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Recommended Citation

Halpern, Andrea. "Perceived and Imagined Tempos of Familiar Songs." *Music Perception: An Interdisciplinary Journal* (1988) : 193-202.

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Source: *Music Perception: An Interdisciplinary Journal*, Vol. 6, No. 2 (Winter, 1988), pp. 193-202

Published by: University of California Press

Stable URL: <http://www.jstor.org/stable/40285425>

Accessed: 19/05/2010 13:50

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Perceived and Imagined Tempos of Familiar Songs

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Two studies investigated the similarity of metronome settings to perceived and imagined familiar songs by subjects unselected for musical ability. In Study 1, mean tempo settings in the two tasks were about 100 beats per minute. Songs with slower perceived tempos tended to be faster in the imagery task and vice versa. In Study 2, subjects set fastest and slowest acceptable tempos for the same set of songs in the imagery mode. These settings were positively correlated with the preferred tempo for the song. Most subjects thought that there were limits on how fast or slow a song could be imagined. These results suggest that tempo is explicitly represented in auditory imagery.

ALTHOUGH people may believe that a synchronized musical performance requires the presence of a conductor, he or she cannot be the only timekeeper in a performance. Because most instrumentalists need to attend to the written score during performances, they only view the conductor sporadically. And even if individual musicians relied exclusively on the visual stimulus of the conductor's hand motion before initiating played or sung notes, the performance would gradually but continually slow down.

Clearly, ensembles can function without a conductor at all. Many ensembles designate one member to begin and end pieces but mostly operate without formal leadership. Professional groups (rock bands, chamber choirs, string quartets) as well as amateur or even unskilled groups (church congregations) nevertheless manage to sound reasonably synchronized. This synchronization may not stand up to close scrutiny, as small but measurable timing deviations have been found even among professional musicians (Rasch, 1979; Sternberg, Knoll, & Zukofsky, 1982). However, the usual impression is of generally successful musical synchronization.

In order to synchronize their performances, members of musical groups must have some representation of the tempo, or speed, of the piece in question. In other words, people must use a memory of a tempo to guide production of time intervals in the subjective present, modified of course by

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feedback from other group members. The current research considers whether the remembered tempo of familiar music may be similar in character and magnitude to the perceived tempo of that same music. When asked to think of a tune, many people report an experience they describe as “hearing the tune played inside my head.” We cannot of course validate this experience directly, but we can indirectly assess to what extent playing tunes inside and outside the head are comparable. For instance, Halpern (1988) asked people to compare two parts of an imagined familiar song. Time to complete a lyric verification or pitch comparison task increased as a function of the real distance in beats between the two parts of the song. This suggested that the representation of the song coded temporal extent. As another example, Weber and Brown (1986) found that describing the pitch contour of newly learned melodies took about the same amount of time and produced comparable error rates whether the tune was perceived or imagined. This view of auditory imagery is similar to that of visual imagery theorists who claim that spatial extent is coded in the visual image (e.g., Kosslyn, Ball, & Reiser, 1978).

The question asked here is whether people represent a constant or preferred tempo of a tune when they claim to be imagining it. Clynes and Walker (1982) had musicians tap their finger to imagined music, and found a very stable tapping rate compared to tapping without imagined music (although the music in question had probably been studied extensively by the subjects). When the subjects were asked to actually play versus “mentally execute” a piece of music, Clynes and Walker found that, counterintuitively, seven of the eight musicians imagined tempos *more slowly* than they performed them. Played and imagined tempos were quite stable over repeated trials, with imagined tempos being slightly more variable than perceived tempos.

We may ask whether ordinary people have an experience of mental tempo when recalling familiar tunes. This article describes two experiments using as subjects people unselected for musical ability. Preferred tempos for imagined and perceived songs were solicited in Study 1. In Study 2, the flexibility of the representation was tested by asking another group of subjects to imagine the slowest and fastest possible tempos for those same songs. Means and variability of the tempos were examined to see if mental tempos were indeed slower and more variable than perceived tempos as Clynes and Walker (1982) found, and to what extent subjects could “speed up” or “slow down” that tempo when instructed to do so.

