Acoustic and phonetic differences in laughter of male children and adults

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Abstract

This paper compares the acoustic differences in spontaneous recordings of child and adult laughter. Results indicate that, mean pitch and intensity of laughter are significantly different in adults and children but they follow expected speech patterns. Children also have higher vocal tract resonant frequencies when compared to adults. However, both groups were similar in differentiating the non-phonated consonantal segment in laughter from the phonated vocalic segment through supralaryngeal dynamics. Consonants were produced with a lower jaw and forward tongue position with the jaw and tongue moving upwards and back respectively for the vowel. Finally, in this study laughter vowels fell within the Peteson and Barney speech vowel data but the spread was large not indicative of a reduced vowel status for laughter vowels.

Index Terms: child laughter, adult laughter, acoustic analysis

1. Introduction

Laughter is a vocalization that precedes speech, and therefore, could also fall at the lower extreme of the speech motor development scale. As children develop from toddlers to adults and their speech matures, one may wonder how exactly this maturation process occurs. This question could lead to some discussion about children's' laughter having acoustic characteristics that can correspond with their overall motoric development. In recent years the acoustics of laughter has been gaining a lot of research attention. It has been found that laughter takes various shapes depending on the social interaction and communicative intent of the person involved [1], [2], and [3]. These various types of laughter accordingly affect the acoustic features of laughter. It has also been reported that acted laughter is acoustically different from spontaneous laughter [4]. Studies looking at the vowels of laughter have found that the vowel space of laughter is more compact and reduced when compared to the vowel system of speech. However, there is some debate as to the actual quality of laughter vowels. Early research looking at isolated spontaneous laughter found that laughter vowels showed a low range of articulation typical to the centralized "schwa" vowel of speech [3]. In contrast, analysis of spontaneous laughter interspersed with speech, found that laughter vowels in Japanese adult females were produced with high F1 comparable to the speech vowel /a/ [5]. This study postulates that laughter is produced with lower jaw/tongue position and low range of articulation only in the front-back dimension of the tongue. A more recent study also report extremely high F1 values in acted laughter and they imply a wide jaw position or a narrow pharyngeal cavity (as in pressed voice) as the articulatory posture of laughter vowels [6].

Most of these studies have focused on the acoustic phenomena in adult laughter. Nwokah and colleagues [2] [7] were the first to qualitatively start discussing the characteristics of normal children's laughter. However, no acoustic study has yet been done on normal children's laughter [8]. A study focusing on the acoustic distinctions in three year old children's laughter concluded that a greater variety of childhood laughter is produced in response to increasingly complex social demands [2]. As more and more researchers continue to look at different types of laughter, and the overall acoustics of adult laughter, an understanding of how laughter develops throughout life becomes increasingly instrumental. Further, in the field of speech pathology understanding the development of speech from early forms of vocalization will help in understanding and diagnosing speech disorders at the early stage of a child's development. Cheng and colleagues [9] for example found that the tongue continues to mature in children until 11 years of age long after the jaw has completely developed. This leads to changing relationships between tongue tip and jaw and tongue body and jaw.

The goal of this preliminary research is to compare acoustic differences between normal male adult and child laughter. It is expected that the developing vocal and speech mechanisms in children would be implicated in the acoustic properties of their laughter, making the acoustics of children's laughter quite different from adult laughter.

2. Method

2.1 Data collection

Spontaneous laughter samples from four male adults and four children were selected from a larger pool of 40 subjects (20 adults and 20 children) recorded at the University of Toledo, Ohio for this preliminary study comparing the acoustics of children and adults laughter. The adults were in their early 20's, while the children were on average five years of age. Laughter was recorded as subjects sat alone in a quiet room and watched two short video clips. A headphone microphone set was placed on the subject as they viewed the videos and all vocalizations were directly recorded onto the computer. To ensure that the laughter samples were spontaneous, subjects were told that the objective of the experiment was to rate the "likability" factor of the two videos ("Which video did you like better?"). Five different videos were selected, two were considered appropriate for eliciting laughter from children, and three were predetermined to be appropriate for the adults. Only a few subjects laughed in the laboratory and many adult subjects chuckled instead. However, for the analysis of laughter the number of calls and bouts of laughter matter more than the number of subjects who took part in the experiment, because even a single individual could produce large variations of laughter. This preliminary study was restricted to the male gender as only one female child produced audibly clear spontaneous laughter.

