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The use and impact of auditory stimulation in animals

Guillaume UBIEMA[1,#], Marine SIWIASZCZYK[1,#], Céline PARIAS[1], Roman BRESSO[2], Christophe HAY[3], Baptiste MULOT[4], Scott A. LOVE[1,*], Elodie CHAILLOU[1,*]
[1] PRC, INRAE, CNRS, IFCE, Université de Tours, France
[2] Musicoprod, 72500 Dissay-sous-Courcillon, France
[3] La maison d'à côté, 41350 Montlivault, France
[4] ZooParc de Beauval & Beauval Nature, 41110 Saint-Aignan, France

*Correspondance : elodie.chaillou@inrae.fr; scott.love@inrae.fr
[#] authors with equal contribution

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Abstract

Music can cause pleasant sensations in humans whereas some noises can cause discomfort. The effects of music and noise have also been somewhat studied in animals, showing different impacts. In this review we aim to illustrate the differences and similarities between animals, in terms of their sensitivity to auditory stimuli (noise or music), by first recalling some generalities about the physical characteristics of sound and the biological bases of hearing. Second, based on the studies reported in this review, we conclude that ambient noise is harmful and/or stressful, and that musical sounds can take many forms with a large range of impacts in animals. Finally, we present two practical examples of the use of music with animals (one in the context of a zoo and the other in cattle breeding) and an example of an experiment designed to understand the impact of music on neonate lambs. These three examples highlight how music can help to improve animal welfare.

Keywords

acoustic ; welfare ; music

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I INTRODUCTION - GENERALITIES ABOUT THE ACOUSTIC PROPERTIES OF AUDITORY STIMULI AND THE BIOLOGICAL BASES OF HEARING

1.1 Acoustic properties of sound

Sound is a physical phenomenon, defined as a mechanical vibration propagating as a longitudinal and periodic wave within a material medium. It is characterized by:

- the amplitude of pressure change expressed in Pascal (Pa),

- the wavelength (λ) which is the distance over which the wave's shape repeats,

- the frequency expressed in Hertz (Hz) which is the number of pressure variations per second,

- the period which is the time interval between two identical and successive vibratory states in which the wave propagates,

- and the propagation speed which depends on the medium (Hansen et al., 2017).

The decibel (dB) is the unit used to measure loudness. In humans, the audibility threshold is set at 0 dB, discomfort being observed with a sound of 110 dB and pain with a sound of 130 dB (https://www.ncbi.nlm.nih.gov/books/NBK390300/).

A large variety of sounds are found in the environment. Based on their frequency profile, it is possible to discriminate between pure and complex sounds (Fig. 1A). Pure sounds are composed of a single sinusoid, whereas complex sounds are composed of several different frequencies. The discriminant between music and noise is in the organization of these different frequencies. For musical sounds, the frequencies are multiples of the fundamental frequency and are often referred to as "harmonics" (Fig. 1B). For noise, the frequencies can also be numerous but without specific organization with each other (Fig. 1C). Thus, noise is a non-periodic sound, which is often perceived as unpleasant or harmful (Walker et al., 2011). By analogy with white light and its visible spectrum, there is also the concept of white and colored noises. Based on physical properties, white noise is a theoretical construct of a signal covering an infinite bandwidth and

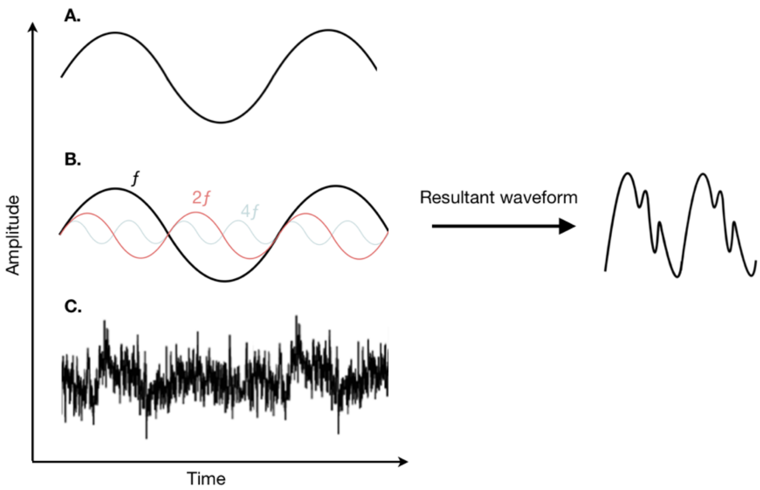

Figure 1: Waveform of different sounds. A. Pure sound. B. Musical sound, f is the fundamental frequency (also named as the 1st harmonic), 2f is the 2nd harmonic (1/2 of the fundamental frequency), 4f is the 4th harmonic (1/4 of the fundamental frequency). C. Noise.

flat power spectral density over the frequency range relevant to the environment (Zhivomirov 2018.) The colored noises, such as violet, blue, pink or red, are distinguished according to their power spectral density and the spectral slope rate (for more details, see table 1 in Zhivomirov 2018). Like musical sounds, ambient noise, white noise and ecological noise could have an impact on health, behavior or the physiology of animals and humans. When investigating this impact it is important to consider the hearing, or audible, range of the species.

1.2 Hearing range

Sound frequencies are classified according to the audible range, that of humans being between 31 Hz and 17,600 Hz, conventionally described as being between 20 Hz to 20,000 Hz, at a sound level of 60 dB in air (Jackson et al., 1999). According to the human hearing range, sounds with frequencies below 20 Hz are classified as infrasound (Leventhall, 2007) and those with frequencies above 20,000 Hz are classified as ultrasound (Carlsen, 1975). However, the idea that a sound with a frequency below 20 Hz is inaudible is disputed (Leventhall, 2007). Indeed, by increasing the sound level (more than 80 dB), it is possible to hear sounds with frequencies below the 20 Hz threshold, this capacity also depending on the age of the person (Leventhall, 2007). Then, to evaluate the impact of the different types of auditory stimulations in non-human animals, it is necessary to take into consideration the hearing range of each species (Fig. 2). For example, the bottlenose dolphin (*Tursiops truncatus*) is able to distinguish sounds from 100 Hz

