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ABSOLUTE MEMORY FOR MUSICAL PITCH: MORE THAN THE MELODY LINGERS ON

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Running head: Absolute memory

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The treatment of the human subjects in this research was in full compliance with the ethical standards of the APA (Principle 9: Research With Human Participants in the "Ethical Principles of Psychologists," APA, 1981) and was reviewed and approved by the Stanford University Human Subjects Committee.

Abstract.

Evidence for the absolute nature of long-term auditory memory is provided by analyzing the production of learned melodies. Additionally, this evidence is applied to a two-component theory of absolute pitch, which conceives of this rare ability as consisting of a more common ability, *pitch memory* and a separate, less common ability, *pitch labelling*. Forty-four subjects sang popular songs and their productions were compared to the actual notes of those songs. Twenty-five percent of the subjects sang in the correct pitch. Analysis of the errors made by other subjects revealed a tight cluster around the correct pitch; 66% of the subjects came within two semi-tones of the correct pitch. This suggests that these subjects may also possess representations of pitch that are more stable and accurate than previously recognized.

Introduction.

One of the enduring and fundamental questions occupying psychologists and philosophers alike asks to what extent our inner, mental world, accurately reflects the external world around us. When we see or hear an object, is our perception accurate or subject to distortion? When we later recall that object, does our memory differ from the initial perceptual experience, adding distortions of its own? Stated casually, we wonder to what extent are our memories of events like photographs or tape recordings of the world.

In asking these questions, we share an interest with our colleagues who, for the last century, have studied that small segment of the population who possess Absolute Pitch (AP). People with AP are able to produce or identify specific pitches without reference to an external standard (Baggaley, 1974); they have *internalized* their pitch references and these remain relatively immutable despite the constant barrage of competing auditory and pitch information to which we are all exposed in daily life (but see Tsuzaki, 1992 for cases where AP possessors do succumb to external distractors). Thus, AP possessors exhibit the property of maintaining stable representations of pitch in long-term memory.

Another form of AP, dubbed *quasi-absolute pitch* (Bachem, 1937, cited in Ward and Burns, 1982), occurs in musicians who have absolute pitch for one note. Violinists, for example, might form a permanent representation of their tuning note, A, and be able to recognize or produce it easily, and then identify other notes using relative pitch to hop around from there. This is clearly different from being able to place notes directly, and serves to demonstrate that AP is not a single ability, but a set of related abilities.

There is a vast literature on AP by musical subjects (see Takeuchi and Hulse, 1992 for a recent review) but very little attention has been paid to the non-musical community, because non-musicians do not have the association between musical terms and tones necessary to complete standard AP tests.

Yet the literature suggests reasons to believe that non-musicians as well may possess some of the components of absolute pitch. Indeed, Dowling and Harwood (1986) believe "people possess [AP] in varying degrees and ... whether the ability shows up depends on the particular task demands the person faces." Lockhead & Byrd (1981) report that their AP possessors made more octave errors than non-AP possessors, and closer examination of the data reveals that their non-AP subjects tended to have errors clustered within a few semi-tones of the target. With even the most conservative notions of what should comprise a response space for probability judgments, these results appear remarkable.

With the great deal of attention paid to empirical, definitional and etiological issues in AP, few have proposed models of AP that shed any light on the nature of AP as a cognitive ability. I suggest that AP is not a mysterious, impenetrable ability, but rather that it consists of two (one hopes less mysterious) component abilities: (1) The ability to maintain stable, long-term representations of specific pitches in memory, and to access them when required; and (2) the ability to attach meaningful labels to these pitches, such as C#, A440 or *Do*. I call the first ability *pitch memory* and the second ability *pitch labelling.* Pitch memory may be a necessary condition for AP, but this remains an open question. It is easy to see how pitch memory could exist without pitch labelling. Less intuitive is the possibility that one could demonstrate pitch labelling and not pitch memory. If some AP possessors could label pitches without conscious memory for pitch, this would parallel findings in *implicit memory.* (Schacter, 1987.)

