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Effect of Voice Change on Singing Pitch Accuracy in Young Male Singers

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Background in music performance and pedagogy. During the voice-change process, singing for adolescent boys may become more difficult and unpredictable. Many boys cease singing when they reach puberty as they experience their voices as unreliable and a potential source of embarrassment. They often leave choirs and singing experiences they have previously enjoyed because they and their teachers believe they can no longer sing in tune, or that their voice range and quality no longer meet requirements of singing in pitch or blending with other voices. Teachers may also be fearful that the boys could do harm to their voices if they sing during this period of change.
Background in music acoustics. There has been little previous scientific research that has assessed acoustically the nature and extent of pitching inaccuracy in adolescent males undergoing voice change. The work of Cooksey (1992, 2000) and Cooksey, Beckett & Wiseman (2000) developed the use of the descending speaking fundamental frequency (SFo) as an indicator of stage of voice change. Cooksey's typology of the six stages of change (Unchanged, Midvoice I, II, IIA, Newvoice and Emerging Adult) provides the theoretical basis for interpreting the pitch findings in the current study.
Aims. The aim of this study was to assess the effects of the male changing voice process on boys' ability to pitch-match to a given note, and accuracy when singing perfect 4ths, 5ths and octaves.
Main contribution. Through analysis of 79 recordings of the perfect 4th, perfect 5th and octave sung by adolescent boys (mean age 13y5m), this study investigated singing-pitch accuracy of boys at varying stages of voice change. This study confirmed Cooksey's finding (2000) that a SFo of 196 Hz [g3] is a critical point in voice-change, and that boys undergoing voice-change rely on their SFo as a reference point for pitching in singing. It was found that the perfect 4th was the most accurately sung interval, followed by the perfect 5th. Boys in all stages of voice-change found the octave difficult possibly due to varying vocal range limitations experienced during the changing voice process.
Implications. In confirming that a SFo of 196 Hz [g3] is the critical point of voice change for adolescent males, and identifying the difficulties in singing perfect 4th, 5ths and octaves for boys as they progress through change, this study allows teachers and students to develop strategies (eg. the use of the SFo as a guide to the appropriate key) to accommodate singing-pitch difficulties in young male singers.

Keywords: Boys' changing voice, pitch-break, voice-break, singing-pitch accuracy

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Introduction

Guidelines for teachers and choral directors list a number of vocal technical reasons for out-of-tune singing. Reasons for singing flat include poor air support, lack of energy, singing too loudly, not listening, dull vowels and poor voice placement. In the case of pitching sharp, reasons include vocal tension, singing too energetically, and incomplete resonance (Telfer, 1995). Research in young voice has focused on pitch acquisition in the vocal development of the preadolescent child. Welch (1998) found a predictable sequence of pitch acquisition, from being word-focused to developing awareness of general melodic contours and pitch variation. Cooper (1995) found no difference in pitch accuracy between boys and girls although boys in year 4 pitched more accurately than boys in year 5. This may have reflected the development of gender variation noted in the voices of 10-year-olds by McAllister (2000) and 11 year-olds by White (2000). Other studies have found considerable gender variation in young children that teachers attributed to boys' inability to focus on or observe pitch changes, psychological inhibition towards singing, inability to co-ordinate the vocal mechanism, low speaking voice, lack of interest in singing, lack of practice in singing and lack of exposure to music in the home (Goetze, Cooper & Brown, 1990). Authors who recognized that changing voice may be a factor include Phillips (1992) (who ascribed this difficulty to register development and management), Cooper & Kuersteiner (1965), Swanson (1973), Collins (1981), Groom (1984) and Cooksey (1977a, 1977b, 1977c, 1978, 1992, 2000). Cooksey developed an 'eclectic theory of adolescent male voice change' that categorized the voice change process into six stages (Unchanged, Midvoice I, II, IIA, Newvoice and Emerging Adult). Of particular interest to this study is the lowering speaking fundamental frequency (SFo) as an indicator of a boy's progress through change (see Table 1).

Table 1. Cooksey's stages of male changing voice by speaking fundamental frequency (SFo).

