15/08**

Attendance was added to the entrance routine. She learned how to turn over her picture and that of the parent who was with her, using rhythmic phrases to say, “I am here. Daddy is here”, language scaffolded by tapping the rhythm on her back or arm. Ability to match vocal pitches was examined. Due to vocal fry, she was unable to raise or lower either sung or voiced pitches. She used few stressed syllables in her speech and found singing physically uncomfortable. Three beat rhythm patterns were introduced, a strong downbeat accomplished by singing Happy Birthday. This was part of a pretend birthday party for various dolls and practice for her mother’s birthday the following week. Continuation of the three beat rhythm pattern was done by dancing to Row, Row, Row Your Boat, and “rowing” in rhythm on the floor and scooter board. Work began on decreasing dependence on her father. She learned the “Bye-bye song” at the end of the lesson, and insisted on taking a specific doll home. The concept of “borrowed” was introduced.

**Lesson 3, 6/20/08**

She brought back the borrowed doll. Conversations always occurred when she came in the door from school so that her mood, energy level, and prior activities were known before going downstairs. She had mastered the sequence of the beginning activities, showing good humor and interest in what was to follow. Duple rhythms were introduced by modeling the teacher’s phrases when kicking and rolling the ball. She refused to sing Happy Birthday to her mother and cried at the request. She jumped on a trampoline with strong objection as the teacher sang the Happy Birthday song, the goal to coordinate the motor movement with the stressed syllables heard in the song. She was not forced to continue the activity, allowed free play so as to self-calm. During free time, the spoken language of her chosen activities was scaffolded into rhythm patterns with strong downbeats. Row, Row, Row Your Boat was done by sitting on the floor, swinging her in rhythm off the floor, and standing on the floor, each with different gravitational points. The act of singing was a significant aversive for her. Observable vocal tension in her face was seen, followed by melt downs with tears and temper. Sensory play regulated her so that she could

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subsequently speak and self-calm. She asked to go home and said "I am all done". The videotape did not function after 16 minutes so that there is no documentation as to the rest of the session, except the agreement of the data collectors that it continued for the full time.

**Lesson 4, 6/27/08**

The entering routine expanded the entrance sequence by sing-spelling of her name. She was encouraged to speak in a higher "dolly" pitch, which her vocal cords would not support. Work continued on the Happy Birthday song with a pretend birthday cake and candle. She engaged in pretend play to prepare for the "party", approximating Happy Birthday with the teacher and father, and with a strong rhythmic beat for the first time. Sensory tunnel work and ball play was done with the father's assistance. She sang a lullaby to her dolls, and listened, danced, and sang to the Alphabet Song. Her singing was largely without pitches with few exceptions. A variety of planned play experiences help her move rhythmically to familiar children's songs. She frequently sought out her father for support, each time her expressive language becoming clearer and more rhythmic. Articulation remained a significant problem. It was observed that she consistently lost the first word or syllable of what was said to her when she repeated it. Use of the bouncing ball simultaneously with speech utterance helped to establish the downbeat, or stressed syllable, of her words. Expressions of "Ah, Ha!", and "Oh, no!" were correctly used both rhythmically and with inflection. She referred to the bunnies, "Lizzie and Ravi", as language fillers when she found language demands difficult. The rabbits became used in a similar way as the language scripts for her doll play.

**Lesson 5, 7/5/08**

All dolls were hidden as a teaching device. She yelled "You-Hoo!" in a two-tone high pitch, calling for them to find out where they were. She mimicked the tick-tock of the clock in Hickory Dickory Dock, with emphasis and expulsion of air on the "H" of the first syllable. Dance movement was independent of her father's help. Alone on the floor, it was observable that she began to feel the downbeat of the rhythm pattern in her body. Pragmatic language was elicited about her mother's birthday, but without full sentences, prosody, and with articulation and fry difficulties. She continued to refuse to sing the Happy Birthday song. Oral motor problems were of increasing concern as well as insufficient breath for speech phrases and volume. She subvocalized the alphabet song in a whisper. Her degree of fatigue was increasingly problematic in that she had a full day of school before coming to the lesson. She clearly had more language than her oral motor problems let her produce. For example, after a dance "performance" she said, "Show's over!" She continued to say "I can't" when first asked to use her high voice to say "You-hoo", later raising the pitch independently. She generally had a slow response and processing time, her oral motor muscles moving particularly slowly. Vocal inflection and prosody remained significant problems.

**Lesson 6, 7/19/08**

Lessons begin to phase out the strong reliance on her father for emotional support and language cues. Continued work was done on producing stressed syllable in words, rhythm activities and improved use of air flow to improve language production. She continued to use sensory activities, water and sand used alternately with language demands of the lesson. Non-understandable language was related to her fatigue and severe oral motor weaknesses.

**Lesson 7, 7/26/08**

Dancing and singing addressed strengthening her torso and rhythmic leg and foot movement. Work continued on stressed syllables, moving to a duple meter, and playing rhythm instruments with music. Singing remained an aversive for her due to difficulty in producing higher pitches and singing songs beyond a whisper. Her slow-to-warm-up period frequently lasted 40 minutes. Jumping on the trampoline, combined with her production of rhythmic speech, consistently caused a meltdown. Piano, drums, and

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guitar interested her and facilitated improved rhythmic experiences without speech. She continued to show a high level of social language in Hello/Goodbye experiences as well as social courtesies. These internal "scripts" were always understood. Forms of pragmatic language and new vocabulary words were often not understood.

