Studying some elicited verbal prosodic patterns in Egyptian children

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Background
Despite the large number of native Arabic speakers, Arabic prosodic skills have not been studied thoroughly.
Objectives
This study aimed to examine the perceptual judgment and acoustic characteristics of some elicited verbal prosodic patterns in a group of typically developing Egyptian children aged 2 years 2 months through 5 years 11 months in order to aid in the early identification of prosodic impairment in this age group.
Participants and methods
The sample included 40 healthy typically developing Egyptian children aged 2 years 2 months through 5 years 11 months old. Participants were divided into two groups: group I included 20 children aged 2 years 2 months to 3 years 11 months old. Group II included 20 children aged 4 years 2 months to 5 years 11 months old.
The prosodic patterns studied included socioaffective as well as grammatical patterns. The prosody of each elicited response was perceptually studied and acoustically analyzed. The results obtained were analyzed statistically using comparative and correlation studies.
Results
(a) Significant differences were found between the two groups with respect to the perceptual scores of all the prosodic patterns studied, except resentment and interrogative patterns. (b) Significant differences were found between the two groups with respect to acoustic values. (c) For all the studied parameters, no significant differences were found between males and females. (d) The highest mean perceptual score obtained by the studied group was that obtained for the interrogative pattern, whereas the lowest ones obtained were for exception and warning patterns. (e) A significant positive correlation was found between age and the Total Perceptual Prosodic Scores (TPPS). (f) A significant negative correlation was found between duration and most of the perceptual scores. (g) A significant positive correlation was found between frequency and most of the perceptual scores. (h) A significant positive correlation was found between energy and most of the perceptual scores.
Conclusion
(a) The production of different Arabic prosodic patterns is associated with changes in frequency, duration, and energy. (b) The easiest prosodic patterns to be imitated by children are the interrogative and resentment patterns, whereas the most difficult ones were the exception, disapproval, and warning patterns. (c) Elicited prosodic patterns do not differ with sex in children.

Keywords:
elicited prosodic tasks, prosodic patterns, prosodic skills, prosodic skills in Arabic-speaking children, prosody

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Introduction

In the field of speech analysis, there are two levels of interest. The first level deals with the segmental features. This level focuses on describing the acoustic and physiological properties of phonemes. The second level focuses on a suprasegmental device or prosody [1]. Prosody can best be described as the 'melody' or 'rhythm' of speech.

Despite its complexity, typically developing children are able to perceive, comprehend, and use prosody automatically [2] from a very early stage in development [3].

Children accurately use prosodic cues from the first-word stage. Afterwards, further development of these skills continues to take place throughout the preschool stage [4].

Broadly speaking, prosody serves to aid the transmission of linguistic and paralinguistic (emotional and attitudinal) information in a manner that is efficient and appropriate for a given language community. Although generally considered a part of phonology, linguistic prosody also interacts with semantic, syntactic, morphologic, and pragmatic domains of language as well [5].

Prosody serves several functions in speech, including, but not limited to, the transmission of affect and marking grammatical and lexical constructs [6]. Affective prosody refers to a speaker's ability to vary the pitch and rate of an utterance to indicate his/her emotional state or attitude, whereas grammatical prosody encompasses the use of prosody to indicate the type of statement being made for example affirmative or interrogative [7].

Some individuals acquire prosodic function very well; for others, it may involve a lifelong struggle [5]. Prosody can be impaired in various communication disorders including autism spectrum disorders and Asperger disorders [8], specific language impairment [9], traumatic brain injury [10], verbal dyspraxia [11], and motor speech disorders.

Recent advances in speech analysis have been instrumental in revealing the nature of prosody and some of its acoustic underpinnings [5] including frequency, duration, and energy. Frequency is the acoustic correlate of pitch. It is affected by the degree of tension in the larynx as well as by the aerodynamic forces and muscle actions [12]. Frequency is widely regarded as an important cue to intonation prominence. This kind of prominence is also called accent. When a word is perceived as accented relative to the surrounding words, it is usually of a higher or a different frequency than the surrounding words [13,14].

The duration of individual speech segments varies markedly, depending on both the segment type and the surrounding phonetic context. Nevertheless, in the context of prosodic distinctions, the overall utterance duration is more important than segment or phoneme duration [15].

Some authors particularly relate stress to loudness. Loudness is the perceived correlate of energy. It is primarily controlled by subglottic pressure. Stressed utterances often show more acoustic energy than weakly stressed ones [16].