Stage of Change	Average SFo range	Vocal Range
Unchanged	220-260 Hz [a3-c4]	220-698 Hz [a3-f5]
Midvoice I	220-247 Hz [a3-b3]	208 Hz-523 Hz [aflat3-c5]
Midvoice II	196-233 Hz [g3-a3]	175-392 or 440 Hz [f3-g4 or a4]
Midvoice IIA	175-185 Hz [f3-f#3]	147-370 Hz[d3-f#4]
Newvoice	131-165 Hz [c3-e3]	123-311 Hz [b2-d#4]
Emerging Adult Voice	110-139 Hz [a2-c#3]	98-293.66 Hz [g2-d4]

The purpose of this study was to investigate the extent to which the process of changing voice would interfere with a boy's ability to pitch perfect 4ths, 5ths and octaves – intervals that are associated with a strong harmonic line. Two categories of hypotheses were generated for this study – one investigating the boys' ability to pitch-match a given starting note, and the second to assess their accuracy when singing perfect 4ths, 5ths and octaves from the starting note chosen by the boy. It was hypothesized that 4ths and 5ths, being smaller intervals not necessarily requiring register change, would be sung most accurately. We also hypothesized that the

interval of an octave would be pitched less accurately because one of the two pitches may be outside the adolescent vocal tessitura and therefore may result in working 'too hard' to vocalise – leading to greater effort, inefficiency and pitching inaccuracy.

Method

Ethics approval was obtained from the Human Research Ethics Committee of the University of Sydney, Australia, from the New South Wales Department of Education and from principals of participating schools. Signed consent forms were obtained from the boys and their parents.

Procedure

Seventy-nine recordings were made of boys reading and singing the intervals of perfect 4th, perfect 5th and octave. The boys were asked about their previous singing training, and these varied from no experience (44.3% of the sample), to school choir experiences (49.4% of the sample) to private lessons (6.3% of the sample). The average SFo for boys in training was 180 Hz (f3) (range: 267.9-116.6 Hz [c4-a#2]), while the average SFo for boys not in training was 153 Hz (d#3) (range: 261.2-115.7 Hz). This would indicate either that voice training raised the average SFo, or that the boys not in training were physically more mature. Average age of the boys was 13y5m [range: 12y–14y7m.]) To assess speaking fundamental frequency (SFo), the boys were recorded reading '*Arthur, the Rat'*, with the fundamental frequencies of the whole passage averaged to give a mean SFo (reading). To assess intervallic singing pitch accuracy, the boys sang '*Happy Birthday'* which includes the intervals of perfect 4th, perfect 5th and octave. A starting note of 131 Hz [c3] and 262 Hz [c4] was given from a keyboard. These frequencies were chosen as the key of C is frequently used in the classroom, and this study wished to examine the response of boys undergoing voice change in this situation. It should be noted that 262 Hz (c4) approximates the SFo for unchanged voices, while 131 Hz (c3) is closer to the SFo for changed voices. These recordings were digitized over the range 0–16 kHz, using Phog Interactive Phonetography System. Fundamental frequency analysis of the intervals of a perfect 4th, 5th and octave as sung in '*Happy Birthday*' were undertaken using Soundswell program (Hitech, Sweden) on an IBM Thinkpad A30. For analysis, the signal sections of the vowels used in the interval leaps were selected and averaged (i.e. for the intervals of the 4th and 5th the vowels were /eI/ and /u/, and for the octave /I/ and /ɜ:/.) These data were arranged in descending SFo order as an indicator of stage of the boys' changing voice.

