Adolescent voice classification in Australian high school choirs

Abstract

Untrained adolescent singing voices are very different to adult voices, yet most Australian high school choir leaders and composers continue to use the adult SATB model. This disconnect may result in discomfort, damage, sense of failure and be reflected in the current decline in choral singing in Australian high schools.

A case study of 70 students from an un-auditioned mixed voice Australian high school choir used the online voice analysis software, Praat to analyse students’ vocal parameters. Students were classified into vocal development stages using the leading models developed by Gackle and Cooksey as guidelines.

Boys’ voices reflected the six different stages described by Cooksey, but pitch, tessitura and mean spoken frequency (SF0) were all lower. Girls demonstrated three distinct development stages but the ranges, tessitura and SF0 were different to Gackle’s findings.

Untrained girls’ voices shared a similar range and tessitura; neither specifically alto nor soprano. No boys fitted the adult parameters of tenor, with boys in the middle of change often having a range of just a few tones. This study’s results support a fluid approach when assigning voice parts in SATB repertoire, with students moving to the part that best suits their voice, and music being modified to accommodate them.

Key Words:
Adolescent voice, Gackle, Cooksey, Praat
Note: C4 is middle C.

Background

Mixed voice choirs are the most common model in Australian co-educational high schools, combining boys and girls from the ages of 12 to 18. (Collins, 2012; S. Harrison, Cowley, Connell, & Southcott, 2008; S. D. Harrison, Welch, & Adler, 2012; Pascoe et al., 2005). The main challenge for conductors of these ensembles is that the majority of members have voices that are in some stage of change (Cevasco, 2008; Cooksey & Welch, 1998; Hower, 2006; Tipps, 2003).

John Cooksey’s model is the most widely accepted for classification of adolescent male voices. (Ashley, 2013; Cooksey, 2000; Freer, 2012b; Phillips, 1995; Thurman, 2012; E. C. Willis & Kenny, 2008). Lynn Gackle is the leading researcher on the changing adolescent girl’s voice. (Dillon, 2013; Gackle, 2011; Welch, 2006). Their research was performed in the UK, USA and Canada where the school systems are different, as is the approach to choral singing (Morton, 2004). No equivalent study has been performed in Australia.

Most Australian choral directors still classify their students according to traditional SATB criteria (Reneau, 2008). The National review of school education (Pascoe et al., 2005), SWOT Analysis of Choral Music (Pietch, 2008) and SWOT Analysis of Music Education (S. Harrison et al., 2008) highlighted the perilous condition of choirs in Australian high schools. Without knowledge of vocal characteristics, it is difficult for choral leaders to select appropriate music for their students or place them in suitable parts.
This case study mapped the vocal characteristics of a non-auditioned, Australian high school choir and applied and adapted the Cooksey and Gackle models’ parameters to classify the voices into vocal stages. Electronic voice analysis software, *Praat*, was used to ensure accuracy and consistency of measurement (Boersma & Weenink, 2015; Styler, 2016).

**John Cooksey’s Model**

There are six stages in Cooksey’s model: unchanged, Midvoice I, Midvoice II, Midvoice IIA (the climax of the change), New Voice and Emerging Adult. Most of the major laryngeal growth occurs during Mid Voice IIA and it can last up to twelve months. Few vocal parts are written for these voices and they are most vulnerable to damage. This is when many boys give up singing (Cooksey, 2000).

**Lynne Gackle’s Model**

Adolescent girls’ voices change during adolescence, but not nearly as dramatically as boys (Gackle, 2006; Sweet, 2015).

Gackle’s model focuses as much on vocal characteristics as range and tessitura. She describes ‘phases of change’ which influence the richness, depth and warmth of the voice. The presence and placement of transition points are also used as a categorizing tool. Her model has four stages: Unchanged, Pre-menarchal (Stage IIA), Post-menarchal (Stage IIB) and Mature (Young Adult) (Gackle, 1991, 2000, 2006, 2011; Reneau, 2008; Thurman & Klitzke, 1994).

