Prosodic Features in the Spoken Language of Children with Autism Spectrum Disorders High Functioning (ASD-HF) According to the Theory of "Phonology as Human Behavior"

Thesis submitted in partial fulfillment of the requirement for the degree of “DOCTOR OF PHILOSOPHY”

By

Hila Chana Green

Submitted to the Senate of Ben-Gurion University of the Negev

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Approved by the Advisor

Approved by the Dean of the Kreitman School of Advanced Graduate Studies
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LIST OF ABBREVIATIONS

IH - Israeli Hebrew
ASD - Autism Spectrum Disorders
HF - High Functioning
ASD-HF - Autism Spectrum Disorders High Functioning
WDD - Without Developmental Disorders
ToBI - Tones and Break Indices
IH-ToBI - Israeli Hebrew Tones and Break Indices
PHB - Phonology as Human Behavior
F0 - fundamental frequency
PR - Pitch Range
IU(s) - Intonation unit(s)
PA(s) - Pitch Accent(s)
PAs/W - Pitch Accents per Word
BT(s) – Boundary Tone(s)
R - Repetition elicitation task
RA - Reading Aloud elicitation task
S - (semi-) Spontaneous speech elicitation task
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ABSTRACT

This dissertation presents a study of the prosodic features of Israeli Hebrew (IH) speaking male children between the age of 9 and 13 years, diagnosed with Autism Spectrum Disorders (ASD) and normal intelligence (ASD-HF).

Prosody in ASD is an under-researched area, even though atypical prosody has been identified as a core feature of ASD and tends to persist even when other aspects of language improved. The atypical prosody tends to limit the social acceptance of the children with ASD-HF mainstreamed into the larger community.

The participants of the study were 20 monolingual IH speaking children comprising ten subjects diagnosed with ASD-HF and ten participants without developmental disorders (WDD), as a control group. Participants in this study were matched peers. Based on the fundamental criterion for peer matching, one peer was excluded from the statistical analysis.

The study established a methodology which enabled the simultaneous analysis of multiple features of prosody. The methodology made use of instrumental measurements, as well as perceptual analysis. The procedures were first used to explore the prosodic features of the IH language and to create the IH-ToBI (Tones and Break Indices) annotation. In the second stage the IH-ToBI was used as a research tool to explore the prosodic features of the ASD-HF subjects.

Data collection was based on three elicitation tasks: repetition, reading aloud of a short story, and (semi-) spontaneous speech. All the data was transcribed using the Autosegmental-Metrical theory of intonation with the IH-ToBI, and with the computerized PRAAT system.

The results were analyzed and explained according to the concept that language is a symbolic tool whose structure is shaped by its communication function, the characteristics of its users, and the principle that language represents a compromise in the struggle to achieve "maximum communication through minimal effort" associated with the theory of Phonology as Human
Behavior (PHB).

The IH-ToBI was used to describe, compare, and contrast the phonetic realization of the prosodic features of intonation (pitch range, phrasing, pitch accents, edge tones, and boundary tones) in the data collected.

The results of the study are presented in two parts: Part I presents the IH transcription of tonal events while part II presents the results of the description and comparison of the prosodic features of ASD-HF versus participants without developmental disorders.

Part II explains the nonrandom distribution of the prosodic features within the context of the theory of Phonology as Human Behavior, and explores the functional process (simplification, reduction, and duplication) used by the ASD-HF subjects in order to achieve "maximum communication with minimal effort".

The dissertation’s main findings are: All ten ASD-HF subjects present differences in prosody as compared with their WDD peers. Not all subjects show differences in all features examined, but every subject shows at least one feature differently. By examining the degree of variability in pitch range - typical, narrow, and wide - the ASD-HF subjects could be subdivided into three categories. ASD-HF subjects were found to produce more high and less low pitch accents, and primarily used three different Edge Tone patterns. They made very limited use of the remaining patterns. A parallel between the linguistic and extra linguistic behavior of ASD-HF subjects was found, as reflected in their limited prosodic patterns and lexical repetitions.

Keywords: Autism Spectrum Disorders High Functioning (ASD-HF), Prosody, Phonology as Human Behavior (PHB), Acoustic analysis.
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To my parents, my thanks for instilling in me an appreciation of the
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CHAPTER 1: Introduction

1.1 Statement of the problem

"Wrong Planet" is a web community designed for individuals with Autism and Asperger Syndrome. In November 30, 2009 12:17 pm, "Laney" posted a new subject "Prosody Changes When Discussing Interests?"

"I know that prosody differences are often a characteristic of AS (Asperger Syndrome). "Robotic speech", or incorrect tone of voice for what is being said. I am guilty of the latter more than the former. The only time I use "robotic speech" is when I get started talking about one of my "things" or when I interject (which is quite often). My eyes unfocused (I'm usually very focused on something, though probably not the eyes of the person I am speaking to!) and I become Miss Monotone for the duration of the monologue. It has taken me 26 years to realize that this happens. Does anybody else notice a change in their prosody when discussing interests, reciting facts or when interjecting?

"Vocally, I'm the opposite of you - when discussing my interests, I have modulation. Otherwise, I tend to mumble or speak in a low rumble that is relatively flat. However, I do tend to experience more stim-like behaviors and difficulty with eye focus when I get enthused about something dear to me" "makuranososhi" (posted: Nov 30, 2009 12:30 pm).

"Interesting topic. I think I also use more intonation, like makuranososhi, and I think I speak a little louder, when speaking about my interests. Though I'll always use less intonation than most other people. I normally tend to speak with a soft voice and don't use much intonation" "Scientist" (posted: Nov 30, 2009
In another thread in the same forum:

"...if a friend of mine hadn't left his video-camera running during an extended conversation a few years ago. On playing it back, I was shocked by how flat I sounded - things that I meant in a jokey kind of way came out flat, almost sounding like insults. I was kind of appalled, honestly". "brightlined" (posted: Jan 13, 2008 8:06 pm).

"kinda singsong; never really monotone, a little high-pitched, but that's me." "pakled" (posted: Jan 13, 2008 10:33 pm).

Atypical prosody has been identified as a core feature of Autism Spectrum Disorders (ASD) and since the initial description, by Kanner (1943) and Asperger (1944, as cited in Frith 1991), the "unnatural" prosody was marked using different narrations such as "monotonous", "odd", "sing-song", "exaggerated", and more. Asperger, translated in Frith (1991) wrote:

"Sometimes the voice is soft and far way, sometimes it sounds refined and nasal but sometimes it is too shrill and ear-splitting. In yet other cases, the voice drones on in a sing-song and does not even go down at the end of sentence. However many possibilities there are, they all have one thing in common: the language feels unnatural..."

(Frith 1991:70)

Research has shown that even when other aspects of language improve, prosodic deficits tend to be persistent and show little change over time. This seems to limit the social acceptance of children with ASD High-Functioning (ASD-HF) mainstreamed into the larger community since they sound strange
to their peers.

In spite of abundant documentation indicating that prosody is a feature of impaired communication in ASD, the research on prosody in autism is limited and has been criticized for: (a) being severely fragmented, (b) lacking normative data and contrast groups, (c) using poorly defined prosodic categories, and (d) employing subjective ratings rather than objective measures (Paul et al. 2005). Furthermore, there has been little research into the prosody of Israeli Hebrew and even fewer studies comparing and contrasting the prosody of typical and atypical IH speaking children (e.g. Frank et al. 1987, 1989, Adi-Bensaid and Bat-El 2004, Adi-Bensaid 2006). The existing research has been limited mainly to describing the phenomenon as a problem, without trying to explain it within the context in which it occurs.

1.2 Research objectives

This dissertation will attempt:

(1) To describe, compare and contrast the phonetic realization of the fundamental frequency and the prosodic features of intonation in the language of children with ASD-HF and children Without Development Disorders (WDD).

(2) To establish a methodology which allows the analysis of more than one feature of prosody simultaneously.

(3) To make use of instrumental measurements, (using recently developed speech technology tools) as well as perceptual analysis.

(4) To explained the results within the context of a linguistic theory which declares that:

   (a) Language is a symbolic tool whose structure is shaped both by its communicative function and the characteristics of its
INTRODUCTION

users (Tobin 1990, 1993, 1994, 2009),

(b) Language represents a compromise in the struggle to achieve maximum communication using minimal effort as presented in the theory of Phonology as Human Behavior (PHB) (Diver 1979, 1995, Tobin 1997, 2009).

1.3 Research questions

(1) Do the pitch values and pitch range of children with ASD-HF differ from those of children without developmental disorders?

(2) Is it possible to distinguish between the prosodic features of intonation of children with ASD-HF versus children without development disorders (WDD) and if so, in which features are these differences evident?

(3) Do the different elicitation tasks influence the prosodic features of intonation of ASD-HF and WDD children and if so, in what way?

1.4 Structure of dissertation

The dissertation is divided into eight chapters: Chapter 1 is the introduction to the dissertation, including the statement of the problem, the research objectives, the research questions, and the structure of the dissertation. Chapter 2 presents the theoretical background of the two main issues bound together by this study: (a) prosody and the Autosegmental-Metrical theory and (b) language and prosody of individuals with Autism Spectrum Disorders High-Functioning (ASD-HF). Chapter 3 presents the pilot study that preceded the present research. Chapter 4 presents the research method i.e. the participants, procedure, and data analysis. Chapter 5 is the first part of the results and presents the IH transcription of tonal events (IH-ToBI) including the theoretical basis of the ToBI transcription framework. Chapter 6 presents
the results of the analysis of the prosodic features of ASD-HF vs. WDD participants. This chapter addresses three main issues: (a) frequency values and pitch range, (b) the prosodic features of intonation, and (c) influences of the elicitation task on the realization of the prosodic features. Chapter 7 interprets the results within the context of the theory Phonology as Human Behavior (PHB) and shows how this functionally oriented theory provides new insights into prosody of individuals with ASD-HF. The discussion is preceded by a summary of the PHB theory itself. Chapter 8 is the conclusion and outlines future directions of research.
CHAPTER 2: THEORETICAL BACKGROUND

Language is a complex, multifaceted system comprising language use (pragmatics), meaning (semantics), form (syntax and morphology), and sounds (phonology and prosody). This study concentrates on phonology and prosody above the word-level by investigating the linguistic description of the prosodic features of speech in general. It focuses on comparing and contrasting IH speaking children diagnosed with Autism Spectrum Disorders High Functioning (ASD-HF) and children Without Developmental Disorders (WDD) of the same age group.

Prosody has become an important research topic in linguistics, language development, and language disorders as well as in other fields such as text-to-speech and speech recognition systems. The background to prosody that follows is divided into two parts. The first part will examine the scope of prosody as both a phonological and acoustic phenomenon. The second part will concentrate on ASD-HF and on the intersection between prosody with language and communication. The chapter will close with a literature review of atypical prosody in autism.

2.1 The scope of prosody

There is no consensus amongst researchers about either the nature of prosodic features themselves or the methodology used for their description. The term ‘prosody’ is deriving from the Greek ‘prosodia’, which is a musical term. Metaphorically, in linguistic contexts it is implied that prosody is the musical accompaniment to the words themselves. It is a general term that describes the way one says a particular utterance.

“prosody describes any acoustic properties that cannot be predicted by looking at the immediate lexical neighborhood”
The `acoustic properties’ are duration (any tempo phenomenon),
intensity (the variation of the air-pressure produced by the lungs that creates
variations in amplitude i.e. the amount of energy present in speech),
fundamental frequency (the frequency of the vibration of the vocal folds, see
2.1.1 below), as well as the co-variation of these 'properties' (Stephens et al.
1983). Prosody describes how these acoustic properties operate in the spoken
unit and how they are manifested as prosodic features (e.g. accent, tone,
pauses, and junctures).

In most languages, prosodic features such as tone are not lexical. However, there are "tone languages" such as Chinese or Xhosa in which tone is a lexical feature and the same word when produced with different tones creates differences in meaning. In these languages, words may be distinguished solely by the fundamental frequency of their vowels. This is not the case in Israeli Hebrew. In Hebrew there are only few ‘minimal pairs’ of words differing in stress location e.g. /BOker/ (morning) vs. /boKER/ (cowboy), /RAtsa/ (she runs/ran) vs. /raTSA/ (he wants) or, /BIra/ (beer) vs./biRA/ (capital), i.e. the same sounds with different stress patterns constitute two different words with different meanings. Nevertheless, many different melodies are possible on any given word or phrase. The choice of the melody is not determined by the choice of the word and even a simple word, such as /ken/ (yes), can be produced with different melodic or intonation contour patterns, as illustrated in Figure 1 below.
Fujisaki (1997:32) states that prosody has two major components: (a) the word accent and (b) the intonation. They are both manifested by the contour of the voice F0. In the paragraphs that follow, I will use this assumption to define prosodic units based on the fundamental frequency (F0) contour characteristics.

2.1.1 Fundamental frequency or pitch

In speech production, the vocal folds vibrate at varying rates over time. The frequency of the vibration of the vocal folds is the F0 of the sound that is produced. Pitch is the perceptual correlate of the F0.

In non-tone languages like Hebrew, the contour of the voice F0 is the acoustic characteristic that is most closely related to prosody for the following reasons:

(a) The F0 contour of an utterance may be regarded as the translation of the linguistic information into vibration of the vocal folds. This is evident in the lexical word accent and the grouping of words into phrases (Ladd 1996). It can be assumed that for Hebrew it is more adequate due to the fact, that Hebrew F0 carries little lexical content,

(b) Methodologically, the analysis of the F0 contour permits the
simultaneous investigation of prosodic features over both the F0 and time domains. This was the basis of the abstract categorization used in the phonological model of intonation proposed by Pierrehumbert (1980) and which I have adopted in this study.

2.1.2 The nature of the prosodic phenomena

There were many attempts during the twentieth century to characterize the nature of prosodic phenomena. However, for many years linguists have found the description and definition of prosodic features to be problematic, especially in work done in modern linguistic theory during the second quarter of the twentieth century. Adversely, more has been achieved by adopting more complex, multi-dimensional frameworks collectively termed ‘non-linear’ models, and in particular the Autosegmental-Metrical theory, also known as Intonational Phonology (Pierrehumbert 1980, Pierrehumbert and Hirschberg 1990, Ladd 1996).

The classical structuralism school of phonology based their theories primarily on the phoneme as the basic distinctive segmental phonological unit. In American structuralism, prosodic features were seen as a rather special kind of phonemes - supra-segmental phonemes, which were considered, located ‘on top of’ segmental phonemes. Phonological descriptions were based on the ‘segment’ i.e. vowels and consonants, and as a result, prosodic features were either ignored or forced into a ‘segmental mold’. Indeed, because prosodic features were seen either as lexical or as non-lexical, even Bolinger, who over several decades made a monumental contribution to the understanding of intonation and prosody, set the gradient nature of intonation into “more-or-less”, as opposed to the “all-or-none” nature of segments (Bolinger 1955:20).

There are many perspectives on ‘prosody’, ‘prosodic features’, ‘intonation’, ‘suprasegmentals’ and their definitions. In some of these, the term ‘prosodic’ is used synonymously with suprasegmental features. Lehiste
(1979) interprets the differences between suprasegmental features and segmental features as differences of kind and differences in degree. The difference in kind is between the segmental features proper, and the features of pitch, stress, and quantity. The last three are, in a way, a secondary, overlaid function of inherent features, e.g. the F0 may serve simultaneously to identify the segment as voiced (voiced/voiceless) and to constitute part of the manifestation of a tonal or intonational pattern.

A further difference between segmental and suprasegmental features appears in the fact that suprasegmental features are established by a systematic comparison of items in sequence, whereas segmental features can be defined without reference to the sequence of the segments in which they appear, i.e. the comparison is made of an item with other items in the phonological inventory. Thus, differences between suprasegmental features and segmental features are simultaneously differences of kind and differences in degree, and these characteristic differences make it possible to offer a tentative definition for the “suprasegmentals”.

Vowels and consonants are combined to produce syllables, words, and sentences. Human beings articulate these segments according to their segmental features and at the same time, our pronunciation varies in other respects as well. There are wide ranges of factors which influence how we modify our speech and these modifications are evident over a sequence of segments, called suprasegmentals. It is part of the nature of prosodic features that they are of the same substance as segmental features. However, prosodic features refer to larger sections of the speech continuum. Suprasegmental features are established by a comparison of items in sequence, whereas segmental features are identifiable by inspection of the segment itself (Lehiste 1976).

The paralinguistic modifications by voice qualifiers such as whisper, creak, falsetto, etc. or by voice qualifications like a giggle, laugh, sob, etc. express the attitude or the emotional state of the speaker. Thus, suprasegmental features include the intonation contour, prominence relations,
phrasing, and pitch range, as well as voice qualifiers and qualifications and other auditory means that can be produced by our vocal tract. Although the terms ‘suprasegmental’ and ‘prosodic’ to a large extent coincide in their scope and reference, it is nevertheless sometime useful and desirable to distinguish between them. A simple dichotomy ‘segmental’ vs. ‘suprasegmental’ does not do justice to the richness of phonological structure above the segment. Prosody is complex, involving a variety of different dimensions. Fox (2000) suggests a distinction that can be made between ‘suprasegmental’ as a **mode of description** on the one hand and ‘prosodic’ as a **kind of feature** on the other. The way that a sentence or an expression is uttered expresses much more than just the information that is lexically encoded in the words. Prosody may influence the interpretation of a sentence and can interact with different levels of meaning. As an expression of the same idea, Cutler and Isard (1980) use for prosody a metaphor of a “sauce of the sentence - it adds to, enhances or subtly changes the flavor of the original. And like a good sauce, the realization of a sentence’s prosodic structure is a blend of different ingredients, none of which can be separately identified in the final product‖ (Butterworth 1980:245). However, the term prosody has been used interchangeably with intonation in the literature. Often prosody is understood as a term with a wider range of characteristics, as for example described by Hirst and Di Cristo (1998:7). These authors restrict the use of “intonation proper” for “supra-lexical”, “post-lexical”, or simply “non-lexical” characteristics.

The prosody of connected speech may be analyzed and described in terms of the variation of a large number of prosodic features. However, three features are most consistently used for linguistic purposes, either singly or jointly. These features are pitch, length and loudness (Cruttenden 1986).

Respectively, the three physical acoustic parameters that are most commonly assumed as being prosodic are F0 (perceived as pitch), duration (perceived as length), and intensity (perceived as loudness) (Lehiste 1970, Cutler and Ladd 1983).
2.1.3 Definition of prosody

Fujisaki claims that all perspectives on prosody may be broadly classified into two categories, characterized by their methodological preference of “taking measurements” or “building models” (Fujisaki 1997:27):

(a) The “Concrete” approaches define prosody in physical terms, as those phenomena that involve the acoustic parameters of pitch, duration, and intensity.

(b) The “Abstract” approaches define prosody by its place in linguistic structure rather than by its phonetic nature, as the phenomena that involve phonological organization at the level above the segment.

Fujisaki’s states that "the study of human communicative behavior through language belongs to the empirical sciences, where one needs to obtain, first and foremost, clear and objective knowledge of the phenomena through making measurements" (Fujisaki 1997:28). For this study, I will adopt Fujisaki’s definition of prosody:

“Prosody is the **systematic organization** of various **linguistic units** into an utterance or coherent group of utterances in the process of speech production. Its realization involves both segmental and suprasegmental feature of speech and serves to convey not only linguistic information, but also paralinguistic and non-linguistic information”.

(Fujisaki 1997:28)

The following sections will focus on the interpretation of the insights drawn from the above definition.

2.1.4 The communication function of prosody

Prosody plays an important role in a range of communicative functions that
enable speakers to construct discourse through expressive language. A number of investigators (e.g. Crystal 1986, Merewether and Alpert 1990, Kent and Read 1992, Panagos and Perlock 1997, Shriberg et al. 2001, McCann and Peppé 2003) distinguish three sub-domains in which the functional levels of prosody can be categorized:

(a) Grammatical functions of prosody which include suprasegmental cues that are used to signal syntactic information within the sentence (Warren 1996): (a) segmenting utterances into phrases by use of juncture or placement of pause e.g. I-scream versus ice-cream, (b) using stress or accent to distinguish parts of speech e.g. perMIT - verb, PERmit - noun, and (c) using intonation to distinguish between statements and questions: "I AM tired (falling pitch)." versus "I am TIRED (rising pitch)?".

(b) Pragmatic functions of prosody are used to carry social information beyond that conveyed by the syntax of the sentence. It conveys the speaker’s intentions, or the hierarchy of information within the utterance, and results in optional changes in the way an utterance is expressed (Van et al. 1981, Winner 1988) i.e. accents used to highlight an element of information within an utterance as the focus of attention, or to call the listener’s attention to information that is new to the conversation e.g. "The CHILD likes chocolate" or "The child likes CHOCOLATE" or "The child LIKES chocolate".

(c) Affective functions of prosody serve more global functions including: (a) changes in register used for varying social functions e.g. differences between the ways an individual talks to peers, to figures of authority, to young children, etc. and (b) changes which convey a speaker’s general emotional state and specific feelings (Bolinger 1989).

2.1.5 Prosodic organization

As already defined, Prosody comprises "... linguistic, paralinguistic and non-
linguistic information” (Fujisaki 1997:28). Ladd (1996) formulates the distinction between linguistic and paralinguistic in terms of “categorical structure” in contrast to “gradient nature”. Linguistic features are categorical, discrete, and arbitrary with respect to their function. They express their function indirectly via an abstract level. On the other hand, paralinguistic features are iconic and gradient. Ladd summarized the differences between language and paralanguage as “a matter of the way the sound-meaning relation is structured” (Ladd 1996:36).

This work will relate only to the **linguistic** layer of prosody and will adopt Fujisaki’s concept of “systematic organization” i.e. an organization by which prosody is composed of different linguistic units that collectively lead to the communication function by acoustic realization above the word level. The underlying assumption is that such an independent structure of prosody exists, and it will now be described within framework of the Autosegmental-Metrical theory (Pierrehumbert 1980, Liberman and Pierrehumbert 1984, Beckman and Pierrehumbert 1986, Pierrehumbert and Beckman 1988, Pierrehumbert and Hirschberg 1990, Ladd 1996).

### 2.1.5.1 Prosodic form

Prosody comprises different features which are realized by different acoustic forms i.e. F0, duration and intensity. Liberman (1960) has argued that the most significant prosodic features are produced by the **linguistic use** of pitch/F0. F0 is a phonetic form with a variety of prosodic functions and can be interpreted phonologically according to these different functions, i.e. the prosody of an utterance is described by fluctuations of the F0 over the course of the utterance. The F0 is determined by the rate of vibration of the vocal folds within the larynx. It is the lowest harmonic in the speech signal. The other frequencies contribute to the perception of both voice quality and the actual phoneme type. F0 varies as a function of the gender and age of the speaker. The average F0 for women is approximately 225Hz (180-400Hz), for
men 120Hz (60-240Hz), and for children 265Hz (Cruttenden 1986).

While F0 involves acoustic measurements measured in Hz, pitch is used as a perceptual term relating to the listener’s judgment as to whether a sound is high or low and to whether the voice is going up or down.

2.1.5.2 Prosodic hierarchy and features

Henceforth, starting with the concept of Intonation unit, the phonologically relevant units of intonation (above the word-level) will be presented and defined in light of Pierrehumbert model of intonation (Pierrehumbert 1986).

2.1.5.2.1 The Intonation Unit (IU)

The starting point for the analysis of the prosodic pitch contour i.e. intonation, is the notion of a unit. All scholars who have investigated intonation have identified such a unit. Therefore, the initial premise in this study is that there exists a basic structural unit and it is the Intonation Unit (IU).

Various approaches have been used to describe the concept of the intonation unit based on physiological, cognitive-semantic, or phonetic-phonological perspectives. Similarly, different terms are used to describe the concept e.g. breath-group, sense-group, intonation group, intonational phrase, and others.

The physiological classification for intonation unit was one of the earliest. Sweet (1906) suggests that speakers “are unable to utter more than a certain number of sounds in succession without renewing the stock of air in the lungs” (Sweet 1906:45). Sweet proposes that language should be divided into “breath-groups”.

The intonation unit has also been defined in terms of the information content. The term “sense-group” was proposed by Kingdon (1958) to mean “groups of words that have a semantic and grammatical unit - not necessarily complete” (Kingdon 1958:162). Another term with a similar concept, the
"information unit" was proposed by Halliday (1985). He identified the unit as the “tone group” and was the first to point out the tone component in the nature of the unit (Halliday 1967). According to Halliday, the speaker must include in every tone group a chunk of new information, which will be phonologically marked.

Chafe (1987, 1992, and 1993) in his cognitive model uses the term “Intonation unit”, which I have adopted. According to Chafe, the Intonation unit is constrained by the cognitive processes occurring during verbalization in the minds of both the speaker and the listener. A phonetic-phonological description for the Intonation unit has been proposed by Crystal (1969:206). He proposes the existence of a unit composed of at least one prominent syllable with a major pitch movement and surrounded by boundaries manifested by many different acoustic cues.

In her study on the phonology of English intonation, Pierrehumbert (1980) suggests that what delimit the "intonational phrase" are boundary tones, which can be either high or low. According to Cruttenden (1986), both phonetic-phonological and grammatical-semantic considerations must be taken into account in the classification of "intonation groups". He proposes that the assignment of intonation-group boundaries should be made a priori by taking into account phonetic cues. Furthermore, in some difficult cases, semantic and grammatical cues should also be considered.

For the purposes of this work, I use the term Intonation Unit (IU) and have attributed the IU with its phonetic-phonological characteristics: (a) there is a "unity of pattern" within the IU i.e. the IU has a distinct intonation pitch pattern, and (b) the IU is delimited by a boundary tone.

The application of quantitative models in the study of prosody has become widely adopted and several attempts (e.g. Wang and Hirschberg 1992, Altenberg 1987, Ostendorf et al. 1990) have been made to classify IU boundaries automatically by means of statistical modeling. However, an algorithm that is able to detect the boundaries of an IU does not exist and the task of assigning IU is still a combination of the identification of acoustic cues.
and considerable perceptual subjective judgment.

While different languages differ in their most prominent cue for delimitation of IUs (Hirst and Di Cristo 1998), the most prominent criteria suggested are: (a) pause, (b) final syllable lengthening or slow speech rate at the end of an IU, and a following (c) fast speech rate at the beginning of the next IU, and (d) pitch reset.

The following hierarchy has been suggested for Hebrew (Laufer 1987, 1996): (a) pitch reset, (b) cross-boundary change of speech rate, and (c) pause. However, this suggestion has been based on elicited speech and not on naturally occurring Israeli Hebrew spontaneous speech. In a preliminary study of Hebrew prosody, Amir et al. (2004) examined quantitatively the detection of IUs when using the four cues mentioned. Only 24% of the IUs conformed to all four cues. The three acoustic cues, final lengthening, pitch reset and pause, were found in more than 50% of the units. Final lengthening and pitch reset together were found in more than 70%. These findings have leaded the researchers to the conclusion that the perceptual IU segmentation is influenced mostly by its boundaries. The researchers point out that the remaining 30% of the units are not accounted for, and that their findings question the hierarchy of cues defined by Laufer (1987, 1996) referred to above.

