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Perceived similarity of exact and inexact transpositions

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Abstract

The purpose of this study was to investigate the perceived similarity between a melody and the exact and inexact transpositions of that melody. Exact transpositions, which preserve the interval structure of the original melody, were formed by manipulating the variables key-distance and pitch-distance. Inexact transpositions, having a different interval structure than the original melody, were created by altering one tone of the exact transpositions. Two types of alteration, retaining the contour of the original melody, were used: (1) a chromatic alteration of one tone fitting the key of the original melody; (2) a diatonic alteration of one tone fitting the key of the transposed melody. The coding model of Deutsch and Feroe (1981) was used as a qualitative predictor of the perceived similarity. The resulting predictions were tested using a paired-comparison paradigm. Results indicate that both pitch-distance and alteration explain a significant part of the variance, whereas key-distance does not contribute significantly. It was also found that exact transpositions are perceptually more similar to the original melody than inexact transpositions, and that chromatically altered transpositions are perceptually more similar to the original melody than diatonically altered transpositions. These results are broadly in accordance with the applied coding model.

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1. Introduction

Making variations on a melody is a powerful technique in music composition. In each variation, some aspects of the original melody or theme remain unchanged while other

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aspects are modified. Variations or transformations may take various forms like changing the rhythm of the melody, changing the metrical basis, changing the harmonisation, ornamenting the melody, or elaborating it in all sorts of ways (see Reti, 1951). These transformations are usually applied in such a way that at least the competent listener will be able to recognise the original melody. Still there are large differences in this respect if we compare, for instance, Mozart's variations on "Ah, vous dirai je Maman" (K. 265, more familiar under the name "Twinkle Twinkle Little Star"), with Bach's "Goldberg Variations" (Klavierübung Teil IV, BWV 988). In the former example the theme can easily be recognised in the majority of the variations, whereas in the latter this is often very difficult or even impossible. One might thus assume that a productive way of studying music perception is by examining to what extent transformed melodies remain perceptually invariant (Hulse et al., 1992).

A transformation not yet mentioned is the *transposition* in which the melody is shifted up or down on the pitch dimension. Transposition is the most common transformation used in music and forms the subject of this study. Two types of transposition were investigated: (1) *exact* transpositions, in which a melody starts on another tone but the intervals, the distances between the tones, remain the same; (2) *inexact* transpositions, in which a melody starts not only on another tone but also some of the intervals are altered. In tonal music, that is, music composed in a key (e.g., C-major, a-minor), a transposition will result not only in a shift on the pitch dimension but may also entail a shift in key. The relationship between the keys in tonal music is represented by the so-called circle of fifths (see Fig. 1) and is named key-distance. One step clockwise or counterclockwise on this circle results in the same key-distance (see, e.g., Piston, 1941/1987, p. 6). Furthermore, each key is, per definition, related to another key by its shortest possible distance on this circle. For example, the keys C and F are related by a key-distance of 1 step counterclockwise, and are not related by a

