THE RECOGNITION VALUE OF THE STEPS OF THE DIATONIC SCALE

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The notes or steps of the major diatonic scale may be designated by the familiar names *do, re, mi, fa, sol, la, si.* The object of the present experiment was to study the relative recognition values of these seven scale notes. The equally tempered diatonic scale was used.

A scale note, like *mi* or *sol,* is not a tone of a fixed frequency but a pitch that has a definite relation to the key-note. As a stimulus it exists, therefore, only in the tonal context that defines the key. The behavior of tones in a melodic series is governed by a number of laws, and, if these laws are broken, the tones lose their character as scale notes and the series of tones loses its established key.

The stimuli used in this experiment were melodic fragments, seven notes long. They are called melodic fragments because each note in the series obeys the melodic laws that govern the scale-step that the note represents. In any such series, the seven notes would mutually define one another as scale-notes, the first three or four notes bearing nearly all the burden of establishing the key. In order to keep this task entirely outside the series proper, each stimulus was preceded by a perfect cadence, which completely established the key.

Each scale-note was used once in each tune. All the notes in a tune lay within the compass of an octave. A tune might, for example, involve the seven scale steps as follows: *si, do, mi, re, sol, la, fa;* with *mi* occupying the highest pitch position and *fa* the lowest. The tune might be pitched at any absolute level that is within a reasonable vocal compass. The procedure was to establish the key first with a perfect cadence (the dominant and tonic chords), then play the tune, pause, and then repeat the tune with one of the notes changed half a step toward the next higher or lower scale note. *S* was instructed to write down the number of the note which he thought had been changed, whether it was the first, second, third, etc.

In the tune any one of the scale notes could be crucial, *i.e.,* changed on the repetition of the tune. Let us suppose that it is the second scale note, *re,* that is crucial. Then *S* should answer with the number "4," because it is the fourth note in the series that was changed. A system of numbering was devised so that the tunes could be catalogued according to their use. The tune we are discussing now would be catalogued as 24, because the second note of the scale, occurring as the fourth note in the tune, is the crucial note.

A test consisted of 49 tunes. This number was chosen so that each note could appear as crucial in each of the seven serial positions. After every seven problems *S* was allowed to rest a little. In each of these subgroups of seven tunes each note appeared but once. All other matters of arrangement were settled by chance, so that no principle of order could be discovered by *S.* The crucial note could have any rank anywhere in pitch with reference to the other six notes in the tune. Every note occurred once as crucial in each of the seven pitch-ranks in the course of any one

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test. The relation of pitch-rank and serial rank of the crucial note was settled by chance in each test, but, since seven tests were used, it was possible to exhaust all 49 possibilities for each scale step. The absolute pitch of the tune was also determined by chance, but no tune was allowed to go below the *G* an octave and a fourth below middle *C*, or above the *G* an octave and a fifth above middle *C*. In other words, no tune went below the easy compass of a bass voice or above that of a soprano voice. This method of deciding the absolute pitch of the tune by chance resulted in the use of all 12 major keys at random during the test.

Administration of the Tests

The tests were given to undergraduate classes in psychology, which varied in size from 30 to 60 students. The administration of a test lasted about 40 min. Every *S* received a blank having seven rows of seven spaces each. The method of taking the test was first explained carefully, and then a practice problem was played and repeated until all the *S*s could hear the change. They were then required to record the number representing the sequential position of the note changed. These numbers were entered in the spaces from left to right so that when seven problems had been played, each blank in the first row contained an answer. At the end of every row, a short rest was taken, during which the *S*s might ask questions. No omissions were allowed. The *S*s were required to guess when they did not know the proper answer.

Immediately before each pair of tunes two chords were played. These chords served a double purpose. In the first place, they were a warning that the problem was to be presented and *S* was thereby prepared for the beginning of the problem. In the second place, the chords, constituting a perfect cadence in the key of the melody, served to establish its tonality. The second of these two functions was essential. Unless the key is established before the problem is played, the first few notes of the standard have to bear the burden of establishing tonality.

If the previous problem has been in another key, then the first few notes of the new problem may easily be misunderstood as members of the other key. The warning chords, however, were sufficient to destroy the perseveration of the previous key and made it possible for every note to appear as a member of the intended key. Since the rigid specifications under which the tunes were written sometimes interfered with their conforming to melodic laws to the fullest degree, a firm establishment of the key prevented any ambiguity that might result from slightly implausible melodic sequences.

