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Research article

An exploratory study of the influence of musical instruments and vocals on dog behaviour

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Abstract: Music exposure has a potentially positive effect of keeping stressed animals calm and providing an interesting stimulus to animals that are bored. Dogs in captivity, and in particular those in a shelter, face a variety of stressors, including boredom, which may reduce their welfare. In this research, a group of dogs (n = 10) in a teaching laboratory, with strict control of noise levels, were exposed to different instruments or vocal forms of music, or to a control treatment of white noise, for short, 10-minute periods, in a changeover experimental design over a period of 10 days. Four songs using strings, wind, keyboard instruments, or vocals were each repeated 10 times and compared to a control treatment. Dogs lay down less, raised their heads more, and showed signs of arousal in response to male vocals and violin, compared with other instruments and vocal types and the control. It is hypothesized that this was due to their association of vocals and stringed instruments with human and conspecific presence, respectively, whereas wind and percussion instruments did not have these effects. It is concluded that male vocals and violins are arousing to dogs and, for this reason, might be best avoided when selecting music to play to dogs in stressful situations.

Keywords: animal shelter; music therapy; dog; musical instrument; instrument classification; vocal

1. Introduction

Music is an emerging therapy for humans, with a wide range of journals and publications available to specialists and, in some cases, to the public [1]. A thorough understanding of its effects may inform its use in other animals [2]. Based on the theory of psychotherapy, it is now known that music has unique physiological, psychological, mental, social, and spiritual effects to improve patients' health and quality of life [3,4]. Music therapists help clients overcome psychological barriers and restore or enhance the health of mind and body by using both active and receptive music experiences, such as improvisation, re-creation, and composition [5].

1.1. Historical development of music therapy for humans

In ancient times, people realized that music could improve their mental health and help treat some diseases. In Egypt, it was used to relieve women's pain during childbirth [6]. The Bible recounts how David was invited to play his lyre to King Saul to relieve him of a bad spirit [7]. Pythagoras, a mathematician, philosopher, musician, and scientist, thought that music should be seen as a "holy science" like geometry and mathematics, because of its ability to bring gentle feelings, and should not be used in entertainment [8].

Ancient Chinese books celebrated the positive influence of music on the spirit; for example, the music record of Chun Qiu and Yue Ji, in which the use of music to treat mental diseases is documented [9]. Similarly, in medieval Catholic temples, the clergy used hymns to treat diseases [10]. Formal recognition of music therapy first appeared in Europe. In the 18th century, the British physician John Brown in his Elementa Medicinae bifurcated diseases into those resulting from over- and under-stimulation [11], a concept also used by the Austrian doctor Peter Lichtental (1780–1853) in examining the power of music. Close to the Mozart family, Lichental described music as a stimulant with a great power, even though excessive volume could lead to headaches, upset, fear, and syncope [12].

One of the first articles formally recognizing the therapeutic value of music appeared in 1789 in a Columbian magazine [13]. However, it was not until the 19th century that music therapy became widely popular in Europe; in the 20th century, it was used extensively during the world wars to treat mental illness among the sick and wounded, as well as prophylactically to enhance the spirits of the troops [14]. The first music therapy program took place at Michigan State University in 1944, followed by one at the National University of Kansas in 1946 [15,16]. National associations for music therapy were established in the United States in the 1950s, in many European countries in the 1960s, and in Australia in 1975 [17,18].

1.2. Music therapy for humans

There are two types of music therapy for humans: receptive and active/expressive [19]. In receptive therapy, therapists guide patients in listening to music [20]. In contrast, active therapy focuses on patient participation, with the therapist encouraging clients to make music, further elevating their spirits [21]. Sometimes, psychotherapy is combined with music therapy, in which case patients are hypnotized and the therapist plays pieces of pre-selected live or recorded music, letting patients imagine freely. The patient relays their feelings, facilitating a better understanding of their problems [22]. The chosen music should improve mood, reduce pain, and relax patients [23]. In applying music therapy to animals, the receptive model is most practical, although animal participation is possible with training.

Music is effective in treating both physical and mental diseases in humans, lowering heart rate and reducing anxiety, with particularly beneficial effects before and after surgery [24]. Alzheimer's disease and other types of dementia are now often treated with music therapy [25]. Music therapy may be combined with traditional Chinese medicine and acupuncture, or converted into a low or medium frequency current [26], which is then transmitted through acupuncture points to the human body. These currents vibrate in the body, resulting in local tremors and muscle contraction, improving blood circulation and keeping the patient calm [26].

Music therapy also plays an important role in diverting patients' attention during medical procedures [20,27] and during recovery from surgery; it reduces anxiety and the need for pain medication and improves systolic blood pressure and heart rate [28]. It is particularly valuable to help cure people with damage to speech-controlling areas of the left brain, from trauma or apoplexy, with the most notable case being Gabrielle Dee Giffords, an American politician. She suffered left brain damage in a shooting incident, but subsequently regained her speech ability after extensive music therapy [29].

