Ethology 89, 115—124 (1991)

ISSN 0179-1613

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Laughter: A Stereotyped Human Vocalization

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PROVINE, R. R. & YONG, Y. L. 1991: Laughter: a stereotyped human vocalization. Ethology 89, 115—124.

Abstract

Laughter is a common, species-typical human vocal act and auditory signal that is important in social discourse. In this first quantitative description of laughter, we identified stereotyped features of laugh-note structure, note duration ($\bar{x}$ = 75 ms), internote interval ($\bar{x}$ = 210—218 ms), and a decrescendo that contribute to laughter's characteristic sound. Laugh-notes and internote intervals have sufficient temporal symmetry and regularity to pass the reversal test; recordings of laughter sound laugh-like when played in reverse. The stereotypic, species-typical character of laughter facilitates the analysis of the neurobehavioral mechanisms of laugh detection and generation and the more general problems associated with the production, perception, and evolution of human auditory signals of which speech is a special case.

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Introduction

Laughter is a common, species-typical human vocal act and auditory signal that is prominent in social discourse (PROVINE 1990, in press; PROVINE & FISCHER 1989). Laughter, like smiling and talking, is performed almost exclusively during social encounters; solitary laughter seldom occurs except in response to media, a source of vicarious social stimulation (PROVINE & FISCHER 1989).

Although many aspects of laughter have been studied (BLACK 1984; FRY 1963; GREGORY 1924; PIDDINGTON 1963; SULLY 1902; STEARNS 1972), including its development (SROUFE & WATERS 1976), social context (BAINUM et al. 1984; PROVINE & FISCHER 1989), contagion (PROVINE, in press), ethnology (APTE 1985), evolution (DARWIN 1872; VAN HOOF 1972), physiological correlates (AVERILL 1969; FRY & RADER 1977; FRY & SAVIN 1988; FRY & STOFT 1971), potential health benefits (COGAN et al. 1987; COUSINS 1976), pathology (BLACK 1982), and relation to humor (CHAPMAN & FOOT 1976, 1977; DURANT & MILLER 1988; MCGHEE & GOLDSTEIN 1983a, b), and tickling (FRIDLUND & LOFTIS 1990), we know less about the structure of laughter than we do about a variety of calls and songs of

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nonhuman species. Most ethologists neglect human behavior (but see EIBL-EIBESFELDT 1989), and language-oriented analyses of human speaking (LEVELT 1989) and listening (HANDEL 1989) do not consider the nearly ubiquitous paralinguistic signal of laughter. However, laughter's stereotypy, simple structure, species-wide distribution, and presumed strong genetic basis, make it ideal for studies ranging from the neurobehavioral mechanisms of vocal production and perception to the origins of human communication.

In this first quantitative description of laughter, we seek features of laugh-note structure, note duration, internote interval, and amplitude dynamics that define laughter's unique sound. This determination of the sonic signature of laughter is a first step in the neurobehavioral analysis of laugh production and perception.

Materials and Methods

The experimenter (PROVINE) recruited 51 subjects (23 males, 28 females) from University staff and students encountered on campus and immediately tested them on their home or neutral territory (e.g. staff in their offices, student passersby in vacant classrooms) to take advantage of the spontaneity and relaxed social setting conducive to laughter (PROVINE & FISCHER 1989). All subjects consented to provide a sample of laughter and were promised anonymity.

The formidable task of evoking laughter from often self-conscious single subjects was accomplished by asking subjects to "simulate hearty laughter", a request that typically triggered the *spontaneous* laughter that was the basis of this analysis. (Voluntary laughter produced by most subjects was so obviously forced and abnormal that it would not be confused with spontaneous laughter.) For many subjects, the request to laugh was itself sufficient to evoke natural laughter. Even reluctant subjects produced spontaneous laughs, especially in response to nonverbal clowning, kidding, and laughter by the experimenter and sometimes present fellow subjects. Contrary to folk wisdom, most laughter occurs in playful social situations similar to those of this study, not as a response to jokes or other structured efforts at humor (PROVINE & FISCHER 1989).

Laughter was recorded on high-bias CrO_2 tape at 4.7 cm/s with a Marantz portable audio tape recorder (#430) and a TOA K-1 cardioid microphone with wind screen. Analyses of audio waveforms and frequency spectra were performed with a Kay Elemetrics 5500 Digital Sonograph (narrow band 117 Hz).

