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Vocal and visual attractiveness are related in women

SARAH A. COLLINS & CAROLINE MISSING
Animal Behaviour and Ecology Group, School of Life and Environmental Sciences, University of Nottingham

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We investigated the relation between visual and vocal attractiveness in women as judged by men. We recorded 34 women speaking four vowels and measured the peak frequency, the first five harmonic frequencies, the first five formant frequencies and formant dispersion. The women were also photographed (head shot), several body measures were taken and their ages were recorded. The voices were played to male judges who were asked to assess the women's age and vocal attractiveness from the recording. The men were then asked to assess the attractiveness of the photographs. Men were in strong agreement on which was an attractive voice and face; and women with attractive faces had attractive voices. Higher-frequency voices were assessed as being more attractive and as belonging to younger women (the lowest frequency produced is a good indicator of age in women in general). Larger women had lower voices and were judged as having less attractive faces and voices. Taller women had narrower formant dispersion as predicted. The results imply that different measures of attractiveness are in agreement and signal similar qualities, such as female age, body size and possibly hormonal profile.

A number of studies have investigated female attractiveness in humans (Barber 1995; Rhodes & Zebrowitz 2002). Attractiveness is often related to visual cues signalling youthfulness (Buss 1989; Jackson 1992; Bereczkei et al. 1997; Rhodes & Zebrowitz 2002), presumably because one of the major indicators of reproductive potential is age (Symons 1979; Rhodes & Zebrowitz 2002) and these women should therefore be preferred as mates. Women with a low waist to hip ratio (WHR), that is, large hips in relation to waist size, are found to be more attractive (Beck et al. 1976; Singh 1993). WHR is related to age (Pond 1978), hormonal profile (Singh & Young 1995) and fertility (Singh 1993). Morphological symmetry is a general signal of fitness (e.g. Thornhill & Møller 1998; Thornhill & Grammer 1999) and has been shown in a number of studies to be related to desirability as a mate (e.g. Rhodes et al. 1998; Perrett et al. 1999). In addition, women who are facially attractive have a more attractive scent (Rikowski & Grammer 1999; Thornhill & Gangestad 1999). This latter result implies that the signals used to judge attractiveness in women, even in different modalities, are concordant (Møller & Pomiankowski 1993). These signals all seem to be cues to youth or fertility.

What about vocal attractiveness? Are some voices more attractive than others, and if so why? Collins (2000) showed that women prefer some male voices over others, and also agree about which voices are attractive. Women judge men with deeper voices as more likely to have a large body or a hairy chest but are wrong in their judgements, because male morphological characteristics are not related to voice characteristics (e.g. van Dommelen & Moxness 1995; Collins 2000). However, men with deeper voices do have higher testosterone levels (Dabbs & Malinger 1999).

Two structures of the vocal apparatus determine basic vocal characteristics: the vocal folds and the supralaryngeal vocal tract (Fant 1960; Lieberman 1984). The size and thickness of the vocal folds determine the fundamental frequency (lowest frequency produced, F0); thicker folds give rise to a lower voice (Fant 1960). The F0 (along with other vocal characteristics) of a woman's voice is affected by hormonal changes during adolescence (Abitbol et al. 1999; Fitch & Giedd 1999) and during the menopause (Helfrich 1979; Abitbol & Abitbol 1998). During adolescence the sub- and supraglottis mucosa become oestrogen dependent, F0 drops and there is an increase in the number of formants produced (Abitbol et al. 1999). Other vocal parameters also change premenstrually (e.g. increased vocal roughness, Chae et al. 2001; loss of upper frequencies and increased hoarseness, Abitbol et al. 1999). These changes are likely to be due to decreased oestrogen causing changes in the vocal cord mucosa and blood supply (Abitbol et al. 1999). Therefore, F0 could signal the general hormonal state and age of the speaker (Mulac & Giles 1996).

Correspondence: S. A. Collins, Animal Behaviour and Ecology Group, School of Life and Environmental Sciences, University of Nottingham, Nottingham NG7 2RD, U.K. (email: sarah.collins@nottingham.ac.uk).

