*Psychol. Belg.*
1991, XXXI-2, 217-237.

# IDENTIFYING MELODIES FROM REDUCED PITCH PATTERNS

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An expanded version of a reduced-pitch-pattern model for melodic processing proposed by Oura and Hatano (1988a) assumes that experienced listeners represent melodies in long-term memory in terms of reduced pitch patterns and modifiers. Whether subjects could identify familiar tunes based on their putative reduced pitch pattens, with or without some additional information about modifiers, was investigated in two experiments. In the first experiment, identification performance of seven college music majors for 14 European folk songs were examined. Identification of tunes from their putative reduced pitch patterns alone was found to be very difficult, but paired associations between tunes and their putative reduced pitch patterns were acquired easily and retained. The second experiment with eleven college music majors showed that presenting one or two characteristic pitches in addition to reduced pitch patterns facilitated their identification. It seems that reduced pitch patterns represent structural properties of tunes but may not be sufficient to characterize them.

The aim of this study was to examine a few predictions from an expanded version of our model of melodic processing (Oura, 1991; Oura & Hatano, 1988a), more specifically, whether musically experienced subjects could identify familiar tunes from their putative reduced pitch patterns alone, that is, sequences of pitches of structural notes given in a notational form. The model is called the reduced-pitch-pattern model and belongs to the family of models assuming the decoding of a series of notes in terms of dominant notes and operators, best exemplified by Deutsch and Feroe (1981). The original version of the model concerns how experienced subjects acquire new melodies, that is, come to represent extended and realistic melodies in long term-memory. In this expanded version, how experienced listeners recognize and recall melodies is also discussed.

The original is a version of the skilled memory model (Chase & Ericsson, 1981, 1982) in the sense that experienced listeners are assumed to generate a long-term memory representation of a presented melody

The authors thank Irène Deliège, Marc Melen, and Ian Cross for their valuable comments and suggestions.

by using their prior knowledge, a "melodic lexicon" which includes prototypes and modifiers. The prototypes are reduced pitch patterns, or sequences of several pitches of "structural notes", which are used frequently in melodies in a given style. Each of them represents a variety of similar melodic segments. The modifiers transform prototypes into actual melodic segments. Prototypes do not contain information about pitches except for those of structural notes nor about rhythmic aspects of melodies. In order to reconstruct real melodies from prototypes, both pitch sequence modifiers and rhythmic modifiers are needed.

When a new melody is presented, experienced listeners first divide it into segments, then abstract structural notes from each segment and extract a sequence of pitches, that is, a reduced pitch pattern. If possible, they code each segment of a melody into a standard form, a prototype (or a reduced pitch pattern) operated on by modifiers. In other words, a segment of a real melody is to be represented in memory as a product of an abstract prototype and a set of modifiers. Modifiers specify which rhythm pattern and what instantiated pitch sequence the segment has. Because the unfamiliar is recoded as a combination of familiar items, experienced listeners can memorize a new melody rapidly and accurately.

Our previous studies (Oura, 1991; Oura & Hatano, 1988b) confirmed several predictions taken from this original version, and thus gave, to a certain degree, an assurance for the psychological reality of our model of melodic memory. One of them (Oura & Hatano, 1988b) showed that musically experienced children and college students could readily learn a new melody that was in a style familiar to them. Their reproduction errors suggest that they coded melodic segments into series of pitches of structural notes and modifiers, the latter of which could be lost or combined with other series of pitches than the correct one. Another study (Oura, 1991) demonstrated that putative reduced pitch patterns were retained even in erroneous reproductions made by musically experienced college students who participated in a learning experiment of a melody in a style familiar to them. In order to derive a putative reduced pitch pattern from each segment of the melody and of the erroneous reproductions made by subjects, the rules for time-span reduction proposed by Lerdahl and Jackendoff (1983) were adopted.

However, the original version does not specify how melodies are represented in long-term memory long after their acquisition, nor how they are accessed in recognizing a presented melody as known. This expanded version assumes that experienced listeners possess, in addition to the melodic lexicon, a mental list of known melodies, which is used as the basis for melodic recognition as well as recall. The number of items in the list (melodies or their segments) is far smaller than the number of melodic segments or their combinations possibly generated from the lexicon (by combining prototypes and modifiers), though it increases as students gain expertise. The expanded version also assumes that listeners try to match a presented melody to items of the list (or compute similarity between a presented melody and each item of the list, and select the one that shows close similarity). Considering that we can recognize familiar melodies very quickly, just from a few initial notes, this matching process must run in parallel to the process of coding it into the form of a prototype plus modifiers, and thus, at least initially, based on surface information. In fact, Deliège (1989; Deliège & Ahmadi, 1990) have shown that surface characteristics play an important role in the recognition of melodies.