What distinguishes true AP subjects from other members of the population may merely be the ability to attach labels to their mental representations of pitch. Such an ability may be available to everyone, but require activation/training during a critical period of development; several researchers have noted that early childhood musical experience is common in the majority of AP possessors (Ward & Burns, 1982; Takeuchi and Hulse, 1992). In addition to addressing memory issues surrounding long-term storage and recall of musical pitch, the present research was designed to test the claim of component abilities by establishing the existence of pitch memory separate from absolute pitch ability.

Considering perception over two decades ago, Wickelgren (1969) noted "All psychophysical judgments involve some kind of memory, but only rarely is much attention given to the memory factors involved." Accordingly, the present study was designed to address the question of whether auditory memories accurately preserve qualities of the distal stimuli they encode.

Subjects were randomly selected, and consequently included both musicians and non-musicians. Subjects were asked to reproduce from memory the notes of contemporary popular and rock songs they had heard many times. It was hypothesized that exposure to a song hundreds of times creates a memory representation in the same key as the song was originally experienced, and that subjects will be able to access this representation in a production task.

Contemporary popular and rock songs are unique in that they are typically encountered in only one version by a musical artist or group, and so the song is heard hundreds or even thousands of times in the same key. In contrast, Halpern (1989) performed a pitch memory study with common folk songs using "Happy Birthday," "Yankee Doodle" and other songs which share the feature that they are performed in many different keys, and there is no objective standard for their performance key.

A further advantage of using rock songs is that subjects learn them on their own and are motivated to do so. The artificial environment of the psychological laboratory is minimized, and experimenter interaction is also kept to a minimum.

Another reason that studying memory for songs is interesting is that song memory differs from memory abilities traditionally studied in laboratory tasks. We typically store the entire melody of a song (or section of the song), and don't lose some of the notes randomly. Songs are typically stored as intact strings, where relations are stored and one item cues the next. (It is rarely the case that someone remembers the fifteenth note of the song, can't remember the sixteenth note, but then remembers the seventeenth again.) Compare this to other memory tasks where discrete bits of information are routinely lost, in memorized pieces of text or paired associate word tasks. The actual note on which a song begins is arbitrary in one sense:

most people have no trouble recognizing songs in transposition. In light of this, it would be interesting if people *did* actually encode the precise starting pitches of songs, and it would indicate that memory preserves the perceptual features of the distal stimuli it encodes.

Traditional notions of absolute pitch are that it is a rare ability occurring in a very small percentage of the population; it is estimated that 1 in 10,000 have the ability (Takeuchi and Hulse, 1992; Profita and Bidder, 1988). If *pitch memory* exists in a larger percentage of the population than this, it provides evidence for the two component model of AP, and suggests that people with pitch memory differ from conventional AP possessors primarily in their lack of pitch labelling ability.

Method.

Subjects.

Forty-nine subjects were recruited from the Stanford Psychology Department during spring and summer quarters, 1990-91. The subjects were Stanford University undergraduates, graduate students and high school summer session visitors and served without pay. The undergraduates and high school visitors served to fulfill a course requirement for Introductory Psychology. Ss did not know in advance they were participating in a study involving music. Ss ranged in age from 16 to 33 years (Mean 19.6; Std dev 1.7).

On arriving at the experimental session, subjects were asked to report musical training and/or years of playing a musical instrument, including voice. One claimed to be a possessor of Absolute Pitch, two claimed to possess relative pitch, though this latter claim was not tested. One subject who claimed to be tone deaf confirmed this condition experimentally. Five subjects had to be excluded for various reasons. (One subject asked to discontinue due to poor health; two were excluded because they reported they didn't know any of the songs in the stimulus set; one subject was excluded due to extreme shyness which rendered his productions inaudible on the tape; one subject was excluded due to experimenter's accidental failure to record his production.)

Materials.

Prior to the experiment, a norming study was conducted using the same type of subject population which would later be used in the experiment. (None of these subjects were subsequently used in the experiment.) In the norming study, 250 Psychology 1 students, Winter Quarter 1990-91, filled out a questionnaire asking them to indicate their familiarity with fifty popular songs. Subjects were also given the opportunity for "free response," to fill in the names of songs they "knew well and could hear playing in their heads."