**Lesson 8, 8/2/08**

Rhythm, pragmatic language, and vocal inflection were the focus of the lesson. Emphasis was placed on performance in order to motivate her independence. Pitch matching and pitch awareness occurred with the piano and other instruments, labeling sounds as higher or lower. She began to keep and maintain a beat to familiar songs through hand clapping, use of wood blocks, and beating the drum. For the first time, her feet began to move in rhythm to music without a request being made. She played the floor piano while sitting on the floor, moving her entire torso in rhythm with a happy affect, displaying great pride in her accomplishment. She discovered her image in the video camera for the first time, appearing to perform for the camera and making an extra effort to do what was asked of her. This was the last session before the summer break.

**Lesson 9, 9/19/08**

Children's songs from the previous eight sessions were reviewed. Matching pitches in lower registers and stressed syllables were reviewed. Diaphragm breathing and air flow was done in play format. Drumming and dancing engaged all of her body rhythmically within a performance format. There appeared to be no loss of skill during the six week break. Increased use of sensory activities occurred, as well as more understandable language within pretend play. She continued to dislike singing, while her dancing contained more complex movement. She continued to show auditory processing delay, seeking out musical instruments as an alternative to expressive language. Her voice volume continued to be very soft, though she complied with requests and showed a strong desire to please.

**Lesson 10, 9/26/08**

Stressed syllables and air flow were the focus of the session. A tape recorder enabled her to listen to her voice. Triplet rhythms aided in adding one more syllable per utterance. Continuous sensory play occurred, the session ending with her spontaneous singing of the ABC song, and the ability to reproduce short rhythm patterns on the drum. She continued to say "I can't" when initially asked to sing, and was more independent, not significantly relying on her father for support.

**Lesson 11, 10/3/08**

Musical rhythms were slowed down to match her delayed auditory processing, with an exaggerated, heavy, stressed syllable on the downbeat. She simultaneously danced to and sang five children's songs through modeling. Many pitches were accurate, the melodic contour audible, and volume increased. Who and What questions were introduced during free play. She continued to enjoy using the microphone. Her articulation improved with slower pacing of rhythms, though showing continued inability to simultaneously say words clearly while keeping the rhythm. However, she sought out rhythm instruments more than in any prior session.

**Lesson 12, 10/10/08**

Slower pacing of rhythms and speech were used to help her improve language processing and output. Who and Where questions were used. Microphone use, combined with her singing children's songs at a slower beat, resulting in improved articulation with stressed syllables. Birthday vocabulary and play focused on pragmatics, Who and What questions, and singing Happy Birthday with a stressed "B" on "birthday."

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**Lesson 13, 10/17/08**

Work on stressed syllables and understandability was done through sensory integration methods. Halloween vocabulary within a play context was used. Stressed syllables combined with simultaneously bouncing the ball on the stressed syllables improved understandability and fluency. She initiated more language than usual, though her arousal levels at the beginning were low, with significant fatigue visible. After sensory activities her articulation consistently improved, as did her arousal level. She continued to miss the first syllable of words heard once and then repeated. She was always interactive and responsive, with soft volume throughout, with the exceptions of exclamations, when higher pitches were heard. She sought out her father when fatigued, saying "I'm tired."

**Lesson 14, 10/24/08**

Who, What, When, and Where questions were applied throughout the lesson to the lyrics of previously learned songs she selected. Work on stressed syllables and breath support was mixed with dancing and pretend play, and continued use of the microphone. Higher pitches were accomplished by making Halloween witch sounds. She enjoyed the keyboard, so that percussive arm and hand movements were used to play along with recorded songs. Other than social exchanges at the beginning of the session, she had no expressive language for 30 minutes, playing in water, and refusing to sing. After 40 minutes, she pretended to read music on the piano and sing with it, interspersed with vestibular play. Her slow-to-warm-up self regulation, impacted on data gathering in that she often was just beginning to engage in expanded expressive language utterances when the session was done. Sensory integration activities appeared to trigger the desire to play drums, her feet moving in rhythm to the music played.

**Lesson 15, 10/31/08**

Continuation of "wh" questions was done through use of Halloween vocabulary in play contexts. Work continued on breathing and downbeat, her blowing air to imitate the amount of syllables in a word. She was exhausted from the Halloween festivities and cried for her daddy to hold her. She continued to say "can't sing" though starting each session by singing the "Going Downstairs Song." After 45 minutes and the opportunity to watch herself in the camera with the microphone, she spontaneously sang Old McDonald, and Twinkle, Twinkle. She mouthed the words, without any sound, to Row, row, row. She continued to use pretend cooking in the play kitchen as a regulatory, non-language based activity.

