THE EFFECTS OF MELODY AND HARMONY ON PITCHING ABILITY IN SIGHT-SINGING

Philip Fine, Department of Psychology, University of Buckingham

Anna Berry, Department of Psychology, University of Oxford

Address for correspondence:

Dr. Philip Fine, Department of Psychology,

University of Buckingham, Buckingham,

MK18 1EG

Email philip.fine@buck.ac.uk

Abstract

This study investigated the effects of melodic and harmonic coherence on sight-singing ability. Twenty-four experienced singers performed an interval singing task, and then sang at sight four novel pieces of music twice each, containing either easy or hard melody and easy or hard harmony. Both harder melody and harder harmony increased errors. Error rate correlated with interval singing performance, indicating the importance of both pattern-recognition and harmonic prediction in sight-singing. Singers made fewer errors on the second reading, indicating the importance of familiarity. A significant correlation between hesitation and overall error rate suggests an increasing role for internal auditory representations with increasing expertise. Finally, less skilled sight-singers were significantly more affected by a disruption in harmony than better sight-singers. Auditory representations seem more important for sight-singing than for most instrumental sight-reading. The findings are discussed in terms of a cognitive framework for pitch determination in sight-singing.

Introduction

The volume of research into sight-reading novel music has increased markedly over the last 15 years (see Sloboda 1984, 1985, Gabrielsson 1999 for reviews). Although sight-reading ability does not necessarily correlate with musical expertise (Wolf 1976, Waters, Townsend & Underwood 1998), it is nevertheless an important, even essential, skill for professional musicians to acquire (Sloboda 1978), particularly orchestral players, accompanists (Ericsson & Lehmann 1994) and choral singers.

Most sight-reading research has been carried out on pianists, few studies investigating other instruments, examples including the flute (Thompson 1987) and strings (Salzberg & Wang 1989). With the exception of Goolsby's research on eye movements (Goolsby 1994a, 1994b), the handful of papers on sight-singers (e.g. Sheldon 1998, Demorest 1998) have generally investigated the effects of rather than the processes involved in sight-singing.

Sight-singing and piano sight-reading differ, however, in a number of important ways. One main difference is the extent to which pitch production is internalised. Despite findings that internal auditory representations are involved in piano sight-reading (Waters et al 1998, Townsend 1997), pianists can still translate the visual stimulus (score) into a motor response (pressing the correct piano key) without knowing the note's pitch internally. However, singers *must* know the sound of any note before its production, and this presumably involves working out its pitch internally. Indeed, singers need a starting note when performing (in the absence of absolute pitch), whereas pianists do not. Another important difference is that, unlike pianists, singers rarely perform by themselves, but more often with other singers, orchestral players or a piano. These other parts therefore potentially provide cues to the pitches to be sung. Certainly, there are no studies in the sight-reading literature where the pianist hears other lines of music simultaneously. Personal experience and anecdotal evidence from singers suggests that these other parts are of great importance in determining the notes to be sung. The present paper is concerned specifically with the influence of other parts on sight-singing ability.

Music sight-reading is normally thought of as a transcription task (cf. Shaffer 1978, 1982), such as copy-typing or reading aloud. Like reading text, it can be fractionated into cognitive sub-tasks and operations: perceptual processes (pattern-recognition, expectation); translation processes from visual / auditory to motor responses; and the formation of auditory representations (e.g. Waters et al 1998). Pattern-recognition ability has been shown to be important in sight-reading. There is a strong correlation between sight-reading skill and the ability to report groups of briefly presented notes (Bean 1938, Salis 1980, Sloboda 1976, 1978), perhaps akin to chess masters' ability to recall board positions (Chase & Simon 1973). This seems due to the use of a more efficient and possibly qualitatively different mechanism (Sloboda 1984). Waters et al (1998) demonstrated correlations between pianists' sight-reading skill with single note recognition speed, with recall of briefly presented music and with pattern matching ability of music (Waters, Underwood & Findlay 1997). Pianists' eye-hand span has also been shown to be related to sight-reading ability (Furneaux & Land 1999, Sloboda 1974, 1977), as has flautists' eye-performance span (Thompson 1987). Expert sight-readers' eye-hand span tends not just to be larger but also expands or contracts to coincide with phrase boundaries, suggesting the processing of higher-order structures (Sloboda 1984). Further evidence from eye-movement research (e.g. Waters et al 1997, Waters & Underwood 1998, Goolsby 1994a, 1994b, Rayner & Pollatsek 1997, Truitt, Clifton, Pollatsek & Rayner 1997, Kinsler & Carpenter 1995) indicates that highly skilled readers scan larger units, sometimes with briefer fixations, and that their fixation pattern is more likely to depend on the type of music being read.