The results of this norming study were tabulated, and those songs receiving the highest vote were selected. Songs on this list that had been performed by more than one group were excluded from the stimulus set because of the possibility that these versions might be in conflicting keys, creating interference with subjects' representations. (Examples of such songs include The Beatles' "Yesterday" and Stevie Wonder's "You Are the Sunshine of My Life.") In addition, songs in which tight vocal harmonies render the main melody hard to discern were excluded. (For example, The Beatles' "This Boy," Janes' Addiction's "Been Caught Stealing" and many songs by the group Wilson Phillips.) The CDs containing the top 58 songs made up the final stimulus set, and consequently over 600 songs were available to subjects in all. The complete list of stimulus CDs is included in Appendix 1, along with song titles chosen.

Apparatus.

Subjects were recorded monophonically on a Sony TCD-D3 DAT recorder, through either AKG SDE-1000 or Akai ACM-100 electret condenser microphones, hidden from subjects' view. The microphone was run through a Yamaha RM200 mixer for amplification. Tape used was Ampex R-467 C60. Data coding was done using a Panasonic SV3900 DAT machine for playback, with a Conn Strobotuner and a Boss TU-100 Digital Tuner in tandem. The left channel output of the SV3900 was fed into the input of the TU-100; a through output of the TU-100 was fed to the input of the Strobotuner. The right channel output of the SV3900 was fed through an amplifier and speakers for the data coder to hear.

Subject productions from the tape were clearly visible on the two tuners. The TU-100 indicated pitch class, number of cents deviation and octave. Pitch class and octave were corroborated on the Strobotuner. Both tuners contained internal calibrators and these were found to be within .1% of each other. The Conn was then calibrated to the Boss. (The Conn was found .1% low, perhaps because it had been purchased from a Conn man.) Compact disc melodies were coded using a Magnavox CD114 Compact Disc player run through a Yamaha CR600 stereo receiver. The "tape out" of the receiver fed the TU-100 which in turn fed the Strobotuner, as before.

Judgments using this coding scheme were accurate to within a quarter-tone, or 50 cents. That is, subject productions were quantized to the nearest quarter-tone.

Procedure.

Subjects first filled out a questionnaire asking about musical background, age, gender and other information. During the experiment, subjects were seated in a sound attenuation booth (Industrial Acoustics Company #102097) with the experimenter. The fifty-eight compact discs chosen from the previous norming study were displayed on a bookshelf. The experimenter followed a written protocol (Appendix 2) asking subjects to select from the shelf and to hold in their hands a CD that contained a song they knew very well. Holding the CD and looking at it may have provided a visual cue for subsequent auditory imaging. Farah and Smith (1983) found mental imagery to be an aid in auditory detection tasks; it seemed plausible that imagery might similarly aid in auditory production.

Subjects were then asked to close their eyes, and imagine that the song was actually playing in their heads. They were further instructed to try to reproduce the notes of that song by singing, humming or whistling. Subjects' productions were recorded on digital tape (DAT), which avoided the pitch and speed fluctuations associated with analog recording.

At a later date, subjects' productions were compared to the actual notes sung by the artists on the compact discs. Errors were measured in semi-tone deviations from the correct pitch, to the nearest quarter-tone. The first five notes the subjects sang were coded and compared to the equivalent five notes on the compact disc. Comparisons were made of the entire five-note sequence, as well as of individual notes within the sequence and the aggregate results of these different coding schemes were not significant. Hereinafter, therefore, data presented refer to subjects' first note productions. In accordance with modern practice in AP research, octave errors were not penalized (Ward and Burns,1982; Miyazaki, 1992; Takeuchi and Hulse, 1992).

Results.

Of the forty-four subjects, eleven (25%) made no errors ($p < .001$; see figure 1 and table 1). Moreover, 66% of the data fall within two semitones of the correct notes ($p < .002$). By chance, responses would occur equally often in each category, and a response in any one category would occur with a frequency of only 8.3%.