Primarily, segmentation of a discourse flow into IUs is made by detecting their boundaries, whereas internal criteria are brought into consideration only secondarily (Cruttenden 1986). This practice has been used successfully in transcribing large corpora (e.g. Du Bois et al. 1993).

2.1.6 The Autosegmental-Metrical approach to intonation

The Autosegmental-Metrical theory is a generative phonological framework in which the tone is specified using an independent string of tonal segments and the prosody of an utterance is viewed as a hierarchically organized structure of phonologically defined features. Prosody does not designate any set of
"distinctive features" but does refer to "meter" which means to the structural organization itself.

Beginning in the late 1970s, the phonological approach to intonation started to develop. Pierrehumbert (1980) integrated suggestions from Bruce’s dissertation “Swedish Word Accents in Sentence Perspective (Bruce 1977)” into a framework for intonational phonology with an exploration of English intonation. This theory developed in Liberman and Pierrehumbert (1984). Pierrehumbert and Hirschberg (1990) further extended the theory to account for the pragmatic meanings of the parts of intonation contours. The development of intonational phonology as a linguistic sub-discipline has laid the groundwork for using linguistic representations and rules in analyzing the structure (organization) of intonational features.

The theory assumed that intonation, and pitch in particular, has a phonological organization. The Autosegmental-Metrical theory adopts the phonological goal of being able to characterize contours in terms of a string of categorically distinct elements and the phonetic goal of providing a mapping from phonological elements to continuous acoustic parameters. Ladd (1996) summarizes the four main assumptions of the theory that demonstrate the foundation underlying the phonological representation (Ladd 1996:42):

(a) Linearity of tonal structure: Tonal structure is linear, consisting of a string of local events associated with certain points in the segmental string. Between such events, the pitch contour is phonologically unspecified and can be described in terms of transitions from one event to the next. In languages like English and IH, the most important events of the tonal string are pitch accents, which are associated with prominent syllables in the segmental string, and edge tones, which are associated with the edges of prosodic domains of various sizes.

(b) Distinction between pitch accent and stress: Pitch accents, in languages that have them, serve as concrete perceptual cues to stress or prominence. However, they are in the first instance intonational
features, which are associated with certain syllables in accordance with various principles of prosodic organization. The perceived prominence of accented syllables is, at least in some languages, a matter of stress, which can be distinguished from pitch accent.

(c) Analysis of pitch accents in terms of level tones: Pitch accents and edge tones in intonational languages can be analyzed as consisting of primitive level tones or pitch targets, High (H) and Low (L).

(d) Local sources of global trends: The phonetic realization or scaling of any given H or L tone depends on a variety of factors (e.g. degree of emphasis, position in utterance) that are essentially orthogonal to its identity as H or L. Overall trends in pitch contours (e.g. gradual lowering of overall range) mostly reflect the operation of localized but iterated changes in scaling factors.

Following the Autosegmental-Metrical approach, Pierrehumbert (1980) proposes a description of intonation that consists of three parts: (1) the grammar of phrasal tones, (2) the metrical representation of the text, and (3) the rules of assigning association lines.

“...the phonological characterization of intonation has three components. The first is a grammar of allowable phrasal tunes. This grammar generates sequences of L and H tones... The second component is a metrical representation of the text... The grid tells us which syllables are stressed... describing the relationship in strength among the stress syllables.... Lastly, we have rules for lining up the tune with the text. The complete phonological representation for intonation is thus a metrical representation of the text with tones lined up in accordance to the rules”

(Pierrehumbert 1980:10)

Pierrehumbert (1980) assumes that the tonal units are morphemes of different kinds and those phonetic rules translate these abstract
representations into concrete F0 contours. Based on the autosegmental-metrical model of intonational phonology the ToBI transcription was designed (informative background about ToBI is presented in 5.1.2 on page 62).

Table 1: The finite state grammar generating tones

<table>
<thead>
<tr>
<th>Boundary tone</th>
<th>Pitch accents</th>
<th>Phrase accent</th>
<th>Boundary tone</th>
</tr>
</thead>
<tbody>
<tr>
<td>H%</td>
<td>H*</td>
<td>H'</td>
<td>H%</td>
</tr>
<tr>
<td>L%</td>
<td>L*</td>
<td>L'</td>
<td>L%</td>
</tr>
<tr>
<td>L*+H</td>
<td>L*+H*</td>
<td>L'+H*</td>
<td>L*+H*</td>
</tr>
<tr>
<td>H*+L</td>
<td>H*+H*</td>
<td>H'+L</td>
<td>H*+H*</td>
</tr>
</tbody>
</table>

2.1.6.1 The Intermediate Phrase

The intermediate phrase reflects juncture phenomena in the prosodic hierarchy. Beckman and Pierrehumbert (1986) and Pierrehumbert and Hirschberg (1990) suggest that the IU consist of smaller constituents, which they called intermediate phrases. The break between intermediate phrases is not as strong as between IU, although like IU the intermediate phrases are used to structure the linear sequence of words into larger units. Besides the above characteristics, an intermediate phrase boundary can block juncture processes like downstep (illustrate in Figure 10 on page 75), or upstep and like IU the intermediate phrases are represented by a boundary tone L or H (for IH, Lp or Hp). Pierrehumbert and Hirschberg (1990) describe these tones as a means to convey information about the relatedness of the intermediate part-phrase to another intermediate phrase in the all IU. Not all languages have an intermediate phrase (Jun 2005).
2.1.6.2 Stress and Pitch Accent

Bolinger (1958) was the first to formulate the relations of stress-accent. He argues that the main means to express stress is pitch and proposed the term accent for prominence in the utterance. The syllable is perceived as accented (prominence) only if it has a considerable pitch change at that place. Bolinger assumed full-fledged meaning for the accents and therefore he gives them morphemic status.

Following Bolinger, Pierrehumbert (1980) assumed that the tonal units are morphemes of different kinds. Pierrehumbert notation represents the F0 contour as a linear sequence of phonologically distinctive units-pitch accents and edge tones. These features are local in nature and do not interact with each other. Their occurrence within the sequence can be described linguistically by the presented grammar. According to Pierrehumbert (1980), pitch accents are the “building blocks” of pitch contours. Ladd (1996) has defined the pitch accents as a local feature of pitch contour associated with a prominence in the utterance. Each IU contains at least one pitch accent.

In Bolinger’s view, ‘stress’ is an abstract lexical property of individual syllables while ‘pitch accent’ (the tone marked with an asterisk character in the Autosegmental-Metrical theory and in the ToBI transcriptions) is actual prominence in an utterance. If a word is prominent in a sentence, this prominence is realized as a pitch accent on the ‘stressed’ syllable of the word.

2.1.6.3 The Edge Tone

The edge tones are the tonal events at the edge of prosodic domains. Edge tones are divided into two types (according to Pierrehumbert 1980, as cited in Ladd 1996:80), phrase accents, and boundary tones.

Phrase accents are H or L tones occurring between the last pitch accent and the boundary tone. Boundary tones associated with the end of intonational unit. The H% boundary tone always indicates a final rise. The L% boundary
tone can best be described as indicating the absence of final rise. After L phrase tone, it indicates a fall to the bottom of the speaking range, but after H phrase tone it indicates a level sustention of the previous one.

2.1.7 Summary

This initial introduction part has demonstrated the scope of prosody from the viewpoint of this specific research. The review included a definition of prosody and an account of prosodic categories related to intonation within the Autosegmental-Metrical approach and Pierrehumbert model of intonation. The terms presented in this first part, are preliminaries before understanding the issue of prosody in children's with ASD.

The next part of the introduction chapter will focus on language and communication in ASD in general and prosody in ASD in particular.
2.2 Autism Spectrum Disorders

Communication, speech, and language in Autism Spectrum Disorders (ASD) present a heterogeneous and complex picture. It has been recognized as one of the founding constituent of the syndrome and it is one of the most frequent reasons for referral among children to the clinic (Tager-Flusberg et al. 2005).

The purpose of the current section is: (a) to define and describe the syndrome of ASD, and the specific sub-group of High-Functioning individuals within the ASD continuum (ASD-HF), (b) to review the linguistic characteristics in ASD-HF individuals from a developmental and functionalist perspective and to review previous studies on prosody in autism.

2.2.1 Definition and diagnosis

The term “early infantile autism” was used by Kanner (1943) to describe a group of eleven children with a previously unrecognized disorder. The common characteristics noted by Kanner were profound withdrawal, an obsessive desire for preservation of sameness, a skilful and even affectionate relation to objects, an intelligent and pensive physiognomy, and either "mutism" or the kind of language that does not serve functional communication (e.g. Fay and Schuler 1980, Kanner 1971).

Shortly after, Hans Asperger (as cited in Frith 1991) published a report in which he described four boys who, despite apparently adequate verbal and cognitive skills, displayed deficits in social interaction and milder autistic behaviors. They demonstrated deficits, which resembled a milder, higher functioning form of autism. Although, unaware of each other, both Kanner and Asperger used the word “autistic” to characterize the disturbances that they observed. The two conditions are, in many ways, similar, and the argument continues as to whether they are varieties of the same underlying abnormality or are separate entities (e.g. Baskin, Sperber and Price 2006,

During the past decades, there has been considerable controversy over the definition of the disorder and different labels had its roots in a particular view of the nature and causation of autism. At present, there is a consensus among clinicians and researchers (Volkmar 1997, Volkmar et al. 2004) about the criteria that are used to define autism, in both the DSM-IV (American Psychiatric Association 1994) or the ICD-10 Classification of Mental and Behavioral Disorders (World Health Organization 1993), the two widespread diagnosis indexes.

In the DSM-IV, “autistic disorder” is listed as a category under the heading of “Pervasive Developmental Disorders” (PDD) and there is a categorical distinction between Asperger syndrome and autism disorders based on language onset. As a result, some researchers have examined whether language skills differentiate the two disorders (e.g. Howlin 2003, Lewis, Murdoch and Woodyatt 2007, Mayes and Calhoun 2001, Szatmari et al. 1995, Szatmari 2000) with results that were inconclusive. However, as proposed by Wing (1988), the autistic disorders are referred to today as Autism Spectrum Disorder (ASD) and the concept of a “spectrum” relates to the relatively heterogeneous disorders as well as the wide variety in functional abilities.

ASD’s are neuro-developmental disorders that emerge early in life, prior to 30 months (Short and Schopler 1988, Volkmar 1997, Volkmar et al. 2005).

It is a behaviorally defined disorder. The three essential criteria for diagnosing autism include: (a) qualitative impairments in social reciprocity and engagement, (b) delays and deficits in language and communication, and (c) the presence of restricted repetitive and stereotyped behaviors, activities, or interests (APA 1994, Wing and Gould 1979). The severity of these impairments varies from individual to individual, and even in the individual himself (Beglinger and Smith 2001, Sigman and McGovern 2005, Ring et al. 2008).
ASD’s range from severe autism (Classic Autism, Retts Syndrome and Childhood Disintegrative Disorder) with associated difficulties, to High-Functioning Autism (HFA) with normal non-verbal ability but early language delay (PDD-NOS; Pervasive Developmental Disorder-Not Otherwise Specified), or even with no language delay (Asperger syndrome).

Epidemiological studies indicate prevalence for autism of 5.2 per 10,000, with 80% of affected individuals exhibiting mental retardation. Prevalence rates increase to 10 per 10,000 when all disorders on the spectrum are included (Fombonne 2003). There is no association between autism and social class (Fombonne 2003), and there is a higher incidence of autism in boys than in girls, with reported ratios averaging around 3.5 or 4.0 to 1 (Bryson 1996, Fombonne 2003). There is strong evidence from twin and family studies that ASD’s are influenced by genetic factors (e.g. Baily et al. 1996, Frith 2004, Happé and Frith 1996). However, there is still much discussion about the primary causes of ASD.

2.2.1.1 High-Functioning Autism

The autistic continuum ranges from the most severe mentally retarded individuals with social impairment as one of several other severe impairments, to highly intelligent and able persons with subtle social impairments (Wing 1991). The various clinical appearances of ASD’s depend upon the combinations of different impairments, which may vary in severity independent of one another, and interact to produce various overt behaviors. As mentioned, experts disagree on whether or not ASD-HF and Asperger syndrome synonymous. Yet, by convention, if an individual with autism has an IQ in the normal range, or above, they are said to have “high-functioning autism”. If an individual meets all of the criteria for high-functioning autism except communicative impairment or even just a history of language delay, they are said to have “Asperger syndrome”.

It should be noted that a diagnosis of “high-functioning autism” exists in
neither the DSM-IV nor the ICD-10. The term high-functioning autism started out as shorthand to described diagnosed autistic individuals who could nevertheless speak and carry on with many every day activities. Low functioning was the conceptual opposite. It was researchers however, that then began using high-functioning autism as a quasi-diagnostic label along with low-functioning autism and sometimes also Asperger syndrome, to distinguish relative levels of adaptation and development. The research community recognizes that high-functioning autism does not happen in people with an IQ of below roughly 70 (Frith 2004, Rapin and Dunn 2003).

2.2.2 Language and communication in autism

Ever since Kanner (1943) published his first description of “infantile autism”, researchers and clinicians have engaged in debates about the nature of the underlying deficits. Diagnostic determinations have changed over the years, but “qualitative impairment in communication” (APA 1994:70) have remained as one of the key diagnostic features of autism. By definition, children with ASD show delays and deficits in the acquisition of language and it is one of the primary diagnostic characteristic (Rutter 1978). Kanner described the clinical language features of 23 children. He noted that eight were mute, but might utter a complete sentence in an emergency. Other features were immediate and delayed echolalia, unusual “first words”, metaphorical substitution, literalness, and pronominal reversals - the feature that Kanner regarded as “typical, almost pathognomonic” of autism (Kanner 1971).

Practically, parents of children with ASD’s often report that the first sign of a problem with their child was the delay in language milestones achievement (Baltaxe and Simmons 1992, Dahlgren and Gillberg 1989), absence of language, or the loss of language that had begun to develop (Kurita 1985, Lord and Paul 1997). This is the one of the most frequent reasons for referral to the clinic, among children who are later diagnosed with ASD (Tager-Flusberg, Paul and Lord 2005). In retrospect, many parents bring
back into memory, that even during the first year of life, their infants were not responsive to adult contact, did not engage in turn-taking and failed to develop joint attention and to make eye contact (Bartak, Rutter and Cox 1975, Grossman, Carter and Volkmar 1997, Osterling and Dawson 1994). The achievement of these milestones appears to be the most powerful predicator of a long-term prognosis of language abilities (e.g. Eisenberg 1956, Rutter and Lockyer 1967, DeMyer et al. 1973, Mawhood, Howlin and Rutter 2000, Anderson et al. 2007). Anderson et al. (2007) found that nonverbal IQ and joint attention emerged as strong positive predicators of verbal outcomes.

Eisenberg (1956) published a follow-up of 63 diagnosed cases of early infantile autism and concluded: “Clinically the degree of disturbance in language function emerges clearly as important guide to prognosis” (Eisenberg 1956:610). Rutter (1970) found that using language productively and flexibly by age five was the best single predicator of positive outcomes for large sample of children. In a wider perspective, early language abilities influence on long-term outcomes of social functioning and academic achievement (Beitchman et al. 2001, Gillberg, Steffenburg and Jakobsson 1987). The centrality of language and communication in the syndrome, the question of a distinguished between autism and AS, and the importance of language to long-term outcomes have lead to the growth of studies in this group of verbal children who diagnosed with ASD-HF. These studies have provided a clinical description of some unique characteristics and domains in the language of individuals with ASD-HF.

In the next section, I will present a selective review of studies conducted on linguistic functioning in children with ASD-HF from the developmental and a functionalist perspective of language acquisition. Preliminary, I will explain briefly the theoretical and methodological framework to which the present dissertation is linked, starting in short from the question “What is Language”.
2.2.2.1 What is language?

In the systemic-functional linguistics approach, language is a systematic resource for expressing meaning in context and “what is language?” depends on the context in which one asks the question (Halliday 1975). From a Saussurian, Prague school communication-oriented approach:

“every linguistic theory is the direct result of a specific set of theoretical axioms that is related to how the linguist defines language, defines a linguistic problem, determines the source, kind and amount of data to be selected and analyzed, chooses a methodology to select and analyzed the data and compares and contrasts the analyses in light of all the above”

(Tobin 1997:4)

The communication-oriented approach defined language as:

“a system of systems that is composed of various sub systems, that are organized internally and systematically related to each other and that is used by human beings to communicate”

(Tobin 1997:6)

With the notion of “system of systems”, the present context defining language under the framework were language is knowledge that can be used as: (a) a tool of communication (Bates 1979), and (b) a system which is shaped both by its communication function and by the characteristic of its users, under the principle, that language represents a compromise in the struggle to achieve “maximum communication through minimal effort” (Diver 1979, Diver 1995, Tobin 1997). The theory is described in more detail in Chapter 7 on page 114.

As with the concept of “tool of communication”, Bloom and Lahey
(1978) deserved the term of "language use" with the attempt to understand what children learn about language and how children with language problems can be helped to learn language. By the definition "a code whereby ideas about the world are represented through a conventional system of arbitrary signals for communication" (Bloom and Lahey 1978:4), they identified three major dimensional view of language that are basic to describing the development of language and for understanding language disorders: (a) content (b) form, and (c) use.

As follows, aspects of each of these three-dimensional will be presented and each will be described more fully were research into ASD took place. This theoretical and methodological framework as developed to normal language acquisition provided the advantage of allowing for more detailed comparisons to matched control subjects, in particular to see if ASD involves a global language deficit, or whether certain domains of language functioning are selectively impaired (Tager-Flusberg 1981).

It should be noted that in much of these studies methodological problems limit the reliability of the findings; most of the studies were done on very small groups of subjects or even in a form of case reports, diagnostic criteria and subject selection are not uniform across all studies, some studies have failed to control. However, the present review is a theoretical background of the knowledge update in the era of ASD language in general and prosody in particular.

### 2.2.2.2 The Content of language in ASD-HF

The development of content in language consists of the acquisition of taxonomy of categories and rule-relations having to do with the nature of objects and the ways in which objects behave and relate to one another. This development depends on the interaction between children’s knowledge and context (Bloom and Lahey 1978). Typically developing children begin producing their first words between the ages of 10 and 18 months. Around
this time, children also show lexical comprehension, responding appropriately to words, and there is a rapid increase in both receptive and expressive vocabulary (Bloom 1973, Dromi 1987).

Among children with autism, there is a wide variation in lexical use, even for those children who acquire functional language. At the start, not only one variable of the ASD, define the upper limits of the mute period of the children. Bartak and Rutter (1976) in a comparative study of autistic children having IQ’s above (HF) and below 70, was found that all were late in speaking. For the lower IQ group the mean age of first use of single word was 4:7 years and for the ASD-HF group the mean age of onset was 2:6 years. The mean age of first phrases to communicate was 6:5 years for the low group and 4:8 years for the ASD-HF classification. They conclude that children with autism appear to learn words later than typically developing children.

Studies on lexical development within this population indicate that autistic children often develop large vocabularies and some take an obsessive interest in words and word meanings (Tager-Flusberg et al. 1990, Tsai and Beisler 1984). Tager–Flusberg (1985, 1986) in an experimental studies with children with autism, matched on verbal mental age to children with retardation and typically developing children, found that children with autism were no different from matched control groups in their organization and representation of object concepts within taxonomic hierarchies (e.g. spaniel-dog-animal). The children with autism recognized the same kinds of systematic and well structured relationships among pictures of objects as do typically developing children at both basic (e.g. car, chair, dog) and superordinate (e.g. vehicle, furniture, animal) levels. Furthermore, in looking at word meaning in both comprehension and production, the children with autism had no difficulty extending words to a range of different exemplars, i.e. referring to pictures of different kinds of dogs as a “dog”. Their extensions were based on prototype organization of their semantic concepts. These findings and other (e.g. Tager-Flusberg 1986, Tager-Flusberg et al. 1994, Kjelgaard and Tager-Flusberg 2001) suggest that for children with ASD, word
meanings acquired in a highly systematic and constrained way as for typically developing children and that vocabulary development can be an era of relative strength for individuals with ASD.

Contemporaneously, it appears that children with ASD exhibit unusual phenomenon in the domain of lexical use: (a) echolalia, (b) preservative and inappropriate repetition of words (Perkins et al. 2006), (c) unusual set of ‘first words’ (Williams 1993), (d) idiosyncratic meanings for words as well as neologisms (Kanner 1946, Rutter 1970), which has been found even in children with high-functioning autism (Volden and Lord 1991), and (e) certain classes of words may be under-represented (in production or in comprehension). For example: mental state terms, particularly terms for cognitive states (Tager-Flusberg 1992, Tager-Flusberg and Sullivan 1994), social-emotional terms (Eskes, Bryson and McCormick 1990, Hobson and Lee 1989), peculiar word choice and abstract language (Simmons and Baltaxe 1975, Tager-Flusberg 1981), and expression of temporal and spatial concepts (Perkins et al. 2006).

2.2.2.3 The Form of language in ASD-HF

'Form' can be described in different ways: in term of units of sounds, phonology, morphology, or syntax. Words can be classified according to adult parts of speech as nouns, verbs, adjectives, and sentences can be described according to sentence types, clause types or phrase structures and so. Regardless of how one can be describing linguistic form alone, “form in language is the means for connecting sounds or signs with meaning” Bloom and Lahey (1978:15).

2.2.2.3.1 Vocal and segmental development in ASD-HF

Phonology refers to the ability to accurately perceive, reproduce, and organize the sound patterns of the language, and it is an important precursor to all
other aspects of spoken language. It was demonstrated that infants discriminate language specific speech contrasts as early as the first 30 days of life (Eimas et al. 1971), spoken babbling observed in infants is instrumental in early linguistic development (Locke 1983).

Few studies have investigated the vocal and the segmental phonological development in autistic children (e.g. Bartak, Rutter and Cox 1975, Bartolucci et al. 1976, Bartolucci and Pierce 1977, Boucher 1976, Kjelgaard and Tager-Flusberg 2001) findings from these studies suggests relatively intact phonological processing or in contrast, delayed and even deviant development. Pierce and Bartolucci (1977) found that articulation in children with autism was not impaired compared to controls with mental retardation and normal controls matched on nonverbal mental age. Bartolucci et al. (1976) found that children with autism, children with mental retardation and normal controls matched on nonverbal mental age spontaneously produced similar samples of both phonemes and phonological errors. Boucher (1976) found unimpaired articulation in a sample of children with autism.

In contrast, Bartak, Rutter and Cox (1975) found that articulation of children with autism was delayed relative to language-delayed controls matched on verbal mental age. Lord and Paul (1997) reports that children with ASD-HF continue to have extraordinary difficulty producing intelligible speech. Kjelgaard and Tager-Flusberg (2001) in an extensive study of 89 children between 4 and 14 years old, aimed to explore the range of language abilities among a large group of children with autism, varying in age and IQ level. The study included a broad range of standardized measures of language, and profiles of language skills were derived from a comparison of standard scores across a range of phonological, lexical, and higher order semantic and syntactic measures. The main findings were that among the children with autism there was significant heterogeneity in their language skills, although across all the children, articulation skills were usually spared.
2.2.3.2 Grammatical development in ASD-HF

Studies of grammatical development have generally concluded that this domain of language is not specifically impaired (Bartak, Rutter and Cox 1975, Pierce and Bartolucci 1977, Tager-Flusberg 1981, Tager-Flusberg et al. 1990). However, in the acquisition of more complex syntactic construction, finding indicates that it might be that grammatical development eventually reaches a plateau and it is evident that there is considerable heterogeneity in the level of achievement at grammatical development within the ASD individuals (Lord and Pickles 1996, Tager-Flusberg, Paul and Lord 2005).

2.2.4 The Use (pragmatic) of language in ASD-HF

Since the mid 80’s most of the language, research in ASD focused on pragmatics, which has been noted as the primary type of language impairment that defines autism. It is claimed that while other areas that were also impaired improved in the higher-functioning individuals during childhood and adolescence, the pragmatic deficits appear to be prominent (e.g. Baron-Cohen 1988, Lord and Paul 1997, Tager-Flusberg 2000b, Wilkinson 1998).

Speech is behavior that occurs in relation to others. All factors about situations, speakers and hearers contribute to both the form and the content of messages i.e., to how people do things with words and to how language works. Consequently, language use consists of the socially and cognitively determined selection of behaviors according to the goals of the speaker and the context of the situation. Following Bloom and Lahey (1978) language is knowledge of the integration of content, form, and use. The children learn rules of a mental plan in the course of development by including the integration of content, form, and use, in the language that they hear and the language that they produce. Pragmatic deficit affects all children within the ASD (e.g. Young et al. 2005, Tager-Flusberg 2000a, b, Philofsky 2007) and it appear to have precursors in infancy, i.e. some of the areas necessary for the development of adequate pragmatic behaviors appear deficient from the start.
For example, abnormal cry behavior to indicate physical needs (Ricks 1975, Ricks and Wing 1975), poor eye contact in face to face interaction and deficiencies in joint attention, difficulties with reciprocal social play. In later childhood and adolescence in the ASD-HF individual, pragmatic difficulties are characterized by deficits in a low understanding of non-literal sequences such as metaphors, jokes or irony, a poor comprehension of command and questions and difficulties with conversational conventions such as politeness, turn-taking and adaptation the speech in context (Aarons and Gittens 1999, Young et al. 2005). In production there are: echolalia and overuse of stereotyped utterances and tangential language, pronouns reversal, misuse of prepositions as in, on, under (etc.), socially inappropriate comments and increased use of idiosyncratic language and neologisms (Dewey and Everard 1974, Lord, Rutter and LeCouteur 1994, Volden and Lord 1991, Fay 1988, Aarons and Gittens 1999, Young et al. 2005).

2.2.3 Prosody in normally developing language

During the past 20 years, several studies have been conducted in order to explore the role of prosody in normally developing language, in both perception and production. Mahler et al. (1975) have demonstrated that newborns prefer speech in their mother’s language over speech in foreign language. In another study, with the same methodology of using low-pass filtered to leave intact only prosodic information, American infants as young as six months are able to distinguish between English and Norwegian words (Jusczyk, Cutler and Redanz 1993). Gleitman and Wanner (1982) proposed that acoustic cues in the speech stream might provide infants with cues to syntactic boundaries, even before lexical knowledge is available. This proposal has become known as “prosodic bootstrapping”.