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F0 can be voluntarily varied within limits; for example males may raise the frequency of their voice to appear more feminine (e.g. in transsexuals, Gunzberger 1993). F0 is also varied in response to other speakers' vocal characteristics: during a conversation speakers tend to converge in frequency (Gregory et al. 2000). Because of the resonance frequencies produced by the vocal tract and the relation between the harmonics (multiples of the fundamental frequency), raising F0 does not make a male voice sound completely 'feminine' (Childers & Wu 1991). However, the lower limit to F0 will be constrained by the musculature and dimensions of the vocal cords.

The dimensions of the vocal tract influence the formant frequencies (emphasized frequencies within vocalizations, Fant 1960; Lieberman 1984). The minimum formant frequency is related to both body size and age in red deer, *Cervus elaphus* (Reby & McComb 2003). Formant dispersion is related to body size characteristics in nonhuman primates (Fitch 1997) and, potentially, in humans (Fitch & Giedd 1999). Formant frequencies are strongly affected by constrictions within the vocal tract (e.g. Fant 1960) and vocal tract morphology (Fitch & Giedd 1999; Lee et al. 1999). However, the lower formants are also strongly affected by the speech content (Moore 1992). Upper formant frequencies are more likely to be affected by vocal tract morphology alone (Scherer 1982). A third, often measured, vocal characteristic is peak frequency (frequency with the highest amplitude), which usually coincides with the first or second formant (S. A. Collins, personal observation) in normal speech.

Most studies of judgements on the basis of the voice involve spoken words or sentences (e.g. personality, Zuckerman & Driver 1989; height and weight, van Dommelen & Moxness 1995; attractiveness, Zuckerman et al. 1995; sex, age, socioeconomic status, Avery & Liss 1996). However, this allows a number of cues to be used in judgements, such as speech patterns and accent. In speech, cultural stereotypes and preferences will be more important than basic vocal signals to physiological or morphological characteristics. This can be circumvented to some extent by looking at judgements made on the basis of vowel sounds, especially if explicit instructions as to pronunciation are given.

In this study we recorded women speaking four vowel sounds and then played these sounds to male judges. We asked them to assess the attractiveness of the voice and how old they estimated the speaker to be. The vowel sounds were analysed for frequency characteristics (Collins 2000). Vowel sounds give a clear indication of both fundamental frequency and formant frequencies of a voice (Wu & Childers 1991), and can thus act as an honest cue to vocal fold and vocal tract dimensions and by extension could signal hormonal and morphological characteristics.

We also presented men with photographs of the women speakers and asked them to judge visual attractiveness. This allowed us to test whether attractiveness as judged through different sensory modalities was consistent.

METHODS

Subjects

Recordings

We used 30 female speakers, all British, aged 19–26 years (mean 21.4 years). Voices were recorded with a Tascam DAP1 DAT recorder and a Sennheiser MKH60 microphone. The microphone was held 20 cm from the mouth and a constant sound recording level was used. The speakers were asked to say the following vowel sounds three times, in their normal speaking voice: A, as in 'cat'; E, as in 'get'; I, as in 'sit'; O, as in 'hot'. Vowel sounds were sustained for a mean of 0.29 s (range 0.25–0.38). These vowel sounds were chosen because they were easy to reproduce for all subjects; two other vowel sounds were dropped because subjects had difficulty reproducing them consistently. Because we wanted to get a general measure of vocal range, we used means for vocal measurements across vowels.

The speakers had the following body measures taken at the time of recording: height (range 156–178 cm), weight (range 47–95 kg), waist circumference at the narrowest point of the waist (range 62–95 cm) and hip circumference at the widest point of the hips (range 80–120 cm). We calculated the waist to hip ratio (WHR=waist/hip circumference; range 0.66–0.85) and the Body Mass Index (BMI=kg/m^2; range 15.5–34.5). We did not record the menstrual cycle stage, although vocalizations do change premenstrually (see above). These changes occur in 33% of women not taking the contraceptive pill (Abitbol et al. 1999).