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# DISCUSSION

While working with Jenny it was often difficult to be objective. Her charm and intense desire to please generated affection and protective instincts from both the investigators and her parents. Therefore, particular effort was made to follow the lesson plan to the degree possible and to consistently follow through on requests. From the outset, there was the impression that sensory integration and anti-gravity activities helped her improve self-regulation and the ability to self-calm. But it soon became apparent that there was no predictable causal connection between improved expressive language and planned sensory activities.

By age four, Jenny had developed effective manipulative behaviors that helped her escape doing activities she found to be difficult. As a result, she presented as a highly confident and happy child. Avoidant behavior was particularly seen concerning many verbal activities because of the magnitude of her vocal fry. The rhythmic use of breath, and when and how much to expel it, became a critical issue. There was an obvious difference in her articulation and vocal clarity when she engaged in social language and the “doll” scripts she enjoyed using during “pretend” times. Her breathing became more diaphragmatic, and her voice volume increased. But whenever any new vocabulary or concept appeared, it seemed to shut her entire body down so that nothing moved. She did not speak above a whisper, and either sat in a lap or alone, without comment or explanation. It appeared that the sensory play helped her to stay on task throughout the session and to engage socially, but did not improve her language output. It also appeared to provide the quickest coding ad retrieval system for memory regarding motor and dance activities.

The six musical elements used with Jenny yielded the following impressions:

1. Sense of rhythm- Jenny began with no observable sense of rhythm. By the last recorded session, she moved her entire body in rhythm to a beat and could independently maintain that beat for at least 90 seconds. She enjoyed movement and dance activities, whose motor patterns increased in complexity with each session. This did not carry over into spoken language. Looby-Loo, a song with a triplet rhythm pattern, was her song of choice during free time.

2. Sense of time- Jenny was able to internalize the difference between “a long time” and a “short (or little) time” during her sessions. Frequently, in order to encourage her to do a difficult activity, the teacher said, “We’ll do only a little time”. Jenny also distinguished between fast and slow songs, as well as those with syncopated rhythms. During dancing activities, she would say “Faster, faster” or “Slow”.

3. Intensity discrimination- Jenny did not enjoy loud sounds and would say “Too loud”. She was encouraged to manipulate the volume control on the CD player to a sound level that was comfortable for her. She never selected loud ranges of sound, preferring medium loud to medium soft. If the volume as less than medium loud, she frequently did not hear the first syllable of the word.

4. Sense of pitch- Jenny’s vocal fry did not permit her to experience sung pitches to any degree. However, she clearly heard and knew the melodies of the songs used in the sessions, confirmed by her body movements and the pantomiming of the lyrics. This was particularly true of a country-Western song that was a favorite of the family. She sang this with her father when they danced together. Even then, however, she did not sing the pitches, but approximated the melodic contour.

5. Timbre (tonal color)- On recordings, Jenny appeared to prefer piano and guitar accompaniments to sung songs. None of her selections had horns, violins or drums. Of the array of instruments that were used in her sessions, she clearly preferred the piano and would gleefully make up songs and perform them without prompting. She also sought out the guitar, and listened and watched intently as it was played. She then explored the sounds made by the guitar strings. She also played drums, but they were not her main choices.

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6. Tonal memory- Jenny knew all environmental sounds, and also recognized the meaning of specific vocal inflections in others. Musically, it is unclear if she had tonal memory and if so, to what degree. However, she knew the titles of songs without their words which confirms one form of tonal memory.

There will be a follow-up study on the full scope of Jenny's 31 sessions within the ABC Study at a later time. As a result of her performance, new research questions are raised. Is there a gradient for the precuneus between the right and left hemisphere? When the rhythmic structures for language output are unsuccessful, are those rhythms replicated in dance and movement patterns through a default mechanism?

The precuneus is the "seat of self-awareness", engaging in higher cognitive functions, allowing people to evaluate themselves and their physical traits (www.wisegeek.com). Dance activities activate the precuneus, bypassing high-level auditory areas in the cerebral cortex (Brow and Parcus, 2008). The precuneus shows exceedingly high metabolic activity, suggesting an organized state of neural activity, referred to as "the default mode of brain function" (Raichie, 2001).

SUMMARY

The key findings in this study were that the application of sensory integration had a negative effect upon the production of understandable language for Jenny. Therefore, it may be stated that the data collection tool used in the study was not valid for this particular child due to her slow-to-warm-up periods, her slow auditory processing, and her severe vocal fry. The study however provided a comprehensive, empirical baseline against which to measure the eight remaining case studies in which children have left hemisphere functioning relative to language.