Numerous studies suggest that infants might use prosodic information to chunk the speech stream into linguistically units (e.g. Garken, Jusczyk, and Mandel 1994, Garken, 1996a). Other studies that focused on speech
production, suggest that prosody also plays a role, from a very early age, to organize the production of language. For example, children preserve stressed and final syllables of words and omit unstressed and non-final syllables (e.g. Echols 1993). According to Garken’s (1996b) explanation, children omit syllables that do not fit into the prosodic hierarchy, and the less well a syllable fits, the more likely is it to be omitted. Therefore, prosodic units serve as planning units in early utterances production. With respect to boundary cues, several studies suggest that children as young as 2 years produce falling fundamental frequency and final lengthening across utterances (e.g. Branigan 1979, Snow 1994).

In summary, examinations of children’s perception and production of prosody, suggest that prosody greatly influences children’s normally development of language. In the normal acquisition process, prosodic features have been shown to be perceived and produced prior to other linguistic features (e.g. Ervin-Tripp 1966, Lenneberg 1967, Liberman, 1967; Jakobson and Halle 1968). It has been proposed that prosodic features may serve as templates that facilitate the acquisition of lexical and syntactic units (e.g. (Bloom 1973, Crystal 1978, 1986, Katz et al. 1996, Snow 1994). It is undoubtedly a complex issue when some of the research into prosody in ASD concluded that even when other aspects of language improve, the atypical prosody tends to be persistent and show little change over time (e.g. Kanner 1971, Simmons and Baltax 1975).

2.2.4 Atypical prosody and past results on ASD

Atypical prosody have been reported in a wide range of developmental conditions including: dysarthria (e.g. Brewester 1989, Crystal 1979, Vance 1994), aphasia (e.g. Cooper and Klouda 1987, Bryan 1989, Moen 2009), hearing impairment (e.g. Parkhurst and levitt 1978, Monsen 1983, Most and Peled 2007), developmental speech and language disorders and/or learning disabilities (e.g. Hargrove 1997, Hargrove and McGarr 1994, Garken and
McGregor 1989, Wells and Peppé 2003), Williams Syndrome (e.g. Stjanovik, Setter and Ewijik 2007, Setter et al. 2007), and ASD that will be reviewed here in detail.

Brewster (1989) classified atypicality of prosody under four categories: (a) dysprosody (b) prosodic deviation (c) prosodic disturbance, and (d) prosodic disability. Dysprosody is at the level of phonetic impairment. It is a direct result of reduced pitch range, decreased loudness, increased duration altered tempo and inappropriate voice. In prosodic deviation, the prosodic features that are used by the speaker represent an adaptation of the prosodic system in order to produce prosodic contrasts. Prosodic disturbances result from problems at other linguistic levels (e.g. a loss of fluency due to word-finding difficulties or misunderstanding of a word/phrase meaning). Prosodic disability describes the inability to deploy appropriately the phonological prosodic features in order to achieve linguistic or emotional contrast. In theory, the atypicality of prosody in ASD may fall under each of Brewster’s categories.

The flowing review concentrates on prosody in ASD. There are only a few studies to date investigating prosodic ability in ASD. McCann and Peppé (2003) in an extensive literature search identified 16 studies between the years of 1980-2002 although the atypicality was emphasized since Kanner’s first description of the syndrome. On the other hand, to be accurate, abnormality in prosody has not been universally reported. For example, Simmons and Baltaxe (1975) found that only four out of the seven adolescents with autism they studied had notable suprasegmental differences in their speech. Paul et al. (2005) reported abnormal prosody in only 47% of the 30 speakers with ASD studied. Moreover, this current literature review is influenced by the arguments that most of the research in this area is limited. The research on atypical prosody has been criticized for being severely fragmented, lacking normative data and contrast groups, using poorly defined prosodic categories, employing subjective ratings rather than objective measures (Paul et al. 2005). McCann and Peppé (2003) claimed that some
earlier studies do not adequately define terms such as ‘autism’ and thus, make them difficult to compare with most recent studies. The studies provide little or no explanation for the heterogeneity of results. Nevertheless, for a preliminary understanding and an attempt to explain the issue of prosody in ASD in the current study, it is necessary to review what has already been established with regard to the realization of the prosodic features of children with ASD.

2.2.4.1 Stress or Accent

Again, ‘stress’ is an abstract lexical property of individual syllables while ‘pitch accent’ is actual prominence in an utterance. If a word is prominent in a sentence, this prominence is realized as a pitch accent on the ‘stressed’ syllable of the word (Bolinger 1989). Stress and placement of stress, is the most extensively studied prosodic feature in ASD. Most studies used perceptual analysis of expressive conversation samples. Baltaxe (1984) investigated the use stress in seven children with autism, seven aphasic and seven typically developing children aged 2:9 to 12:2. The groups were matched by expressive language level as determined by MLU. Data were obtained using questions that were counterfactual to the play situation and then analyzed perceptually by two listeners. Children with autism were perceived as mis-assigning stress twice as often the typically developing children. They also assign stress to more than one stress syllable, which other children in both typically developing and aphasic groups did not produced at all. Fosnot and Jun (1999) investigated the prosody of four children with autism, four children who stutter and four typically developing controls. Participants were males aged 7-14 years. They found that the children with autism produced more pitch accents than the other two groups of children in their research. In another research, MacCaleb and Prizant (1985) reports similar findings. They investigated the use of contrastive stress in four children with autism. The children were males aged 4:8 to 14:10. Contrastive stress in
this research context was 'new information' in spontaneous conversation, based on 20-30 minutes of videotaped interaction. All utterances were coded as both new or old information and then analyses for lexicalization and contrastive stress.

In a study of the same participant of Balatax (1984), Baltaxe and Guthrie (1987) found that the children with autism are more likely to stress the first element of utterances where the last element would have been more appropriate. In Fine et al. (1991) stress assignment was one of several features that were investigated in order to describe the use of intonation in pervasive developmental disorders (PDD). In this study, participants were 23 individuals with Asperger syndrome aged 8-18 years, 19 individuals with ASD-HF aged 7-32 years and 34 psychiatric outpatients aged 7-18 years. Data was based on an interview of approximately 10 minutes with each subject. The interview deals with common topics such as school, family and vacation. The data were coded by a professional phonetician who perceptually marked the stress assignment, which were then judged appropriate or inappropriate. In this study, in reference to stress, the authors concluded that, in contrast to the findings from Baltaxe and Guthrie (1987), the subjects with ASD-HF showed appropriate placement of stress on the last content word of an intonation unit. In this research the authors found differences between the ASD subtypes (i.e. Asperger syndrome and high-functioning autism). The ASD-HF group is distinguished by a comparatively greater use of stress on function words and comparatively infrequent use of marked stress on content words. Incompatible findings were reported in Shriberg et al. (2001). In the study, there are two experimental groups within the ASD: 15 males with high-functioning autism and 15 males with Asperger syndrome. The subject’s ages ranged from 10 to 49 years. The control group for this study was created by compiling audiotapes used for other studies and the group consisted of 53 male ranging in age from 10-30 years. Findings indicated that, compared to the typically developing participants, significantly more participants in both the ASD-HF and Asperger groups had residual articulation distortion errors.
Speakers with Asperger syndrome were more voluble than speakers with ASD-HF, but otherwise there were few statistically significant differences between these two groups of speakers with ASD. Significant differences between subjects with ASD and typical speakers were reported for the percentage of utterances coded as inappropriate within the prosody domains of phrasing and stress (i.e., inappropriate emphasis within and across words). They reports that adults with high-functioning autism used stress appropriately in the majority of utterances.

Paul et al. (2005) examined the perception and production of a range of specific prosodic elements in an experimental protocol involving natural speech among speakers with ASD between 14 and 21 years of age, in comparison with a typical control group. This study suggests that speakers with ASD show differences from typical age-mates in select areas of prosodic performance. It provides support, first, for the finding reported by Shriberg et al. (2001) that stress is an area of particular difficulty for these speakers. Tasks involving stress that were most affected included both production and perception of pragmatic/affective or emphatic stress. Production of grammatical or lexical stress was also affected, and perception of lexical stress showed a difference that approached significance. Thus, they concluded that both understanding and producing appropriate stress patterns appear to be difficult for these speakers with ASD, regardless of whether stress is used in the service of grammatical or pragmatic/affective functions.

2.2.4.2 Prosodic phrasing and sentence type

Prosodic phrasing refers to the ‘segmentation’ of speech by features such as pause, final syllable lengthening, and tone occurring at speech boundaries. Only few studies have examined the frequency and place of pauses in utterances in the speech of individuals with ASD. Findings are contradictory. Fine et al. (1991) examined the use of intonation in three groups of subjects (groups detailed mentioned above). Concerning the number of intonation
units in the sample, they conclude that there are no differences in mean number of intonation units spoken by each of the groups. In terms of the location of the pause in speech, all three groups were very similar. The authors concluded that functionally the groups of speakers divide their messages into intonation units appropriately.

Thurber and Tager-Flusberg (1993) investigated pauses in narrative speech. Results confirm those of Fine et al. (1991). Children with ASD use grammatical pausing in a way similar to typically developing children. Peppé (2007) investigated the prosodic boundary in children with ASD-HF and Asperger syndrome (AS) and found that children with ASD (high-functioning autism and Asperger syndrome) can use prosodic boundaries in speech for “linguistic distinctions” and assumed that it is possible that factors other than prosody contributed to the perception of atypicality.

Only one study was found that investigated the use of intonation to convey sentence-type in individuals with autism. Fosnot and Jun (1999) included an experiment that involved reading aloud sentences with and without question marks. The children with autism, unlike the other children, tended to make all utterances sound like statements, but the number of participants was very small and the study assumed an ability to read and to understand what is meant by punctuation marks. A study on affective prosody is not in the scope of the current research and will not be reviewed.

2.2.5 Summary

Inadequate language is a defining feature of the ASD. It is a behaviorally and dimensionally defined developmental disorder. In view of the centrality of language impairments in ASD, only little is known about the precise development of linguistic knowledge and language use in ASD. Part of the reasons is that language in ASD has been studied with the intention to describe a psychological deficit underlying the syndrome and language use was regarded almost only as a proof. For example, to support the hypothesis
that autism results from impaired ‘mindreading’ (Baron-Cohen 1995, Tager-Flusberg 1993), conducted a research on mental state term (Tager-Flusberg 1992, Tager-Flusberg and Sullivan 1994) another, with the intention of supporting the hypothesis that autism results at least in part from primary socio-emotional deficits (Hobson and Lee 1989).

Considering the results in the studies previously described it appears to be impossible to draw a unified conclusion on language ability of ASD. Instead, it seems appropriate to accumulate findings that clarify what aspect of language abilities has been examined. In a similar way, in the era of prosody and prosodic features in ASD, a single conclusion on either the realization of the features and the functional use in language is far from being understood. From all of the above, despite problematical methodology, it is generally assumed that individuals with ASD express stress/accent a-typicality.

At present, research into prosody provides neither a full description nor an explanation for the atypical prosody produced by many individuals with autism.
CHAPTER 3: RESEARCH DESIGN

3.1 Pilot study

A pilot study (Green 2005, 2009a, Green and Tobin 2008b) was designed in order to examine the research objectives presented above and to develop efficient procedures and methodologies. The main research question of the pilot study was: "Is it possible to distinguish the phonological representation of the intonation contours of children with ASD-HF versus children WDD according to the ToBI framework within the Autosegmental-Metrical theory?"

3.1.1 Participants

The data of the pilot study were drawn from the speech samples of four children in two case studies: two subjects diagnosed with ASD as HF (ASD-HF) and two matched participants without developmental disorders (WDD) selected by their teacher who was not aware of the research aims. Subjects were recruited from two classes of a mainstream elementary school with special education classes for children with ASD. The ASD children receive their regular academic program together with their peers and remedial assistance for both academic and social issues in the special education classes.

All participants were male, their parents were born in Israel and were monolingual speakers of Israeli Hebrew and none of the members of the immediate families of the subjects had learning or other known disabilities. They were matched by age and academic proficiency as reported by their teachers.

To confirm that the subject group matched the requirements of the research parameters, the following inclusion criteria were used:

(a) a diagnosis of DSM-IV Autistic disorder or Asperger disorder on the basis of clinical interview by the child psychiatrist,
(b) IQ test results, the subjects were found to be within the norm for their chronological age, both in their performance and verbal IQ (WISC-R),
(c) educational "Evaluation Committee" ("Vaadat Hasama") determined
that the children require special education services appropriate for children with ASD.

### 3.1.2 Speech material

The speech material was gathered from reading aloud (RA) and (semi-) spontaneous speech (S) elicitation tasks. Each subject read a short story considered by the teacher to be appropriate for the age and grade of the subjects. Ten sentences of the story were analyzed: seven complex declarative sentences (181 words) and three simple WH questions (12 words). For S, natural language samples were collected during an interaction between the participants and the researcher. The goal was to produce a fluent narrative, preferably a monologue, or a series of monologues, from the child. Approximately 100 IUs of each participant’s spontaneous speech task were analyzed.

### 3.1.3 Results

The results of the pilot study describe, compare and contrast the intonation components of pitch accents and edge tones of the ASD-HF and WDD groups in each elicitation task.

#### 3.1.3.1 Pitch Accents

In the RA task, the ASD-HF subjects produced more PAs than the WDD control group. Differences were also found in the kinds of PAs. All subjects produced high PAs (L+H*, H*, H*+L) more frequently, but the ASD-HF subjects showed a greater use of high PAs, as well as a dissimilarity in their use within the ASD-HF group. The use of high PAs by the two ASD-HF participants was 70.0% and 81.2% of the total, while the WDD subjects produced 64.2% and 66.1% of high PAs respectively (see Table 2).
The S sample contained 405 IUs (approximately 100 IUs of each participant). The ASD-HF subjects produced more PAs than the WDD controls with a greater use of the high PAs. The S analysis of high PAs by the two ASD-HF subjects was 75.6% and 79.5% of the total number. Differences between the two ASD-HF subjects were smaller, when compared with the RA task. The PAs of the WDD subjects show that the use of high PAs is 64.4% and 64.3% and hence similar to the RA task (see Table 3).

Table 3: Pilot study - IUs and PAs in the S elicitation task

<table>
<thead>
<tr>
<th>Component</th>
<th>N-ASD-HF</th>
<th>T-ASD-HF</th>
<th>D-WDD</th>
<th>A-WDD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of IUs</td>
<td>96</td>
<td>103</td>
<td>108</td>
<td>98</td>
</tr>
<tr>
<td>PAs per IU</td>
<td>3.84</td>
<td>3.69</td>
<td>3.12</td>
<td>3.2</td>
</tr>
<tr>
<td>% of high PAs</td>
<td>75.6</td>
<td>79.5</td>
<td>64.4</td>
<td>64.3</td>
</tr>
</tbody>
</table>

### 3.1.3.2 Edge Tones

The RA sample contained 169 IUs of which 162 were analyzed. 7 IUs were excluded because the visibility of the edge tones (on the PRAAT software) was unclear or absent. The results indicate that for all subjects the most frequent use of edge tones is a contour pattern of L% final. For declarative sentences, the ASD-HF and the WDD use almost the same patterns in sentence-final position (H*LP%, L*LP%): i.e. 79% of the edge tones were similar, except that they showed a preponderance of high PA (similar to the PA component). The HFA subjects have more L% final than their WDD peers. With regard to the edge tones patterns in the RA task, the WDD subjects exhibit more similar contour patterns (58.2% and 62.7%) of L% final while the ASD-HF subjects exhibit dissimilar patterns. One ASD-HF participant produced 53.9% of L% final which is more similar to the contour patterns of the control WDD subjects and the other ASD-HF participant used an L% final in 83.7% of his IUs boundaries, far more than all the others. These differences in the falling pattern are even more prevalent when we compare the two groups. The HFA subjects used more final lowering patterns than the WDD controls but with
less diversity (see Figure 2).

Figure 2: RA edge of prosodic domain

The S sample contained 405 IUs (about 100IU of each subject). The most frequent use of boundary tones at the edge is a contour pattern of L% final for both groups. Comparing the WDD controls with the ASD-HF subjects, the WDD controls are more similar (58.2% and 62.7%) for L% final while the ASD-HF subjects exhibit dissimilarity. While one ASD-HF subject has 53.9% of L% final and is more similar to the WDD controls, the other uses an L% final in 83.7% of his IUs tone boundaries. Comparing the matched HFA-WWD peers, the differences are more pronounced. While one WDD subject has 62.7% of final lowering, his ASD-HF peer has 53.9% the other WDD subject produces 58.2% of final lowering and his ASD-HF peer produces 83.7%. When considering the edge tones in the contour pattern at the end of the IU, we observed again that the ASD-HF subjects use the final lowering pattern more than the WDD controls with less diversify in their use. For both groups
the contour pattern of $H^*LpL%$ at the edge of prosodic domain was the most frequent one (see Figure 3).

Figure 3: Spontaneous speech edge of prosodic domain

3.1.4 Conclusions and limitations

The pilot study reflects the advances made in the linguistic study of intonational phonology as well as the technological progress in the computer description and analysis of prosodic intonation. In doing so, new ways have been examined to describe the particular intonation of children who meet the criteria for ASD-HF and who are mainstreamed in a regular school environment. The fundamental research question in this pilot study asked whether it is possible to distinguish the phonological representations of the intonation contours of children with ASD-HF versus children WDD according to
the ToBI framework within the Autosegmental-Metrical theory.

Results from the analysis do in fact clearly show differences between subjects with ASD-HF and the WDD control group even though this pilot study concentrated only on two components of the intonation contour (PAs and edge tones). The chosen methodology allows the representation of intonation in a script form of the linear sequence of speech, based on acoustic measurements and doing so facilitates a phonological representation of the differences in intonation between the research and control participants.

The following pitch contour differences were found: The ASD-HF subjects produced more high PAs (L+H*, H* and H*+L) and within the ASD-HF group there is a greater variation than in the WDD control group.

The other intonation feature examined were the edge of the IU, i.e. the last PA, the phrase accent, and the boundary tone of an IU. ASD-HF subjects exhibited a limited repertoire of prosodic edge tones patterns within the norm of the language. These patterns are repeatedly used both in the RA and in the S elicitation tasks. Conversely, the prosodic patterns found in the WDD control group, showed a greater number and a larger degree of variations for the same tasks.

The pilot study placed another research question that focused on the influence of the elicitation tasks on the intonation features of ASD-HF and WDD children. The results in both tasks showed a similar tendency. However, in S the characteristics were more pronounced than in the RA elicitation task. In the WDD control group, no differences between the RA and S were found. However, differences were observed between the two ASD-HF subjects in the research group. One subject (N-ASD-HF) exhibited a similar distribution of the prosodic events that were examined in both tasks. The second subject (T-ASD-HF) exhibited: (a) more high PAs in the S than in RA, (b) the predominant edge tone in RA (H*LpL%) occurred even more frequently in S, an increase to a more patterned speech by the T-ASD-HF subject in the S.

The variation of results between the two ASD-HF subjects and the similarity between the WDD control participants, seem to indicate that the differences are not age related and may reflects the specific differences between individuals who are diagnosed with ASD, a topic that is developed
further in the current research. The pilot study has laid the way for the entire dissertation with the insight drawn from both the procedure and material used to elicit the repetition, reading aloud and semi-spontaneous speech in the dissertation.
CHAPTER 4: RESEARCH METHOD

4.1 Participants

The empirical basis of this study is drawn from the speech samples of 20 children between the ages 9-13 years, in two main groups:

(a) Group A: subjects diagnosed clinically with ASD-HF (N=10),
(b) Group B: the control group, participants without developmental disorders (WDD, N=10). The analysis of the samples of this group provides the basis for the characterization of the prosodic features of IH.

Two children were excluded from the original groups: one ASD-HF child did not receive special education assistance within the school prior to his current grade, grade 3. Consequently, his potential age matched peer was also excluded.

All participants are male. Participants and their parents were born in Israel and were monolingual speakers of IH. Intelligence (IQ score) and language measures of length (MLU-in Words) were taken into account as well.

All participants in this study come from comparable socioeconomic backgrounds and attend mainstream schools. Their mothers all have at least 12 years of education, an indication of socioeconomic status, since maternal education level is the most significant predictor of language functioning in children (Dollaghan et al. 1999). None of the members of the participants' immediate families has learning or other known disabilities. Relevant information on each group is provided in the following two paragraphs.

4.1.1 Group A: Children with ASD-HF

Ten children with ASD aged 9-13 years participated in this study. They were recruited from mainstream schools that have special education classes for children with ASD. Seven children attend these special education classes while three of the children are mainstreamed in regular classes, following a recent
pedagogical decision in favor of full-time mainstreaming.

The ASD diagnosis was made by a child psychiatrist who determined that the child met the Diagnostic and Statistical Manual for Mental Disorders-Forth Edition (DSM-IV: American Psychiatric Association, 1994) criteria for autism, including qualitative impairments in social functioning, communication, and repetitive behaviors.

Each child's special needs were discussed and defined by a "Evaluation Committee", known as the "Va’adat Hasama", entrusted with the placement of special needs pupils in appropriate class settings. For all of the children in this group the committee determined that a special class for children within the ASD spectrum is required.

IQ scores were re-assessed by the school psychologist within the current year using the Wechsler Intelligence Scale for Children - a Revised Edition (WISC-R). For the purposes of this research, High Functioning is defined by an IQ 85 and above. All ASD subject’s have typical, within the average, school performance in the mainstream class in language and reading, as reported by their teachers. Information on group A is presented in Table 4 below, together with details of each child.

Table 4: ASD-HF subject’s characteristics

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Age</th>
<th>Grade and Class</th>
<th>Intelligence (WISC-R)</th>
<th>Mother’s years of Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-ADR-ASD</td>
<td>9:0</td>
<td>3-m</td>
<td>109</td>
<td>94</td>
</tr>
<tr>
<td>2-ITE-ASD</td>
<td>9:1</td>
<td>3-s</td>
<td>121</td>
<td>91</td>
</tr>
<tr>
<td>3-UDX-ASD</td>
<td>10:8</td>
<td>5-s</td>
<td>108</td>
<td>94</td>
</tr>
<tr>
<td>4-YOL-ASD</td>
<td>11:0</td>
<td>5-m</td>
<td>111</td>
<td>101</td>
</tr>
<tr>
<td>5-RAE-ASD</td>
<td>11:5</td>
<td>5-m</td>
<td>86</td>
<td>97</td>
</tr>
<tr>
<td>6-BAB-ASD</td>
<td>11:11</td>
<td>6-s</td>
<td>109</td>
<td>97</td>
</tr>
<tr>
<td>7-ETR-ASD</td>
<td>12:5</td>
<td>6-s</td>
<td>100</td>
<td>102</td>
</tr>
<tr>
<td>8-TOB-ASD</td>
<td>12:8</td>
<td>7-s</td>
<td>108</td>
<td>99</td>
</tr>
<tr>
<td>9-NOR-ASD</td>
<td>13:0</td>
<td>7-s</td>
<td>90</td>
<td>99</td>
</tr>
<tr>
<td>10-OMG-ASD</td>
<td>13:0</td>
<td>7-s</td>
<td>89</td>
<td>85</td>
</tr>
</tbody>
</table>

m= mainstream class, s=special education class

4.1.2 Group B: Children without developmental disorders

The control group was composed of children without developmental disorders (WDD) and was drawn from the same schools as group A.

Similar to the group A subjects, in their teachers' judgment all the
children in group B are average students i.e. they do not exhibit any particular academic difficulties or exceptional abilities. None has received special education support services. The group members have not been tested to determine their IQ scores, but from the information received in interviews with the teachers and parents it can be assumed that they have intelligence in normal range. Their parents report that they have not been referred to a specialist for any developmental reasons. Information on group B is presented in Table 5 below, together with details of each child.

<table>
<thead>
<tr>
<th>Participants</th>
<th>Age</th>
<th>Grade and Class</th>
<th>Mother’s years of Education</th>
</tr>
</thead>
<tbody>
<tr>
<td>11-AVY-WDD</td>
<td>9:0</td>
<td>3-m</td>
<td>13</td>
</tr>
<tr>
<td>12-NIS-WDD</td>
<td>9:3</td>
<td>3-m</td>
<td>15</td>
</tr>
<tr>
<td>13-IDR-WDD</td>
<td>10:7</td>
<td>5-m</td>
<td>17</td>
</tr>
<tr>
<td>14-YVO-WDD</td>
<td>10:11</td>
<td>6-m</td>
<td>16</td>
</tr>
<tr>
<td>15-ITS-WDD</td>
<td>11:6</td>
<td>6-m</td>
<td>17</td>
</tr>
<tr>
<td>16-AVS-WDD</td>
<td>11:9</td>
<td>6-m</td>
<td>16</td>
</tr>
<tr>
<td>17-LIS-WDD</td>
<td>12:3</td>
<td>6-m</td>
<td>13</td>
</tr>
<tr>
<td>18-IDW-WDD</td>
<td>12:6</td>
<td>7-m</td>
<td>16</td>
</tr>
<tr>
<td>19-OMX-WDD</td>
<td>12:11</td>
<td>7-m</td>
<td>14</td>
</tr>
<tr>
<td>20-IDS-WDD</td>
<td>12:9</td>
<td>7-m</td>
<td>17</td>
</tr>
</tbody>
</table>

4.1.3 Age and the language measures for peer matching

Condouris et al. (2003) investigated the relationship between scores on standardized tests versus measurements derived from natural language samples obtained from 44 children diagnosed with autism between the ages of 4 to 14 years old. The two groups of measures were significantly correlated suggesting that both standardized and spontaneous speech measures tap the same underlying linguistic abilities in children with autism.

In this study, two language measures were used for peer matching. In addition to similar chronological ages (within two month), the peers were matched on the basis of (a) language fluency in (semi-) spontaneous-speech sample as measured in MLU-W (within one word) and (b) the standardized score of the verbal part in the IQ test within the norm or above. Match between subjects and controls are presented in Table 6.
Table 6: Matched peers

<table>
<thead>
<tr>
<th>ASD-HF subjects</th>
<th>Group A</th>
<th>Age</th>
<th>MLU-W</th>
<th>WDD control group</th>
<th>Group B</th>
<th>Age</th>
<th>MLU-W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-ADR-ASD</td>
<td>9:0</td>
<td>5.62</td>
<td></td>
<td>11-AVY-WDD</td>
<td>9:0</td>
<td>5.28</td>
<td></td>
</tr>
<tr>
<td>2-ITE-ASD</td>
<td>9:2</td>
<td>5.34</td>
<td></td>
<td>12-NIS-WDD</td>
<td>9:3</td>
<td>4.04</td>
<td></td>
</tr>
<tr>
<td>3-UDX-ASD</td>
<td>10:8</td>
<td>7.86</td>
<td></td>
<td>13-IDR-WDD</td>
<td>10:7</td>
<td>6.94</td>
<td></td>
</tr>
<tr>
<td>4-YOL-ASD</td>
<td>11:1</td>
<td>5.77</td>
<td></td>
<td>14-YVO-WDD</td>
<td>10:11</td>
<td>5.16</td>
<td></td>
</tr>
<tr>
<td>6-BAB-ASD</td>
<td>11:11</td>
<td>7.42</td>
<td></td>
<td>16-AVS-WDD</td>
<td>11:9</td>
<td>7.18</td>
<td></td>
</tr>
<tr>
<td>7-ETR-ASD</td>
<td>12:5</td>
<td>5.14</td>
<td></td>
<td>17-LIS-WDD</td>
<td>12:3</td>
<td>5.22</td>
<td></td>
</tr>
<tr>
<td>9-NOR-ASD</td>
<td>13:0</td>
<td>6.5</td>
<td></td>
<td>19-OMX-WDD</td>
<td>12:11</td>
<td>5.86</td>
<td></td>
</tr>
<tr>
<td>(*)10-OMG-ASD</td>
<td>13:0</td>
<td>4.8</td>
<td></td>
<td>20-IDS-WDD</td>
<td>12:11</td>
<td>6.1</td>
<td></td>
</tr>
</tbody>
</table>

(*) Participants 10 and 20 do not meet the requirements of the definitions used for peer matching, and are consequently excluded from comparison between the groups. Their results are, however, included when the discussion is about differences within the groups. This will be discussed in Chapter 6.

