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Singing pitching accuracy from years 3 to 6 in a primary school

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1. ABSTRACT

A significant minority of children reach their teens unable to sing a note in tune against a reference played, for example, on a piano. It has been demonstrated previously that the use of the SINGAD (SINGing Assessment and Development) visual feedback system can enable accurate conscious pitching skills to be developed from the age of five years. This paper describes the SINGAD system in use and presents results gathered during an assessment of 177 children from years 3-6 (aged 8-11 years) inclusive of a York primary school during November 1993. The variation in pitching accuracy across the four years is discussed and boy/girl differences are considered.

2. INTRODUCTION

Human learning derives from our ability to make sense of our experiences [e.g. 1-7]. Our perceptions and conceptions shape our subsequent interactions with the environment in which we find ourselves. Children have a tendency to organise experiences in idiosyncratic ways, creating a constant challenge to their teachers. The tendency towards idiosyncracy can become especially problematic in the field of music education where they are operating in a temporal plane whilst making use predominantly of the auditory sense. It has been argued elsewhere [8-10] that one of the reasons that a significant number of schoolchildren have difficulty singing in-tune is because they are commonly placed in a classroom music situation where they are allowed to practice their mistakes; they are provided with inadequate and/or inappropriate feedback that is not very meaningful.

In an attempt to address this issue (and to interrogate further the underlying theoretical position), a computer-based system was designed and implemented, known as SINGAD (SINGing Assessment and Development), that could provide visual feedback of vocal pitch activity [11, 12]. The design drew on empirical research data that demonstrated the efficacy of visual feedback in the development of conscious pitch control [13]. The intention was to design an interactive system that provided real-time visual feedback and which could be used in the classroom with and without teacher involvement. SINGAD allows: (a) pitching ability to be quantitatively assessed against reference notes played by the computer and (b) the development of pitching skills by means of a real-time pitch line plotted on the screen. It has been demonstrated that the use of SINGAD can enable the development of vocal pitching skills in primary school children [14, 15].

This paper describes the results of an assessment of years 3 to 6 (pupils aged 8-11 years) inclusive in a York primary school in November 1993 to establish the range of vocal pitching abilities across these years at the start of a year-long SINGAD experiment.

3. THE SINGAD SYSTEM

The original version of SINGAD was written in BBC BASIC and 6502 assembler code [16, 17] and it gained its fundamental frequency (Fo) input from a peak-picking device originally designed for use with cochlear implants [18]. Experience highlighted three key limitations of the this version [11]: (1) the stimuli available from the internal loudspeaker of the BBC range of microcomputers could only be altered in amplitude and fundamental frequency which sometimes lead to a number of ambiguous pitched responses (most often octave errors) even from experienced singers, (2) the assessment data which could be stored for further analysis was limited by the available 32kBytes of RAM; in practice this meant that only the mean fundamental frequency of 255 cycles sung in response to each stimulus could be stored, and (3) the stimuli used for the assessment were randomly ordered single pitches which have little "musical" usefulness since pitch matching a single note is rarely required in a musical context.

These limitations were addressed in new version of the SINGAD system written for the Atari ST range of microcomputers [12] as follows: (1) the musical instrument digital interface (MIDI), available as standard on the Atari, was used so that any music synthesizer equipped with a MIDI could be used to play the musical stimuli, allowing the user to select any sound available on the synthesizer, (2) all F0 data sung by a subject in response to the SINGAD assessment stimuli could be stored enabling extensive analyses to be carried out at a later date, and (3) a library of stimuli were created, ranging from randomly ordered single notes to a series of patterns of 3 or 5 notes designed to form musically meaningful melodic fragments in a *major*, *minor* or *pentatonic* context; each set having available 5, 10 or 15 *trials*, each trial consisting of 1, 3 or 5 *stimuli*.

The Roland CP-40 pitch-to-MIDI converter has been used to record the F0 data from the subjects and a standard synthesizer is used to play the assessment stimuli. The software is written in Lattice ANSI 'C'. An example SINGAD assessment screen is shown in figure 1 with the F0 contour produced by a subject for trial 1. The user interface is entirely mouse driven apart from the need to type in filenames for data storage. The *INIT* and *HIDE* (toggles to *SHOW* when pressed) buttons shown in the figure allow the random order of the trials shown in 'piano-roll' format along the upper part of the screen to be changed and hidden (shown) respectively. (It is important that the subject is not in a position to make use of the displayed trial patterns during an assessment session, as the object of a SINGAD assessment is to measure the responses to an acoustic input in the absence of any visual feedback.) Other buttons allow the user to: see a *HELP* page, *RUN* the assessment session, *SAVE* assessment data to disk, *LOAD* assessment data from disk, *PRINT* the current screen (shown depressed to produce the screen dump), and *QUIT*. Pressing the left or right mouse buttons while pointing to the items in the narrow strip at the top of the screen allows the following to be altered: *tonality* (major, minor, pentatonic), number of *trials* (5, 10, 15), number of *stimuli* per trial (1, 3, 5), MIDI *velocity* of the played notes, *stimulus time* (length of each stimulus or note) in centiseconds (cs), and *inter stimulus time* (length of silence between each stimulus in a trial) in cs.