Prediction and expectation of the subsequent note(s) to be performed are important cues. As musicians become more knowledgeable of the conventions of harmony and musical structure, they are more likely to employ prediction. In so called proof-reading errors, skilled pianists play what they expect rather than printed errors (Wolf 1976, Sloboda 1976). Priming studies have shown that one chord can influence the processing of subsequent chords (Waters et al 1998, Bharucha 1987, Bharucha & Stoekig 1986). Furthermore, the formation of internal auditory representations is likely to be important in sight-reading, as shown by correlations between sight-reading ability and ability to memorise music from notation (Eaton 1978, Nuki 1984) and improvisation ability (McPherson 1995). Waters et al (1998) suggest firstly that auditory imaging may allow performers to monitor their reading and secondly that this auditory representation is needed for the priming and predictive ability already mentioned. Ward & Burns (1978) have provided some evidence for the first of these suggestions by showing that auditory feedback is used by singers to keep themselves in tune, although removing auditory feedback only impairs pianists' expressive aspects of performance (Repp 1999) and not their sight-reading ability (Banton 1995). It seems, then, that pattern-recognition, predictive ability and internal auditory representations are all integral to sight-reading ability.

The two principle aims of this paper, then, are to investigate a) the influence of other lines of music on sight-singing ability, and b) whether pattern-recognition and predictive ability are as important in sight-singing as in piano sight-reading. Melody was disrupted in an attempt to interfere with pattern recognition. Disruption of harmony was done to interfere with prediction. The present experiment is a necessary preliminary to future research on the importance of auditory representations in sight-singing.

Method

Subjects

Twenty-four experienced choral singers, mostly members of an accomplished choir, took part. Their experience of singing regularly in choirs ranged between 2 and 44 years, but, by their own estimation, they were all of a fairly high sight-singing standard. The number of instruments played and years of piano playing experience were also recorded.

Stimuli

The interval singing test consisted of 10 written pairs of notes, of different intervals, both ascending and descending, constructed so that consecutive intervals were as unrelated as possible. There was one set of stimuli for each SATB (soprano, alto, tenor, bass) voice range. The initial stimuli in the sight-singing tests were 4 different Bach chorales, all in 4/4 time. They were between 9 and 15 bars long , were homophonic in nature and had fairly simple rhythm. Each original chorale was then manipulated as follows. In the harmony manipulation the subject's part was left unchanged, but the other three parts were altered so as to make the harmony discordant and unpredictable. In the melody manipulation, the subject's part was made visually more random and jumpy but it still fitted harmonically with the other three parts, which were unchanged. Each harmony or melody manipulation was carried out for each of the SATB parts. In the hardest condition, both the harmony and melody were disrupted so that the piece was quasi-random, but with the same rhythmic structure and sometimes the same contour structure as the original chorale. This resulted in a total of 40 stimuli: 4 original chorales, 4 hard harmony / hard melody stimuli, and 16 each of hard harmony or hard melody stimuli.

The interval singing test involved responding to a heard tone, and the sight-singing test required subjects to hear the other parts. All these auditory stimuli were played on a Clavinova and recorded onto cassette tapes, which the subjects heard whilst responding. The tapes also contained full verbal instructions. Subjects' responses on both tasks were recorded with a second tape machine for subsequent scoring.

Procedure

First, each subject performed the interval singing test. On each trial the subject was shown the written interval and heard the first note from the tape, and then sang the interval. Subsequent trials were obscured so that intervals could not be worked out in advance. For the sight-singing tests, the subjects sang the four chorales, one for each condition, with a second (consecutive) attempt at each. The chorales' speed was 50 beats per minute and the other 3 parts were heard during the singing. The order of chorales and order of conditions (original chorale, hard harmony, hard melody, and both hard harmony and hard melody) were counterbalanced between subjects. Before each chorale, one bar of beats (or three beats if the music began on the up-beat) was given on the tone which was the subject's first note. Hence the subject knew when and on what note to come in.

Results

The interval singing test was scored out of twenty. Two marks were awarded for a correct interval produced within 1.5 seconds. A correct interval but with a delay of more than 1.5 seconds gained one mark, a delay indicating less developed pattern-recognition, albeit with some melodic ability. An incorrect interval or no response gained no marks. Performance was wide ranging with a mean of 9.52 ± 4.45.

In the sight-singing test, rhythmic errors were ignored, and marks were awarded on the basis of pitch alone. Each note was marked out of three: one mark for singing anything, i.e. not getting lost; two marks for singing the correct note but with hesitation or correction; and three marks for a perfect performance. One type of error, especially prevalent in the hard harmony condition, was an initial mistake followed by singing the next section correctly within itself but transposed up or down. When this occurred, productions were marked twice, once indicating how many incorrect intervals were sung (interval errors E_I) and once measuring how many incorrect notes were sung (note errors E_N). A percentage error score for each attempt at each piece (for both E_I and E_N scores) was calculated. Results appear in Table 1.

