Short Communication

jfms Journal of Feline Medicine and Surgery

Journal of Feline Medicine and Surgery
2016, Vol. 18(8) 673–678

DOI: 10.1177/1098612X15588968
jfms.com
SAGE

A pilot study exploring the effects of musical genres on the depth of general anaesthesia assessed by haemodynamic responses

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Abstract

Objectives This pilot study aimed to investigate whether and how music and musical genres may influence the depth of anaesthesia, as measured using changes in arterial blood pressure (ABP), including systolic blood pressure (SBP), and heart rate (HR) across three different surgical time points.

Methods This work focused on a sample of 12 female cats (*Felis catus*) that were subjected to an elective ovariohysterectomy (OVH), and three different surgical time points were considered (T1, coeliotomy; T2, ligature placement and transection of the ovarian pedicle; and T3, ligature placement and transection of the uterine body). All of the cats were subjected to stimulation with 2 min segments of three music tracks from different genres (pop [PM], classical [CM] and heavy metal [HM]). At the same time, ABP and HR measurements were obtained using a multi-parametric monitor. For statistical analysis, P values <0.05 were considered significant.

Results For all cats, music exposure induced statistically significant changes in the parameters under study; the same finding was observed for the genre of music. The majority of cats experienced the same variation pattern, with lower values when exposed to CM, intermediate values when exposed to PM and higher values when exposed to HM.

Conclusions and relevance Our results indicate that the development of sensory processing of acoustic stimuli is maintained by cats under general anaesthesia and reveal the influence of music on the autonomous nervous system, as measured using HR and SBP.

Accepted: 6 May 2015

Introduction

Considering the complexity of auditory processing, it appears plausible that music promotes a variable activation of distinct brain areas, producing different physiological responses.[1–13] Anaesthetic agents exert both direct and indirect effects on cardiovascular function, resulting in a dose-dependent systemic depression that affects autonomic nervous system parameters, such as heart rate (HR) and arterial blood pressure (ABP). These changes may act as indicators of the depth of anaesthesia in the patient. Strong relationships exist between HR and ABP and the depth of anaesthesia.[14–16] The aim of this pilot study was to assess whether and how music and specific genres of music influence the depth of anaesthesia, as measured using changes in HR and ABP, including systolic (SBP), across three different surgical time points.

Materials and methods

The study protocol design was the same as that utilised for the paper previously published by Mira et al[17] that studied 12 female domestic breed *Felis catus* presented for elective ovariohysterectomy surgery. Signed consent

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Table 1 Descriptive statistics of heart rate values (bpm) and systolic arterial pressure (mmHg), according to the music genre and surgical time for the sample studied

Parameter	n	Statistics	T1			T2			T3		
			PM	CM	HM	PM	CM	HM	PM	CM	HM
HR	12	CI	35	34	42	43	39	48	35	29	33
		max	142	138	145	148	145	156	145	138	146
		min	107	104	103	105	106	108	110	109	113
		$\bar{x}$	122.75	118.08	124.83	125.83	121.42	129.83	123.58	121.67	125.42
		SD	12.88	10.48	13.68	13.29	11.04	14.81	11.68	9.03	10.10
SBP	12	CI	81.00	86.00	84.00	98.00	63.00	98.00	86.00	66.00	78.00
		max	148.00	149.00	153.00	160.00	149.00	165.00	158	147.00	163.00
		min	67.00	63.00	69.00	62.00	86.00	67.00	72.00	81.00	85.00
		$\bar{x}$	109.75	107.00	115.42	117.83	112.83	122.00	105.92	106.75	115.42
		SD	27.77	24.05	27.88	25.04	18.49	25.13	23.95	19.03	24.13

Data mean ($\bar{x}$) and dispersion (SD) measures obtained in a 95% confidence interval (CI), presenting the minimum (min) and maximum (max) values in the sample (n) considered
HR = heart rate; SBP = systolic blood pressure; T1 = coeliotomy; T2 = ligature placement and transection of the ovarian pedicle; T3 = ligature placement and transection of the uterine body; CM = classical music; HM = heavy metal music; PM = pop music