Music not only has positive effects on the rehabilitation of patients with aphasia but also plays an important role in the physical therapy of Parkinson's disease, dementia, and stroke patients. Patients' emotional functioning and physiological characteristics, like blood pressure, heart rate, and respiration, improve during the rehabilitation programs [30]. In dementia patients, music reduces depression, improves self-esteem and cognition [31, 32], keeps them calm, and reduces behavioral problems. In cancer patients and arthritis sufferers, it reduces pain and hence the need for pain medication [33].

1.3. Music exposure for other animals

Music can have positive benefits for farm, zoo, companion, and particularly laboratory animals. Some studies have shown physiological correlates; for example, in asthmatic rats, music (Mozart's Sonata K.448) reduced serum IL-4 and corticosterone [34]. A study with mice found that music by Mozart improved brain function more than Beethoven's Fur Elise, the so-called Generalised Mozart Effect [35]. In rats, music reduced pain associated with bone cancer and increased feed intake and weight gain [36].

One possible explanation for the benefits associated with playing music to animals is that it mimics communication between conspecifics. Tamarin monkeys appear to respond to music according to their perception of its similarity to vocalizations within the group [37]. Music created to replicate the acoustics of threat and affiliative vocalizations invoked increased arousal and calm behavior, respectively. Music for animals may therefore be most effective if it reflects the melodic contours of the vocalizations of that species. When it does not, it could explain the failure of, for example, monkeys showing preferences for music created for humans over silence [38]. This allelomimetic characteristic of some music has been successfully utilized in developing music for cats, which showed more positive reactions to music simulating suckling and purring [39]. When this music was played, the cats rubbed the speakers and purred back, appearing calmer as a result.

Dogs in shelters are classic candidates for music exposure, due to the dog vocalizations within their environment, which could be suppressed by music, and a lack of other stimulation. However, in one study, blocking out environmental noise with music was not successful in aiding sedation in dogs [40]. Some positive behavioral responses to music have been observed in shelters: classical music increased time spent sleeping and reduced vocalizations [41–43], whereas heavy metal music increased body shaking, indicating nervousness. Classical music also increased heart rate and its variability in teaching dogs kept in laboratory settings, suggesting both arousal and stress reduction, respectively [44]. Classifying music according to human-appreciated genres may, however, hide a range of responses, depending on the characteristics of the music. Even if effective, the benefits of music in shelters may be short-lived, with dogs in one study becoming refractory after one week [43]. Other possible locations where dogs may benefit from gentle and soft music include their home and veterinary clinics [45].

Many musical variables remain to be explored, such as instrument type, volume, pitch, timbre, and repetitiveness. Responses to pitch are likely to be relative rather than absolute, according to one study [40]. In investigating the influence of different instruments on the effects of music exposure on dogs, the impact of instrument type is potentially important. There are two main ways to classify musical instruments according to their method of producing a sound. The first is the Western orchestra classification method, with four main groups: strings, brass, woodwind, and percussion [46]. Keyboards may be added as a fifth; alternatively, keyboard instruments can be classified within the four basic types. String sounds are made by plucking or rubbing strings; brass by vibrations of the lips as air is blown through brass tubes; woodwind instruments are wooden tubes that are blown into, sometimes past a vibrating reed; and percussion instruments are struck, some making several simultaneous sounds, some just one. Keyboard instruments use a variety of techniques to make their sound, striking or plucking a string, forcing air through a pipe, or occasionally (as in the carillon) striking a bell.

A more scientific classification method was proposed by Erich von Hornbostel and Curt Sachs in 1914, grouping instruments solely by the way they produce sounds [47]: chordophones, aerophones, membranophones, and idiophones. Chordophones use vibrating strings, as in the zither, lute, lyre, bow, and harp. In aerophones, sound is created by vibrating air, as in the whistle, a blowhole instrument, reed instruments, cup mouthpiece instruments, and the organ. The sound of membranophones is made by vibrating a stretched membrane, as in the tubular, kettle, vessel, frame, and friction drums and mirliton fit. In an idiophone, sound is made by vibrating the instrument itself, during percussion, shaking, concussion, scraping, stamping, and plucking. In a third classification system from China, instruments are grouped by their component materials [46].

This research aimed to explore the behavioral responses of dogs to different types of music, including both instrumental and vocal, in an attempt to understand the underlying emotional response (aroused or calm). This avoids concerns about studies only comparing musical genres, which may contain different samples of music with varying effects on dogs' behavior. Dogs were exposed to clips containing three different kinds of music (string, wind, and keyboard), pure vocals, and a control sound. From the behavioral responses, we hoped not only to determine the best type of music to play to keep dogs calm but also to learn whether dogs can classify similar instrument types and vocals.

2. Methods

In order to test the responses to music without outside interference, we used dogs in a teaching laboratory setting in a veterinary school where they could be kept very calm and where we had control over the environment. There, we used a standard amplifier and speaker system to play music representative of string, wind, or keyboard instruments and vocals to dogs, during which period their behavior was recorded and then analyzed.

2.1. Animals

Ten research dogs, six females and four males, of mean (± SEM) age 2.77 ± 0.440 years and weight 30.1 ± 2.08 kg were used from the University of Queensland veterinary teaching laboratory, which houses dogs for teaching students (Figure 1). Although the precise pedigree of the dogs was not known, observationally there were 5 greyhounds, 2 boxers, and 1 each of Labrador, kelpie, and mastiff. Animals were brought into the facility on average 74 ± 54.9 days prior. Dogs were weighed at the beginning of the experiment, on January 25, 2019.