An interesting question here is whether the reduced pitch pattern or prototype of melodies in the list, which certainly constitutes a stable component of the representation, is dissociable from modifiers and resultant surface features and can serve as the basis for recognition. We have some plausible reasons for both affirmative and negative answers to this issue. It seems likely, on one hand, that the reduced pitch pattern is dissociable from modifiers and resultant surface features, because it is the core of a melody, and must be reflected in performance (Meyer, 1973). Moreover, recognition of a transformed melody is possible only after it is coded into the standard form in such cases as sophisticated variations. On the other hand, since the reduced pitch pattern is not a unique or characteristic feature of the melody, keeping it dissociable from other features is not worth expending mental effort on because the mental list is primarily for recognizing and recalling a very selected set of characteristic melodies. Moreover, some evidence has appeared for the integrated nature of a long-term memory representation of melodies (e.g., Serafine, Crowder & Repp, 1984; Serafine, Davidson, Crowder & Repp, 1986). Only by empirical studies can we decide which answer is more tenable.

Thus we examined, in our two experiments, this issue in terms of the following three questions: Can musically experienced subjects identify familiar tunes from their reduced pitch patterns (more accurately, putative reduced pitch patterns) alone? Can they identify tunes better when given some additional feature information (that may suggest major modifiers)? Can they readily learn associations between tunes and their reduced pitch patterns? So, let us explicitly indicate predictions from the expanded version of our model, and then describe the experiments.

## Predictions

Let us assume that the putative reduced pitch pattern of a melodic segment derived by applying the time-span reduction rules is a good approximation to each student's reduced pitch pattern. If the reduced pitch pattern is not only a crucial but also a dissociable component of the segment in memory representation, it will be possible for an experienced listener to identify the segment from its putative reduced pitch pattern. In contrast, if it is a crucial but not a dissociable component, it alone cannot serve as the basis for recognizing a tune. This is because computing similarity between a given putative reduced pitch pattern and memory representation of each melodic segment in the list is very hard, or because computed similarity between the putative reduced pitch pattern and the melodic representation in the list that has the reduced pitch pattern (with many surface features induced by modifiers) is apparently low. However, association between putative reduced pitch patterns and the corresponding tunes can easily be learned, because the latter can be reconstructed by applying proper modifiers, and remembering these proper modifiers (or how to "instantiate" each of the putative reduced pitch patterns) seems fairly simple.

More specifically, the following three predictions were examined by the two experiments. 1a) The original tune would be identified easily from its putative reduced pitch pattern. 1b) The original tune would be identified from the combination of its putative reduced pitch pattern and some additional features (indicating or suggesting proper major modifiers). 2) Even if (1b) is proven to be correct, paired associations between tunes and their putative reduced pitch patterns would be acquired easily and retained.

## Experiment 1

Experiment 1 was conducted in order to examine these three predictions; that is, whether or not subjects could identify tunes from their putative reduced pitch patterns alone, whether presenting durational patterns in addition to putative reduced pitch patterns would make the identification easier, and whether or not paired association between tunes and their putative reduced pitch patterns could be acquired easily. Reduction of tunes was made by using the rules for time-span reduction by Lerdahl and Jackendoff (1983).

## *Method*

*Subjects.* Seven female college students majoring in music education participated in this experiment. They were 22-25 years old and had had piano training of 12 years or more. Three of them had absolute pitch and said, after the experiment, that they had some trouble recognizing one or two tunes because they memorized these tunes in their original keys.

*Materials.* Fourteen British and German folk songs (without song texts) were used as materials because (1) they appeared in several musical textbooks for junior-high school and high school students and thus were expected to be familiar to the subjects, and (2) we could obtain their putative reduced pitch patterns without serious difficulty. Titles of these songs were "Irish Lullaby", "Annie Laurie", "Auld Lang Syne", "Home Sweet Home", "Long Long Ago", "Love's Old Sweet Song", a British folk tune arranged by H. Kobayashi and titled as "Picnic" in Japan, "Der letzte Abend", "Sandmännchen", "Freut euch des Lebens", "Lorelei", "Heidenröslein" by H. Werner, "Wiegenlied" by F. Schubert, and "Stille Nacht, Heilige Nacht". The putative reduced pitch patterns were written in C major in order to prevent subjects from identifying songs by their original keys. The putative reduced pitch patterns of these tunes were extracted by considering the entire tunes, but only the first four measures of them were presented to the subjects. These putative reduced pitch patterns are shown at Figure 1.

