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Contributed Paper

Reinforcing Property of Music for Non-human Animals: Analysis with Pigeons

Shigeru Watanabe*, Takako Suzuki, and Yumiko Yamazaki

Abstract

Music has reinforcing effects not only for humans but also for other nonhuman animals, such as songbirds. Here we analyzed the potential reinforcing effects of music for pigeons. Pigeons were trained on concurrent chain schedules in which the initial link was a variable interval schedule and the terminal link was associated with different music in addition to food reinforcement. In the first condition, music by J. S. Bach and I. Stravinsky were used as auditory stimuli. In the second and the third conditions, one of the two music pieces and white noise were used as auditory stimuli. One subject preferred Bach and another subject preferred Stravinsky in the first condition, but their preference for music was less than 60% of choice. One bird consistently preferred white noise to music. Overall, these results demonstrated no reinforcing effects of music for pigeons. Analysis of responding rate during the terminal link showed the music did not have facilitative or suppressive effect on the operant responding. Because reinforcing properties of music have been shown for humans and songbirds but not by pigeons, it is suggested that a common phylogenetic contingency among humans and songbirds produced music preference in these animals.

Key words: Reinforcement, music, concurrent-chain schedule, pigeon

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Introduction

Humans are predominately visual animals but audition is also important, particularly for communication, because human language is basically auditory communication. Humans have produced visual art and auditory art since antiquity. Evidence of visual art, such as cave drawings, has been traced back as far as 30,000 years ago (Lewis-Williams, 2002). It is, however, impossible to find such physical records of musical art. But most cultures including naïve people have their own music, suggesting that music should have long history comparable to our visual art. Music, as stimulus, has three different properties on humans, namely a discriminative effect, a direct facilitative/inhibitory effect, and a reinforcing effect.

Table 1 summarizes experiments on the three properties (see also Rickard et al., 2005 for review). Perceptual invariance is crucial factor of music discrimination and starlings are capable to discriminate timbres (Braaton & Hulse, 1991), Rhythms (Hulse et al., 1984) and pitch (Hulse et al., 1992; 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), rats have discriminated "*Frere Jacques*" from its reversed sequence (Poli and Previde, 1991), "Yesterday" by The Beatles from "*Die Zauberfloet*" by Mozart (Okaichi and Okaichi, 2001) and Bach from Stravinsky (Otsuka et al., 2009). Shinozuka et al (unpublished data) successfully trained goldfish to discriminate Bach from Stravinsky. Java sparrows were able to discriminate consonance from dissonance also (Watanabe et al., 2005). Music is arti-

Table 1. Experiments of music with animals.
P: postive result, N: negative result.

Function	Species	Comments	Results	Authors
discrimi- nation	monkey	octave generalization	P	Wright et al., 2000
		short melodies	P	D'Amato & Salmon, 1982
	elephant	short melodies	P	Reinhert, 1967
	cow	approaching	P	Uetake et al., 1997
	rat	music	P	Okaichi & Okaichi, 2001
			P	Poli and Previde, 1991
			P	Otsuka et al., 2009
		short melodies	P	D'Amato & Salmon, 1982
	pigeons	music	P	Porter & Neuringer, 1984
	starling	chord	P	Hulse, Bernard and Braaten, 1995
	Java sparrow	music	P	Watanabe & Sato, 1999
	carp	consonance	P	Watanabe et al., 2005
		music	P	Chase, 2001
	goldfish	chord	P	Fay, 1992
		music	P	Shinozuka & Watanabe (unpublished)
reinforce- ment	cotton-top tamarin	preference	N	McDemorth & Hauser, 2004
			N	McDemorth & Hauser, 2007
	common marmoset	preference	N	
	Java sparrow	preference	P	Watanabe & Nemoto, 1998
	hen	pecking	N	McAdie et al., 1993
direct effect	chimpanzee	aggressive behavior	P (reduction)	Howell et al., 2003
	monkey	delayed response	P (suppressive)	Carlson et al., 1997
	dog	resting time	P	Wells et al., 2002
	rat	visual discrimination (4-choice)	P/N	Bates and Horvath, 1971
		bar press	P	Joeph and Pal, 1982
		T-maze learning	P	Rauscher et al., 1998
	prenatal/pup	spatial learning	N	Kim et al., 2006
	mice	plus maze	P	Chikahisa et al., 2007
		drug induced sterotypy	P	Morton et al., 2001
		social behavior	P	Peretti & Kippschull, 1991
	perinatal mice	maze learning	P	Chikahisa et al., 2006
	hen	immobility	P	Campo, et al., 2005
	chicks	head shakes and yawn	P	Panksepp & Bernatzky, 2002
	chicks	passive avoidance	P	Toukhsati & Rickard, 2001