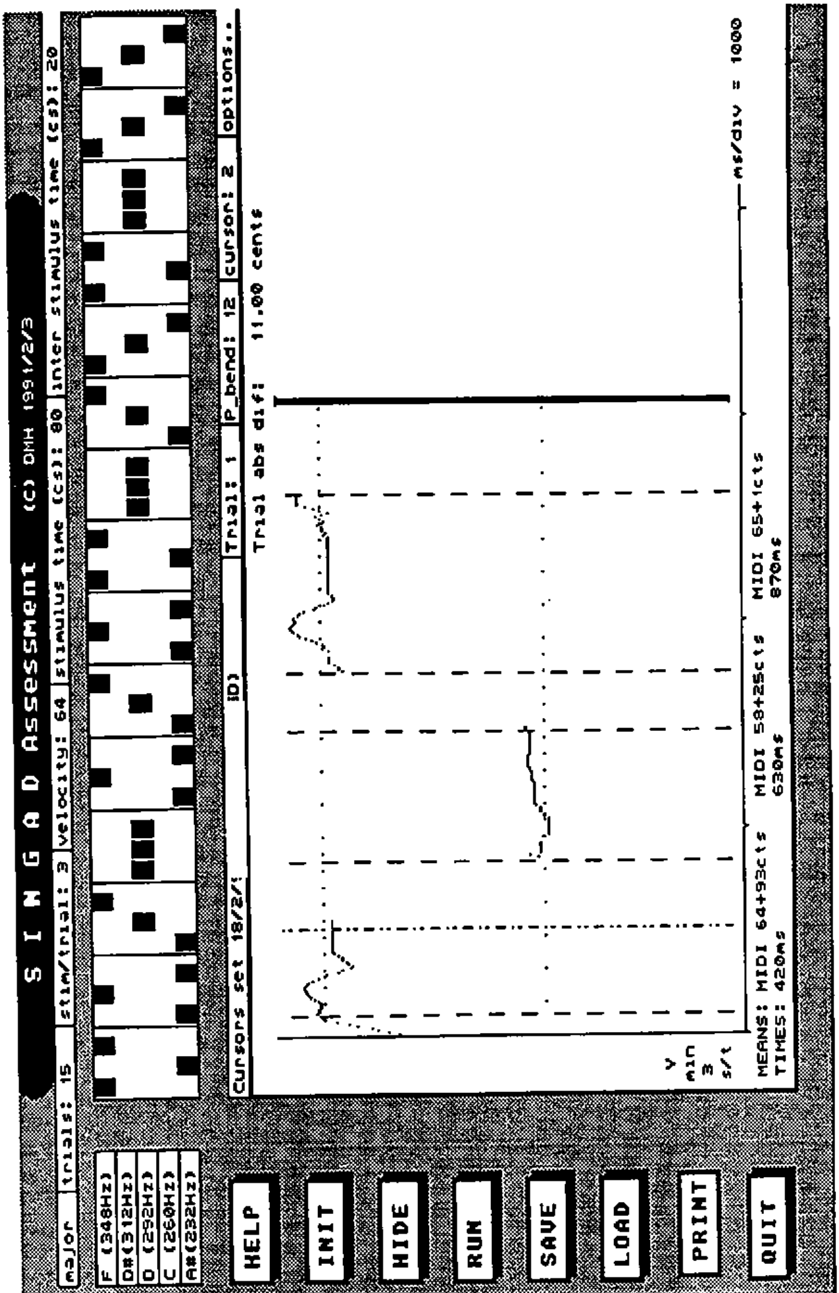

Figure 1: Example SINGAD assessment screen

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3. SUBJECTS AND DATA RECORDED

The subjects (N=177) were all pupils at Kingsway Junior School, Clifton, York. Subject numbers are given by class year in table 1, i.e. year three (aged 8) N=47; year four (aged 9) N=39; year five (aged 10) N=50; and year six (aged 11) N=41. Every pupil present in each class on the recording days was assessed. SINGAD assessments were carried out by two experimenters, each using an Atari SINGAD system set up at opposite corners of the school library. Sounds were played via piano patches on Roland expanders (sound canvas and D110) connected to Boss micro monitors.