Photographs

The speakers had a head shot photograph taken in front of a plain background, with a neutral facial expression. The subject's hair was tied back and she wore a hair band to ensure that all the hair was off the face. She had no lipstick or eye make up and all visible jewelry was removed. The photographs were taken indoors under standard conditions (height of subject relative to background, etc.) on colour film using a Nikon FE10 camera, with a 35–70-mm lens, two flashguns and reflectors.

Analysis of Vowels

We made logarithmic power spectra of each vowel of the middle spoken set (AEIO=one set) from each speaker, using the Avisoft SASlab sound analysis program (sampling frequency 11 kHz).

We calculated the following measures from the spectrum (Fig. 1): the overall peak frequency, the peak frequency of the first five harmonics frequencies (harmonic 1 is F0) and the mean spacing in frequency between the harmonics (harmonic spacing),

Linear predictive coding (LPC) analysis was used to measure the peak frequencies of the first five formants (Burg method, using Praat 4.0.11, P. Boersma & D. Weenink, http://www.praat.org). The mean spacing between the formants (formant dispersion), the mean spacing between formants 1 and 3 (LowDispersion),

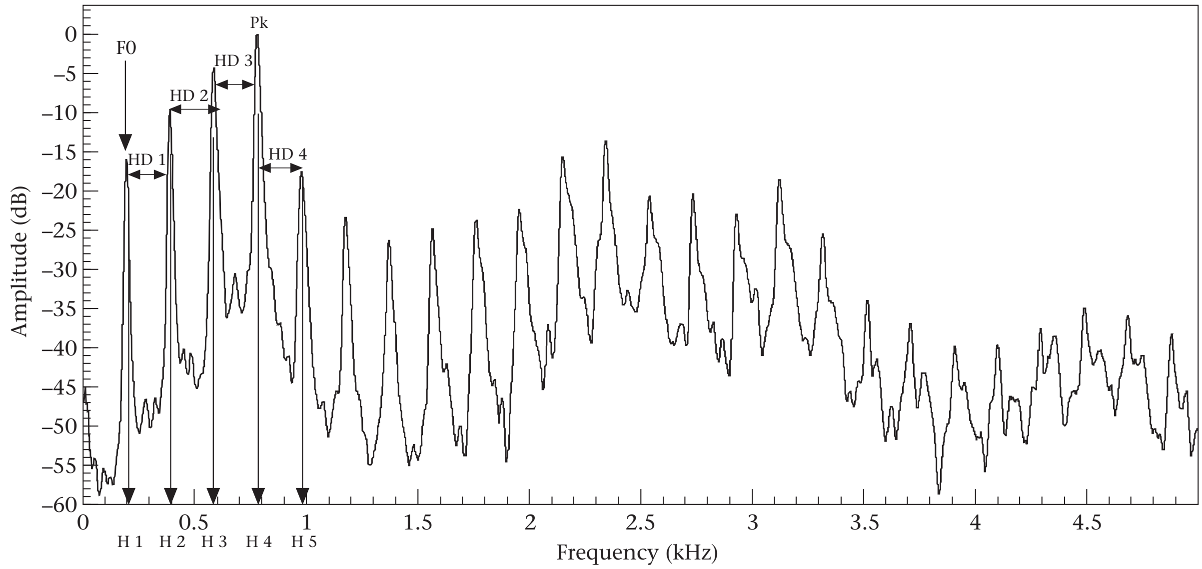

Figure 1. Power spectrum of the vowel A. HD 1–4=harmonic difference (harmonic spacing is the mean of HD 1–4); H 1–5=harmonic peak frequency; F0=fundamental frequency; Pk=peak frequency of vowel.

and the mean spacing between formants 4 and 5 (High-Dispersion) were calculated from the above. We calculated both formant dispersions because formants 1–3 are strongly influenced by the particular vowel being spoken (Fant 1960). For each speaker a mean for each of the above measures was calculated over all four vowels.