Table 2 Shapiro–Wilk test, repeated measures ANOVA and Friedman's test results for heart rate (bpm) and systolic arterial pressure (mmHg) values organised according to music genre and surgical time

Surgical time point	Type of test		Music genre	n	HR		SBP	
					s	*P*	*s*	*P*
T1	Shapiro–Wilk		C	12	0.917	0.263	0.936	0.445
			PM	12	0.902	0.171	0.915	0.246
			CM	12	0.945	0.570	0.945	0.564
			HM	12	0.950	0.636	0.926	0.338
	ANOVA	Sig *Mauchly* test	–		**–**		<0.001	
		P value	–		**–**		0.066	
	Friedman	χ^2	–		18.630		–	
		P value	–		**<0.001**		–	
T2	Shapiro–Wilk		C	12	0.908	0.200	0.910	0.210
			PM	12	0.960	0.786	0.946	0.578
			CM	12	0.955	0.704	0.953	0.678
			HM	12	0.952	0.673	0.942	0.530
	ANOVA	Sig *Mauchly* test	–		0.163		–	
		P value	–		**<0.001**		–	
	Friedman	χ^2	–		–		13.042	
		P value	–		–		**0.005**	
T3	Shapiro–Wilk		C	12	0.986	0.997	0.839	**0.027**
			PM	12	0.858	**0.047**	0.893	0.128
			CM	12	0.857	**0.045**	0.915	0.247
			HM	12	0.894	0.134	0.916	0.256
	ANOVA	Sig *Mauchly* test	–		0.393		–	
		P value	–		**<0.001**		–	
	Friedman	χ^2	–		–		21.700	
		P value	–		–		**<0.001**	

Statistically significant values are shown in bold
s = statistic; Sig = significance; HR = heart rate; SBP = systolic blood pressure; T1 = coeliotomy; T2 = ligature placement and transection of the ovarian pedicule; T3 = ligature placement and transection of the uterine body; CM = classical music; HM = heavy metal music; PM = pop music; C = control

Table 3 Descriptive statistics with repeated-measures ANOVA test and Wilcoxon's signed-rank test of heart rate values (bpm) and systolic blood pressure (mmHg), according to music genre and surgical time point

Surgical time points	Pairs of genres		ANOVA test				Wilcoxon's signed-rank test			
			HR		SBP		HR		SBP	
			Md	Sig	Md	Sig	Z	Sig	Z	Sig
T1	PM	C			10.583	0.691	–	–	–	–
	CM	C			13.333	0.195	–	–	–	–
		PM	–	–	4.917	1.000	−2.302	0.021	–	–
	HM	C	–	–	−10.583	0.691	−1.140	0.254	–	–
		PM	–	–	2.750	1.000	−2.043	0.041	–	–
		CM	–	–	−5.667	**0.003**	−2.831	**0.005**	–	–
T2	C	PM	3.333	0.729	−13.333	0.195	–	–	–	–
		CM	7.750	**0.007**	−2.750	1.000	–	–	–	–
		HM	−0.667	1.000	−8.417	**0.018**	–	–	–	–
	PM	C	−3.333	0.729	−4.917	1.000	–	–	–	–
		CM	4.417	0.308	5.667	**0.003**	–	–	–	–
		HM	−4.000	**0.007**	8.417	**0.018**	–	–	–	–
	CM	C	−7.750	**0.007**	–	–	–	–	−0.178	0.859
		PM	−4.417	0.308	–	–	–	–	−0.979	0.328
		HM	−8.417	**0.008**	–	–	–	–	−0.550	0.582
	HM	C	0.667	1.000	–	–	–	–	−2.125	0.034
		PM	4.000	**0.007**	–	–	–	–	−3.106	**0.002**
		CM	8.417	**0.008**	–	–	–	–	−2.127	0.033
T3	C	PM	11.250	**0.001**	–	–	–	–	−3.084	**0.002**
		CM	13.167	**0.000**	–	–	–	–	−2.827	**0.005**
		HM	9.417	**0.012**	–	–	–	–	−2.121	0.034
	PM	C	−11.250	**0.001**	–	–	–	–	−0.157	0.875
		CM	1.917	1.000	–	–	–	–	−3.074	**0.002**
		HM	−1.833	1.000	–	–	–	–	−2.316	0.021
	CM	C	−13.167	**0.000**	10.583	0.691	–	–	–	–
		PM	−1.917	1.000	13.333	0.195	–	–	–	–
		HM	−3.750	0.143	4.917	1.000	–	–	–	–
	HM	C	−9.417	**0.012**	−10.583	0.691	–	–	–	–
		PM	1.833	1.000	2.750	1.000	–	–	–	–
		CM	3.750	0.143	−5.667	**0.003**	–	–	–	–