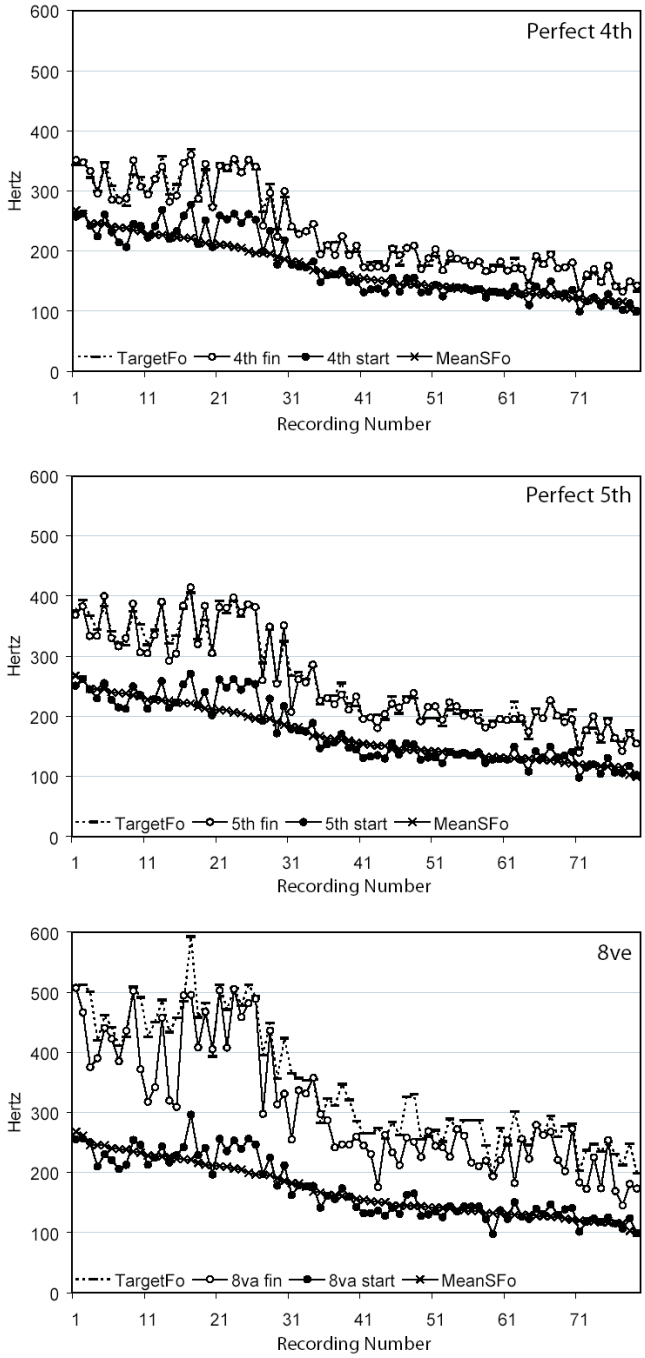

Figure 1. Mean SFo in descending order and attempt at perfect 4th, perfect 5th and octave with start and finish against target fundamental frequency (target Fo).

Results

Results are given in Figure 1. Each boy's ability to pitch-match to a given starting-note of 131 Hz or 262 Hz depended on his stage of voice-change. When their SFo reading was in the range 196.3–267.9 Hz [g3–c4] the boys tried to pitch-match to 262 Hz [c4]. Eleven attempts of 27 were in the range 252–272 Hz. Three attempts were the same as the boys' SFo, six were flatter than their SFo (but within a semitone), and two were more than a semitone flat of their SFo (reading). Even when the SFo was in the range 196–210 Hz, six attempts out of seven to pitch 262 Hz (c4) were in the range 246.4–261.9 Hz. When the SFo (reading) was in the range 167–196 Hz [e3–g3], matching to 131 or 262 Hz proved out of range, and the boys defaulted to their SFo pitch. Two attempts were sharp of the SFo, four attempts were flat of the SFo, and one attempt was pitch-matched to the SFo. Six of seven attempts were in the range 148.4–182.4 Hz. Boys whose SFo was in the range 137–167 Hz [d flat3–e3] attempted to sing the lower given note of 131 Hz [c3], with more successful attempts when SFo readings were lower than 154 Hz [d#3]. Of 22 attempts, eight attempts were pitch-matched to the SFo, and seven were able to pitch-match to 131 Hz (c3). Three attempts were sharp of the SFo and four were flatter than the SFo. For boys with a SFo reading of 99.48–136.2 Hz, the most successful attempts occurred when the SFo and given starting note were close. Of 22 attempts, seven in this range pitch-matched to 131 Hz, but the SFo for six of these attempts was also 131 Hz. Six attempts were sharper than the SFo and eight were flatter.

These attempts to pitch-match to a given starting-note confirmed the importance of a SFo of 196 Hz [g3] in the voice-change process as the point of change between attempting the upper starting note of 262 Hz [c4] or the lower starting note 131 Hz [c3]. In addition, when the SFo reading was above 196 Hz [g3], the overall frequency range used 200–520 Hz [g3–c5]. When the SFo was lower than 196 Hz [g3], the overall frequency range was in the range 100–360 Hz [g2–f4]. In Figure 1, this downward shift in singing pitch range can be seen between data points 28 and 29.