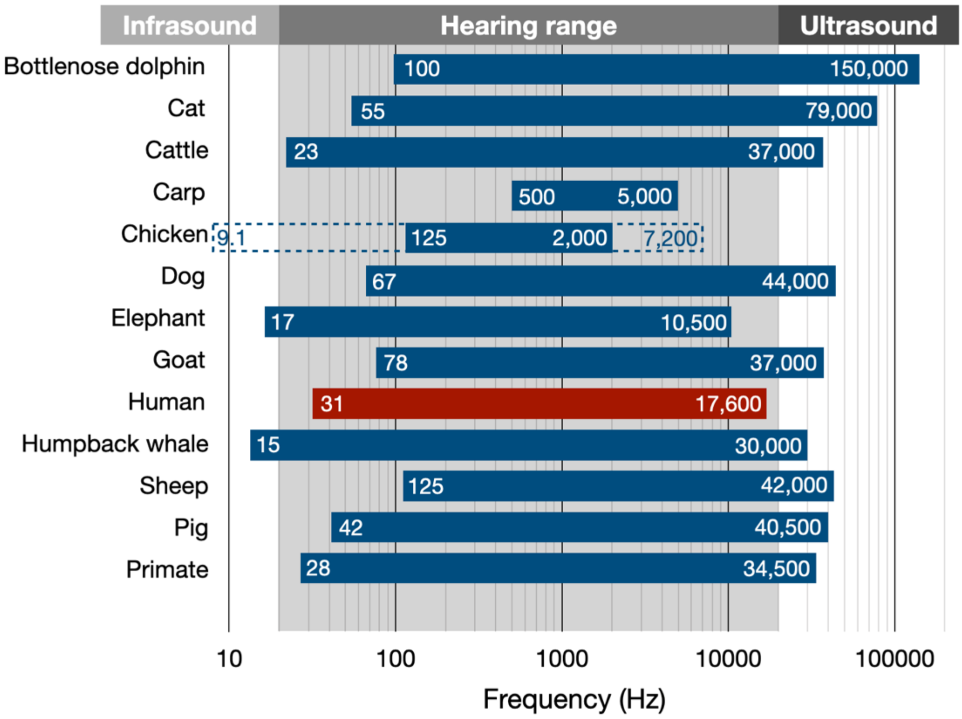

Figure 2: Distribution of hearing ranges defined in Human (red) compared to other mammals (blue). The hearing ranges on terrestrial animals were established at 60 dB: Elephant: (Heffner and Heffner, 1980); Cat, Cattle, Dog, Goat, Human, Sheep, Pig (Heffner 1998); Non-human Primate: (Heffner 2004); Chicken (Hill et al., 2014). Note that Chicken' hearing range was extended from infrasound (9.1 Hz) like Elephant and Humpback whale. Carp (Vetter et al., 2018); Bottlenose dolphin (Houser and Finneran, 2006); Humpback whale (Tubelli et al., 2018).

to ultrasounds up to a frequency of 150,000 Hz (Houser and Finneran, 2006) while the humpback whale (*Megaptera novaeangliae*) and the elephant (*Elephas maximus*) are able to detect infrasound as low as 15 (Tubelli et al., 2018) and 17 Hz (Heffner and Heffner, 1980), respectively. This capacity to detect infrasound is not restricted to large mammals as it has been shown that chickens (*Gallus gallus domesticus*) are also able to detect infrasound as low as 9 Hz (Hill et al., 2014).

1.3 Biological basis of hearing

1.3.1 The auditory system

Hearing is a complex biological system that analyses auditory stimuli through acoustical (frequencies spectra) and spatial (localization of the stimuli) information. Anatomically, the auditory system includes a peripheral part with the outer, middle and inner ear, and a central part with a specific neuronal network (Evans 1992). The reception and amplification of auditory signals are performed by the outer and middle ear; the transmission of signal frequencies is performed from the middle ear to the inner ear, including the cochlea. The cochlear nerve encodes the auditory signals, according to their frequencies, through the hair cells (mechanosensitive cells) from the cochlea. This first step of the hearing process, involving the peripheral auditory system, allows to translate acoustic oscillations into spatio-temporal patterns of neuronal discharges (Evans, 1992). The second step concerns the central auditory system with the neuronal network starting from the cochlear nucleus to successive brainstem and thalamic structures, before integration by auditory cortex (Evans, 1992; Pickles, 2015; Fig. 3). Briefly, neuronal discharge from the cochlear nucleus is transmitted to the lateral and median olivary nuclei through bilateral projections. After this first relay, the signal is transmitted through ipsilateral projections (lateral lemniscus tract) from the olivary nuclei to the inferior colliculi. The last relay from the inferior colliculi to the auditory cortex involves the medial geniculate body of the thalamus (Evans, 1992; Šuta et al., 2008). Throughout these ascending neural paths, integration is ensured during each relay to refine the neuronal encoding of the auditory information presented to the cortex (Pickles, 2015).

The examination of the auditory system in different vertebrates shows that it presents similarities in its organization with a peripheral auditory system with external part, middle ear and inner ear, and a central peripheral auditory system, including brainstem, thalamic and cortical projections (Itatani and Klump, 2017; Köppl, 2011; Ladich and Winkler, 2017; Reis et al., 2017; Roberto et al., 1989; Rouiller and Welker, 2000; Šuta et al., 2008). However, across vertebrates anatomical differences are also observed for the external auditory system, the upstream part of the tympanic membrane (Ladich and Winkler, 2017). Amphibians have an external tympanic membrane and no real external organ. Fishes have no outer or middle ear, their role being partially performed by the swimbladder. Birds and land mammals possess external auditory canals to conduct acoustic oscillations to the tympanic membrane. In cetaceans, external auditory canals and tympanic membrane are present but do not conduct the acoustic oscillations. Whatever the species, most of the similarities are observed in the inner ear organization (Ladich and Winkler, 2017). It is interesting to note that the anatomo-functional organization of the peripheral auditory system enables a species to hear the sound frequencies produced by that species (Ladich and Winkler, 2017). In other words, the frequency hearing range of a species corresponds to the frequency range of sounds produced by the species. Concerning the central auditory system, most of the brain structures identified in humans have also been anatomically identified in other mammals or their homologous structures in other vertebrates (birds, fishes, etc.; Oertel, 1999;

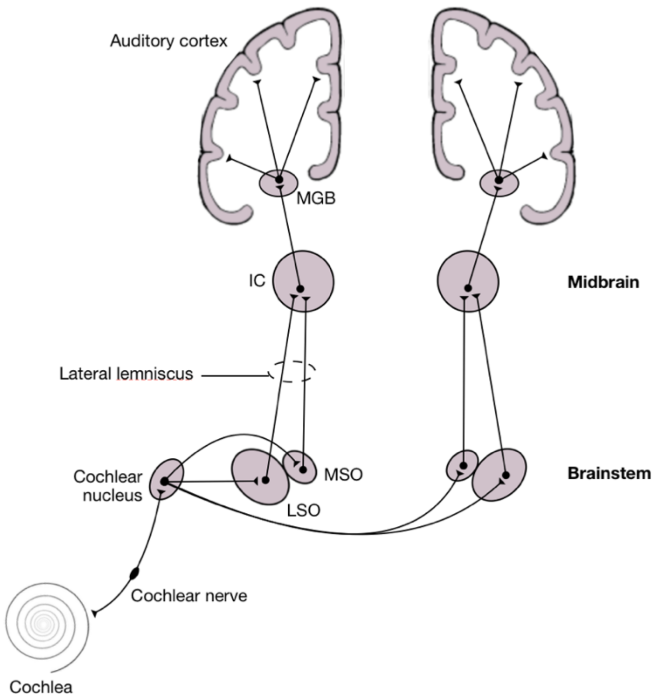

Figure 3: Schematic representation of the neuronal network of the auditory system from cochlea (inner ear) to the auditory cortex. Based on mammal brain anatomy: LSO, lateral part of the superior olivary nucleus; MSO, median part of the superior olivary nucleus; IC, inferior colliculi; MGB, medial geniculate body.