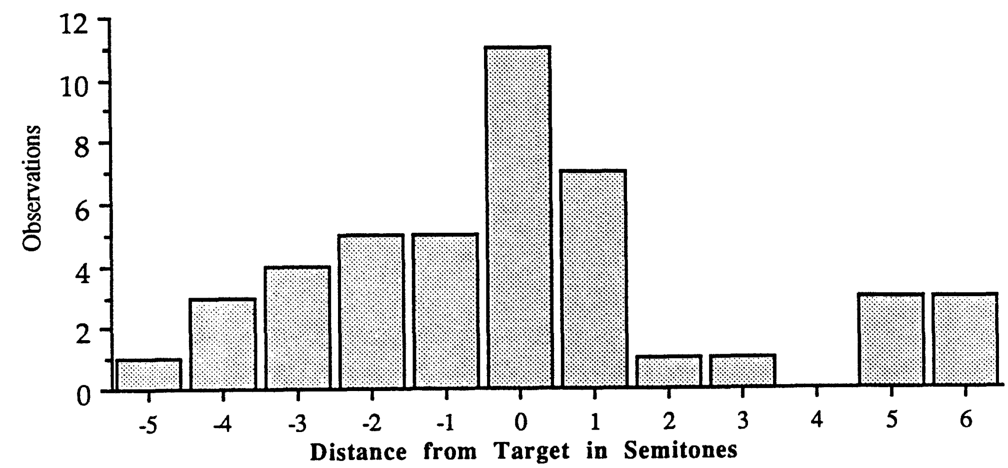

Figure 1. Subjects errors in semi-tones from correct note. 25% of subjects (11 out of 44) hit their target note. 12 subjects made errors of ± one semi-tone; 6 subjects made errors of ± two semi-tones. Octave errors were not penalized.

Absolute Value of Distance	No. of Observations	Cumulative Observations	Percentage Observations	Expected by Chance
0	11	11	25%	8%
1	12	23	52%	25%
2	6	29	66%	42%
3	5	34	77%	58%
4	3	37	84%	75%
5	4	41	93%	92%
6	3	44	100%	100%

Table 1. Percentage of responses falling in each error category, and cumulative table of errors. (Note error categories are absolute value.)

A correlational analysis (standard linear regression model) tested whether any of the questionnaire response items were related to success at this task. One factor found to be a significant predictor of ability in this task was previous piano playing experience ($p < .04$, chi square; see figure 2). Specifically, subjects who answered that they had at some time played piano performed better as a group than subjects who answered they had never played piano. One might reasonably ask if this item correlated with further or overall musical training, and if we had not merely selected those subjects with greater musical sophistication, but this was not the case; the piano lessons item was not significantly correlated with subsequent musical involvement. Only four subjects met our criterion of being musicians, five or more years of study on an instrument, and meeting this criterion did not correlate significantly with performance. There was no correlation between performance and gender, musical training, amount of time spent listening to music, or amount of time singing out loud (including in the shower or car) or other items on our questionnaire. There was a small, but not significant, negative effect of age, such that the younger subjects tended to do better. It is possible that the younger subjects may have known the songs better than the older subjects.

