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# 1

## How Animals Perceive Music? : Comparative Study of Discriminative and Reinforcing Properties of Music for Infrahuman Animals.

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### I. Introduction

Humans are predominately visual animals but audition is also important, particularly for communication, because human language is basically auditory communication. Music, as stimulus, has two different properties on humans, namely a discriminative effect and a reinforcing effect.

Perceptual invariance is a crucial factor of music discrimination and starlings are capable to discriminate timbres (Braaton & Hulse, 1991), rhythms (Hulse et al., 1984) and pitch (MacDougall-Shackleton & Hulse, 1996). There had been experiments using simple melodies, for example D'Amato and Salmon (1982) or Reinhert (1967). Since Porter and Neuringer (1984), who demonstrated successful discrimination between Bach and Stravinsky in pigeons, there have been several reports on music discrimination in animals. Java sparrows have been shown to discriminate the music of Bach from that of Schoenberg (Watanabe & Sato, 1999) and they were able to discriminate consonance from dissonance, that was a feature of modern music such as Schoenberg, also (Watanabe et al., 2005). Rats have discriminated "*Frere Jacques*" from its reversed sequence (Poli & Previde, 1991), "Yesterday" by The Beatles from "*Die Zauberfloet*" by Mozart (Okaichi & Okaichi, 2001) and Bach from Stravinsky (Otsuka et

al., 2009). Chase (2001) reported music discrimination in carps. Shinozuka et al (unpublished data) also successfully trained goldfish to discriminate Bach from Stravinsky. Music is artificial stimuli produced by humans for humans, thus different species perceive the same music as different stimuli depending on their auditory ability. The experimental results suggest that nonhuman animals are capable of discriminating between complex music stimuli regardless of their auditory perceptual abilities. Although negative results might be not published, the ability to discriminate different forms of music appears to be widely spread throughout the animal kingdom from fish and birds to primates.

The second property of music is its ability to have a pleasurable or reinforcing effect on the listener. Hearing music often creates a pleasurable experience in humans (i.e., it has reinforcing properties for us). But the reinforcing properties of music on nonhuman animals have not well investigated, furthermore most of the published results failed to obtain reinforcing effect of music. Two species of primates which have been tested, the common marmoset (*Callithrix jacchus*) and the cotton-top tamarin (*Saguinus oedipus*), and they did not show a preference for music stimuli (McDermott & Hauser, 2004; 2007). McAdie et al. (1993) trained hens to peck two keys associated with food reinforcement, then replayed a piece of “*The Theme of Local Hero*” contingent upon pecking one key. The music presentation did not affect the behavior. Strict experimental works did not show clear reinforcing effect of music but it is used as a tool of environmental enrichment for captive animals (for example, Howell et al., 2003; Wells et al., 2002). These observations are not controlled experiment but suggest some positive effect of music for captive animals. One exceptional result was obtained from songbirds. We demonstrated that Java sparrows show a preference for music style (Watanabe & Nemoto, 1998). In contrast to the ability to discriminative styles of music, the property of reinforcement is not widely spread throughout the animal kingdom, but rather to limited species, humans and songbirds.

Here I described experiments carried out in my laboratory and compare three species, namely rats, pigeons and songbirds.

## II. Experiments with rats

Recently, we used Bach's *Tocatta and Fugue* and Stravinsky's "*The Rite of Spring*" for training of rats (Otsuka et al., 2009). These stimuli had been used as stimuli for musical discrimination by pigeons (Porter & Neuringer, 1984), hence we can compare our data with that of pigeons. An operant chamber with a single lever was used. A small speaker was mounted behind the front panel, and the music stimuli were presented with CD players. The two players played music stimuli continuously on a relay circuit controlled by a computer connected by one of the players to the speaker. Two musical stimuli were used for the discrimination training. One was one of the Bach's *Tocatta and Fugue in D Minor* (BWV 565) and *F Major* (BWV540) for organ and the second was *Ritual of the Rival Tribes, Procession of the Sage, Dance of the Earth, and Sacrificial Dance from The Rite of Spring* for orchestra by I. Stravinsky. Two additional music stimuli were used in the transfer test. One was Bach's *Prelude in E flat minor*, BWV.565, Chorale from "*The Easter Cantata*", BWV.4 (vocal and piano) and the other, Stravinsky's *The Firebird Suite* for the orchestra.