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# APPENDIX

## Table 2 - Means Procedure by Session

---------------------------------------- Session=1 ----------------------------------------

The MEANS Procedure

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 62 | 2.4193548 | 0 | 8.0000000 | 150.0000000 | 1.3495401 |
| Non_under | 62 | 0.5483871 | 0 | 3.0000000 | 34.0000000 | 0.9352377 |
| Circle | 62 | 1.0000000 | 1.0000000 | 1.0000000 | 62.0000000 | 0 |
| Length | 62 | 2.5645161 | 0 | 6.0000000 | 159.0000000 | 1.6458688 |
| Sensior_Inter | 62 | 0.6129032 | 0 | 1.0000000 | 38.0000000 | 0.4910624 |
| Lang_Init | 62 | 1.0806452 | 0 | 4.0000000 | 67.0000000 | 0.9107444 |
| Rhythm_Act | 62 | 0.2419355 | 0 | 2.0000000 | 15.0000000 | 0.468183 |
| Vol_Inc | 62 | 0.0483871 | 0 | 1.0000000 | 3.0000000 | 0.2163345 |

---------------------------------------- Session=2 ----------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 62 | 1.7741935 | 0 | 5.0000000 | 110.0000000 | 1.1511841 |
| Non_under | 62 | 0.1129032 | 0 | 3.0000000 | 7.0000000 | 0.4826443 |
| Circle | 62 | 0.9838710 | 0 | 1.0000000 | 61.0000000 | 0.1270001 |
| Length | 62 | 2.5322581 | 0 | 8.0000000 | 157.0000000 | 1.9052795 |
| Sensior_Inter | 62 | 0.7258065 | 0 | 1.0000000 | 45.0000000 | 0.4497487 |
| Lang_Init | 62 | 1.2096774 | 0 | 4.0000000 | 75.0000000 | 0.7921148 |
| Rhythm_Act | 62 | 0.4677419 | 0 | 1.0000000 | 29.0000000 | 0.5030315 |
| Vol_Inc | 62 | 0.3387097 | 0 | 1.0000000 | 21.0000000 | 0.4771345 |

---------------------------------------- Session=3 ----------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 16 | 4.4375000 | 3.0000000 | 8.0000000 | 71.0000000 | 1.5041609 |
| Non_under | 16 | 0.2500000 | 0 | 2.0000000 | 4.0000000 | 0.5773503 |
| Circle | 16 | 1.0000000 | 1.0000000 | 1.0000000 | 16.0000000 | 0 |
| Length | 16 | 6.1250000 | 3.0000000 | 12.0000000 | 98.0000000 | 2.2766935 |
| Sensior_Inter | 16 | 0.2500000 | 0 | 1.0000000 | 4.0000000 | 0.4472136 |
| Lang_Init | 16 | 1.8125000 | 1.0000000 | 4.0000000 | 29.0000000 | 0.9105859 |
| Rhythm_Act | 16 | 0.1250000 | 0 | 1.0000000 | 2.0000000 | 0.3415650 |
| Vol_Inc | 16 | 0 | 0 | 0 | 0 | 0 |

---------------------------------------- Session=4 ----------------------------------------

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| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 60 | 2.8833333 | 0 | 7.0000000 | 173.0000000 | 1.9922874 |
| Non_under | 60 | 0.1166667 | 0 | 4.0000000 | 7.0000000 | 0.5551505 |
| Circle | 60 | 1.0000000 | 1.0000000 | 1.0000000 | 60.0000000 | 0 |
| Length | 60 | 4.1166667 | 0 | 10.0000000 | 247.0000000 | 2.8882677 |
| Sensior_Inter | 60 | 0.5833333 | 0 | 1.0000000 | 35.0000000 | 0.4971671 |
| Lang_Init | 60 | 1.6500000 | 0 | 12.0000000 | 99.0000000 | 1.6346357 |
| Rhythm_Act | 60 | 0.3000000 | 0 | 3.0000000 | 18.0000000 | 0.6714518 |
| Vol_Inc | 60 | 0 | 0 | 0 | 0 | 0 |

------------------------------------------ Session=5 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 62 | 1.9838710 | 0 | 6.0000000 | 123.0000000 | 1.7694302 |
| Non_under | 62 | 0.4677419 | 0 | 7.0000000 | 29.0000000 | 1.3147055 |
| Circle | 62 | 1.2096774 | 0 | 5.0000000 | 75.0000000 | 1.1613601 |
| Length | 62 | 3.4677419 | 0 | 15.0000000 | 215.0000000 | 3.6382203 |
| Sensior_Inter | 62 | 0.5967742 | 0 | 1.0000000 | 37.0000000 | 0.4945499 |
| Lang_Init | 62 | 0.7580645 | 0 | 5.0000000 | 47.0000000 | 1.1115708 |
| Rhythm_Act | 62 | 0.8064516 | 0 | 7.0000000 | 50.0000000 | 1.1138283 |
| Vol_Inc | 62 | 0.1451613 | 0 | 1.0000000 | 9.0000000 | 0.3551390 |

------------------------------------------ Session=6 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 60 | 1.7333333 | 0 | 10.0000000 | 104.0000000 | 1.6556699 |
| Non_under | 60 | 0.2166667 | 0 | 4.0000000 | 13.0000000 | 0.6131792 |
| Circle | 60 | 1.5833333 | 0 | 5.0000000 | 95.0000000 | 1.4762718 |
| Length | 60 | 2.6666667 | 0 | 11.0000000 | 160.0000000 | 2.7163452 |
| Sensior_Inter | 60 | 0.6000000 | 0 | 1.0000000 | 36.0000000 | 0.4940322 |
| Lang_Init | 60 | 0.4833333 | 0 | 2.0000000 | 29.0000000 | 0.6507275 |
| Rhythm_Act | 60 | 0.4833333 | 0 | 1.0000000 | 29.0000000 | 0.5039393 |
| Vol_Inc | 60 | 0.2000000 | 0 | 3.0000000 | 12.0000000 | 0.5142050 |