ficial 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, Table 1 shows that the ability to discriminate different forms of music appears to be widely spread throughout the animal kingdom from fish and birds to primates.

In humans, music can affect mood change in either a depressive or a vigor direction. The second property of music is its direct effect on behavior. Music therapy used music to change mood in people suffering some type of dysfunction (Snyder & Chlan, 1999). In humans probably, the most well known direct effect of music is so-called “Mozart” effect. Although even a meta-analysis of the published literature gives contradictory results (Chabris, 1999; Hetland, 2000), Carlson et al. (1997) found that Mozart’s piano concerto #21 impaired performance of delayed response in monkeys. Raucher et al. (1998) exposed rats to music for 60 days (12 hrs in each day), and then tested the animal on T-maze learning. The Mozart’s music but not white noise facilitated the learning. This experiment was, however, later criticized by Steele (2003, 2006). Because rats cannot hear low frequency sound (approximately lower than 500 Hz), the rats must hear a kind of distorted Mozart, not the Mozart perceived by humans. Bates and Horvath (1971) failed to find facilitative effect of the Mozart but found suppressive effect of Schoenberg’s chamber symphony.

As shown in Table 1, results of the direct effects are contradictory even in the same species. One reason is procedural differences. Different experimenters employed different behavioral indices, learning paradigms, emotional response, or social behavior. The methods used to present musical stimuli differed also. Some researchers pre-

sented music stimuli at the time of performance, while others gave music for long period before behavioral testing. Type of music and loudness of music also have crucial role to produce the direct effect. Joseph and Pal (1982) found facilitative effects of music (both classical and rock) on bar pressing of rats, while Bates and Horvath (1971) reported no facilitative effect of Mozart and Schonberg on a 4-choice task. Exposure to music in prenatal pups facilitates spatial learning in rats (Kim et al., 2006) and mice (Chikahisa et al., 2006). Peretti and Kippschull (1991) compared effects of different types of music, such as classical, country, easy listing, jazz and rock, on the social behavior of mice and found different effects depending on music. For example, classical and country music facilitated social interaction, whereas jazz increased aggressive behavior. Reduction of anxiety and an increase of amphetamine-induced stereotypy were reported in mice (Chikahisa et al., 2007). Analysis of direct effect of music in birds is rare, but Campo et al., (2005) reported negative effect of classical music in immobility in hens. Direct effect of music may be well known effect of music for humans but we need further experimental researches to clarify the direct effects of music in infrahuman animals.

The third 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). In nonhumans, artificial and non-biologically relevant sensory stimuli (e.g., switching on a lamp for rats; Berlyne, 1969; looking at an electric toy train for chimpanzees, Butler, 1953, etc.) have so called sensory reinforcement on animals. But the reinforcing properties of music on nonhuman animals have not well investigated. As shown in Table 1, 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, 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. But music is used as a tool of environmental enrichment (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). Specifically, the results showed that birds stayed longer on a perch associated with music by Bach or Vivaldi than on a perch associated with music by Schoenberg or Carter. 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.