Rouiller and Welker, 2000). The existence of a central auditory system throughout the animal kingdom is not sufficient to confirm the ability of animals to perceive, analyze, recognize and/or interpret all types of sounds such as music. However, behavioral studies have highlighted the ability of different vertebrates to use vocal communication.

1.3.2 Acoustic communication and emotion in animals

Animals can communicate with each other using vocalizations (Sebe et al., 2008). Vertebrates have different repertoires of vocalizations that are used for communicating in social contexts and/or their emotional state. For example, 11 types of vocalizations have been identified in guinea pigs, some of which can lead to a behavioral response in conspecifics (Berryman, 1981), 21 in cats, which differ according to context (Tavernier et al., 2020) and a dozen in elephants, which vary with age (Soltis, 2009). Ewes can discriminate between their own offspring and other lambs based on vocalization alone (Sebe et al., 2008). For cattle (Green et al., 2018) and sheep (Guesdon et al., 2015, 2012), two gregarious species, vocalizations can also reflect the emotional state of individuals, particularly in situations of social separation. These observations are not specific to terrestrial mammals, since vocalizations are essential in most bird species, particularly songbirds (Filippi et al., 2019) and are present in marine mammals (Erbe et al., 2016), amphibians (Velásquez, 2014), crocodilians (Vergne et al., 2009) and fishes (Ladich and Winkler, 2017). Several authors have hypothesized that non-human animal vocalizations can be compared to human language and music, on the basis that these different sound productions have rhythm (Ravignani et al., 2019) and a temporal profile (Filippi et al., 2019). Such a hypothesis is all the more conceivable since it can be based on biological foundations such as animal hearing ability (see part 1.2) and strong similarities in the auditory system throughout the non-human animal kingdom (see part 1.3).

Considering the universality of both the auditory system and vocal communication, it is legitimate to postulate the existence of a universal effect of music within the animal kingdom, in particular as a means of improving welfare, a use that has been reported several times in different media[1] and more rarely in research journals (Alworth and Buerkle, 2013; Dhungana et al., 2018). To address this question, we propose to consider auditory stimuli along two axes: auditory stimuli qualified as noise and auditory musical stimuli. For each of these, we will review the scientific literature that examines its influence on animal emotional responses[2].

II IMPACT OF NOISE EXPOSURE ON DIFFERENT WELFARE-RELATED PARAMETERS

The French Ministry of Ecology defines noise as,

"an acoustic phenomenon producing an auditory sensation considered unpleasant or disturbing. Excessive noise has effects on the organs of hearing (physiological dimension), but can also disturb the body in general, especially sleep and behavior (psychological dimension). (...) Noise pollution can result from three main sources: transport, neighbors and activities."[3]

The World Health Organization has developed preventive strategies to reduce noise exposure (WHO, 2018). From a physical point of view, noise is defined as a complex, non-periodic sound. In non-human animals, various studies have demonstrated the harmful effects of noise on the health and welfare of farm animals or animals kept in zoos.

2.1 Ambient noise

The impact of ambient noise is examined according to the animals' habitat. For example, farm animals are exposed to many different types of sounds throughout their life, especially within their housing from machinery, human intervention and motor vehicles, during transport, and in slaughterhouse. This noise is generally of high intensity and can cause deleterious behavioral and neurophysiological effects to the animal during chronic or sudden exposure. In sheep (1-3 years of age), it was found that the addition of ambient noise (90-100 dB) during transport did not change their heart-rate, salivary cortisol levels or behavior (Hall et al., 1998). This indicates that the extra noise did not further stress, or appease, the sheep in this already stressful situation. In contrast, the noise associated with the handling (human voices, metal-on-metal clanging, etc.; 85-95 dB) of crossbred beef heifers increases their heart-rate and movement (Waynert et al., 1999). However, these increases in heart-rate and movement were lower after five days of exposure, suggesting that the animals had gotten used to the noise presented and its significance had changed. Evaluation of chronic exposure to ambient noise was studied in growing castrated male Landrace pigs (Otten et al., 2004). At 12 weeks of age, individuals were submitted to a 120 min-period of broadband noise (mixture of noises between 0 and 23 kHz, 90 dB) either daily or every 2-3 days for four

[1] https://www.livescience.com/33780-animal-music-pets.html
https://www.youtube.com/watch?v=_2raNqztPX0 ; https://www.youtube.com/watch?v=1ZW4Ska8gvA ; https://www.petmd.com/blogs/thedailyvet/aobrien/2013/march/music-influences-milk-production-in-cows-29895 ; https://www.sciencesetavenir.fr/nature-environnement/la-musique-adoucit-les-vaches_4441

[2] As best as possible, we will specify the information relating to animals and/or to experimental plan which could influence the emotional responses in addition to the auditory stimuli (gender, age, breed…).

[3] https://www.ecologique-solidaire.gouv.fr/bruit-et-nuisances-sonores

weeks. In this experimental context, the pigs exposed to noise every day had delayed daily weight gain, and alteration of their corticotrope axis (higher plasma cortisol and adrenal corticotropic hormone, ACTH), which is involved in the response to stress (Otten et al., 2004). In pigs exposed to noise every 2-3 days, higher levels of glucocorticoid receptor binding in the hippocampus and alteration at the adrenal levels of the corticotrope axis such as modification of the cell densities in the adrenal medullary were observed (Kanitz et al., 2005). Together, these results suggest a negative emotional impact of acute or chronic noise-exposure in farm animals. Similar conclusions have been made in dogs who were exposed to an alarm for 3-mins (75 dB, 0.25-8 kHz) and subsequently displayed muscle contraction, piloerection and salivation, associated with increased heart rate and blood pressure, and an increased plasma ACTH, noradrenaline and cortisol (Engeland et al., 1990). Consequences of noise exposure have also been studied in chickens, this animal model presenting interest for evaluating the impact of *in ovo* exposure (Donofre et al., 2020; Kathpalia et al., 2019; Sanyal et al., 2013). As for farm mammals and dogs, noise exposure produced stress as indicated by increased corticosterone in 42-day-old broilers (acute exposure of 10 min at 80 dB and 100 dB, Chloupek 2009), and heterophilic/lymphocyte ratio in 36-week-old hens (exposure of 60 min/day at 90 dB (Campo et al., 2005). *In ovo* exposure to noise (110 dB, 30-3000 Hz, for 15 min/hour from day 10 to hatching; Kathpalia et al., 2019; Sanyal et al., 2013) lead to increased noradrenaline plasma at 1-day-old, impaired spatial orientation with decreased expression markers of maturation in hippocampus (synaptophysine, postsynaptic density-95: Sanyal et al., 2013; Brain-derived neurotrophic factor: Kathpalia et al., 2019). Together these studies affirm that farm animals (mammals and birds) are sensitive to noise exposure (90-110 dB) and that noise has a stressful character that can alter the animal's health from a physiological, behavioral, neurobiological and developmental point of view. Moreover, these alterations are also observed at intensities below the human discomfort threshold (110 dB).