The main functional patterns of Arabic prosody are grammatical (as in verbal disapproval statements, embedded phrases, demonstrative pattern, interrogative forms, exception indication, and negation forms) and attitudinal or emotional (as in exclamation, puzzlement, warning, anger/resentment expressions, and wishful thinking indication). The variations in prosody across these patterns involve changes in pitch, stress, and duration [15].

Prosodic development can be influenced by the ambient language and, thus, it is expected to differ – to some extent – from one language to the other depending on the adaptations added to the child's prosodic and vocalic properties by his/her developing communication needs and constraints. However, for all languages, the ability to efficiently produce different prosodic patterns is expected to start emerging at the age of 1–2 years and almost ends with the final stage at 5–6 years of age [17].

In the clinical assessment of prosody, clinicians usually rely on their own perceptual evaluation, which is sometimes unspecified, depending mainly on evaluating whether a certain problem is informally perceived or not. However, there are some limitations with perceptual analysis including the lack of consensus of definitions and the relevance of the screened parameters [18].

The sound spectrogram has been used previously in earlier researches to study the acoustic correlates of different prosodic patterns [19]. The sound spectrograph is an electronic instrument that gradually records the changing intensity level and frequency components of a complex sound wave. The display of the running short-term spectrum is referred to as a spectrogram. Frequency is plotted on the vertical axis, increasing from bottom to top. Intensity is represented on the 'gray scale' or the darkness of the pattern. Time appears on the horizontal axis and proceeds from left to right [20].

Despite being the language of over 300 million individuals and despite the fact that prosodic studies have been published worldwide for many languages, Arabic prosody has always been underinvestigated in comparison with other languages. It would be impractical and inappropriate to apply the previously mentioned prosodic studies on other languages to the Arabic language.

Arabic language is unique in nature; it contains different tone types and different places of tonic accent [21]. It has a complicated prosodic system compared with other languages such as English. Moreover, Arabic syllables are almost equal in duration [22]. Also, there are specific patterns and rules that control the proper utterance of Arabic language, for example, the place of stress [23,24], tone types, places of tonic accent [22]. Thus, prosodic rules that apply to these languages are completely different from those of Arabic [23,24].

Objectives

This study aimed at examining the perceptual judgment and acoustic characteristics of some elicited verbal prosodic patterns in a group of typically developing Egyptian children aged 2 years 2 months through 5 years 11 months old in order to aid in the early identification of prosodic impairment in this age group.

Participants and methods

This research was carried out during the period between the years 2008 and 2010. The study protocol was approved by the Otolaryngology Department Council of

Cairo University. Consent to participate in this research was obtained from the children's parents before commencement of the study.

The sample in this study included 40 healthy typically developing Egyptian children aged 2 years 2 months to 5 years old 11 months old. The children were equally divided into two sex-matched groups according to their chronological age. Group I included 20 children (age range = 2 years 2 months to 3 years old 11 months old; mean age = 2 years 11 ± 7 months). There were 10 males and 10 females. Group II included 20 children (age range = 4 years 2 months to 5 years 11 months old; mean age = 5 years ± 8 months old). There were 11 males and nine females. The children were selected randomly from a group of typically developing Egyptian children in nurseries and schools in greater Cairo area. All children were from families of moderate socioeconomic status. They were all reported to be free from any hearing difficulties, language delay, serious medical/chronic problems, intellectual disabilities, and psychological impairment.

Participants were tested individually in a quiet room. Prosodic imitation tasks were introduced to the child under study. The tasks were aided with visual stimuli in the form of pictures showing various scenes. These tasks aimed at eliciting the production of various prosodic patterns by the children under study.

For each of these patterns, sets of stimulus materials, each comprised of four pictures, were introduced sequentially to each child. In each set, the first picture was used as a demo. The second picture was used as a trial item to make the child familiar with the stimulus introduced (the children received no scores for demos and trials).

The other two pictures served as test stimuli to elicit appropriate prosodic patterns from each child. For each picture, a verbal stimulus was presented to the child along with the picture introduced. The assessor verbally described the introduced scene and then asked the child to quote what one of the persons in the picture was saying, for example, while showing the child the picture of a mother angry with her daughter because she has broken a cup, the assessor says, 'ماما زعلانة من البنت علشان كسرت الكوباية وهي هتقول لها انها زعلانة منها' '----------فبتقول لها'. The child – being familiar with the task because of the previously introduced demos and trials – was then supposed to say 'أنا زعلانة منك' using proper intonation pattern. If the child did not understand, the assessor would repeat the task again, provided that the child had not already produced an incorrect response.

The prosodic patterns studied included socioaffective/emotional as well as grammatical patterns. The former included resentment, disapproval, exclamation, wishful, and warning patterns, whereas the latter included interrogative, demonstrative, exception, embedding, and negation patterns. The prosody of each elicited response was, thereafter, studied perceptually as well as acoustically as follows:

Perceptual judgment/subjective impression

Ten elicited prosodic patterns were studied (five affective and five grammatical).

