Boiling frogs and tipping points:
Which sung pitch range is best for boys during voice change?

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Just before Easter, I was at a performance of one of the Bach Passions at a major London Cathedral. The boy soloist stepped out to sing the first soprano solo and his performance fell apart; he managed to sing about half of the notes but these were cracked and breathy, the other half just didn't come out. It was heart breaking; a child of 13 years old should not have been put in this position. Apparently, during the rehearsals and in the afternoon run-through, he was 'fine'. Perhaps someone hadn't noticed that he had grown taller and his speaking voice sounded different. Perhaps they weren't aware of the fragility of voices at this stage of development. Perhaps they just hoped that all would be all right on the night. So what can we learn from this situation?

The question of how and what boys should sing during adolescent voice change has challenged educators and choir leaders for the many years. The established historic and cultural practices can now be reassessed in the light of more recent quantitative analyses of vocal function. We have an emerging body of evidence that backs up the theories of the last fifty years. In the Cathedral choral tradition, boys have traditionally remained singing the soprano part (treble) until their adolescent laryngeal growth renders this either impractical or uncomfortable, or until they reach the upper age limit for the choir. In the twentieth century, there were several movements to suggest that boys could remain singing throughout puberty, but that their voice would develop more healthy phonatory habits in the longer term if they were encouraged to move down through the choral parts of alto, tenor or bass, alongside the lowering pitch of their speaking voice. In order to allocate the most appropriate vocal range, the boy's voice needs to be assessed frequently during his period of growth. Chronological age is only a guide for biological age; there will always be outliers at either end of the development distribution curve who will appear to be outside of the median developmental stage [1]. At worst, the decisions concerning the allocation of choral parts are based on chronological rather than biological age; for example, in many schools choirs all boys up to the age of 13 will sing treble, 13-14 alto and 14-16

tenor or bass. This fits the average vocal pitch ranges of each age group and it removes the need for individual assessment, but risks inappropriate labelling; many boys in this system will simply be unable to sing their allocated voice part due to their developmental mismatch with the average for their age. In many of the Cathedral foundations, the decision to remove a boy from the treble part will be based on perceived comfort levels; herein it is proposed that this method of evaluation is too subjective to be reliable.

In terms of research in this area, the principal investigator was initially John Cooksey, who assessed and monitored hundreds of boys' voices from the ages of 11 to 16 years [2]. He noted five distinct stages of voice change, measurable by assessing the average pitch of the boy's speaking voice. These five stages, assessed by listening, were subsequently compared alongside Tanner's five stages of physical development during adolescence, which are assessed by physical examination [3]. The physical and vocal stages of development were shown to occur simultaneously [4], and these are both known to be a direct consequence of increasing testosterone levels in the body [5]. As a result, we are confident to make an accurate judgement of the boy's overall adolescent growth stage simply by listening to his speaking voice.

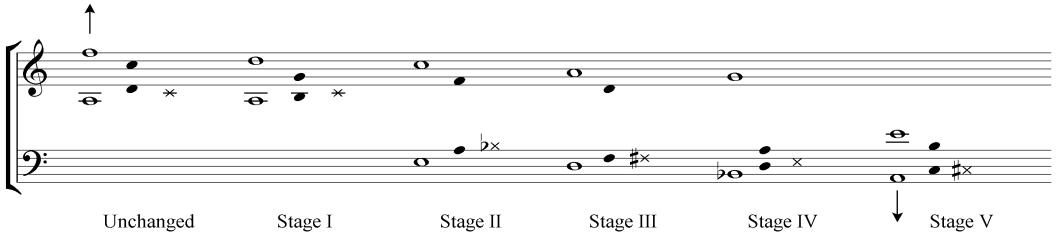

Figure 1 – The pitch ranges of each stage of male voice change [6]

- Extended singing range (unfilled note).
- Overall speech range (filled note).
- Speech fundamental frequency (cross).

This average fundamental frequency of the speaking voice can be assessed using various software apps. If these are not available, a rough measure (to the nearest +/- one semitone) can be ascertained simply by asking the boy to count backwards from 20 and noting the pitch at which his voice settles most comfortably; this pitch is

usually three to four semitones above his lowest comfortable singing pitch [7]. If the boy is singing outside of his most comfortable pitch range, there may be signs of vocal discomfort or strain. Observable signs of strain may be visual (increased jaw or neck tension) and aural (voice becoming hoarse, scratchy, breathy or constricted) [8]. These subjective criteria will nonetheless become increasingly evident beyond certain pitches. There tends to be more stability and less individual variation around the lower pitch range limit throughout the different stages of voice maturation than around the upper pitch range limit [9]. Therefore, it is more reliable to judge the developmental stage by the lower singing range and by the fundamental frequency of speech.