Analysis of intervallic pitching accuracy was based on the boys' relative pitching ability. Target pitches were calculated using the boy's starting note in Hertz for each interval and the appropriate ratio for that interval. For the perfect 4^{th}, the ratio was 4:3, for the perfect 5^{th}, the ratio was 3:2 and for the octave the ratio was 2:1. This produced a result using just temperament rather than equal temperament. On this basis, the perfect 4^{th} was sung most accurately, followed by the perfect 5^{th}. There was an unexpectedly large number of sharp attempts at the perfect 5^{th}: 41% were sharp – and this was particularly noticeable when the SFo was in the ranges 205–227 Hz (Cooksey's Midvoice II), and 136–150 Hz (Cooksey's Newvoice). Sharpness in the SFo 136–150 Hz range may have been due to the boy's mean SFo being just above the given note of 131 Hz, the boys' inability to perceive this difference and/or his developing skill-level in vocal muscular control. Least accurate was the octave with 51 attempts pitched lower than a semitone from the target (25 of these were a minor 3^{rd} or more flat). Twelve attempts were accurately pitched and six attempts were sharp.

To assess group trends, the results were analysed with boys grouped by SFo into Cooksey's stages of change, and the group data averaged (see Figure 2). This showed that irrespective of the starting note given, the boys relied heavily on their SFo as their starting point. For boys in Unchanged stage, SFo average was 264.5 Hz, and average starting note 260 Hz. SFo for Midvoice I stage averaged 233.12 Hz, and the starting note average was 239.2 Hz. Midvoice II boys (average SFo: 214.23 Hz) were attempting to pitch-match to 262 Hz (the average starting note was 242 Hz [range: 199–268.4 Hz], but as the SFo dropped into the Midvoice IIA range, the boys reverted to their SFo as their starting pitch 183 Hz [g flat3]. Newvoice boys defaulted to a starting pitch around 142 Hz [d flat3] – near their averaged SFo of 146 Hz, and emerging adult stage boys used starting pitches near their averaged SFo of 125 Hz [b2]–124 Hz.

The group trends for intervallic accuracy confirmed the hypotheses. The perfect 4th was accurately sung from the default starting note by boys in all stages (Unchanged stage attempts – average target 346 Hz, actual average 349 Hz; Midvoice I – target 319 Hz, actual average 314.66 Hz; Midvoice II – target 322.6 Hz, actual average 318 Hz; Midvoice IIA – target and actual average 245 Hz; Newvoice – target and actual average 189 Hz; Emerging Adult voice – target and actual average 166 Hz). This confirms that relative pitching of a perfect 4th is accurate. The perfect 5th was less accurate from the default starting note. For boys in Unchanged voice, the average target was 384 Hz; the average actual was 376 Hz. For boys in Midvoice I, the average target was 353 Hz, but the actual result was 350 and for Midvoice II, the target was 355 Hz, and the actual result 350 Hz. For Midvoice IIA, the result was less accurate – with an average target of 277 Hz, and an actual result of 266 Hz. Newvoice and Emerging Adult range attempts were the most accurate. For Newvoice, target and actual were 212 Hz, and for Emerging Adult – the target was 189 Hz and the actual average 187 Hz.

Attempts at the octave were inaccurate for all groups. For Unchanged voices, the average target was 512 Hz, but the actual average 486.65 Hz. For Midvoice I, the average target was 466 Hz, but the actual result 404 Hz, while Midvoice II target was 472 Hz, and the actual result 419 Hz. For Midvoice IIA, the target was 371 Hz, but the actual average 313 Hz. The target average for Newvoice stage attempts was 290 Hz, but the actual result was only 250 Hz, while Emerging Adult attempts target average was 273 Hz, but the actual average result 217 Hz. The evidence indicates that octave leaps require skills that need development in adolescent male changing voices.