Adolescent girls’ voices are neither alto or soprano and classifying them before their voices are mature is an area of concern (Alderson, 1979; Cooper & Kuersteiner, 1973; Gackle, 2006; Sweet, 2015).
Mean Spoken Fundamental Frequency

Mean spoken fundamental frequency (SF0) is a person’s average spoken pitch. Cooksey and Gackle used the SF0 as one of the criteria for classification (Cooksey, 2000; Gackle, 2006).

Phonation Gaps

‘Blank spots’ have been observed in some boys’ ranges, usually between C4 and F4. Cooksey found that they tended to occur at the end of Midvoice IIA and into New Voice.

Methodology

A case study of a mixed voice Australian high school choir was undertaken with detailed quantitative analysis of individual SF0, range, tessitura, transitions and phonation gaps (Duus, 2012; Elizabeth C. Willis & Kenny, 2011) and qualitative analysis of tone and spectrograms (Barrett, 2007; Reneau, 2008; Wolverton, 1993) using Praat voice analysis software (Boersma & Weenink, 2015; Styler, 2016). Data was analysed using SPSS statistical software.

Ethics approval was granted by the University of Newcastle and permission obtained from the Principal of St Columba Anglican School for students to participate in the case study. Participant Information Letters and Consent Forms were distributed to potential participants. Seventy completed consent forms were returned.
Students were tested individually using an Earthworks M30 condenser microphone and *Praat* voice analysis software which allowed the accurate recording and measurement of frequency (pitch) using spectrograms, which were also used for analysis of vocal quality.

**Voice Testing Procedure**

Each student was lead through the same gentle vocal warm up for one minute. Tests were recorded on *Praat* and frequencies read from spectrograms with a setting of 75-500 Hz autocorrelation analysis. Tests were repeated three times. Mean frequencies were calculated.

Spectrogram analysis used a long frame setting with a window length of 0.03 and range from 70 to 5000 Hz.

**Tests**

Spectrogram: sustained *ah* vowel sound on B3 (B2 for older boys). Scattering and formants observed. Spoken Fundamental Frequency: read *Rainbow Passage* using normal speaking voice. Mean pitch calculated from spectrogram. Range: *la, la* in semitones from near SF0 down to lowest sustainable pitch and then up to highest pitch. The ‘falsetto’ range of boys also measured where applicable. Tessitura: Sing/ hum *Advance Australia Fair/ Happy Birthday*, changing key until comfortable. Record candidate-selected tessitura range on *Praat* to *La*. Transitions: *Do Re Me Fa So Fa Me Re Do* in repeated phrases, moving *Do* up one semitone from the lowest comfortable pitch. Transitions observed aurally and measured from spectrograph. Phonation gap: slow glissandi working through each semitone, ascending and descending.

**Results**
70 students volunteered for the case study: 41 girls and 29 boys. Ten (14%) had had formal vocal training over the previous 12 months. The age range was from 12 to 18 years, with a mean of 14.71 and median of 15 years.

**Classification into vocal development stages**

The case study students were classified following Cooksey and Gackle’s parameters plus the researcher’s observations of the students’ vocal qualities. The resulting case study criteria are described as van Gend.

**Classification of boys**

Table One: Comparison of classification criteria: Cooksey vs van Gend

<table>
<thead>
<tr>
<th>Boy’s Vocal Stage</th>
<th>Spoken SFO (Hz)/Pitch</th>
<th>Range (Hz)/Pitch</th>
<th>Tessitura (Hz)/Pitch</th>
<th>Spectrogram/ Voice Qualities</th>
<th>Phonation gaps/instability</th>
<th>Transitions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mid Voice I</strong> van Gend</td>
<td>193-242 G3-B3 Mean 221.53 A3</td>
<td>187-679 F3#-E5/F5</td>
<td>219-439 A3-A4</td>
<td>As above. Generally strong voices with treble timbre.</td>
<td>Discomfort above A4</td>
<td>F4# B4</td>
</tr>
<tr>
<td><strong>Mid Voice II</strong> van Gend</td>
<td>186-215 F3#-A3 Mean 200.68 G3</td>
<td>175-676 E5-F5</td>
<td>192-360 G3-F4#</td>
<td>As above but no falsetto. Increased airiness and discomfort with narrowing of tessitura.</td>
<td></td>
<td>E4/F4 G4#/A4</td>
</tr>
<tr>
<td><strong>Mid Voice IIA</strong> Cooksey</td>
<td>174-185 F3-F3#</td>
<td>147-370 D3-F4#</td>
<td>185-294 F3#-D4</td>
<td>Turbulence in all registers with weakening upper AND lower partials. Fewest harmonics. Most unstable and least clear vocal quality.</td>
<td></td>
<td>E4-B4 to falsetto (G4 most common).</td>
</tr>
</tbody>
</table>
The St Columba case study (CS) demonstrated six phases of change with only one unchanged voice. There was a gradual lowering of SF0, low tessitura and low range at each stage. These frequencies were consistently lower than Cooksey’s means. The CS group showed a more marked drop in all frequencies from Mid Voice II to Mid Voice IIA than Cooksey’s model.