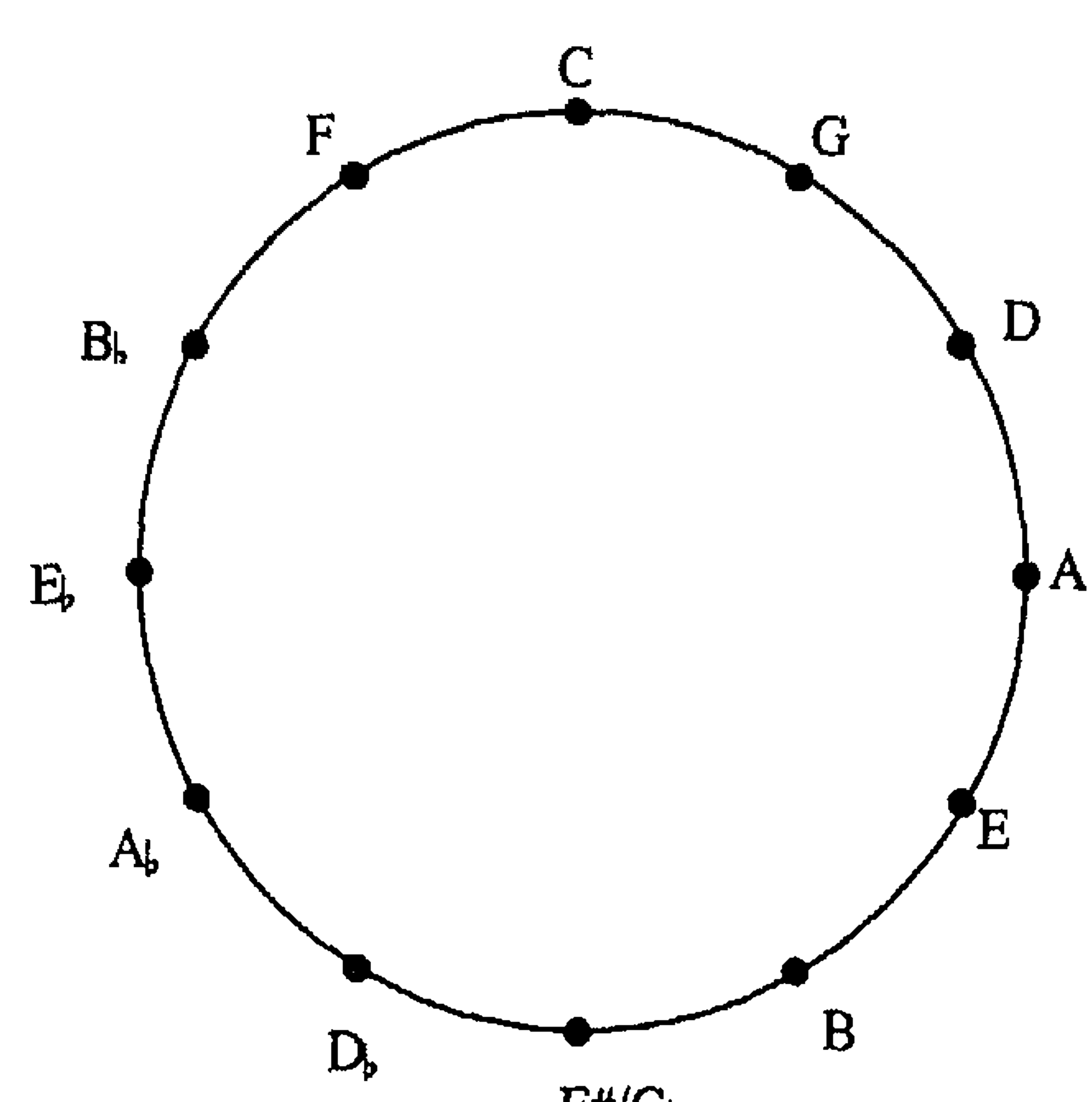

Fig. 1. Circle of fifths used to represent the relation between the major keys. Every step on this circle corresponds to an increase in key-distance. A step to the left results in a flat key; a step to the right results in a sharp key.

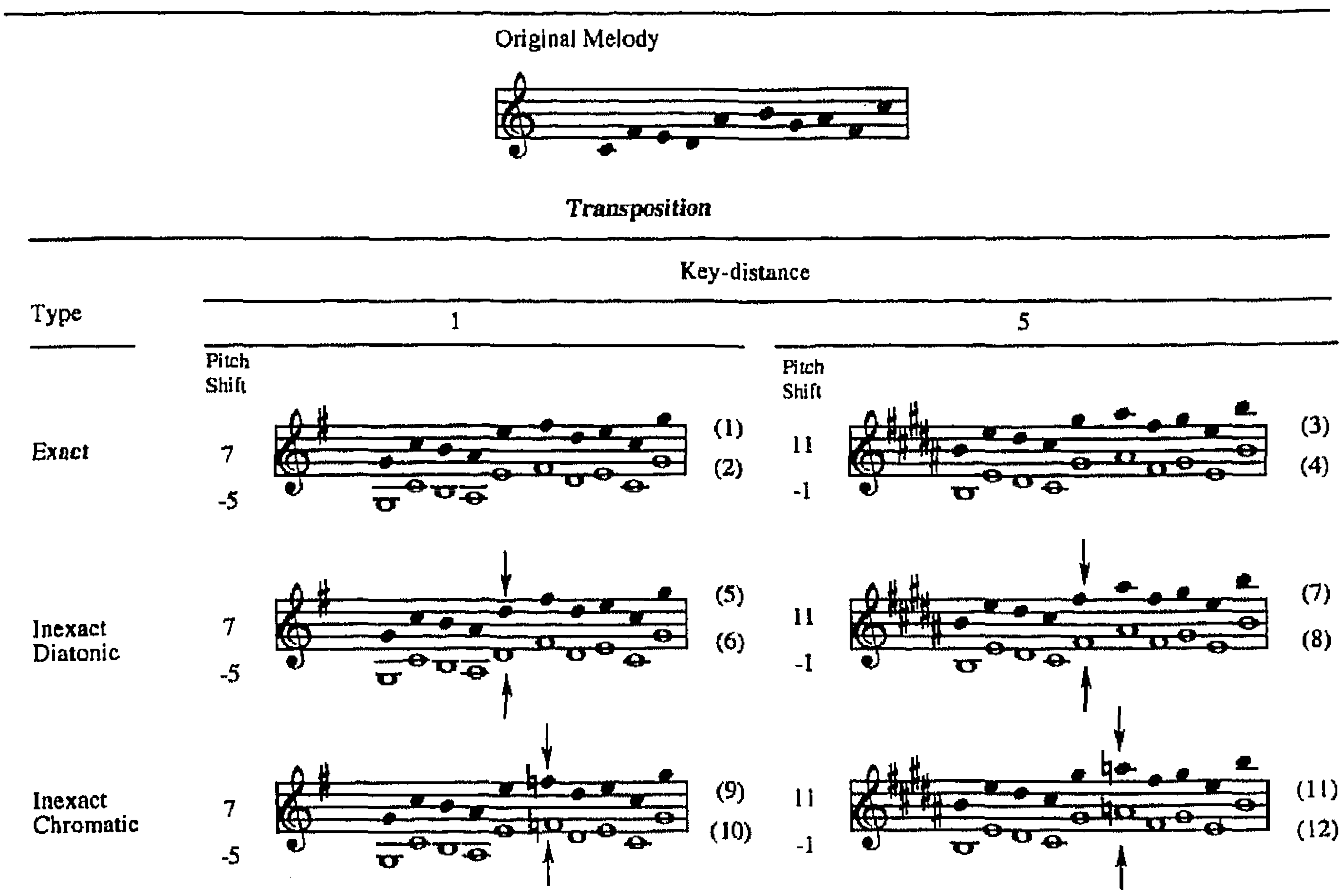

Fig. 2. Examples of exact transpositions and inexact transpositions (diatonically altered; chromatically altered). The original melody is presented in the key of C-major. The melody is transposed using two key-distances each combined with two pitch shifts. Alterations are indicated by an arrow in the score.