4.2 Procedure

4.2.1 Language speech sampling

Written parental consent was obtained prior to the collection of speech samples and participants were then asked whether they agreed to take part in the study. There were between two to three sessions between the researcher and the participants. The purpose of the first meeting was for the participant to become familiar with the researcher. The speech samples were collected in the second (and where necessary, third) meeting. All sessions took place at the participant's house, in his own room.

There were three types of elicitation tasks:

(a) Repetition (R): this task comprised four sentence pairs: a WH-Question (WHQs) and its answer.

(b) Reading Aloud (RA): participants were asked to read a short story.

(c) Semi-spontaneous speech (S): these were produce spontaneous speech sequences in response to open questions, relevant to the child's daily life.

In order to conduct acoustical analyses the speech files were digitized at a rate of 44.1KHz with 16-bit resolution, directly into a laptop computer (Hp Compaq 6710b), using the speech-recording software Audacity (a software package for recording and editing sound files) and a small microphone. The
data was subsequently analyzed using the speech analysis program Pratt, version 4.6.13 and subsequently upgraded to version 5.0.30 (Computer program, from http://www.praat.org/). The sound files of each participant were saved in separate folders that were grouped within the top-level directories RECORDING-ASD or RECORDING-WDD.

4.2.1.1 Repetition speech sampling

This task comprised four sentence pairs – a WH-Question (WHQs) and its response. Each participant listened to the pre-recorded question and answer, and repeated them. There were three iterations of this task, the last of which was recorded. The WHQs and their response demonstrate simple declarative grammatical structure.

The purpose of this was twofold: (a) to produce a visible pitch track on the PRAAT program to serve as a starting point for each of the participants before analyzing different and more lose speech material (such as the S). The sentences were chosen to contain as many sonorant-segments as possible (sonorant produced without turbulent airflow in the vocal folds and can be produced continuously at the same pitch and therefore, theoretically, a change in pitch is due to suprasegmental features and not the segments themselves), (b) natural language does not necessary produce the question types required for this research.

4.2.1.2 Reading-Aloud speech sampling

Subjects read a short story about a girl and a porcupine. The story was taken from a Hebrew studies textbook and was chosen so that it did not include content that might be unclear to children with ASD (i.e. metaphor). The text was printed with "niqqud" (Hebrew diacritics for vowels) in 20-point font. The story includes 12 sentences (simple sentences, compound sentences, complex sentences, exclamations, and two WHQs) in 94 words. Participants were asked to read the story three times, first in silent reading and then twice by reading aloud. Only the third elicitation was recorded.
4.2.1.3 (Semi-) Spontaneous speech sampling

It has been often pointed out that while the speech style known as “read-aloud” can be very useful in research dealing with controlled data (e.g. for comparative purposes) it fails to capture several linguistic phenomena that are important when making assumptions about the “real” spoken language used in everyday communication (Swerts and Collier 1992, Beckman 1997). For that reason, researchers make use of spontaneously uttered speech. However, the definition of what characterizes “spontaneous speech” and the elicitation methods employed to collect this speech style are surrounded by controversy. Speech is usually labeled as being either spontaneous or read. This polar classification does not take into account the continuum that lies in between (Fujisaki 1997, Laan 1997). In general, speech is designated spontaneous in terms of a series of linguistic aspects that are often present in unprepared utterances (or utterances prepared to a minimum degree), such as the occurrence of dis-fluencies and repairs, the frequent use of abbreviations, a more relaxed syntax, and the incidence of “fillers,” like ‘eh’, ‘em’ and ‘ems’. Studies have demonstrated that listeners are able to make a clear judgment about speech using a binary classification (spontaneous versus read) (Laan 1997, Levin, Schaffer and Snow 1982). This would suggest the validity of such a classification.

However, Fujisaki (1997) adopts a gradual rather than binary classification. He has proposed that the main characteristic of spontaneous speech is that it must occur “by its own internal force, motivation, etc., rather than by external ones” (Fujisaki 1997:38). Accordingly, any sort of preparation or planning would decrease the degree of spontaneity in speech. According to Fujisaki (1997), the higher degree in spontaneity in speech is only found in free dialogues, which is characterized by the non-specification of format, topic or task. Beckman argues along a similar line, proposing that if spontaneous speech is what the researcher desires, then speech in a laboratory setting (which she defines as “a communicative situation where the speaker is cooperating obligingly with the experimenter’s purpose”) must be avoided (Beckman 1997:15).
4.2.2 Processing of speech data, transcription and coding

This section introduces the basic categories and symbols used in order to create the stream of speech representation required for the prosodic research. It describes how the sequences of words were segmented, saved, and transcribed prior to analysis.

All samples were segmented into utterances or sentences. Each sentence or utterance received an identification code using the following pattern: child code - research group - elicitation task - ordinal number, e.g. AVS-WDD-RA-11 is the eleventh sentence in the RA speech sample of child “AVS” belonging to the WDD control group, while AVS-WDD-RQ-2 is the second repetition question of the same child.

The next step used PRATT to segment each sentence or utterance into IUs. An utterance is defined as equivalent to the IH-ToBI categorization for break index of 4u, and the IU is defined as unit ending in a break index of 4. As this work employs the IU as the basic unit for all prosodic transcription and coding, a very systematic procedure was built and it is a substructure for the extraction of the results. In this manual procedure, each tier is analyzed and transcribed on the tier. See Figure 6 on page 71 below. The notations were chosen to delineate events required for this specific research. They can be read by PRAAT scripts.

For example, the start of an utterance is denoted by a 'B' symbol and the end of an utterance by a '4u' symbol. An IU starts with B and ends with a '4'. These symbols are placed in the Break Indices tier. This information may then be read by a script to determine whether an edge tone is at the end of an utterance, or at the end of an IU at the end of an utterance. Alternatively, the minimum, maximum, and range of pitch of each IU can be found. The Break Indices tier is used as a reference to focus a search for events in other tiers.

Standard Hebrew spelling was used in the Word tier (following; Berman 1978). The use of standard spellings increase readability and has the advantage of making it possible to search for the occurrence of a word or phrase (which could not have been done with phonetic transcription) e.g. to count the number of times a word is repeated. Moreover, this allowed the
conversion of data from the PRATT Word tier to CHAT (Codes for the Human Analysis of Transcripts MacWhinney 2000) format and the use of CLAN (Computerized Language Analysis) to analyze the data of all the ~50 utterances.

Although the original intention was to use the analysis in order to find the numerical characteristics of the speech samples (e.g. number of content words (token) per utterance, number of content words (type) per utterance, and Type per Token Ratio), in the end this PRAAT script was only used to convert to the CHAT format and to count the number of words per utterance. By the end of this stage each participant’s data was in four files, named according to the following schema: three capital letters representing the child code, the group designation (ASD or WDD), and the elicitation task (RQ, RReply, RA and S). For example, see example (1).

Example (1):

AVS-WDD-RQ.PRAAT.collection: Contains the 4 sound-files and TextGrids of the 4 questions of the repetition task.
AVS-WDD-RReply.PRAAT.collection: Contains the 4 sound-files and TextGrids of the 4 replies to the questions of the repetition task.
AVS-WDD-RA.PRAAT.collection: Contains all the sound files and TextGrids of the 12 reading aloud elicitation task sentences.
AVS-WDD-S.PRAAT.collection: Contains all the sounds files and TextGrids of the semi-spontaneous speech elicitation task.

### 4.2.3 Data analysis

#### 4.2.3.1 The PRAAT scripts

Four scripts were written to extract data from the transcriptions. Scripts are short programs that are used to automate PRAAT activities and enables:

1. The analysis of large data sets.
2. Quick processing of information and results from all IUs.
3. Preparation for the use of simple statistics tools e.g. export to Excel.
4. Generation of summary information for control purposes, i.e. to
identify errors in the manual transcription process (illustrated in Figure 4 and Figure 5 below).

Figure 4: Script output showing summary information
This example illustrates how the script output enables the identification of a coding error. In the example the erroneous HpL%% (should be HpL%) would have led to an incorrect statistical analysis of boundary tones.

------ Statistics ----
- Boundary Tones
LpL%: 33 40.74%
HpH%: 6 7.41%
HpL%: 34 41.98%
LpH%: 7 8.64%
HpL%: 1 1.23%

OMGS13: %FS%
OMGS13: 20%L+H°L+Hi°Hi°HpL%
OMGS13: %FS%
OMGS13: 21%L+H°L+Hi°HpL°L°LpL%

Figure 5: Script for the identification of an error at the end of an U/IU
This figure demonstrates a coding error at the end of an IU. An error such as this is likely to influence the results that compare boundaries of the intonation units inside the utterance with the one at the end of the utterance.
4.2.3.2 PrintLabelsWORDtier.PRAAT

This script was written to extract a transcript text file. The script collects data in the standard CHAT transcription format. Meta data (age of the child, year of school, group of the child) was manually added. These files were processed to determine the MLU in word (MLU-W).

MLU is a measure suggested by Brown (1973) to indicate the length of utterances produced by children, where an utterance is a sequence of words preceded and followed by change of turn in a conversation. A higher MLU is taken to indicate a higher level of language proficiency. It is calculated in morphemes or in words (MLU-W) by dividing the number of morphemes or words by the total number of utterances.

In children WDD, MLU correlates significantly with age up to approximately MLU 2.5–3.0 (Bowerman 1973, Klee 1992). Parker and Brorson (2005) compared MLU-W and MLU in morphemes scores of 40 language transcripts from typically developing, English speaking children between the ages of 3:0 and 3:10. Results indicated that MLU in morpheme and MLU-W are almost perfectly correlated. This finding suggests that MLU-W can be used as a measurement of a child's gross language development.

MLU is a valid predictor of syntactic complexity and diversity up to approximately MLU 4.0 (Klee 1992). In this study, the use of MLU-W was for:
(a) indication of fluency in language (b) a level for match peers while SD is less than one word.

4.2.3.3 PrintTONEtier.PRAAT

This script was used to extract labels and statistics from the TONE tier of the in Pratt object TextGrids. The script extracts the tone tiers’ labels and performs a statistical analysis of the intonation patterns. In particular, the output files contain:
(1) Number of utterances,
(2) Number of IUs,
(3) Percent of analyzed IUs,
(4) Average of IUs per utterance,
(5) Distribution of boundary tones,
(6) Distribution of edge tones,
(7) Distribution of the different PAs.

The script creates three files for each sample:

1. `<obj-name>TONEtier.txt`: contains the tone labels of the whole sample sorted by utterances and IUs.
2. `<obj-name>.TONEtier.4u_only.txt`: contains the tone labels of the last IU in each utterance.
3. `<obj-name>.TONEtier.no_4u.txt`: contains the all tone labels except those of the last IU of each utterance.

### 4.2.3.4 PrintIntermediatePhrases.PRAAT

This script analyzes intermediate phrases, and extracts the following statistics:
Number and percent of IUs with at least one intermediate phrase,
Distribution and average by word count of intermediate phrase locations within the IU,

Although the script was originally written to extract all the above information, this research only required the results in (1) which are presented in section 6.3.1 below.

### 4.2.3.5 PrintPITCHtier.PRAAT

This Pratt script was written to extract the pitch values and pitch range (in semitones) of each IU for the S sample. The F0 is first extracted by Pratt, using the analysis settings as recommended in the Pratt manual, following which every IU was manually checked by viewing the narrow-band spectrogram. All F0 measurements are made using either a peak picking algorithm (F0 max, F0 min), or by calculating the average values and the pitch range. Non-linguistic sounds such as laughs and coughs as well as different realizations of "fillers" were excluded from this analysis.

The following data are produced by this script:

1. Minimum F0 (in Hz): specifies the minimum visible output low pitch i.e.
the local peak F0 value of the participants' wave form in every IU.

(2) Maximum F0 (in Hz): specifies the maximum visible output high pitch i.e. the local peak F0 value of the participants' wave form in every IU.

(3) Absolute minimum F0/Absolute maximum F0 (in Hz): the extreme minimum and extreme maximum F0 values of all IUs of a particular participant.

(4) Average F0 (in Hz): the average of all the minimum and all the maximum F0 values of all IUs of a particular participant.

(5) Standard Deviation (SD) F0: standard deviation of all minimum and maximum F0 values of all IUs of each a particular participant.

(6) Pitch Range (in semitones, ST) of each participant's sample: the range between the minimum and maximum F0 values of all IUs of a particular participant.

4.2.3.6 Mixed-Methods analysis

This study integrates mixed-method analysis into the research strategy. The use of quantitative and qualitative methods is intended to provide a more comprehensive understanding of the analyzed phenomena. The Mann-Whitney Test was employed for both descriptive and test statistics. Case studies, with the richness of an empirical description "emphasize the rich, real-world context in which the phenomena occur" (Eisenhardt 2007:25). "Each case serves as a distinct experiment that stands on its own as an analytic unit. Like a series of related laboratory experiments, multiple cases are discrete experiments that serve as replications" (Yin 1994).
CHAPTER 5: ISRAELI HEBREW TRANSCRIPTION OF TONAL EVENTS

5.1 Introduction to the IH-ToBI adaptation

There are various models for the representation of prosodic and intonation events within the linguistic domain of knowledge. The intonational transcription I propose for Israeli Hebrew adopts the theoretical framework of the Autosegmental-Metrical theory of intonational phonology, as described in Chapter 2. I have named the system used to transcribe the prosody as IH-ToBI (Israeli Hebrew Tones and Break Indices) due to its representational similarity to ToBI transcription systems used with other languages. Before approaching the main objective of this study, it is necessary to make an inventory of the prosodic and intonational features of Israeli Hebrew.

The IH-ToBI prosodic transcription includes an inventory of pitch accents, phrase accents, and boundary tones along with descriptions of the phonetic realization of these features, based on data collected from Hebrew speaking children. Ten monolingual Hebrew speakers between the ages of 9-13 years, produced a total of 1,350 IUs, collected in three elicitation tasks: (1) repetition, (2) reading aloud, and (3) (semi-) spontaneous-speech. The procedure followed is described in section 4.2.1 on page 52 above. This Israeli Hebrew prosodic inventory, and the annotation presented, is far from complete. However, in itself it is an essential and important starting point for further investigation of the prosody and intonation of Hebrew.

The chapter is organized into two parts. The first provides a brief theoretical background of the ToBI transcription framework, and the relevant aspects of the IH language. The second part presents the IH-ToBI transcription of prosody, i.e. the patterns of pitch accents, phrase accents and boundary tones and shows how the different sentence types appear. I have tried to define the set of basic prosodic features of Israeli Hebrew, and have further analyzed their distributions throughout Hebrew prosodic phrases.
5.1.1 Theoretical basis

Beginning with Bruce (1997) and Pierrehumbert (1980), “phonological” theories of intonation replaced the “universal” theory (Bolinger 1978, 1986, 1989). This change was due to the understanding that intonation has a decidedly phonological component distinct from its phonetic implementation, and therefore cross-linguistic differences can be either phonetic (gradient differences, e.g. late vs. early peak alignment) or phonological (categorical differences, e.g. mono-tonal or bi-tonal pitch accent) (Gussenhuven 1984, Ladd 1996). Thus, phonological aspects of intonation can be categorized according to the inventory of the phonological tones, and to the meanings assigned to phonological tones of a specific language.

5.1.2 ToBI transcription framework

ToBI (Tones and Break Indices: Beckman and Hirshberg 1994, Beckman and Ayers 1997) transcription is an annotation system designed for use in labeling intonation and prosody in databases of spoken Mainstream American English (MAE_ToBI). It has been expanded into a general framework for the development of prosodic annotation systems of different typological languages (Jun 2005). ToBI has been applied to languages that: (a) vary geographically (e.g. English, German, Greek, Japanese, Korean, Chickasaw), as well as to: (b) languages that vary in the type and degree of lexical specifications, i.e. languages with lexical stresses, lexical pitch accents, both (e.g. Swedish), and to: (c) tone languages (e.g. Mandarin, Chickasaw). The MAE_ToBI system defines five salient assumptions about the prosodic intonation structure in the language (Jun 2005). Beckman et al. (2005) suggested how ToBI can be extended within and across languages:

(a) The prosodic pattern for an utterance can be projected onto separate tiers representing conceptually independent structural types, i.e. the intonation contour can be represented linearly by an autosegmental string of tones, and the prosodic groupings should be represented hierarchically, for example by the break index value for the disjuncture
between any two words.
(b) The four tiers of the MAE_ToBI are obligatory parts of the MAE_ToBI record. The originators of MAE_ToBI “fully expected individual sites to add other ToBI tiers or other completely independent annotations as needed, in order to customize shared databases to their own purposes” (Beckman et al. 2005:31).
(c) The intonation contour is decomposed into relatively high and relatively low pitch levels (H vs. L tones). These pitch levels are static targets in paradigmatic contrast to each other. The local pitch range is determined by a variety of effects, such as phrasal prominence relationships, occurrence of ‘downstep’ (a compression of phrasal pitch range that reduces within the phrase) and ‘upstep’ (a rising of the phrasal pitch range beginning at an H phrase accent).
(d) Tones for any phrase are distinguished functionally as being either edge tones or as being affiliated with pitch accents. The pitch value of a tone depends on its function as well as on its position. For example an L tone at the beginning of an L+H* rising pitch accent can be higher than an L% tone at the following intonational phrase boundary.
(e) The function of a tone also determines its timing relative to the autosegmental projection of consonants and vowels, i.e. a pitch accent is aligned with the segments of the relevant stressed syllable whereas an edge tone is aligned with the segments at the relevant phrase boundary. There are contrasting High (H) versus Low (L) edge tones at two levels of intonational phrasing, associated with two different degrees of boundary strength: (a) the intermediate phrase and (b) the intonational phrase (Beckman et al. 2005).

5.1.3 Israeli Hebrew

ToBI assumes a phonological rather than a phonetic model, and the ToBI system of one language is not appropriate for describing the prosodic system of another language (Jun 2005). Therefore, I will briefly describe the Israeli Hebrew (IH) language with a focus on phonology. I will start with relevant
history since it is evident that prosody (as well as other domains) is influenced by the cumulative experience of the speakers of the language.

5.1.3.1 Relevant history

At the beginning of the 20th century, Hebrew once again became a spoken vernacular, and the national language of the Jewish majority of the state of Israel. The Hebrew language is usually divided into four major historical periods: (1) Classical or Biblical Hebrew, (2) Mishnaic or Rabbinical Hebrew, (3) Medieval Hebrew and (4) Modern Hebrew also known as Israeli Hebrew, Contemporary Hebrew or Ivrit (Berman 1978, Glinert 1989, Rosén 1977, Ravid 1995, Tobin 1997). Pre-20th Hebrew was “no one’s mothers tongue” (Izre’el 2003). Nevertheless, Hebrew has always been a written language and was used as language of liturgy, religious studies and for the writing of secular literature and poetry (e.g. Judah-Halevi (c.1075-1141).

In the first decade of the 20th century, with the waves of immigration into Palestine, called ‘Aliya Shnia’ ('Second Immigration'), a rapid spread of spoken Hebrew took place (Bar-Adon 1975, Haramati 1979, Izre’el 2003), and by the mid-20th century the majority of the young population used Hebrew as their primary language. Sociolinguistic data on the emergence of Hebrew as a spoken language indicates that the growth of the Hebrew language was through the school system, suggesting that the acquisition of the language occurred first in the children, and was followed in the parents (Haramati 1979, 1981).

The genetic affiliation of Hebrew is to the Northwest Semitic sub-branch of the Afro-Asiatic language family. This affiliation is manifested in its morphology and lexical persistence, which was drawn from Biblical Hebrew. The phonology of Israeli Hebrew, as well as certain syntactic phenomenon such as word order, no longer reflect the characteristics of Biblical Hebrew, but has been strongly influenced by European languages (Tobin 1997). It seems safe to assume that prosody was influenced in a similar way. Prior to this dissertation, there was no IH-ToBI or a detailed transcription of IH intonation.
It is not my intention in the following paragraphs to go into detail regarding the structure of Israeli Hebrew (which has been treated in detail e.g. Rosén 1977, Berman 1978, Glinert 1989, 1994) however, a general treatment of the Israeli Hebrew structure is necessary in order to highlight two central issues: (a) prosodic analysis is language specific, i.e. each language defines the units of analysis and the distribution of their appearance, e.g. the types of PAs differ, and (b) mutual influences between the structure of the language and its prosody are likely, e.g. word order might influences the pitch contour.

5.1.3.2 IH structure and morphology

The preferred word order in Israeli Hebrew is Subject–Verb–Object (SVO), but Israeli Hebrew word order is relatively free and all possible alternations can appear in specific contexts, e.g. (2).

Example (2):

Gloss: S-V-O /ejal axal banana ḏehuba/ Eyal ate banana yellow

Translation: 'Eyal was eating a yellow banana'

Gloss: O-S-V /banana ḏehuba ejal axal/ Banana yellow Eyal ate

Gloss: O-V-S /banana ḏehuba axal ejal/ Banana yellow ate Eyal

Adjectives always follow the nouns and numerals they modify, with exception of the numeral ‘one’ that always precedes it. Definite nouns are preceded by the definite article ha- ('the'), which also appears in the modifying adjective (ha-banana ha-tsehuba). All other function words also appear before the phrase. The conjunctive marker ve- ('and') appears before the last element in the list and the subordination marker je- ('that') appears before the subordinate clause. Question words; mi ('who'), ma ('what'), mataj ('when'), ejfo ('where') appear at the beginning of the phrase (Bat-El 2003). Like other Semitic languages, the isomorphic connection between phonology,
morphology, syntax and semantics is much more overt when compared with
the Indo-European languages. The vast majority of the words of the language
can be analyzed into consonantal roots signaling broad semantic fields. These
roots are combined with fixed morphophonemic patterns for what is
traditionally called nominal, verbal, and adjectival forms (Tobin 1997). Nouns
in IH exhibit prosodic and vocalic restrictions called mishkal (‘weight’).

In the verb system, Israeli Hebrew morphology is characterized by the
non-concatenative Semitic type structure. A verb must belong to one of the
five to eight (Tobin 1995) morphological classes called “binyanim”
(‘constructions’) or “building blocks”. Each “binyan” has a specific structure
and vocalic pattern, and some also have a prefix. The entire “binyan” shares a
discontinuous string of consonants, traditionally called the ‘consonantal root’.
For some “binyanim”, these properties must be specified for each tense and
not every root has a verb in all the “binyanim”. Verbs are also accompanied by
affixes indicating tense, person, number, and gender (Bat-El 2006).

5.1.3.3 Israeli Hebrew segmental inventory

The phonemic inventory of general spoken Israeli Hebrew has approximately
18 consonants and 5 vowels. Biblical Hebrew has 22 consonants and a more
complex vowel system where vowel length is phonemic. There is a vast
literature discussing the phonemic changes that have taken place in Hebrew,
which I will not include here since all of my subjects are speakers of general
spoken Israeli Hebrew. Tables 5 presents the consonant inventory of biblical
and general spoken Israeli Hebrew according to the theory of Phonology as
Human Behavior (PHB) (Tobin 1997:91). The five vowels of general spoken
Israeli Hebrew are /i, e, a, o, u/ where the /e/ phoneme is generally
pronounced as /ɛ/. 
Table 7: The Biblical Hebrew and Israeli Hebrew consonant system

<table>
<thead>
<tr>
<th>Active Articulators</th>
<th>Biblical Hebrew</th>
<th>Israeli Hebrew</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lips</td>
<td>/p, b, m/</td>
<td>/p, b, m, f, v/</td>
</tr>
<tr>
<td>Apex</td>
<td>/t-T, d, n, ts , s, z, l/</td>
<td>/t, d, n, ts, s, z, l/</td>
</tr>
<tr>
<td>Anterodorsum</td>
<td>/ʃ, j/</td>
<td>/ʃ, j/</td>
</tr>
<tr>
<td>Posterodorsum</td>
<td>/k, g/</td>
<td>/k, g, x, u/</td>
</tr>
<tr>
<td>(Lips/velum +) psterdorsum</td>
<td>/w, q/</td>
<td>/w, q/</td>
</tr>
<tr>
<td>Pharynx</td>
<td>/ʔ, h/</td>
<td>/h/</td>
</tr>
</tbody>
</table>

5.1.3.4 Israeli Hebrew stress

Israeli Hebrew has final primary stress by default and secondary stress occurs on alternating syllables to the left. There are several studies on the stress pattern of Hebrew (Rosén 1977, Bolozky 1978, Melčuk and Podolsky 1996, Falk 1996, Bat-El 1993). Primary stress in Hebrew nouns is lexically determined and not a result of the segmental basis or the prosodic structure of the word. The following examples are taken from Bat-El (1993:192):

1. /náxal/ (`river'; with non-final stress) - /nagár/ (`carpenter'; with final stress).
2. /ʔártik/ (`ice-cream bar'; with non-final stress) and /nartík/ (`sheath'; with final stress).

Stress in Hebrew verbs is usually final. Stress in nouns is mostly ultimate or penultimate (Berman 1978, Bat-El 1993, Graf 2001, Becker 2003). Bat-El (1993:193) classified the Hebrew noun stress patterns into three lexically distinct stress groups. The distinction between the groups is based on the surface correlation of the position of stress in the base form and the position of stress in the corresponding suffixed form. The three groups are:

(a) Plain formatives: stress is ultimate in the base and ultimate in the suffixed form e.g. /gamád/-/gamadím/ (`dwarf-dwarves'), /xatúl/-/xatulá/ (`cat-cats').
(b) Extrametrical formatives: stress is penultimate in the base and ultimate in the suffixed form e.g. /délet/-/dlatót/ (`door-doors'), /náxal/-/nexalím/ (`river-rivers').
(c) Accented formatives: stress remains in the same position when a suffix is added e.g. /salát/-/salátim/ (`salad-salads'), /sabón/-/sabónim/ (`soap-soaps').
In Israeli Hebrew, lexical stress has a contrastive role only in a few words. Stress can distinguish grammatical function like /ö̃xel/ (‘food’-noun) and /oxél/ (‘eating’-verb) or different words /ràts̮a/ (‘running’-verb) /raṭšā/ (‘wanted’-verb).