The CS students had wider ranges and tessitura than Cooksey’s model, except for Mid Voice IIA boys who demonstrated the same very limited tessitura and range.

Cooksey described falsetto appearing during Mid Voice II but no CS candidates demonstrated this until Mid Voice IIA and even then, it was unstable and uncomfortable without the particular qualities associated with falsetto. These boys were mostly untrained, so are unlikely to have the technique to access true falsetto (O’Connor, 2015). The range they produced above their second transition is probably more realistically described as head voice, as observed by Leck in his description of the boys ‘expanding’ voice (Leck, 2009). When

|---------------|----------|---------|--------|-------|--------|--------|---------|----------|---------|--------| |- | | | |
| New Voice Cooksey | | 131-165 | C3-E3 | 123-311 | B2-D4# | 147-233 | D3-A3# | Lower and upper partials increasing in strength. Some vibrato. | E4-F4 to falsetto |
| New Voice van Gend | | 95-163 | G2-E3 | Mean | 128.56 | C3 | 99.5-289 | G2-C4#/D4 | Falsetto | 541 Hz | C5# | 133-231 | C3-A3# | As above. Vocal tone richer and heavier. Voice stabilising but still fragile. Falsetto not secure. | D4-F4/F# | unstable, particularly with ascending passages. Gaps common. | G3 | D4# | Transition to falsetto F4# |
| Emerging Adult Cooksey | | 110-139 | A2-C3# | 98-294 | G2-D4 | 123-208 | B2-G3# | Some weakness in upper partials. Lower partials strong. No vibrato |

(Cooksey, 2000; Freer, 2012a; Welch, 2006)
falsetto/head range was included, the ranges of the CS group were considerably wider than Cooksey’s model, as he did not include falsetto/head. These ranges do not reflect singing capacity however, as the voices were light, unstable and often preceded by a phonation gap between C4-F4. Only the Emerging Adult CS boys had a smooth transition from mid to head voice.

Figure 1: Comparison of vocal parameters Cooksey vs van Gend (Hz)

Cooksey’s upper ranges seem limited, particularly for boys in the early stages of change (C5 and A4).

Tessitura was the best tool for assessing comfortable singing range for the CS boys and tended to sit between the SF0 and the second transition point. A boy’s spoken voice can be a
useful tool to indicate his development, but not enough to classify him. There was a wide
distribution of ages within each vocal development stage.

Vocal Quality

Vocal qualities played a significant role in CS classification (Table One). Observations of
turbulence and formants in spectrograms, discomfort in upper range, vocal clarity,
development of phonation gaps and ‘falsetto’ and richness of tone all informed the process.
As vocal change is constant, each classification has to be seen as a phase.

Transition points affected the comfort of singing, tonal changes and tessitura in the CS. They
were not included in Cooksey’s model yet were found to be a useful tool for the CS.
Phonation gaps tended to occur around the second transition point.