2.2 Acoustic analysis

The eight subjects chosen for this study produced approximately 130 spontaneous outbursts of laughter syllables. From each speaker`, five bouts of laughter were selected for the acoustic analysis. Only clear audible bouts were selected. Each bout contained on average a sequence of three to four calls (syllables) of laughter. Inaudible vocalizations like those whispered or produced below the breath were eliminated from the study. Chuckles and giggles were also eliminated. In total, approximately 73 adult syllables/calls and 55 child syllables/calls were analyzed. Acoustic analyses were conducted using PRAAT, (the Paul Boersma phonetic analysis program).

In PRAAT, each individual subject's laughter sample was segmented into bouts which were further segmented into calls following the protocol used in [10]. A typical call had a consonant-vowel like combination with the phonated/voiced vowel following a long unvoiced/non-phonated consonant. The acoustic measurements conducted included *Vowel intensity, Consonant intensity,* V*owel pitch,* C*onsonant resonant frequencies, and Vowel resonant frequencies*. *Consonant intensity* and *Vowel intensity* were measured as the average RMS value obtained for the entire duration of the consonant and vowel segments respectively. *Vowel pitch* was calculated as the mean fundamental frequency over the entire duration of the vowel. To compare vowel quality of child and adult laughter the *Vowel resonant frequencies* were calculated by measuring first formant (F1) and second formant (F2) values at a single point at the center of the vowel. The consonantal/non-phonated segment in laughter is much longer than in speech. In our data the consonant was mainly the glottal fricative /h/ which due to its relatively large resonant cavity (area in front of the constriction) evidenced clear resonant frequencies. In this study we attempted to analyze the quality of the *Consonant resonant frequencies* by measuring the F1 and F2 at a single point of the consonant segment. The resonant frequencies of vowels and consonants were measured to determine any differences in articulatory dynamics between laughter consonantal and vowel like segments as an effect of developmental changes.

3. Results

3.1 Intensity

Table 1 lists the means, standard deviation and co-efficients of variation for *Consonant intensity*, *Vowel intensity* and *Vowel pitch.* In general, *Vowel intensity* of laughter vowels, like speech, is higher than the consonantal non-phonated segments for both adults and children. The co-efficient of variation values for both *Consonant intensity* and *Vowel intensity* are

Table 1. *Mean, standard deviations and co-efficient of variation for Consonant and Vowel intensity and Vowel pitch.*

	Age	N	Mean	Std. Deviation	Co-efficient of Variation (CV)
Consonant Intensity (dB)	Adult	76	57.55	8.66	.15
	Child	56	47.27	11.37	.24
Vowel Intensity (dB)	Adult	77	64.53	11.20	.17
	Child	59	55.80	13.58	.24
Vowel Pitch (Hz)	Adult	75	166.61	59.49	.36
	Child	55	332.0	81.88	.25

low indicating this data is pretty robust. The variation however, is higher for children when compared to vowels for both *Consonant* and *Vowel intensity*.

In the graphic representation (Figure 1) comparing *Vowel intensity* separately for adults and children, we see that adult vowels have the highest intensity. From Table 1 we can also infer that the adult *Vowel intensity* is the highest when compared to adult consonants and children vowels and consonants as well. T-test comparing adult to child *Vowel intensity* show that the difference in *Vowel intensity* across the different age groups is significant, t (134) =4.10, *p*<.001.