Stimulus Series

We divided the speakers randomly into three groups (A–C), to reduce the listening time for judges. Three tapes were made, each consisting of the voices of one group. The middle set of vowels of a speaker was recorded on to a DAT tape using a Tascam DA302 Dual DAT deck. The speed of utterance and overall amplitude were equalized across subjects. Within each group the speakers were recorded on to the stimulus tape in three orders; the vowels of a speaker were always in the order AEIO.

Preference Tests

As judges we used 30 randomly chosen British men, aged 17–30 (mean age 22.14) divided into three groups of 10 (A–C). Each group of judges rated one group of speakers. The only criterion for assigning judges to groups was that they did not know the women in their stimulus group. All preference tests were conducted in a quiet room. The judges were played the stimulus voices on a Tascam DAP1 DAT recorder through Ross RE 4230 Speakers.

Judges were given a questionnaire which asked them to assess for each speaker: (1) the attractiveness of the voice (on a scale of 1–10, with 10 being very attractive; vocal attractiveness score) and (2) the age of the speaker in years. The judges heard each speaker's vowel series twice. Each of the three orders was used in rotation.

After rating the voices, the judges were shown the photographs of the 10 speakers, and asked to rate each face for attractiveness on a scale of 1–10 (with 10 being very attractive; visual attractiveness score). The judges saw the photographs of the women in a different order to that in which they heard them speaking and the photographs were shown in a different order to each judge. The judges were played the stimulus tapes before rating the photographs because seeing the photographs of the female subjects first would influence the judges' age guesses, which were intended to be based solely on vocal information.

Analysis of Judgements

Collins (2000) observed that when judges were asked to rate subjects they would use the first as a 'standard', leading to variation in the range of estimates for different judges. Using Kendall rank scores overcomes this problem (Collins 2000). This ranks an individual judge's scores from lowest to highest and takes the mean rank for a female, from all judges. The mean Kendall rank score was calculated for vocal attractiveness, speaker age and visual attractiveness scores. We also calculated the mean age estimate for each speaker in years.

Statistical Analysis

All of the body and vocal measures and the listener judgements were tested for normality. Appropriate transformations were performed when necessary (weight, hip and waist were log transformed; BMI was square-root transformed).

The vocal parameters were highly correlated, as were the body measures. Therefore, we conducted

Table 1. Rotated component matrix for principal components analysis on vocal characteristics

	Component matrix			
	Harm	Formdisp	Forms	Peakf
Peak frequency	−0.24	0.20	−0.13	0.86
Fundamental frequency	0.92	−0.17	0.04	−0.17
Harmonic 2	0.96	−0.14	0.07	−0.10
Harmonic 3	0.98	−0.09	0.07	−0.08
Harmonic 4	0.98	−0.01	0.09	−0.06
Harmonic 5	0.97	0.03	0.14	−0.06
Mean Harmonic spacing	0.94	0.07	0.16	−0.03
Formant 1	−0.04	0.08	0.11	0.95
Formant 2	0.21	0.13	0.79	0.00
Formant 3	0.06	0.48	0.68	0.05
Formant 4	0.09	−0.07	0.86	−0.03
Formant 5	−0.07	0.93	0.20	0.16
Average dispersion	−0.02	0.82	0.43	−0.11
Low dispersion	0.08	0.41	0.57	−0.55
High dispersion	−0.15	0.94	−0.16	0.16
Variance explained (%)	38	19.6	16.6	13.7

Harm: Harmonics; Formdisp: formant dispersion; Forms: formants; Peakf: peak frequency.