Classification of girls

Table Two: Comparison of Classification Criteria: Gackle vs van Gend

<table>
<thead>
<tr>
<th>Girl’s Vocal Stage</th>
<th>Spoken SF0(Hz) / Pitch</th>
<th>Range Hz/ Pitch</th>
<th>Tessitura Hz/ Pitch</th>
<th>Spectrogram/ Voice Qualities</th>
<th>Transitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stage IIA</td>
<td></td>
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<tr>
<td>Gackle</td>
<td>245-275 B3-C4#</td>
<td>220-784 A3-G5</td>
<td>294-587 D4-D5</td>
<td>Breathy tone across range. Difficulty in lower register. Difficult to create volume in middle and upper range. “Cracking” may occur. Singing may be uncomfortable.</td>
<td>One between F4-A4</td>
</tr>
<tr>
<td>Stage IIA</td>
<td>208-253 G3#-B3 Mean 234 A3#</td>
<td>201-696 G3-F5</td>
<td>239-460 A3#-A4#</td>
<td>As above but more discomfort in upper register than lower. Timbre similar to treble, but lighter and with some breathiness. Sounds “young”.</td>
<td>Two –approx. F4# and C5</td>
</tr>
<tr>
<td>van Gend</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Stage IIB</td>
<td>222-275 A3-C4#</td>
<td>220-698 A3-F5</td>
<td>247-523 B3-C5</td>
<td>Peak of change. Increased breathiness. Limited range. Timbre huskier and heavier with limited tessitura. Lower range easiest to produce.</td>
<td>Two F4-A4 D5-F#5</td>
</tr>
<tr>
<td>Stage IIB</td>
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<td></td>
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<tr>
<td>van Gend</td>
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</table>
The CS girls’ low range, tessitura and SF0 were all lower than Gackle’s model. Stage IIB (the phase of greatest change) was the lowest. The CS’s lower SF0’s could be due to different testing methodology. Gackle tested SF0 by counting backwards and then estimation on a keyboard, which has potential inadequacies (E. C Willis & Kenny, 2007).

Gackle’s model’s low range was A3. In the CS, the only girls who struggled to sing below A3 were 12 years old. Interestingly, the older girls with the most limited low range had trained voices (mean = G3#). The girls in Stage IIB, the period of greatest change, had the lowest mean range of F3 (179.86Hz).

The CS tessituras tended to lie between their SF0 and second transition. Three students in Stage IIB placed their tessituras between their SF0 and first transition. None included notes above their second transition in their tessitura. Girls in Gackle’s studies had much wider tessituras which extended beyond their second transition point.

Gackle’s Young Adult girls had one transition point, whereas all the girls in the CS showed two areas of transition. Transition point frequencies were remarkably consistent across the CS cohort with discomfort in both Stage IIA and Stage IIB at these points, particularly at second transition.
**Vocal Quality**

Table Two describes the vocal qualities observed at each stage. Breathiness, timbre, discomfort and stability were all important criteria. Spectrogram analysis showed airiness, creating scattering across upper registers for most girls, with more stable formants developing in Young Adults.

The strongest and most comfortably sustained sound was achieved between A3#- A4 for Stage IIA, A3- F4 for Stage IIB, and A3- C5 for Young Adult.
Many girls were unaware they had a head voice, and stopped at their second transition. When encouraged, they were able to access their head voice up to or near the mean ranges described in Table Two. Only eleven of the forty-one CS girls demonstrated a confident transition into their head voice and five of them were trained.

The trained girls had a consistently higher lower and upper tessitura, range and SF0 than the untrained girls in the same vocal development stage, but they demonstrated the same changes in vocal quality and comfort. The trained girls’ vocal parameters were the most similar to Gackle’s model which suggests that her test cohort may have had trained voices.

**Conclusion**

Adolescent voices go through several clear stages of mutation and this has an impact on their singing capacity. The vocal parameters of adolescents, particularly those with untrained voices, are not the same as adult voices. Adolescent voices are less stable, they may have difficulty sustaining volume and can experience discomfort, particularly in their head voices, during change. In some phases, such as Mid Voice II, their ranges do not fit any of the SATB parameters. Singing adult repertoire can result in discomfort, loss of confidence and damage. The models developed by Cooksey and Gackle serve as a useful scaffold, but candidates in this study showed significant differences in range and tessitura when compared to the models.

In day to day rehearsal situations, music can be modified to be more suitable for adolescent voices. Students should be encouraged to move to the part/s that best fits their voice, rather than staying in a rigid soprano, alto, tenor or bass position. By recognising and normalising the process of constant vocal change for adolescent singers, conductors can free the students
to respond to their voices. Girls should learn to sing their full range and boys be encouraged to find a place in the music where they can be comfortable and confident. This will be a vital step towards rebuilding Australia’s high school choir culture.

**Bibliography**