Statistically significant values are shown in bold
Md = mean difference; Sig = significance; HR = heart rate; SBP = systolic blood pressure; T1 = coeliotomy; T2 = ligature placement and transection of the ovarian pedicule; T3 = ligature placement and transection of the uterine body; CM = classical music; HM = heavy metal music; PM = pop music; C = control

forms were obtained from the owners. After achieving an adequate and stable anaesthetic plane, repeated measurements of HR and ABP (ie, SBP) were made at three different surgical time points (STPs): T1, coeliotomy; T2, ligature placement and transection of the ovarian pedicle; and T3, ligature placement and transection of the uterine body. Three different musical genres were considered: pop (PM), 'Torn' by Natalie Imbruglia; classical (CM), 'Adagio for Strings (Opus 11)' by Samuel Barber; and heavy metal (HM), 'Thunderstruck' by AC/DC. For data recording, a multi-parameter electronic monitor was used to assess the physiological parameters, such as HR and ABP (using a non-invasive oscillometric method). For statistical analysis, we used SPSS Statistics for Windows, and a 95% confidence interval was defined as significant, with P values of <0.05.

Results

The elective ovariohysterectomy surgery required a mean time of 35.2 ± 2.3 mins, during which parameters associated with haemodynamic responses, such as HR and ABP (ie, SBP) were recorded. The HR results are shown in Tables 1–3 and Figure 1. The lowest mean HR values for all STPs were recorded with CM stimulation, and the highest HR values were recorded with HM stimulation. The results of Friedman's test for T1 (due to the

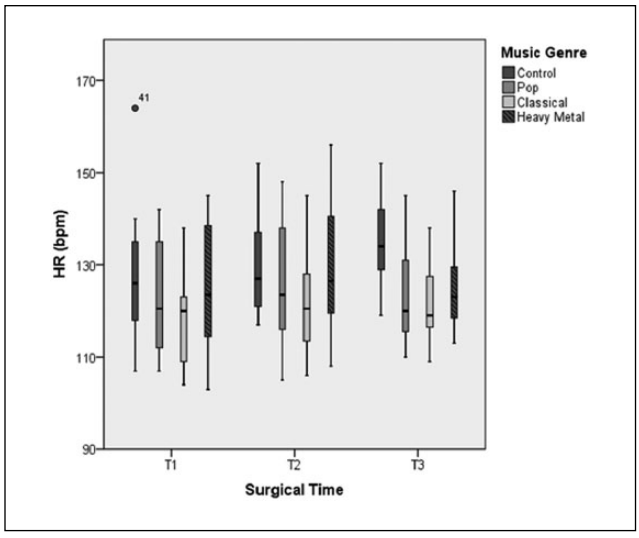

Figure 1 Variation of heart rate (HR) over the three surgical times considered under general anaesthesia and with stimulation of the three different music genres