key-distance of 11 steps clockwise. Consequently, the maximum distance on this circle is 6 steps (e.g., from C to F♯/G♭).

1.1. Exact transpositions of tonal melodies

As stated above, a tonal melody that is transposed along the pitch dimension may also change in key. Examples of this are presented in Fig. 2. This figure presents a melody in the key of C-major (indicated "Original Melody"), which has been composed using all seven tones of the major scale. Melodies 1 to 4 are exact transpositions of the original melody formed by varying both key-change and pitch-shift. The melodies 1 and 2 are transposed respectively 7 semitones upward and 5 semitones downward, both resulting in a key-change to G-major (i.e., one step clockwise on the circle of fifths). The melodies 3 and 4 are transposed 11 semitones upward and 1 semitone downward, respectively, both resulting in a key-change to B-major (i.e., five steps clockwise on the circle of fifths). The magnitude of the key-change was above expressed by key-distance. Similarly, the magnitude of the pitch-shift is expressed by pitch-distance. Consequently, the examples of the exact transpositions may be specified by the variables pitch-distance and key-distance, that are confounded to some extent.

Both variables have been shown to influence the perceptual similarity between a melody and its transpositions. The perceptual effect of key-distance caused by a transposition, the so-called key-distance effect, has been reported in several studies

(Bartlett and Dowling, 1980; Cuddy and Cohen, 1976; Cuddy et al., 1981; Cuddy et al., 1979; Takeuchi and Hulse, 1992; Trainor and Trehub, 1993; Van Egmond et al., in press). The effect of pitch-distance has been the subject of only a few studies. Interestingly, research indicates that, for well-structured tonal melodies, the perceived similarity is much more influenced by pitch-distance than by key-distance (Francès, 1958/1988, p. 177; Hershman, 1994; Van Egmond and Povel, 1994b,Van Egmond et al., in press).

1.2. Inexact transpositions of tonal melodies

In Fig. 2, melodies 5 to 12 are examples of inexact transpositions. These inexact transpositions are derived from the exact transpositions (melodies 1 to 4) by altering one tone of the exact transpositions. Consequently, the change in key as well as the shift along the pitch-dimension of the inexact transpositions is identical to that of the exact transpositions. In the examples in Fig. 2, two types of alteration are used to create the inexact transpositions from the exact transpositions: (1) a diatonic alteration, is realised by changing one tone into another tone that belongs to the key of the (transposed) melody; (2) a chromatic alteration, is realised by changing one tone into a tone that does *not* belong to the key of the (transposed) melody. In Fig. 2, the altered tones are indicated with arrows and are chosen such that the contour of the melody remains unchanged. Diatonically altered transpositions (i.e., melodies 5 to 8) are created by shifting the fifth tone of the exact transpositions a major second downward. Chromatically altered transpositions (i.e., melodies 9 to 12) are created by lowering the pitch of the sixth tone of the exact transpositions a half step.

Thus, inexact transpositions are characterised not only by a change in key and in a shift on the pitch dimension, but also by a change of the interval structure. Several studies have shown that a change in the interval structure of a melody greatly influences similarity judgements, and that the judged (dis)similarity depends on the type of change (e.g., Bharucha, 1984; Croonen, 1994; Edworthy, 1983, 1985; Trainor and Trehub, 1992, 1994). In particular, chromatic alterations – which do not fit the transposition key – lead to a judgement of dissimilarity (Trainor and Trehub, 1992, 1994).

It should be noted, however, that some chromatically altered transpositions contain only tones of the original key, and can therefore be interpreted in the key of the original melody. Such transpositions are exemplified by the melodies 9 and 10 shown in Fig. 2. The combination of transposing to G-major and then changing the F♯ into an F, leads to a transposition of which all tones can be conceived in the key of C-major. These inexact transpositions are called tonal transpositions and are judged as being very similar to the original melody (e.g., Dewitt and Crowder, 1986; Dowling, 1978, Dowling, 1986; Takeuchi and Hulse, 1992; Van Egmond and Povel, 1994a). In contrast, the same alteration (lowering the sixth tone of the melody a half step) in combination with a transposition to B-major results in an inexact transposition that cannot be interpreted in the key of C-major (i.e., the melodies 11 and 12). This latter transposition is not perceived as similar to the original melody (see Bartlett and Dowling, 1980). In brief, research indicates that similarity judgements of transposed melodies are dependent on the type of transposition as well as on the type of alteration.