A *reversal test* involving the estimation of the normality of recorded laughter played backward was performed to evaluate the temporal symmetry of laughter. The time order of laughter was reversed by monophonically recording laughter on both tracks of a 0.6-cm two-track AM tape recorder at 19 cm/s and then reversing the position of the tape reels and playing the tape.

Results

The waveform and sound spectrogram of a typical "ha-ha" laugh (the most common variant) with 6 notes performed by a 46-year-old male are shown in Fig. 1. Laugh-notes begin with a voiceless aspirant (hissing sound not produced by vibration of the vocal cords) of about 200 ms duration similar to that of the English /h/ in "ha". Although this aspiration is most obvious in the first note of a laugh sequence, it is present before and after each note. That there is at least limited temporal symmetry of the sonic envelope of laugh-notes is suggested further by note reversibility; recorded "ha" laugh-notes played backward still sound like "ha". The un-voiced /h/ that is heard to initiate laugh notes may be, at least in part, an onset effect of the abrupt and forcefully voiced laugh-note.

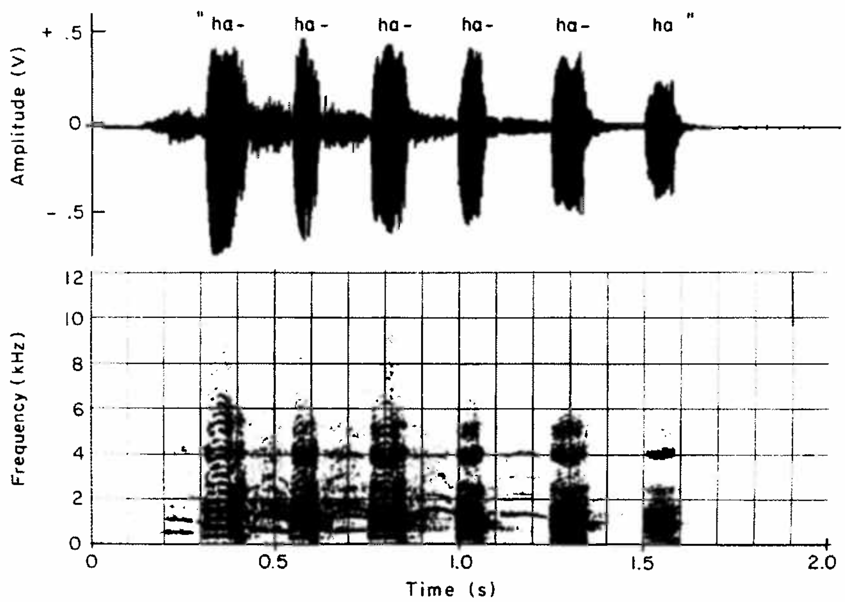

Fig. 1: Above: Waveform of a 6-note laugh from a 46-year-old male. Below: Frequency spectrum of the above laugh. In the frequency spectrum, the evenly spaced horizontal bands of the voiced laugh-notes are harmonics of the notes' fundamental frequency. Both the waveform and the frequency spectrum show the unvoiced aspiration that precedes and follows each voiced laugh-note. Although the explosively voiced notes may have frequencies above 16 kHz, most power is in frequencies below 8 kHz

Additional, indirect evidence of laugh-note symmetry and the arbitrariness of laugh notation is found in the comparison of laugh notation of different languages. In Italian operas, for example, laughter is notated as "ah" in contrast to the "ha" in the parallel English translation. However, laughter is sung identically in both languages.

The voiceless /h/ that initiates a laugh-note is followed by a forcefully voiced vowel-like sound, /a/ being the most common variant. A specific vowel sound does not define laughter because vocalizations composed of notes having one of a variety of vowel-like sounds (i.e. "ha-ha", "ho-ho", "he-he") are at least occasional laugh forms of some people. However, except in unusual instances, the same vowel is used in all notes of a given laugh. At different times, someone may perform "ha-ha-ha" and "ho-ho-ho" laughs, but never "ha-ho-ha-ho" laughs. The vowel-like vocalization is characterized by prominent harmonics (multiples) of the note's fundamental frequency (Fig. 1 below; Fig. 2). The laugh-notes, however, usually had less prominent formant structure than is associated with vowels. (Formants are frequency bands whose amplitudes are modulated by resonances in the vocal tract.)