Study 1

This study tested whether subjects preferred a particular tempo for familiar songs, both when the songs were actually heard and when they were

merely imagined. The stimulus songs were chosen to be known to subjects from many contexts and in many versions. Thus, the represented tempo should not be tied to a memory for any particular version, as might be the case with a current rock tune, or a symphony, where tempo is usually indicated by the composer.

METHOD

Subjects

Participants were 20 Bucknell University undergraduates who received \$2.00 for the 30-min session. In both experiments, subjects were required to have been raised in the United States to ensure their familiarity with the stimulus songs.

Materials

Nineteen well-known songs served as stimuli. Examples are "Do Re Mi," "Happy Birthday," and "Yesterday." These had been rated as highly familiar in previous work (Halpern, 1984). For the perception phase of the study, music was presented by an Apple II computer controlling a Mountain Music synthesizer. The notes were sine waves adjusted to a comfortable listening level via a Yamaha amplifier and headphones. The imagery phase employed a Franz electronic metronome.

Procedure

Subjects were first shown the list of stimulus songs and asked if they were all familiar. Only subjects indicating familiarity with the songs participated. They were then shown the lyrics of the beginning part of each song, and were asked to clap out the beats while reciting the lyrics in order to verify that experimenter and subjects agreed on beat placement. Upon satisfactory completion of this initial phase, half the subjects received the perception task, and half, the imagery task.

Perception Task

Subjects were given a list of the stimulus song titles and a number that identified each to the computer. Upon entering the number into the computer, subjects heard the first part of the tune at a very slow tempo. The computer program allowed the listeners to change the tempo until the song sounded "correct" to them. To change the tempo, metronome markings in beats per minutes (bpm) were entered. Only bpm values actually found on the metronome were allowed as responses. This limitation was imposed to make answers comparable to the imagery task, where the metronome was used. For example, subjects could enter "108" or "112", but not "110" because this was not a metronome setting. The listeners could hear and adjust a given tune until they were satisfied, and then they reported the preferred tempo.

Imagery Task

Subjects were given a list of stimulus song titles. They were instructed to imagine the tune in their head and set the metronome to coincide with the beats in the imagined tune. They then reported the setting.

In order to minimize the possibility that subjects simply memorized the settings for each song, they received one of three different random orderings of titles in each task. In addition,

they were not told about the second task when participating in the first one. The two tasks were separated by a short rest break, so that on the average, about 15 min intervened between the two tasks for the same song.

RESULTS

The 19 songs by 20 subjects results in 380 observations for each task. Some of the results are reported as ratios of perceived to imagined tempo, yielding a total of 380 ratios. Although care was taken to ensure that subjects and experimenter agreed on beat placement, logically, beat placement is arbitrary under transformations of powers of two. That is, "London Bridge" can be clapped in the following two ways: "Lóndon bridge is fálling dówn, fálling dówn, fálling dówn" or "Lóndon bridge is fálling dówn, fálling dówn, fálling dówn" (i.e., half as many claps). Thus, ratios of perceived to imagined tempo in the vicinity of 0.5 or 2.0 could *either* mean that subjects were imagining tempos half or twice as they perceived them, *or* that their beat placement had changed across the two tasks. It was thus thought prudent to discard data where the ratios were larger than 1.9 or smaller than 0.6, which amounted to 8.7% of the data. An exception was made in the first analysis reported below.

A one-factor ANOVA (using all the data) tested whether the average tempo settings for the 19 songs differed from one another. This was in fact the case: For the perception task [$E(18,342) = 31.6$] and for the imagery task [$F(18,342) = 9.3$]. Repeating the analysis with just those six subjects who had complete data sets revealed a similar pattern: For the perception task [$F(18,90) = 13.1$] and for the imagery task [$F(18,90) = 4.8$], all $p < .001$.