1.3. Modelling the similarity of exact and inexact transpositions

In this paragraph we present a formalised approach, based on the model of Deutsch and Feroe (1981), to predict similarity ratings of transposed melodies. The coding model of Deutsch and Feroe (1981) represents melodic sequences in terms of structural descriptions of the elements from an (pitch) alphabet and takes the form: {{(Structure); Alphabet}; Reference Element}. In tonal music, the alphabet is often a diatonic scale and the reference element is that element of the scale at which the structural description starts.

Using this model, the original melody in Fig. 2 can be coded as: $\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ C\};\ \hat{1}_4\}$. In this code the capital C corresponds to the C-major diatonic scale, and the $\hat{1}$ indicates the first tone of the scale (i.e., the first scale degree). The subscript 4 indicates the specific octave placement of the scale degree (where C_4 corresponds to the middle C on a piano). The combination of scale degree, subscript, and key thus uniquely specifies a tone (in this example the tone C_4). The structure part of the code contains the operators n, and p, that respectively denote: next element in the alphabet and previous element in the alphabet, while the * indicates the location of the reference element in the code. A superscript denotes the argument of the operator in terms of number of steps in the alphabet (thus n^3 means move 3 steps upward in the alphabet). A number preceding an operator indicates the number of times the operator is applied (thus 2p equals p, p).

In a similar fashion, the codes of the transpositions in Fig. 2 can be derived. These codes are presented in Table 1, in which those parts of the codes that are different from the original melody are underscored. By comparing the codes of the transpositions with those of the original melody, the differences can be inferred. For example, the upward transposition of the melody (to the key of) G-major (melody 1 in Fig. 2) results in:

Table 1
Deutsch and Feroe-codes for melodies of Fig. 2 as a function of key-distance (KD), pitch-distance (PD), and type of transposition

Type	KD 1			KD 5		
	PD	Deutsch and Feroe code		PD	Deutsch and Feroe code	
Exact	7	$\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ \underline{G}\};\ \hat{1}_4\}$	(1)	11	$\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ \underline{B}\};\ \hat{1}_4\}$	(3)
	5	$\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ \underline{G}\};\ \hat{1}_{\underline{3}}\}$	(2)	1	$\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ \underline{B}\};\ \hat{1}_{\underline{3}}\}$	(4)
Inexact Diatonic	7	$\{\{(*,n^3,2p,\underline{n}^3,\underline{n}^2,\underline{p}^2,\underline{n},\underline{p}^2,n^4);\ \underline{G}\};\ \hat{1}_4\}$	(5)	11	$\{\{(*,n^3,2p,\underline{n}^3,\underline{n}^2,\underline{p}^2,\underline{n},\underline{p}^2,n^4);\ \underline{B}\};\ \hat{1}_4\}$	(7)
	5	$\{\{(*,n^3,2p,\underline{n}^3,\underline{n}^2,\underline{p}^2,\underline{n},\underline{p}^2,n^4);\ \underline{G}\};\ \hat{1}_{\underline{3}}\}$	(6)	1	$\{\{(*,n^3,2p,\underline{n}^3,\underline{n}^2,\underline{p}^2,\underline{n},\underline{p}^2,n^4);\ \underline{B}\};\ \hat{1}_{\underline{3}}\}$	(8)
Inexact Chromatic	7	$\{\{(*,n^3,2p,n^4,2,(n,p^2),n^4);\ \underline{C}\};\ \underline{\hat{5}}_4\}$	(7)	11	$\{\{(*,n^3,2p,n^4,2,(n,p^2),n^4);\ \underline{E}\};\ \underline{\hat{5}}_4\}$	(11)
	5	$\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ C\};\ \underline{\hat{5}}_{\underline{3}}\}$	(8)	1	$\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ \underline{E}\};\ \underline{\hat{5}}_{\underline{3}}\}$	(12)

Note: The numbers in parentheses correspond to the numbers of melodies in Fig. 2. The changed elements in the Deutsch and Feroe code of the transpositions relative to that of the original melody are underscored. The code of the original melody in C-major is: $\{\{(*,n^3,2p,n^4,2(n,p^2),n^4);\ C\};\ \hat{1}_4\}$.

reference element, $\hat{1}_4$; alphabet, G, that is, the melody starts on G_4 (see Table 1, example 1). For this case, the pitch-distance between the original melody and the transposition equals the distance between C_4 and G_4 being: 7.

Besides pitch-distance three additional differences can be inferred from the comparison of the codes of the original melody and their transpositions, these are: (1) the difference in scale degree, which is independent of octave placement; (2) difference in alphabet, that is, key-distance; (3) structural differences between the melodies as expressed in the differences between the structural part of the codes. Examples of these differences can be found in Table 1. This table shows that the codes of the different transpositions vary as follows: The *exact transpositions* (i.e., codes 1 to 4), apart from a difference in pitch-distance, differ in only one aspect of the code as compared to the original melody, namely in the alphabet (indicating the key-distance). The codes of the *diatonically altered transpositions* (i.e., codes 5 to 8) differ in six aspects compared to the original code: (1) the structure, 5 changes; (2) the alphabet, 1 change. The codes of the *inexact chromatic transpositions* (i.e., codes 9 and 10) differ only in the reference element (i.e., scale degree), but not in the alphabet, thus yielding one change. This is in contrast to the codes of the chromatically altered transpositions (i.e., codes 11 and 12) that change in reference element (scale degree) and alphabet, thus yielding two changes. The latter two transpositions have been coded in the key of E-major, because the (altered) tone A is not found in B-major.