We shall describe in detail how the rules of time-span reduction were applied to the first four measures of "Lorelei". As far as this tune is concerned, the obtained reduction of later parts does not alter that of the first four measures. The first stage of the reduction analysis was to determine its grouping structure (see Figure 2).

When deciding the grouping structure, we treated breathing signs as indicators of phrase boundaries; these were either explicit or implicit, that is, suggested by the end of a sentence or clause in the song text. Thus we assigned a phrase boundary after the ninth note of the tune


*Figure 1.* Fourteen folk tunes used as materials and their putative reduced pitch patterns.


*Figure 2.* Grouping structure of Lorelei and rule applications for analysis.

because of the end of a sentence in the song text. Where an intervallic distance greater than the fourth appeared, GPR (grouping preference rule) 3a (change of register) was applied. GPR 3d (change of length) was applied where a change in the length of notes occurred[1]. Where more than two rules were applied, GPR 4 (intensification) was also applied.

As a result, the tone series of the first four measures of the melody was found to be divided into 11 parts, and 9 out of 11 parts were very small groups containing only one or two notes, which should be strongly avoided (GPR 1). In regard to the three notes of the second measure, for example, GPR 3d (change of length) was applied between the last note of the first measure and the first note of the second measure, between the first two notes of the second measure, between the second and third notes of the second measure, and between the third note of the second measure and the first note of the third measure. That is, each of the three notes of the second measure formed a very small group. In order to avoid very small groups, three out of the four applications of GPR 3d should have been overridden by GPR 1. Though the boundary between the second and the third notes of the second measure was strengthened by applications of "breathing sign" and GPR 4, the existence of the other three boundaries could not be supported by the application of any other rules. So, the boundary between the second and the third notes of the second measure was confirmed, and the other three boundaries were cancelled, that is, applications of GPR 3d for these three were overridden by GPR 1.

In the same way, every application of GPR 3d except for that

[1] Deliège (1987) showed that GPR 3d did not work well to decide grouping structure. If all the applications of 3d will be cancelled, phrase boundaries in the first four measures of "Lorelei" should be assigned between the fourth and fifth notes and between the ninth and tenth notes. The resulting time-span reduction of these measures is, however, the same as the one we derived.

between the third and fourth notes of the melody was overridden by GPR 1. Then, we found that the fourth note of the melody constituted a very small group, by the application of GPR 3d between the third and the fourth notes of the melody and by the application of GPR 3a (change of register) between the fourth and fifth notes of it. However, the choice as to which application should be cancelled could not be made at this stage because Lerdahl and Jackendoff (1983) had not assigned any relative strength to these two rules. So, this decision was deferred to the time-span reduction stage.

The second stage of analysis was to determine the metrical structure of the melody (see Figure 3). At the eighth-note-level, beats were assigned by MWFR (metrical well-formedness rule) 1 (attack point) and MWFR 4 (equal spacing). Beats coinciding with beginnings of notes were marked by MPR (metrical preference rule) 3 (event).


*Figure 3.* Metrical structure of Lorelei and rule applications for analysis at the eighth-, dotted-quarter- and dotted-half-note-levels.

MPR 5a (length of pitch-event) marked the beginnings of the quarter-notes and the dotted-quarter-note. Pitch prolongations into the next beat were marked by MPR 5e (length of duration) and by MPR 5f (length of harmony) marked where the harmony changed. At the dotted-quarter-note and the dotted-half-note-levels, a dactylic pattern and a trochaic pattern were preferred respectively, because a combination of the preference rules intensified the first beats of the measures. At both the dotted-quarter-note and dotted-half-note-levels of analysis, beats were also assigned by the MWFRs 1 and 4, and marked by MPRs 3, 5e and 5f. MPR 5a (length of pitch-event) marked the beginnings of the dotted-quarter-notes at the dotted-quarter-note-level of analysis.

