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Absolute Pitch as a Learned Phenomenon: Evidence Consistent with the Hick-Hyman Law

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An analysis of reaction time data collected by Miyazaki (1989) provides additional support for absolute pitch as a learned phenomenon. Specifically, the data are shown to be consistent with the Hick-Hyman law, which relates the reaction time for a given stimulus to its expected frequency of occurrence. The frequencies of occurrence are estimated by analyzing a computer-based sample of Western music. The results are consistent with the view that absolute pitch is acquired through ordinary exposure to the pitches of Western music.

THE manner by which absolute pitch is acquired has been a topic of considerable research and debate (reviewed by Ward & Burns, 1982, and by Takeuchi & Hulse, 1993). If absolute pitch is a learned phenomenon, then we might expect recognition to be affected by the familiarity of certain tones (Takeuchi & Hulse, 1991, 1993). In an earlier issue of *Music Perception,* Ken'ichi Miyazaki (1989) published reaction time data for an absolute pitch identification task (see Figure 1, *y*-axis). In Miyazaki's experiment, musicians possessing absolute pitch were asked to identify presented pitches by responding on an electronic keyboard. Stimuli were presented over a broad range from C_1 to B_7. The published reaction time data was collapsed by Miyazaki according to pitch class. Simple inspection of Figure 1 reveals shorter reaction times for "white keys" than for "black keys"—implying a disposition toward the notes of the C-major scale. This difference might be an artifact of the smaller physical size of the black keys. However, the possible confound of motor response bias was discounted by later controlled experiments carried out by Miyazaki (1990) and Takeuchi and Hulse (1991).

A number of classic experiments in psychology have demonstrated that when selecting among alternative responses, reaction time measures are related to the number of alternatives, the probability of each alternative,

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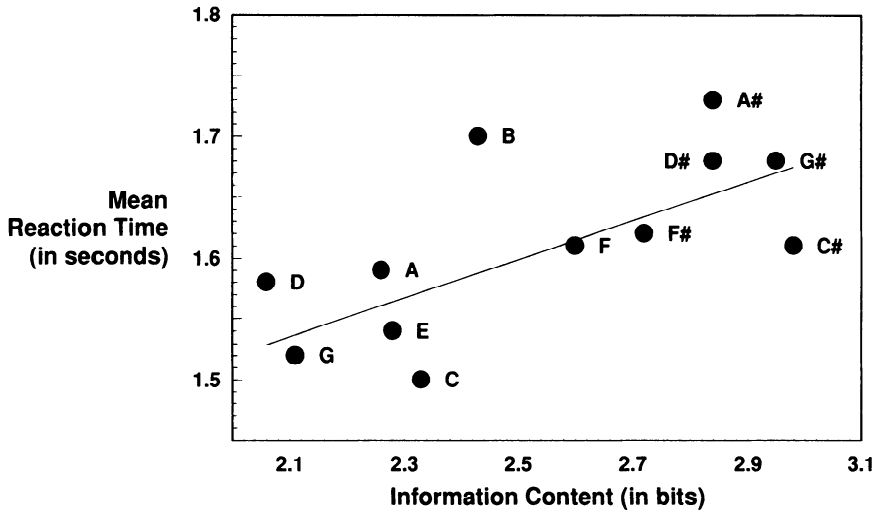

Fig. 1. Mean reaction time for absolute pitch judgments (Miyazaki, 1989) related to information content for various pitch classes. Information content was determined by measuring the frequencies of occurrence of various pitch classes from a sample of works by Bach and Haydn (46,060 notes). The figure shows a significant positive correlation consistent with the Hick-Hyman law. The results imply that the phenomenon of absolute pitch is conditioned by exposure to tonal music and that it is learned in the same manner as for innumerable other forms of learning.

and the sequential context (i.e., how subsequent events constrain each other). One of the most fundamental and well-known relationships was described independently by Hick (1952) and Hyman (1953)—and is known in contemporary psychology as the Hick-Hyman law.