Affective prosodic patterns

(1) Resentment pattern: To elicit the anger prosodic pattern from each child, each child was shown pictures depicting a resentment scene, for example, a picture of a girl who has broken a glass and her mother is telling her that she is angry with her 'أنا زعلانة منك'.
(2) Disapproval pattern: To elicit the disapproval prosodic pattern from each child, each child was shown pictures depicting a disapproval scene, for example, a picture of a child drawing on the wall and a man disapproving of what he is doing and telling him that this is wrong 'كده عيب'.
(3) Exclamation pattern: To elicit the surprise prosodic pattern from each child, each child was shown pictures depicting an exclamation scene, for example, the picture of a child who has just received a wonderful unexpected toy and is saying 'الله! لعبة جميلة'.
(4) Wishful pattern: To elicit the wishful prosodic pattern from each child, each child was shown a picture of a girl looking at the window of a toy shop full of wonderful toys, hoping that her dad would get her a present and saying 'يا رب بابا يجيب لي لعبة'.
(5) Warning pattern: To elicit the warning prosodic pattern from each child, each child was shown a picture of a boy holding an electricity plug and a man standing beside him and warning him that this is dangerous by saying 'أوعى الفيشة تكهربك'.

Grammatical prosodic patterns

(1) Interrogative pattern: To elicit the interrogative pattern from each child, each child was shown pictures depicting interrogative prosodic patterns, for example, the picture of a woman at a sweets shop and asking whether there is chocolate 'في شيكولاتة؟'.
(2) Demonstrative pattern (e.g. pointing or referring to a certain object or person): To elicit the demonstrative prosodic patterns from each child, each child was shown pictures depicting demonstrative prosodic patterns, for example, a picture of a child writing in his copybook 'ده ولد بيكتب'.
(3) Embedding pattern (i.e. embedding a phrase within a sentence): To elicit the embedding prosodic pattern from each child, each child was shown pictures depicting this pattern, for example, the picture of a child watching the television 'أهو الولد الياتفرج على التليفزيون'.
(4) Negation pattern: To elicit negation prosodic patterns from each child, each child was shown pictures depicting this pattern, for example, the picture of a boy standing in the rain with another boy and telling him, 'I didn't see the sun' 'أنا ماشفتش الشمس'.
(5) Exception pattern: To elicit the exception prosodic pattern from each child, each child was shown pictures depicting an exception pattern, for example, the picture of a lady taking all the flowers from the vase and leaving one 'أخدت كل الورد ماعدا واحدة'.

Perceptual scoring

(1) The performance of the child under study was, then, numerically rated on a four-point scale depending on the accuracy and depending on production as follows:
   (a) Zero = incorrect or no response for both pictures introduced.
   (b) 1 = one correct response with a prompt (imitation or gestures) for either one of the two introduced pictures.
   (c) 2 = two correct responses with prompt (imitation or gestures) for the two introduced pictures or one independent response for either one of the introduced pictures.
   (d) 3 = one correct independent response for one picture and a correct response with prompt (imitation or gestures) for the other picture.
   (e) 4 = two independent correct response for the two pictures introduced.

(2) Afterwards, the subtotal perceptual scores obtained for all the prosodic patterns studied, by each child, were summed up to obtain his/her TPPS out of 40.

Instrumental evaluation

The child's utterances were captured as signals and were analyzed by a spectrogram, a program of Computerized Speech Lab. The following were obtained: the average frequency (in Hz) from the beginning to the end of the utterance, the average energy (in dB) from the beginning to the end of the utterance, and the duration of the sound wave of the entire utterance (in s).

Statistical studies

Data were analyzed using Statistical Package for the Social Sciences version 17 (SPSS; SPSS Inc., Chicago, Illinois, USA). Numerical data were expressed as mean, SD, and range. For quantitative data, comparison between two groups was carried out using the Mann–Whitney test (nonparametric *t*-test). A *P*-value less than 0.05 was considered significant. The Spearman-ρ method was used to test the correlation between numerical variables ($r > 0.3$ = no correlation, $r = 0.3$–0.5 = fair correlation, $r = 0.5$–0.1 = good correlation).