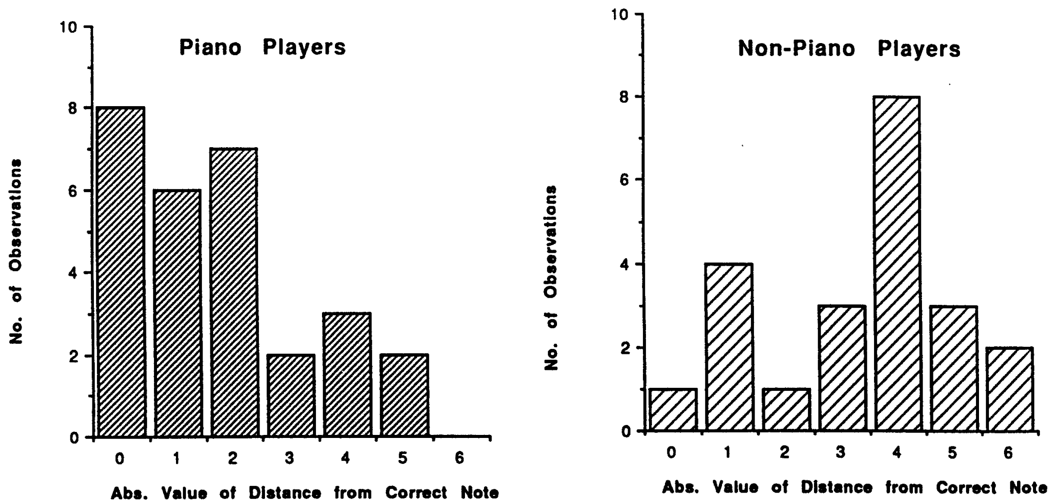

Figure 2. Errors of subjects who indicated that had at some time played piano, for any length of time (left) versus subjects who had not (right).

Casual reports by some subjects to the experimenter indicated that subjects had not heard the songs they chose to sing in the previous two days, and many had not heard the songs in a week or more. This suggests that subjects' long term memory for the songs was being tested.

Discussion.

The result that 25% of Ss tested reproduced pitches without error provides strong evidence that they possess accurate pitch memory. To perform in this task, subjects needed to encode the songs they have learned in their original keys, store the information and recall it without distorting the actual key of the song. Their memory for pitch can thus be characterized as a *stable, long term memory representation.*

The ability seems significant when compared to other memory tasks in which proactive and retroactive interference can distort or destroy the memory trace. (Massaro, 1970, and others, have studied effects of interference on short term memory for pitch.) Presumably, subjects have routinely heard many other songs in addition to the one tested and yet were able to maintain the tested song as a distinct trace in memory.

The errors made by subjects who "missed" are also instructive. If these people had no absolute memory, we would expect their errors to be evenly distributed at all distances from the correct note. Yet we find 52% of the subjects came within one semi-tone, and 66% came within two semitones. This suggests that those subjects who made only slight errors may have pitch memory but that it is more or less affected by other factors. We might speculate that their errors are the result of:

(a) a pitch memory whose resolution is only fine enough to make distinctions to the nearest semi-tone or whole-step (indeed, some have claimed this level of resolution qualifies one as an Absolute Pitcher; Miyazaki, 1992);

(b) production problems, in which the subjects were unable to get their voices to match the sounds they heard in their heads;

(c) self-correction or self-monitoring deficits, in which the subjects either knew they were singing the wrong note but could not correct it, or didn't know they were singing the wrong note because of an inability to compare their own productions with their internal representations;

(d) exposure to the songs in keys other than the correct keys. This could have happened if subjects listened to, and learned, the songs on cassette machines or phonographs with inaccurate speed.

The evaluation of explanations (a) - (c) will require further empirical work.

To address explanation (d), one of the questionnaire items asked subjects where they had heard the songs before. Cassette players and phonographs may vary as much as 5% in their speed (approximately one semi-tone) whereas CD players do not vary in pitch. A correlational analysis, however, failed to establish a relationship between accurate performance and source of learning of the material.

How do the mental representations of pitch memory possessors differ from AP subjects who label pitches? It may be the case that pitch memory subjects store what Bower (1967) calls the *primary code,* that is, the actual (filtered) sensory data, and that pitch labelling AP subjects store a secondary code, the label for the stimuli at the time of encoding. One view has been that AP Ss differ from non-AP possessors in their ability to store verbal pitch names rather than relying on echoic memory (Takeuchi and Hulse, 1992; Zatorre and Beckett, 1989). Siegel (1974) demonstrated that, at long time intervals, AP subjects performed better than non-AP possessors only when pitch names could be used. When frequencies presented lacked a definite pitch class, differences between the two groups disappeared. However, Zatorre and Beckett (1989) demonstrated that AP subjects' retention of note names is not affected by verbal interference using the Brown-Peterson interference paradigm. They argue that AP possessors must therefore be relying on multiple coding strategies, including auditory, kinesthetic and visual imagery. (But see Takeuchi and Hulse, 1992 for arguments against Zatorre and Beckett's conclusions.)

In the present study, it seems that pitch memory possessors are able to store the primary code and retrieve this representation at will, so that they can produce the correct pitches. Alternatively, they may be relying on some of the multiple coding strategies outlined by Zatorre and Beckett. If they are using verbal encoding, it is not obvious what those verbal labels might be, in the absence of musical note names.