These codes may now be used to make predictions concerning the perceptual (dis)similarity of a melody and its transpositions. In particular, it is hypothesised that the more differences there are between the code of the original melody and that of the transposed melody, the more dissimilar the two melodies will appear to be. This leads to the following predictions:

(1) The exact transpositions (i.e., melodies 1 to 4) should be judged as most similar to the original melody because their codes differ only with respect to one aspect of the code: key.

(2) The chromatically altered transpositions are divided in two groups: (a) melodies 9 and 10, the tonal transpositions; (b) melodies 11 and 12, which are not interpretable in the key of the original melody. Like the exact transpositions the tonal transpositions also differ with regard to only one aspect of the code (in this case reference element) and would therefore be judged as equally similar to the original melody as the exact transpositions. The melodies 11 and 12, however, differ with respect to two aspects of the code (i.e., key and reference element) and will thus be judged as more distinct from the original melody than the comparable exact transpositions and tonal transpositions.

(3) The diatonically altered transpositions (i.e., melodies 5 to 8) should be judged as the most dissimilar from the original melody because their codes differ with respect to 6 aspects: key; 5 structure operators.

In the experiment reported below we have studied the perceived similarity between a melody and different exact and inexact transpositions using a paired-comparison paradigm. In this paradigm a listener compares a combination of a melody and a transposition with another combination of the same melody and a different transposition and indicates in which combination the transposition is more similar to the original melody. The advantage of this paradigm over the commonly used standard-comparison paradigm is that it allows a more direct estimate of the similarity between a melody and a transposition.

2. Method

In this experiment the perceived similarity between a tonal melody and various exact and inexact transpositions was studied. The melody was transposed using two different key-distances each combined with two pitch-distances. From each exact transposition two additional inexact transpositions were created, using a diatonic and a chromatic alteration of one tone in the melody. This resulted in a total number of 12 transpositions, which were presented combined with the original melody in a paired-comparison paradigm.

2.1. Participants

Thirteen graduate and undergraduate students of the University of Nijmegen served as participants. The mean age of the participants was 22 years. All of them had played or were playing an instrument for several years, with an average of 9 years. They received course credits or money for their participation.

2.2. Stimuli

The original melody and the 12 transpositions are shown in Fig. 2. The transpositions were constructed by combining two key-distances, two pitch-distances, and three levels of alteration. A cadence, containing the chords V and I of the original key, preceded the original melody to induce its key.

2.3. Apparatus

Stimuli were presented using a Roland Rhodes 760 synthesiser controlled by an Atari 1040 STf computer through MIDI (Musical Instrument Digital Interface). Different instruments were used to enhance the perceptual separation between cadence and melodies: the cadences were presented using a piano sound (Acoustical Piano 1), and the melodies using a harpsichord sound (Harpsichord 3). The relative loudness of the two instruments was left to the standard setting of the synthesiser. The stimuli were presented through a loudspeaker at a comfortable listening level that could be adjusted by the participants. Stimulus presentations and response collection were controlled by a program on the Atari computer.

2.4. Design and procedure

The cadence, the original melody, and the transpositions were presented using a paired-comparison paradigm. A graphical representation of this paradigm is shown in