Adolescent Growth

The duration of puberty can be from eight months to over four years [10], commencing at any time between the ages of ten and fifteen; the average age of onset is 12.5 years [11]. Physical growth through adolescence is in growth spurts or stages. The growth of the larynx mirrors the observable overall growth of the individual [12]. If the individual is undergoing a growth spurt with a noticeable height gain, the larynx and its associated skeletal and muscular anatomy will be undergoing related enlargement. This is then followed by a period of stabilization. This growth pattern is caused by hormonal levels and cannot be accelerated or decelerated except by artificial hormonal input. The maximum change in pitch occurs at the same time as the maximum growth, between Tanner stages 3 and 4. Although the habitual pitch of the speaking voice is mainly dependent on vocal fold length; the noticeable drop in pitch observed between stages 3 and 4 is largely due to increased vocal fold mass more than sudden elongation of the vocal folds [13]. Skeletal growth and muscle mass are directly related [14]; an increase in skeletal size will usually result in increased muscle length. This increased muscle length precedes increased strength, affecting overall co-ordination. This mismatch in size and physical co-ordination is observable immediately following an overall growth spurt. The boy will not only have a skewed proprioceptive awareness of his body in relation to the world around him, he will also have reduced muscular co-ordination [15]. During this time, all his previously acquired motor skills will be compromised until his muscular strength catches up with the increase in muscular length. From this knowledge, we could infer that a boy whose larynx is growing rapidly may be less able to co-ordinate the fine adjustments

necessary for skilled vocal behavior. This could be an explanation for the reduced vocal range in mid-puberty as illustrated in Figure 1. It is also possible that this reduced coordination will result in measurable and audible instabilities in the voice, such as huskiness.

Measuring vocal efficiency and healthy function

The sheer number of variables to consider will confound any evaluation of best practice in singing: efficient muscular function, economic effort levels, and effective musical interpretation. Even attempts to pinpoint the most appropriate pitch range will bring associated caveats and subjectivity. Any singer will inevitably spend some of their time working at the extremes of vocal ability because it is often where the most exciting and emotionally driven vocalizing occurs [16]. The degree of balance between these extremes and 'comfort' will vary across individuals, depending partly on vocal technique and skill, but also on the particular robustness of their changing vocal system. Perceived levels of comfort have been used to evaluate technical efficiency across genres in singers [17]; however, this may not be appropriate when measuring subtle changes to comfort levels over time. Growth changes over time are not necessarily noticeable, as represented by the 'boiling frog syndrome' (It is said that if one drops a frog into a pot of boiling water, it will jump out. But if one places a frog in a pot of cool water and gradually increases the temperature, the frog will remain in the water until it is boiled). The boy will not necessarily be aware of the subtle alterations in phonatory efficiency within a particular pitch range if he is using that range on a daily basis.

Physical stress and anxiety levels

In all physical activity, efficient use is essential for injury prevention [18]. In singing, a decrease in efficiency will be linked to a compromised level of healthiness, whether or not the boy concerned perceives this. If taken further, a decrease in efficiency will incrementally increase the stress on the tissues that could eventually lead to a collapse of the system. Physical stress theory [19] states that a physical activity should function within the maintenance stress range of the individual, this depends on prior strength and training. An increase in levels of stress to the tissues, depending on the magnitude, time and direction of movement, will ultimately cause the system to reach the maximum stress threshold. This process, although requiring a gradual change over

time, will go unnoticed until the cumulative effect of this vocal behaviour passes the threshold of tolerance [20]. As the maximum stress threshold is reached, the ability of the system to perform the function will exhibit an acute response, the system will collapse with either a drastically reduced ability to function, or in some cases, acute pain. This appears to be a single event, and the singer will seek to identify it as such. It is, however, the result of a longer-term cumulative build-up of stress to the system.

This tipping point into system collapse fits with Catastrophe theory [21], in which cognitive anxiety is a factor alongside physiological arousal and performance outcomes. This is illustrated in Figure 2.