Results

1. The highest mean perceptual score obtained by the studied group was that obtained for the interrogative pattern, whereas the lowest ones obtained were those for exception and warning patterns (Table 1).
2. Significant differences were found between the two groups in the TPPS as well as disapproval, exclamation, wishful, demonstrative, embedding, and negation patterns. However, nonsignificant differences were found between the two groups for resentment and interrogative perceptual scores (Table 2).
3. Significant differences were found between the two groups in all the acoustic parameters studied (Table 3).
4. Nonsignificant differences were found between the scores obtained by both male and female children both perceptually and acoustically (Tables 4 and 5).
5. A significant positive correlation was found between the age of the children under study and the perceptual scores obtained for all the parameters studied as well as the TPPS (Table 6) (it was impossible to carry out any correlation studies with the interrogative perceptual score as all children obtained equal values on this item).
6. A significant negative correlation was found between duration and most of the prosodic perceptual scores obtained. However, a significant positive correlation was found between frequency and energy values and most of the perceptual scores obtained (Table 7).

Discussion

Prosody serves to aid the transmission of emotional and attitudinal information in a manner that is efficient and appropriate in a given context and community. It is a tool of human expression that is conveyed acoustically by means of durational, intensity, and frequency cues [5]. Prosodic cues are not independent and in fact systematically covary (e.g. both loudness and pitch may be increased in stressed syllables) to some degree.

In their early stages of development, infants respond to the prosody of familiar voices. As children grow, they start to use the prosodic patterns they have learnt during the first 18–24 months in their own speech [25]. At such a young age, the prosodic characteristics of speech are supposed to be better traced and retained than single segments. Thus, prosody is essential for the child's speech perception, thereby exerting an inevitable effect on the child's speech production, and on the process of language acquisition as a whole [26].

In the current study, some prosodic patterns elicited were subjectively as well as acoustically studied in a group of typically developing Arabic-speaking children. For young children, imitation prompts were sometimes essential to elicit relevant prosodic patterns.

WH expressions or questions (questions that start with WH question words such as; where, who, what, when, why, etc.) are syntactically simpler and can be produced easily by children as early as 2 years. However, finer

Table 1 Mean minimum and maximum values of the perceptual prosodic scores

Perceptual prosodic scores	Mean	SD	Minimum	Maximum
Resentment pattern	3.8	0.6	2.0	4.0
Disapproval pattern	1.2	1.3	0.0	3.0
Exclamation pattern	2.8	1.7	0.0	4.0
Wishful pattern	2.0	1.9	0.0	4.0
Interrogative pattern	4.0	0.0	4.0	4.0
Exception pattern	1.0	1.8	0.0	4.0
Demonstrative pattern	2.7	1.7	0.0	4.0
Embedding pattern	1.9	2.0	0.0	4.0
Warning pattern	1.0	1.8	0.0	4.0
Negation pattern	1.9	2.0	0.0	4.0
Total Perceptual Prosodic Score	22.3	12.6	6.0	39.0

Table 2 Comparison between subtotal perceptual scores obtained by the two groups under study

	Group I (2 years 2 months to 3 years 11 months old) $N=20$				Group II (4 years 2 months to 5 years 11 months old) $N=20$					
Perceptual scores	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mann–Whitney *U*-test	*P*-value
Resentment pattern	3.5	0.8	2.0	4.0	4.0	0.0	4.0	4.0	130.000	0.060
Disapproval pattern	0.0	0.0	0.0	0.0	2.4	0.8	0.0	3.0	10.000	<0.001*
Exclamation pattern	1.5	1.7	0.0	4.0	4.0	0.0	4.0	4.0	30.000	<0.001*
Wishful pattern	0.2	0.4	0.0	1.0	3.9	0.4	3.0	4.0	0.000	<0.001*
Interrogative pattern	4.0	0.0	4.0	4.0	4.0	0.0	4.0	4.0	200.000	1.000
Exception pattern	0.0	0.0	0.0	0.0	2.0	2.1	0.0	4.0	100.000	0.006*
Demonstrative pattern	1.5	1.6	0.0	4.0	4.0	0.0	4.0	4.0	20.000	<0.001*
Embedding pattern	0.0	0.0	0.0	0.0	3.9	0.4	3.0	4.0	0.000	<0.001*
Warning pattern	0.0	0.0	0.0	0.0	2.0	2.1	0.0	4.0	100.000	0.006*
Negation pattern	0.0	0.0	0.0	0.0	3.9	0.4	3.0	4.0	0.000	<0.001*
Total Perceptual Prosodic Score	10.6	3.9	6.0	17.0	34.0	4.9	25.0	39.0	0.000	<0.001*

*$P<0.05$ significant.