2.2 White noise

Although ambient noise has been shown to have adverse health effects, some noise may have positive effects. This is the case with white noise. This sound occurs when a variety of sounds of different frequencies are played at a constant level. In clinical uses, white noise is thought to facilitate sleeping after artery surgery (Williamson, 1992). It also improves learning in healthy adults (Angwin et al., 2017) and could be a possible therapeutic option for children with attention deficit hyperactivity disorder (Pickens et al., 2018). It has also been found to improve performance in cognitive tasks in adult monkeys (*Macaca arctoides*) exposed to white noise (80 dB) for 15 min before the task (Carlson et al., 1997) and also to have a calming effect on infant Japanese macaques (5-27 days old) in stressful situation (Kawakami et al., 2002). However, the impact of white noise is not always beneficial. Whereas 2-day-old hen chicks, spent more time in a food-conditioned place, they spent less time in white noise-conditioned place (Jones et al., 2012), suggesting that white noise can also be an aversive stimulus during a conditioned place preferences test.

2.3 Ecological sounds

Other noises such as so-called "ecological" sounds, which consist of auditory stimuli in relation with the animal's natural environment, can also be beneficial to animals. In particular, rainforest sounds, containing sounds of animals (e.g. birds, primates, elephants) and forests (e.g. rain, river, wind), have been used in several studies. The sound of a rainforest has a tendency to increase social interactions and resting time on captive gorillas by masking ambient noise (8-41 years old; Wells et al., 2006). But this effect is questioned in adult gorillas since some studies have reported increased agitation in 12-23 years old gorillas (Ogden et al., 1994) while others have reported no effect on anxiety behavior (Brooker, 2016). These differences between studies could be due to the different experimental designs (duration of exposure, animal housing, etc.) or to interindividual variability.

On the basis of the studies reported in section 2, it is difficult to conclude whether or not exposure to ambient noise, white noise or environmental noise has adverse or positive effects, since these noises were broadcast at different intensities. Nevertheless, at equivalent sound level (60-80 dB), it seems that exposure to white noise (ocean waves) or conspecifics vocalizations would be more beneficial than exposure to ambient noise (noises truck, train…) at least in chickens (Campo et al., 2005; Donofre et al., 2020). But controlling the sound level parameter alone is not sufficient to compare the effects of exposure to these different noises. In addition to the duration, or even suddenness, or frequency of exposure, it is also important to consider all the characteristics of auditory stimulation. In particular, as we will see in the following section, exposure to musical sounds will not have the same effects depending on the level, of course, but also on the instruments, the harmonies and the tempo.

III IMPACT OF MUSIC EXPOSURE ON DIFFERENT WELFARE-RELATED PARAMETERS

3.1 How to define music?

Music is one of the oldest forms of art and is an integral part of our daily lives. Music could be defined as an aggregation of notes or as a succession of notes. But, for André Manoukian, French pianist, jazzman and composing author, this succession of notes could be considered like music when this sound creates a “sound sensation”[4] . This transformation is done when the notes are submitted to a rhythmic arrangement. However, our ear is able to discriminate dissonances and consonances, a phenomenon based on the notion of beat, when several frequencies are heard simultaneously. Consonances lead to a calming effect and dissonances to a feeling of being aggressed, harmony being the art of combining both sensations, in occidental music. A. Manoukian defined “the harmony” (accordance) as a low proportion of frequencies between the “A” (440 Hz) and the octave (880 Hz), in other words when the proportion is equal to a whole number. For songwriter Frank Zappa[5], written music on a score becomes a musical experience when converted into “twirling air molecules”; then each air disturbance caused voluntarily is seen as a composition. Moreover, for this composing author, because each (physical) component of a sound could be perceptible (audible), any sound can be consumed as music. For both A. Manoukian and F. Zappa, music has the capacity to create a personal sensation.

According to the diverse components of music such as intensity, tempo, pitch, timbre, nuances, and instruments, and because not all individuals are sensitive to the same music (or component), the large panel of impacts of music exposure is not surprising.

[4] Comments from his column on the radio show “Par Jupiter”, France Inter, 2020-08-26 “Le Cluster”.

[5] Zappa par Zappa, juin 2005, Eds De L’Archipel, 396p, ISBN 2840877159 (original edition 1989).

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Music exposure can provoke different emotional states in human beings, which can have both beneficial and harmful effects on health. In particular, it has been shown that music can be used as a therapeutic element in the emergence of a new discipline: music therapy. It can regulate cardiovascular parameters (Koelsch and Jäncke, 2015), relieve pain (Cheung et al., 2018; Lee, 2016), neurodegenerative diseases (García-Casares et al., 2018) and psychiatric disorders such as depression, anxiety, schizophrenia, sleep disorders and dementia (Wang and Agius, 2018). In this context, many authors also advocate that music has beneficial effects on animals. By analogy with the idea of a “sound sensation” proposed by A. Manoukian and F. Zappa, examining the impact of musical exposure on animals requires considering their emotional reaction and the parameters that characterize musical sound such as intensity, tempo or instrument.

3.2 Sound level

To our knowledge, very few studies have compared the impact of different sound levels of music on animals, *i.e.* a study comparing two different exposure intensities of the same piece of music. In subadult meat chicks, the impact of music exposure was studied with two styles of music (dinner *vs.* rock’n roll) at two different sound levels (70 *vs.* 85 dB). Whatever the level applied, chicks exposed to music expressed stress-related behavior from the first exposure and expressed jerking head motion after two weeks of exposure (Christensen and Knight, 1975). The sound level chosen for an experiment is often chosen as a function of the ambient noise level in the environment. For example, rainbow trout or common carp reared in tanks (with recirculating water system) are exposed to ambient noise levels close to 122 dB and the impact of music exposure was evaluated at a level of 130 dB (Papoutsoglou et al., 2013, 2010, 2007). In these different studies, the animals from the control conditions were exposed to ambient noise such as animal voices and fans (Campo et al., 2005), the noise of chickens (Christensen and Knight, 1975) or machines (Papoutsoglou et al., 2013, 2010, 2007) at a level smaller than those used for music exposure. In this context, two questions could be asked concerning the reported stressful impacts of music described. In chickens, for example: is it the consequence of sound level (75 dB in Campo et al., 2005; 70 and 85 dB in Christensen and Knight, 1975) or the consequence of novelty or unknown noise. In chicks, prenatal exposure to music has been evaluated at two different levels. At 110 dB, prenatal music exposed chicks (from E10) performed better in spatial orientation, learning and memory at 1 day old than prenatal noise exposed chicks (Sanyal et al., 2013). Similar effects were reported with a level of 65 dB (Chaudhury et al., 2010). At 110 dB as well as 65 dB, the cognitive impacts of prenatal music exposure are associated with neuronal modifications in auditory nuclei (Alladi et al., 2005, 2002; Kathpalia et al., 2019) and hippocampus (Chaudhury et al., 2010, 2009, 2008, 2006; Chaudhury and Wadhwa, 2009; Sanyal et al., 2013), through different actors of neogenesis. However, depending on the study and the variable measured, these effects were also found when chicks were prenatally exposed to species-specific sounds at the same level.