2.2. Housing and management

The ten individual kennels were of solid walls, with dimensions of 2.9 × 1.4 × 2.7 m high, with access through a guillotine door to an outdoor exercise yard of equal area (Figure 1c). Dogs were contained in the internal area during the administration of treatments and allowed into the outdoor area afterward for 15 min before being returned for a second period of administration of treatments. No person was visible to the dogs during treatment administration. Three people interacted with the dogs on a daily basis, all female.

The internal area had a raised platform bed with clean, soft bedding and a toy provided daily to each dog (Figure 2). Pelleted food was offered thrice daily at 07:30, 14:00, and 18:00, and water was freely available through automatically refilling bowls.

(a) (b)

(c)

Figure 1. Positioning of kennels and cameras (a) inside the facility, with 10 individual kennels in a row. The red circle shows the position of camera 1. (b) indoor area; the green circle shows the position of camera 2. (c) outdoor area of the kennels.

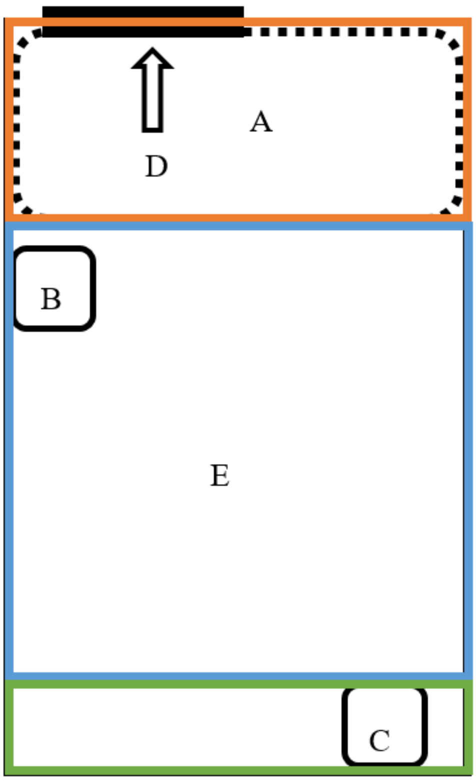

Figure 2. Overhead diagram showing the inside of the kennel. A: The raised bed at the back of the kennel, for dogs to lie, sit, or stand. B: Automatically refilling water bowl. C: Shelf for the feeding bowl. D: Guillotine door to the outdoor area. E: Floor area in the middle of the kennel (blue), with the front of the kennel in green.

2.3. Experimental procedure

2.3.1. Selection of music

Using the Western orchestra classification method, we selected three distinct but common musical instruments as the main contributing sound, each of three distinct instrument categories: stringed instruments, with violin, cello, and double bass; wind instruments, with trumpet, trombone, and saxophone; and keyboard instruments, with piano, accordion, and organ. Vocals were male, female, and children, and there was a control group of white noise. Frequency ranges of these musical instruments and vocals, determined from scientific literature, as well as of the white noise used, are presented in Table 1.

Musical pieces were selected that were continuous, slow, stable, harmonically simple, and available from the Internet, played with the chosen musical instruments, and as vocals. Four pieces were selected as the test songs ("Twinkle, Twinkle Little Star", "Let It Go", "Jingle Bells", and "My Heart Will Go On"), and versions played by all the selected musical instruments as solos and the relevant vocals were downloaded (Appendix A). All the clips were edited to reduce noise using a professional audio workstation (Adobe Audition, https://www.adobe.com/products/audition.html). Frequencies of these songs were analyzed in $\log_{10}$ form using sound processing software (Audacity, https://www.audacityteam.org/) to produce a frequency profile and peak frequency. When playing the pieces to the dogs, Adobe Audition, a digital audio workstation, was used to adjust the volume to approximately the same level [70 decibels (dBA)] for all pieces, tested with a decibel meter in each kennel. Dogs have good hearing capabilities and can hear volumes below 70 dB [48], but the decibel meter test was used to ensure that the volume of each piece was set at 70 dB. A comparison of white noise volume in six equidistant locations in each kennel found only small, but significant, differences between kennels and little variation within kennels (mean dB ± SD; kennel 1: 54.0 ± 0.80; kennel 2: 54.5 ± 0.75; kennel 3: 53.3 ± 0.75; kennel 4: 54.4 ± 0.54; kennel 5: 53.7 ± 0.43; kennel 6: 54.8 ± 0.37; kennel 7: 55.3 ± 0.57; kennel 8: 55.1 ± 0.70; kennel 9: 55.5 ± 0.77; kennel 10: 55.1 ± 0.56; $P < 0.001$).

Table 1. Frequency range (pitch) of the experimental instruments, vocals, and white noise used in the study, with dogs' vocalization for comparison.