Table 1

Percentage errors on sight-singing tasks as a function of harmony, melody and attempt.

	Easy harmony				Hard harmony			
Attempt	**Easy melody**		**Hard melody**		**Easy melody**		**Hard melody**	
	E_N	**E_I**	**E_N**	**E_I**	**E_N**	**E_I**	**E_N**	**E_I**
1	7.8	7.2	27.8	27.1	28.3	24.5	49.4	47.4
2	4.5	4.5	25.0	25.0	25.2	19.8	46.0	44.4

Arcsin transformations were carried out (Hays 1993) on the proportion error data prior to running two 3-way (harmony x melody x attempt) repeated-measures ANOVAs, one for E_I and one for E_N. Harmony was highly significant for both E_I ($F(1,23) = 42.91, p < 0.001$) and E_N ($F(1,23) = 51.66, p < 0.001$), less coherent harmony leading to more errors. Melody was also highly significant for both E_I ($F(1,23) = 62.71, p < 0.001$) and E_N ($F(1,23) = 53.28, p < 0.001$), with harder melody leading to more errors. Significantly fewer errors were made on the second attempt than the first for E_I ($F(1,23) = 5.93, p < 0.05$) and E_N ($F(1,23) = 5.46, p < 0.05$). There were no significant interactions.

On the basis of overall error scores, the subjects were divided into two groups for sight-singing ability. Results are shown in Table 2. Two four-way (harmony x melody x attempt x group) mixed ANOVAs were now carried out, again on arcsin transformed data, for E_I and E_N. Group was highly significant in E_I ($F(1,22) = 42.81, p < 0.001$) and E_N ($F(1,22) = 40.24, p < 0.001$), indicating a meaningful group division. Group by harmony was significant for E_I ($F(1,22) = 7.77, p < 0.05$) and E_N ($F(1,22) = 4.65, p < 0.001$), less skilled readers being more affected by hard harmony than better readers. No other interactions approached significance.

Table 2

Percentage errors on sight-singing tasks, splitting subjects into two groups according to sight-singing ability.

		More skilled readers				Less skilled readers			
		Easy melody		**Hard melody**		**Easy melody**		**Hard melody**	
Harmony	**Attempt**	E_N	E_I	E_N	E_I	E_N	E_I	E_N	E_I
Easy	**1**	0.7	0.7	19.1	19.1	15.0	13.6	36.5	35.5
	2	0.3	0.3	16.3	16.3	8.7	8.7	33.8	33.8
Hard	**1**	12.5	9.6	40.8	36.8	44.2	39.3	57.0	58.0
	2	11.3	5.0	34.9	32.9	39.0	34.6	57.0	55.8

Two Spearman correlations compared the number of hesitations with overall sight-singing performance, for E_I and E_N. Unfortunately the hesitation data for two subjects were lost, so this analysis used data from 22 subjects. This correlation proved to be significant for both E_I ($r_s = 0.4363, p < 0.05$) and E_N ($r_s = 0.5129, p < 0.02$). Less skilled sight-singers made more hesitations.

Two final sets of Spearman correlations were carried out, comparing interval test scores, overall sight-singing error scores, the number of years' singing experience, the number of years playing the piano and the total number of instruments played. The results are shown in Table 3. More skilled sight-singers tended to perform better on the interval test (E_I $r_s = .5820, p < 0.01$; E_N $r_s = .5644, p < 0.01$) and have more singing experience (E_I $r_s = .4466, p < 0.02$; E_N $r_s = .4486, p < 0.02$). The number of years playing the piano correlated with the total number of instruments played ($r_s = .4723, p < 0.02$).

Table 3

Spearman correlation coefficients r_s between test performance and musical training.

		Singing experience	**Interval test**	**Piano experience**	**No. of instruments**
Interval test		.1761			
Piano experience		.0339	.1025		
No. of instruments		-.1736	-.1023	.4723*	
Sight-singing errors	**E_N**	-.4486*	-.5644**	-.2003	-.0410
Sight-singing errors	**E_I**	-.4466*	-.5820**	-.1714	.0270

* $p < .02$; ** $p < .01$

Discussion

This study investigated sight-singing performance as a function of melodic and harmonic difficulty. Our results indicate that interval singing performance correlates with sight-singing performance, and disrupting the sung line (i.e. harder melody) impairs sight-singing performance. This melodic disruption tended to increase the size and variability of the presented intervals, interfering with more extended pattern recognition, such as scales or repeating motifs, and hence decreasing sight-singing performance. In agreement with previous findings (Waters et al 1998, Sloboda 1977, 1984) that more skilled sight-readers have better pattern matching abilities, the findings suggest either that certain intervals are easier to read than others or that prediction improves with increasing sight-singing skill. Disrupting the line even without altering the harmonic constraints of the piece impairs these predictive abilities (e.g. Waters et al 1998).