Table 2. Rotated component matrix for principal components analysis on body characteristics

	Components	
	Body	Whrhgt
Body mass index	0.96	−0.21
Waist to hip ratio	0.14	−0.79
Height	−0.09	0.70
Weight	0.97	0.03
Hip circumference	0.92	0.24
Waist circumference	0.95	−0.24
Age	0.26	0.34
Variance explained (%)	52	20

Body: Body size; Whrhgt: waist to hip ratio and height.

two principal components analyses (PCA) with varimax rotation to reduce objectively the original set of variables to a smaller number of uncorrelated composite variables or components (e.g. harmonics correlation coefficients: all *r*s>0.9 were reduced on to one component). The vocal parameters were reduced to four components (harmonics, Harm: voices with higher harmonic frequencies (including the fundamental frequency) have a high score; formant dispersion, Formdisp: voices with a wider High-Dispersion score and higher frequency formants 4 and 5 score highly; formants, Forms: voices with a wider Low-Dispersion score and higher formant frequencies 2 and 3 have high scores; peak frequency, Peakf: voices with a high peak frequency and formant 1 have a high score; Table 1) and the body measures to two components (body size, Body: women with a high BMI, weight and large hips and waist score highly; waist to hip ratio and height, Whrhgt: women who are tall with a low waist to hip ratio score highly; Table 2).

The level of agreement between the judges' ratings of vocal attractiveness and their age estimates was calculated with the Kendall coefficient of concordance.

All analyses were conducted on the components unless otherwise stated. Backwards stepwise regression was used to determine (1) which body components predicted which vocal components, (2) which vocal components predicted judgements, and (3) which body components predicted visual attractiveness judgements. We tested whether fundamental frequency (F0) was related to age (with a Spearman correlation; Montepare & Zebrowitz-McArthur 1987), and whether height was related to average formant dispersion (with a regression), as suggested by Fitch & Giedd (1999). We used the original parameters because we were testing for specifically predicted relations. The relation between vocal judgements and facial attractiveness was tested with a Pearson correlation. For all analyses we used SPSS version 9.0 and all statistical tests are two tailed.

RESULTS

Acoustic Parameters and Body Characteristics

There were no differences between the three groups of speakers in body or vocal characteristics (ANOVAs: all NS) so groups were combined for all analyses.

Specific tests

Women with higher HighDispersion scores were shorter ($F_{1,28}$=5.8, P=0.02, R^2=0.17; Fig. 2a) and older women tended to have a lower F0 (r_S=0.35, N=30, P=0.055).

General tests

Women with higher Harm scores (higher harmonics) had lower Body scores ($F_{1,28}$=4.4, P=0.04, R^2=0.14; Fig. 2b). There were no other significant relations.

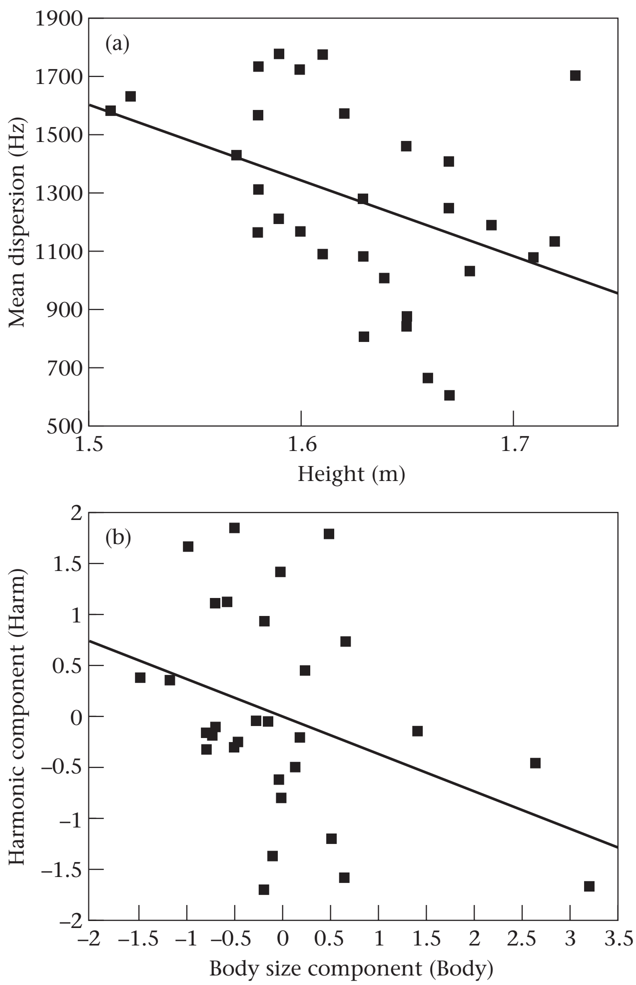

Figure 2. The relation between (a) mean dispersion of formant 4–5 and height and (b) harmonic and body size components.