YEAR	3	3	3	4	4	5	5	6	6
N	15	16	16	19	20	26	24	22	19

Table 1: Subject numbers by class year. (N = 177)

The choice of assessment stimuli was based on three factors: (1) a pitch range (b^b3 to f4) which would be comfortable for all subjects to sing, (2) a tonality (major) likely to be familiar to all subjects, and (3) musically meaningful patterns of notes (tonic mediant and dominant). Three stimuli per trial were used as five stimulus trials were considered too complex for the majority of subjects. The five stimulus patterns used for the experiment are shown in figure 2. In order to gain sufficient data to be representative for each subject, each trial was played 3 times and the 15 trials were randomly ordered. Each stimulus lasted for 80cs and the inter stimulus time was 20cs, thus stimuli were played at a rate of 1 per second in each trial. Thus each subject was required to respond to a total of 45 stimuli, and in the experiment as a whole 7,965 notes (45*177) were recorded.

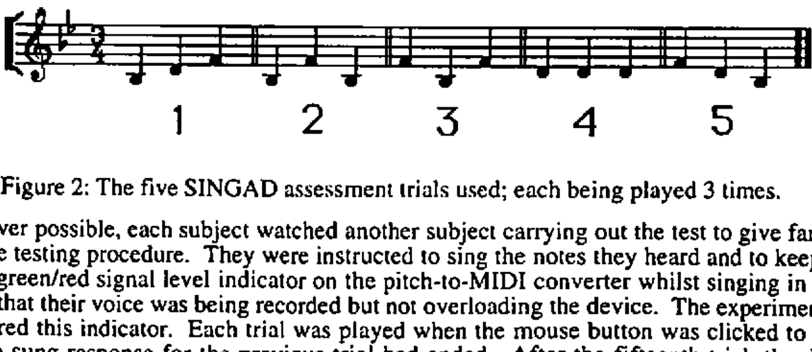

Figure 2: The five SINGAD assessment trials used; each being played 3 times.

Whenever possible, each subject watched another subject carrying out the test to give familiarity with the testing procedure. They were instructed to sing the notes they heard and to keep an eye on the green/red signal level indicator on the pitch-to-MIDI converter whilst singing in order to ensure that their voice was being recorded but not overloading the device. The experimenter also monitored this indicator. Each trial was played when the mouse button was clicked to indicate that the sung response for the previous trial had ended. After the fifteenth trial, the data was stored to disk for later analysis.

4. DATA ANALYSIS AND RESULTS

The F0 contours for each of the 15 trials for each subject were analysed by moving six cursors (see figure 1) to mark the start and end of each stimulus. This was carried out by hand for each of the 7,965 stimuli (a total of 15,930 cursor placements). The placement of the cursors is a matter of judgement due to, for example, vibrato, very short notes, and legato singing. In this experiment, all cursors were set by the same researcher. The SINGAD software calculates the following statistics for data between each pair of cursors: maximum F0, minimum F0, F0 mean, F0 standard deviation, the number of samples measured (sampling period is 5ms), the time between the cursors, and the average difference between the mean sung F0 values and the stimuli played.