5.1.3.5 Previous studies on Israeli Hebrew intonation

Israeli Hebrew is an intonational language. It uses pitch to give a certain meaning to an utterance as a whole. The limited quantity of research into the intonational phonology of Hebrew includes: (a) on the phrase level (e.g. Laufer 1987, 1996, Izre’el et al. 2001, Becker 2003, Mixdorff and Amir 2002, Amir et al. 2004) (b) in developmental prosody on the word level (e.g. Ben-David 2001), and (c) developmental clinical prosody (e.g. Frank et al. 1987, 1989, Adi-Bensaid and Bat-El 2004, Adi-Bensaid 2006).

However, a full investigation of either the Israeli Hebrew intonation patterns or the structure of Israeli Hebrew prosody has not been published yet. Therefore, the description of Israeli Hebrew intonation patterns and prosodic structure is still in a preliminary stage.

5.2 Israeli Hebrew transcription of tonal events

A major goal in the first stage of the present work was to create a systematic procedure for transcribing data with the purpose of describing, comparing and contrasting the prosodic features of children WDD and children with ASD-HF.

The IH-ToBI record of an intonation unit has eight parts. The first two parts are continuous phonetic records and the remaining six parts are symbol strings and meta-data. The first phonetic record is an audio recording of the intonation unit and is represented on the top row in the illustration below. The second record is a representation of the F0 contour. The remaining six parts are the:

(3) Tone tier: provides an Autosegmental transcription of an utterance, and uses diacritics to cover both distinctive tonal targets and the
phonetic realization of the tonal target.

(4) Word tier: provides an orthographic version of the utterance divided to words.

(5) Break-Indices (Index) tier: provides numerals indicating the relative level of disjuncture and letters indicating the start of the IU ('B') and the location of the end of the utterance ('4u').

(6) Phonetic tier: provides an IPA transcription of a word and marks the position of the pitch accent with a "/" before the accented syllable.

(7) Comment tier: where information is noted if it cannot be deduced from labels in other tiers or from the speech signal itself. This tier includes two kinds of information. Information which binds with (a) the transcription context e.g. nonverbal noise produced in the vocal tracts of speech, ps=pitch setting of the IU, reset of speech, restart of speech, upstep, blocking of upstep, creaky voice, etc. (b) the situation context e.g. behavioral comment, laughter, anger, desire to do something else, talking to the mother, overlap, etc.

(8) Pitch values and duration values tier.

5.2.1 Israeli Hebrew intonation

5.2.1.1 Israeli Hebrew prosodic groping of words

Speakers organize their speech into groups of words, which appear in a prosodic structure. This structure encodes the groups into hierarchical
constituents that are defined both by tone and by the degree of perceived disjuncture among words, within and between groups (Beckman and Ayers 1997, Ladd 1986, 1996). From this corpus-based analysis, I assume that above the word level, IH has three prosodic constituents in each single utterance: (1) the intermediate phrase (ip), (2) the intonation unit (IU), and (3) the utterance (U) or intonation unit complex, as illustrated in Figure 7.

Figure 6: IH prosodic grouping of words

```
Utterance (U)
   \--- Intonation Unit (IU)
       \--- Intermediate Phrase (ip) ...
       \--- Intermediate Phrase ...
   \--- Intonation Unit
```

5.2.1.2 The Utterance and the Intonation Unit (IU)

The utterance is the highest intonation component of the prosodic hierarchy. A minimal instantiation of a utterance would occur on a one-word utterance, as shown in Figure 1 on page 8, and in Figure 7 below. Usually utterances are more complex and can include more than one intonation unit in a single utterance, as shown in Figure 9.
Figure 7: A one-word utterance
This example [word tier: /e:sporT/ (‘sport’) from: YVO-WDD-S-6; age 10:11], illustrates an utterance which comprises one IU with one word

Figure 8: An utterance with three IUs
This example illustrates an utterance comprised of 3 IUs: [word tier: /ze ke ’ilu (pause:#0.5+reset) ze hemshe’ shel ha- sereT ha-qodem (#0.81ms) keliu raq ha- shem hishtana (#long)/ (‘It’s as if it’s a continuation of the previous movie, as if only the name changed’) from: YVO-WDD-S-27; age 10:11].
In the ToBI transcription framework the grouping of words is reflected in the Break-Index (BI) tier. The IH-ToBI Break-Index tier is an adaptation of the MAE_ToBI with various adaptations required by the purposes of this research.

5.2.1.3 The Break-Indices tier

The Break-Indices (BI) tier captures the prosodic grouping of words. Labels provide information about the degree of prosodic association between adjacent words or phrases in the utterance. The perception of disjuncture may be cued by several events such as pauses, segmental lengthening, F0 movements (lowering and creaky voice), restart, and reset of pitch, etc. These categories of association strength or 'break indices' are based on work by Mari Ostendorf, Patti Price, and Stefanie Shattuck-Hufnagel (Price et al. 1991).

In the general ToBI framework, groupings of IUs in the utterance are not marked. In this research, it is important to distinguish between the tonal events at the end of an IU and the tonal events of the whole utterance. For this purpose, a transcription marker has been added to indicate the beginning of an IU (B) and the end of an utterance (4u). The Break-Index '3' delimits the end of an intermediate phrase which represents a level of disjuncture that is less disjointed from the next phrase than a full IU i.e. the intermediate phrase is tonally marked, but not as strongly as the IU (BI '4'). In Israeli Hebrew the intermediate phrase also provides "blocking" i.e. blocking of upstep or blocking of downstep. Pierrehumbert and Hirschberg (1990) claim (for English) that a new register can be selected by a speaker for each intermediate phrase. The example in Figure 10 presents an IU with two intermediate phrases. In this IU there is one L intermediate phrase (Lp) and another H intermediate phrase (Hp). The first intermediate phrase provides a blocking downstep. Table 9 on page 85 below summarizes the Break-Index tier labeling for the IH-TOBI.

The presence of an intermediate phrase in Hebrew seems to be evident from the phonetic realization of the utterance. In the example presented in Figure 9 below the phonological intermediate phrase within the utterance is cued by a sense of disjuncture, and phrase-final lengthening which is less
strong than the disjuncture perceived on the intonation unit boundary. It is a clear suspension of the downstep pattern.

Figure 9: An IU with intermediate phrase
This example [word tier: /kol mine dvarim `ani `ohev `et ha- shiurim `et ha- morot/ (`All kinds of things (I) like the lessons the teachers),] illustrates a utterance with two intermediate phrases. The first intermediate serves as blocking of down step.

5.2.1.4 The Tone tier

The Tone Tier represents the intonational structure of the utterance. In Israeli Hebrew three types of tonal events can be identified: pitch accents, the event that associates with stressed syllables and two types of phrasal tones; phrase accent and boundary tones. Therefore, on the tones tier the perceived pitch contour is transcribed in terms of: (1) Pitch Accents (PAs) and symbols for pitch range modifiers i.e. downstep, upstep, highest PA of the phrase, and peak delay - all placed before or after the target tone, (2) Phrase Accents, and (3) Edge Tones (the last phrase accent and the final boundary tone). These tonal events will be explained in the following sub-sections.
5.2.1.4.1 The Pitch Accents and the pitch range modifiers

In Hebrew every intonational phrase contains at least one Pitch Accent (PA). PA’s are localized pitch events that associate with the stressed syllable but in contrast to stress (which is lexically determined), in the tone domain it is not expected that every stressed syllable will be accented. In the Autosegmental-Metrical theory, Pitch accents are perceptually significant changes in F0 aligned with particular words in an utterance, and gives them prominence. For Israeli Hebrew I have identified five PAs: two mono-tonal: H* and L*, and three bi-tonal: L+H*, H*+L and L*+H. As in other language's descriptions, the H and L tones are described as high or low relative to each speaker’s pitch range. Each speaker has an upper limit and a lower limit, and tones considered high are roughly in the top three-quarters of the range while tones perceived as low are within the bottom quarter (Jun 2005). It is clear that further research is necessary before conclusions about the prosodic features of Israeli Hebrew intonation and their role in the language can be reached.

5.2.1.4.2 The realization of PA(s)

A prosodic word is a content word. Each content word is expected to have only one stress and therefore it may bear only one PA. The five PAs are:

1. H*: A high PA starting from the speaker’s middle range and is realized as a F0 peak preceded by a small rise. It is by far the most frequently used PA in IH.

2. L+H*: A rising PA. The accented syllable is perceived as high. The PA is preceded by a syllable with a low pitch target followed by a rise in the accented syllable. In this PA the peak might be late in the accented syllable.


4. L*: A Low pitch accent.

5. L*+H: A low pitch accent. The L*+H differs from the L* primarily by a rising pitch movement that follows the L* target. This PA is in contrast with the L+H* PA. In the L+H* PA the H tone appears roughly in the middle of the accented vowel and even if the peak is late (L+H*<) this
PA is perceptually perceived as high. In contrast, the L*+H PA always show a late alignment of the H tone and is perceptually perceived as low. Figure 10 presents the Israeli Hebrew PAs and their schematic representation.

Figure 10: Israeli Hebrew five PAs schematic representation

<table>
<thead>
<tr>
<th>PA Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>H*</td>
<td>Lowered by a process of downstep.</td>
</tr>
<tr>
<td>L+H*</td>
<td>Lowered by a process of downstep.</td>
</tr>
<tr>
<td>H*+L</td>
<td>Lowered by a process of downstep.</td>
</tr>
<tr>
<td>L*</td>
<td>Lowered by a process of downstep.</td>
</tr>
<tr>
<td>L*+H</td>
<td>Lowered by a process of downstep.</td>
</tr>
</tbody>
</table>

5.2.1.4.3 The pitch range modifiers

The basic PA’s may additionally be scaled within a modified pitch range. In the present data, I classify four different modifications:

1. Lowering by a process of downstep. When this occurs the affected tone is marked by a proceeding ‘!’ symbol.
2. Phrases may contain sequences of pitch accents where each accent involves a step up in pitch or a step up to a boundary tone. In the transcription, each accent of such a sequence is marked by a ‘^’ symbol before the PA symbol.
3. Peak delay marked by a ‘<’ after the associate syllables.
4. The highest PA of a phrase ‘i’.

Table 9 on page 85 below summarizes the IH-ToBI Transcription and Coding of the Tone tier and the pitch range modifiers.

5.2.1.4.4 The phrase accents and the boundary tones

As previously mentioned, IH-ToBI identifies two levels of phrasing: (a) the intermediate phrase and (b) the intonation unit. Each intonation unit contains at least one intermediate phrase. The edge tones for these phrases determine the contour from the last tone of the last pitch accent until the end of the phrase. There are two types of phrase accents in Israeli Hebrew: (a) ‘Hp’ and (b) ‘Lp’. Hp has roughly the same F0 value as the peak corresponding to the
most recent H tone, which creates a plateau at the end of the phrase. Lp can either be a F0 minimum low in the range, or be down-stepped in relation to a previous tone.

In IH-ToBI, I identified three types of boundary tones: (a) an initial boundary tone ‘%’, (b) a high boundary tone ‘H%’, and (c) a low boundary tone ‘L%’. The two final boundary tones combine with the phrase accents in four different combinations i.e. the last intermediate phrase accent (Hp or Lp) combines with the intonational boundary tones to yield the configuration of LpL%, LpH%, HpL% or HpH%. These boundaries appear to have specific pragmatic functions. By analyzing the distribution of these configurations appearing in the (semi-) spontaneous speech and the reading aloud corpus, it is evident that LpL% is the most frequently used boundary tone in Israeli Hebrew (see Figure 11 and Figure 12 below).

Figure 11: Distribution of PAs and edge-tones in the S elicitation task
Further investigation of boundary tones related to sentence type is discussed in 5.2.2 below. The most frequently occurring prosodic features of boundary tones in Israeli Hebrew are shown in Figure 13.

5.2.1.5 The Word tier

The word tier contains a straightforward orthographic presentation of all words in the utterance using Hebrew transliteration. The word transcriptions are aligned with their locations in the speech waveform. In Hebrew this obligatory tier provides a transliteration in the Roman alphabet of the Hebrew characters, since the language is written from right to left and the annotation
is built from left to right. The Hebrew transliteration is adopted from Berman (1978). From the tier I extract the relevant data using the "PrintLabelsWordtier" script, which is able to calculate the language-length measure (MLU-W) and thereby create the language matched peers (for details see section 4.1.3 above).

5.2.1.6 The Phonetic tier

This tier is goal directed for the purposes of the present research and the special population i.e. children with ASD-HF. The prosodic transcription uses the IU as the unit of analysis and a phonetic tier is not obligatory in the ToBI framework (Jun 2005). However in cases where the study population has irregular speech (e.g. where irregular articulation is raised or when there is cross-word assimilation, or when there is a stress emplacement i.e. the accented syllable is not the stressed syllable according the dictionary lexicon) it is valuable to include a tier that can show the interrelationships between the phonetic and prosodic layers. This phonetic tier marks the PA using the '⁄' symbol within the word, indicating that the accent is on the syllable following it.

5.2.2 Types of sentences

The results of this study indicate that the same pitch accent patterns are found in different type of sentences and only the edge tones of the Intonation Units (IUs) are different. Therefore, when considering the prosodic realization of sentences type, the investigation will focus mainly on the edge tones.

5.2.2.1 Declarative sentences and continuation

In the most frequent intonation contour of simple Israeli Hebrew declarative sentences, the common terminal intonation contour is LpL%, in which the pitch decreases at the very end of the utterance and the configuration is manifested as a low plateau. In this case, the utterance is only one IU. In
longer declarative sentences when the utterance includes more than one IU, it is common that only the last IU is manifested as a low plateau at the end of the utterance, while other IUs within the utterance have either LpH% or HpL% form. Table 8 below, presents low (L%) boundary tone results according to the two positions of an IU in the utterance: (a) L-boundary tone at the end of an utterance i.e. in the last IU of an utterance, and (b) L-boundary tone within the utterance i.e. in all IUs of an utterance excluded the final one.

Table 8: Boundary tones by IU position

<table>
<thead>
<tr>
<th>Elicitation Task</th>
<th>Percentage of L-boundary tone at the END of an U</th>
<th>Percentage of L-boundary tone WITHIN the U</th>
</tr>
</thead>
<tbody>
<tr>
<td>(semi-) spontaneous speech</td>
<td>76.95 (SD=12.2)</td>
<td>64.24 (SD=13.1)</td>
</tr>
<tr>
<td>Reading Aloud</td>
<td>95.5 (SD=6.1)</td>
<td>63.64 (SD=13.2)</td>
</tr>
<tr>
<td>Note: in the R elicitation task most sentences were one IU sentence</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It can be concluded that for Hebrew the L-boundary tone signals finality. It is more pronounced in the RA elicitation task.

In Hebrew, the absence of finality i.e. signaling a continuation, is marked by a high (H) boundary tone or high phrase accent (Hp) with a L-boundary tone i.e. LpH%, HpH%, HpL%. In these continuation contours, the F0 is not at the bottom of the speakers range and denote that the speaker has not yet terminated his idea. This pitch contour pattern at the edge of the IU is one of the major characteristics of spontaneous speech. Figure 14 and Figure 15 are examples of continuation and finality in Israeli Hebrew intonation.
Figure 14: Example of HpH% pitch continuation and HpL% finality contours
This example [word tier: / veu neelam/ (0.32)/ve/ ‘axshav lo mos’im ‘oto/ (‘and he disappears and now we can’t find him’)], illustrates an utterance with 3 IUs. The second IU illustrates a continuation rise (HpH%) while the last IU shows a low boundary tone (HpL%) signaling finality. From: IDS-WDD-S-17, age: 13:0.

Figure 15: Example pitch contour of LpH% continuation
This example [word tier:/lesaxek ‘im xaverim qe ‘ilul (0.79)/lehipagesh/ (‘to play with friends like meet’) illustrates an utterance with 2 IUs. The first IU illustrates continuation rise (LpH%), while the last IU shows a low boundary tone (LpL%) signaling finality. From: AVS-WDD-S-22, age:11:9.

5.2.2.2 Interrogative: Wh-Questions

The prosodic features of the ends of phrases and the signaling of interrogative mode in speech through intonation are a topic that has long attracted the interest of intonation researchers in both descriptive phonetics and intonation models (e.g. Bolinger 1978, 1989, Cruttenden 1986, Ladd 1996, Hirst and Di Cristo 1998). Not only does question intonation vary in different languages, but also different types of questions (i.e. WH, yes/no, echo or tag questions)
can result in different kinds of intonation patterns (Bolinger 1989, Hirst and Di Cristo 1998, Ladd, 1996, House 2002). In this study, I will focus on WHQs which is the most frequent questions type in Hebrew. The following description of the intonation patterns of IH WHQs is based on the transcription and analysis of: (a) four WHQs of the R elicitation task (it should be noted that the R sentences contain mostly sonorant consonants and vowels in order to provide a visible continuous contour of F0), and (b) two WHQs of the RA elicitation task. This empirical basis is very limited. The corpus of the WHQs prosodic patterns produced by the Hebrew WDD participants contains only 60 utterances. Nevertheless, the results permit a straightforward description of the WHQs.

In very general terms, the most commonly described tonal characteristic for questions is high final pitch and overall higher pitch (Hirst and Di Cristo 1998). In many languages, yes/no questions are reported to have a final rise, while WHQs typically are associated with a final low. However, Cruttenden (1986) claimed that WHQs can often be associated with a large number of different contours. Bolinger (1989) for example, presents various contours and combinations of contours, which he relates to different meanings in WHQs. House (2005) in a production study, examined the extent to which optional final rises occur in a set of 200 WHQs extracted from a large corpus of spontaneous speech in Swedish. The results confirm the possibility of a final rise in Swedish interrogative intonation. He found that 22% of the questions ended in a phrase final rise and that children produced more questions with final rises (32%) than women (27%) or men (17%). This shows that the gender, age and possibly other factors as well, may influence the prosodic contour, and therefore the following description may be relevant only to Hebrew speaking boys between the ages of 9 to 13 years. Thus further investigation of Israeli Hebrew prosodic interrogative in general, and WHQs in particular, is necessary for a wider understanding of the prosodic features of IH intonation. Since this is not the primary goal of the present dissertation, this limited description will suffice and will now be further discussed.

In Hebrew, WH-words appear in the initial position of the sentence. The WH-word may or may not appear as the most prominent word of the sentence e.g. in Figure 16 the WH-Word /mataj/ ('when') is clearly the most prominent
word in the WH-sentence. The L+H PA starts from a low pitch and rises to the higher-level pitch of the WH-sentence (L+Hi*). In contrast

Figure 17 presents the same sentence by another WDD participant, and in this case the WH-word is realized as L* followed by L+H* and L+^Hi*. Both examples demonstrate the same pattern of a transition from low to high at the start of the WH-sentence, and this is a characteristic of WHQs in Israeli Hebrew. In addition, these examples do not show any differences at the phrase final of the WHQ, which is in this case HpL% followed by a L PA. This phrase final of HpL% was not the only phrase final pitch contour although it is the most frequent one in the repetition task. A very frequent pitch contour is HpH% which is a final-rise. All WHQs phrase finals in the RA elicitation task were final-lows realized either as LpL% or HpL% pitch contours. Figure 18 and Figure 19 show the final-rise and the final-low in Hebrew WHQs.

Figure 16: Example of WH-Word as the most prominent word of the IU
This example [word tier: /maty Ziv ganav `et ha- krembo?/ (‘When did Ziv steal the crembo’) illustrates the WH-Word “maty” (‘when’), were it is the most prominent word of the sentence. From: NIS-WDD-R-3, age: 9:3.
Figure 17: Example of WH-Word, not the most prominent word of the IU
This example [word tier: /maty Ziv ganav `et ha- krembo?] ('When did Ziv steal the crembo?') illustrates the WH-Word "maty" ('when') when it is not the most prominent word of the sentence. The most prominent word in this case is "ganav" ('steal'). From participant: AVS-WDD-R-3, age:11:9.

Figure 18: WHQ-Phrase final HpH% rising contour
This example [word tier: /ma Ziv ganav?] ('What did Ziv steal?') illustrates a WHQ with rising pitch contour at the edge of the IU. From: ITS-WDD-R-2, age:11:6.
Figure 19: WHQ-Phrase-final LpL% falling contour

This example [word tier: /ma Ziv ganav?/ ('What did Ziv steal?')] illustrates a WHQ with falling pitch contour at the edge of the IU of the WHQ in the RA elicitation task. From: IDR-WDD-RA-2, age10:7.

5.2.3 Summary

In this first chapter of results, I have presented a prosodic analysis of Israeli Hebrew within the Autosegmental-Metrical approach, concentrating on intonation, and phrasing.

IH-ToBI differentiates and defines two levels of phrasing: the intermediate phrase and the intonation unit (IU), which contains one or more intermediate phrases.

The IH-ToBI prosodic transcription of intonation includes an inventory of five pitch accents, two phrase accents, and three boundary tones. All patterns are described and summarized in Table 9 on page 85 below. This IH-ToBI annotation constitutes the basis of the description and comparison of the prosodic features of children with ASD-HF and children WDD. The following chapters will present these results.
Table 9: IH-ToBI transcription and coding

<table>
<thead>
<tr>
<th>IH-ToBI Tiers</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tone</td>
<td></td>
</tr>
<tr>
<td>PAs</td>
<td></td>
</tr>
<tr>
<td>L+H*</td>
<td>A rising PA. It is by far the most frequently used PA in IH. The accented syllable is perceived as high. This PA is preceded by a syllable with a low pitch target which leads to a rise in the accented syllable. In this PA the peak might be late in the accented syllable.</td>
</tr>
<tr>
<td>H*</td>
<td>The high PA lacks the initial dip associated with the L tone and is realized as a small rise.</td>
</tr>
<tr>
<td>H*+L</td>
<td>A falling pitch accent.</td>
</tr>
<tr>
<td>L*</td>
<td>A low pitch accent.</td>
</tr>
<tr>
<td>L*+H</td>
<td>A low pitch accent followed by a high tone. The L*+H differs from the L* primarily by a rising pitch movement following the L* target. This PA is in contrast with the L+H* PA. In the L+H* PA the H tone appears roughly in the middle of the accented vowel and even if the peak is late (L+H*&lt;), this PA is perceptually perceived as high. In contrast, the L*+H PA always show a late alignment of the H tone and is perceptually perceived as low.</td>
</tr>
<tr>
<td>*</td>
<td>Ambiguous pitch accent</td>
</tr>
<tr>
<td>PhA</td>
<td></td>
</tr>
<tr>
<td>Lp</td>
<td>F0 minimum low in the range / downstepped in relation to a previous tone.</td>
</tr>
<tr>
<td>Hp</td>
<td>The same F0 value as the peak corresponding to the most recent H tone / upstep in relation to the previous H tone.</td>
</tr>
<tr>
<td>BT</td>
<td></td>
</tr>
<tr>
<td>%</td>
<td>Initial boundary tone</td>
</tr>
<tr>
<td>L%</td>
<td>Final low boundary tone</td>
</tr>
<tr>
<td>H%</td>
<td>Final high boundary tone</td>
</tr>
</tbody>
</table>

Word | An orthographic tier containing a straightforward transcription of all the words in the utterance, written in Latin alphabet to transliterate IH words (following; Berman, 1978). The word transcriptions are aligned with their locations in the speech waveform. |

Break-Indices | |
| B | Marking the beginning of an IU |
| 1 | Marking typical word boundaries in a fluent sequence of words |
| 1p | Marking a short dis-fluent break |
| 0 | Marking two words produced as one |
| 2 | Marking mismatch between tones and perceived juncture |
| 3 | Marking of intermediate phrase (ip) |
| 3p | Marking a dis-fluent break long enough for an ip boundary |
| 4 | Marking the end of an IU |
| 4u | Marking the end of an utterance |

Phonetic | Provides an IPA transcription of a word with the indication of the PAs placement using ‘/’ before the accented syllable. |

Comments | Information is only encoded if it cannot be derived from labels from other tiers or from the speech signal. It includes two kinds of information: (a) information bound to the transcription context e.g. nonverbal noise produced in the vocal tracts of speech, ps=pitch setting of the IU, reset of pitch restart of speech, upstep, blocking of upstep, creaky voice and so on, and (b) situation context e.g. behavioral comment: laughter, anger, etc. |
RESULTS PART II

CHAPTER 6: ASD-HF vs. WDD PROSODIC FEATURES

6.1 Groups and speech samples statistics

The two groups of participants are presented in paragraph 4.1 on page 49 above. This paragraph presents the group statistics with the purpose of showing that: (a) Subjects of group A meet the criteria of the HF category of the ASD continuum and (b) Participants of groups A and B can be matched according to the criteria determined (in paragraph 4.1) and consequently their speech samples can be compared and contrasted.

All subjects WISC-R test (group A, N=10) were within the norm for the verbal IQ (VIQ) test as well as for the performance IQ (PIQ) test. In the VIQ test, subjects perform between 86 IQ to 121 IQ score (mean=103.1, SD=11.42) and in the PIQ test, subjects perform between 85 IQ to 102 IQ score (mean=95.9, SD=5.11). Add to these verbal results, subjects’ MLU-W does not show significant differences from the MLU-W results of group B. For participants in group A MLU-W was between 4.8 to 7.86 (mean=6.06, SD=0.988) and for participants in group B, MLU-W was between 4.04 to 7.18 (mean=5.74, SD=0.923). Table 10 below summarizes these results.