The third stage of analysis was to determine the time-span segmentation. At the local levels, metrical structures determined smaller groupings. The largest level of subgroup bracketing, however, conflicted with this grouping structure. That is, the third note of the second measure belonged to the antecedent subgroup in the metrical structure, though it had belonged to the succeeding group in the grouping structure. In an out of phase region like this, the grouping structure overrode the metrical structure; the brackets of the second and the third measures at the dotted-quarter-note level were altered to form the augmented time-span (see Figure 4). That is, the third note of the second measure belonged to the first bracket of the third measure as an anacrusis.

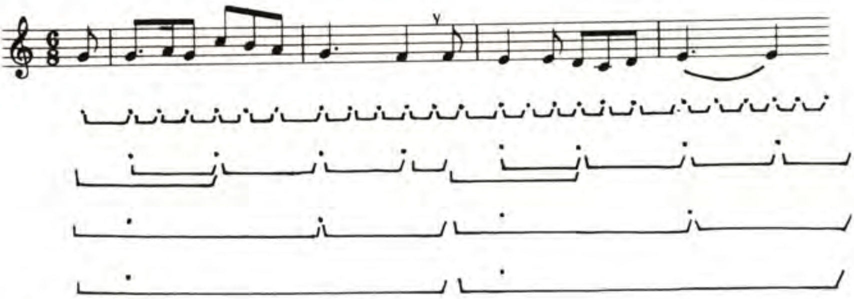

*Figure 4*. Time-span segmentation of Lorelei.

*Figure 5*. Time-span reduction of Lorelei.

The final stage of analysis was the time span reduction (see Figure 5). The dotted-quarter-note-level reduction was made by TSRPR (time span reduction preference rule) 1 (metrical position); that is, notes at the relatively strong metrical position were selected as most prominent. Then, the indented tone series at the first and second measures of dotted-quarter-note-level were checked by TSRPR 6 (linear progression) and changed from G-C-G-F to G-A-G-F[2].

*Procedure*. Subjects were told in advance that the tunes to be presented were either in six-eight or in common time and that the putative reduced pitch patterns of the first four measures (that is, two segments) would be notated in C major regardless of their original keys and would be written in eight half-notes (or seven half notes and one whole note). The procedure of the experiment contained six stages as follows.

Stage 1) Each subject was individually given a list of the titles of 14 British and German folk songs. Then she heard these songs which were transposed into C major and were played on a keyboard, in order to ascertain whether or not she knew them. Titles of songs the subject did not know were deleted from the candidate list for her thereafter. All the subjects knew at least nine songs.

Stage 2) The subject was presented with one of the notated musical examples, in which putative reduced pitch patterns derived from the first four measures of these songs were written down in C major. She was also given the list of song titles at the same time and was asked to identify the title of the song from which each putative reduced pitch pattern was derived. The time allowed for each trial was 30 seconds. The presentation order of notated musical examples was randomized among subjects.

Stage 3) Procedure of stage 3 was the same as that of stage 2 except that the subject was presented with notated musical examples in which durational patterns were given in addition to putative reduced pitch patterns.

Stage 4) Each original song was presented auditorily once with a notated version of its putative reduced pitch pattern. Songs were presented successively with no intervening time interval.

Stage 5) A piece of Japanese traditional music was presented for five minutes in order to prevent rehearsal of the paired associations.

[2] In addition, the second note A seemed more preferable than C because A implied local harmony of the second half of the first measure, IV, stronger than C.

Stage 6) The same procedure as that of stage 2 was repeated. That is, the subject was presented with one of the notated musical examples of putative reduced pitch patterns and asked to identify the song from the list of song titles.

Finally, the subjects were asked how effective the durational patterns were when trying to identify the titles of the songs.

*Results*

Proportions of the correct answers were calculated for each subject for each stage by dividing the number of correct answers by the number of known songs. At stage 2, the mean proportion of the correct answers was 39.8 percent (range; 22.2% ~ 46.1%). When durational patterns were added at stage 3, however, the mean proportion of the correct answers increased twice as much as that in stage 2, that is, 78.3 percent (range; 55.6% ~ 100%). Rhythmic modifiers were potent cues for identification of tunes.

Once paired associations between the titles of songs and their putative reduced pitch patterns were established at stage 4, the mean proportion of the correct answers increased up to 84.5 percent (range; 70.0% ~ 100%) at stage 6. Paired associations seemed to be acquired easily.

A one-way ANOVA revealed a significant main effect for stage ($F(2,12) = 20.43$, $p < .001$). Tukey analysis revealed significant differences between stage 2 and stage 3 and between stage 2 and stage 6 ($p < .01$).