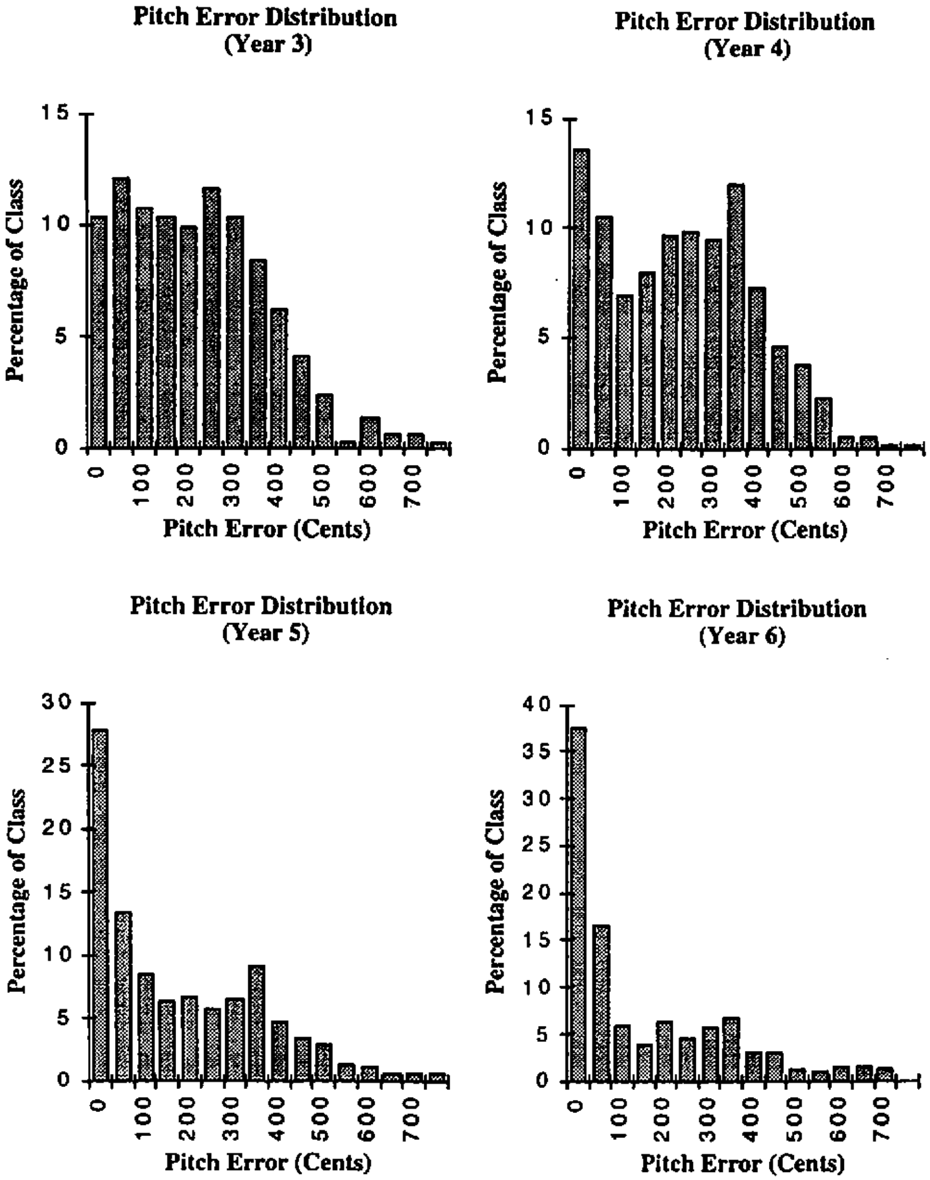

Figure 3: Mean absolute deviation from the stimulus in cents by year.
NB: year three (aged 8) N=47; year four (aged 9) N=39; year five (aged 10) N=50; year six (aged 11) N=41.

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At present, mean F0 measures are considered to be the most useful in terms of assessing pitching accuracy; perceptual experiments [e.g. 19] suggest that that the mean F0 value is an appropriate measure for notes of the duration used in the experiment.

SINGAD saves two files: a binary file for future loading to the program, and an ASCII summary results file of the F0 analyses. The ASCII summary files were transferred to a Macintosh computer and analysed via a spreadsheet (Excel) via a custom written Excel macro. The mean absolute deviation from the stimulus is plotted in figure 3, as a histogram, for each of the four years in the school. Note that the Y axis is plotted as a percentage of the total number of events in order to normalise the results and so allow comparisons between the years. The X axis is is plotted in cents where 100 cents equals one semitone. The bin sizes were set at 50 cents (half a semitone) as this provided a reasonable balance between measuring pitching accuracy and having sufficient events per bin to be useful.

5. DISCUSSION

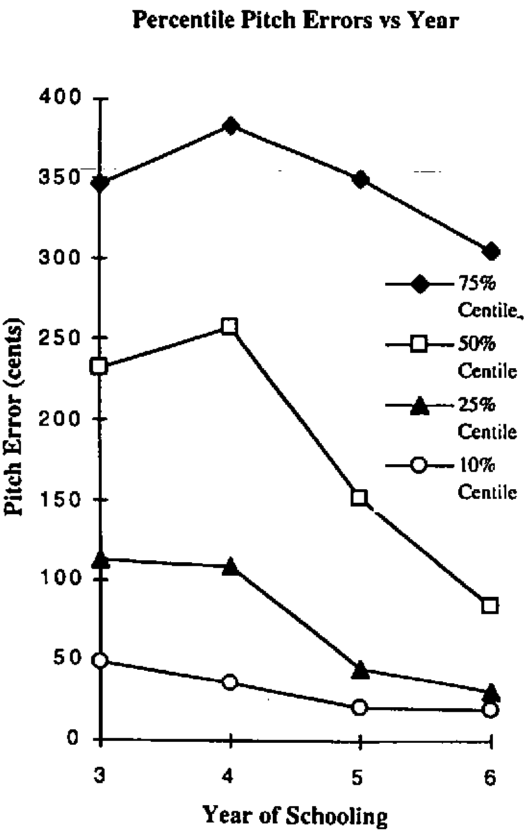

Figure 4: Percentile pitching error by year.