Further, it is necessary to show that the speech sample data of groups A and B are such that the samples of the two groups can be compared based on the size of the speech sample corpus. The R and RA tasks are structured i.e. all the participants read or repeated the same sentences. This is obviously not so for the S task and therefore it will be shown that there is no significant difference between the size of the sample of the S task of groups A and B. Table 11 presents the number and percent of IUs that were transcribed and analyzed in each group.
Table 10: Statistical analysis of participant’s criteria

<table>
<thead>
<tr>
<th></th>
<th>Group A (ASD)</th>
<th>Group B (WDD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VIQ/PIQ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>86/85</td>
<td>4.04</td>
</tr>
<tr>
<td>Max.</td>
<td>121/102</td>
<td>7.18</td>
</tr>
<tr>
<td>Mean</td>
<td>103.1/95.9</td>
<td>5.74</td>
</tr>
<tr>
<td>SD</td>
<td>11.42/5.11</td>
<td>0.923</td>
</tr>
<tr>
<td>MLU-U</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>4.8</td>
<td>12</td>
</tr>
<tr>
<td>Max.</td>
<td>7.86</td>
<td>17</td>
</tr>
<tr>
<td>Mean</td>
<td>6.06</td>
<td>15</td>
</tr>
<tr>
<td>SD</td>
<td>0.988</td>
<td>1.764</td>
</tr>
<tr>
<td>Mother education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Max.</td>
<td>17</td>
<td>17</td>
</tr>
<tr>
<td>Mean</td>
<td>15</td>
<td>15.4</td>
</tr>
<tr>
<td>SD</td>
<td>1.764</td>
<td>1.518</td>
</tr>
<tr>
<td>Age of participants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Min.</td>
<td>9:0</td>
<td>9:0</td>
</tr>
<tr>
<td>Max.</td>
<td>13:0</td>
<td>13:0</td>
</tr>
<tr>
<td>Mean</td>
<td>11:04:02</td>
<td>11:03:6</td>
</tr>
<tr>
<td>SD</td>
<td>1:04:08</td>
<td>1:04:02</td>
</tr>
</tbody>
</table>

*VIQ= verbal IQ, PIQ= performance IQ, MLU-U= mean length of utterance in words.*

Table 11: Speech sample data

<table>
<thead>
<tr>
<th>Group</th>
<th>Number of IUs¹</th>
<th>Percent of analyzed IUs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>S</td>
</tr>
<tr>
<td>A (ASD)</td>
<td>959</td>
<td>83.55 (SD=9.08)</td>
</tr>
<tr>
<td>B (WDD)</td>
<td>984</td>
<td>95.83 (SD=6.43)</td>
</tr>
<tr>
<td>Z</td>
<td>0.399</td>
<td>0.751 (SD=6.43)</td>
</tr>
<tr>
<td>Exact Sig. (p)</td>
<td>0.73</td>
<td>0.489 (SD=4.122)</td>
</tr>
</tbody>
</table>

1. It is not necessary to indicate the number of IUs of the R or RA tasks since all participants read or repeated the same sentences. Man-Whitney significant difference \( p<0.05 \)

A statistical analysis of the results presented above shows no significant difference between the number of IUs of the S task \( (p=0.73) \) of each group. There is also no significant difference in the percent of analyzed IUs of the S task \( (p=0.489) \) or of the RA task \( (p=0.796) \). Therefore, it can be concluded that there is no significance difference between the speech sample data of the two groups and that this data can be used in the prosodic analysis that follows.

The comparative results to be presented below are frequency values and pitch range, phrasing and segmentation, pitch accents, boundary tones and edge tones.
6.2 Frequency values and Pitch Range

In Autosegmental-Metrical theory, equivalent prosodic patterns of intonation in an utterance will share the same pitch accents and boundary tones, but need not share the same frequency values or pitch ranges (Ladd 1996, Patterson and Ladd 1999). The fundamental frequency (F0) of a sound is responsible for the pitch that we hear and the range of the F0 is part of what characterizes the speaker.

Meaning and prominence is created in most languages by inflection of the voice i.e. varying the pitch. The pitch range specifies the span over which the variation may occur. In phonetics, the F0 of individual sounds and the long-term average F0 are invariably measured in Hertz (Hz). However, when a comparison is being made between two frequencies, or when a frequency range is being quoted, it is usual to use semitones (Hewlett and Beck 2006). Murray and Arnott (1993) suggest that a logarithmic scale best models speaker intuitions about pitch range (PR). Semitone conversion is used to normalize the PR data. This procedure makes it possible to compare the PR of the subjects, even when they have different F0 values. Semitone conversion is usually used as research method when comparing subjects of different ages, genders, or languages. In this study, the PR in semitones (ST) for each participant was obtained using the following formula:

\[ ST = 12 \times \ln\left(\frac{f_{\text{max}}}{f_{\text{min}}}\right)/\ln(2), \]

in which \( f_{\text{max}} \) is the maximum pitch in Hz and \( f_{\text{min}} \) is the minimum pitch in Hz for a particular participant. This procedure is following the procedure used by Setter et al. (2007) in examining the PR of children with Williams syndrome. This section presents results, which attempt to answer the question: Do the frequency values and PR of children with ASD-HF differ from that of children WDD?

In order to answer this question, a Pratt-script 'printPITCHtier.Pratt' (explained in detailed in 4.2.3.1 on page 56 above) was used to extract the information detected from all S samples of both ASD-HF subjects and WDD controls. The F0 for each participant is shown in Table 12 below. This table presents the absolute F0 and the average F0 values refer to the maximum and
minimum F0 of ASD-HF subjects (Group A) and WDD controls (Group B).

A total of 1,943 IUs were quoted and examined in order to compare between the groups, 860 IUs of group A (N=9) compare with 888 IUs of group B (N=9), but when comparison has been made within the groups than group A comprise 959 IUs (N=10) and group B 984 IUs (N=10).

<table>
<thead>
<tr>
<th>Participants</th>
<th>No of IUs</th>
<th>Absoute F0</th>
<th>Average F0</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Min. (Hz)</td>
<td>Max. (Hz)</td>
<td>Range (ST)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min. (Hz)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Min. (Hz)</td>
</tr>
<tr>
<td>ASD-HF</td>
<td>1-ADR</td>
<td>89</td>
<td>87.7</td>
<td>524.1</td>
</tr>
<tr>
<td></td>
<td>2-ITE</td>
<td>98</td>
<td>67.9</td>
<td>423.2</td>
</tr>
<tr>
<td></td>
<td>3-UXD</td>
<td>116</td>
<td>71.5</td>
<td>526.2</td>
</tr>
<tr>
<td></td>
<td>4-YOL</td>
<td>98</td>
<td>73.9</td>
<td>650.5</td>
</tr>
<tr>
<td></td>
<td>5-RAE</td>
<td>102</td>
<td>86.6</td>
<td>529.8</td>
</tr>
<tr>
<td></td>
<td>6-BAB</td>
<td>99</td>
<td>81.3</td>
<td>713.8</td>
</tr>
<tr>
<td></td>
<td>7-ETR</td>
<td>80</td>
<td>85.2</td>
<td>399.9</td>
</tr>
<tr>
<td></td>
<td>8-TOB</td>
<td>78</td>
<td>90.2</td>
<td>167.1</td>
</tr>
<tr>
<td></td>
<td>9-NOR</td>
<td>100</td>
<td>75.1</td>
<td>519.5</td>
</tr>
<tr>
<td></td>
<td>10-OMG</td>
<td>98</td>
<td>97.6</td>
<td>411.2</td>
</tr>
</tbody>
</table>

| WDD          | 11-AVY    | 99         | 85.2       | 494.2      | 31.8     | 157.2      | 269.       | 9.0      | 32.46    | 41.59 |
|              | 12-NIS    | 94         | 75.6       | 492.6      | 32.4     | 165.3      | 273.4      | 8.7      | 37.45    | 58.65 |
|              | 13-IDR    | 108        | 92.0       | 542.2      | 30.7     | 207.8      | 373.5      | 10.2     | 44.83    | 67.92 |
|              | 14-YVO    | 97         | 82.8       | 505.3      | 31.3     | 167.       | 288.6      | 9.5      | 48.48    | 52.69 |
|              | 15-ITS    | 92         | 94.0       | 502.3      | 29.0     | 169.9      | 284.1      | 8.9      | 30.23    | 61.01 |
|              | 16-AVS    | 97         | 76.1       | 440.6      | 30.4     | 170.8      | 275.3      | 8.3      | 44.57    | 53.18 |
|              | 17-LIS    | 97         | 84.1       | 427.9      | 28.2     | 187.7      | 274.3      | 6.6      | 30.26    | 32.15 |
|              | 18-IDW    | 100        | 72.4       | 363.7      | 29.6     | 145.3      | 231.2      | 8.0      | 28.36    | 37.00 |
|              | 19-OMX    | 102        | 78.1       | 470.5      | 31.1     | 102.7      | 170.2      | 8.7      | 11.74    | 67.15 |
|              | 20-IDS    | 97         | 84.1       | 427.9      | 28.2     | 187.7      | 274.3      | 6.6      | 30.26    | 32.15 |

10-OMG-ASD and 20-IDS-WDD are excluded from group comparisons.

There are no summary statistics for F0 available for IH children in general. From this data I can summarizes that within all WDD children’s 984 IUs, the absolute minimum F0 for a single IU was between 72.4Hz to 94Hz (mean=82.44Hz, SD=7.03Hz), the absolute maximum F0 for a single IU was between 363.7Hz to 542.2Hz (mean=466.72Hz, SD=51.85Hz). The absolute PR for a single IU, was between 28ST to 32ST (mean=30.27ST, SD=1.47ST).

The average minimum F0 for a single IU was between 103Hz to 208Hz (mean=166.14Hz, SD=28.365Hz), the average maximum for single IU was between 170.2Hz to 373.5Hz (mean=271.39, SD=50.311Hz). The average PR was 6.6ST to 10.2ST (mean 8.45ST, SD=1.148ST).

For the research ASD-HF subjects (959IUs), the absolute minimum F0
for a single IU was between 67.9 Hz to 97.6 Hz (mean=81.7 Hz, SD=9.4 Hz), the absolute maximum F0 for a single IU was between 167.1 Hz to 713.8 Hz (mean=486.530 Hz, SD=150.447 Hz). The absolute PR was between 11ST to 38ST (mean=29.98ST, SD=7.913ST). The average minimum F0 for a single IU was between 101 Hz to 247 Hz (mean=175.15 Hz, SD=38.524 Hz), the average maximum F0 for single IU was between 134.7 Hz to 399.3 Hz (mean=306.75 Hz, SD=72.587 Hz), the average PR was between 5ST to 13.7ST (mean=9.16ST, SD=2.771ST).

The Mann-Whitney test statistics was used to investigate whether there were significant group differences (group A vs. group B, N=18) in frequency values and PR. No significant differences were found. Although the test points for no significant differences between the groups, this is due to the higher SD present in group A compare with the SD results in group B. The high SD blurs statistical differences between the groups. Table 13 presents the SD results of pitch values and PR by groups.

<table>
<thead>
<tr>
<th>Standard Deviation</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absolute Minimum F0 (in Hz)</td>
<td>9.407</td>
<td>7.031</td>
</tr>
<tr>
<td>Absolute Maximum F0 (in Hz)</td>
<td>150.447</td>
<td>51.855</td>
</tr>
<tr>
<td>Absolute Range (in ST)</td>
<td>7.913</td>
<td>1.470</td>
</tr>
<tr>
<td>Average Minimum F0 (in Hz)</td>
<td>38.524</td>
<td>28.365</td>
</tr>
<tr>
<td>Average Maximum F0 (in Hz)</td>
<td>72.587</td>
<td>50.311</td>
</tr>
<tr>
<td>Average Range (in ST)</td>
<td>2.771</td>
<td>1.148</td>
</tr>
</tbody>
</table>

Figure 20 presents the absolute PR by groups and participants. It is evident that there is greater variation across group A, the subjects with ASD-HF. Therefore, I will now focus within that group.

The results on F0 variability within the ASD-HF subjects can be subdivided into three types of PR compared with the WDD controls:

(a) Typical PR (TPR), ranging from 28.2ST to 32.4ST,
(b) Narrow PR (NPR), PR is lower than 28.2ST,
(c) Wide PR (WPR), PR is wider than 32.4ST.

The ASD-HF subjects can be sub divided into these three distinct groups according to characteristic of their PR (Green 2009a, Green and Tobin 2008a, b). These three types are exemplified in Figure 21.
Figure 20: Absolute PR (in ST) by groups and participants

Figure 21: Example of PR types
A is an example of ASD participant with a TPR. B is an example of ASD participant with WPR and C is an example of ASD participant with NPR. (These examples are presented with full textgrid and IH-ToBI transcription in Green and Tobin 2009b).
6.3 Intonation

6.3.1 Phrasing and segmentation

This section deals with phrasing and segmentation of utterance into IUs and the segmentation of the IU into intermediate phrases within the IU by:

(a) Number of IUs per utterance: This ratio is the proportion of the IUs segmented in an utterance. In the Break-Index tier of the ToBI-IH, the start of an IU is delineated by 'B', the end is delineated by '4', and the end of an utterance is delineated by '4U'. See Table 9 on page 85.

(b) Percentage of IUs with at least one intermediate phrase: This is the number of IUs with intermediate phrases relative to the total number of IUs of the speech sample, and is defined by '3' in the IH-ToBI Break Indices tier transcription.

6.3.1.1 IUs per utterance

Table 14 presents the results of number of IUs per utterance in the RA and S (~50 utterances per participant) elicitation tasks.

Group A subjects produced more IUs per utterance in both the RA ($p=0.094$) and S elicitation tasks ($p=0.73$) which were not statistically significant. A comparison of matched peers presented in Figure 22, shows that in eight of the nine matched peers, in the RA task the ASD-HF subjects produced more IUs per utterance while in the S task only five (of nine) ASD-HF subjects produced more IUs per utterance.
Table 14: Segmentation of utterances

<table>
<thead>
<tr>
<th></th>
<th>IUs per utterance in the RA elicitation task</th>
<th>IUs per utterance in the S elicitation task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Min. IU/U</td>
<td>Max. IU/U</td>
</tr>
<tr>
<td>Group A</td>
<td>2.08</td>
<td>3.75</td>
</tr>
<tr>
<td>Group B</td>
<td>1.60</td>
<td>3.63</td>
</tr>
</tbody>
</table>

Min. IU/U= the lowest result in the group, Max IU/U= the highest result in the group.

6.3.1.2 Intermediate phrase segmentation

According to the Autosegmental-Metrical theory and specifically to IH-ToBI, speakers may divide speech into intermediate phrases within each IU. Table 15 presents the percentage of intermediate phrase per speech-sample, in both the RA and the S elicitation tasks.
Table 15: Intermediate Phrase by groups and elicitations

<table>
<thead>
<tr>
<th></th>
<th>Percentage of Intermediate Phrase in the RA elicitation task</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Group A</td>
<td>8.7</td>
<td>36.36</td>
<td>14.52</td>
<td>8.94</td>
</tr>
<tr>
<td>Group B</td>
<td>8.33</td>
<td>26.09</td>
<td>13.28</td>
<td>5.41</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Intermediate Phrase percentage in the RA elicitation task</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Minimum</td>
<td>Maximum</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Group A</td>
<td>14.33</td>
<td>37.37</td>
<td>21.98</td>
<td>7.48</td>
</tr>
<tr>
<td>Group B</td>
<td>5.32</td>
<td>25.26</td>
<td>15.41</td>
<td>4.89</td>
</tr>
</tbody>
</table>

Group A produced more IUs with intermediate phrases than group B. In the RA task 14.52% of the IUs had at least one intermediate phrase and in the S task 21.98% of the IUs had at least one intermediate phrases. The variability within group A is greater than of group B (In the RA task: group A, SD=8.94 and group B SD=5.41. In the S task group A SD=7.48 and group B SD=4.89.

In group B there is no difference between the two elicitation tasks while in group A subjects produced more intermediate phrases in the RA task than in the S elicitation task.

6.3.2 Pitch Accents

This section presents the results of a quantitative and qualitative analysis of the acoustic realization of Pitch Accents (PAs). Three variables are analyzed by:

(a) Frequency of high PAs occurrences,
(b) Distribution of the different IH PAs,
(c) PAs per word, followed by a case investigation of one high PAs/W subject and his matched peer, in order to explore the differences found at the lexical word level.

6.3.2.1 Frequency of high PAs occurrences

6.3.2.1.1 Group comparison

Group A produced more high PAs than group B in both the RA and S elicitation tasks that was not statistically significant. Both groups produced more high
PAs in the RA task than in the S task. These results are presented in Table 16.

Within group A, in the RA elicitation task the quantity of high PAs as a percentage of total PAs was between 70.59% and 87.38% with a mean of 77.99% (SD=5.37). In the same task, within group B it was between 64.38% and 89.53% with a mean of 75.30% (SD=6.955).

<table>
<thead>
<tr>
<th>Group</th>
<th>Task</th>
<th>Range of high PAs</th>
<th>Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>A (N=9)</td>
<td>RA</td>
<td>70.59 - 87.38</td>
<td>77.99</td>
<td>5.37</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>70.74 - 84.88</td>
<td>77.43</td>
<td>4.62</td>
</tr>
<tr>
<td>B (N=9)</td>
<td>RA</td>
<td>64.38 - 89.53</td>
<td>75.30</td>
<td>6.96</td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>65.79 - 84.33</td>
<td>74.17</td>
<td>5.23</td>
</tr>
</tbody>
</table>

In group A in the S elicitation task the quantity of high PAs as a percentage of total PAs was between 70.74% and 84.88% with a mean of 77.43% (SD=4.621), while in group B it was between 65.79% and 84.33% with mean of 74.17% (SD=5.227).

6.3.2.1.2 Peer comparison

In a comparison of peers within the groups, in seven of the nine matched peers the ASD-HF participant showed a greater use of high PAs in the S task. In the RA task, in six matched peers the ASD-HF participant shows a greater use of high PAs.

In group B only two participant (15-ITS and 17-LIS) demonstrate above 80% use of high PAs, while in group A four participants produced above 80% use of high PAs (1-ADR, 2-ITE, 7-ETR, and 9-NOR). No participants in group A produced less than 70% high PAs while in group B there are three participants with less than 70% high PAs (14-YVO, 16-AVS and 18-IDW). Table 16 presents the frequency of high PAs by participants in the RA and the S tasks.
### Table 17: Percentage of high PAs by participants and elicitation task

<table>
<thead>
<tr>
<th>ASD-HF subjects</th>
<th>WDD participants</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RA</td>
</tr>
<tr>
<td>1-ADR-ASD</td>
<td>85.34</td>
</tr>
<tr>
<td>2-ITE-ASD</td>
<td>78.31</td>
</tr>
<tr>
<td>3-UDX-ASD</td>
<td>70.59</td>
</tr>
<tr>
<td>4-YOL-ASD</td>
<td>78.95</td>
</tr>
<tr>
<td>5-RAE-ASD</td>
<td>74.16</td>
</tr>
<tr>
<td>6-BAB-ASD</td>
<td>73.13</td>
</tr>
<tr>
<td>7-ETR-ASD</td>
<td>87.38</td>
</tr>
<tr>
<td>8-TOB-ASD</td>
<td>77.21</td>
</tr>
<tr>
<td>9-NOR-ASD</td>
<td>80.82</td>
</tr>
<tr>
<td>*10-OMG-ASD</td>
<td>74.10</td>
</tr>
</tbody>
</table>

### 6.3.2.2 Distribution of the types of IH PAs

The results, presented in Table 18, show that there is no significant difference between groups A and B in the frequency of occurrence of the different types of PA being compared.

<table>
<thead>
<tr>
<th>Elicitation</th>
<th>Frequency of occurrence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Group H*</td>
</tr>
<tr>
<td>RA</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>33.85</td>
</tr>
<tr>
<td>B</td>
<td>36.09</td>
</tr>
<tr>
<td>S</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>33.45</td>
</tr>
<tr>
<td>B</td>
<td>38.04</td>
</tr>
</tbody>
</table>

* *1 Indeterminate PA

The two most common PA types in both elicitions were H* and L+H*. The L+H* PA occurs slightly more often in group A and this might correspond with age. Figure 23 shows the results of H* and L+H* in RA and S tasks. The younger participants of group B make greater use of L+H* (e.g. 11-AVY age 9:0 had 36.27% of L+H*, 13-IDR age 10:7 had 44.23% of L+H* PAs) while the older participants showed a more frequent use of H* (e.g. 17-LIS age 12:3 with 20.9% of L+H* and 54.85% of H*, 19-OMX age 12:11 with 17.39% of L+H* and 57.19% of H*). The analysis of these two types of PAs shows that in group B there is a trend towards an increased use of H* PA with age and a decreased use of L+H* PA with age. Group A shows a similar trend but it is less marked. Therefore the difference between group A and group B, could be a result of a minor delay in the development of the use of PA in children with ASD-HF and is more pronounced in the unstructured nature of
the S elicitation task.

Figure 23: Distribution of H* and L+H* in RA and S elicitation tasks

<table>
<thead>
<tr>
<th></th>
<th>Distribution of H* in RA Task</th>
<th>Distribution of H* in S Task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage</td>
<td>Percentage</td>
</tr>
<tr>
<td></td>
<td>1    2   3   4   5   6   7   8   9   10</td>
<td>1    2   3   4   5   6   7   8   9   10</td>
</tr>
<tr>
<td>ASD</td>
<td>11.2 39.8 17.7 49.5 36 29.9 36.9 35.4 35.6</td>
<td>18.7 33.7 25.0 43.4 43.0 24.1 38.3 39.3 27.5</td>
</tr>
<tr>
<td>WDD</td>
<td>30.3 37.2 26.4 26 41.6 20.9 60.5 41.9 37.3</td>
<td>28.3 36.7 23.4 37.3 23.5 28.6 54.8 52.3 57.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Distribution of L+H* in RA Task</th>
<th>Distribution of L+H* in S Task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Percentage</td>
<td>Percentage</td>
</tr>
<tr>
<td></td>
<td>1    2   3   4   5   6   7   8   9   10</td>
<td>1    2   3   4   5   6   7   8   9   10</td>
</tr>
<tr>
<td>ASD</td>
<td>68.1 31.3 48.2 23.1 32.5 38.8 40.7 30.2 42.4</td>
<td>49.0 31.4 40.1 27.9 22.9 40.9 29.9 28.1 45.2</td>
</tr>
<tr>
<td>WDD</td>
<td>37.4 31.4 46.1 32.8 33.7 48.8 18.6 20.4 33.3</td>
<td>36.2 30.2 44.2 18.4 43.3 33.8 20.9 13.9 17.3</td>
</tr>
</tbody>
</table>

### 6.3.2.3 PAs per Word

Table 19 presents the results of PAs per Word (PAs/W) by groups and elicitation tasks.
Table 19: PAs/W by group and elicitation task

<table>
<thead>
<tr>
<th></th>
<th>PAs/W in the RA task</th>
<th></th>
<th>PAs/W in the S task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>minimum</td>
<td>maximum</td>
<td>Mean</td>
</tr>
<tr>
<td>Group A</td>
<td>0.720</td>
<td>1.478</td>
<td>0.988</td>
</tr>
<tr>
<td>Group B</td>
<td>0.784</td>
<td>0.989</td>
<td>0.896</td>
</tr>
</tbody>
</table>

In group A the PAs/W in the RA task is between 0.720 and 1.478 (mean=0.988, SD=0.231) while in the S task the PAs/W is between 0.719 and 1.308 (mean=0.974, SD=0.191). In group B the PAs/W in the RA task is between 0.784 and 0.989 (mean=0.896, SD=0.075), while in the S task, the PAs/W is between 0.736 and 0.979 (mean=0.872, SD=0.069). There was no statistically significant difference between groups in either elicitation tasks. Nevertheless, the SD shows that the variability within group A is much greater than that within group B (SD of group A is approximately 3 times the SD of group B).

However it is worth noting that four subjects in group A had PAs/W>1, whereas all of the participants in group B had PA/W<1. Table 20 present the PAs/W of each subject in group A.

Table 20: PAs/W of group A

<table>
<thead>
<tr>
<th>Subject</th>
<th>PAs/W</th>
<th>RA</th>
</tr>
</thead>
<tbody>
<tr>
<td>S</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-ADR</td>
<td>1.174</td>
<td>1.247</td>
</tr>
<tr>
<td>2-ITE</td>
<td>0.786</td>
<td>0.883</td>
</tr>
<tr>
<td>3-UDX</td>
<td>0.886</td>
<td>0.914</td>
</tr>
<tr>
<td>4-YOL</td>
<td>0.854</td>
<td>0.989</td>
</tr>
<tr>
<td>5-RAE</td>
<td>0.859</td>
<td>0.946</td>
</tr>
<tr>
<td>6-BAB</td>
<td>1.061</td>
<td>0.720</td>
</tr>
<tr>
<td>7-ETR</td>
<td>1.156</td>
<td>1.107</td>
</tr>
<tr>
<td>8-TOB</td>
<td>0.719</td>
<td>0.811</td>
</tr>
<tr>
<td>9-NOR</td>
<td>0.938</td>
<td>0.785</td>
</tr>
<tr>
<td>10-OMG</td>
<td>1.308</td>
<td>1.478</td>
</tr>
</tbody>
</table>

The next section will present an individual case investigation to illustrate the behavior of a subject that exhibits the high PA/W.
6.3.2.4 Case investigation of high PAs/W ratio

In order to evaluate the high PAs/W ratio exhibited in four subjects within group A, a case investigation of the matched peer 1-ADR-ASD and 11-AVY-WDD was done. The corpus includes 248 IUs: 60 IUs from the RA elicitation (28 IU from the ASD-HF subject and 32 IUs from his WDD peer) and 188 IUs from the S elicitation task (89 IUs from the ASD-HF subject and 99 from his WDD peer). Using the "PrintLabelsWORDtier.PRAAT" script output, further classification of the placement of PAs was made. Each PA was mapped into one of the following categories:

(a) PA in a Content Word (CW): A content word is a word, typically a noun, verb, adjective, or adverb, that carries semantic content, bearing reference to the world independently of its use within a particular sentence or utterance.

(b) PA in a Function Word (FW): A function word (or a form word) is a preposition, article, auxiliary, or pronoun, that chiefly expresses grammatical relationships, has little semantic content of its own, and belongs to a small, closed class of words whose membership is relatively fixed.

When a CW or a FW has more than one PA, it is counted once in its category and in the "more than one" category as well. This analysis is presented in Table 21, and lists the percentage of accented words by category and elicitation task.

<table>
<thead>
<tr>
<th></th>
<th>RA</th>
<th>&gt; 1</th>
<th>S</th>
<th>&gt; 1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FW</strong></td>
<td><strong>CW</strong></td>
<td></td>
<td><strong>FW</strong></td>
<td><strong>CW</strong></td>
</tr>
<tr>
<td>1-ADR-ASD</td>
<td>64.86%</td>
<td>92.98%</td>
<td>14.89%</td>
<td>62.55%</td>
</tr>
<tr>
<td>11-AVY-WDD</td>
<td>35.14%</td>
<td>89.47%</td>
<td>2.13%</td>
<td>24.71%</td>
</tr>
</tbody>
</table>

FW = percentage of PAs in function words; CW = percentage of PAs in content words; >1 = percentage of words with more than one PA.

From the results, it can be seen that for participant 1-ADR-ASD, function words are accented almost twice as often as his WDD peer in both the RA and S tasks (in the RA task 64.86% vs. 35.14% and in the S task, 62.55% vs. 24.71%). Moreover, the most pronounced difference is that the participant 1-ADR-ASD produced a higher percentage of words with more than one PA in a
word (RA: 14.89%, S: 16.49%), while his WDD peer hardly ever adds more than one PA in a word (RA: 2.13%, S: 1.79%). These results are illustrated in the example (3).