------------------------------------------ Session=7 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 60 | 1.5000000 | 0 | 7.0000000 | 90.0000000 | 1.8272884 |
| Non_under | 60 | 0.1500000 | 0 | 2.0000000 | 9.0000000 | 0.4044247 |
| Circle | 60 | 0.8500000 | 0 | 4.0000000 | 51.0000000 | 1.1172757 |
| Length | 60 | 1.9666667 | 0 | 10.0000000 | 118.0000000 | 2.6615063 |
| Sensior_Inter | 60 | 0.5166667 | 0 | 1.0000000 | 31.0000000 | 0.5039393 |
| Lang_Init | 60 | 0.3500000 | 0 | 2.0000000 | 21.0000000 | 0.6331252 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Rhythm_Act | 60 | 0.3333333 | 0 | 1.0000000 | 20.0000000 | 0.4753827 |
| Vol_Inc | 60 | 0.1000000 | 0 | 1.0000000 | 6.0000000 | 0.3025317 |

------------------------------------------ Session=8 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 58 | 2.7241379 | 0 | 8.0000000 | 158.0000000 | 2.1009029 |
| Non_under | 58 | 0.2931034 | 0 | 5.0000000 | 17.0000000 | 0.9552922 |
| Circle | 58 | 0.9137931 | 0 | 5.0000000 | 53.0000000 | 1.1126779 |
| Length | 58 | 3.2241379 | 0 | 10.0000000 | 187.0000000 | 3.1234434 |
| Sensior_Inter | 58 | 0.5000000 | 0 | 1.0000000 | 29.0000000 | 0.5043669 |
| Lang_Init | 58 | 0.9137931 | 0 | 8.0000000 | 53.0000000 | 1.3282951 |
| Rhythm_Act | 58 | 0.6379310 | 0 | 4.0000000 | 37.0000000 | 0.8522061 |
| Vol_Inc | 58 | 0.1896552 | 0 | 2.0000000 | 11.0000000 | 0.4375729 |

------------------------------------------ Session=9 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 60 | 2.0666667 | 0 | 8.0000000 | 124.0000000 | 1.9646595 |
| Non_under | 60 | 0.4833333 | 0 | 6.0000000 | 29.0000000 | 1.2001648 |
| Circle | 60 | 1.1333333 | 0 | 4.0000000 | 68.0000000 | 1.0809078 |
| Length | 60 | 2.5666667 | 0 | 12.0000000 | 154.0000000 | 2.7393347 |
| Sensior_Inter | 60 | 0.6833333 | 0 | 1.0000000 | 41.0000000 | 0.4691018 |
| Lang_Init | 60 | 0.4000000 | 0 | 4.0000000 | 24.0000000 | 0.8477288 |
| Rhythm_Act | 60 | 0.3666667 | 0 | 1.0000000 | 22.0000000 | 0.4859611 |
| Vol_Inc | 60 | 0.0166667 | 0 | 1.0000000 | 1.0000000 | 0.1290994 |

------------------------------------------ Session=10 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 59 | 3.0847458 | 0 | 9.0000000 | 182.0000000 | 1.9851877 |
| Non_under | 59 | 0.4237288 | 0 | 5.0000000 | 25.0000000 | 1.1326409 |
| Circle | 59 | 2.0508475 | 0 | 6.0000000 | 121.0000000 | 1.4314657 |
| Length | 59 | 4.0847458 | 0 | 12.0000000 | 241.0000000 | 2.6606205 |
| Sensior_Inter | 59 | 0.5423729 | 0 | 1.0000000 | 32.0000000 | 0.5024778 |
| Lang_Init | 59 | 0.6949153 | 0 | 3.0000000 | 41.0000000 | 0.8760066 |
| Rhythm_Act | 59 | 0.1864407 | 0 | 1.0000000 | 11.0000000 | 0.3928050 |
| Vol_Inc | 59 | 0.0847458 | 0 | 1.0000000 | 5.0000000 | 0.2808936 |

------------------------------------------ Session=11 ------------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 59 | 3.0338983 | 0 | 15.0000000 | 179.0000000 | 3.1181676 |
| Non_under | 59 | 0.2203390 | 0 | 5.0000000 | 13.0000000 | 0.7671667 |
| Circle | 59 | 1.4576271 | 0 | 5.0000000 | 86.0000000 | 1.6538569 |
| Length | 59 | 3.8644068 | 0 | 15.0000000 | 228.0000000 | 3.8257640 |

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| | | | | | | |
|---|---|---|---|---|---|---|
| Sensior_Inter | 59 | 0.3898305 | 0 | 1.0000000 | 23.0000000 | 0.4918981 |
| Lang_Init | 59 | 0.5084746 | 0 | 3.0000000 | 30.0000000 | 0.7959571 |
| Rhythm_Act | 59 | 0.1694915 | 0 | 1.0000000 | 10.0000000 | 0.3784060 |
| Vol_Inc | 59 | 0.2372881 | 0 | 1.0000000 | 14.0000000 | 0.4290721 |