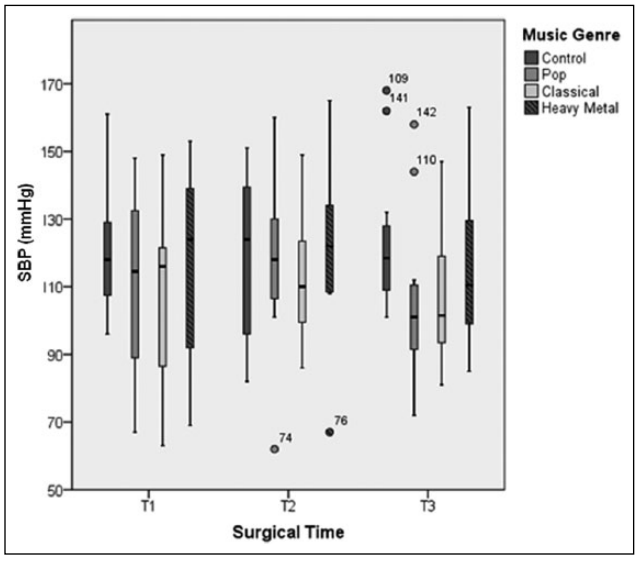

Figure 2 Variation of systolic blood pressure (SBP) over the three surgical times considered under general anaesthesia and with stimulation of the three different music genres

presence of a significant outlier value) and repeated-measures ANOVA for the remaining STPs revealed statistically significant differences between the music genres and the CT for all times (P <0.001 for T1, T2 and T3). Wilcoxon's signed-rank (for T1) and post-hoc Bonferroni (for T2 and T3) tests yielded statistically significant differences during T1 for the comparisons CT/CM (P=0.002) and HM/CM (P=0.005), during T2 for the comparisons CT/CM (P=0.007), PM/HM (P=0.007) and HM/CM (P=0.008) and during T3 for the comparisons CT/PM (P=0.001), CT/CM (P <0.001) and CT/HM (P=0.012). The SBP results are shown in Tables 1–3 and Figure 2. Most patients exhibited lower SBP values when exposed to CM, intermediate values when exposed to PM and higher values when exposed to HM, at all STPs. Statistically significant differences were observed between the music genres and the control for T2 (P=0.005) and T3 (P=0.002). Pairwise comparisons between stimulus conditions (using the post-hoc Bonferroni test) for the data obtained during T1 revealed statistically significant differences for the pairs PM/HM (P=0.003) and CM/HM (P=0.018). For T2 and T3, the Wilcoxon's signed-rank test with the Bonferroni correction revealed statistically significant differences in T2 for the comparison PM/HM (P=0.002) and in T3 for the comparisons CT/PM (P=0.002), CT/CM (P=0.005) and PM/HM (P=0.002).

Discussion

The autonomic response to stimuli can be evaluated using physical parameters, such as the haemodynamic responses of HR and ABP, and these parameters, particularly ABP, may act as useful indicators of the depth of anaesthetic during surgery.][18] For all studied patients, the obtained results support the possibility that music exposure induced statistically significant changes in HR (P <0.005 for T1, T2 and T3) and SBP (P=0.005 for T2 and T3). According to the study results, the majority of the patients experienced the same pattern variations, with lower values for HR and ABP (ie, SBP) after exposure to CM, intermediate values after exposure to PM and higher values after exposure to HM.

These results suggest that acoustic stimulus sensory processing development is maintained in cats under general anaesthesia and that some effects on autonomic nervous system activity that influence haemodynamic responses, such as HR and ABP, can be modulated by music and by the genre of music to which an individual is exposed. This finding is consistent with several studies carried out in humans and rats[19–21] that concluded that exposure to music affects autonomic nervous system activity and regulates cardiovascular function. Music therapy studies suggest that the classical genre is more beneficial for health, the pop genre is more beneficial for motivation and the heavy metal genre promotes anxiety and aggression.[21–23] Nevertheless, a discussion of some aspects of the methods used in this pilot study is mandatory. The ABP indicates the extent of tissue perfusion and acts as an indirect indicator of several cardiovascular parameters, including the studied HR. In the present study, ABP was measured using the oscillometric method because it was easily accessed. It is, however, less precise than Doppler which has been shown to correlate well with SBP measurements in both conscious