Agreement Between Judges and Judgements

There was agreement on all judgements within each group except for the age judgements in group C. We therefore excluded this group from any analyses that included the age judgement (Table 3), because the mean judgement of a nonconcordant group is not a valid measure. If group C is included there is no change in the significance of the results.

Women with high visual attractiveness scores had more attractive voices (r_{28}=0.404, P<0.05; Fig. 3). This relation remained significant when the age of the woman was partialled out (r_{27}=0.41, P<0.05). Age rank and vocal attractiveness were negatively correlated ($r_{18}=-0.59$, P<0.01): women with younger-sounding voices were scored as more vocally attractive.

Subject Characteristics and Judgements

High visual attractiveness scores were predicted by low Body scores ($F_{1,28}$=8.8, P=0.006, R^2=0.24). Women with low Body scores also had more attractive voices ($r_{28}=-0.4$, P=0.03).

Table 3. Kendall coefficients of concordance, showing agreement between judges

	Vocal attractiveness	Age
Group A		
χ^2_9	39.411	28.390
W	0.438	0.315
P	<0.001	<0.005
Group B		
χ^2_9	54.160	28.844
W	0.602	0.320
P	<0.001	<0.005
Group C		
χ^2_9	53.977	10.233
W	0.600	0.114
P	<0.001	NS

N=10 for all groups.

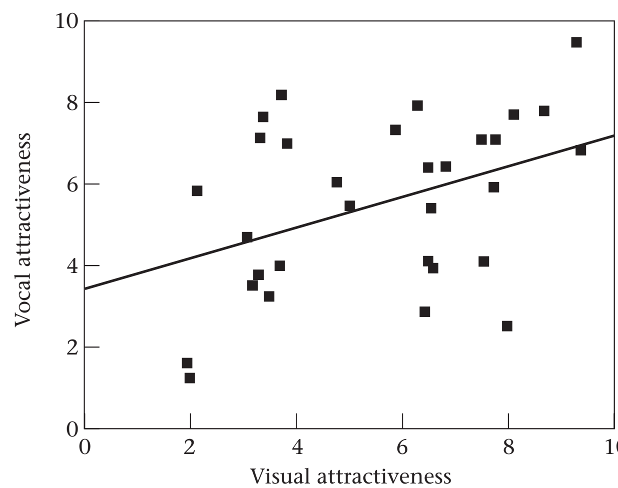

Figure 3. The relation between visual and vocal attractiveness.

Women with higher Harm, Formdisp and Forms scores were judged to have more attractive voices ($F_{3,26}$=4.5, P=0.01, R^2=0.34: Harm: β=0.321, P=0.05; Fig. 4a; Formdisp: β=0.363, P=0.03; Forms: β=0.321, P=0.05). Women with higher Harm scores were also judged to be younger ($F_{1,18}$=6.3, P=0.02, R^2=0.26; Fig. 4b).

No correlation was found between the actual age of the subject and judges' age estimates (r_{18}=0.11, NS).

DISCUSSION

Our main findings are as follows. First, visual and vocal attractiveness were related in women. Second, women with relatively higher formants and fundamental frequency were judged as having more attractive voices and women with a higher fundamental frequency (Harm component) were also judged as likely to be younger. Third, both facial and vocal attractiveness were negatively related to body size. Fourth, women with larger