The Hick-Hyman law predicts that reaction time is related to exposure. Specifically, the greater the expectancy for a given stimulus, the shorter the reaction time for that stimulus. In learning situations, the most commonly occurring stimuli are associated with the shortest reaction times.

The Hick-Hyman law uses information theory to quantify the reaction time to stimulus events. The reaction time can be expressed by the equation $RT = a + bH$ where H is the information content of the stimulus. Mathematically, H can be expressed as the logarithm base 2 of the multiplicative inverse of the probability of the stimulus.[1]

Given Miyazaki's reaction time data for various pitch classes, we have an opportunity to evaluate the degree to which absolute pitch responses are predicted by the Hick-Hyman law. We can do this by comparing such response-time data with estimates of the probabilities for the correspond-

1. Our appeal to this law is illustrative rather than crucial to the argument proposed in this study. Any equation that relates reaction time monotonically to the frequency of occurrence of pitch classes is suitable.

ing pitch classes. Choosing a representative sample of "all music" is a difficult task. Rather than pursuing a truly random or representative sample, we selected two reasonably large samples of music available in computer-readable form: Johann Sebastian Bach's 15 two-part keyboard *Inventions* and 10 string quartets by Joseph Haydn.

Although these works are exemplars of standard tonal repertoire, they date from different stylistic periods and have different instrumentation. A useful index of their reliability as sample data (representing general musical exposure) can be created by measuring the similarity of the pitch-class distributions for the two repertoires. The correlation between these two frequency distributions was determined to be +.95. This large positive correlation suggests that the two samples are likely to have been drawn from the same "population"—namely, the corpus of Western tonal music.

The above frequency distributions were used to calculate the information content for each pitch class. The ratio of the occurrence of each pitch class to the total number of notes used in the analysis provides an estimate of the probability of occurrence for that pitch class.

Figure 1 plots Miyazaki's mean reaction time data against the mean information content for each corresponding pitch class. The absolute pitch reaction times show a significant correlation with the logarithm of the average of the Bach and Haydn estimates of occurrence for individual pitch classes [$r = .67$ ($df = 10$, $p < .017$)]. This implies that the Hick-Hyman law accounts for 45% of the observed variance in the absolute pitch reaction times. These values were calculated for equally weighted averages for the Haydn and Bach samples. Individual sample results are as follows: $r = .72$ ($df = 10$, $p < .008$) for the Haydn sample (37,252 notes) and $r = .58$ ($df = 10$, $p < .047$) for the Bach sample (8,808 notes). The correlations for the black and white keys taken as separate groups were also found to be skewed in the predicted direction—indicating that the effect of pitch-class familiarity is independent of the difference between white and black keys.

As already mentioned, much existing research has already implied that absolute pitch is acquired via learning. The results here support this view, but furthermore imply that the mechanism by which absolute pitch is learned is the same as for innumerable other forms of learning investigated by psychologists.

References

Hick, W. E. On the rate of gain of information. *Quarterly Journal of Experimental Psychology,* 1952, **4,** 11–26.

Hyman, R. Stimulus information as a determinant of reaction time. *Journal of Experimental Psychology,* 1953, **45,** 423–432.

Miyazaki, K. Absolute pitch identification: Effects of timbre and pitch region. *Music Perception,* 1989, *7*(1), 1–14.

Miyazaki, K. The speed of musical pitch identification by absolute-pitch possessors. *Music Perception,* 1990, *8*(2), 177–188.

Takeuchi, A. H., & Hulse, S. H. Absolute pitch judgments of black- and white-key pitches. *Music Perception,* 1991, *9,* 27–46.

Takeuchi, A. H., & Hulse, S. H. Absolute pitch. *Psychological Bulletin,* 1993, *113*(2), 235–361.

Ward, W. D., & Burns, E. M. Absolute pitch. In D. Deutsch (Ed.), *The psychology of music.* New York: Academic Press, 1982, 431–451.

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