In conclusion, the impact of music sound level is not clear since it was evaluated in interaction with other environmental factors such as light intensity (*i.e.* Papoutsoglou et al., 2010), including the frequency factor that differs between music and control noise (*i.e.* Kathpalia et al., 2019). Perhaps the main precaution to take when testing the impact of music exposure is to present it at a level equivalent to that of the control noise (ambient noise). Finally, even within a piece of music, the sound level can vary. These variations in music are called nuances. They are expressed by indications ranging from pianissimo to fortissimo, and crescendo and decrescendo, nuances to which we must also add the notion of tempo.

3.3 Tempo

Tempo is the speed at which a piece of music is played and is expressed as the number of beats per minute (bpm). Tempo lower than 40 bpm is named largissimo and tempo higher than 188 bpm is named prestissimo. Based on the work from Karageorghis and Terry (Karageorghis and Priest, 2012), in humans, tempo, musicality, cultural impact[6] and association[7] are the four characteristics of the piece of music that contribute to its impact on motivational and physiological responses (heart rate at rest, during physical exercise). Among these factors, tempo is suggested to be the most relevant. Several studies aimed to demonstrate a significant relationship between tempo and heart rate at rest or during exercise (Karageorghis et al., 2006; Navarro et al., 2018; van Dyck et al., 2017).

In animals, a famous YouTube video[8] of Snowball, a 12-year-old male cockatoo "dancing in rhythm" to music, led Patel and colleagues to study this phenomenon in 2009 (Patel et al., 2009a). Then, Snowball was subjected to a tempo of 108 bpm (moderato – allegretto) that was increased and decreased. Snowball was found to be able to synchronize to the tempo and even with variations (Patel et al., 2009b). This ability to synchronize the motor activity with music tempo was also observed in a 1-year old female lion (Cook et al., 2013).

The question of tempo was also examined with studies of preference. For example, adult marmosets and tamarins expressed a preference for slow tempo (65 bpm, adagio) compared to faster tempo (370 bpm, prestissimo; Mc Dermott and Hauser, 2007). At the same prestissimo (200 bpm), 4 week old piglets were more often seen walking, standing or tail wagging compared to piglets exposed to adagio (65 bpm; Li et al., 2019). This suggests that fast tempi would stimulate piglets and in a positive way since tail wagging is an indicator of positive emotion in pigs (Reimert et al., 2013). Finally, young and adult gorillas were more active when they were exposed to music, with fast tempi (106-111 bpm) inducing higher activity than slow tempi (33-57 bpm) (Brooker, 2016).

It is therefore certain that tempo has a considerable influence on behavior and that a fast tempo increases animal activity. However, increased activity does not necessarily indicate well-being and positive emotion. In some cases, it may express emotional stress and a desire to escape. Further research is therefore necessary to conclude more precisely whether a tempo has a positive or negative effect on the animals.

3.4 Musicality

Musicality refers to harmony and to melody. As seen above (part 3.2.), musicality is suggested to play an important role in the motivational impact of music (Karageorghis and Priest, 2012). To take into account this factor, we need to investigate the capacity of animals to be sensitive to harmony and to discriminate instruments and/or voice in a piece of music. Harmony is the combination of successive musical sounds. In theory, “harmony is the science which regulates the formation and sequence of chords. [...] We noticed that superimposed melodic lines frequently provided chords of the type: C-E-G. It has been recognized that a string which

[6] “Cultural impact concerns the pervasiveness of the music within society or a sub-cultural group” (Karageorghis and Priest, 2012).

[7] “association refers to the extra-musical associations that may be evoked” (Karageorghis and Priest, 2012) such as a film.

[8] https://www.youtube.com/watch?v= N7IZmRnAo6s

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vibrates, a ball which is struck, generate sounds in the same chords."[9] Consonant sounds (chords) are recognized by individuals as a unity, this cohesion and stability produces a pleasant listening sensation. Conversely, dissonant sounds give an impression of instability and an unpleasant listening sensation. Depending on culture, lifestyle and habits, it is therefore easy to understand that what seems consonant to one individual will seem dissonant to another. In this context, how could we define a consonant and dissonant sound for animals? Some authors addressed this question in European starlings (age unknown) (Hulse et al., 1995), adult Java sparrow (Watanabe et al., 2005) and 6 to 7 years old Japanese macaques (Izumi, 2000) by using operant conditioning tests. All found that the animals were able to distinguish between consonant and dissonant sounds. Moreover, there is an "innate" preference for consonant sounds in infant chimpanzee (17 weeks old) (Sugimoto et al., 2010) and in subadult chicks (2 months old) (Chiandetti and Vallortigara, 2011).
Furthermore, some authors examined whether instrument and voice in a piece of music are differently perceived by animals. In this aim, effects of different types of music on social behavior were examined in chimpanzees (Videan et al., 2007). The animals (male and female between 4 and 48 years old) were subjected to known classical (Pavarotti), easy-listening (Enya) vocal or instrumental music. These pieces of music also differed by their tempo (95-170 bpm for classical vocal and 50 to 90 bpm for easy-listening vocal). The authors concluded that instrumental music was more effective at increasing affiliative behaviors whereas vocal music was more effective at decreasing agonistic behaviors (Videan et al., 2007). Dogs presented with classical music (100-143 bpm) spent more time sleeping and less time vocalizing than dogs presented with heavy metal music (102-151 bpm), who spent more time body shaking (Kogan et al., 2012). This suggests a calming effect of classical music and an excitatory or stressful effect of heavy metal (Kogan et al., 2012). Because the characteristics such as sound level, harmony are unknown, it is difficult to fully understand these differences between types of music in the case of animals. However, they do support the idea that animals are able to express a preference between different types of music.

3.5 Music preferences

As mentioned before (3.1.), chimpanzees (Sugimoto et al., 2010) and chicks (Chiandetti and Vallortigara, 2011) are able to express preferences for consonant sounds compared to dissonant sounds. But, when animals are subjected to different pieces of music and to silence, individuals do not necessarily express the same preference - preferences are personal. For example, in four adult Java sparrows, two preferred Bach to Schoenberg or silence, and Vivaldi to Carter or silence. The two others preferred silence to Bach or Schoenberg. Interestingly, when preference was tested against noise, one of these two latter birds ran away from noise (Watanabe and Nemoto, 1998). Musical preferences have also been reported in growing piglets (Li et al., 2019) and adult tamarins and marmosets (Mc Dermott and Hauser, 2007). In milking cows, a study reported that the use of country music is efficient for conditioning cows on voluntary approach to an automatic milking system (Uetake et al., 1997).

The evidence of positive or negative impacts of auditory stimulations on animal physiology, immune system and behavior needs to be further investigated. Whereas harmful impacts of high levels of noise are reported in a large panel of species, positive impacts of music are more questionable but appear more evident in birds and primates than in other species. However,

[9] Definition from the collective book « Initiation à la musique. A l'usage des amateurs de musique et de radio », Ed. du Tambourinaire, 1935, 418pp, (personal translation).

music is being more and more used in animal experimental facilities, for indoor reared farm animals or in zooparks. In the final section of this review, two examples of the practice of using music with animals (one in the context of a zoo and the other in cattle breeding) will be highlighted as well as an example of an experiment designed to understand the impact of music on motherless lambs reared with formula-milk.