The next hypothesis tested was that perceived and imagined tempos for each tune were equal. For each song, the average ratio of perceived to imagined tempo for each song across subjects was tested against a ratio of 1.0. These one-sample tests showed that only 3 of the 19 songs had ratios statistically indistinguishable from 1.0 ($p < .05$). For 7 of the songs, imagined tempos were faster than perceived; for 9, perceived tempos were faster than imagined.

Overall, the means across subjects of imagined (97.6 bpm) and perceived (99.2 bpm) tempos did not differ, $t(18) = .48$. Imagined tempos were more variable [mean standard deviation = 22.3 bpm] than perceived tempos [mean standard deviation = 15.4 bpm, $t(18) = 5.3$, $p < .001$], but only when computing the standard deviation across subjects. When computing the SD across songs for each subject, results did not differ for the two tasks [19.5 bpm for imagined, 22.1 bpm for perceived, $t(19) = 1.5$, NS].

For all the songs taken together, perceived and imagined tempos were positively correlated [$r(17) = .63$, $p < .01$]. There was also a tendency for songs with slower perceived tempos to be imagined faster than they were

perceived, whereas songs with faster perceived tempos slowed down in the imagery task [point biserial correlation (17) = .66, $p < .01$; mean perceived tempo was correlated with whether a song's tempo was slower in the perception or imagery task; see Figure 1 and Table 1].

DISCUSSION

Subjects had no difficulty in following instructions for this study, suggesting that the measurement of internal tempo was a meaningful concept to them. The generally positive relationship between perceived and imagined tempo was qualified by the different patterns shown for different sets of songs. Imagined tempos seemed to regress to a middle range, between the faster and slower perceived tempos. Although at least part of this effect may simply be due to statistical regression, it is interesting to note that this middle range is about 100 bpm, or 600 msec per beat. This figure is commonly cited as being a "natural" or "preferred" rate for tapping, and the rate at which temporal discrimination is easiest (Fraisse, 1982).

There was no evidence that imagined tempos were generally slower than perceived, contrary to Clynes and Walker (1982). Subjects agreed more

Fig. 1. Scatter diagram comparing perceived and imagined tempos in Study 1.

TABLE 1
Mean Tempos (beats per min) for Each Song in Experiments 1 and 2

Song	Experiment 1			Experiment 2	
	Perceived	Imagined	Preferred	Fast	Slow
Do Re Mi	88	102	112	165	70
Happy Birthday	109	101	120	163	65
Happy Days	133	126			
Hark	69	88			
Hey Jude	90	85	85	151	55
Frere	124	101	106	168	63
London Bridge	86	101	113	170	65
Mary	93	109			
My Country	103	100	111	173	64
O Come	69	83			
Old MacDonald	93	109			
Row Row Row	114	91			
Sound of Music	104	85			
This Land	104	105	116	169	69
Three Blind Mice	123	110			
Twinkle Twinkle	83	99	113	168	63
When the Saints	128	112	131	175	71
White Christmas	81	74	85	143	59
Yesterday	89	73			

with one another about the preferred tempo for perceived versus imagined songs. This may have been caused by subtle cues to tempo in the actual computer-generated notes, or perhaps by the slight differences in instructions necessary for performance of the two tasks, again contrary to Clynes and Walker (1982). However, as individuals, the listeners were equally variable in their judgments in the two tasks. This suggests that for a particular person, the processes and/or representations used in each task are similar.

The observation that faster perceived tempos (shorter internote intervals) tend to slow down in imagery and vice versa is similar to results found by several researchers for judgments of durations in memory (reviewed by Estes, 1985). In those studies, subjects must judge the duration between two presentations of an item in a list. Short lags are overestimated and long lags are underestimated. Despite this “leveling” tendency, we showed that different songs had quite different preferred tempos. The next study probed the lability of the representation of these tempos by asking subjects how fast and slow particular songs can be imagined.