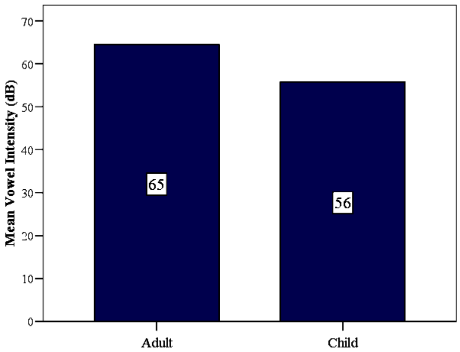

Figure 1. *Bar graphs representing mean Vowel intensity separated by age group. Mean values represented in bars.*

Figure 2 is a bar graph showing the mean value of adult *Consonant intensity* to be approximately 58 dB, while the child value is 47 dB. Independent-sample T-test proved that this difference in *Consonant intensity* between adult and child consonants was also significant, t (130) =5.90, *p*<.001. Therefore the findings in this group of subjects indicate that adult laughter is louder and less variable than children's laughter in general. These results are expected given the less developed respiratory system of children when compared to adults.

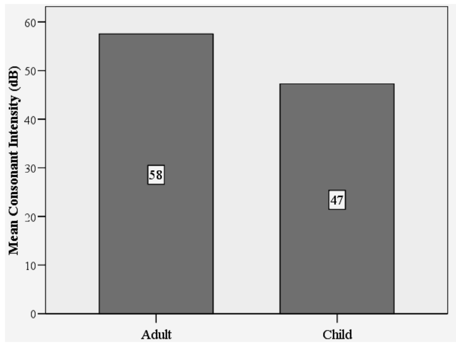

Figure 2. *Bar graphs representing mean Consonant intensity separated by age group. Mean values represented in bars.*

3.2 Pitch

Figure 3 compares the *Vowel pitch* differences in adults and children laughter vowels. There was a significant effect for age, t (128) = -13.35, p < .001, with children producing higher pitch than adults. Interestingly, when we look at the co-efficients of variation in *Vowel pitch*, we note greater variability in adults than children. These findings are contrary to the variability we see in intensity values. One possible explanation for the high variability in adults could be due to the fact that male adult laughter was more inhibited than the children in general. These findings tend to imply that in laughter, adult males have higher intensity but lower pitch similar to their speech characteristics.

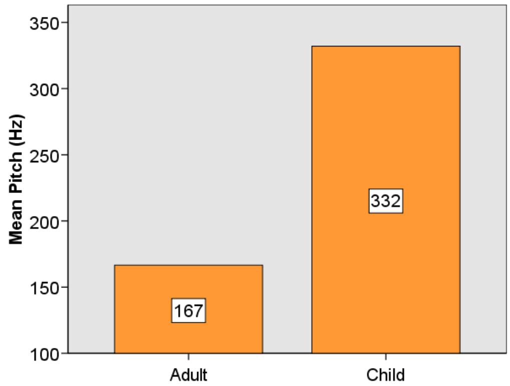

Figure 3. *Bar charts representing mean pitch for adult and child laughter vowels. Mean F0 values in hertz shown in bars.*

3.3 Vowel quality

Figure 4 plots the F1 values against the F2 values for both adults and children laughter vowels. F1 is plotted on the y-axis and F2 on the x-axis. The scales are reversed to depict actual articulatory movements within the vocal tract. Adult values are represented by asterisk and child values are represented by inverted triangles. For comparison with speech vowels, data from the Peterson and Barney [11] study for four of the extreme speech vowels are indicated on the graph.