Previously, we trained rats on a concurrent chain schedule in which the terminal links were associated with different music, Bach or Stravinsky (Otsuka et al., 2009). The rats did not show a strong preference for either style of music, although one subject showed a weak preference for Bach and another subject preferred Stravinsky. We examined the validity of the concurrent chain procedure as a method of preference measurement with conspecific vocalization evoked by an aversive experience. During responding in one terminal link the vocalization was presented, whereas white noise was presented during the other terminal link. Most of the rats preferred white noise to the conspecific vocalization. Thus, the association of auditory stimuli in terminal links in the concurrent chain schedule is sensitive to detect preference for auditory stimuli in rats. Here, we examined reinforcing property of music for pigeons using the similar concurrent chain schedule. Piece of Bach and Stravinsky were used, because pigeons discriminated these stimuli (Porter & Neuri-

nger, 1984). We also analyzed performance in the terminal link to examine the direct effect of music exposure on operant behavior.

Method

Subjects

Four experimentally naïve pigeons (*Columba livia*) were used. They were housed in individual cages and maintained at about 80–85% of their free-feeding weights. Grit and water were freely available in their home cages. The room where they were housed was artificially lit from 8:00 AM to 8:00 PM.

Apparatus

The experimental chamber was a standard operant chamber (29 cm (W) × 24 cm (D) × 31 cm (H)). The front panel was equipped with two identical response keys (2.5 cm in diameter). They were located 20.5 cm from the floor, and were 16.0 cm apart from each other (center-to-center). A feeder was attached to the front panel to present food (hemp seeds). A room lamp (DC28 V) was located 1.1 cm from the top of the back panel. The chamber was enclosed in a sound-attenuated cubicle (ENV-018 M, MED Associates). A personal computer (ProMate V2133L, NEC) was used to control the experiment. A speaker (SC-A 25, AIWA), connected to a CD player (XP-300, AIWA) through a relay circuit, was attached 5 cm below each key on the front panel.

Stimuli

Two musical stimuli were used for the discrimination training. One stimulus was Bach's *Toccatà 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. The duration of each music stimulus was approximately 8 min.

White noise was produced using computer software (SoundEdit 16 version 2J, Macintosh). Intensities of all auditory stimuli were approximately 80 dB (SPL), measured at the standing position of a pigeon in the chamber.

Procedure

Pecking to either the left or the right key was established through an autoshaping procedure. Pigeons were then trained to respond to both keys on a concurrent schedule of VI 10-s VI 10-s, VI 20-s VI 20-s, and VI 30-s VI 30-s for a total of 21 days until they showed stable and continuous responding under each schedule. Next the pigeons were trained on a concurrent-chain (CONC CHAIN) schedule. In the initial link, the left and the right keys were lit by white lamps, and identical VI 30-s schedules operated independently on each key, with a COD (change-over delay) of 2-s. 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-s with limited hold of 7-s. Responding during the terminal links was reinforced by a 4-s access to grains followed by a 4-s blackout period, and then the initial link keys were illuminated. If the pigeon did not respond within 14-s in a terminal link, the key and the house light were turned off for 4-s. 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. Because the birds showed some fluctuation in responding in earlier sessions in these 10 sessions, we analyzed responding in the

last 3 of each 10 sessions in each musical condition.

Data analysis

Two indices were used for analysis. The first was relative response ratio in the initial link, calculated by dividing the number of response to one lever by total number of responses to either lever. It was used as index of choice or preference. The second index was relative response ratio in the terminal link. First, the number of choices of each key divided the total number of responses to each key, and then the relative ratio of responding in the terminal links was calculated by dividing the response per choice of one key by the total of responses per choice of the two keys. This was used as index of direct effect on responding under FI schedule. If one music stimulus has a facilitative or a suppressive effect on operant responding, then responding during the terminal link to one music stimulus should differ from that during the terminal link with the other music stimulus.