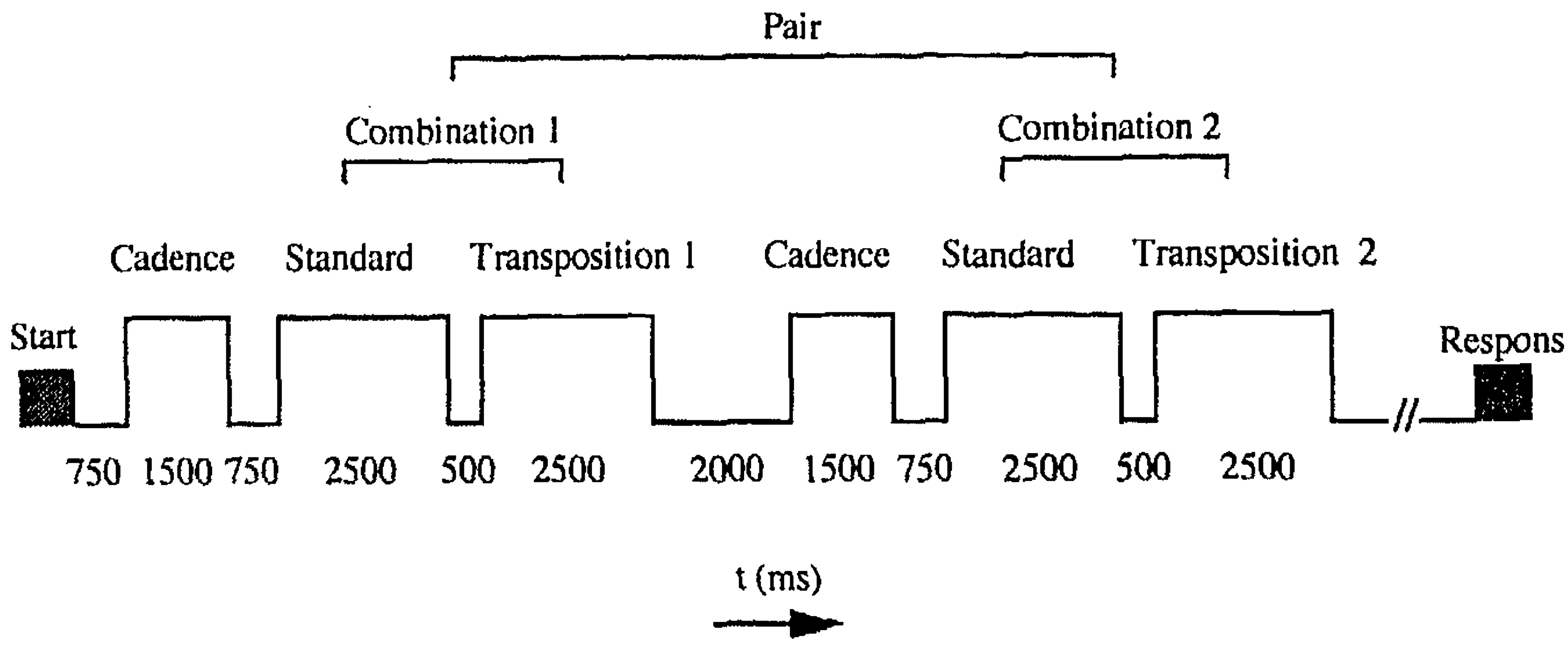

Fig. 3. Graphical representation of the used paired comparison paradigm. A pair consists of two combinations that contain the same standard melody but different transpositions (comparison melodies). Standard melodies are preceded by a V-I cadence. Numbers indicate the duration of the different parts and pauses in a trial (in ms).

Fig. 3, showing one experimental trial. The original melody is always followed by a transposition, together this is called a combination. As shown in the figure two combinations form a pair. Because each transposition is combined with the original melody, 12 different combinations result. Consequently, the 12 combinations formed 66 pairs, which corresponds to 66 trials.

The participant's task was to indicate in which combination (s)he perceived the transposition as more similar to the standard (see Fig. 3). After each trial the participant could either choose to answer immediately or to repeat the trial (the number of repetitions was left to the participant). The experiment was started after a participant was familiarised with the procedure using 6 practice trials, in which no feedback was given.

The order of presentation of the trials and the order of the two combinations within a trial was randomised per participant. In each trial the key for cadence and standard melody was randomly selected out of twelve possible keys, with the first tone of the standard melody ranging from G_4 to $F\sharp_5$. The lowest tone (tonic) of the cadence was always two octaves below the lowest tone of the standard. The key of the comparison melody was, of course, varied relative to the selected key for the standard melody.

Timing and order of cadences, standard melody, and transpositions are shown in Fig. 3. A trial began 750 ms after a start button was pressed. Only the inter onset interval (IOI) of the tones was controlled, the decay in tone-amplitude during the IOI being determined by the synthesiser. The tones of the cadences had an IOI of 750 ms. Between the cadence and the standard melody was a pause of 750 ms. All tones of the standard melody and the transpositions had an IOI of 250 ms. There was a pause of 500 ms between standard and comparison melodies and a pause of 2000 ms between Transposition 1 and the next cadence.

3. Method of analysis

For each of the 66 pairs a preference score per participant was obtained. The mean of the preference scores for all participants reflects the chance that within a pair one stimulus is preferred over the other stimulus. The proportions were analysed by means of the BTL-model (Bradley and Terry, 1952; Luce, 1959), yielding scale values for each type of transposition. The BTL-model is a variant of the model of comparative judgement of Thurstone (1927). A scale value represents a relative measure of similarity for a stimulus (standard and transposition). The individual contributions of the factors *pitch-distance*, *key-distance*, and *alteration*, describing the relation between the original melody and its transposition, were subsequently determined by applying multiple regression analysis to the scale values.

4. Results

To begin, the applicability of the BTL-model was tested using a Pearson Chi-square test for goodness of fit. Results indicated that the BTL-model was tenable ($\chi^2(55) = 66.7$, $p > 0.10$).

Fig. 4 shows the obtained scale values as a function of pitch-distance. In the figure, for each data point, the key-change and the type of transposition has been noted. The