Given the above qualifications in regard to the temporal symmetry effects revealed by note reversal and the variety of vowel sounds that can serve in laugh-

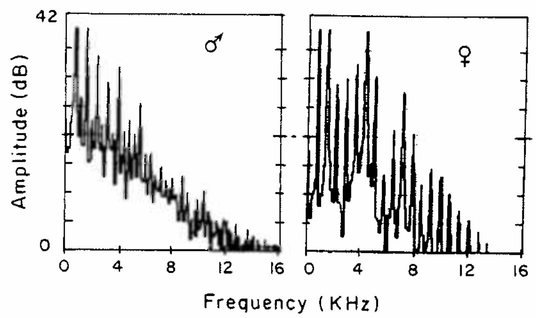

Fig. 2: Spectra showing the distribution of power into various frequencies of the center 25 ms of the first note of a typical male and female laugh. The periodic fluctuations of the spectra correspond to harmonics (multiples) of the laugh-notes' fundamental frequency. The spectral peaks are more numerous and closely spaced in the male than female record, a finding consistent with the lower fundamental frequency and pitch of the male laugh

notes, the description of a laugh-note as "ha" is necessarily only an approximation in English notation of its sonic structure.

The marked harmonic structure of laugh notes is revealed by the regular, multiple peaks in power spectra that show the amplitudes of the frequencies composing the center 25 ms of the first note of multi-note laughs of a typical male and female (Fig. 2). The power spectra of the first note of one laugh from each subject showed the 23 males to have a significantly lower average (± SD) fundamental frequency ($\overline{X}$ = 276 ± 95 Hz) than the 28 females ($\overline{X}$ = 502 ± 127 Hz) (F [1,49] = 49.78, $p < .00005$), a conclusion consistent with the apparently lower pitched male laugh.

Durations of the first 4 notes, the largest number of notes performed by all subjects, sampled from 51 laughs (one laugh per subject), were nearly identical for the 23 male and 28 female subjects (Fig. 3, lower traces). Note duration for males averaged (± SD) 75 ± 20 ms compared to 75 ± 21 ms for the females. There were no gender differences in the average note duration of the first 4 notes of laughs (F [1,49] = .0151, p = .9026) or of all notes from laughs having 4 or more notes (F [1,49] = .0002, p = .9647). Note duration varied significantly with position in a laugh for the first 4 notes for females ($p < .01$) but not for males ($p < .1$) and was significant for combined subjects (Table 1). When all laughs of 4 or more notes

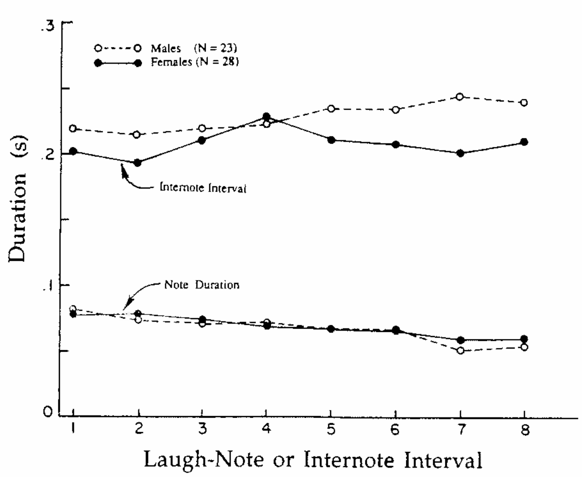

Fig. 3: Duration of internote intervals (top traces) and notes (bottom traces) for males and females as a function of position in a laugh. All 51 subjects contributed to the first 4 note durations and 3 internote intervals although some subjects produced up to 16 notes ($\bar{x}$ = 4 notes)

(range = 4—16 notes, x̄ = 4 notes) were considered, a significant negative correlation was found between note position and duration for all groups (Table 1). With the exception of a few subjects who sustained the vowel of the terminal laugh-note, notes late in a sequence tended to be shorter than those occurring earlier, especially for long laughs.

Table 1: Correlation coefficients (r) of note position versus note duration, internote interval, and note amplitude, and mean note duration versus mean internote interval for males, females, and combined subjects

	First 4 notes			All notes		
	r	df	p	r	df	p
Note duration						
Males	−.22	69	<.1	−.43	163	<.01
Females	−.30	84	<.01	−.52	192	<.01
Combined	−.25	153	<.01	.47	355	<.01
Internote Interval						
Males	.02	46	>.05	.47	140	<.01
Fermales	.20	56	>.05	.23	164	<.01
Combined	.12	102	>.05	.33	304	<.01
Note Duration vs. Internote Interval						
Males	.60	21	.001	.45	21	.033
Females	.57	26	.001	.48	26	.01
Combined	.57	49	<.0005	.46	49	.001
Note Amplitude						
Males	−.40	69	<.01	−.74	163	<.01
Females	−.40	84	<.01	−.70	192	<.01
Combined	−.40	153	<.01	−.72	355	<.01