IV EXAMPLES OF PRACTICE

4.1 Preventing stress with music at the ZooParc de Beauval[10]

At the ZooParc de Beauval, the use of auditory stimulation began in 2001-2002 with the installation of speakers in the African savannah building that is dedicated to herbivores. These species are very reactive. Because of their gregarious nature, all the animals in the different groups could react sharply in a crowd movement after a sudden, loud or unknown noise. In addition to caregivers and veterinarians, the animals are exposed throughout the day to visitors, maintenance and construction workers. Caregivers first used radio with music and talk shows before changing to streaming music playlists. In this way, the animals were subjected to a large panel of music styles with different variations of rhythm and pitch. At night, background music was stopped to allow the animals to have a resting period with lesser ambient noise than during the day. The sound level of the auditory stimulations was neither measured nor fixed. The aim being that the level was sufficient to mask a large panel of ambient noise (metallic doors, engines…) but to be not too loud, at the risk of compromising the communication and the safety of the people working with the animals.

After the introduction of music the caregivers observed that the animals were more likely to keep calm and quiet when they were working in the building. For example, the Nyala (*Tragelaphus angasii*) housed in the Hippopotamus building with ambient music are less stressed than the Sitatunga (*Tragelaphus spekii*) housed on their own in an old building without music. Because of the positive impact of the auditory stimulation, is was also applied in the Asian savannah building since 2011-2012.

However the use of music is not applied to all species at the ZooParc de Beauval because not all species are as reactive to specific events as herbivores. In these other cases, specific protocols have been developed to handle individuals safely when necessary. For example, non-human primates are trained for simple medical procedures; carnivores such as lions, and tigers are not handled within the group; and species living in tropical buildings are presented with environmental sounds such as waterfalls and bird vocalizations.

Such a music exposure is therefore beneficial for the animal welfare whether it is a direct or indirect effect.

4.2 Music used in Wagyu breeding in the aim to produce a very high quality of meat[11]

Christophe Hay discovered the Kobe meat in Japan and testifies never having felt such as a sensation on the palate. Determined to produce meat of this quality in France, he first worked

[10] Information collected during the phone interview with Baptiste Mulot, head of veterinarian (ZooParc de Beauval, Saint-Aignan, Loir-et-Cher), done the 21st of September 2020 by E. Chaillou and M. Siwiaszczyk.

[11] Information collected during the phone interview with Christophe Hay, Michelin-starred chef (La maison d'à côté, Montlivault, Loir-et-Cher, France) done the 22nd of September 2020 by E. Chaillou and M. Siwiaszczyk.

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with a Wagyu beef breeder but noticed that the quality of the meat was irregular. Therefore, he decided to buy his own herd of Wagyu in 2019 (now composed of 52 animals) in order to take care of animal well-being, control each stage of breeding and therefore the quality of the meat. His herd is raised by one of his childhood friends, in natural meadows. The breeding method of Wagyu is very specific. First, animals spend 36 months in meadows and then 9 months in a park of 15 m^2. The animals still have visual contacts with their conspecifics and access to cattle brushes. During these 9 months, all feeding is controlled and made up of 65% of flax and cereals. The aim of Christophe Hay is to respect the animal and to produce the best meat. Thus specific attention is paid to the well-being of these animals to keep them as calm and relaxed as possible. In this aim, and to provide a "presence" in their park when the breeder is not there, they are presented with calm music from a yoga playlist. To provide the animals with rest time the music is not continuous throughout the entire day. Instead it is played for 2 hours in the morning and 2 hours in the afternoon. The animals are also massaged with brushes by the breeder for 30-45 minutes every day. These enrichments have been observed to indeed relax the animals and to therefore produce high quality meat, which is well marbled. The efficiency of this practice is demonstrated by the reaction of the Wagyu. This breed is known to be reactive and afraid by many situations, such as human contact. Interestingly, the rearing conditions developed by Christophe Hay and his friend, modify the valence of human which is spontaneously and voluntary approached by the individuals.

In this practice, music is included in a large panel of breeding practices, all of them playing a role in the well-being of the Wagyu. To maintain the best conditions possible throughout the life of the animal, Christophe Hay and his colleagues hope to be authorized to stream music during transport from the farm to the slaughterhouse. In this context, the animals could be maintained in a novel and stressful environment (track, slaughterhouse) with a known element, the music.

4.3 The use of music to counteract the negative impacts of motherless rearing conditions[12]

The aim of this study was to investigate the possibility that music exposure could counteract the negative impacts of maternal deprivation in sheep, which also results in formula-milk feeding rather than breastfeeding. This rearing condition is known to alter development in several mammal species. In lambs, this practice is commonly used in milk production and to save lambs when they cannot be reared by their mother. Our hypothesis was that music stimulates lambs which could be more active when they are exposed to music.

4.3.1 Method

To test our hypothesis, we designed a protocol in which male lambs were split into two groups at 7±1 days of age. In the first week of life the lambs were separated from their mother at 24 h after birth (allowing colostrum ingestion) and subsequently trained to drink formula-milk with rubber teats. Both groups, control (CONT, n=10) and music (MUS, n=10), were reared in two distinct parks (length 5 m, width 3 m, height 1.7 m) equipped with video monitoring. To avoid noise pollution between the groups the parks were located in two distant rooms. The walls of the both parks were covered with honeycomb boxes to improve sound diffusion and the ground was covered with straw. Each park was equipped with a water-drinker, 3 rubber teats for *ad libitum*

[12] This study was designed to test our hypothesis on male and female. Male lambs were born between the 4th and 6th of March, were subjected to the experimental design the 11th. The study was stopped the 16th of March due to the Covid-19 pandemic, which means no females were included.

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access to formula-milk, a trough containing hay, a trough containing granules, heating light to prevent hypothermia, and traffic cones for allow playing enrichment (Fig. 4). Light was switched on from 8:30 am to 6:00 pm. The MUS park was equipped with two speakers set at 1.7 m high, for music streaming and the CONT park was equipped with two dummy speakers set at the same height. In CONT group, the sound level of ambient noise varied between 30 and 71 dB. In the MUS group, the level of noise (ambient and music) varied between 31 and 66 dB.