Results

Choice in the initial link: Figure 1 shows the proportion of responses during the initial link (CONC VI 30-s VI30-s). The vertical axis indicates the proportion of responses to the Bach key to the Stravinsky key (top), the Bach key to the noise key (middle) and the Stravinsky key to the noise key (bottom), respectively. The side of the keys was changed on 11th session. The pigeons did not show strong preference during the training with Bach and Stravinsky but slight preference for the left key. A single group *t*-test (expectation = 0.50) showed that there was a tendency to respond more to Stravinsky only in session 14 ($t(3) = 6.19, P < 0.5$). The pigeons did not show strong preference in the sessions with Bach and noise. There was a significant difference in relative responding between the Bach and the noise keys in the initial links in the 6th, 18th, and 20th ses-

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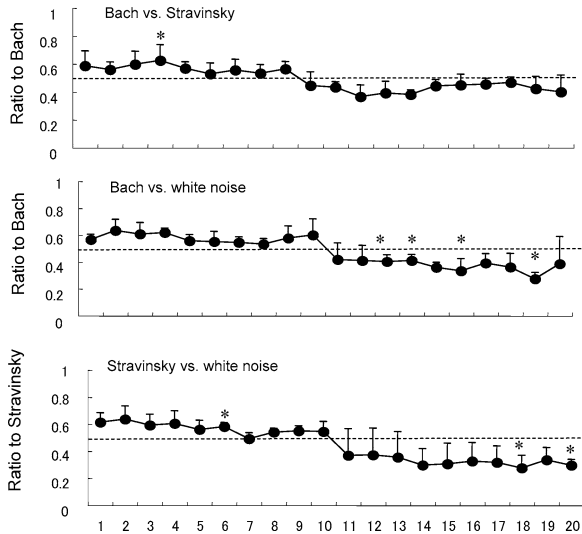


Figure 1. Mean proportion of responses during the initial link. The vertical axis is the proportion of Bach choice to Stravinsky (top), Bach to white noise (middle), and Stravinsky to white noise (bottom). Side of the key was reversed on 11th session. Small vertical bars indicate standard deviation. * $P < 0.05$

sions ($t(3)=4.56, 4.07$ and $8.03, P < 0.05$), but the direction of the preference was reversed in the 6th and 18th and 20th sessions. Thus, the statistically significant difference reflects the side preference rather than preference for one of the auditory stimuli. During Stravinsky and noise training, the birds did not show a clear preference for Stravinsky or the noise. There was a significant difference between the Stravinsky and noise in the 4th session ($t(3)=6.19, P < 0.01$) in the first half of the training, while there was a significant difference between the initial links in 13th, 14th, 15th, and 19th sessions 8 $t(3)=3, 21, 3.34, 6.42, 8.07, P < 0.05$). Because the pigeons responded more to Stravinsky when it was associated with the left key and emitted more responses to the noise when it associated with the left key, their preference reflected side preference rather than preference for one of the au-

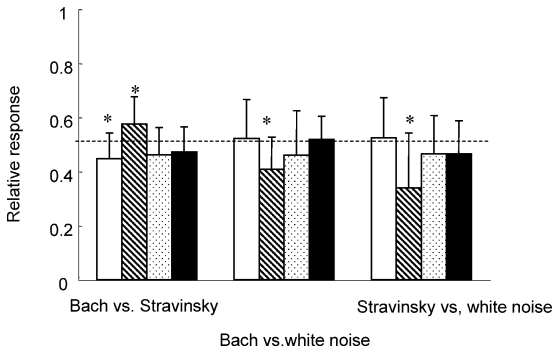


Figure 2. Individual means of choice in the initial link. Vertical axis indicates proportion of Bach choice (Bach vs. Stravinsky) or music choice (Bach vs. white noise and Stravinsky vs. white noise). Small vertical bars indicate standard deviation. * $P < 0.05$

ditary stimuli.

Figure 2 shows individual means of the response ratio in the initial link. One bird showed a significant preference for Bach to Stravinsky ($t(19)=2.43, P<0.5$), while other bird showed a reversed preference ($t(19)=3.19, P<0.01$). 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. During training with the noise, one bird showed preference for the noise to Bach ($t(19)=3.44, P<0.05$) and to Stravinsky ($t(19)=3.38, P<0.05$). Thus, this bird disliked the musical stimuli. The bird that had a weak preference of Stravinsky did not show any preference between music and noise. In conclusion, we cannot find clear musical preferences in the pigeons although there was some significant deviation from chance level.