The Bach (*Tocatta and Fugue*) and Stravinsky (*The Rite of Spring*) pieces were presented in a random order during one training session. One presentation played continuously for two minutes followed by a 30-sec interval. For half of the animals, responses made during Bach were reinforced on the VI10" schedule, while responses made during Stravinsky were extinguished. For the other half, the reinforcement contingency was reversed. This training continued until the subjects showed more than 85% discrimination ratio for two successive sessions. Four rats attained the criterion of discrimination but two rats did not reach the criterion after 60 sessions of training. The fastest rat learned the discrimination by 18 sessions and the slowest by 59 sessions. These results showed that rats are capable of discriminating these two pieces of music. Long-Evans rats reached 65% discrimination ratio after 25 sessions of discrimination training between "*Frere Jacques*" and its reversed sequence (Poli & Previde, 1991). Although it is hard to directly compare these results due to procedural differences among the experiments, wistar rats have the ability of music discrimination also. Rats have higher auditory information processing comparable to songbirds and humans even though the rats had

different auditory ability. According to Fay (1988), the lowest threshold of the human audiogram is between 1200-1300Hz, pigeons around 1000Hz, and rats around 10,000Hz. Thus, rats are sensitive to much higher frequencies than these than both pigeons and humans. Because the audiogram of rats differs from that of humans, it is hard to say the rats and humans hear exactly the same auditory stimuli even if the stimuli are physically the same. The present results suggest that rats can discriminate man-made and not biologically relevant sounds, such as music, even though the distribution of their audiogram is so different.

Music stimuli that had never been presented during the training sessions were presented in the transfer test. One was Bach's *The Easter Cantata*", and the other Stravinsky's *The Firebird Suite*. The testing procedure was identical to the discriminative training except for the stimuli. The rats in the Bach S+ group received reinforcement during presentation of Bach stimuli and Stravinsky S+ during the Stravinsky stimuli. In the transfer tests 4 rats maintained their discrimination although the discrimination ratios were lower than 0.85 in 3 of 4 rats. These results show that the rats were able to discriminate novel music on the basis of learned music discrimination. Thus, rats can not only discriminate musical stimuli but also learn category of music as other animals described above.

The property of music is its ability to have a pleasurable or reinforcing effect on the listener. We also examined reinforcing properties of music using concurrent chain schedule in rats (Otsuka et al., 2009). Nine experimentally naive male Wistar rats were used. An operant chamber was used. Two retractable levers were positioned on the front panel. Two small speakers were mounted behind the front panel, and music stimuli were presented with CD players. The music stimuli used in this experiment were identical to those of the discrimination experiment. Rats were trained on a Concurrent-Chain schedule (Conc [Chain VI30"-FI7"] [Chain VI30"-FI7"]). One session consisted of forty trials. In the initial link, two levers were inserted into the testing chamber and a VI schedule was effective on either lever. When the VI schedule was completed on one of the two levers, the terminal link started. In the terminal link, the lever selected in the initial link remained in the chamber and the other lever was withdrawn. FI 7" was effective on the remaining lever. Then, after the four seconds of blackout, the next trial began. One of the two music stimuli was presented