---------------------------------------- Session=12 ----------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 59 | 3.7118644 | 0 | 10.0000000 | 219.0000000 | 2.9772172 |
| Non_under | 59 | 0.7627119 | 0 | 6.0000000 | 45.0000000 | 1.3561988 |
| Circle | 59 | 0.0677966 | 0 | 2.0000000 | 4.0000000 | 0.3142812 |
| Length | 59 | 0.0677966 | 0 | 2.0000000 | 4.0000000 | 0.3650416 |
| Sensior_Inter | 59 | 0.5423729 | 0 | 1.0000000 | 32.0000000 | 0.5024778 |
| Lang_Init | 59 | 0 | 0 | 0 | 0 | 0 |
| Rhythm_Act | 59 | 0.0847458 | 0 | 3.0000000 | 5.0000000 | 0.4656525 |
| Vol_Inc | 59 | 0 | 0 | 0 | 0 | 0 |

---------------------------------------- Session=13 ----------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 60 | 1.8000000 | 0 | 12.0000000 | 108.0000000 | 2.4411723 |
| Non_under | 60 | 0.2500000 | 0 | 2.0000000 | 15.0000000 | 0.5084039 |
| Circle | 60 | 1.5000000 | 0 | 6.0000000 | 90.0000000 | 1.5238221 |
| Length | 60 | 2.6333333 | 0 | 12.0000000 | 158.0000000 | 2.8401878 |
| Sensior_Inter | 60 | 0.8333333 | 0 | 1.0000000 | 50.0000000 | 0.3758230 |
| Lang_Init | 60 | 1.2666667 | 0 | 5.0000000 | 76.0000000 | 1.3259684 |
| Rhythm_Act | 60 | 0.4333333 | 0 | 1.0000000 | 26.0000000 | 0.4997174 |
| Vol_Inc | 60 | 0.0166667 | 0 | 1.0000000 | 1.0000000 | 0.1290994 |

---------------------------------------- Session=14 ----------------------------------------

| Variable | N | Mean | Minimum | Maximum | Sum | Std Dev |
|---|---|---|---|---|---|---|
| Understand | 60 | 2.0833333 | 0 | 15.0000000 | 125.0000000 | 2.8241793 |
| Non_under | 60 | 0.2833333 | 0 | 2.0000000 | 17.0000000 | 0.5551505 |
| Circle | 60 | 1.2666667 | 0 | 7.0000000 | 76.0000000 | 1.5278950 |
| Length | 60 | 4.1000000 | 0 | 30.0000000 | 246.0000000 | 5.5987287 |
| Sensior_Inter | 60 | 0.8666667 | 0 | 1.0000000 | 52.0000000 | 0.3428033 |
| Lang_Init | 60 | 1.1666667 | 0 | 5.0000000 | 70.0000000 | 1.3675001 |
| Rhythm_Act | 60 | 0.3500000 | 0 | 1.0000000 | 21.0000000 | 0.4809947 |
| Vol_Inc | 60 | 0 | 0 | 0 | 0 | 0 |

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## Table 3 – Frequency Distribution by Variable

The FREQ Procedure

| Date | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 07JUN2008 | 62 | 7.78 | 62 | 7.78 |
| 15JUN2008 | 62 | 7.78 | 124 | 15.56 |
| 20JUN2008 | 16 | 2.01 | 140 | 17.57 |
| 28JUN2008 | 60 | 7.53 | 200 | 25.09 |
| 12JUL2008 | 62 | 7.78 | 262 | 32.87 |
| 19JUL2008 | 60 | 7.53 | 322 | 40.40 |
| 26JUL2008 | 60 | 7.53 | 382 | 47.93 |
| 02AUG2008 | 58 | 7.28 | 440 | 55.21 |
| 19SEP2008 | 60 | 7.53 | 500 | 62.74 |
| 26SEP2008 | 59 | 7.40 | 559 | 70.14 |
| 03OCT2008 | 59 | 7.40 | 618 | 77.54 |
| 17OCT2008 | 59 | 7.40 | 677 | 84.94 |
| 24OCT2008 | 60 | 7.53 | 737 | 92.47 |
| 31OCT2008 | 60 | 7.53 | 797 | 100.00 |

| Understand | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 0 | 179 | 22.46 | 179 | 22.46 |
| 1 | 146 | 18.32 | 325 | 40.78 |
| 2 | 144 | 18.07 | 469 | 58.85 |
| 3 | 127 | 15.93 | 596 | 74.78 |
| 4 | 68 | 8.53 | 664 | 83.31 |
| 5 | 67 | 8.41 | 731 | 91.72 |
| 6 | 33 | 4.14 | 764 | 95.86 |
| 7 | 8 | 1.00 | 772 | 96.86 |
| 8 | 9 | 1.13 | 781 | 97.99 |
| 9 | 6 | 0.75 | 787 | 98.75 |
| 10 | 6 | 0.75 | 793 | 99.50 |
| 12 | 2 | 0.25 | 795 | 99.75 |
| 15 | 2 | 0.25 | 797 | 100.00 |

| Non_under | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 0 | 661 | 82.94 | 661 | 82.94 |
| 1 | 69 | 8.66 | 730 | 91.59 |
| 2 | 32 | 4.02 | 762 | 95.61 |
| 3 | 21 | 2.63 | 783 | 98.24 |
| 4 | 6 | 0.75 | 789 | 99.00 |
| 5 | 5 | 0.63 | 794 | 99.62 |
| 6 | 2 | 0.25 | 796 | 99.87 |
| 7 | 1 | 0.13 | 797 | 100.00 |