Data reveal that both children and adult laughter vowels aggregated within the Peterson and Barney speech vowel quadrilateral. However, we see in Figure 4 that laughter vowels though central to speech vowels are not reduced to the schwa vowel quality. These results corroborate with earlier findings of the Japanese laughter study [4] and [5]. Figure 4 also show that children and adult laughter vowels form significantly distinct groups with children vowels occurring in front of the adult vowels on the F2 scale, t(134)=-2.71, *p*=.008. Independent sample t-test analyses also confirmed a

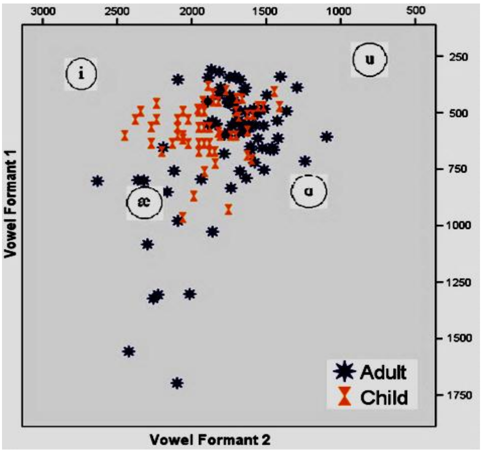

Figure 4. *F1 and F2 (Hz) plot of vowels separated by age. Vowels indicated on chart are the prototypes of Peterson & Barney [11] adult speech vowels.*

significant difference in children and adult vowels on F1 axis, t(101)=1.98, *p*=.05(equal variance not assumed). Children therefore have both higher F1 and F2 values when compared to adults. It is well known that the first two formants are determined by vocal tract configuration with F1 related to articulatory closure of the vocal tract and F2 related to the forward/backward positioning of the tongue in the vocal tract. A high F1 indicates a more open mouth or lower jaw and a high F2 predicts a more back or palatal tongue position [13]. The significantly higher F1 and F2 values for children when compared to adults then purports that first, children produces laughter vowels differently from adults, and second, that children have a lower jaw and more forward tongue position than adults when producing laughter.

3.4 Consonant resonance

Since we see very strong resonance in the unvoiced consonant (non-phonated) segments, we decided to study the characteristics of these resonances. A finding of no change in the unvoiced segments when compared to the voiced segments would lead us to believe that the only difference in these two acoustic segments is the presence or absence of vocal fold

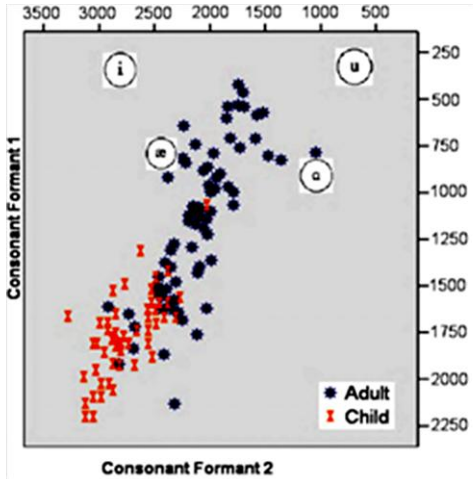

Figure 5. *F1 and F2 (Hz) plot of consonants separated by age. Vowels indicated on chart are the prototypes of Peterson & Barney [11] adult speech vowels.*

vibrations. This would be the expected articulatory kinematics of the typical laugh syllable with the glottal fricative /h/ as the syllable consonant. The tongue and jaw configuration would be that of the ensuing vowel due to co-articulation of the relatively independent vowel and consonant articulators.

Figure 5 is a scatter-plot of adults and children F1 and F2 values calculated at the unvoiced segment of the call or syllable. Again, adults are represented by asterisks and children by inverted triangles. Comparing the F1 and F2 values of the consonant resonances, we see a segregation of child and adult values. The F1 values for children ranged from approximately 1000 – 2250 Hz; while the adults ranged from 500 - 2200 Hz. The children's F2 values for consonants ranged from approximately 2000 - 3500 Hz; while the F2 values for adults ranged from 1000 – 3000 Hz. T-test analysis conducted on first formant values (jaw/tongue height) indicate a significant effect of age with children having higher F1 values indicative of a lower jaw and/or tongue position when compared to adults, t(130)=-9.78, *p*<.001. T-test analysis on the second formant (tongue forward/backward movement) also show significant effects of age with children have higher F2 values indicating a more forward tongue position when compared to adults, t(130)=-9.54, *p*<.001. Therefore, like the vowels, children's laughter consonants are also produced with a lower jaw position and more forward tongue placement.