Example (3):

This example is a sentence from the RA elicitation task: yom `exad yac'a `orit lesaxeke ba-xacer lefet'a ra'ata kadur Qatan umuzar munax ba-gina. (Translation: One day Orit went to play in the yard and suddenly saw a small, strange ball in the garden). In this example, the subject (1a below) produced the sentence with three IUs. Every word has a PA. FW are emphasized with a PA as well as a CW. The words /baxacer/ (yard) and /qatan/ (small) have two PAs each. In contrast, the matched pair (1b below) produced the same sentence with only two IUs. Not every word has a PA and none of the words has more than one PA.

(3a) 1-ADR-ASD:

<table>
<thead>
<tr>
<th>IU-1: /yom`exad</th>
<th>yac'a</th>
<th>`Orit</th>
<th>lesaxeke</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloss: day</td>
<td>one</td>
<td>to go out</td>
<td>(name)</td>
</tr>
<tr>
<td>FW</td>
<td>CW</td>
<td>CW</td>
<td>CW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IU-2: /ba-xacer/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloss: in+yard</td>
</tr>
<tr>
<td>FW+CW</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IU-3: /lefet'a</th>
<th>ra`ata</th>
<th>Kadur</th>
<th>qa-Tan</th>
<th>umuzar</th>
<th>munax</th>
<th>ba-gina</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gloss: suddenly</td>
<td>to see</td>
<td>ball</td>
<td>small</td>
<td>and+strange</td>
<td>placed</td>
<td>in+garden</td>
</tr>
<tr>
<td>FW</td>
<td>CW</td>
<td>CW</td>
<td>CW</td>
<td>FW+CW</td>
<td>CW</td>
<td>FW+CW</td>
</tr>
</tbody>
</table>

(3b) 11-AVY-WDD:

<table>
<thead>
<tr>
<th>IU-1: /yom `exad</th>
<th>yac'a</th>
<th>`Orit</th>
<th>lesaxeke</th>
<th>ba-xacer/</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>IU-2: /lefet'a</th>
<th>ra`ata</th>
<th>kadur</th>
<th>qatan</th>
<th>umuzar</th>
<th>munax</th>
<th>ba-gina/</th>
</tr>
</thead>
</table>

### 6.3.3 Boundary tones and the edge of the IU

#### 6.3.3.1 Boundary tones

This section presents the investigation of the boundary tones. Two variables were defined (and extracted from PRAAT script "PrintTONEtier.PRAAT") in order to examine whether there is a difference between a boundary tone at the END of a complete sentence or utterance, and a boundary tone at the end of IUs WITHIN the sentence or utterance. The variables quantify the:

(a) Low-final boundary tones at the END of an utterance or a sentence,

(b) Low-final boundary tones at the end of IUs WITHIN an utterance or a sentence.
Group B WDD participants produced more low-final boundary tones at the END of a sentence (RA: 96.13%) or an utterance (S: 77.04%), than WITHIN the sentences or utterances (RA: 63.19%, S: 64.53%). There is also a clear difference between the two elicitation tasks. There are far more low-final boundary tones at the END of an RA sentence (96.13%) than at the END of an S utterance (77.04%). The results are presented in Table 22.

Table 22: Low-final boundary tones

<table>
<thead>
<tr>
<th></th>
<th>Group B</th>
<th>Group A</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RA L%BT SD</td>
<td>S L%BT SD</td>
</tr>
<tr>
<td>END of utterance</td>
<td>96.13 6.46</td>
<td>77.04 9.98</td>
</tr>
<tr>
<td>WITHIN utterance</td>
<td>63.19 13.95</td>
<td>64.53 10.92</td>
</tr>
<tr>
<td></td>
<td>80.45 18.32</td>
<td>80.00 16.65</td>
</tr>
</tbody>
</table>

L%BT = low-final boundary tone

In contrast, group A does not exhibit a difference between the two elicitation tasks and produces the same quantity of low-final boundary tones at the END of sentences (80.45%) or utterances (80%). These results are statistically significant (p =0.04).

WITHIN the sentence or utterance there is no difference between group A and group B, although group A produced slightly more (not statistically significant) low-final boundary tones WITHIN the utterances.

The WDD participants in the WITHIN category consistently make less use of a low-final boundary tone compared with the END category. This prosodic pattern is the way that continuation is expressed in the IH language (discussed in section 5.2.2.1 on page 78 above).

It was also found that in the RA elicitation task, the WDD participants make greater use of low-final tone at the END of a sentence than at the END of an utterance in the S elicitation task. This difference indicates that the WDD participants are aware of the difference between the elicitation tasks. Unlike the S, the RA is structured, clear, and the end of a sentence is marked by a period. This may explain the high use of low-final boundary tones (96.13%) by the WDD participants.

As previously discussed in the examination of other prosodic features, the standard deviation of the results of group A is higher than of group B and points to a greater variability within the group. Figure 24 shows the low-final boundary tones of ASD-HF subjects that exhibited a dissimilar pattern. To
focus the discussion, the results of the ASD-HF subjects that exhibited a pattern similar to the WDD participants were excluded. In this examination, two fundamental differences become evident:

(a) With respect to the use of low-final boundary tone, some of the ASD-HF participants do not show a clear difference between the END and the WITHIN categories. This is particularly evident in subject 4-YOL-ASD and subject 10-OMG-ASD. This inflexible behavior does not take into account the different contexts in which speech is occurring.

(b) Some of the participants make greater use of low-final boundary tone WITHIN the utterance than at the END of the utterance in the S elicitation task (2-ITE-ASD, 4-YOL-ASD, 8-TOB-ASD), and in the RA elicitation task (4-YOL-ASD, 10-OMG-ASD).

Figure 24: ASD-HF subject's low-final boundary tones

<table>
<thead>
<tr>
<th></th>
<th>2-ITE</th>
<th>4-YOL</th>
<th>8-TOB</th>
<th>10-OMG</th>
</tr>
</thead>
<tbody>
<tr>
<td>END-RA</td>
<td>100.0</td>
<td>83.3</td>
<td>84.3</td>
<td>81.8</td>
</tr>
<tr>
<td>END-S</td>
<td>86.1</td>
<td>83.6</td>
<td>71.5</td>
<td>86.4</td>
</tr>
<tr>
<td>WITHIN-RA</td>
<td>75.0</td>
<td>87.5</td>
<td>64.2</td>
<td>86.2</td>
</tr>
<tr>
<td>WITHIN-S</td>
<td>95.2</td>
<td>90.9</td>
<td>86.5</td>
<td>72.7</td>
</tr>
</tbody>
</table>

END-RA=low-final boundary tone at the end of sentences in the RA elicitation task, END-S=low-final boundary tone at the end of utterances in the S elicitation task, WITHIN-RA=low-final boundary tone at the end of IUs within the sentence of the RA elicitation task i.e. all IUs excluded the last IU of the sentence, WITHIN-S=low-final boundary tone at the end of IUs within the utterance of the S elicitation task.

6.3.3.2 The edge of the intonation unit

This section presents results of the intonation contour at the edge of the intonation unit (IU) i.e. the contour pattern of the last PA adjacent to the edge tone.

In IH-ToBI, the two final boundary tones combine with the phrase
accents in four different combinations to yield one of the configuration LpL%, LpH%, HpL% or HpH%. (For detailed explanation, see section 5.2.1.4.4 on page 75 above). Of the five IH PAs, the last PA is grouped into H* (for H*, L+H*, and H*+L) and L* (for L* and L*+H). Therefore, the last PA of an IU and the adjacent edge tone provides eight different contour patterns at the edge of the IU.

The following two sentences illustrate this prosodic feature of the edge of the IU.

Example (4):

Word tier: / ra'ã  'et ha- qadur /
Tone tier: % L+Hi* H*+L L*+H HpH%
Break Indices: B 4
Gloss: to see the ball
Translation: Saw the ball

Example (5):

Word tier: / ca'ax  `aba /
Tone tier: % L* H* LpH%
Break Indices: B 4
Gloss: to laugh Dad
Translation: Dad laughed

These two examples are taken from the sample of the 6-BAB-ASD-RA subject. In example (4) the edge of the IU contour pattern is L*HpH% (the L*+H PA + the Hp phrase accent + the H% boundary tone). In example (5) the edge of the IU contour pattern is H*LpH%.

6.3.3.2.1 Group comparison

Table 23 present the results of the comparison between the edge of the IU contour patterns of the S elicitation task of groups A and B.
Subjects of group A use certain contour patterns more frequently (H*LpL%, L*LpL%) than group B, and use certain other contour patterns less frequently (H*HpH%, \( p=0.063 \), L*HpH%, \( p=0.094 \)). These differences are not statistically significant. However, the contour patterns that are more frequently used by group A are also used more frequently by group B. The same can be said for the least frequently occurring patterns.

In the low-final edge contour patterns, the most frequently occurring pattern for both groups is H*LpL%. While the second most frequently occurring pattern in group B is L*LpL%, in group A the second most frequently occurring pattern is H*HpL% which supports the finding (in section 6.3.2 above) that ASD-HF children make more frequent use of H* (high pitch accent).

In the high-final edge contour patterns, the most frequently occurring pattern for group B is H*HpH% while for group A it is H*LpH%.

In the RA elicitation task, presented in Table 24 below, no statistical significance was found and the order of the use of the different edge contour patterns is the same for both groups.
Table 24: Rank of edge-distribution in the RA elicitation task

<table>
<thead>
<tr>
<th></th>
<th>Group A (n=9)</th>
<th></th>
<th>Group B (n=9)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>%</td>
<td>SD</td>
<td></td>
<td>%</td>
</tr>
<tr>
<td>1</td>
<td>H*LpL%</td>
<td>36.9</td>
<td>15.2</td>
<td>H*LpL%</td>
</tr>
<tr>
<td>2</td>
<td>L*LpL%</td>
<td>15.6</td>
<td>11.1</td>
<td>L*LpL%</td>
</tr>
<tr>
<td>3</td>
<td>H*HpL%</td>
<td>12.6</td>
<td>10.3</td>
<td>H*HpL%</td>
</tr>
<tr>
<td>4</td>
<td>H*LpH%</td>
<td>11.7</td>
<td>10.3</td>
<td>H*LpH%</td>
</tr>
<tr>
<td>5</td>
<td>L*HpL%</td>
<td>9.6</td>
<td>3.8</td>
<td>L*HpL%</td>
</tr>
<tr>
<td>6</td>
<td>L*LpH%</td>
<td>6.8</td>
<td>8.7</td>
<td>L*LpH%</td>
</tr>
<tr>
<td>7</td>
<td>H*HpH%</td>
<td>5.3</td>
<td>6.9</td>
<td>H*HpH%</td>
</tr>
<tr>
<td>8</td>
<td>L*HpH%</td>
<td>1.5</td>
<td>3.4</td>
<td>L*HpH%</td>
</tr>
</tbody>
</table>

6.3.3.2.2 Peer comparison

A variation in the distribution of edge contour patterns arises when comparing the edge contours of the matched peers within the groups.

Although in a group comparison the ASD-HF subjects made use of the different patterns in a similar manner to the WDD participants, that is not the case when a comparison is made between peers. Subjects of group A may be divided into two sub-groups:

(a) Four of the subjects produced a full repertoire of edge contour patterns, similar to the control group. Figure 25 is an example of the full repertoire prosodic behavior by the ASD-HF subject ETR in the S elicitation task.

(b) Of the nine matched peers, in the S elicitation task five of the subjects produced a varied limited repeatedly used repertoire of the edge contour patterns (3-UDX-ASD, 4-YOL-ASD, 6-BAB-ASD, 8-TOB-ASD, and 9-NOR-ASD). In the RA elicitation task, only two of these subjects showed this limited use (3-UDX-ASD, 8-TOB-ASD). Figure 26 presents the distribution of the edge contour patterns of the two subjects in the RA elicitation task and Figure 27 presents the results of the five subjects in the S elicitation task.
Figure 25: Full repertoire of edge contour patterns
This figure shows the comparison between the edge contour patterns of 7-ETR-ASD, age: (12:5) and his matched peer LIS-WDD, age: (12:3) in the S task. The ASD-HF subject uses the same patterns as his peer and has the full repertoire of edge contour patterns.

Figure 26: Limited repeatedly used repertoire in the RA elicitation task
Figure 27: Limited repeatedly used repertoire in the S elicitation task

- 3-UDX-ASD vs. 13-IDR-WDD
- 4-YOL-ASD vs. 14-YVO-WDD
- 6-BAB-ASD vs. 16-AVS-WDD

- 8-TO8-ASD vs. 18-IDW-WDD
- 9-NOR-ASD vs. 19-OMX-WDD

ASD-HF vs. WDD PROSODIC FEATURES
In addition to the limited use of edge contour patterns, the degree of restriction differs from subject to subject, and even in the same subject, between the two elicitations e.g. 3-UDX-ASD. Two examples from Figure 26 and Figure 27 will now be highlighted.

The first example demonstrates the restricted use of edge contour patterns. In the S speech sample of subject 4-YOL-ASD, the two most frequent edge contours (H*LpL%, H*HpL%) comprise 72.34% of all the edge contour patterns, while his peer (14-YVO-WDD) used four different edge contours for a similar frequency of edge contour patterns (71.46%). The two most frequent edge contour patterns of this matched peer comprised only 46.80% of the edge pattern repertoire.

The next example may provide a partial explanation of why the restricted use is not evident when the comparison is examined by group. Even though the group makes use of the full repertoire of edge contour patterns this is not true of the individual subjects. Subject 6-BAB-ASD used the H*LpL% and the L*LpL% as the two most frequent edge contours and they comprised 66.95% of the different patterns used, while the L*LpL% edge contour is not often used by other subjects (e.g. 4-YOL-ASD described above).

The most noticeable prosodic behavioral pattern in the matched peers comparison is that each of the subjects produced two to three patterns much more frequently than the WDD peer who used more patterns, and that the appearance of all the other edge patterns was much reduced.

### 6.3.4 Different elicitation tasks

This section summarizes the results of the analysis in order to focus on the third research question: Do the different elicitation tasks influence the prosodic features of intonation of ASD-HF and WDD children and if so, in what way? The prosodic features of intonation in the RA and S elicitation tasks of the subject group will be summarized and compared.

(a) In the RA elicitation task, the subjects produced a slightly higher ratio of IUs per utterance as compared with the S elicitation task. Similarly, they produced a higher percentage of intermediate phrases as
compared with the S elicitation task.

(b) In S speech, the number of subjects that produced more PAs is larger by one than the number of subjects that produced more PAs in the RA elicitation task (7/9 vs. 6/9).

(c) The subjects that produced the higher and atypical PAs/W (i.e. PAs/W > 1) showed similar characteristics in both elicitation tasks, except for one subject (6-BAB-ASD) where the high PAs/W occurred only in the S elicitation task.

(d) While WDD participants showed a significant difference in frequency of occurrence of low-boundary tones at the end of an utterance as compared to the frequency of occurrence within the utterance, this is not evident in the subject group. The subjects showed a similar frequency of occurrence of low-boundary tones at the end of an utterance in both elicitation tasks. The frequency of occurrence of low-boundary tones within the utterance was not consistent in the subject group. Certain subjects had more final low-boundary tones within the utterance rather than at the end of the utterance. This is especially remarkable because the WDD participants showed consistent behavior both in the differences between the elicitation tasks and in the position of the low-boundary tones.

(e) A greater number of subjects showed a limited, repeatedly used repertoire of edge tones in the S elicitation task (5/9) when compared with the RA elicitation task (2/9). These two subjects showed the limited, repeatedly used repertoire in both elicitation tasks.

From the results, it is possible to conclude that the differences in the realization of prosodic features in the elicitation tasks arise when there is no atypical prosody. As opposed to that, ASD-HF subjects with atypical prosody present the same type of atypicality in the realization of prosodic features in both elicitation tasks. This atypicality is more pronounced in the S elicitation task.
6.3.5 Summary of results

The description of the intonation patterns presented in this chapter is based on extracting linguistic information from the measurable physical data of F0. It was noticeable that there is inter- and intra-participant variability in both groups. However, within group A this variability is greater and more pronounced. Nevertheless, the availability of the comparable data derived from the analysis, allows for the extraction the specific prosodic behavior of some of the ASD-HF subjects. The importance of this will be discussed in Chapter 7.

No significant statistical differences were found between the groups in either the F0 or PR values, due to the higher Standard Deviation present in group A. However, an investigation of the participants within the groups shows no difference in the use of low F0 but a different use of the high F0 values. In the ASD-HF subjects, the maximum F0 of an IU might be lower or much higher, compared with participants in group B. This high F0 value might sound strident to the listener. Three types of PR were found within the ASD-HF subjects: Typical PR (TPR), Narrow PR (NPR), and Wide PR (WPR).

Subjects in group A produced more IUs per utterance in both the RA and S elicitation tasks but without statistical significance. A comparison of matched peers shows that in the RA task eight of the nine and in the S task, five of nine ASD-HF subjects produced more IUs per utterance as compare with their peers.

Group A produced more IUs with intermediate phrases than group B. In group B there is no difference between the two elicitation while in group A, subjects produced more IUs with intermediate phrases in the S task in comparison with the RA elicitation task.

Group A produced more high PAs than group B in both the RA and S elicitation tasks but without statistical significance. In a comparison of peers within the groups, in seven of the nine matched peers, the ASD-HF participant showed a greater use of high PAs in the S task and in five matched peers, the ASD-HF participant shows a greater use of high PAs in the RA task. There is no significant difference in the frequency of occurrence of the different types of PA being compared, but a small preponderance in the occurrence of the
L+H* within the ASD-HF subjects. This may indicate a minor delay in the development use of PAs by ASD-HF subjects.

Concerning the PA prosodic feature, the most prominent results deal with PAs/W and placement of PAs. In the case investigation of a subject that produced more PAs/W (1-ADR-ASD), it was evident that this subject produced more PAs in function words than his peer did, and in particular more than one PA per word.

Examination of boundary tones in relation to the elicitation tasks shows significant differences and greater variability within group A. Unlike the WDD participants, there is no clear discrimination between the low-final boundary tones of the END and the WITHIN categories. This is a stiff behavior, and demonstrates unawareness of the context in which speech is occurring.

The subject group uses certain edge contour patterns more frequently and other edge contour patterns less frequently than the control group. Subjects of group A may be divided into two sub-groups: subjects that make use of a full repertoire of edge contour patterns and subjects that make use of a limited repeatedly used repertoire that varied between individuals, and between elicitations of the same individual.

The results indicate there is no doubt that the peer matched comparison and the comparison within subject group, lead to a better understanding of the nature of the prosodic behavior of children with ASD-HF. Table 24 summarizes the area of a-typicality in the analysis of the prosodic features of ASD-HF subjects compare to their matched WDD peers.
Table 25: Area of atypicality in subjects’ prosodic features
This table summarizes the atypicality in the prosody of the ASD-HF subjects. Moderate atypicality is marked by + and severe atypicality is marked by x. The atypicalities are defined as follows:
For IU/ U:  The difference between the peers is higher than the SD of the group (RA task = IU/U >0.04, S task= IU/U >0.224).
For ip: The difference between the peers is higher than the SD of the group (RA task= ip/U>3.53, S task= ip/U>2.59).
For high PA: The percentage of high frequency PAs is higher than both the mean of the group and the percentage of high frequency PAs of the peer (RA task= PA>77.99%, S task= PA> 77.43%).
PAs/W: The ratio of PA/W is higher than that of the peer. When the PA/W>1 it is marked by x.
For BT (E/W): The percentage of frequency of occurrence of the END and the WITHIN category is not higher than the SD of the END category (7.766) or when the WITHIN category is higher than the END category.
For BT (RA/S): There is no difference in the frequency of the low-final boundary tone between the RA and the S elicitation tasks (less than the average SD=12.519).
For ET: The subject produced limited repeatedly used repertoire of the edge contour patterns.

<table>
<thead>
<tr>
<th>Subject</th>
<th>PR</th>
<th>Phrasing &amp; Segmentation</th>
<th>Pitch Accents</th>
<th>BT</th>
<th>ET</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NPR</td>
<td>WPR</td>
<td>IU/U</td>
<td>ip</td>
<td>high PA</td>
</tr>
<tr>
<td>1-ADR</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>2-ITE</td>
<td>+</td>
<td></td>
<td>+</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>3-UDX</td>
<td>+</td>
<td>+</td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>4-YOL</td>
<td>+</td>
<td></td>
<td>x</td>
<td>x</td>
<td>+</td>
</tr>
<tr>
<td>5-RAE</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>6-BAB</td>
<td>+</td>
<td></td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>7-ETR</td>
<td>+</td>
<td></td>
<td>+</td>
<td>+</td>
<td>x</td>
</tr>
<tr>
<td>8-TOB</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9-NOR</td>
<td>+</td>
<td>+</td>
<td>x</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10OMG</td>
<td>+</td>
<td>+</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

PR=Pitch Range, NPR=narrow pitch range, WPR= wide pitch range, IU/U= Intonation Unit per utterance, PAs=Pitch Accents, BT=Boundary tones, ET= Edge tones.

This summary of the findings indicates that each of the subjects exhibits one or more atypical prosodic features. Certain prosodic features are more likely to have atypical behavior and these are the pitch range, the segmentation within the IU into intermediate phrases (in particular in spontaneous speech), the prominence of a word (PAs), and the presence of an edge of an IU in spontaneous speech. However, the degree of the atypical
behavior, and the type and number of prosodic features that are atypical, varies from individual to individual.

In the next chapter, the results will be explained within the context of the PHB theory.
CHAPTER 7: PHONOLOGY AS HUMAN BEHAVIOUR (PHB) - A FRAMEWORK FOR THE DISCUSSION OF THE PROSODIC FEATURES OF THE SPEECH OF CHILDREN WITH ASD-HF

"The ultimate task of phonology is to discover the cause of the behavior of speech sounds. To do this phonologists must refer to the way speech is created and used by human beings..."


The primary contribution of the theory of Phonology as Human Behavior (PHB) is that it provides a motivation and an explanation for the nonrandom distribution of phonemes within the speech signal in language (e.g. Diver 1979, 1995, Davis 1987, and Tobin 1997). In this study, the PHB theory is used as a way to observe, and provides a motivation and explanation for the nonrandom distribution of the prosodic features produced by ASD-HF subjects, i.e. to explain why the distribution of the distinct prosodic features for this particular population is not randomly motivated.

The chapter introduces the theoretical background of the PHB theory and summarizes the basic theoretical and methodological principles with an application to the current study. The discussion of the research findings, is conducted within this functionally oriented theory, and highlights new insights into the prosodic behavior of individuals with ASD-HF.

7.1 The theory of Phonology as Human Behavior (PHB)

In contrast to the Nativism approach premise that the mind of a newborn child is equipped with an internal structure (innate) of linguistic knowledge, the non-Nativistic approaches refer to language as a system that interacts with other physiological, cognitive and behavioral systems. PHB is one of the theories that explain the acquisition of the phonology of the first language within the Nativistic approach but without relying on the innate ability.
The theory of PHB was introduced by William Diver (1979) as a part of a larger, functionalist neo-Saussurean sign-based theory of language first called Form-Content Analysis (FCA) and later the Columbia School.

PHB may be viewed as part of the historical development of a larger twentieth century structural, functional, cognitive, and naturalistic approach to linguistics. This tradition began with Ferdinand de Saussure’s (1916/1972 as cited in Tobin 1988, 1997) concept of system and the dichotomies of *langue* and *parole*, and phonetics versus phonology, based on a classification of sounds according to their articulatory and acoustic features. The dichotomy between the abstract code and its concrete realization based on distinctive features that create communication oppositions, was further developed by Trubetzkoy (1939) and Jakobson (1941) of the communication-oriented Prague School (Tobin 1988, 1997).

The strict opposition-based communication factor adhered to by the Prague School was further supplemented by the introduction of the human factor to phonology through the concepts of “asymmetry” and “economy of effort in phonological change” by Martinet (1995, in Tobin 1988, 1997). Martinet maintained that phonological systems are arranged asymmetrically and change in such a way that their nonrandom diachronic distribution reflects the search for equilibrium and harmony within the system as it is affected by the principle of least effort in human behavior. This principle of minimal effort postulated by Martinet implies that speakers strive for a minimal number of distinct phonemes, thus requiring the least amount of effort.

However, Diver (1979) has shown that a more complete theory of phonology has to take into account both the communication factor and the human factor. Diver maintains that there is a constant struggle between the need for maximum communication and the desire for minimal effort – later referred to as “language synergy” (Tobin 1990). The communication factor (requiring a large number of maximally distinct linguistic units which demands a great deal of effort) will be in conflict with the human factor (striving for minimal effort) resulting in a synergetic trade-off between the two (Tobin 1988, 1997).

Tobin (e.g. 1997, 2009a, b) clarifies that every linguistic or phonological analysis is the direct result of a specific set of the theoretical and
methodological assumptions, which are related to how the linguist:

1. defines language and the sound system of language,
2. defines a linguistic or phonological problem,
3. determines the source, kind and amount of data to be selected and analyzed,
4. chooses a methodology to select and analyze the data,
5. evaluates, compares and contrasts analyses in light of all of the above.

These assumptions will be presented in the next few paragraphs with an application to the theory of PHB and to prosody in general, and to the prosodic feature examined in the current research in particular.

7.1.1 Language and the sound system of language

The semiotic definition of language as a system of systems used by human beings to communicate was clarified in the section on theoretical background (section 2.2.2.1 on page 27 above). This definition has been subsequently simplified:

“language is seen as a symbolic tool whose structure is shaped both by its communicative function and by the characteristics of its users”

(Tobin 2008, 2009).

This definition highlights the differences between the sign-oriented versus the sentence-oriented generative paradigm and in this current discussion allows the prosodic features to be explained both theoretically and methodologically. The holistic Saussurean sign (signe linguistique) combining a signal (significant) and an invariant meaning (signifié) is the main unit of analysis, rather than the sentence and its component parts. In prosody, the acoustic parameters combining the distinct prosodic features can form the units of analysis, e.g. intonation unit, pitch accents, boundary tones, and edge tones.

Columbia School theory does not distinguish between “deep” or “underlying” and “surface” forms, concentrating on actual language use only.
In sentence-oriented terms, this implies that the theory does not employ derivations composed of formal rules or other constraints. In prosody, the distribution of the various prosodic units represents the actual distinct prosodic features used in the language.

Columbia School theory does not recognize a dichotic distinction between grammar and lexicon but rather views them as a continuum. In prosody for example, the division of an utterance into IUs and intermediate phrases is strongly related to both grammar of tone (Pierrehumbert 1980) and the semantic-pragmatic function of prosody. Furthermore, the division into IUs demonstrates that the "whole is greater than the sum of its individual parts", adding to and motivated by the synergistic definition of language in general and the theories of CS and PHB in particular.