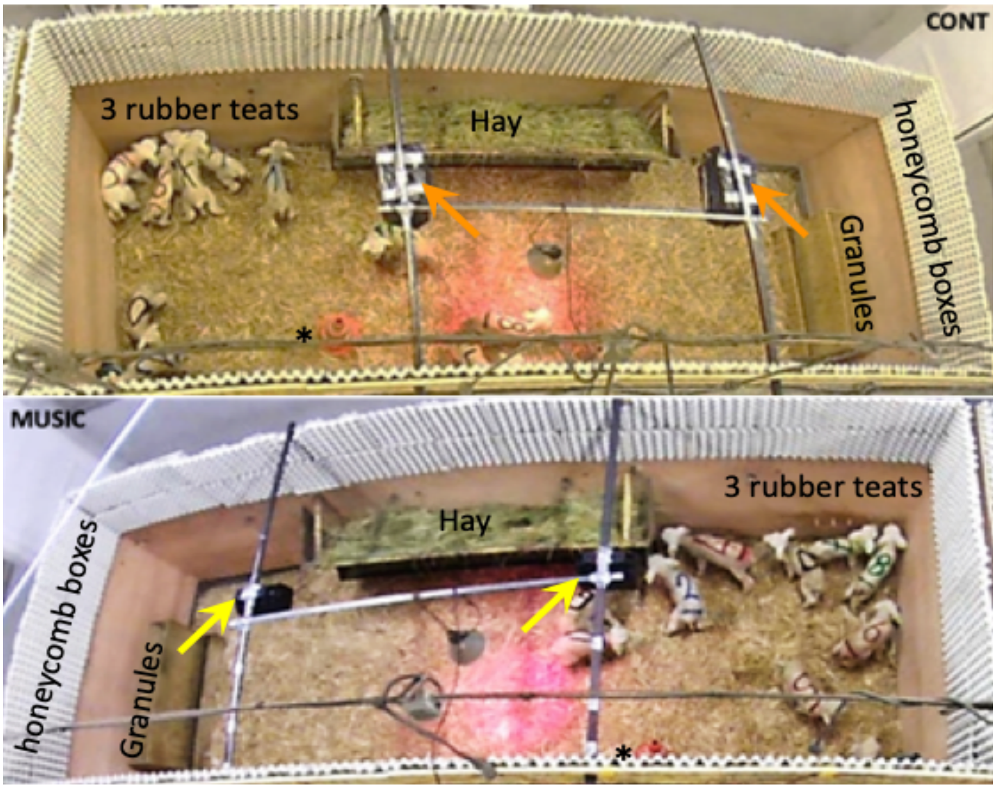

Figure 4: Organization of the two distinct parks of control lambs (CONT) and of music-exposed lambs (MUSIC). Note that the CONT park is equipped with two dummy speakers (orange arrows) to simulate the presence of speakers as in the MUSIC park (yellow arrows). For the rest, the both parks present exactly the same equipment: trough with hay, through with granules, 3 rubber treats, heating light, honeycomb boxes and traffic cone (*).

Playlists were created with extracts from radio broadcasts "Radio Classique". These extracts mainly contained instrumental or vocal pieces, and some spoken extracts (announcing of pieces of music). The music streaming was performed for 45 min every 90 min from 10:30 am to 5:15 pm (total of 3:45 hours a day).

Audiovisual recording was performed continuously from 7:30 am to 18:30 pm. Behavioral observations (Table 1) were realized for three days every 10 sec on four distinct 5-min phases: before and after the 1st music streaming of the day (10:30 am), and before and after the last music streaming of the day (17:15 pm). For each lamb, 12 phases were observed (30 scans per phase) and data have been expressed in mean ± SD of number of times a behavior was observed (the maximum value being 30). The first observation (obs1) was done about two hours after the arrival of lambs in their respective park and human interventions (blood samples, weight…).

The impact of music exposure was tested by ANOVA repeated measures (# observation) with independent factor (CONT vs MUS) followed by post-hoc analyses corrected by Holm.

Behavior	Definition
Posture	
Stand up	Lamb is standing on all fours
Lying down	Lamb's sternum is in contact with floor
Locomotion	
Walk	Progress slowly
Run	Progress fast
Exploration	Lamb is standing, nose in contact with sniffing movements of a part of park (walls, floor...)
Feeding	
Formula-milk	Lamb is feeding to the automatic milk supplier
Water	Lamb is drinking to the water-drinker
Hay	Lambs is eating hay
Granules	Lamb is eating granules to the trough

Table 1: Ethogram used for behavioral observations

4.3.2 Results

Looking at the mean number of times a behavior was expressed (Table 2), we noted that the highest occurrence was found for lying down posture, that the activity was related to the time of day (AM vs. PM observation sessions), and that the activity profiles differed throughout the three days and between groups. Statistical analyses confirmed these results (Table 2), suggesting that music impacts maintenance behaviors soon after three days of exposure. Group effects were found for locomotion and exploration, and interactions were found for all behaviors studied.

The two first days, control lambs were seen lied down more often during morning than afternoon (significant statistical differences were found between obs. 1 and 3, 2 and 4, 5 and 7, 6 and 8). The profile observed in music lambs is different since they were always seen lying down during the four observations of the day 1 (Fig. 5). The 2nd day, control and music lambs presented similar profiles and we noticed that during afternoon the control lambs were more often seen lying down than the music lambs (significant statistical differences were found between both groups for obs. 7 and 8). The day 3, music lambs seemed to be more active since they were less often seen lied down than the control lambs.

According to their age (7 days the day 1 of the observations), lambs were very rarely seen in locomotion (less than 5 times out of 30 scans per observation), this activity being more frequent afternoon (obs. 3, 4, 7, 8, 11, 12) than morning (obs. 1, 2, 5, 6, 9, 10). Consistent with number of time lambs seen lying down, control lambs were more often seen in locomotion the afternoon than music lambs (significant statistical differences between control and music lambs for the obs. 3 and 4). From the 2nd day, the both groups presented the same profiles for locomotion.

Behaviors	Group effect (CONT *vs* MUSIC)	Observation effect (repeated measures)	Factors interactions (Group x Observation)
Lying down posture	$p = 0.54$ $F_{1,20} = 0.40$ $\eta^2 = 7.7 \times 10^{-4}$	**$p < 0.001$ $F_{11,220} = 36.57$ $\eta^2 = 0.41$**	**$p < 0.001$ $F_{11,220} = 28.31$ $\eta^2 = 0.32$**
Locomotion	**$p = 0.002$ $F_{1,20} = 12.41$ $\eta^2 = 0.052$**	**$p < 0.001$ $F_{11,220} = 8.03$ $\eta^2 = 0.20$**	**$p < 0.001$ $F_{11,220} = 6.13$ $\eta^2 = 0.15$**
Exploration	**$p = 0.002$ $F_{1,20} = 12.70$ $\eta^2 = 0.021$**	**$p < 0.001$ $F_{11,220} = 44.91$ $\eta^2 = 0.44$**	**$p < 0.001$ $F_{11,220} = 27.66$ $\eta^2 = 0.28$**
Feeding	$p = 0.114$ $F_{1,20} = 2.72$ $\eta^2 = 0.009$	**$p < 0.001$ $F_{11,220} = 11.00$ $\eta^2 = 0.22$**	**$p < 0.001$ $F_{11,220} = 15.84$ $\eta^2 = 0.31$**

Table 2: Results of the statistical analysis

While locomotion was rarely found throughout the scans, exploration was found more than 20 and feeding behavior more than 10 times out of 30 scans (Fig. 5). The first day, only some control lambs were seen in exploration and it was only during afternoon (significant statistical differences between obs. 1, 2 and obs. 4). Music lambs were more often seen in exploration than controls (significant statistical differences between control and music lambs for obs. 7 and 8). The profile for feeding activity was similar to thus found for exploration: its frequency was higher in the afternoon than in the morning and increased throughout the study. Moreover the profiles between control and music lambs were inverted from the 1st to the last day of the study (Fig. 5): day 1 control lambs were more often seen eating than music lambs (significant statistical differences for the obs. 4) and day 3 the contrary was found (significant statistical differences for the obs. 11 and 12).