The tests were played on a harmonium, with a single eight-foot stop drawn. This instrument was preferable to a piano because, when the bellows are kept full, it gives tones of equal loudness and there is no chance for *E* to accent any of the notes. A metronome, set at 80 beats per minute, was used as a guide. The tests followed the metronome one note to a beat, with a short space occurring between the warning signal and the standard, and also between the standard and the variant. When the *S*s were asked for comments, a few of them complained that the metronome was a distraction, but most of them said that it was not. At any rate it is probable that the metronome did not affect the results since it was a constant factor throughout the experiment. There were, however, other distracting factors which probably did affect the results. The tests were given in a room with a high ceiling and plaster walls. It was near the street and there was a great deal of traffic noise. Coughing and other disturbances in the room probably reverberated. It may be that distractions

like these disturbed the regularity of the results. The erratic behavior of one or two problems in otherwise reliable tests might easily be a consequence of such distractions.

RESULTS

Every test had 49 problems. Every note was changed seven times, once in each of seven problems. The noticeability of the change can be measured by the number of Ss who answered the problem correctly. Every problem received a score which is the number of people in the group who answered correctly. For example, Problem 52 might get a score of 19 on the first test, meaning that *sol* is the note that is varied, that it occurs as the second note in the tune, and that 19 people in the group tested noticed a change in the second note and answered 2 in the proper blank on their test sheet. In the second test, Problem 52 might get a score of 28, if more people noticed the change. These raw scores cannot be compared directly. It may be that the second group is superior; or it may be that the pitch-rank of the crucial note is more advantageous; or it may be that the relation of the pitch-rank and the serial position makes the crucial note more prominent. It is the relation of the score to the other 48 scores for a specific test of a specific group that matters. This relation can be expressed by a number that is the quotient of the raw score's deviation from the mean, divided by the standard deviation. This new number is called the x/σ-score. The recognition value of each scale step was measured 49 times in the course of the seven tests, so that each scale step received 49 of the x/σ-scores. It is possible to take an average of these scores because they all represent the degree of difficulty of the change measured in a way that shows the comparative difficulty under the same conditions. Given below is a list of the average x/σ-score for each scale step, and with it is given the standard deviation of the distribution of the 49 scores.

Do	Mean = .25 ± .08	S.D. = .84
Re	Mean = .27 ± .08	S.D. = .83
Mi	Mean = .19 ± .08	S.D. = .80
Fa	Mean = −.42 ± .09	S.D. = .97
Sol	Mean = −.19 ± .10	S.D. = 1.08
La	Mean = .27 ± .08	S.D. = .88
Si	Mean = −.33 ± .08	S.D. = .88

An examination of the distributions of the x/σ-scores for the seven notes shows that the average x/σ-score in the case of *do*, *re*, *mi*, and *la* is better than the general average for all 343 problems. In fact, the distributions for *do*, *re*, and *la* practically coincide, and that of *mi* deviates very slightly. The distribution for *sol* has a mean that is a little below the general average, and a standard deviation that is larger than that for any of the other six distributions. The distribution for this note shows a tendency toward bimodality. A positive value for x/σ-score means that the problem was easier than average, while a negative one means that the change was difficult to detect. The means for *fa* and *si* fall definitely below the general average. The pronounced negative tendency of *fa* and *si* is the most striking feature of the whole array of data.

Of course, there is much overlapping of distributions, even between the highest and the lowest. This was to be expected. Even a tune of only seven notes is a complex of many factors, of which scale step is only one, probably one of the weaker ones from the standpoint of recognition value. Tunes will vary greatly in difficulty,

and hence the scores of the notes will also vary. The other factors should tend to cancel out in a large number of tunes and allow the influence of scale step to be shown in the central tendency of each distribution.

The fact that changes in *fa* and *si* tend to be difficult to detect is probably related to the function of these changes in modulation. *Si,* whenever changed, was lowered a semitone, resulting in a modulation to the subdominant key, a modulation which is very frequent. *Fa,* whenever changed, was raised a semitone, resulting in a modulation to the dominant key, also very frequent. Since these two modulations are to the two most closely related keys, we should expect such a change easily to pass unnoticed.

The bimodality of the distribution for *sol* suggests a double function for that interval. One possible explanation lies in the dual rôle of this step as a member of both tonic and dominant harmony. More extensive investigation is needed at this point.

CONCLUSIONS

Under the conditions of the present experiment, the seven notes of the diatonic scale were found to differ reliably in their average recognition value. The notes that are changed for the simplest modulations are the ones that have the lowest recognition value, *i.e. fa* and *si. Do, re* and *la* have the highest recognition value, whereas *mi* and *sol* are closer to average.

Recognition value is defined by the conditions of the experiment. Only the major mode in equal temperament was used and the change in the crucial note was always a change of a semitone to a note outside the key. Perhaps the method of substituting some other note within the key, or the use of melodic fragments in the minor mode would give different results. The present experiment is a first step in the study of the psychological properties of the scale and its parts, and also in the study of melodic structure.