One of the most striking features of multi-note laughter is the periodicity of its component notes, a property revealed in the distribution of onset-to-onset internote intervals (INI) (Fig. 3, upper traces). The average INI (± SD) for the first 3 intervals (the largest number performed by all subjects) of laughs with 4 or more notes was 218 ± 40 ms for the 23 males, 203 ± 49 ms for the 28 females, and 210 ± 50 ms for the 51 combined subjects. When all INI's of 4-note and longer laughs were considered, a significant positive correlation was found between INI and note position for males, females, and for combined subjects (Table 1). When the analysis was limited to the first 3 INI's, no significant correlations were found between interval position and duration for males, for females, or for combined subjects (Table 1). No significant gender difference was found between either the mean duration of the first three INI's ($F[1,49] = 1.3901$, $p < .2441$) or the mean duration of all INI's ($F[1,49] = 2.0696$, $p < .1566$).

Significant positive correlations were found between mean note duration and mean INI for males, females, and combined subjects for both the first 3 notes and INIs and for all notes and intervals of laughs having 4 or more notes (Table 1). Thus, a common mechanism may influence both note duration and INI or compensate for note duration by adjusting INI, or vice-versa. However, the relative stability of note duration and INI during laughter indicates that such adjustments, if present, operate with a limited range.

In contrast to the relative temporal stability of note duration and INI, note amplitude measured as the peak-to-peak voltage from the screen of a storage oscilloscope decreased dramatically during laughter (Fig. 4). A significant negative correlation was found between note amplitude and note position for all groups for the first 4 notes (the largest number of notes performed by all subjects) and for all laughs (range = 4—16 notes, $\bar{x}$ = 4 notes) (Table 1). The decrescendo characteristic of most laughter probably results from the depleted air supply available for notes late in a sequence.

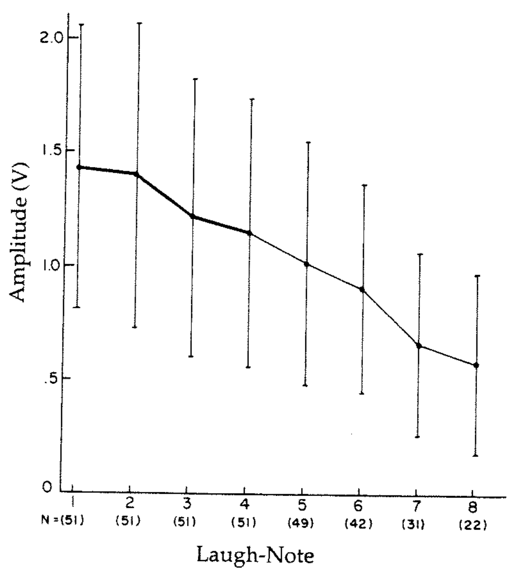

Fig. 4: Changes in note amplitude during laughter. Most laughs had a strong decrescendo. Four notes were the maximum produced by all 51 subjects (range = 4—16 notes, $\bar{x}$ = 4 notes)

The magnitude of the decrescendo of normal laughter was demonstrated dramatically by playing recorded laughs in reverse; the sound of multi-note laughs proceeding with a crescendo instead of a decrescendo was striking and bizarre. Note amplitude is an exception to the already considered temporal symmetry of note structure and regularity of internote interval (INI) that permits reversed laughs to sound laugh-like. Although the degree of laugh degradation caused by reversal requires evaluation, the contrast between reversed laughter and speech was informative. Unlike laughter, speech did not pass the *reversal test.* Because the complex frequency and amplitude modulations of human phonemes are temporally asymmetric, reversal rendered speech unintelligible.

Discussion

Laughter is shown here to have a sonic signature characterized by stereotyped features of note structure, note duration, internote interval and a decrescendo. The species-wide distribution of laughter, its probable strong genetic basis, and its simple structure make laughter ideal for analyses of the neural basis, development, and evolution of human vocal production and perception. Laughter lacks the sonic complexity, subtlety, and cultural diversity that complicate similar studies of speech and language. The simplicity of laughter is more characteristic of bird songs and animal calls than of speech, a point probably appreciated by DARWIN (1872) who included a report of tickle-evoked laughter in chimpanzees in his treatment of laughter.