Responding during the terminal link: If presentation of the music stimuli has facilitating or inhibiting effects on pecking, then this should affect responding during the FI terminal-link. Figure 3 shows mean relative response rate during the terminal-link. During

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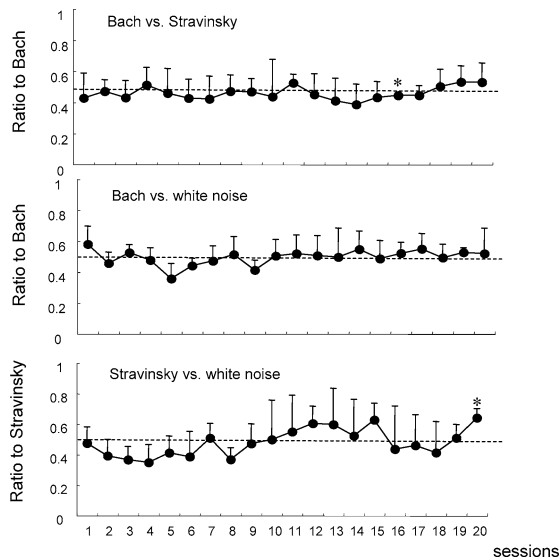


Figure 3. Mean proportion of response rates in FI 7s component (i.e., terminal link). Vertical axis is proportion of Bach choice to Stravinsky (top), Bach to white noise (middle) and Stravinsky to white noise (bottom). Side of the key was reversed on 11th session. Small vertical bars indicate standard deviation. * $P < 0.05$

training with Bach and Stravinsky, there was a higher response ratio to Stravinsky in the 16th session ($t(3) = 5.8$, $P < 0.05$). During the training with Bach and noise there was no case of significant difference from chance level. The birds showed higher responding to Stravinsky in the 20th session during the training with Stravinsky and the noise.

Figure 4 shows individual means. Two pigeons emitted more responses to the Stravinsky key during the training with Bach and Stravinsky. One pigeon responded more often to the noise key during the training with Bach and noise, and another pigeon responded more often to the noise key during the training with Stravinsky and noise. However, the relative response ratio was within 0.39 to

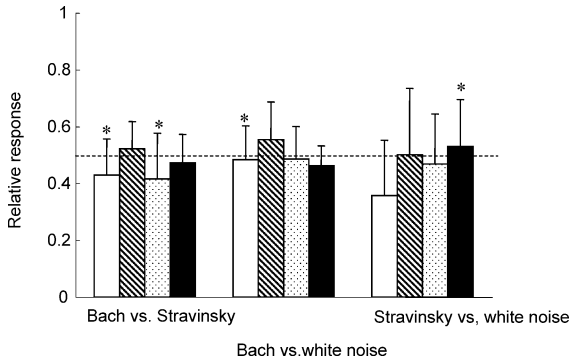


Figure 4. Individual means of proportion of response rates in the terminal link. Vertical axis indicates proportion of responding in Bach link (Bach vs. Stravinsky) or music link (Bach vs. white noise and Stravinsky vs. white noise). Small vertical bars indicate standard deviation. * $P < 0.05$

0.56, suggesting no strong effect of auditory stimuli on responding in the FI schedule. We did not find facilitative nor suppressive effect of music on operant responding in pigeons.

Discussion

No pigeons showed a clear preference for music stimuli, even though some deviation from the chance level of choice was observed. One bird showed a weak preference for Bach but another one showed a weak preference for Stravinsky. Thus, there is no general tendency of music preference in pigeons. In contrast, most of the Java sparrows tested in a previous study preferred Bach to Schoenberg and no birds preferred Schoenberg to Bach, even though some birds did not show clear preference for Bach (Watanabe & Nemoto, 1998). We have to point out that there were procedural differences between the present experiment and that with Java sparrows, which may explain the contradictory findings. Watanabe and Nemoto (1998) measured perching responses of Java spar-