Name of instrument	Frequency range (Hz)	Reference
<u>Strings</u>		
Violin	196–3136	[62]
Cello	65–995	[62]
Double bass	41–247	[62]
<u>Wind</u>		
Trumpet	165–988	[62]
Trombone	82–587	[62]
Saxophone	104–659	[62]
<u>Keyboard</u>		
Piano	28–4186	[62]
Organ	16–7040	[62]
Accordion	180–1000	[62]
<u>Vocalization</u>		
Male	85–180	[63]
Female	165–255	[63]
Children	250–300	[63]
<u>Dog</u>		
Howling	150–780	[64]
Barking	1000–2000	[65]
Growling	80–300	[65]
<u>Control</u>		
White Noise	358	

2.3.2. Selection and playing of the music clips

Test clips were looped so that each lasted for 10 minutes. Between 10:00 and 13:10, clips of musical instruments, vocals, and control (white noise) were played in a randomized order determined by Excel (Table 2). Each 10-minute clip was followed by a 20-minute washout period. Dogs received 6 clips daily over 10 days (from January 23 to February 3, 2019), on consecutive days except for a weekend in the middle, with a total of 60 clips.

Four speakers and two stereo sound sets (Logitech Speaker System Z623) were set up in an equidistant pattern on the floor in the corridor outside the kennels, to play the same music to all dogs simultaneously. The air conditioner was turned off during the experimental processes to prevent excessive noise interfering with test results, but air temperature was monitored on site. A warning sign on the entrance door kept people out of the corridor during the tests.

Table 2. Playing order of the music/control clips.

Day	Number of chosen clips
1	1, 11, 21, 31, 41, 51
2	2, 12, 22, 32, 42, 52
3	3, 13, 23, 33, 43, 53
4	4, 14, 24, 34, 44, 54
5	5, 15, 25, 35, 45, 55
6	6, 16, 26, 36, 46, 56
7	7, 17, 27, 37, 47, 57
8	8, 18, 28, 38, 48, 58
9	9, 19, 29, 39, 49, 59
10	10, 20, 30, 40, 50, 60

2.3. Behavior recording

Video data were collected from each kennel every day throughout the treatment period, using two digital video cameras (Signet Mini CCB cameras with infra-red facility) per kennel to make behavioral observations, connected to a digital video recorder (TECHview 960H Professional 16 Channel DVR),. In each kennel, one camera was installed in the corner by the door and a second on the middle of the ceiling. This allowed us to view the entire kennel, with no blind spots.

Dog behavior was continuously videorecorded from 9:40 am to 1:30 pm daily (190 minutes for 6 treatments, 20 minutes before starting treatment and 20 minutes after the last treatment each day), to make sure all relevant material was recorded. Researchers did not enter into the kennel area during this period, to avoid any disturbance that might influence the dogs' behavior.

Recordings were stored in two hard drives (Seagate FreeAgent® GoFlexTM External Hard Drive 500GB USB 3.0 Black and My Passport UltraTM External Hard Drive 1TB USB 3.0 Black), the first to back-up the original videos and the second to store edited and sorted videos.

Dog behavior was classified using an ethogram (Table 3) with five main categories: location, posture, self-maintenance, tail position, and other activities. Using event logging software for video/audio coding of observations (Boris Observation; www.boris.unito.it), dogs were assigned behaviors in the five main categories, with behaviors recorded as state events or point events, according to the length of each bout. The number of events was divided by the total duration of each clip (600 s) to obtain the percentage of time for state event behaviors (duration) and frequency of occurrence for point events (counts).

2.5. Statistical analysis

All analyses were completed in Minitab (https://www.minitab.com/en-us/). Behavior durations were analyzed by a mixed effects model with song as the random factor, day, time of day, instrument type, and dog number as fixed factors, and instrument and instrument type as independent variables. Instrument type in the previous treatment exposure of the dogs was initially included in the model; however, as it was not significant for any behavior variable, it was excluded from the final model. A Bonferroni correction was included in determining the critical P value (0.003) to account for multiple comparisons. If there were significant treatment effects, differences between individual means were analyzed by Fisher's LSD test. Residuals of the model were inspected for normal distribution and analyzed by the Anderson–Darling test. In the case of non-normally distributed means, values were converted to $\text{logarithm}_{10}+1$ or square roots before reanalyzing the data. If residuals still did not approximate a normal distribution, data were converted to one-zero format (i.e., a dog did or did not perform the behavior in each treatment period) and analyzed with a binary logistic regression model with 1/0 output and instrument and instrument type as categorical factors. In this case, differences between instrument and instrument types are provided with odds ratios and 95% confidence intervals.

Table 3. Ethogram for dog behavior recording as state events (S), recorded as durations, and point events (P), recorded as frequency of occurrences.