Further, statistical analysis reveals that consonants are significantly different from vowels. Paired sample t-tests comparing vowel and consonant F1 values across both children and adults reveal that these F1 values are significantly different with consonants having higher first formant values, t

(125) =14.73, *p*<.001. Similar testing on F2 for vowels and consonants also reveal significant differences with consonants again having higher second formant frequencies, t (125) = 10.26, *p*<.001. Therefore, we can assume that consonants are produced with lower jaw and more forward tongues when compared to vowels. These findings were contrary to what we expected in that formant values of consonants are not similar to vowels even for the glottal fricative consonant /h/. Both children and adults in our study however, tend to distinguish the consonant from the vowel in a single laughter syllable using the same supra-laryngeal articulation pattern involving the jaw and tongue. As a person laughs, they start producing the non-phonated consonant with a low jaw and forward tongue position and move into the phonated vowel by raising the jaw and backing the tongue.

4. Conclusions

In this study we found that there were several significantly different acoustic and phonetic variations in child and adult laughter. The laughter vowels and consonants were louder and less variable in adults when compared to children. These findings are not different from speech where adults, especial male adults have louder voices. Just like speech we also note that children's laughter vowels have higher fundamental frequencies when compared to their aged cohorts. Human anatomy/physiology developmental research have found that the respiratory system of children continue to develop till the age of 7 years, however, they also report that even after 7 years, children have higher sub-glottal pressure than adults [12]. So children seem to have a compensatory strategy to facilitate voicing in the absence of a well-developed respiratory system, and it takes them some time to lose these strategies. It is possible that this high sub-glottal pressure resulted in the observed high pitch in children (along with thinner vocal folds) independent of intensity manipulation. It is also possible that adults and children reacted differently to the experimental set up, with adults being more inhibited in their laughter when compared to children affecting pitch more than the inherent intensity. Future analysis measuring airflow in children and adults during laughter could help disambiguate the independence of intensity and pitch we see in this data.

Laughter vowels in both children and adults were within the Peterson & Barney data for speech however, again we see that these vowels though centralized on the F2 axis were definitely not reduced. .In this study of Mid-western American subjects' laughter, children and adult were found to be different in that children appear to produce laughter with a more open mouth and also a more forward tongue when compared to adults. However, we need to understand if this articulatory kinematics is relative to each cohort's speech vowels. At this time we are still in the process of analyzing these subjects' speech data.

The most interesting finding of the paper was the difference noticed in laughter vowels and consonants. The consonantal like segment seen in laughter is clearly differentiated from the vowel in both children and adult. Both adults and children produce a single laughter call with a lower jaw position and more forward tongue for the consonantal segment but as they move into the vowel the jaw is raised and the tongue is forced further back.

Developmental trends can be noticed in this initial study comparing adult and child laughter. Young children appear to use more extreme jaw and tongue position to produce laughter but as they develop, they learn to modulate their jaw and tongue in a more controlled manner imitating more speech like productions. Another developmental indicator is the variability (though limited in this study) in each measurement that shows a lack of consistency within the child's production in comparison to adults that can also indicate a less developed articulatory strategy for producing syllables.

Further work is required to understand if these results are consistent over a larger group and across gender. In the follow-up study, we hope to create a speech vowel quadrilateral using the speech vowels of the subjects recorded in our study to better understand the differences in vowel quality of adult and child laughter. The vowel quality results reported here also need to be corroborated with articulatory analysis using EMA or WAVE systems. However, the difficulty in obtaining spontaneous laughter will be confounded even more when subjects are taped with electrodes.

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