Table 3 Comparison between acoustic parameters of the two groups under study

		Group I (2 years 2 months to 3 years 11 months old)				Group II (4 years 2 months to 5 years 11 months old)					
Prosodic patterns	Acoustic parameters	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mann–Whitney *U*-test	*P*-value
Resentment pattern	Duration	2.4	0.1	2.2	2.5	2.0	0.3	1.6	2.4	42.000	<0.001*
	Frequency	294.5	9.7	279.0	310.0	307.9	9.8	291.0	319.0	51.000	<0.001*
	Energy	42.0	7.9	32.0	52.0	50.0	10.0	33.0	62.0	84.000	.001*
Disapproval pattern	Duration	1.9	0.5	1.3	2.5	1.2	0.1	1.1	1.4	27.000	<0.001*
	Frequency	287.0	12.2	268.0	306.0	304.0	10.0	287.0	316.0	51.000	<0.001*
	Energy	42.5	7.9	32.0	53.0	51.0	10.0	34.0	63.0	84.000	0.001*
Exclamation pattern	Duration	2.5	0.1	2.3	2.6	2.4	0.1	2.3	2.5	84.000	0.001*
	Frequency	288.0	7.9	278.0	298.0	296.0	10.0	279.0	308.0	84.000	0.001*
	Energy	42.0	7.9	32.0	52.0	50.1	10.1	33.0	63.0	84.000	0.001*
Wishful pattern	Duration	1.6	0.1	1.4	1.8	1.4	0.2	1.3	2.4	50.000	<0.001*
	Frequency	202.3	9.1	191.0	217.0	250.3	37.4	206.0	296.0	30.000	<0.001*
	Energy	43.5	9.2	29.0	58.0	56.0	10.0	39.0	68.0	63.000	<0.001*
Interrogative pattern	Duration	2.0	0.5	1.5	2.6	1.5	0.1	1.4	1.6	16.000	<0.001*
	Frequency	257.0	23.9	225.0	289.0	287.3	10.3	270.0	299.0	42.000	<0.001*
	Energy	40.0	8.5	27.0	53.0	51.0	10.0	34.0	63.0	75.000	<0.001*
Exception pattern	Duration	2.5	0.1	2.4	2.6	2.4	0.1	2.2	2.6	59.000	<0.001*
	Frequency	236.0	7.9	226.0	246.0	244.0	10.0	227.0	256.0	84.000	0.001*
	Energy	39.0	7.9	29.0	49.0	47.0	10.0	30.0	59.0	84.000	0.001*
Demonstrative pattern	Duration	2.4	0.6	1.8	3.1	1.7	0.1	1.6	1.9	30.000	<0.001*
	Frequency	259.8	42.7	83.0	283.0	279.7	25.8	212.0	312.0	121.000	0.033*
	Energy	44.5	8.0	34.0	55.0	53.0	10.1	36.0	65.0	86.000	0.002*
Embedding pattern	Duration	2.5	0.5	1.9	3.0	1.9	0.2	1.8	2.4	39.000	<0.001*
	Frequency	234.8	9.1	224.0	249.0	256.8	11.8	239.0	276.0	24.000	<0.001*
	Energy	39.5	10.4	23.0	56.0	52.5	8.7	37.0	62.0	55.500	<0.001*
Warning pattern	Duration	2.3	0.1	2.2	2.5	2.2	0.1	2.1	2.3	94.500	0.004*
	Frequency	269.5	7.6	259.0	279.0	277.5	10.0	260.0	289.0	81.000	0.001*
	Energy	42.5	8.3	33.0	53.0	51.0	10.0	34.0	63.0	81.000	0.001*
Negation pattern	Duration	2.1	0.3	1.8	2.5	1.7	0.1	1.6	1.9	30.000	<0.001*
	Frequency	196.3	9.1	185.0	211.0	257.8	51.0	200.0	317.0	30.000	<0.001*
	Energy	70.0	30.8	31.0	109.0	107.0	10.0	90.0	119.0	42.000	<0.001*

*$P<0.05$ significant.

acoustic changes start to be observed at an older age. This was previously found to apply not only for the English language but also for other languages such as German and Romaine languages, in which acoustic correlates for acoustic WH questions in the form of duration, frequency, and energy were found to be more prominent in older children than younger ones [27].

The interrogative pattern is a grammatical prosodic pattern. Children at a very young age have a limited repertoire of vocabulary and are able to produce only short phrases. They are obliged to use these phrases to cover all their communicative intents. To do so, they need to vary the prosodic style of the limited number of short phrases they have to cover as much communicative intent as possible. In the current study, the production of elicited interrogative pattern subjectively appeared to be of no problem for group I. This shows that the interrogative patterns are the easiest to be produced by young children.