Two weeks after the experiment, one subject, who knew 13 songs out of the 14 and could identify 6 songs correctly at stage 2, and all the 13 songs at stage 3, and 10 songs correctly at stage 6 of the main experiment, participated in an additional experiment, in which the same procedure as that of stage 2 of the main experiment was given. She could identify 11 songs correctly. She was not told anything about the additional experiment, and she said that she had not been reminded of the experiment at all for those two weeks. So it is unlikely that her good performance during the additional experiment was due to mental rehearsal during those two weeks. This result suggests that the paired associations were well retained.

Numbers and percentages of correct answers for each song made by the subjects who had known it are shown at Table 1.

Table 1. — *Number and Percentage of Correct Answers for Each Song*

| Title of the song | $n^a$ | Stage 2 | | Stage 3 | | Stage 6 | |
|---|---|---|---|---|---|---|---|
| Irish Lullaby | 1 | 0 | (0%) | 1 | (100%) | 1 | (100%) |
| Annie Laurie | 7 | 3 | (42.9%) | 7 | (100%) | 7 | (100%) |
| Auld Lang Syne | 7 | 1 | (14.2%) | 3 | (42.9%) | 7 | (100%) |
| Home Sweet Home | 6 | 1 | (16.7%) | 2 | (33.3%) | 3 | (50%) |
| Long Long Ago | 7 | 6 | (85.7%) | 7 | (100%) | 7 | (100%) |
| Love's Old Sweet Song | 1 | 0 | (0%) | 0 | (0%) | 1 | (100%) |
| Picnic | 7 | 1 | (14.2%) | 5 | (71.4%) | 6 | (85.7%) |
| Der letzte Abend | 1 | 0 | (0%) | 1 | (100%) | 0 | (0%) |
| Sandmännchen | 1 | 0 | (0%) | 1 | (100%) | 1 | (100%) |
| Freut euch des Lebens | 2 | 1 | (50%) | 1 | (50%) | 1 | (50%) |
| Lorelei | 7 | 3 | (42.9%) | 7 | (100%) | 6 | (85.7%) |
| Heidenröslein | 7 | 4 | (57.1%) | 7 | (100%) | 6 | (85.7%) |
| Wiegenlied | 7 | 0 | (0%) | 5 | (71.4%) | 4 | (57.1%) |
| Stille Nacht Heilige Nacht | 7 | 7 | (100%) | 7 | (100%) | 7 | (100%) |

[a] Number of subjects who knew the song.

In order to examine differences between stages for each song, a McNemar test was applied for seven of the songs: We did not apply this test to five songs which only one or two subjects knew, and "Long Long Ago" and "Stille Nacht, Heilige Nacht", which were identified well even at stage 2, that is, from their putative reduced pitch patterns alone. By comparing identification performances between stage 2 and stage 3, adding durational pattern was found to have a facilitative effect on four songs; "Wiegenlied" ($p < .05$), "Annie Laurie", "Picnic" and "Lorelei" ($p < .10$). Comparison between stage 2 and stage 6 showed that after the paired association session, their identification performance had improved on four songs; "Auld Lang Syne", "Picnic" ($p < .05$), "Annie Laurie" and "Wiegenlied" ($p < .10$). In comparison between stage 3 and stage 6, a significant difference was found with "Auld Lang Syne" ($p < .10$), in which performance after the paired association session was better than that in stage 3, that is, durational patterns being presented with the putative reduced pitch patterns.

*Discussion*

The task of identifying tunes from their putative reduced pitch patterns alone was difficult, and thus Prediction 1a does not seem tenable. However, because identification performance may vary according to the subjects' procedural competence (Greeno, Riley, & Gelman, 1984) for using putative reduced pitch patterns as cues for reconstructing melodies, further investigation, especially that using more skilled subjects or involving pretraining in the use of putative reduced pitch patterns is needed.

Presenting durational patterns, in addition to putative reduced pitch patterns, is helpful for identifying tunes. Four subjects out of the seven reported that they had depended entirely on durational patterns when identifying tunes, and the remaining three said that they had relied mainly on durational patterns. However, since Deutsch (1972) demonstrated that recognizing tunes based on durational patterns alone was difficult, they probably used both putative reduced pitch patterns and durational patterns as cues for identifying melodies.

The subjects' performance at stage 6, that is, after the associations between putative reduced pitch patterns and the corresponding tunes had been presented may have been a little inflated, because they had explored to find tunes corresponding to putative reduced pitch patterns in earlier stages. However, considering that the associations were learned in just a single trial without rehearsal and that one of them who tested could retain the associations two weeks later, we can reasonably conclude that the associations are acquired easily. Prediction 2 was supported.