Study 2

If songs are represented at a particular tempo, is that tempo subject to transformation under appropriate instructions? At one extreme, we may predict that the “speed” with which a song is imagined is subject to the same

limits as auditory perception. Bolton (1894) found that the subjective feeling of rhythm broke down when internote intervals were shorter than 115 msec or longer than 1580 msec. The fastest and slowest imaginable tempos may be of similar magnitude (or at the extreme metronome settings of 288 msec per beat to 1500 msec per beat) and constant across song. At the other extreme, the representation of tempo may be so intrinsic to the song representation that subjects would have a difficult time imagining tempos too far removed from the preferred ones.

Initially we thought to compare perceived and imagined tempos as in Study 1. However, pilot work showed that asking the subjects how fast or slow they could perceive a tune did not make sense. Even at the extreme tempo settings, subjects still said they could match a tune with its name, although they found the tempos unappealing. Consequently, we used only an imagery task in this study.

METHOD

Subjects

Twenty Bucknell undergraduates volunteered for the study.

Materials

Ten songs from Study 1 served as stimuli (see Table 1).

Procedure

The familiarization phase proceeded as in Study 1. Next, for each song, the subject used the metronome to find the preferred tempo of the song. The preferred tempo was explained as "that at which [you] would normally imagine the song." Thus, this phase was essentially a replication of Study 1. For half the songs, slowest tempo was probed next, followed by fastest tempo, and vice versa for the other half. Ordering of fast/slow was rotated against songs so that half the subjects set slow tempo first for a particular song while the remaining subjects set the fast tempo first for that song.

For each of the two remaining tasks, the subjects started with the metronome at the preferred tempo and moved the dial toward the fastest (208 bpm) or slowest (40 bpm) metronome tempo, as appropriate. Each time the subjects changed the tempo on the metronome, they rated the difficulty of imagining the song at that tempo. The ratings were on a four point scale, where "1" signified "very easy" and "4" signified "very difficult." The subjects were told to record on their answer the first metronome setting receiving a rating of 4. If the subjects skipped any settings on the metronome, they were told to try the tempos falling between the marking receiving a 4 and the previous one to ensure that they had selected the first tempo meriting a rating of 4. (The selected tempos are hereafter referred to as "slowest" or "fastest" tempos.)

Each subject received a different order of songs, and worked at the task at his or her own pace. Time for completion was approximately 30 min. After the task, subjects were asked about their musical backgrounds and also if they thought limits to the speed of imagined songs existed.

RESULTS

For each of the three tasks, mean tempo settings differed significantly among the 10 songs [$F(9,171) = 11.4, 4.4$, and 3.9 for the preferred, fast, and slow tasks, respectively (all $ps < .001$)]. The mean fastest tempo of 164 bpm and slowest tempo of 65 bpm did not coincide with the metronome limits of 208 and 40 bpm. This implies that subjects were discriminating among the songs and not simply choosing the extremes on the metronome for their answers.

The mean preferred tempo was 109 bpm. This is significantly faster than the mean imagined tempo from Study 1 of 98 bpm [$t(9) = 6.2, p < .001$]. However, tempos in these two studies were strongly correlated [$r(8) = .94$]. That is, under slightly different instructions in Study 2 (participants set a “preferred” tempo here as opposed to the “correct” tempo in Study 1), subjects set tempos faster but in a very similar ordering to Study 1 (see Table 1).

Significant positive correlations were obtained among the different tasks in Study 2. The preferred tempo correlated with the fast tempo [$r(8) = .87$] and slow tempo (.88); and the fast and slow correlated with each other (.73, all $p < .01$).