All young children (group 1) were able to produce the interrogative pattern. This suggests mastery of this pattern by the age of 2–4 years. Similarly, no significant differences were found in the resentment pattern between the two groups, suggesting mastery of this pattern in the young age group as well (Table 2).

Table 4 Comparison of perceptual scores obtained by male and female children

	Males ($N=21$)				Females ($N=19$)					
Elicited prosodic patterns	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mann–Whitney *U*-test	*P*-value
Resentment pattern	3.7	0.6	2.0	4.0	3.8	0.5	2.0	4.0	192.000	0.851
Disapproval pattern	1.2	1.4	0.0	3.0	1.2	1.4	0.0	3.0	199.000	1.000
Exclamation pattern	2.8	1.8	0.0	4.0	2.7	1.7	0.0	4.0	187.500	0.748
Wishful pattern	2.1	1.9	0.0	4.0	1.8	1.9	0.0	4.0	178.000	0.573
Interrogative pattern	4.0	0.0	4.0	4.0	4.0	0.0	4.0	4.0	199.500	1.000
Exception pattern	1.0	1.7	0.0	4.0	1.1	1.8	0.0	4.0	194.500	0.893
Demonstrative pattern	2.8	1.7	0.0	4.0	2.6	1.7	0.0	4.0	179.000	0.592
Embedding pattern	2.0	2.0	0.0	4.0	1.8	2.0	0.0	4.0	183.000	0.668
Warning pattern	1.0	1.7	0.0	4.0	1.1	1.8	0.0	4.0	194.500	0.893
Negation pattern	2.0	2.0	0.0	4.0	1.8	2.0	0.0	4.0	183.000	0.668
Total Perceptual Prosodic Score	22.6	12.7	6.0	39.0	21.9	12.8	6.0	39.0	191.500	0.830

Table 5 Comparison between the acoustic values obtained by male and female children

		Males (number=21)				Females (number=19)					
Prosodic patterns	Acoustic parameters	Mean	SD	Minimum	Maximum	Mean	SD	Minimum	Maximum	Mann–Whitney *U*-test	*P*-value
Resentment pattern	Duration	2.2	0.3	1.6	2.5	2.2	0.3	1.6	2.5	189.000	0.789
	Frequency	301.0	12.4	279.0	319.0	301.4	11.5	279.0	319.0	197.000	0.957
	Energy	45.6	10.1	32.0	62.0	46.4	9.8	32.0	62.0	190.000	0.810
Disapproval pattern	Duration	1.6	0.5	1.1	2.5	1.5	0.5	1.1	2.5	196.000	0.936
	Frequency	295.3	14.6	268.0	316.0	295.7	13.6	268.0	316.0	197.000	0.957
	Energy	46.4	10.2	32.0	63.0	47.1	9.8	32.0	63.0	191.000	0.830
Exclamation pattern	Duration	2.4	0.1	2.3	2.6	2.4	0.1	2.3	2.6	180.500	0.611
	Frequency	291.6	10.1	278.0	308.0	292.4	9.8	278.0	308.0	190.000	0.810
	Energy	45.6	10.1	32.0	62.0	46.5	9.9	32.0	63.0	189.500	0.789
Wishful pattern	Duration	1.5	0.3	1.3	2.4	1.5	0.2	1.3	1.8	192.000	0.851
	Frequency	225.0	36.3	191.0	296.0	227.6	37.0	191.0	296.0	189.000	0.789
	Energy	49.5	11.9	29.0	68.0	50.1	11.2	29.0	68.0	191.500	0.830
Interrogative pattern	Duration	1.7	0.4	1.4	2.6	1.8	0.5	1.4	2.6	191.000	0.830
	Frequency	272.1	24.4	225.0	299.0	272.1	23.8	225.0	299.0	196.000	0.936
	Energy	45.2	11.2	27.0	63.0	45.8	10.5	27.0	63.0	190.000	0.810
Exception pattern	Duration	2.4	0.1	2.2	2.6	2.4	0.2	2.2	2.6	188.000	0.768
	Frequency	239.6	10.1	226.0	256.0	240.4	9.8	226.0	256.0	190.000	0.810
	Energy	42.6	10.0	29.0	58.0	43.4	9.8	29.0	59.0	189.000	0.789
Demonstrative pattern	Duration	2.1	0.5	1.6	3.1	2.1	0.6	1.6	3.1	190.000	0.810
	Frequency	276.2	17.8	253.0	312.0	262.5	48.9	83.0	312.0	176.000	0.537
	Energy	48.3	10.2	34.0	65.0	49.2	9.9	34.0	65.0	188.500	0.768
Embedding pattern	Duration	2.2	0.4	1.8	3.0	2.2	0.5	1.8	3.0	194.000	0.893
	Frequency	245.2	15.7	224.0	276.0	246.4	15.2	224.0	276.0	191.500	0.830
	Energy	46.0	12.5	23.0	62.0	45.9	10.7	23.0	62.0	194.000	0.893
Warning pattern	Duration	2.2	0.1	2.1	2.5	2.2	0.1	2.1	2.5	190.000	0.810
	Frequency	273.1	9.6	259.0	289.0	273.9	9.9	259.0	289.0	192.000	0.851
	Energy	46.6	10.1	33.0	63.0	46.9	10.3	33.0	63.0	195.000	0.915
Negation pattern	Duration	1.9	0.3	1.6	2.5	1.9	0.3	1.6	2.5	190.000	0.810
	Frequency	225.5	47.8	185.0	317.0	228.7	49.0	185.0	317.0	189.000	0.789
	Energy	88.8	30.1	31.0	119.0	88.2	29.4	31.0	119.0	199.000	1.000