4.3.3 Preliminary conclusions

Regardless of the studied behavior, it can be concluded that the lambs are more active in the afternoon than in the morning, and that exposure to music has not modified this organization.
When the lambs were not seen lying down, they were in exploration or feeding activities, and the number of times animals were active was higher on day 3 compared to days 1 and 2. This finding could be explained by the age of the animals (10 days at the end of our study).
The interpretation of day 1 is difficult and could be contradictory for each of the 2 groups. The high level of activity observed in the control lambs could be interpreted as stress or on the contrary as well-being since the animals expressed exploration and feeding behaviors. For lambs exposed to music, their inactivity can be interpreted as a certain well-being since they slept without disturbance when exposed to music. But, again, the interpretation of this result can be totally different and the inactivity can be seen as stress-related behavior such as immobility.
The differences found on days 2 and 3 are consistent with our hypothesis: lambs exposed to music are more active than controls (evidenced by exploration and feeding behaviors).

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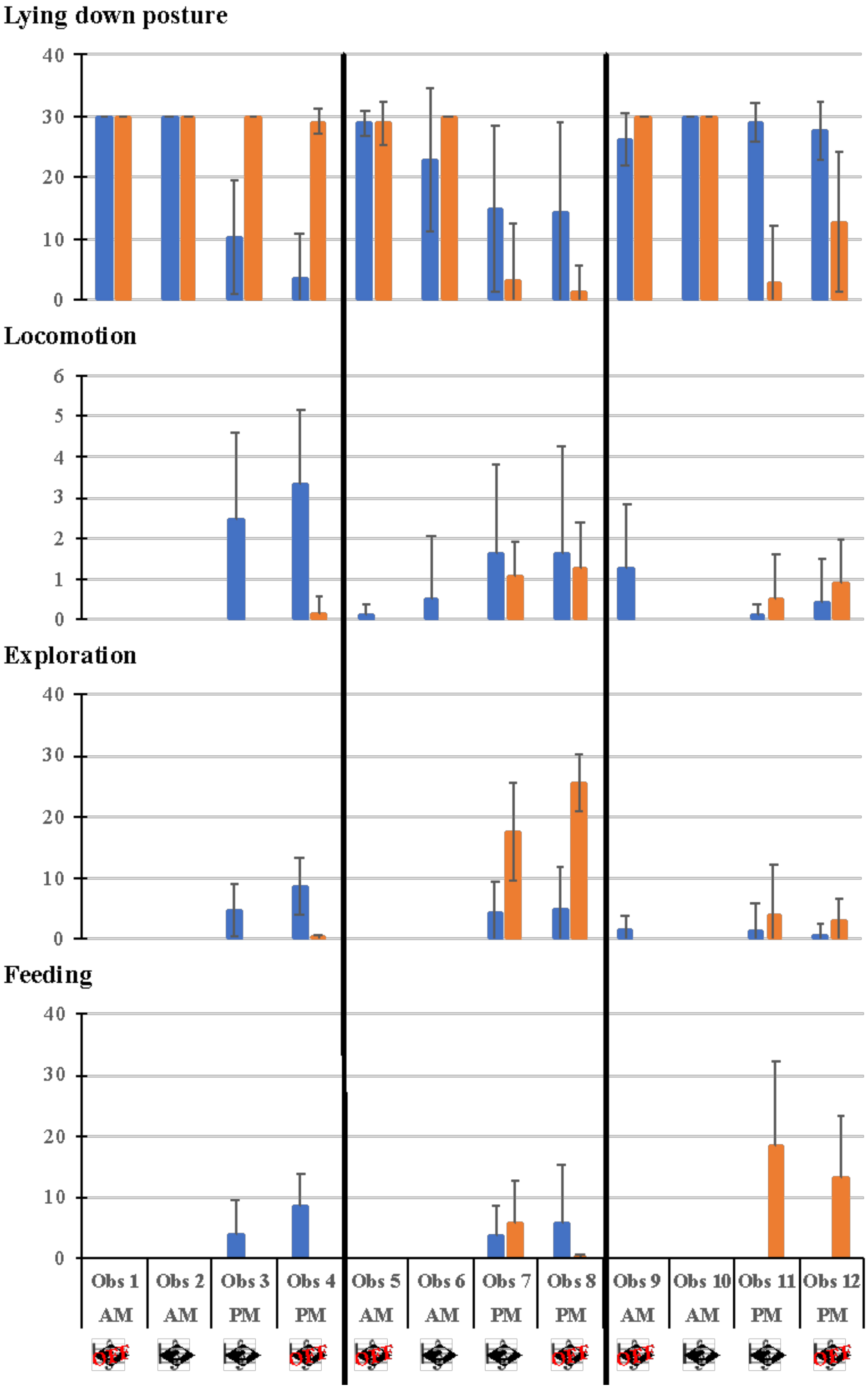

Figure 5: Mean number of times control (n = 11 in blue) and music (n = 11 in orange) were observed in lying down posture, locomotion, exploration or feeding for 30 scans (every 10 seconds for 5-min period) done morning (AM) or afternoon (PM) during three successive days when the lambs were 1 week old.

Altogether, these preliminary observations suggest that the conditions of music exposure used in our experimental design were able to modify the maintenance and exploratory behaviors after only three days of exposure.

V CONCLUSION AND REFERENCES

This review of the literature highlights that different kinds of sounds can impact differently on a large panel of functions, such as individual health, behavioral and physiological indicators of stress, or welfare, in humans as well as throughout the animal kingdom. While there are clear differences in the hearing ranges between vertebrates, there are also universalities in some parts of the auditory system, from its external part to the auditory neuronal network, and in an ability to communicate vocally and express emotions. This evidence provides support for the hypothesis that an ability to perceive and be impacted by music could be wide-spread in the animal kingdom.

The research reviewed shows that noise can have either negative or positive impacts on animals depending on the type of noise they are exposed to, the level of the noise and on other as yet unknown factors. More specifically to music, level, tempo and musicality appear to be important factors in determining its impact on an animal. However, more research systematically varying these factors in a variety of species is required to better understand their individual and interacting impact.

The examples provided here also highlight that, in practice, various stakeholders believe that music provides positive animal welfare benefits; while the limited scientific research reviewed indicates that several factors (duration, sound level, tempo musicality etc.) should be considered carefully to ensure that the impact is indeed positive. In this aim, two complementary fields of investigation could be conducted, both of which require an interdisciplinarity approach. The first field of investigation would aim to describe the acoustic environment of animals, especially in captive/indoor conditions (zoo, livestock or pets), ac-cording to auditory stimulations and auditory abilities of a species. This first field of investigation exists and could progress by associating bioacoustics, neuroscience, ethology and comparative / evolutionary disciplines. The second field of investigation concerns the impact of music exposure to animal welfare. Studies performed in this aim are rare, not always published, whereas practices already exist in breeding and zoos. Developing participatory sciences with people who use music with animals, ethologists, animal caregivers, breeders, veterinarians is a relevant approach to evaluate the impact of music on animal welfare.

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