Among many possible extensions of this experiment, two manipulations seem most urgently required. First, we have to investigate students' melodic identification performance when a list of alternative tunes is not presented. The subjects of Experiment 1 may have tried to extract putative reduced pitch patterns from the listed tunes and match them in turn with the presented putative reduced pitch pattern, instead of attempting to match the presented putative reduced pitch pattern to each of their memory representations of British and German tunes. Although we believe this was not the case, because the available amount of time for identifying the tune from the presented putative reduced pitch patterns, 30 sec., was too short for this strategy, and extracting putative reduced pitch patterns from the memory representations of tunes would be rather difficult, this possibility could not completely be ruled out here. Second, it might be interesting to examine whether adding a few characteristic pitches to a reduced pitch pattern will improve identification performance, because adding these pitches will enable experienced listeners to infer what pitch sequence modifiers should be applied to reconstruct the melody. Giving pitch sequence modifiers which characterize features in surface structure, in addition to a putative reduced pitch pattern, would be useful for identifying the melody.

## Experiment 2

Experiment 2 was conducted in order to examine whether or not identification performance would be improved by adding one or two characteristic pitches to a putative reduced pitch pattern, when subjects were not given a list of possible alternatives. Characteristic pitches were selected from the following; 1) the highest or the lowest pitches of a melodic segment, 2) the first pitch of a melody, 3) the first pitches of phrases, 4) the first pitches of measures. The first two kinds of pitches, that is, the highest or the lowest pitches of a melodic segment, and the first pitch of a melody seemed to be more effective than the other two kinds, because the former two were more noticeable than the latter two. Subjects were instructed that the putative reduced pitch patterns represented well-known European songs, but no titles were given.

### *Method*

*Subjects.* Eleven female college students majoring in music education participated in this experiment. They were 20-21 years old, and not the same as the subjects of the first experiment. Two of them majored in vocal music and had had piano and vocal training of 4-5 years. The remaining nine subjects majored in piano playing and had had training of 10 years or more.

*Material.* Materials were six putative reduced pitch patterns derived from the first four measures of six European folk songs; "Lorelei", "Long Long Ago", "Auld Lang Syne", "Picnic", "Annie Laurie", and "Home Sweet Home". Two characteristic pitches each were selected (see Figure 6). As to the two notes selected for "Lorelei", the first one was selected because it was the highest pitch of a melodic segment. The second one was selected because it was the lowest.

*Procedure.* Subjects were told that songs to be used were several European folk songs and were either in six-eight or in common time. The subjects were also told that the putative reduced pitch pattern of the first four measures of each song was transposed in C major and


*Figure 6*. Two characteristic pitches selected for each of the six songs. Pitches which were added at stage 2 were assigned a numeral identifier (1) and at stage 3 an identifier (2).

written in eight half-notes (or seven half-notes and one whole note). However, they were not given a list of possible song titles.

The procedure for each tune consisted of three stages lasting 5 minutes each; in stage 1, the notated version of a putative reduced pitch pattern alone was presented: in stage 2, one characteristic pitch was added to the putative reduced pitch pattern: in stage 3, a second characteristic pitch was added.

In these three stages, the subjects were individually asked to identify the original tune and to play any tunes which came to their mind. When the subjects could identify the original tune at the first or the second stage of the procedure, the remaining stage(s) for that tune were omitted. At the end of the experiment, subjects were presented auditorily original tunes which they could not identify from their putative reduced pitch patterns, in order to ascertain whether or not they knew these tunes. Subjects were also asked what strategies they used for identifying melodies during the experiment.

If the subjects could not identify the first three tunes, the experiment was terminated. Three of the subjects, one vocal music major and two piano majors, could not identify the first three tunes so they abstained from the remaining part of the experiment. The remaining eight subjects were ranked according to their identification performance, and assigned alphabetic identifiers from A to H. The top five (A — E) were classified as good performers (range of proportion of correct answers; 60.0% ~ 83.3%), the bottom three (F - H), poor performers (range; 16.7% ~ 33.3%).

*Results and discussion*

Identification performances made by the eight subjects for each stage of the six tunes are shown in Table 2. The five good performers made 17 correct identifications altogether, and ten out of the 17 correct answers were induced at stage 2 or 3, that is, after characteristic pitch(es) were given. The three poor performers made only one correct answer each, all of which was made after characteristic pitches were given.