Examination of Figure 1 reveals that most of the errors made fall to the left of center, that is, subjects tended to sing flat when making errors. The explanation of this is uncertain. It may be merely the "lounge singer effect," wherein amateur singers tend to undershoot notes and to sing flat. Alternatively, it may be a range effect such that subjects found themselves attempting to sing songs that were above their range. (It is more likely that popular songs would be too high for average singers than too low because popular music taste has, for two decades, tended to prefer those singers - particularly male vocalists - with higher voices.)

Some colleagues have criticized the present experiment on the grounds that subjects may have had trouble finding the note they were trying to reach; that because they were not experienced singers, their vocal productions may not have accurately matched their internal mental representations of the note. If this were the case, then the 25% we found to have accurate pitch memory only represents a minimum instance of the ability; other subjects may have possessed accurate pitch memory but have been unable to demonstrate it by singing.

Some colleagues have suggested that performance on this task indicates only that people who have heard a song hundreds of times are able to sing it back to an experimenter, that this is more a study of *overlearning* than anything else. I do not argue this point, it may be that subjects only perform well on overlearned stimuli. But this does not detract from the demonstration that they possessed a kind of absolute pitch memory. That there is any condition in which they can succeed in this task indicates the existence of a significant ability. One might wish to investigate the range of conditions over which this ability manifests itself, but that is a separate empirical matter. The ability to perform without error - even with overlearned stimuli - requires that people keep stable representations of the starting pitch in memory, precisely the ability we investigated in this study.

Some have suggested that subjects in this task merely relied on motor memory from their vocal chords to find the correct pitches. There is, of course, always some degree of kinesthetic memory involved in the generation of pitch (Ward and Burns, 1978, Cook, 1991). Anytime one sings a note, the initial pitch of that note is, by necessity, determined by kinesthetic memory; only on long notes does auditory feedback have time to correct a wrong note. To claim that subjects "merely" relied on kinesthetic memory is to miss the point. Any kinesthetic memories used by the subjects would have to be associated with memories for a particular song and its starting pitches. In this sense, kinesthetic memory is not a distinct or separate cognitive entity, but rather an integrated part of memory for the song. Clearly, successful subjects in this study demonstrated the ability to keep this memory distinct from other auditory and musical memories, despite daily bombardment by competing sounds and pitches. Moreover, as mentioned above, Zatorre and Beckett (1989) argue that true AP possessors *do* rely on kinesthetic memory to some extent, and this is not interpreted as diminishing the achievements of AP possessors.

It might be asked, why not test Ss using a recognition test instead of production? One reason is that it is impossible to change the pitch of a musical recording without changing the timbre of the voice and instruments, providing salient clues that the pitch had been altered. With the changes required for good experimental design (even utilizing the latest digital pitch shifting technologies), Mick Jagger would sound like Minnie Mouse, or Madonna would sound like the Addams Family's Lurch.

Another reason might be that the testing tone could dominate the remembered internal representation. It is a common anecdotal experience that it is difficult to keep a phone number in working memory while an uncooperative associate (or sibling!) is blasting competing numbers in our ears. As this study shows, generating an internal representation of pitch seems an effective way of recalling stored pitches; but the internal representations tapped may be weak and tenuous. As soon as the external pitch is heard it may wipe out the weaker internal pitch temporarily. Tsuzaki (1992) states, "We define AP as performance without reference to an external standard but the definition does not include being *influenced* by external referents or contexts." That internal reference is influenced by external structure (e.g. diatonic scale structure) has been demonstrated empirically. AP possessors identify black-key pitches less accurately and less speedily than white-key pitches (Miyazaki,1990; Takeuchi and Hulse, 1991).

Tsuzaki (1992) showed that even true AP possessors can lose their sense of internal pitch temporarily when presented with distractors. The amount of time required to recalibrate to one's internal standard following distraction still remains an empirical question. It seems likely then that those possessing only a component of AP, such as pitch memory, might also display reduced performance under conditions of external distractors.