Disrupting harmonic coherence also impaired sight-singing ability. Modern, atonal music is much harder to sing, especially at sight, than tonal music from the classical or earlier periods, due to the feeling that the singer "knows where the piece is going". This is due to the composers' use of harmonic cadences and structures together with the readers' predictive ability based on priming (Waters et al 1998). Prediction becomes harder in atonal harmony, and there is a greater likelihood of singing incorrect notes. Furthermore, auditory feedback cannot be used to correct the note if the singer is either unaware of the error or does not have enough time available. Indeed, singers skilled at interval (pattern) recognition can transpose an extended section of a piece (an E_I error), sometimes without realising. This can only be corrected when the music reaches a point at which prediction makes the difference between the sung pitch and the required pitch clear and explicit. With the exception of three subjects, all errors of this type were made in hard harmony conditions.

Auditory feedback can be seen both in increased hesitation in less skilled sight-singers and in the "swoops" that less skilled sight-singers sometimes produce before eventually landing on the right note, suggesting that the formation of the auditory representation develops with increasing experience and skill. Singers become less accurate in their tuning, more so for less experienced singers, when deprived of feedback from their voices by white noise delivered to the ears (Ward & Burns 1978, Sundberg 1987). It is likely that auditory information from other parts is also used in the same way. In this study, the other three parts were both seen and heard. Their resulting auditory cues are probably more important than their visual cues for providing feedback. When the subjects were split into two groups on the basis of their sight-singing performance, the less skilled group was significantly more affected by hard harmony than the more skilled group. This suggests that less skilled readers rely more on harmonic cues than more skilled readers, or at least are less willing to ignore them in atonal circumstances. More skilled readers may also rely to a greater extent on their interval singing abilities.

Finally, each piece of music was sung through twice, in two successive attempts. The second reading was significantly better than the first, illustrating the importance of familiarity on sight-singing performance.

Sight-reading novel music involves many factors, and the precise nature of the tasks involved depends on the instrument in question. In singing, unlike keyboard instruments, a single note is produced at a time, and the level of proprioception involved is much smaller for singing than for virtually any other instrument (Sundberg 1987). Although auditory representations have been shown to be involved in piano sight-reading (Waters et al 1998, Townsend 1997), we believe that they are perhaps of less importance than in singing. Certainly pianists can play the first note of a piece cold, showing that piano playing does not in fact necessitate inwardly hearing the pitch of the notes being produced, but singers (without absolute pitch) must hear and have named a note in order to start a piece correctly. In strings and woodwind instruments, tuning requires inwardly hearing the notes, but once the fingers (and bow for stringed instruments) are in the correct places, roughly the right note will be produced, even in the absence of an auditory representation. However, for singers (and to an extent brass players), it is of vital importance to know what the next note will sound like before producing it. We have little conscious proprioceptive feedback from the vocal cords, although unconscious feedback is developed naturally to assist us in speaking (Sundberg 1987). But singing training and experience do enable the development of a "muscle memory for pitch" in singers (Sundberg 1987). Indeed, singers report that by using what is called "relative pitch" they can sometimes know if they are more than a tone or two out, sensing whether the note being sung "feels" too high or low in the vocal cords. However, this proprioceptive memory is rarely precise. This argues for the necessity of a pre-formed internal auditory representation in enabling correct pitch production.

The framework shown in Figure 1 provides a succinct way of representing these processes. It is not explicitly based on previous models, but is designed to accommodate both the present data and anecdotal evidence from singers. It includes the importance of interval recognition and prediction, and the role of both auditory representations and auditory feedback. It also shows the importance of harmony in multi-part music.

The individual processes, such as interval recognition and the formation of auditory representations, develop with experience. More skilled sight-singers tend to have better interval singing (i.e. pattern perception), are better at multimodal integration (combining the auditory cues and the visual score), and have better predictive abilities than less skilled sight-singers, although they are also more able to ignore harmony when it is atonal and therefore not helpful or even disruptive to pitch determination. More skilled sight-singers also tend to produce fewer swoops and hesitations, suggesting a more developed internal auditory representation, together with a more advanced proprioceptive "muscle memory" in the vocal cords. They probably also make more use of auditory feedback, even in atonal music.

The present findings suggest that the formation of auditory representations is an important skill in the development of sight-singing. Falkner, in his book on voice training, notes "It is a good habit to hear a note before it is sung" and ear training and playing by ear are important in the development of musical literacy, performance skill and creative musicianship (Seashore 1938 / 1967, Falkner 1983). Indeed the Kodaly method of music training emphasised the development of aural imagination or the "inner ear" in teaching sight-reading skills (Hargreaves 1986). Thus perhaps the first step in acquiring sight-singing skill is to adopt an integrated auditory and notational form of music tuition.

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