Table 2. — *Identification Performance for Each Stage of Six Songs Made by Eight Subjects*

| | Title of the song | | | | | |
|---|---|---|---|---|---|---|
| | Lorelei | Long Long Ago | Auld Lang Syne | Picnic | Annie Laurie | Home Sweet Home |
| | Stage | | | | | |
| Subject | 1 2 3 | 1 2 3 | 1 2 3 | 1 2 3 | 1 2 3 | 1 2 3 |
| | Good performers | | | | | |
| A | x x O | O | x O | x x O | x x x | O |
| B | unknown | O | x x x | O | unknown | x O |
| C | unknown | O | x x O | x x x | unknown | unknown |
| D | x x x | O | x O | x x x | O | x O |
| E | x x O | x x x | x x O | x x O | unknown | x x x |
| | Poor performers | | | | | |
| F | unknown | x x O | x x x | x x x | unknown | unknown |
| G | unknown | x x x | x O | unknown | unknown | x x x |
| H | x x x | x O | x x x | x x x | x x x | x x x |

The proportion of correct identification for the total group was 19.0% at stage 1, whereas 56.7% at stage 3. These results suggest that putative reduced pitch patterns alone were not effective as a cue for identifying melodies, and that the characteristic pitches facilitated the identification of original melodies. Prediction 1b, not 1a, seemed to be supported. A McNemar test was applied to four of the songs: As to "Lorelei" and "Annie Laurie", this test was not applied because only three or four subjects knew these songs. A significant difference between stage 1 and the remaining two stages was obtained, however, for only one tune, "Auld Lang Syne" ($p < .03$).

The poor performers were found to use two identification strategies. One of these strategies was to try to recall every European folk song they knew first and then, in purely trial-and-error fashion, to superimpose it on the given putative reduced pitch pattern, in order to examine whether or not it was the correct answer.

The other was to try to reconstruct melodies by adding pitches to the first two pitches of the presented sequence. In other words, attention was fixed to a few pitches out of the presented sequence of pitches. For example, a poor performer played the first two pitches of the sequence repeatedly with or without additional pitches tentatively added. She recalled many songs but could not reach the correct answer.

These two strategies seemed not to be effective for using information from the presented tone sequence fully. Poor performers seemed to suffer from lack of procedural competence in using putative reduced pitch patterns as cues for retrieving melodies.

The good performers did not adopt these two strategies. They did not fix their attention to a few pitches out of the presented sequence as the poor performers did. Rather, the good performers paid attention to the whole sequence of pitches presented. They seemed to hear the whole sequence of pitches carefully most of the time. When any operation was conducted, it was not for a few pitches out of the presented sequence but for the whole sequence of pitches.

One of the good performers (subject B) played whole sequences of pitches again and again. She reported that she had played these sequences repeatedly at first and then added several pitches tentatively. But, she said, she could not explain well how to add pitches. She said that she had played the sequence absent-mindedly while waiting for a melody to emerge from the sequence of pitches. Indeed, most of what she played for the three tunes for which she could reach the correct answer was the whole sequences of pitches presented.

Another good performer (subject A) said that, in some cases such as "Long Long Ago", she could reach the original, without special effort, while hearing the sequence of pitches played. Sometimes, she said, she had put each note in several probable positions within a measure in order to get some idea of the original tune. These two good performers seemed to succeed in constructing appropriate melodic representations based on the information obtained not only from the putative reduced pitch patterns but also from their characteristic pitches. As a result, they could recognize a resemblance between the originals and the reconstructed tunes.

## GENERAL DISCUSSION

The present two experiments revealed that (1) identifying tunes just from presented putative reduced pitch patterns was hard even when a short list of possible tunes was given, (2) associative learning between putative reduced pitch patterns and tunes was easy and the association was well retained, (3) durational patterns presented with putative reduced pitch patterns provided a powerful additional cue for identifying tunes from a list, and (4) giving a characteristic pitch or two in addition to a putative reduced pitch pattern made the identification much easier, though the percentage of correct identification was about 50 on the average. These results seem to reject Prediction 1a and support 1b and 2.