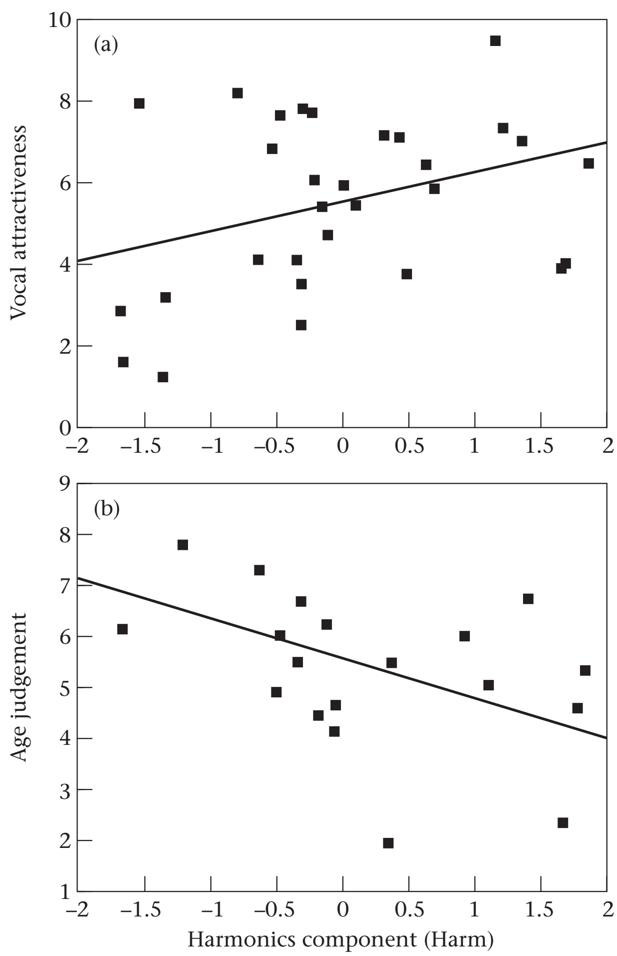

Figure 4. The relation between the Harm component and (a) vocal attractiveness; and (b) estimated age rank.

bodies (Body component) had lower harmonics. Finally, average formant dispersion across formants 4–5 was dependent upon height; shorter women had wider dispersion as predicted by Fitch & Giedd (1999).

Our study shows that two signals in different modalities (vocal and visual) both indicate female attractiveness. In a previous study (Zuckerman et al. 1995), judgements of vocal and visual attractiveness were weakly correlated. However, the judges in Zuckerman et al.'s study were exposed to spoken sentences, which means that they were able to use speech patterns as well as the frequency attributes of the voice to make their judgements. This result was replicated in our study when judges heard only vowels. The visual and auditory signals may be cues to the same characteristic, for example age, body size or hormonal profile, or they may signal different characteristics which happen to be correlated, for example body size and personality (more dominant women may be larger and lower their voices, Gregory et al. 2000). The use of multiple ornaments as signals of quality has been discussed extensively. Different signals may be 'backup' messages of the same qualities, or 'multiple messages' (Johnstone 1995, 1996). This suggests that in women the voice and face could be 'backup' messages to suitability as a mate (both cues signalling youth and fertility). However, only further studies can discriminate between the above possibilities.

Age is known to be important in male mate choice (Rhodes & Zebrowitz 2002). Across a wide age range there will be cues in both the face and voice to individual age. However, our sample covered a narrow age range and the small differences in age did not translate into differences in the voice. When a voice sounded 'younger' the woman was judged as having a more attractive voice (there was a high correlation between assessment of age and vocal attractiveness). Men may have assumed that deeper voices belonged to older women, as there is a relation across a wider age range (Montepare & Zebrowitz-McArthur 1987; Hollien et al. 1997). However, we found no effect of actual age on facial or vocal attractiveness. Therefore, the relation between facial and vocal attractiveness in our study was not due to a correlation of both with age. Zuckerman et al. (1995) found that judgements of maturity were positively correlated with judgements of attractiveness in males and females. However, another study found a correlation only in males (Berry 1990).