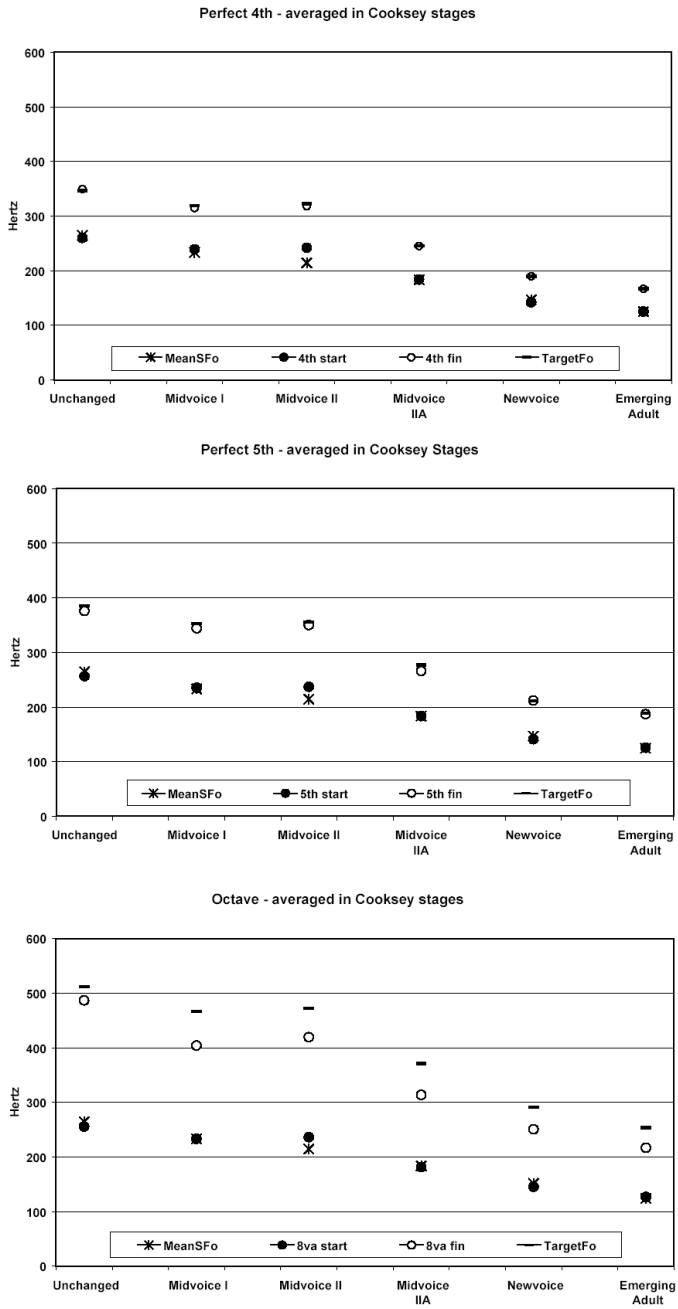

Figure 2. Data grouped by Cooksey Stages – Mean SFo in descending order and attempt at perfect 4th, perfect 5th and octave with start and finish against target fundamental frequency (target Fo) for each group.

Conclusions and implications

This study confirms Cooksey's findings (2000) that a SFo of 196 Hz [g3] is an accurate indicator of imminent change, and that boys use their SFo pitch as a singing reference point. Boys with a SFo of 196 Hz [g3] and higher use notes above this as part of their singing-pitch range, but this is difficult for boys with a SFo lower than 196 Hz [g3]. The SFo is therefore recommended as a pedagogical starting point for boys in singing difficulty and its use is recommended to teachers and choral directors as a guide to the appropriate key for boys at varying stages of vocal development. Because of the restricted vocal range experienced by boys in Cooksey's Midvoice II, melodic lines with narrower intervals such as perfect 4ths and 5ths are recommended over leaping octaves in vocal lines – these should be avoided for all boys in early stages of change. These narrower intervals were usually pitched either accurately or flat, although a high percentage of newly-changed voices (Cooksey's Newvoice category) pitched the perfect 5th sharp.

It is hoped that this study will encourage teachers and choral directors to research the changing voice and the developmental physiological changes involved. Both pitching accuracy and blending with other voices are significantly influenced by these physiological changes that young singers undergo during puberty. Understanding these changes will develop a realistic approach to the difficulties the boys are experiencing, and allow the development of further strategies to deal with this challenge. It is essential for the boys to develop new skills to overcome the temporary inefficiencies of their new vocal instrument, but these skills require practice and perseverance.

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