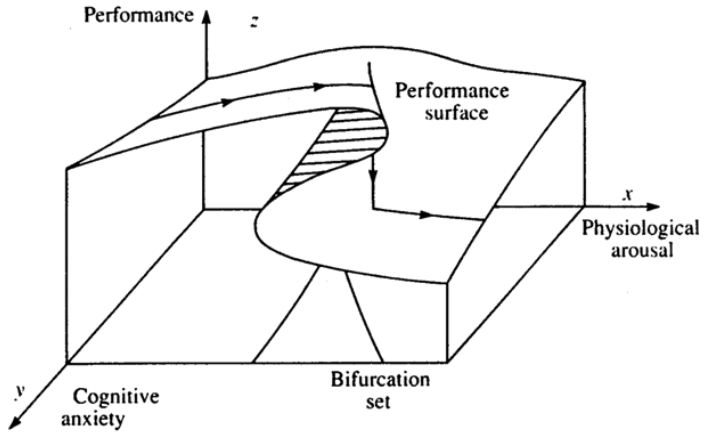

Figure 2: Catastrophe model of performance [21]

The inverted U from Yerkes-Dodson Law [22] relies on two variables: arousal and performance. As arousal increases so does performance, until a peak is reached whereupon any further increase in arousal will result in a decreasing level of performance. The addition of a third variable, that of an increase in cognitive anxiety, can lead to a significant bifurcation of the system, leading to a catastrophic change in performance outcome. This would suggest that collapse or injury is more likely to occur during the increased cognitive anxiety of a performance rather than during rehearsal, given that music performance anxiety (MPA) is highest at the beginning of a performance [23]. Cumulative trauma disorders from misuse or overuse will have a chronic build-up with a tipping point into acute symptoms [24]. The same can happen in the healthy function of the voice; performers who have experienced sudden voice loss will seek for ‘in the moment’ causality, whereas some functional voice loss is an

acute response to a chronic disorder [25]. In boys experiencing adolescent voice change who continue to sing in the treble pitch range, this acute response can manifest as a sudden inability to sing; hence the term 'voice-break'. There are many documented experiences of overnight voice-break; we know that this extent of growth is not possible overnight: the experience must in fact be the tipping point of functional collapse as a result of over-reaching the maximum stress threshold.

Suggestion for a model of best practice

The teenage boy will be experiencing this rapid level of growth for the first time, he will not necessarily know that the subtle changes in his vocal ability have the potential to cause a stress-related injury. His teachers and musical directors have a direct duty of care to advise him of the consequences of this, and to prevent it from happening by encouraging him to sing in his lower pitch range at the appropriate stage of his vocal development. It is possible that, as the larynx grows, the boy retains the ability to sing with the soprano (treble) sound. Although this has not been longitudinally assessed in boys undergoing voice change, the question to consider is whether this extended use of the upper pitch range is advisable during adolescent voice change, and if so, for how long. This can now be viewed in the light of evidence relating to the reduced efficiency of voice production, despite the appearance of comfortable, healthy phonation [9]; and secondly, the potential for sudden onset of voice loss as a result of accumulated stress.

These findings could inform the practice of singing teachers and choir trainers. The current advice to boys during voice change tends to be to sing in the lowest comfortable pitch range for the duration of this time. These results may suggest that it is possible to maintain a singing voice with a high tessitura, at least during some of the early stages of voice change, but at some point a judgment call will need to be made on the potential for injury. The Cooksey system of five stages may be a useful guide for less experienced teachers and singers. It is relatively simple to implement, and it is unlikely to be misinterpreted. The 'extended range' school may be more applicable to experienced boy singers, who may have a larger accessible pitch range. However, at some point during this period, the potential for sudden onset of voice loss will significantly increase. In addition to the incremental build-up, any additional increase in cognitive anxiety, such as during a performance, would additionally

increase the risk of sudden voice loss. Hence there would need to be expert judgment to know the safe duration for any extended period of higher-pitched singing for the changing voice. Consequently, it is recommended that the practice of singing with the extended range would need further research before it could be assumed to be based on a sound pedagogical judgment.

It has been shown that the attitude and effectiveness of the conductor are key elements for the effort, self-worth and success of boys' choir members [26, 27]; it would be assumed that a recognized choral foundation would be best placed to provide this experience for the children concerned. In the environment for this particular research, the training provided by the choral conductors for the boys tends to be primarily musical, without any specific reference to vocal technique. Many choral foundations also employ a singing teacher, in order to guide the boys in the healthiest voice use. However, singing teachers in the UK are not formally trained, licensed or regulated; specific knowledge of children's voices is generally gained through personal experience rather than structured training. Due to the paucity of knowledge of vocal health and singing pedagogy, the level of training offered to choristers in UK cathedrals is at best, variable.

Summary

The evidence from vocal health research, Physical Stress Theory and Catastrophe Theory, and the information derived from detailed acoustic analysis of voice production suggest that the appearance of relatively easy phonation in the upper pitch range can be deceptive. There is a high level of expertise needed in order to finely judge the approaching tipping point into vocal catastrophe, and this may in fact be impossible to anticipate. In order to ensure a safe and fulfilling musical experience for all concerned, it is recommended that until further research in undertaken, that the Cooksey system is implemented to evaluate the changing voice rather than the extended range system.

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