(Watanabe et al., 2009) using the concurrent chain schedule similar to that used for rats (Otsuka et al., 2009). We also analyzed performance in the terminal link to examine the direct effect of music exposure on operant behavior. Four experimentally naïve pigeons (*Columba livia*) were used. The experimental chamber was a standard operant chamber. The front panel was equipped with two identical response keys. The chamber was enclosed in a sound-attenuated cubicle. A speaker connected to a CD player through a relay circuit, was attached 5 cm below each key on the front panel. Two musical stimuli used for the training of the rats (Otsuka et al., 2009) were used. One stimulus was Bach's *Tocatta and Fugue* and the second was pieces from *The Rite of Spring* by I. Stravinsky. The pigeons were trained on a concurrent-chain (Conc [Chain V]-FI · [Chain VI-FI]) schedule. In the initial link, white lamps lighted the left and the right keys, and identical VI 30" schedules operated independently on each key. After the pigeons completed either of the schedules, the terminal link was initiated on that key, and the unselected key was turned off. During the terminal link, the musical stimuli were presented. Both terminal link schedules were fixed interval FI 7". Responding during the terminal links was reinforced. Each session consisted of 40 initial- and terminal link cycles. Three different pairs of musical stimuli in the terminal links were presented in the following order: (1) Bach vs. Stravinsky, (2) Bach vs. Noise, and (3) Stravinsky vs. Noise. One condition continued for 20 sessions and was divided into two phases of 10 sessions each. The relation between the position of the keys and auditory stimuli was reversed between the first 10 and the last 10 sessions in each condition.

The pigeons did not show strong preference during the training with Bach and Stravinsky but slight preference for the left key. The pigeons did not show strong preference in the sessions with Bach and noise. During Stravinsky and noise training, the birds did not show a clear preference for Stravinsky or the noise. One bird showed a significant preference for Bach to Stravinsky, while another bird showed a reversed preference. Thus, these birds indicated significant deviation from the chance level but the mean responding ratio is less than 0.6, indicating no strong musical preference. In conclusion, we cannot find clear musical preferences in the pigeons although there was some significant deviation from chance level.

## IV. Experiments with Java sparrows

We examined the discriminative stimulus property of music in Java sparrows (Watanabe & Sato, 1999). Subjects were adult Java sparrows (*Padda oryzivora*). An experimental chamber was a cage with two perches. A photo sensor fixed on each perch detected the position of the bird. A tray connected with a dispenser was placed in front of one of the perches (response perch). The dispenser was designed to drop a few seeds of millet onto the tray. A speaker connected with two CD players was placed in front of the other perch (ready perch). The chamber was placed in a sound insulated box and a computer from outside the box controlled the experiment. The computer switched the speaker between the two CD players, which continuously played two different music. The birds were divided into Bach group and Schoenberg group. When the subjects stayed on the ready perch for 3 sec, *French Suite opus 5* (G minor) BWV816 by J. S. Bach or *Suite for Piano opus 25* by A. Schoenberg was played through the speaker. In the Bach group, moving to the response perch within 10 sec after the start of the Bach music was reinforced, and a response while the Schoenberg was played resulted in a blackout for 2 sec. A correct perching or no response for 10 sec to the Schoenberg started the next trial, while no response for 10 sec to Bach or incorrect perching resulted in a repetition of the same trial up to 5 times. In the Schoenberg group, a response to the Schoenberg music was reinforced and that to the Bach was extinguished. One session consisted of 40 trials, and the two music stimuli were presented 20 times each in accordance with the Gellerman series. The training continued until the subjects attained a correct response ratio (the sum of correct perching and correct non-perching trials divided by 40 trials) above 80% on two successive sessions. Then the subjects received two different tests. Test 1: *Orchestra opus 3 D-major* BWV 1068 by Bach and Five orchestra pieces opus 16 by Schoenberg were used. Test 2: *Violin Orchestra minor* RV356 by Vivaldi and *Variation for Orchestra* by E. Carter were used

The subjects required 33 to 52 sessions to reach the criterion. After the discrimination, they showed generalization to new music by Bach and Schoenberg. When Vivaldi and Carter were played in Test 2, all five birds showed significant discrimination. Thus, the birds showed generalization



from Bach/Schoenberg discrimination to Vivaldi/Carter. The results are consistent with the findings that pigeons showed stimulus generalization from Bach to Buxtehude and Scarlatti, and from Stravinsky to Eliot Carter and Walter Piston (Porter & Neuringer, 1984). Furthermore, the Java sparrows indicated more human-like classification of music than the pigeons, in that the Java sparrows showed generalization from Bach to Vivaldi while the pigeons did not. Although the difference in musical instruments could have affected the pigeons' generalization as pointed out in the introduction, the results imply the difference in auditory perception between the songbird and the non-song bird. In sum, Java sparrows could learn discrimination of music by Bach and Schoenberg, and showed generalization to new music by the same artists, as well as to Vivaldi and Carter, even where these music stimuli did not have a reinforcing property. These results suggest that music may have stimulus properties common to humans and birds.