Categories	Behavior	Description	S/P
Location	Front	Animal located close to the front door	S
	Middle	Animal located on floor area of the kennel	S
	Back	Animal located on the back bed	S
Posture	Lie down, head up	Most of body in contact with the ground with head up	S
	Lie down, head down	Dog is reclining in a ventral or lateral position, neck relaxed, head on the ground	S
	Sit	Hindquarters in contact with the ground, front legs extended	S
	Stand	Positioned with four feet in contact with the ground and legs almost or fully extended	S
Self-maintenance	Drink	Takes water into the mouth	S
	Groom	Behaviors directed to their own body, including licking	S
	Scratch	Using hind legs to scrape on the neck area	S
Activities	Bar/wall pawing	Using paws to reach through mesh/against wall in a digging motion	S
	Body shake	Dog shakes its whole body briefly as is drying itself	P
	Circling	Dog repeatedly (>3 times) walks around in small circles	S
	Sniff ground	Walks with nose close to ground, sniffing it	S
	Lick nose/lip	Tongue extends upward to cover nose, before retracting into mouth	P
	Nosing	Push object with the nose	P
	Object play	Any vigorous or galloping gaited behavior directed toward a toy or other object, including chewing, biting, shaking it from side to side, batting it with a paw	S
	Pace repetitively	Dog repeatedly (>3 times) paces around kennel in a fixed route	S
	Door scrabble	Scrabble at door with front legs	S
	Pant	Mouth open with tongue extended accompanied with rapid breathing	S
	Paw lift	A forepaw is lifted off the ground and held there	S
	Play bouncing	Forequarters are lowered to the ground, with rump raised	S
	Vocalization	Sound emitted via the buccal cavity, often repeated in quick succession	S
	Wall/door bounce	Standing on hind legs with front legs rebounding off wall/off door, usually repetitive	S
	Yawn	Mouth open wide for a period of a few seconds, then closes	P

	Stand wall/wire	Standing on hind legs with front legs resting against wall/wire	S
	Chew/play with bedding	Play with or take quilt, pillow, blanket into mouth	S
	Door pawing	Use paw to hit front door	S
	Wall scrabble	Repeatedly scratch at wall with front legs	S
	Lick object	Tongue extends to touch object before retracting into mouth	S S
	Roll on ground	Rotation of body on ground	S
	Spin	Turn around	
Tail's status	Tail high/medium	Tail in high/medium position, from -30° to +90°	S
	Tail low	Tail in low position, from -30° to -90°	S
	Tail move	Motion of the tail	S
	Tail still	No motion of the tail	S

3. Results

3.1. Effects of instrument type

Dogs receiving the male vocal and cello treatments lay down less and stood more than those receiving the control, accordion, child vocals, piano, saxophone, and trombone treatments (Table 4). Those receiving the violin lay down less than those receiving the control, accordion, and child vocals. When dogs receiving the male vocals were lying, they had their head down less than in all treatments except the cello, organ, and violin. Dogs receiving the male vocals walked for longer than those listening to the control, accordion, child, and female vocals treatments. Ear movements were increased during male vocals and the double bass compared to all other treatments, except the cello, sax, and violin. Grooming was longest in dogs exposed to the child vocals, and to a lesser extent, the double bass, and least in dogs exposed to the trumpet, cello, and control treatments.

Dogs spent most of the time in the middle of the room, some time at the front, and little time at the back. Whilst there were no significant effects of treatment on the proportion of time that dogs spent in the front, back, or middle of the room, the ratio of time spent in the middle to that spent at the front was affected by treatment. Dogs receiving male vocals and, to a lesser extent, the violin, spent relatively more time in the front of the room than in the middle, i.e., they had a lower ratio of middle to front, compared to most other treatments. Dogs moved their tails more in the cello and male vocals treatments, compared with the control, child vocals, and trombone treatments. The positioning of the tail (high/middle or low), was not affected by treatment. There were no treatment differences in the relatively rare recordings of sitting, pacing, sniffing ground, yawning, scratching, and chewing (Table 5).

Table 4. Effects of instrument, vocals, and control treatments on the mean behavior of dogs.