The possible tenuousness of internal representations compared to external stimuli argues against a paradigm of using a piano or other instrument to play possible starting notes of the song and asking Ss to choose the correct one. The salience of a melody (the sequence of relative pitches) may cause a temporary reference shift in the subject's mind. Presented with a musical note by the experimenter, it would be easy for most subjects to imagine the song starting on that note, and their entire template for the song could temporarily shift. Thus, any implied transposition created by the experimenter introducing a note is a potential "source of interference, and introduces a potential confound" (G. H. Bower, personal communication, February 14, 1992). The advantage of the paradigm employed here is that it reduced experimenter influence to a minimum; subjects learned the stimulus under ecological conditions, outside the laboratory, and were tested under similarly ecological conditions in the laboratory.

Directions for further research.

1) Investigate the recovery time for recalibration to internal pitch standards either using AP subjects (following Tsuzaki's 1992 paradigm) or using subjects from the general population in the present paradigm. Once

our sense of internal pitch is upset by an external distractor, how long does it take to recover our internal standard, and what conditions can promote or hinder the recovery time?

2) If subjects' internal representations of music contain absolute representation of pitch, it may be the case that they also contain absolute representations of tempo. A follow up study using the present paradigm could analyze subject productions to see if they conform to the tempo of and rhythm of the original stimuli.

3) As noted above, there are many arguments for using the production test employed in the present study. To see just how tenuous internal pitch representation is, or to see if production difficulties in untrained singers were a mediating factor in success rate, a follow up study could employ a recognition task with a similar group of subjects and stimulus materials. Subjects in such a study would be asked if a note selected randomly matches the starting note they hear in their heads for a given song. An additional group of subjects might be tested on a production task using a variable speed oscillator instead of vocal production. In most cases, recall memory is a more demanding task than recognition memory. This follow up could answer whether this is true with pitch memory as well.

4) In what other sensory domains does absolute memory exist? A number of studies have addressed the role of labelling in memory for color (Brown and Lenenberg, 1954; Heider, 1972; Bornstein, 1976), but no studies have addressed absolute memory for color in situations where labelling was discouraged or not possible, or in production paradigms. One researcher has intuited that absolute memory for color is not very good ("people are always

returning pillows to the furniture store that they thought matched their sofa at home," Eleanor Rosch, personal communication, May 1992). In addition, color production is not a task that people engage in with the frequency or casualness that they do singing. Nevertheless, an exploration into absolute color memory - using both production and recognition paradigms - seems an interesting endeavor.

Conclusions.

We began by wondering to what extent our internal representations and memories of music are like tape recordings of that music. The present study provides evidence for the absolute nature of auditory memories. Memory for musical pitch was shown to be accurate in 25% of the subjects tested. These subjects were able to maintain stable and accurate representations of memories over a long period of time with much intervening distraction. The ability is correlated to a subject's exposure to pianos, but otherwise independent of a subject's musical history.

The data in the present study also provide evidence for a two-component theory of Absolute Pitch; specifically, they support the existence of a *pitch memory* component independent of *pitch labelling*. The data indicate that the portion of the population possessing some form of AP (pitch memory) may be significantly larger than previously thought. The problem of why AP, as traditionally defined, exists in such small numbers may now become more tractable. It may be that a large percentage of people possess pitch memory but never acquired pitch labelling, possibly because they lacked musical training or exposure during the proper critical period.

It has long been thought that recognition tests are the best tools in the memory researcher's repertoire because they are more sensitive and more accurate than production tasks. The present paradigm may be one in which a production task yields the best results, though this remains an emiprical question. Internal representations for perceptual stimuli - specifically musical pitch - may be clear and accurate until an external referent, with all of its salience and sheer volume, takes precedence over the internal one.

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Appendix 1.