We also examined reinforcing properties of music in a songbird, Java sparrows (Watanabe & Nemoto, 1998). Four experimentally naive adult Java sparrows were used. The experimental chamber for the test was a modified cage for small birds. There were three perches in the cage and a photo sensor detected perching at each perch. An audio speaker connected to a CD player was placed at the each end of the chamber. In the first test, perching on one of the end perches connected a line from a CD-player that continuously played *French suite opus 5* (G-major) BWV816 by J.S.Bach to a speaker. Perching on the other end perch connected a line from another CD-player playing *Suite for piano opus 25* by A.Schoenberg to a speaker. Each music was presented continuously as long as the subject stayed at each perch. Staying at the center perch had no effect.

Two birds preferred Bach in the first test. The birds received the second test with new music by Bach and Schoenberg, that is, *Philharmonic Suite opus 3 D-major* BWV 1068 by Bach and *Five Philharmonic Suite opus 11* by Schoenberg. These birds again showed preference of music by Bach. The birds then received the third test with Vivaldi *Violin Orchestra minor* RV356 and *Variation for Orchestra* by E. Carter. Both birds preferred Vivaldi to Carter. Birds not showing music preference in the first test with Bach vs. Schoenberg received following two tests to examine whether they did not like music at all or preferred music to a white noise. One bird

showed preference of Bach to white noise but another one did not show a significant preference of Bach to noise. One bird significantly spent longer time on the silent perch than the Schoenberg perch or the noise. These results may suggest some “aversive stimulus properties” of Schoenberg. Another bird did not show differential staying between Schoenberg and noise.

In summary, two of the four birds showed consistent preference of Bach to Schoenberg and that of Vivaldi to Carter. One more bird showed preference of Bach to a white noise. These results demonstrated that music by Bach has reinforcing properties for these Java sparrows.

## **V. Conclusion**

The rat experiment (Otsuka et al., 2009) demonstrated the discriminative stimulus property of music stimuli, but poor reinforcing stimulus properties for rats. The rats were able to discriminate complex musical stimuli as humans and songbirds did even though they had different sensory capacity. As describe in Introduction, variety of species, from fish to songbirds, demonstrated musical discrimination. Hence, ability of discriminating complex auditory stimuli may widely spread in the vertebrates regardless of their different audiograms. Animals may be able to discriminate complex auditory stimuli by training if there is psychophysical difference between them. On the other hand, reinforcing property depends on species. Phylogenetic contingency (evolution) may be a crucial factor for the reinforcing properties. Particularly, music is made by humans, thus it is adjusted to human auditory perception. Because the identical music stimuli were used in the two experiments with rats, the difference between the two properties is clear. One possible reason for the lack of reinforcement of the music stimuli is that the discrimination method used in these experiments might be not suitable to measure the reinforcing effect. Because the measurement is based on choice between two terminal links, the measurement does not result in the differences in choice when the two terminal links are equally reinforcing or aversive. Examination with different combinations of different music stimuli should answer this empirical question. Different species have different hearing range (Heffner

& Heffner, 2007), thus music can be distorted or filtered stimulus for particular animals. Music for rats differs from that for human even if the music itself has the same physical features. Modification of music to match rat's audiogram should be a next step of analysis of reinforcing property of musical stimulus.