	Control	Accordion	Cello	Child vocals	Double bass	Female vocals	Male vocals	Organ	Piano	Sax.	Tromb.	Trumpet	Violin	SED	F-value	P-value
Lie down total, % time	97.4^{A}	96.6^{A}	91.2^{CD}	99.4^{A}	95.6^{ABC}	95.3^{ABC}	86.7^{D}	95.4^{ABC}	96.5^{AB}	96.4^{AB}	96.5^{AB}	96.7^{AB}	92.5^{BCD}	4.30	3.34	<0.0001
head up, % time	11.4	8.2	16.2	11.6	18.7	14.8	25.3	19.0	13.5	18.0	11.2	8.8	21.3	8.81	2.29	0.007
head down, % time	86.2^{AB}	90.9^{A}	74.8^{CDE}	85.9^{ABC}	76.6^{BCD}	$80.0^{A\text{-}D}$	63.0^{E}	75.9^{CDE}	$83.2^{A\text{-}D}$	$78.5^{A\text{-}D}$	85.1^{ABC}	88.8^{AB}	71.5^{DE}	1.06	3.54	<0.0001
Stand, √% time	4.57^{DEF}	1.39^{EF}	14.5^{AB}	0.45^{F}	$8.11^{B\text{-}E}$	8.26^{BCD}	15.3^{A}	$7.66^{C\text{-}F}$	4.62^{DEF}	6.11^{DEF}	5.58^{DEF}	3.48^{DEF}	13.6^{ABC}	0.594	3.93	<0.0001
Walk, √% time	2.87^{B}	3.11^{B}	8.66^{AB}	2.45^{B}	6.53^{AB}	3.46^{B}	11.5^{A}	5.54^{AB}	5.78^{AB}	4.64^{AB}	5.04^{AB}	4.79^{AB}	8.63^{AB}	0.40	3.12	<0.001
Ear movements, events/10 min	2.07^{FG}	0.73^{G}	5.04^{ABC}	1.47^{FG}	5.75^{AB}	2.90^{DEF}	6.17^{A}	$3.26^{C\text{-}F}$	$3.38^{C\text{-}F}$	$3.75^{B\text{-}E}$	$2.71^{D\text{-}G}$	2.13^{EFG}	$4.49^{A\text{-}D}$	1.75	5.69	<0.0001
Groom, % time	1.40	2.13	0.55	9.68	7.23	4.05	4.36	5.39	1.96	2.31	2.99	0.33	4.26	4.30	2.30	0.01
Front position, % time	4.97	9.44	10.03	4.62	9.94	8.28	8.36	9.35	5.27	6.48	6.39	0.99	12.90	0.909	0.58	0.86
Middle position, % time	93.3	89.7	84.7	93.2	85.3	85.5	80.7	90.5	92.7	89.4	89.3	92.2	80.5	1.11	0.86	0.59
Back position, % time	1.16	0.27	2.87	2.32	3.25	5.35	8.51	0.00	0.04	3.35	2.91	5.90	4.49	0.603	1.14	0.34
Middle+1/Back+1	552	575	452	568	483	461	417	519	519	506	513	526	463	82.98	1.66	0.08
Middle+1/Front+1	521^{ABC}	513^{AB}	375^{CDE}	555^{A}	415^{BCD}	422^{BCD}	288^{E}	484^{ABC}	$442^{A\text{-}D}$	475^{ABC}	495^{AB}	505^{AB}	336^{DE}	104.29	3.00	0.001
Back+1/Front+1	5.23	4.22	5.46	17.6	18.0	11.7	9.6	-15.5	4.67	18.0	16.3	33.6	24.4	30.400	0.97	0.49
Tail move, % time	0.09^{C}	0.11^{BC}	2.39^{A}	0.0^{C}	0.60^{BC}	1.15^{ABC}	1.77^{AB}	0.93^{ABC}	0.70^{BC}	0.34^{BC}	0.0^{C}	1.14^{ABC}	1.23^{ABC}	0.144	2.08	0.03
Tail still, % time	99.9	100	97.7	100	99.2	98.6	98.2	99.0	99.5	99.2	100	96.8	98.9	0.217	1.59	0.09
Tail high or middle, % time	3.11	1.03	1.84	0	0.35	1.52	3.95	3.74	1.18	1.32	0	3.69	3.41	0.435	0.78	0.67
Tail low, % time	96.8	99.0	98.2	100.0	99.7	98.5	96.0	96.2	98.6	98.6	100.0	96.3	96.5	0.439	0.75	0.70

**Sax. = saxophone; Tromb. = trombone*

Within rows, means with different superscript letters are significantly (P < 0.05) different by Fisher's LSD test.

Table 5. Number of times less frequent behaviors were recorded in dogs (n = 10) for each musical instrument, vocal, and control treatment.

	Accordion	Blank	Cello	Children	Double bass	Female	Male	Organ	Piano	Sax.	Tromb.	Trumpet	Violin	P-value
Sit	1	2	2	4	2	6	6	2	0	2	1	3	1	-*
Pace repetitively	2	2	5	0	2	2	5	2	1	2	1	1	2	-*
Sniff ground	6	15	5	3	3	2	6	5	3	6	6	5	10	0.44
Yawn	5	7	5	2	5	5	9	4	3	2	5	4	2	0.40
Body scratch	3	6	3	2	2	1	7	3	1	2	1	0	1	-*
Chew bedding	5	6	3	0	4	4	6	4	2	5	3	2	4	-*
Roll on the ground	6	5	4	0	1	4	0	3	4	2	6	3	3	-*

**could not be analyzed due to the large number of zero values. Sax. = saxophone; Tromb. = trombone*

Table 6. Effects of aggregated groups of musical instruments, vocals, and control treatments on the mean behavior (% of time) of dogs.