rows associated with playback of music. That is, the birds were able to hear music as long as they stayed at the perch. In contrast, the pigeons in the current experiment heard music just for 7-s. Furthermore, the Java sparrows had a choice of three perches and one of them associated with no auditory stimulus, while the concurrent chain schedule in the current study employed just two pecking keys. Another procedural difference was presence of food. In the current experiment, food reinforcement in the terminal link might have masked the reinforcing properties of music. We had confirmed the reliability of the concurrent chain schedule to examine preference for auditory stimuli presented in the terminal link in rats (Otsuka et al., 2009) but the masking effect might have been stronger for pigeons. Music itself was different. We used Bach and Stravinsky in the present experiment while Bach and Schoenberg were used in the Java sparrow experiment. Java sparrow could discriminate the Bach and Schoenberg (Watanabe & Sato, 1999), and the music used in the present experiment had been discriminated by pigeons also (Porter & Neuringer, 1984). Thus, the present results were not due to an inability of pigeons to discriminate the music stimuli.

One pigeon preferred white noise to Bach or Schoenberg. No Java sparrows preferred the white noise to Bach, yet they preferred white noise to Schoenberg in our previous experiment. Preference for the white noise to Bach might suggest that a monotonic stimulus caused subjective shortening of the terminal link. Pigeons showed preference for a terminal link with a stable visual stimulus to a terminal link with a gradually changing color stimulus in the concurrent chain schedule (Bragason, 1995). In the present schedule, however, music started from a randomly selected point of an 8-min sample. Thus, it is impossible to assume that music functions as a clock in the FI schedule. In addition, a psychophysical study of the temporal perception of a stable tone and cooing in pigeons suggests

that the tone was judged to be longer than the coo (Miki & Santi, 2001). Therefore, it is not plausible to explain the preference for white noise by subjective shortening of duration of the terminal links.

Two pigeons emitted more responses during presentation of Stravinsky in the terminal link in comparison to responding during presentation of Bach, but the difference was less than 10%. These two birds did not emit more responses during Stravinsky in Stravinsky vs. white noise sessions. Thus, the facilitative effect of Stravinsky is not a stable phenomenon. In the music vs. white noise sessions, one bird showed facilitative effect of Bach and another one that of Stravinsky. As shown in Table 1, the direct effect of music is not stable across different experimental conditions. The present results neither demonstrated a strong or a steady direct effect of music reinforcement.

Because hens also showed no music preference (MaCadie et al., 1993), it is possible to assume that there are no reinforcing properties of music for non-songbirds. 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 & Slabbekooorn, 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; Masatak, 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 5 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 (Holy & Guo, 2005). Thus, ultrason-

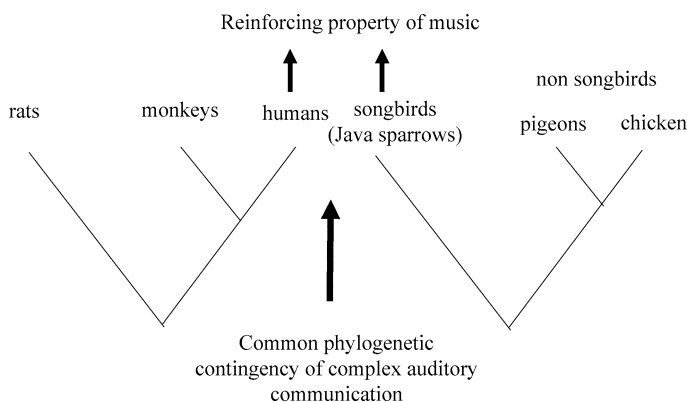


Figure 5. Evolution of reinforcing property of music. At present humans and Java sparrows are exceptional animals showing music preference behavior. One common nature of these species is learning of complex vocal communication systems. The reinforcing property of complex auditory stimulus might have positive effects in the evolution of such systems.

ic music may have reinforcing effects for mice. More studies are clearly necessary to more fully understand the evolution of reinforcing effect of music.

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