and anaesthetised cats. Still, this method has been reported to provide a consistent measurement of SBP.[14,24] Relative to the baseline control data, the majority of the HR or SBP values recorded in the three STPs under music stimulation were lower, reflecting the presence of mechanisms that are associated with a decrease in cardiac output that leads to slower removal of the anaesthetic from the alveoli due to reduced blood flow. As a result, the anaesthetic drug stays in the alveoli longer and the patient consumes less anaesthetic. Therefore, this pilot study presents the possibility of using music as an additional element in individual surgical anaesthetic protocols based on the modulation of autonomic nervous system activity by music, which promotes reduced anaesthetic consumption by stabilising haemodynamic clinical signs, such as HR and SBP.[25]

Although the medetomidine–ketamine combination is no longer considered a gold standard anaesthetic protocol for cats, this combination continues to be widely used and represents a suitable combination for anaesthesia in this species.[26–28] Ketamine can balance the depressive cardiovascular effects of medetomidine,[27] increasing HR and ABP values within 20 mins of its administration. This combination produces anaesthesia in less than 4 mins, with duration of active surgical anaesthesia between 25 and 50 mins.[27,29] Additionally, the authors recognise that opinions may vary regarding the administration of certain premedication drugs, such as atropine and opiates, which can both cause changes in the cardiovascular system. The use of atropine, an anticholinergic medicine with a short activity that may cause tachycardia, increasing myocardial oxygen consumption and the potential for myocardial hypoxaemia development, can be useful in conjunction with opioid or alpha-2 agonist administration to offset the potential bradycardic effects and the drop in cardiac output that are associated with these drugs.[29,30,31] The sympathomimetic properties of ketamine counter bradycardia but do not reverse the decrease in cardiac output. Therefore, the use of atropine as a premedication can correct this situation.

In addition, the observed changes in HR and ABP parameters were assumed to occur due to the music genre rather than due to different isoflurane concentrations because across the STPs, a standard 1% isoflurane vaporisation volume was applied for all of the patients.[32] Moreover, as Cullen et al[30] concluded, the haemodynamic responses recorded during the first hour of general anaesthesia are not related to the concentration of isoflurane that is administered to the patient but are directly related to noxious stimuli. In this pilot study, noxious surgical stimulus was suspended by the addition of analgesic components, such as buprenorphine, which prevent sympathetic stimulation and haemodynamic responses. Regardless of the employed protocol, the selection of the appropriate dosing and combination of drugs for each individual will always promote a safer procedure.[33,34] During the analysis of the results, the potential effects of the anaesthetics and presurgical drugs used in the protocol were considered with respect to their potential cardiovascular effects, as this study focused on such effects.[34] Because the surgical procedure time exhibited a mean of 35.2 mins and the STPs started 10 mins after drug administration and because the cardiovascular effects of ketamine and atropine occur during the 20 mins following their administration, any increase in HR and ABP values that resulted from the peak effects of ketamine and atropine would be registered during only the T1 STP.

Conclusions

The results are very encouraging, and the clinical implications of these data are significant in the context of judging anaesthetic depth based on haemodynamic responses. However, further controlled studies with larger samples are needed based on this pilot study to determine the value of playing music throughout surgical procedures and to explore the effects that this might have.

Acknowledgements The authors thank CIISA – Interdisciplinary Centre for Research in Animal Health, Faculty of Veterinary Medicine of Lisbon, University of Lisbon, Portugal (FMV/ULisboa), and Anjos of Assis Veterinary Medicine Centre (CMVAA), Barreiro, Portugal.

Funding This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Conflict of interest The authors do not have any potential conflicts of interest to declare.

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