Columbia School theory concentrates on language-specific analyses rather than the more formal sentence-oriented concept of universal grammar. Methodologically, this study makes use of speech samples in different elicitation tasks, comparing and contrasting the "language-specific" behavior of WDD participants and subjects diagnosed with ASD-HF.

7.1.2 A linguistic or phonological problem

In Chapter 1, the dissertation begins with the section named "Statement of the problem". There, the linguistic problem of the prosody of ASD-HF children was determined first by the "users" of the language who nicknamed themselves according to their own understanding of how their speech sounds: "Robotic speech", "Miss monotone", "relatively flat", "louder", "less intonation", "kinda sing-song", and then as a reflection by the researcher with the general term found in the literature: "Atypical prosody".

7.1.3 Determines the source and chooses a methodology

The researcher met the "users" of the language: the WDD children and the children diagnosed with ASD-HF, in their homes. Since the environment might affect the language produced, it was important to conduct the data collection
sessions in the participant’s natural environment. Participants produced speech samples relevant to their daily life. Methodologically, the nonrandom distribution within each of the prosodic units was compared and contrasted between the two groups of participants and within each group of participants.

7.1.4 Evaluates, compares and contrasts analyses

There are four orientations associated with the theory of PHB:

(a) the communication factor,

(b) the physiology of the vocal tract,

(c) the acoustic medium,

(d) the human factor.

The "physiology of the vocal tract" is related to how human beings learn to control specific musculature in order to produce phonemes by altering the airstream. The acoustic medium refers to the way in which human beings perceive these articulated phonemes. In prosody, the "physiology of the vocal tract" refers to the way human beings learn to control specific musculature in the production of distinctive prosodic features and their combinations e.g. high PA (H*) versus low PA (L*), low-final boundary tone (L%) versus high-final boundary tone (H%), and the edge of intonation contour pattern e.g. L+H*LpH%. Within the context of the present research group - subjects with ASD-HF - there is no clear evidence of a disruption of motor speech control. Therefore, the discussion will concentrate on the communication factor and the human factor.

The "communication factor" for the theory of PHB may be summarized as "the systematic and nonrandom combination of distinctive phonological units to create meaningful oppositions in linguistic signs of all sizes and levels of abstractness" (Tobin 2009a:87). In this study of the prosodic domain, the abstract units are the IUs, the intermediate phrases, the pitch accents, the boundary tones, and the edge tones.

The "human factor" includes: (a) human intelligence, (b) human economy and efficiency i.e. that human beings invest just enough effort to
perceive only those distinctive articulatory, acoustic and prosodic features necessary for communication, and (c) limitations of memory.

PHB supports the idea that there is a dynamic interplay between the "communication factor" and the "human factor". This synergetic interaction between the communication factor and the human factor can be seen as a "mini–max" struggle - the desire to create "maximum communication with minimal effort" and the trade-off between the human and the communication factors in language related to the opposing roles and needs of encoders and decoders (Tobin 1997:195). The more cooperation there is between the encoder and the decoder - within the appropriate linguistic and situational contexts of the speech act - the greater the chance for successful communication (Tobin 1990:59). This fundamental mini-max principle is not limited to phonetics/phonology only but is fundamental to language in general (Tobin 1990).

This motto of the PHB theory has served to explain the nonrandom distribution of phoneme systems within and across more than 42 different languages (Diver 1979, Davis 1987, Tobin 1997, 2002b, 2009). Further, PHB theory has been applied to other areas such as the developmental and clinical phonology (e.g. Tobin 1997,1999, Miyakoda 2002, Tobin and Miyakoda 2004, 2006), bilingual Hebrew-English language acquisition (Gan et al. 1996), Israeli Sign Language (Fuks and Tobin 2008), historical, psycholinguistic and sociolinguistic issues (e.g. Contini-Morava et al. 2004, Davis et al. 2006, Reid et al. 2000, Tobin 1993, 1997, 2004), a client decision-making model in a therapeutic situation (Paltiel-Gedalyvich 2009), and to prosody (Enbe 2003, Enbe and Tobin 2007, Green 2005, 2009a, Green and Tobin 2008a, b, 2009, b, c).

According to Tobin (1997), functional processes that reach the speech clinic clearly reflect an extreme case of the struggle for maximum communication with minimal effort. The simultaneous coexistence of several functional and/or idiosyncratic processes of simplification (the human factor) reduce the number of communicative distinctions (the communication factor) exploited by the speaker. Tobin (2009) summarizes the major principles of PHB for phonological analysis and its applications to developmental and clinical phonology:
(1) We begin with the phonetic observations, articulatory and acoustic, within which there are no observable units (child language inventory and clinical intake).

(2) By means of the communication orientation, we can establish the number of distinctive units of a language (as found in a child or patient).

(3) Consideration of the acoustic and physiological characteristics of the units (and the ones found in a child and patient) suggests a variety of characterizations.

(4) In choosing among these characterizations, it is apparent that the characteristics of the units must be of such a kind that the human user can learn them (both in normal developmental and pathological language acquisition).

(5) We do not know in advance, deductively, in exactly what way the human factor will interact with the communication and other factors.

(6) Phonotactic skewing in language (diachronic and synchronic) and in developmental and pathological data reflect the learning process of the speakers (including children and clinical patients).

(7) This skewing viewed consistently with the human factor against the background of the other factors of communication, acoustics and physiology informs us of the characteristics we are confronted by.

(8) Phonology is not random but motivated: the frequencies of the phonological units and the ways they combine are determined both by their phonetic make up and by the speaker's (child's or patient's) exploitation of or coping with that make up in the act of communication.

(9) Gestures enhancing communicative distinctiveness are favored and more difficult articulatory gestures are disfavored.

(10) There is a conflict between the communication and the human factors in the search for maximum
communication with minimal effort in the diachronic development of a language and its current synchronic state.

(11) This conflict is even more keenly felt in language acquisition where functional errors and processes may be observed and even more so in the clinic where developmental and pathological errors and processes show an even more extreme conflict between the communication and human factors.

(12) The theory of PHB can explain the connection and interrelationship between the phylogeny, ontogeny and pathology of the development of sound systems in human language in a principled way.

(Tobin 2009:95)

### 7.2 Exploring the prosody as human behavior

Chapter 6 above presents the results in terms of the distribution of the prosodic features that were examined. This current chapter is an attempt to explain the nonrandom distribution of the prosodic features found in the WDD participants and to compare and contrast them with the nonrandom distribution of the prosodic feature of the ASD-HF subjects according to the orientation of the PHB theory.

#### 7.2.1 The human factor

As noted in the theoretical background, the three essential criteria for diagnosing autism include: (a) qualitative impairments in social reciprocity and engagement, (b) delays and deficits in language and communication, and (c) the presence of restricted repetitive and stereotyped behaviors, activities, or interests (APA 1994, Wing and Gould 1979) and therefore ASD is a behaviorally defined disorder. Since the human factor in communication is also behavioral, the ASD defining characteristics can be seen as being synonymous with the idiosyncratic process of the individuals in the communication process.
In order to explore the relationship between the human factor and the atypical prosodic features found in the subjects, two main issues will be discussed: (a) the "wide variety" within the ASD population and (b) the restricted, repetitive behavior.

### 7.2.1.1 "A wide variety" or group versus individuals

The term "spectrum" in Autism Spectrum Disorder indicates the variation in the observable characteristics within the population. This heterogeneity, together with strong indications of hereditability (e.g. Baily et al. 1996, Frith 2004, Happe' and Frith 1996a) has led to a discussion as to whether this variation is associated with either distinct subtypes with quite different clinical symptoms (e.g. Volkmar et al. 1997, Fein et al. 1999), or a clinical variability, as a result of a gradient in the overall severity (e.g. Beglinger and Smith 2001, Sigman and McGovern 2005, Ring et al. 2008).

One of the major findings of this research was the "no statistical significance" in the group comparison, explained by the high standard deviation within the research group. This high standard deviation points to a pronounced variation in the subjects' performance. Beglinger (2001) emphasizes that the heterogeneity within individuals diagnosed with ASD is evident and substantial in various different functional aspects e.g. level of functioning, course of development, response to treatment, etc. He notes that this heterogeneity is largely ignored by the DSM-IV and ICD-10, the two primary tools for classification of autism. For example, while most children with ASD have a stable course with only minimal fluctuations in symptoms (Volkmar et al. 1997), some show less severe symptoms with age (Folstein et al. 1998, Seltzer et al. 2003) while others deteriorate during adolescence (APA 1994, Gillberg 1992).

Previous research into prosody in ASD (e.g. Balataxe 1984, Paul et al. 2005) has also found variation in performance. The authors found that not all subjects perform with deviant prosody but each research examined only a single feature of prosody. The current study found that all subjects present differences in prosody as compared with their peers; not all subjects show
differences in all features examined, but every subject shows at least one feature differently.

The characteristic of heterogeneity within the ASD classification has methodological implications for research procedure. In this research, it was the aggregation of peer comparisons that lead to the exploration of the prosodic behavioral features in the group of subjects diagnosed with ASD-HF.

7.2.1.2 Restricted repetitive behaviors

Restricted repetitive behavior has been a defining feature of the autistic disorder since the original description of autism (Kanner 1943), and a wide range of specific forms of abnormal repetition have been identified and described (e.g. APA 1994, Kanner 1943, Rutter 1996, Lewis and Bodfish 1998, Turner 1999, Bodfish et al. 2000, Szatmari et al. 2006, Richler et al. 2007). The restricted repetitive behavior can be observed across individuals with ASD, and multiple categories of abnormal repetition can occur within the individual with autism (Wing and Gould 1979). These behaviors can be socially inappropriate and stigmatizing (Varni et al. 1979).

Turner (1997) proposed a taxonomy of repetitive behavior, consisting of eleven categories and in a later review (Turner 1999) suggested that human repetitive behaviors can be divided into (a) lower-level and (b) higher-level categories. Lower-level repetitive behaviors include dyskinesia (involuntary, repetitive movements), tics, repetitive manipulation of objects, repetitive forms of self-injurious behavior and stereotyped movements. Turner's review indicates that although some stereotyped movements and repetitive manipulation of objects might be differentiating features of autism, there are some lower-level repetitive behaviors that may rather be related to ability level or the presence of organic pathology (e.g. Fecteau et al. 2003, Bodfish et al. 2000, Lam and Aman 2007, Esbensen et al. 2009).

The high-level repetitive behaviors include circumscribed interests, attachments to objects, insistence on maintenance of sameness and repetitive language. Turner (1999) suggested that certain types of higher-level behavior may be characteristic of and restricted to individuals with ASD once a certain
level of development has been achieved.

Combining Turner’s category of repetition in language as part of the ASD determining high-level repetitions with the parallels found in this research between the prosodic and lexical behaviors, repetitive prosody and lexical repetition can also be included in the high-level category of restricted repetitive behavior.

Example (6) below illustrates the parallels found between the lexical domain and the prosodic domain of one subject.

Example (6):

(a) The following is an example of the lexical repetition found in the semi-spontaneous speech of BAB-ASD (age 11:11) regarding his “interest” (hitanyenut) in the “sciences” (mada’im). The data are taken from the same short conversation:

U3: [ ani mi# hahit’anyenut sheli be’ika(r) mada’im ]
   I from my INTEREST ESPECIALLY LIKE SCIENCE

U4: [ hit’anyenti bemada’im kvar begil ca’r ]
   I was INTERESTED in SCIENCE since I was young

U5: [ meod ahavti mada’im ]
   I LIKED very much SCIENCE

U6: [mada’im # shama’ati shemada’im # ze ha’olam shemisvivenu] SCIENCE—I heard that SCIENCE is the world around us

U13: [ ani ohev et kol hamikco’ot aval be’iqar mada’im ]
   I LIKE all the subjects BUT ESPECIALLY SCIENCE

U14: [ be’iqar mada’im ]
   ESPECIALLY SCIENCE

U15: [ ani yoter beqeTa shel mada’im ]
   I am more into SCIENCE

(b) In addition to the lexical repetition presented above, this subject exhibited repetition behaviors in the prosodic domain. He produced more than one PA/W and in particular, a limited, repeatedly used repertoire of edge tones (see Figure 27 on page 107 above). The repetitive behavior of the prosodic features is more pronounced in the S elicitation task.

The parallels between the prosodic and lexical domains and the defining restricted repetitive behavior of ASD suggest that linguistic behavior of the prosodic features appears in the same manner as other behaviors i.e. linguistic and non-linguistic. A reasonable assumption would be that lexical
repetition may also appear in the same manner but this is a question that requires further research.

7.2.2 Functional processes influencing prosodic features

In order to achieve "maximum communication with minimal effort", individuals with ASD-HF use functional processes (the communication factor) that are the manifestation of the "mini-max" struggle. This section discusses and explains the results presented in Chapter 6 within the context of a number of functional processes. These processes are:

(1) Simplification of prosodic patterns

(a) ASD-HF subjects produced more IUs per utterance.
(b) ASD-HF subjects produced more intermediate phrases within the IUs and in particular in the S elicitation task.
(c) ASD-HF subjects used certain edge contour patterns more frequently and other edge contour patterns less frequently. The nonrandom distribution of these most frequent edge contour patterns by the WDD participants indicates that these might be the easiest to use.

Explanation: Communication is a complex and effort-intensive process, and even more so for individuals with ASD. Breaking the utterance into more IUs, and the IUs into more intermediate phrases, makes these basic units simpler to produce. While this simplification minimizes the effort, it almost certainly interferes with the necessary equilibrium between the human and communication factors and causes the speech to sound "different".

(2) Reduction of prosodic patterns

(d) ASD-HF subjects reduced the high-final edge contour pattern that signals continuation within an utterance.

Explanation: In Israeli Hebrew there are three most frequent patterns for signaling continuation within an utterance (LpH%, HpH%, and HpL%. See section 5.2.2.1 on page 78). The high-final continuation rise edge contour pattern requires greater effort than the low-final edge contour pattern and is
reduced and replaced with the HpL% in order to achieve maximum communication.

(e) ASD-HF subjects limit their repertoire of distinct edge tone patterns that are in use by their WDD peers.

Explanation: In Israeli Hebrew, eight different edge contour patterns are possible at the end of IU. The limited patterns used by ASD-HF subjects includes both the final-rise and the final-low distinction, which create sufficient communication oppositions while decreasing the effort.

(3) **Duplication and repetition of prosodic patterns**

(f) ASD-HF subjects produced more high PAs.

Explanation: the duplication often is a way to avoid more difficult prosodic patterns such as the L* pitch accent and the bi-tonal L*+H pitch accent.

(g) ASD-HF subjects produced more PAs/W.

Explanation: The ASD-HF subject may sense that accented words are more readily understood and they are aware that they talk "differently", so they may be putting more effort into producing those accented words that deliver more communicative, perceptual and cognitive information to be sure that they are being maximally understood.

(h) ASD-HF subjects produced repeatedly used edge tones.

Explanation: This is an outcome of the reduced repertoire of patterns and of the inherent repetitive behavior of individuals diagnosed with ASD. This behavior is consistent with the "minimal effort" by including those patterns that are simplest to produce.

This chapter applies PHB theory to the research results. During communication, individuals with ASD-HF as defined by behavioral characteristics (the human factor), use functional process of simplification, reduction and duplication of the prosodic patterns to reduce the effort resulting in more repetitive prosodic patterns and lexical repetition which reflects their extra-linguistic behavior as well.
CHAPTER 8: SUMMARY AND CONCLUSION

8.1 Summary and conclusions

This dissertation deals with prosodic features of children diagnosed with ASD-HF who mainstreamed in regular schools.

The dissertation established methodology, which allows the analysis of more than one feature of prosody simultaneously and described, compared and contrasted the phonetic realization of the fundamental frequency and the prosodic features of intonation in the language of children with ASD-HF and children WDD.

By using recently developed speech technology tools, this dissertation presented an extensive investigation of the prosody of children with ASD-HF between the ages of 9-13 years, and provided an annotation procedure for describing the Israeli Hebrew intonation within the Autosegmental-Metrical theory and the ToBI framework (IH-ToBI).

The IH-ToBI concentrates on intonation and phrasing. It differentiates and defines two levels of phrasing: the intermediate phrase and the intonation unit, which contains one or more intermediate phrases. The prosodic transcription of intonation includes an inventory of five pitch accents, two phrase accents, and three boundary tones. This IH-ToBI annotation constitutes the basis of the description and comparison of the prosodic features of children with ASD-HF and children WDD. The inventory of the Israeli Hebrew intonation, and the annotation presented, is far from complete. However, in itself, it is an essential and important starting point for further investigation of the prosody and intonation of Israeli Hebrew.

The empirical basis of this study is drawn from the speech samples of 20 participants: 10 subjects diagnosed with ASD-HF and 10 participants WDD served as control group. The speech sample analysis yielded quantitative results, of group comparison, peer comparison and of subjects within the ASD-HF group. The peer comparison highlights the greater variations within the ASD-HF subjects, as compared with their peers and between themselves.
SUMMARY AND CONCLUSION

The results are explained within the theory of PHB and explore the functional process of simplification, reduction, and duplication that the ASD-HF subjects exhibited more extensively in the communication process, when compared with the WDD participants. Theses functional processes are manifested in the nonrandom distribution of the prosodic features.

From this study it can be concluded that not all ASD-HF subjects present an a-typicality in each of the different prosodic features examined (pitch range, phrasing and segmentation of the utterance, pitch accents, edge tones and boundary tones), but no subject performed in the same way as his WDD peer.

Pitch range (PR): the variability within the ASD-HF subjects can be subdivided into three types: Typical PR, Narrow PR, and Wide PR.

Phrasing and segmentation of the utterance into smaller units: ASD-HF subjects create more IUs in a single utterance and create more intermediate phrases within the IU.

Non-random distribution of the PAs in the ASD-HF subjects: It was found that ASD-HF subjects produce more high PAs and less low PAs. If the variations in intonation are a result of differences in the kinds of PAs and transitions between the prominent components, then when the prominence in the ASD-HF subjects exists in a more frequent single high PA and there are consequently fewer transitions, a monotonous accent is created.

Non-random distribution of the edge tones in the ASD-HF subjects: The ASD-HF subjects primarily use three different edge tone patterns, although they do make a very limited use of all the other patterns. Therefore the problem is in the pragmatic use of the patterns available to them and not in their absence due to their lack of competence to produce them. Both the monotonous accent and the repetitiveness of edge tones create a stiff sounding prosody in subjects within the ASD-HF group.

In this research, it is maintained that there is a parallel between the extra linguistic behavior (“restricted repetitive and stereotyped behaviors”) of ASD-HF subjects and their linguistic behavior, as reflected in their limited prosodic patterns and lexical repetitions. These parallels reflect the effective way that ASD-HF subjects demonstrate the motto of PHB: “Maximum Communication with minimal effort”. Although the ASD-HF subjects are
capable of producing a wide range of prosodic patterns, they choose to concentrate on a limited repertoire of the most basic prosodic patterns which create "clear-enough" communication. This may also be found in their repetition of the same lexical items which should be furthered studied.

Within communication, the form, content, and use of language are all essential components (Bloom and Lahey 1978). Aspects of each of these three dimensions of language were described more fully in the Theoretical Background. It was noted that certain domains of language function are selectively impaired, in particular the pragmatic use of the language. The appropriate use of language within social and situational contexts is defined as pragmatics. Landa (2005) attributes pragmatic language use to a broad array of social linguistic skills and hence, pragmatic difficulties can be present in the domain of the communicative intention, presupposition, or discourse management. Similarly, from this research it can be concluded that the limited use of the prosodic patterns represent a pragmatic deficiency. The problem is in the limited use of the patterns available and not their absence due to a lack of competence to produce them. From the results, it is possible to conclude that the differences in the realization of prosodic features in the elicitation tasks arise even when there is no atypical prosody. As opposed to that, ASD-HF subjects with atypical prosody present the same type of atypicality in the realization of prosodic features in both elicitation tasks although the atypicality is more pronounced in the S elicitation task.

8.2 Limitations

To my knowledge, the current dissertation is the first, albeit a preliminary, extensive investigation of the array of different prosodic features of intonation within the ASD-HF population using a control group and different elicitation tasks. However, this research has several limitations. Although the groups were comparable, in this research all participants' mothers had a very high education and therefore, the results cannot be extrapolated to the general population. This study concentrates on the prosodic features but did not make connections between the features themselves, whether, for example,
individuals with narrow pitch are more likely to present the limited restricted repertoire of edge tones or produce much more high PAs. Such possible connections would be of extreme interest and importance.

8.3 Future directions

The above discussion demonstrates parallels between the non-linguistic behavior of restricted repetitive behavior and the repetitive behavior of language both in the lexical domain and in prosody. These parallels need further research. The current research paves the way for interdisciplinary research, of both the non-linguistic behavior (of the restricted repetitive behavior) together with the linguistic behavior found. In doing so, it is an extension of one research objective (see section 1.2 (2) on page 3) into the use of the methodology developed, in order to better understand the research results within the context of other domains of language (e.g. semantics).

Another important issue is the perception-production relations in speech. This study concentrates on prosodic production of the subjects diagnosed with ASD-HF i.e. the realization of the distinct prosodic features in their speech. Since the ability to produce appropriate prosodic distinctions does not necessarily entail the ability to perceive the same distinctions, a complete picture of atypicality in prosody within a clinical population requires investigation of prosodic perception as well as of prosodic production, preferably in the same subjects. Doing so will lead to a more coherent understanding of the atypicality of prosody within the ASD-HF individuals.

Finally, the results of this thesis have clinical implications for the field of speech pathology. Prosodic analysis is necessary to help uncover the factors responsible for the atypicality in order to determine the direction of the therapeutic processes used in the clinical practice. As noted by Peppé (2009), there is remarkably little published literature on methods of improving deficits in prosodic functioning in children. Therefore, another line of functional research of both linguists and clinicians is to adopt the methodology presented, in order to develop a natural language assessment tool prior to intervention.
LIST OF REFERENCES


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The work presents a study of the prosodic features of Hebrew-speaking boys aged 9-13 years old, who are diagnosed with a range of ASD and normal intelligence, and a group of children with high-functioning autism.

The research in the field of prosody, especially among children with ASD, is limited and is primarily focused on the stage of autism as well. Prosodic deficiency is a significant feature of the condition, which tends to remain weak even when other aspects of language show improvement over time.

The prosodic deficiency adds to the social challenges faced by children with autism-high functioning in society around them.

In the study, 20 children, all of whom are Hebrew-speaking, participated. Ten children were diagnosed with high-functioning autism, while ten were without developmental issues and served as a control group. The participants were pairs of individuals of the same age, with one child being without developmental issues and the other being diagnosed with high-functioning autism.

The research methodology involved analyzing prosodic features of the Hebrew language through several prosodic indicators. The research used the IH-ToBI technology and the PRAAT software to analyze and present the results based on the idea that language is a tool designed through the communicative role, the features of the speakers, and the principle according to which communication represents the compromise to achieve "maximum communication with minimal effort," as described in phonological behavior.

The research examined the prosodic features of the Hebrew language in children with and without developmental issues, using three methods for data collection: repetition, reading a short story, and spontaneous speech during interaction. All collected data were transcribed and analyzed using the IH-ToBI technology and PRAAT software.
نعשה חישוב ש-IH-TOsBI על מנת לחוות, להשוות ולהעריך את הביטויים הפונטיים של הצורות הפרוזודיות של הנגנה (טווח תדירויות הדיבור, פיסוק המבصب הדרג, מתאר סיום הנגנה וברזל הדרייב הרגנה) בשוות והתלים.

הператор של המחקר מזוהה במקומ: חלק ראשוני ייצוג את התיעוכו

הاورונים הפונטיים של הנגנה השפתי-העפרית. החלק שני-custom את הת процедур של מתאר הצורות הפרוזודיות של הנבדקים עם סמו וביתוחבודה

לעומת המשותפים לבל ייצוג הת PROC.

הליך השני מוצג את ההופה האינטראקציה של הצורות הפרוזודיות, ברכשר עם התוריים פונולוגיה עת החכנת האדום והורף את ההיליך

הפונקציונליים (פשוע, הפר_relation)があり בין שמות במספר הנבדקים עם אוטיס-בתפקוד-גבזו, מתערה לחשף "ממסולים תושבי במידה ממוקמת".

המציאים Italics של מחקר זה: כל שעת הנבדקים עם אוטיס

ה랏קד גובתי מראים הבולים הפרוזודיה החשובה לעכ-זוג לבל-זוג לא עצים

הラットקר את כל הבולים היא הבולים הכל הצורות הפרוזודיות אבל כל bab.

הראות بدا רוזה את דובט. ב المحلي לשון בוטה תדריון הדיבר, מראות כי נפג עם הנבדקים עם אוטיס-בתפקוד-גבזו השליש קבוצות.

תעור רגיל, גובלו מוצמג גוזו רבח, של תדריון דיבר. הנבדקים עם אוטיס-

ה랫קד-גבזו ישרIRT דרך הצויה בופית הדClientId זחר שלידו יש ביבר השgetDisplay.

בשלשה רוזו של מציאר סיו טו כיסף תדריון הנגנה מבט העמיד את שיאר

ה뜨ור הנתרות. מתיאה הקבלת צ-התרחגון הלשון והרצים-לונזית של

 MDBK עם אוטיס-בתפקוד-גבזו, שבאה לי עד ביוטו בצלמומי הצורות הפרוזודיות

התרחג על עצים בחרותינו לשון מליון.

**مفנת יולי:** חעור התっこותו אוטיסטיות בתפקוד-גבזו, פורוזי, פונולוגיה

**החכנתו האדום, ייות אקוסטי.”**
העבדה נועשתה בהדרכת פרופסור ישי טובין
במחלקה לספריות זרות ובלשנות
בפקולטה למדעי הרוח
מתאר הצורה הפרוזודית בשפה דבורה של ילדים
עם אוטיזם בתפקוד גבוה לאור התיאוריה
"פונולוגיה בחטנהות האדם"

מחק르 ונלי חכל שי הנדרשות לקרבכת תואר "דוקטור לפילוסופיה"

הילה חנה גרין

חוגש לὄνομα ὁνομαζόμενον βο-γόριον βόγτβ

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אישור המנהלה

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אישור דיק ביט הספי ללימודי מחבר מתכדמים על"ש קרייטיימן

שבט תש"ע

באר שבע

פברואר 2010
מתאר הצורה הפרוזודית בשפה דבורה של ילדים עם אוטיזם בתקופת!<br>בגרהלאור התיאורית פונולוגיה כתחנתה הלאומית וקצרים בתקיפת Хоורתאיילוספיה המחבר לשב מילו של הדרשות לקבצלת חורר "דרקמר פילוסופיה" מאת הילה חנה גרין שווית עדיפנית אויבריפוא וגריינב-גריינבenganב פברואר 2010 שבט תש"עبار שבע