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| Circle | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 0 | 252 | 31.62 | 252 | 31.62 |
| 1 | 342 | 42.91 | 594 | 74.53 |
| 2 | 99 | 12.42 | 693 | 86.95 |
| 3 | 62 | 7.78 | 755 | 94.73 |
| 4 | 23 | 2.89 | 778 | 97.62 |
| 5 | 15 | 1.88 | 793 | 99.50 |
| 6 | 3 | 0.38 | 796 | 99.87 |
| 7 | 1 | 0.13 | 797 | 100.00 |

| Length | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 0 | 264 | 33.12 | 264 | 33.12 |
| 1 | 57 | 7.15 | 321 | 40.28 |
| 2 | 74 | 9.28 | 395 | 49.56 |
| 3 | 106 | 13.30 | 501 | 62.86 |
| 4 | 99 | 12.42 | 600 | 75.28 |
| 5 | 52 | 6.52 | 652 | 81.81 |
| 6 | 45 | 5.65 | 697 | 87.45 |
| 7 | 30 | 3.76 | 727 | 91.22 |
| 8 | 27 | 3.39 | 754 | 94.60 |
| 9 | 8 | 1.00 | 762 | 95.61 |
| 10 | 16 | 2.01 | 778 | 97.62 |
| 11 | 4 | 0.50 | 782 | 98.12 |
| 12 | 8 | 1.00 | 790 | 99.12 |
| 13 | 1 | 0.13 | 791 | 99.25 |
| 15 | 2 | 0.25 | 793 | 99.50 |
| 16 | 2 | 0.25 | 795 | 99.75 |
| 20 | 1 | 0.13 | 796 | 99.87 |
| 30 | 1 | 0.13 | 797 | 100.00 |

| Time_On | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 0 | 3 | 0.38 | 3 | 0.38 |
| 1 | 794 | 99.62 | 797 | 100.00 |

| Sensior_Inter | Frequency | Percent | Cumulative Frequency | Cumulative Percent |
|---|---|---|---|---|
| 0 | 312 | 39.15 | 312 | 39.15 |
| 1 | 485 | 60.85 | 797 | 100.00 |

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| | | | Cumulative | Cumulative |
|---|---|---|---|---|
| Lang_Init | Frequency | Percent | Frequency | Percent |
| 0 | 394 | 49.44 | 394 | 49.44 |
| 1 | 241 | 30.24 | 635 | 79.67 |
| 2 | 99 | 12.42 | 734 | 92.10 |
| 3 | 47 | 5.90 | 781 | 97.99 |
| 4 | 9 | 1.13 | 790 | 99.12 |
| 5 | 5 | 0.63 | 795 | 99.75 |
| 8 | 1 | 0.13 | 796 | 99.87 |
| 12 | 1 | 0.13 | 797 | 100.00 |

| | Cumulative | Cumulative | | |
|---|---|---|---|---|
| Rhythm_Act | Frequency | Percent | Frequency | Percent |
| 0 | 533 | 66.88 | 533 | 66.88 |
| 1 | 249 | 31.24 | 782 | 98.12 |
| 2 | 5 | 0.63 | 787 | 98.75 |
| 3 | 7 | 0.88 | 794 | 99.62 |
| 4 | 2 | 0.25 | 796 | 99.87 |
| 7 | 1 | 0.13 | 797 | 100.00. |

| | | | Cumulative | Cumulative |
|---|---|---|---|---|
| Vol_Inc | Frequency | Percent | Frequency | Percent |
| 0 | 717 | 89.96 | 717 | 89.96 |
| 1 | 78 | 9.79 | 795 | 99.75 |
| 2 | 1 | 0.13 | 796 | 99.87 |
| 3 | 1 | 0.13 | 797 | 100.00 |

Frequency Missing = 795

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## Table 4- Liner Regression Analysis

The REG Procedure
Model: MODEL1
Dependent Variable: Understand

| | |
|---|---|
| Number of Observations Read | 797 |
| Number of Observations Used | 797 |

Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 6 | 1760.12548 | 293.35425 | 103.38 | <.0001 |
| Error | 790 | 2241.78167 | 2.83770 | | |
| Corrected Total | 796 | 4001.90715 | | | |

| | | | |
|---|---|---|---|
| Root MSE | 1.68455 | R-Square | 0.4398 |
| Dependent Mean | 2.40402 | Adj R-Sq | 0.4356 |
| Coeff Var | 70.07223 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|---|
| Intercept | 1 | 1.30224 | 0.17512 | 7.44 | <.0001 |
| Session | 1 | 0.03981 | 0.01517 | 2.62 | 0.0089 |
| Circle | 1 | -0.03136 | 0.06433 | -0.49 | 0.6261 |
| Length | 1 | 0.40930 | 0.02712 | 15.09 | <.0001 |
| Sensior_Inter | 1 | -0.52839 | 0.12905 | -4.09 | <.0001 |
| Lang_Init | 1 | 0.07408 | 0.06379 | 1.16 | 0.2459 |
| Rhythm_Act | 1 | -0.34190 | 0.09978 | -3.43 | 0.0006 |