Although no significant difference was found between the two groups for perceptual interrogative scores, acoustic studies showed significant differences between the duration, frequency, and energy values obtained for the interrogative patterns by the two groups. This indicates the importance of the acoustic measures in detecting subtle prosodic changes and deviations.

Many of the children in group I were able to produce the resentment pattern. However, some required modeling/imitation prompts to help them produce this pattern. Some were able to produce demonstrative patterns and exclamation patterns. The emergence of these patterns at this age could be partially related to the development of pragmatic skills; children start to use language to express more abstract feelings and socially interact with others in various ways. In addition, at this age, some children start to join nurseries, where their interactions with peers and adults expand enormously.

Wishful thinking and negation prosodic patterns were elicited from most of the children. However, warning, exception, and disapproval were the most difficult ones not only for group I but also for group II, suggesting mastery of these patterns at an older age.

The results of the current study showed that embedded patterns could only be produced by older children (group II). This is in agreement with the results of the other researches carried out previously on other languages; in English, embedded phrases patterns were found to be mastered by the age of 7–8 years [28].

Older children were informally observed to use appropriate melody for the warning expression with more ease and consistency than younger children. These results were in agreement with the results obtained previously by other researchers who reported that by the age of 6 years, the retrieval and use of correct verbal prosody of warning become clearly developed in the English language [25].

In the current study, the frequency and energy values obtained by the younger group for most of the studied prosodic patterns were less than the values obtained by the older group. This held true for all the parameters studied. Similar findings have been reported for older French-speaking children aged 5–6 years by other researchers, whose studies reported significantly higher frequency and energy values for older age group versus younger groups [29].

In the current study, the resentment (anger) pattern was found to be negatively correlated with duration and positively correlated with frequency. However, no significant correlation was found between the perceptual score and the energy values of this pattern. Earlier researches have shown a significant correlation between anger prosody and frequency in other languages [30].

The disapproval pattern was found to be accompanied by a shorter duration and higher frequency and energy values. Previous researches on other languages, for example, Dutch have shown that the disapproval prosodic pattern was found to be accompanied by a long duration and little pitch variation [31]. These differences between acoustic parameters of Arabic and other languages show that each language has its unique prosodic system and structure.

The exclamation pattern was found to be positively correlated with energy and frequency values. This is in agreement with the findings obtained previously by other researchers whose studies showed that the acoustic correlates for exclamation statements were mainly in the form of high frequency and energy values [32].

Wishful thinking, similar to the negation pattern, was also found to be associated with high frequency and energy values. These results are in agreement with the results obtained previously for the English language in which variant speaking styles such as wishful thinking were found to be objectively accompanied by changes in prosodic cues, namely, frequency and energy [33].

Although exception patterns were one of the difficult tasks, older children (group II) were perceptually observed to use more appropriate melody and intonation for exception expressions. This was acoustically manifested in the form of increased frequency and energy values associated with reduced duration.

Statistical studies of the obtained duration values for demonstrative patterns showed a significant difference between the two groups. The perceptual scores of this pattern were found to be negatively correlated with duration and positively correlated with energy values. In earlier researches carried out on the English language,

Table 6 Correlations between age and perceptual prosodic scores using the Spearman ρ method

Perceptual patterns	Age
Resentment pattern	
Correlation coefficient	0.614
P-value	0.000
Disapproval pattern	
Correlation coefficient	0.794
P-value	0.000
Exclamation pattern	
Correlation coefficient	0.867
P-value	0.000
Wishful pattern	
Correlation coefficient	0.872
P-value	0.000
Exception pattern	
Correlation coefficient	0.751
P-value	0.000
Demonstrative pattern	
Correlation coefficient	0.853
P-value	0.000
Embedding pattern	
Correlation coefficient	0.872
P-value	0.000
Warning pattern	
Correlation coefficient	0.751
P-value	0.000
Negation pattern	
Correlation coefficient	0.875
P-value	0.000
Total Perceptual Prosodic Score	
Correlation coefficient	1.947
P-value	0.000

$r > 0.3$ = no correlation, $r = 0.3–0.5$ = fair correlation, $r = 0.5–0.1$ = good correlation.