As stated above, if a wider age range of subjects had been used then it is almost certain that age would have emerged as the main factor predicting attractiveness. The small differences in age of subjects probably caused the lack of agreement on age estimates by men in group C. There were a large number of ties, that is, men estimated several women as being the same age. Men of almost all age groups show a strong preference for young women; this preference is not relative to their own age but is absolute (Kenrick & Keefe 1992), older men preferring relatively younger women. Age would have been such a strong effect (Rhodes & Zebrowitz 2002) in our study if older women subjects had been included that it is possible that other cues would have been relatively unimportant. However, women of the same age do not have faces of identical 'youthfulness' or vocalizations at identical frequencies (F0 or formant frequencies). A woman with a relatively higher voice for her age group may have a different hormonal profile than one with a lower voice (Abitbol et al. 1999). For example, relatively high-frequency voices may signal higher oestrogen levels (as in WHR, Singh 1993). Women with young-looking faces for their age may also have young-sounding voices for their age. Across a wide age range vocal and facial attractiveness will be predicted mainly by age, but within age groups by hormonal profile.

We did not control for menstrual cycle differences. The changes in vocal characteristics that occur in 33% of women premenstrually are small compared with inter-individual differences, and occur only in women not taking the contraceptive pill. Differences occur in the roughness of the voice (Chae et al. 2001) and in the suppression of some upper harmonics, giving the voice a narrower frequency range (Abitbol et al. 1999). Therefore, we do not believe that our results are influenced by menstrual cycle differences between women, although we will address this in subsequent studies.

Body size is another attribute that could be signalled by both the voice and face. It was negatively related to ratings of facial attractiveness, although the judges saw only the speakers' faces in photographs. This relation between body size and facial attractiveness could be interpreted as support for Thornhill & Grammer's (1999) theory that women's faces and bodies comprise a single ornament that honestly signals quality. If this were the case then women with attractive faces would have attractive smaller bodies, but preference for small bodies may hold true only in western societies (Ford & Beech 1951; Westman & Marlowe 1999). Recent work by Tovée et al. (1999) suggests that body size (specifically BMI) is a more important determinant of attractiveness than WHR, despite the latter's apparent biological significance. We did find that women with larger bodies had lower-frequency voices. However, how body size affects F0 (Harmonic 1) is not clear. Fitch & Giedd (1999) found that the vocal tract size is predicted by both height and weight in women and larger vocal tracts produce lower-frequency formants and a narrower formant dispersion (Moore 1992; Fitch 1997). We did find a relation between height and the dispersion of the higher formants in the predicted direction. Unfortunately this does not help to explain the relation between body size and F0. It is possible that larger women have larger vocal folds (although this is not the case in men, Fitch 1997). If so, the face and voice are cues to the same attribute, body size (i.e. they are backup messages).

As yet we cannot discount the possibility that women with smaller bodies tend to use higher frequencies because of differences in their self-perceived attractiveness, personality differences or social expectation. For example, smaller women may affect 'babylike' voices. Women may also use higher voices in social than professional situations (Davies 2000). Perhaps differences in motivation to appear professional between larger and smaller women cause differences in F0. This is speculative, but we would like to test this in future studies.

Several authors have suggested that use of multiple signals increases the accuracy of assessment (Møller & Pomiankowski 1993; Singh 1993; Rikowski & Grammer 1999). In women it appears that there is potential for voice, scent (Rikowski & Grammer 1999) and face (Berry & Zebrowitz-McArthur 1988; Buss 1994) to signal suitability as a mate. In contrast in men, although the attractiveness of face and scent are related (Rikowski & Grammer 1999), the attractiveness of the voice and face are not (S. A. Collins, unpublished data). In men the voice reflects hormonal profile (testosterone), but not other body characteristics. The reason for the difference may lie in the evolutionary significance of the lower-frequency voice of men which may be related to male–male competition (S. A. Collins, unpublished data). Fitch & Giedd (1999) suggested that the vocal tract elongation in men exaggerates the impression of size conveyed by the male voice by lowering the formant frequencies disproportionately. It may be specifically designed to fool opponents with respect to their body size in aggressive displays (Fitch & Giedd 1999; Fitch & Reby 2001).

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