Most subjects agreed that at least some of the songs had tempo “limits,” beyond which it was difficult to imagine the songs (only two subjects claimed that no limits existed). The four subjects with the most extensive musical backgrounds also were able to imagine the songs at the most extreme tempos. The average difference between the fast and slow tempos was 153 bpm for the four musicians, versus 87 bpm for everyone else.

DISCUSSION

Subjects again were able to following directions in this study, suggesting that both the concept of *having* an imagery-like mental representation and *transforming* it made sense to the participants. The values recorded for the slowest and fastest tempos were dependent on the preferred tempo. This implies that we are not dealing with an absolute limits on the speed with which a tune is imagined. For instance, the mean fastest imaginable tempo for “When the Saints Come Marching In” was 32 bpm faster than that for “White Christmas.”

Although subjects were unselected for musical ability, we did note that the four identified musicians claimed to be able to imagine the tunes at more extreme tempos than the other people. It is difficult to imagine that even the musicians had had experience with this precise task in the course of their musical education. They have have had experience in other sorts of mental musical transformations, however. Conductors in particular probably find

that being able to imagine the sounds of the orchestra from simply looking at the score to be a useful skill. As someone decorating a room would value the ability to imagine the sofa in different colors in different locations before actually executing the plan, a conductor would value being able to imagine adding or subtracting instruments to the ensemble or speeding up and slowing down the tempo. We may expect that conductors would show the most flexibility in auditory imagery tasks, and would make an interesting group to study.

General Discussion

These two studies suggest that familiar tunes are represented in memory with a particular tempo, but that the tempo can be mentally transformed up to a certain point. We should keep in mind that although the tunes in this study mostly had simple rhythms, some had syncopation (“Yesterday,” “When the Saints”) and others began on an upbeat (“This Land is Your Land,” “O Come All Ye Faithful”). Thus, the transformations are not confined to very regular rhythms.

It is tempting to think of tunes being stored in memory with parameters of tempo, rhythm, pitch, etc. somehow explicitly or literally represented. Under this scheme, a command to activate a particular tune simply “unpacks” the memory trace in real time. On the other hand, visual imagery theorists like Kosslyn (1981) propose that the imagery experience is a “surface representation” generated from an underlying “deep structure” in long term memory. To simplify, the deep structure is an abstract (symbolic) description of the imaged object or scene. In the case of musical imagery, conceiving of the tempo as a symbolic encoding at a deep level has logical appeal. Some form of internal timekeeping mechanisms must operate to allow us to judge remembered or ongoing durations or produce events at designated time intervals. Perhaps the deep level of auditory imagery contains a setting for the internal timekeeper attached to a node for a tune title. This setting would be considered a default value that could be changed if necessary.

If the tempo setting can be coded symbolically, then subjects should be able to access it directly. To test this, we could ask people to decide which of a pair of song titles denoted the faster song. If people have to “unpack” the tunes, then time to decide should be no faster than the sum of the durations of the first two or three notes of each tune pair (as determined by the average settings in this study, or by asking the same participants to set tempos). If time to decide varies as a function of other factors, perhaps whether a song is labeled as “fast” or “slow,” or as a function of the dif-

ference in average tempo setting, then evidence for a symbolic coding of tempo would be strengthened.

Nevertheless, the results of Study 2 suggest that even if tempo is represented symbolically at a deep level, the characteristics of the surface representation impose limits on the expression of such a coding. Those characteristics cannot be specified at this time, but may have to do with the speed at which a tune loses its musical coherence. For instance, the upper limit on imagined tempo may be a function of the shortest interval between two notes (rather than two beats) occurring in the first phrase, and the lower limit a function of the longest internote interval.^{1,2}

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1. This research was partially supported by grant BNS-8607405 from the National Science Foundation.

2. I wish to thank Susan Chiavetta and Susan Milton for running subjects in Studies 1 and 2, respectively, and Maureen Schmitter for help in data analysis. Thanks also to Diana Deutsch and an anonymous reviewer for comments on an earlier version of this manuscript.