Table 7 Correlation between perceptual scores and acoustic findings of the prosodic patterns studied using the Spearman ρ method

	Prosodic patterns								
	Resentment	Disapproval	Exclamation	Wishful	Exception	Demonstrative	Embedding	Warning	Negation
Duration									
Correlation coefficient	−0.478	−0.697	−0.469	−0.634	−0.713	−0.789	−0.713	−0.421	−0.704
P-value	0.002	0.000	0.002	0.000	0.000	0.000	0.000	0.007	0.000
Frequency									
Correlation coefficient	0.529	0.568	0.502	0.764	0.560	0.193	0.769	0.592	0.771
P-value	0.000	0.000	0.001	0.000	0.000	0.232	0.000	0.000	0.000
Energy									
Correlation coefficient	0.234	0.436	0.502	0.642	0.560	0.495	0.608	0.560	0.719
P-value	0.146	0.005	0.001	0.000	0.000	0.001	0.000	0.000	0.000

$r > 0.3$ = no correlation, $r = 0.3–0.5$ = fair correlation, $r = 0.5–0.1$ = good correlation.

frequency and energy levels were found to be the acoustic correlates of demonstrative prosodic patterns [34]. As for North-American English, no precise acoustic correlates were found for this pattern [35].

Energy and frequency values obtained for the embedding pattern were found to be higher for the older group (group II). This pattern, similar to the warning pattern, was found to be positively correlated with energy values, suggesting increased stress during the production of these patterns. This is in contrast with the results obtained previously for other languages; for example, the Japanese language, in which embedded phrases were found to be associated with soft unstressed utterances of reduced energy [36].

Nonsignificant differences were found between the prosodic patterns of the female and male children in the current study on the acoustic as well as perceptual levels. This might be attributed to the young age of the studied group.

A significant positive correlation was found between the age of the children in all the studied groups and the TPPS. Similar findings have been reported by other authors whose studies indicated an increase in prosodic scores with age in a group of typically developing English-speaking children. This is related not only to prosodic development but also to the development of other linguistic aspects, namely, semantics (meaning), syntax (grammar), and pragmatic (social use of language). These aspects play an important role in prosodic function and competence [37]. In addition, the production of various prosodic patterns requires complex interactions of various physiological mechanisms of articulation, phonation, and respiration timed with a linguistic message. The regulation and coordination of pitch, loudness, and rhythm by speakers requires the efficient use of the underlying physiological mechanism to create systematic patterns of changes in fundamental frequency (F0), intensity, and relative duration across a phrase or a sentence. These interactions are expected to develop by age, thereby facilitating the production of various prosodic patterns.

The significant positive correlation obtained between the total perceptual scores and age also adds to the construct validity of the screening tool designed as the results reflect agreement with the construct/hypotheses that prosodic skills, like any other skill, are expected to develop with age.

In the current study, the duration values of the studied prosodic patterns were found to be significantly shorter in the older than in the younger group. Changes in duration may be related to the development of the articulatory organs, thus facilitating rapid speech production in children. However, changes in frequency and energy may be related to an increase in the efficiency of motor programming and planning that typically developing children are expected to achieve as they grow. Moreover, prosody can be affected by modifications in the overall voice quality and pitch [38]. All these aspects are expected to develop and change as children grow.

Conclusion

(a) The production of different Arabic affective and grammatical prosodic patterns is associated with changes in frequency, duration, and energy. (b) The easiest prosodic patterns to be imitated by children aged 2–6 years are the interrogative pattern, whereas the most difficult ones are the exception, disapproval, and warning patterns. (c) Prosody, like any other skill, develops with age. (d) Elicited prosodic patterns do not differ with sex in children. (e) Arabic prosody shares some common characteristics with the prosody of other languages in terms of both acoustic correlates and age of mastery. However, there are still some unique features that distinguish Arabic prosody from the prosody of other languages.

Recommendations

(1) Because prosodic styles can vary markedly from one language to the other, transferring of rules, norms, and evaluation tools used to study prosodic skills from one language to the other should be avoided.
(2) Further researches on Arabic language prosody are recommended.

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Conflicts of interest

There are no conflicts of interest.

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