In avian studies, it is possible to assume that there are no reinforcing properties of music for non-songbirds, because pigeons could discriminate music (Porter & Neuringer, 1984) but did not show reinforcing effects of the same music (Watanabe et al., 2009) and hens also showed no music preference (McAadie et al., 1993). As described in the introduction, the reinforcing effects of music have not been thoroughly examined and at present, humans and songbirds (Java sparrows) are exceptional species showing preference for a particular music. One common characteristic of humans and songbirds is that both have well developed vocal communication although human language is extraordinary in that it has a seemingly unlimited capacity for sending meaningful messages. In fact, similarities between music and animal songs have been pointed out (Gray et al., 2001, see also Marler & Slabbekoom, 2004). Both humans and songbirds have to learn their communication system after birth. During song learning, birds first produce subsongs then modify them to complete full song. Their song-producing behavior during this period is maintained by self-reinforcement. Similarly, human infants first produce babbling and acquire their native language through experience. Thus, self-reinforcement appears to play a crucial role in the acquisition of language. The reinforcing effects of complex auditory stimuli, such as music, may be involved in the self-reinforcing behavior in both humans and songbirds. The common nature of language and music has been also often pointed out (Aiello, 1994; Masataka, 2007, Molino, 2000, Patel, 2003, Schellenberg & Peretz, 2008). Thus, bird song, human language, and music have similar aspects. Therefore, the common phylogenetic contingency that had been effective in developing complex vocal communication might be associated with the similar behavioral effects of music in these animals. Figure 2 summarizes the evolution of reinforcing property of music. It is predicted that other species with well-developed auditory communication system, such as an elephant or a dolphin, should show reinforcing property of music. One recent experiment suggests that mice also sing ultrasonic songs

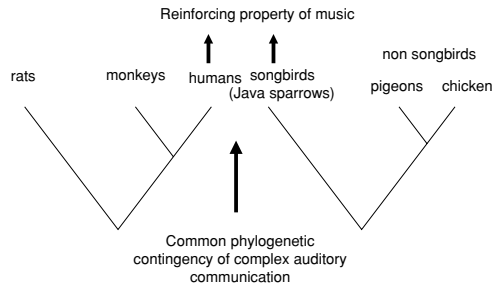


Figure 2. Evolution of reinforcing property of music. At present humans and Java sparrows are exceptional animals showing music preference behavior. One common nature of these species is learning of complex vocal communication systems. The reinforcing property of complex auditory stimulus might have positive effects in the evolution of such systems.

(Holy & Guo, 2005). Thus, ultrasonic music may have reinforcing effects for mice. More studies are clearly necessary to more fully understand the evolution of reinforcing effect of music.

## References

- Aiello, R. (1994). Music and language: Parallels and contrasts. In R. Aiello, J. A. Sloboda, R. Aiello & J. A. Sloboda (Eds.), *Musical perceptions*. Pp. 40-63, Oxford University Press (New York)
- Braaten, R. F., & Hulse, S. H. (1991). A songbird, the European starling (*Sturnus vulgaris*), shows perceptual constancy for acoustic spectral structure. *J. Comp. Psychol.*, 105, 222-231.
- Chabris, C. F. (1999). Prelude or requiem for the Mozart effect? *Nature*, 400, 826-827.
- Chase, A. R. (2001). Music discrimination by carp (*Cyprinus carpio*). *Anim. Learn. & Behav.*, 29, 336-353.
- D'Amato, M. R., & Salmon, D. P. (1982). Tune discrimination in monkeys (*Cebus apella*) and in rats. *Anim. Learn. & Behav.*, 10, 126-134.
- Fay, R. R. (1988). *Hearing in vertebrates; A psychophysics data book*. Hill-Fay Associate, (Chicago)
- Gray, P. M., Krause, B., Atema, J., Payne, R., Krumhansl, C., & Baptista, L. (2001). The music of nature and the nature of music. *Science*, 291, 50-54.
- Hetland, L. (2000). Listing to music enhances spatial reasoning: Evidence for the "Mozart effect". *J. Aesth. Educ.*, 34, 105-148.
- Holy, T. E., & Guo, Z. (2005). Ultrasonic songs of male mice. *PLoS Biol.*, 3, 2177-2186.
- Howell, S., Schwandt, M., Fritz, J., Roeder E., & Nelson, C. (2003). A stereo music system as environment enrichment for captive chimpanzees. *Lab. Anim.*, 32, 31-36.
- Hulse, S. H., Humpal, J., & Cynx, J. (1984). Discrimination and generalization of