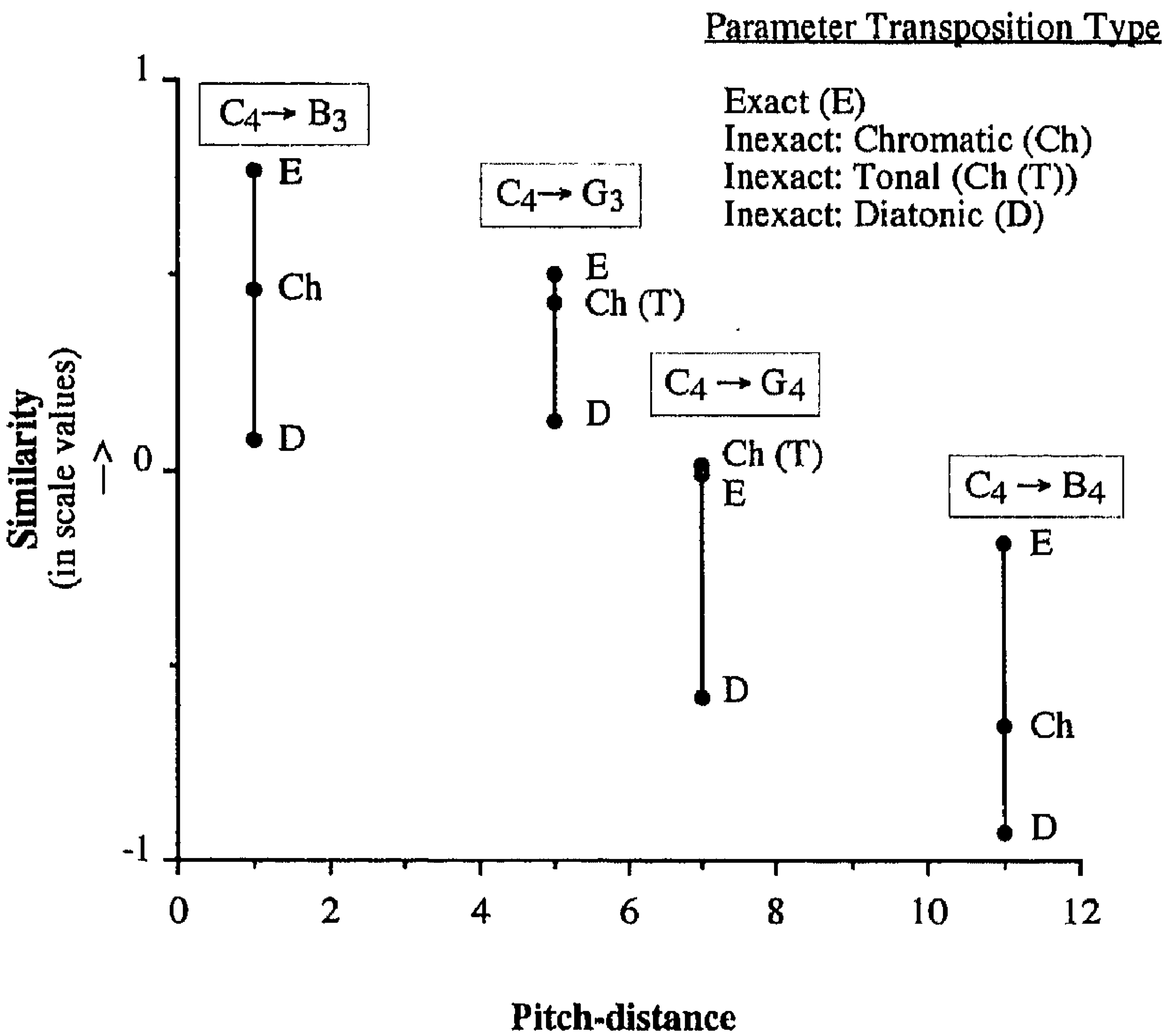

Fig. 4. Similarity values plotted as a function of pitch-distance. Above the data points the specific transposition is indicated. Besides each point the type of transposition is presented: exact transposition (E); chromatically altered transposition (Ch); tonal transposition (Ch (T)); diatonically altered transpositions (D). Lines are added to improve readability only.

Table 2
Intercorrelations between independent variables and correlations between independent variables and dependent variable

	Pitch-distance	Key-distance	Alteration
Dependent variables			
Pitch-distance	–		
Key-distance	0.00	–	
Alteration	0.00	0.00	–
Independent variable			
Similarity	−0.80	−0.16	−0.49

following trends may be inferred from the data displayed in the figure. First, an important general trend is that similarity decreases with increasing pitch-distance (similarity decreases moving from left to right in the figure). Second, key-distance (C → G versus C → B) appears to have a minimal effect on similarity judgements. Third, for each level of the variable pitch-distance, similarity decreases as function of transposition type in the following order: exact transposition, chromatically altered transposition, diatonically altered transposition. Fourth, the two chromatically altered transpositions that are conceivable as tonal transpositions (i.e., those combined with a key change from C to G, indicated with Ch(T) in Fig. 4) are judged as being much more similar to the original melody than the two chromatically altered transpositions that cannot be conceived as tonal transpositions (i.e., those combined with a key change from C to B, indicated with Ch in Fig. 4). In fact, the tonal transpositions are judged as having almost the same similarity value as the exact transpositions.

The partial effect of each independent variable (i.e., pitch-distance, key-distance, alteration) on the dependent variable (i.e., similarity) was determined using a multiple regression analysis. Table 2 presents the intercorrelations of the independent variables and the correlations between the independent variables and the dependent variable. As none of the independent variables are (inter)correlated, these variables could be entered in any specific order in the regression analysis. As key-distance only had a small,

Table 3
Multiple regression analysis on the scale-values

Variable	Individual contributions of variables				
	Coefficient	SE	Partial F	p-value	Partial R^2
Intercept	0.95				
Pitch-distance	−0.11	0.02	45.91	0.0001	0.63
Alteration	−0.30	0.07	17.56	0.0023	0.24
			Total contribution $F(2,9) = 31.74$, $p = 0.0001$, $R^2 = 0.88$		

Note: Independent variables: Pitch-distance and Alteration. Dependent variable: Similarity, based on BTL-model.