Analysis of the raw data (which confirmed observations made during the testing) reveals a range of vocal pitch matching behaviours. The most accurate singers were generally within a quarter of a tone, and the least accurate were up to a fourth away from the stimulus. Some subjects always phonated the same sequence of pitches regardless of the stimulus, or an inverted set of pitches such as F, Bb, F for Bb, F, Bb. This is reflected in the results which show a wide deviation and appear to be multimodal.

There is a peak at low errors which increases in height with increaing age of the subjects. However, there is also a peak around 350-400 cents which corresponds to a pitching error between a minor third (300 cents) and a major third (400 cents). It could be conjectured that if, for example, a child sang another note in the stimulus for a given note, it is likely to be in error by a major or minor third since the stimuli themselves were based on a major triad which consists of a major third (Bb to D) and a minor third (D to F).

The nature of the distributions makes it difficult to develop a simple one figure metric of children's pitching abilities.Using the mean is inadequate given the dramatic changes in the distributions between the years. A better way might be to measure the frequency error below which a certain proportion of the class fall, for example, the error achieved by 50% of the population. The data is shown in this form in figure 4 as a function of year of schooling for a variety of centiles. From these graphs one can see that even in year 6 there are children with poor vocal pitch accuracy. There is also evidence that even in the youngest year about 10% of the children can pitch well and so comparative improvement over the 4 years is less marked. The most sensitive measures of development seem to be the 25% and 50% centiles which show a considerable difference across the 4 years. These are plotted with respect to gender in figure 5.

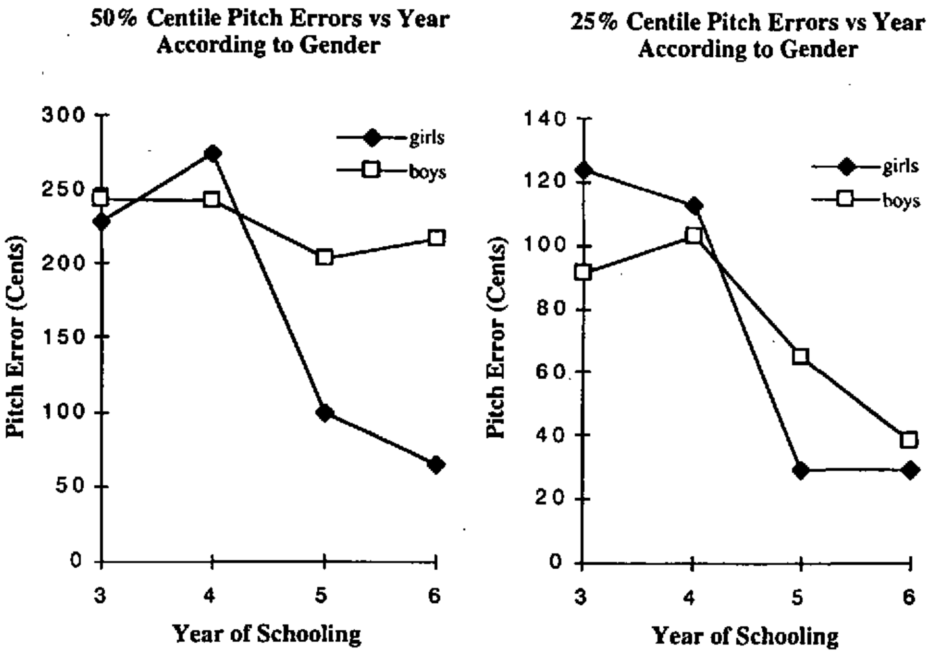

Figure 5: 50% and 25% centile pitching errors by year and gender.

6. CONCLUSIONS

Analysis of a singing assessment experiment for years 3 to 6 in a primary school has been carried out which suggests the following:

- a greater proportion of each class appears more accurate with increased age (see figure 4)
- for girls, years 5 and 6 appear much more accurate than years 3 and 4 (see figure 5)
- for boys, half of each age group appear persistently inaccurate in all four years (see figure 5)
- almost double the number of children are within a semitone in year 6 than in years 3 and 4 (see figure 3)
- the use of different percentile measures must be considered carefully in such work since they reveal a changing spread of abilities within each year.

7. ACKNOWLEDGEMENTS

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