One of laughter's most curious and informative properties is its contagion, the tendency of laughter to spread through a group in a chain reaction (PROVINE, in press). The power of contagious laughter as a social synchronization process is suggested by a persistent epidemic of laughter that began among 12- to 18-year-old girls in a boarding school in Tanganyika and spread throughout a district, requiring the closing of schools (RANKIN & PHILIP 1963). Although the contagious nature of laughter is widely known and is the basis of "laugh tracks" on broadcast comedy shows, "laugh boxes", and "laugh records", researchers have not pursued the hypothesis that *laughter itself* is sufficient to trigger laughter and mediate the phenomenon of contagion (PROVINE, in press). Most research on contagious laughter evaluated the effectiveness of prerecorded "canned" laughter in enhancing audience laughter and/or perceived humorousness without considering laugh-evoking properties unique to the stimulus of laughter. The phenomenon of contagious, laugh-evoked laughter suggests that laughter may be a releasing stimulus for the stereotyped, species-typical vocalization of laughter. The present research is a step toward defining the properties of the laugh-evoking stimulus.

Of further ethological interest is the paradoxical social message of laughter. Laughter among friends increases social cohesion, but to be jeered or ridiculed is to be expelled from a group, an unpleasant and potentially dangerous event. The latter, negative message of laughter may explain the aversiveness of repeated exposure to recorded laughter (PROVINE, in press). Jeering may have a counterpart among nonhumans. Mobbing, a synchronized group response by some birds and mammals to drive invaders from their territories, is functionally akin to human jeering and involves a simple, repetitive cry much like laughter (EIBL-EIBESFELDT 1989, p. 315).

Phenomena of laughter are relevant to several central issues in speech science. Contagious laughter involves the replication in the perceiver of the motor pattern that originally generated the vocalization in the sender. This intimacy between laugh production and detection suggests a highly specialized functional relation and/or co-evolution of vocalization and perception, a conclusion relevant to motor theories of speech perception and associated issues of modularization of function (MATTINGLY & STUDDERT-KENNEDY 1991).

Our subjective response to the auditory stimulus of laughter suggests that laughter is an especially potent vocal stimulus. Consider the sound of distant laughter at a crowded social gathering. Laughter emerges as a clear and distinct vocal signal from the muffled jumble of conversation. Laughter is easily parsed from the noisy flow. The subjective discontinuity in the detection of laughter may be an example of categorical perception (LIBERMAN & MATTINGLY 1989), a property of which is the ability to perceive discontinuities (categories) such as phonemes in an otherwise linear message.

A first step in the neurobehavioral analysis of laugh production and perception is the sonic description of laughter, the task of the present research. Future psychophysical studies must determine which parameters of laughter (i.e. note structure, note duration, internote interval, amplitude dynamics) are necessary for the perception of laughter and the activation of the hypothetical laugh detector or releasing mechanism. Although the existence of such auditory feature detectors in humans is debated (MATTINGLY & STUDDERT-KENNEDY 1991), the evolution of a detector for species-typical and sonically simple laughter seems more likely than for complex and culturally variable speech. In this regard, laughter may be a human vocal and social behavior amenable to research approaches associated with the search for the neural substrate of bird song (KONISHI 1965; MARLER 1983; NOTTEBOHM 1991). A similar research tactic has been pursued in the visual domain to determine the facial features triggering contagious yawning (PROVINE 1986, 1989) and the perception of smiles (LEONARD et al. 1991).

Conclusion

Given the relative wealth of research on laughter in the context of humor or social dynamics, it is a surprise that so little attention has been directed to the act of laughter, a ubiquitous behavior perfectly suited for ethological and neuroethological analyses. Ethologists may have neglected humans in favor of other animals that are less likely to have the veneers of learning and socialization that presumably obscure or distort species-typical behavior. In the case of laughter, this reservation may not be fully justified. Laughter is an ancient mode of pre-linguistic vocal communication that is performed in parallel with, but has not been displaced by, modern speech and language. Laughter should be a central theme, not a footnote, in the study of human social communication.

Acknowledgements

The authors thank Drs. R. BILGER, A. CARAMAZZA, A. C. CATANIA, M. CERRI, M. DEMOREST, K. DERRICKSON, and S. FELDSTEIN for assistance with various aspects of the research, and the National Zoological Park for providing access to their Sound Laboratory for the Sonographic analysis.

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Received: March 6, 1991

Accepted: June 20, 1991 (G. Barlow)