The SAS System

The REG Procedure
Model: MODEL1
Dependent Variable: Non_under

| | |
|---|---|
| Number of Observations Read | 797 |
| Number of Observations Used | 797 |

Analysis of Variance

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 6 | 9.98925 | 1.66488 | 2.09 | 0.0527 |
| Error | 790 | 630.56282 | 0.79818 | | |
| Corrected Total | 796 | 640.55207 | | | |

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| | | | |
|---|---|---|---|
| Root MSE | 0.89341 | R-Square | 0.0156 |
| Dependent Mean | 0.33124 | Adj R-Sq | 0.0081 |
| Coeff Var | 269.71496 | | |

Parameter Estimates

| Variable | DF | Parameter Estimate | Standard Error | t Value | Pr > \|t\| |
|---|---|---|---|---|---|
| Intercept | 1 | 0.32459 | 0.09288 | 3.49 | 0.0005 |
| Session | 1 | 0.01090 | 0.00805 | 1.35 | 0.1761 |
| Circle | 1 | 0.02643 | 0.03412 | 0.77 | 0.4387 |
| Length | 1 | -0.00863 | 0.01439 | -0.60 | 0.5488 |
| Sensior_Inter | 1 | -0.20821 | 0.06844 | -3.04 | 0.0024 |
| Lang_Init | 1 | 0.02328 | 0.03383 | 0.69 | 0.4915 |
| Rhythm_Act | 1 | 0.06863 | 0.05292 | 1.30 | 0.1951 |

## Table 5- Logistic Regression Analysis

The SAS System

The LOGISTIC Procedure

Model Information

| | |
|---|---|
| Data Set | ABC2012.ABC2012 |
| Response Variable | Sensior_Inter |
| Number of Response Levels | 2 |
| Model | binary logit |
| Optimization Technique | Fisher's scoring |

| | |
|---|---|
| Number of Observations Read | 797 |
| Number of Observations Used | 797 |

Response Profile

| Ordered Value | Sensior_ Inter | Total Frequency |
|---|---|---|
| 1 | 1 | 485 |
| 2 | 0 | 312 |

Probability modeled is Sensior_Inter=1.

Model Convergence Status

Convergence criterion (GCONV=1E-8) satisfied.

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Model Fit Statistics

| Criterion | Intercept Only | Intercept and Covariates |
|---|---|---|
| AIC | 1069.024 | 969.297 |
| SC | 1073.705 | 1006.744 |
| -2 Log L | 1067.024 | 953.297 |

Testing Global Null Hypothesis: BETA=0

| Test | Chi-Square | DF | Pr > ChiSq |
|---|---|---|---|
| Likelihood Ratio | 113.7269 | 7 | <.0001 |
| Score | 104.2173 | 7 | <.0001 |
| Wald | 91.0706 | 7 | <.0001 |

Analysis of Maximum Likelihood Estimates

| Parameter | DF | Estimate | Standard Error | Wald Chi-Square | Pr > ChiSq |
|---|---|---|---|---|---|
| Intercept | 1 | 0.5905 | 0.2122 | 7.7457 | 0.0054 |
| Understand | 1 | -0.1786 | 0.0455 | 15.3793 | <.0001 |
| Non_under | 1 | -0.2488 | 0.0879 | 8.0109 | 0.0046 |
| Session | 1 | 0.0557 | 0.0201 | 7.6828 | 0.0056 |
| Circle | 1 | -0.0621 | 0.0840 | 0.5471 | 0.4595 |
| Length | 1 | -0.1056 | 0.0414 | 6.5124 | 0.0107 |
| Lang_Init | 1 | 0.1591 | 0.0853 | 3.4793 | 0.0621 |
| Rhythm_Act | 1 | 0.6840 | 0.1594 | 18.4240 | <.0001 |

Odds Ratio Estimates

| Effect | Point Estimate | 95% Wald Confidence Limits | |
|---|---|---|---|
| Understand | 0.836 | 0.765 | 0.915 |
| Non_under | 0.780 | 0.656 | 0.926 |
| Session | 1.057 | 1.016 | 1.100 |
| Circle | 0.940 | 0.797 | 1.108 |
| Length | 0.900 | 0.830 | 0.976 |
| Lang_Init | 1.172 | 0.992 | 1.386 |
| Rhythm_Act | 1.982 | 1.450 | 2.708 |

Association of Predicted Probabilities and Observed Responses

| | | | |
|---|---|---|---|
| Percent Concordant | 72.0 | Somers' D | 0.444 |
| Percent Discordant | 27.6 | Gamma | 0.446 |
| Percent Tied | 0.4 | Tau-a | 0.212 |
| Pairs | 151320 | c | 0.722 |

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