Compact Discs Used in Study

Artist	Album Title	Song(s) Selected
Abdul, Paula	*Forever Your Girl*	Cold Hearted Snake
		Forever Your Girl
Basia	*Time and Tide*	Time and Tide
Beatles	*Abbey Road*	Octopus' Garden
	Past Masters, Vol. 2	Lady Madonna
	Rubber Soul	Nowhere Man
		Michelle
		Norwegian Wood
Bowie, David	*Fame and Fashion (All Time Greatest Hits)*	n/a
Brickell, Edie and the New Bohemians	*Shooting Rubber Bands at the Stars*	What I Am
Carpenters	*The Singles 1969-1973*	Sing
		Top of the World
Chapman, Tracy	*Tracy Chapman*	She's Got Her Ticket
Chicago	*Greatest Hits, Vols. 1 & 2*	n/a
Cowboy Junkies	*The Trinity Session*	n/a
Cure, The	*Kiss Me, Kiss Me, Kiss Me*	Just Like Heaven
	Staring At The Sea	In Between Days
	The Head on the Door	n/a
Dire Straits	*Brothers in Arms*	n/a
Eagles, The	*Hotel California*	Hotel California
En Vogue	*Born to Sing*	n/a
Gabriel, Peter	*Sixteen Golden Greats*	Mercy Street
		Big Time
		Red Rain
Jackson, Michael	*Bad*	n/a
	Thriller	Thriller
		The Girl is Mine
Joel, Billy	*Greatest Hits Vols 1 & 2*	Still Rock and Roll
		Piano Man
		Just the Way You Are
		Movin' Out
		You May Be Right
		Only the Good Die Young
John, Elton	*Greatest Hits*	n/a
Led Zeppelin	*IV*	Stairway to Heaven
Madonna	*Like A Prayer*	Like A Prayer
		Express Yourself
		Oh Father
	Immaculate Collection	Like A Virgin

Miller, Steve	*Greatest Hits 74-78*	n/a
O'Connor, Sinéad	*I do not want what I haven't got*	Three Babies
		Emperor's New Clothes
		Nothing Compares 2 U
		I Am Stretched On Your..
	The Lion and The Cobra	Just Like You Said It Would Be
Penn, Michael	*March*	This and That
Petty, Tom	*Tom Petty and the Heartbreakers*	n/a
	You're Gonna Get It	n/a
Pink Floyd	*Momentary Lapse of Reason*	n/a
Pink Floyd	*Dark Side of the Moon*	n/a
Police, The	*Synchronicity*	Walking In Your Footsteps
		Every Breath You Take
	Zenyatta Mondatta	n/a
Prince	*Music from Purple Rain*	n/a
	1999	I Would Die For You
Queensrÿche	*Operation Mindcrime*	Silent Lucidity
Ross, Diana and The Supremes	*Greatest Hits*	n/a
Simon, Paul	*Graceland*	Under African Skies
Simon and Garfunkel	*Bookends*	n/a
Simon and Garfunkel	*Bridge Over Troubled Water*	n/a
Sinatra, Frank	*Songs for Swinging Lovers*	It Happened in Monterey
		You're Getting To Be A Habit With Me
Smiths, The	*Louder Than Bombs*	Panic
		Stretch Out and Wait
	The Smiths	n/a
Springsteen, Bruce	*Born in the U.S.A.*	n/a
Sting	*The Dream of the Blue Turtles*	Russians
Talking Heads	*Little Creatures*	n/a
Taylor, James	*Fire and Rain*	Fire and Rain
		Sunny Skies
Tears for Fears	*Songs from the Big Chair*	Shout
	Sewing the Seeds of Love	
U2	*War*	Sunday Bloody Sunday
Vega, Suzanne	*Solitude Standing*	Tom's Diner
	Suzanne Vega	The Queen and the Soldier
Winwood, Steve	*Roll With It*	n/a
ZZ Top	*Afterburner*	Legs
	Eliminator	n/a

Appendix 2.

Experimenters' Protocol

We're conducting a study in memory. We want to see if people have memory for specific sounds. I'm going to ask you to select a popular song you know well, and I want to see how accurately you can remember the actual pitch, or notes, of the song, by singing or humming or whistling a few notes of it.

Look through the collection of CDs here and choose one that has a song you've heard many times, and is one that you can hear in your head.

Hold the CD in your hands, close your eyes and try to imagine that the song is playing exactly as you remember it.

Now sing or hum or whistle part of the song.

Was that an accurate representation of what's in your head? Do you want to try again?

What part of the song was that?

Let's try it again with another song.