Why are putative reduced pitch patterns not powerful cues for identifying tunes? Our melodic processing model assumes that an experienced student abstracts a sequence of pitches of the structural notes (i.e., a reduced pitch pattern) from a segment of the melody while listening to it, and also specifies pitch sequence modifiers that transform the reduced pitch pattern into a "surface" form of an instantiated pitch sequence and rhythmic modifiers that produce the "surface" durational pattern. This decomposition process enables a listener to learn a new melody promptly, because any new melody within his/her familiar style can be recoded as a combination of familiar components (reduced pitch patterns and modifiers), quite limited in number. In the processes of memorizing, and probably in the early phase of storing, reduced pitch patterns and modifiers are dissociable, thus some unimportant modifiers may be lost, and others may be attached to other reduced pitch patterns than the original one, as revealed in our earlier studies (Oura, 1991; Oura et al., 1988b).

However, the present findings strongly suggest that reduced pitch patterns of stored melodies can not be retrieved, being dissociated from other components. In other words, it is impossible even for an experienced student of music to match a given putative reduced pitch pattern directly to reduced pitch patterns of the stored tunes in the mental list of known melodies. It must be rare that a putative reduced pitch pattern itself happens to be similar to the corresponding tune in memory representation (i.e., all modifiers can be ignored), and thus usually a student has to instantiate the putative reduced pitch pattern in a variety of ways before he/she can recognize which tune is represented by it. However, a large number of different modifiers can be applied to a putative reduced pitch pattern, and human beings are probably not very good at applying all possible operators systematically and exhaustively. It is not very likely that the student can reconstruct the tune from the putative reduced pitch pattern by choosing the right modifiers so that s/he can identify the tune represented by the putative reduced pitch pattern.

Once associated, putative reduced pitch patterns could readily trigger the corresponding tunes even two weeks later, at least when only a small number of associations were held. This suggests that once a student learns how to instantiate a putative reduced pitch pattern, in other words, what modifiers should be applied to the putative reduced pitch pattern, s/he can hold that information without difficulty. In this sense, putative reduced pitch patterns contain essential characteristics of tunes, which can serve not only to classify tunes (Bigand, 1990), but also to reconstruct tunes combined with modifiers. Putative reduced pitch patterns are not informative enough to enable the choice of proper modifiers without any constraints, but once the proper modifiers are given, putative reduced pitch patterns can easily be associated with them.

Our subjects could identify tunes when presented with durational patterns in addition to putative reduced pitch patterns. In fact, some of them said that they used durational patterns as the only cues for choosing tunes from among the given alternatives. We would like to propose two alternative interpretations for this result, though not necessarily mutually exclusive. First, because a durational pattern designates the duration for all notes constituting a tune, it involves rich information, as rich as involved in a putative reduced pitch pattern and pitch sequence modifiers combined. Second, unlike a reduced pitch pattern, a durational pattern can easily be separated from other components of the memory representation of the tune. We may sometimes practice how to perform a durational pattern, disregarding pitches.

Therefore, a presented durational pattern can readily be matched with durational patterns of the tunes listed.

However, it is impossible to reconstruct a tune based on a presented durational pattern alone. Unless it is unique, to identify a tune relying on the durational pattern may not be easy either, when possible alternative tunes are not given. It usually serves as an additional cue for identifying a tune. When combined with a putative reduced pitch pattern, a presented durational pattern may have a facilitative effect on identification of the tune by constraining how the putative reduced pitch pattern is instantiated.

Adding a characteristic pitch or two facilitated the identification of tunes. This effect may have been just apparent in part, because our subjects had spent some time trying to retrieve a tune before a characteristic pitch was added. However, we believe that it had a real effect, by making the presented pitch sequence more similar to the memory representation of the target tune, and also by constraining the range of possible pitch sequence modifiers to instantiate a given putative reduced pitch pattern. Since our subjects did not seem accustomed to applying modifiers to instantiate a given putative reduced pitch pattern, and also there could be a large number of possible modifiers, "hints" given by characteristic pitches could be very helpful. An informal investigation revealed that adding two randomly chosen pitches was not effective at all, whereas adding two characteristic pitches, operationally defined above, was effective, as reported.

Many future studies are needed to examine and elaborate further upon our model of melodic processing. Two lines of studies are being conducted in our laboratory: (1) Comparing students' performance for a putative reduced pitch pattern (with or without a few characteristic pitches) and for a sequence of pitches randomly chosen, an equal number of pitches (ordered as they are); (2) Examining students' immediate responses after listening to a putative reduced pitch pattern. Results of these studies, combined with earlier ones, are expected to specify the nature of the memory representation of a melody, especially of a reduced pitch pattern.

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