insignificant correlation with similarity ($r = -0.16$, $F(1,10) = 0.32$, $p > 0.50$) it was not entered in the regression analysis. The three levels of the variable alteration were coded as: none (0); chromatic (1); diatonic (2). These values and the values of pitch-distance (i.e., 1, 5, 7, 11) were entered in the regression analysis, of which a summary is shown in Table 3. The overall F-test shows a significant (regression) relation between the two independent variables and the dependent variable. The total amount of explained variance is 88%, of which pitch-distance explains the major part (63%) and alteration explains an additional smaller part (24%). Coefficients for both pitch-distance and alteration differ significantly from zero (indicated by the partial F-tests). Because these coefficients are negative, an increase in pitch-distance or in alteration (from 0 to 2) results in a decrease of similarity, which is consistent with the relation between the independent variables and dependent variable shown in Fig. 4.

5. Discussion

Two main topics were investigated in this study: (1) the influence of the experimental variables *key-distance*, *pitch-distance*, and *alteration* on the perceived similarity between a melody and its transposition; (2) the applicability of the model of Deutsch and Feroe (1981) in predicting the similarity between a melody and its transpositions. In the following paragraphs we shall discuss these two topics in succession.

The findings observed with respect to the effect of the variables key-distance, pitch-distance, and alteration may be summarised as follows. (1) Key-distance has a minimal effect on similarity judgements. (2) Pitch-distance has the largest effect on the similarity judgements, in the sense that an increase in pitch-distance resulted in a decrease of similarity. (3) Six out of the eight altered transpositions are judged as less similar to the original melody than the same unaltered transpositions. (4) Type of alteration has a systematic effect on similarity judgements: a chromatically altered transposition was always judged more similar to the original melody than a comparable diatonically altered transposition. (5) Tonal transpositions (transpositions that can be conceived in the key of the original melody) are judged as being similar to the exact transpositions. (6) Chromatically altered transpositions having the same interval structure as tonal transpositions, but that cannot be interpreted in the key of the original melody are judged as being quite different from the exact transpositions. The different results for the two chromatically altered transpositions (having the same interval structure but transposed to different keys, discussed above in points 5 and 6) show that there exists an interaction between key-distance and alteration, but the overall effect of key-distance for all transpositions is minimal.

These findings confirm earlier findings in the literature, that have shown that: (a) Pitch-distance has a larger effect on the perceived similarity between a melody and its transposition than key-distance (Francès, 1958/1988; Hershman, 1994; Van Egmond et al., in press); (b) Tonal transposition are judged as almost similar to the exact transpositions (e.g., Dewitt and Crowder, 1986; Dowling, 1978, 1986; Takeuchi and Hulse, 1992; Van Egmond and Povel, 1994a); (c) Type of alteration determines to what extent the perceived similarity will be affected (e.g., Bharucha, 1984; Croonen, 1994; Edworthy, 1983, 1985; Trainor and Trehub, 1992, 1994).

The second topic concerned the predictions derived from the model of Deutsch and Feroe (1981), applied both to the original melody and to the transpositions. We previously suggested that, for a given pitch-distance, the number of differences between the code of the original melody and that of the transposed melody will determine the perceived similarity: the more differences, the more dissimilar a transposition would be judged compared to the original melody.

The code of the *exact transpositions* changed in only one aspect (i.e., alphabet). Our findings indicate that these transpositions were judged as more similar to the original melody than most of the comparable inexact transpositions. The code of the *tonal transpositions* also changed with regards to one aspect (i.e., reference element). These transpositions were perceived as almost similar to the comparable exact transpositions. Consequently, these almost equal similarity values of the exact transpositions and tonal transpositions show that if a listener's similarity judgement is based on the code described in this study, these judgements are equally influenced by a change in key (i.e., alphabet) or a change in scale step (i.e., reference element). The other *chromatically altered transpositions* change in two aspects of the code (i.e., alphabet and reference element). These transpositions – having the same interval structure as the tonal transpositions – were clearly judged as more dissimilar to the original melody than the comparable exact transpositions (the latter being changed on only one aspect of the code). Thus, this result shows that a change in one aspect of the code affects the perceived similarity less than a change in two aspects of the code. The code of the *diatonically altered transpositions* changes in 6 aspects of the code (i.e., 5 in structure and 1 in key). These transpositions were judged as the most dissimilar to the original melody than comparable other transpositions. These findings are consistent with our prediction that the more aspects of the code are changed the more dissimilar the transposition will be judged.

In conclusion, our findings show that the variables pitch-distance and alteration together explain the major part of the perceived similarity between a melody and its transposition, whereas key-distance did not affect a listener's similarity judgement. Comparison of the differences between the Deutsch and Feroe-codes of the original melody and its transpositions resulted in predictions that were consistent with the findings of our experiment. However, although differences between the resulting codes indicate which transposition will be judged more similar to the original melody than another transposition, but these differences do not, as of yet, permit to make predictions concerning the size of the effect. Furthermore, it was found that the paired-comparison paradigm allows to collect similarity judgements of melodies differing in transposition and in structure. In this way, it should be possible to derive classes of melodies that are perceptually similar to one another. In future research we plan to investigate the possibility to derive such a measure of similarity using the herein described paradigm and coding model.

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