	Control	Keyboard instruments	Stringed instruments	Vocals	Wind instruments	SED	F-value (4, 570)	P-value
Lie down total, % time	97.6^{A}	96.7^{A}	93.1^{B}	93.9^{B}	97.0^{A}	0.044	4.01	0.003
head up, √% time	18.2^{D}	25.9^{BC}	34.3^{A}	31.3^{AB}	23.4^{CD}	0.109	6.13	<0.0001
head down, % time	86.8^{A}	82.5^{A}	74.2^{B}	75.6^{B}	84.8^{A}	0.107	4.86	<0.0001
(head down+1)/(head up+1)	359^{A}	226^{B}	134^{C}	171^{BC}	236^{B}	110.9	10.78	<0.001
Stand, √% time	4.39^{B}	5.03^{B}	11.89^{A}	8.93^{A}	4.65^{B}	0.604	5.68	<0.0001
Walk, √% time	2.63^{C}	5.16^{BC}	8.04^{A}	5.89^{AB}	4.53^{BC}	0.414	4.17	0.003
Ear movements, events/10 min	2.03^{C}	2.62^{BC}	5.10^{A}	3.60^{B}	2.72^{BC}	1.732	8.95	<0.0001
Groom, √% time	3.25	7.67	9.93	11.50	6.73	0.070	3.53	0.007
Front position, % time	5.38	7.92	10.44	7.57	4.79	0.084	1.33	0.26
Middle position, % time	92.7	91.2	84.1	85.6	90.2	0.105	2.31	0.06
Back position, % time	1.32	0.0	3.51	5.67	3.92	0.0591	3.10	0.02
Middle+1/Back+1	548	538	471	470	515	80.251	3.89	0.004
Middle+1/Front+1	519^{A}	478^{A}	380^{B}	408^{B}	495^{A}	104.7	5.80	<0.0001
Back+1/Front+1	5.82	-3.10	16.36	12.37	22.67	29.02	2.40	0.05
Tail move, % time	0.06^{B}	0.68^{AB}	1.44^{A}	0.98^{AB}	0.35^{B}	0.148	2.61	0.03
Tail still, % time	100.00	99.55	98.46	98.89	98.85	0.218	1.57	0.18
Tail high or middle, % time	2.92	2.10	2.06	1.85	1.60	4.39	0.26	0.90

3.2. Effects of different groups of instruments

Dogs receiving the control, keyboard, and wind treatments lay down more and stood less than those in the vocal and strings treatments (Table 6), and those receiving the vocal and strings had a reduced proportion of lying with their head down, compared with the control. Walking and ear movements were both increased in strings and vocals compared with the control and were increased in strings compared with wind and keyboard instruments. From the ratios of positions, it can be seen that dogs in the vocal and string treatments were more likely to be at the front than the middle of the kennel, compared to the other treatments. Dogs also moved their tails more in response to string instruments than to the control and wind instruments. More dogs sat in response to vocals than control (OR 9.2, CI 2.1–40.8), keyboard (OR 6.0, 1.7–21.2), and string (OR 3.6, CI 1.3–10.0) instruments (P = 0.001) (Table 7). There was no difference due to treatment in sniffing, yawning, scratching, or chewing, but rolling on the ground tended to be higher in response to the keyboard instruments than the vocals.

Table 7. Number of times less frequent behaviors were recorded for each musical instrument group, vocal, and control treatment.

Behavior	Control	Keyboard instrument	Stringed instrument	Vocal	Wind instrument	P-value
Sit	2	3	5	16	6	0.001
Pace repetitively	2	5	9	7	4	0.20
Sniff ground	15	14	18	11	17	0.69
Yawn	7	12	12	16	11	0.39
Body scratch	7	9	10	13	7	0.34
Chew bedding	6	11	11	10	10	0.70
Roll on ground	5	13	7	4	11	0.09
Drink	1	0	6	2	3	-*

**Could not be analyzed due to the large number of zero values.*

4. Discussion

4.1. Sensitivity to music types

The research suggests that dogs were more aroused by male vocals, as they put their head up, stood, and walked more frequently than in other treatments. They also spent relatively more time than in other treatments at the front of the kennel, which was closest to the speakers. Compared with most other sounds used, the male vocals frequency is deeper and potentially more threatening; however, as some musical instruments have equally low frequencies, e.g., the double bass, that seems not to be the characteristic of male vocals to which the dogs are responding. Although we acknowledge that male presence does not necessarily equate to dominance, this may be due to past experiences of men or an instinctive response to what they perceive as a dominant presence, which makes them feel aroused [49]. The frequency of the male vocals was lower than most instruments (and obviously female and child vocals), except the double bass, so it is of interest that ear movements were increased just in these two treatments. This suggests that the pitch of the sound had some influence on the alert response of the ear movement.

Conversely, children's vocals are high and soft, and dogs were not alerted by this sound. However, the trend toward an increase in grooming when children's voices were played, as well as the double bass, which was of low frequency, suggests that some anxiety may have been induced. However, it is important to stress that after the Bonferroni correction, this was not statistically significant. Excessive grooming has been reported in many species in response to stress, especially in primates [50–52]. Dogs may recognize that children sometimes have not yet learned to treat dogs with respect, and the dogs may associate this with the pitch of their voices. The double bass is close in frequency and tone to a dog's growl, potentially appearing menacing and causing anxiety.

Dogs receiving the cello or violin sounds also lay down less, and like dogs receiving male vocals, were more likely to have their heads up when they did lie down. Dogs receiving the cello also moved their tails more. One study has suggested that the pitch of the violin sounds like the howling of a dog, and that a long note from a violin can induce dog howling [53]. The frequency range of dog barking and howling varies between 150 and 2000 Hz, and the peak frequency range of the violin used for the songs in this study overlapped with this (Appendix 1). Indeed, the violin tended to have the highest peak frequency of any instrument or vocal. It is therefore possible that the dogs associated the playing of the violin with the howling of a dog [54]. However, there were other instruments with similar dominant frequencies in some songs, in particular the piano, so it is likely that the dogs also used other components of the music than frequency to form this association. The piano produces sound through hitting strings with small hammers [55], whereas the violin produces an extended sound when a bow is drawn across strings, making them vibrate [56]. Comparing these two methods of sound production, the duration of sound from the violin is more likely to be similar to dogs' howling, which might be the reason why dogs were aroused in the violin treatment. There is ample anecdotal evidence on the internet of violins stimulating dogs to howl.