- rhythmic and arrhythmic sound patterns by European starlings (*Sturnus vulgaris*). *Music Percept.*, 1, 442-464.
- MacDougall-Shackleton, S. A., & Hulse, S. H. (1996). Concurrent absolute and relative pitch processing by European starlings (*sturnus vulgaris*). *J. Comp. Psychol.*, 110, 139-146.
- Marler, P., & Slabbekooorn, H. (Eds) (2004). *Nature's music*. Elsevier, San Diego 2004
- Masataka, N. (2007). Music, evolution and language. *Develop. Sci.*, 10, 35-39.
- McAdie, T. M., Foster, T. M., Temple, W., & Matthews, L. R. (1993). A method for measuring the aversiveness of sounds to domestic hens. *Appl. Anim. Behav. Sci.*, 37, 223-238.
- Mcdoermott J., & Hauser M. D. (2004). Are consonant intervals music to their ear? Spontaneous acoustic preferences in a non-human primates, *Cognition*, 94, B11-B21,
- Mcdoermott J., & Hauser M. D. (2007). Nonhuman primates prefer slow tempos but dislike music overall. *Cognition*, 104, 654-668.
- Molino, J. (2000). Toward an evolutionary theory of music and language. In N. L. Wallin, B. Merker, S. Brown, N. L. Wallin, B. Merker & S. Brown (Eds.), *The origins of music*. pp. 165-176, The MIT Press, (Cambridge).
- Okaichi, Y., & Okaichi, H. (2001). Music discrimination by rats. (In Japanese) *Jap. J. Anim. Psychol.*, 51, 29-34.
- Otsuka, Y., Yanagi, K., & Watanabe, S. (2009). Discriminative and reinforcing stimulus properties of music for rats. *Behav. Proc.*, 80, 121-127.
- Patel, A. D. (2003). Language, music, syntax and the brain. *Nature Neurosci.*, 6, 674-681.
- Poli, M., & Previde, E. P. (1991). Discrimination of musical stimuli by rats (*Rattus norvegicus*). *Internl. J. Comp. Psychol.*, 5, 7-18.
- Porter, D., & Neuringer, A. (1984). Musical discrimination by pigeons. *J. Exp. Psychol.: Anim. Behav. Proc.*, 10, 138-148.
- Rauscher, F. H., Robinson, K. D., & Jens, J. J. (1998). Improved maze learning through early music exposure in rats. *Neurol. Res.*, 20, 427-432.
- Reinhert, von J. (1967). Akustische Dressurversuche an einem Indischen Elefanten. *Zeit. Tierpsychol.*, 14, 100-126.
- Schellenberg, E. G., & Peretz, I. (2008). Music, language and cognition: Unresolved issues. *Trends in Cog Sci.*, 12 (2), 45-46.
- Watanabe, S., & Nemoto, M. (1998). Reinforcing properties of music in Java sparrow (*Padda oryzuvora*). *Behav. Proc.*, 43, 211-218.
- Watanabe, S., & Sato, K. (1999). Discriminative stimulus properties of music in Java sparrows. *Behav. Proc.*, 47, 53-58.
- Watanabe, S., Uozumi, M., & Tanaka, K. (2005). Discrimination of consonance and dissonance in Java sparrows. *Behav. Proc.*, 70, 203-208.
- Watanabe, S., Suzuki, T., & Yamazali, Y. (2009). (in press) Reinforcing property of music for nonhuman animals: Analysis with pigeons. *Philosophy*.
- Wells, D. L., Graham, L., & Hepper, P. G. (2002). The influence of auditory stimulation on the behavior of dogs housed in a rescue shelter. *Anim Welf.*, 11, 385-393.