4.2. Dogs' categorization of music

By grouping all the experimental music into four categories, whilst analyzing for the type of instrument, it was apparent that string instruments and vocals made dogs excited or nervous, as they stood and walked more, and when they lay down, they had their head up continually, with their ears moving frequently. This gives some support to the idea that string instruments as a group, not just the violin, may represent an arousing stimulus to dogs. They also sat most frequently in vocal treatments, suggesting stress. In contrast, when receiving sound from wind and keyboard instruments, dogs showed calm behavioral responses compared with the other treatments. They preferred to be lying down during these treatments, stood and walked seldom, and did not want to move their bodies. For calming purposes, these two instrument groups are recommended.

Music has often been classified by genre in studies of its effects on animals. In one study, shelter dogs appeared relaxed and calm with classical music, but were not interested in radio programs [57]. A summary of studies investigating the effects of music on dogs suggests that they do have musical preferences, that they howl when they hear wind instrumental music, especially reed instruments like clarinets and saxophones, and that sometimes a violin or a long note from a human could also lead them to howl [53]. It was suggested that classical music helps reduce stress, and that rock music leads dogs to be tense and anxious [53].

In our research, dogs had calm responses to wind instrument treatments. Some studies may not have controlled for factors such as volume of the music or the type of dogs used, including their emotional state and body condition [58]. Ensuring research dogs are in a calm, happy state before the research is important to facilitate a positive association with music [59]. We fed dogs at 07:30 am regularly, after which a staff member took them out for a walk, some play, and toileting. The kennels were kept very clean, with the floor mopped daily, and the dogs were given a set of clean blankets daily. Thus, the dogs were given comfortable surroundings. Effects could be different in noisier and less calm surroundings, for example, dog shelters [60].

Most of the previously published data describing the effects of music therapy with dogs did not mention the details of the selected pieces of music. There is a general view that dogs feel relaxed and calm with classical music; nevertheless, classical music has many different types, and different types of classical music may have different effects on animals. For example, Tchaikovsky's 1812 Overture may not have the same effect as Grieg's Peer Gynt suite. Few researchers have given this any attention.

In veterinary clinics, playing accordion songs may give a positive benefit to pets who are nervous in the atmosphere of the animal hospital. It would make them calm and reduce the possibility of a stress response. In shelters, using accordions instead of violins or male vocals may help build a peaceful and calm environment for kenneled dogs.

4.3. Limitations of the study

There were several limitations to our study. First, all the pieces of music were found on YouTube and other video websites, and they had variable qualities. Although the songs were processed after downloading, there were still some qualitative differences between each piece of music, which may have affected the dogs' responses.

Second, we chose "Twinkle, Twinkle Little Star", "Let It Go", "Jingle Bells", and "My Heart Will Go On", four simple songs, as the experimental music. These four songs have different characteristics; for example, "Let It Go" and "My Heart Will Go On" are popular songs, while "Twinkle, Twinkle Little Star" and "Jingle Bells" are nursery rhymes. The song was deliberately used as the replicate in this study, as has been recommended for playback experiments with animals [61]. Further testing with different songs is required to enable results to be more broadly applicable.

The small sample size was all that was possible in this exploratory research; however, it proved sufficient to elicit highly significant differences in behavior between treatments. Animal ethics requires that we use the minimum number of animals for any research. As this study was not replicating any previous study and was entirely novel, we had to estimate the length of the washout period (20 minutes) without prior knowledge and assumed that the dogs would not habituate to the study protocol in 10 days of playing music.

Finally, due to the fact that we only had four speakers, we could only ensure that the distances between each of them were equal. However, there were small but significant differences in volume between kennels; therefore, the decibels of music heard by each dog were similar but not identical.

In the future, using software to compose specific music pieces or using continuous tones of different instruments would provide basic information on dogs' responses to music. The rhythm, pitch, timbre, and volume could all be controlled, the tone being the main distinguishing element between all pieces of music. Later, research with dogs in a more stressful environment could produce a clearer conclusion about the influence of different instruments on the effects of music exposure on dogs.

Conclusions

This exploratory research used novel methods to evaluate dogs' responses to various instruments and vocals. Male vocals and stringed instruments, especially the violin, led to dogs lying down less and raising their heads more, which may indicate that they were paying more attention to these stimuli than to wind and keyboard instruments, such as the accordion. Further research is needed to explore the responses of dogs to wind and keyboard instruments, as they may have a potential calming effect on dogs in stressful environments.

Author contributions

Conceptualization, methodology, final analysis, editing, project administration and fund acquisition, Clive Phillips; Investigation, initial analysis and writing original draft, Han Meng.

Use of AI tools declaration

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Conflicts of interest

The authors declare no conflict of interest.

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