Full-Length Article

Characteristics of Music to Improve the Quality of Sleep

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Abstract

Background: Several studies on the effects of music on sleep disorders have demonstrated that music listening can improve sleep quality in patients with sleep disorders. To our knowledge, nevertheless, none of them have elucidated the characteristics of such music itself.

Objective: The purpose of the present study was to elucidate the characteristics of the types of music that may improve sleep quality.

Methods: In 25 tracks used in the previous study, we calculated 4 analysis indicators: scaling exponent of the spectrum of melody's zero-crossings, redundancy of note values, density of notes and tempo.

Results: The characteristics of music to improve sleep quality were slow tempo, small change of rhythm, and moderate pitch variation of melody. Based on the results derived from cluster analysis, the music pieces studied were largely categorized into 3 groups. A comparison of these 3 groups showed no significant differences with respect to the scaling exponent of the melody and the density of notes, whereas it showed significant differences with respect to the redundancy of note values and tempo.

Conclusions: Our study revealed several characteristics of the types of music that improve sleep quality. The identification of these characteristics contributes to providing personalized music therapy to patients.

Keywords*: sedative music; insomnia; music analysis; sleep quality; passive music therapy*

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Introduction

Sleep disorders are very common in the general population. Of these disorders, insomnia has the highest prevalence rate. Approximately one-third of adults in the general population are estimated to suffer from symptoms of insomnia. Of this one-third, a proportion ranging from 10% to 15% shows inability to function properly during the day and a proportion ranging from 6% to 10% evidence symptoms meeting insomnia disorder criteria.[1] Moreover, recent studies have shown that sleeping has a significant effect on our health. Sleep duration is closely associated with the onset of lifestyle-related diseases, such as obesity, diabetes, hypertension, dyslipidemia, and ischemic cardiac disease.[2,3]

Several studies on the effects of music on sleep disorders have shown that music listening can improve sleep quality in patients with sleep disorders.[4]-[17] A meta-analysis of sleep analysis in 2014 (involving 10 trials performed to study the association between music and sleep quality) demonstrated that music listening resulted in a significant improvement of sleep quality in patients with sleep disorders exposed to various physical and psychological conditions. ($Z = 4.24$, $p < 0.001$).[4] According to a Cochrane meta-analysis conducted in 2015 which included 6 trials investigating the association between music and sleep quality in patients with insomnia, music was found to be effective in improving subjective sleep quality in adults presenting with symptoms of insomnia ($Z = 8.77$, $p < 0.00001$).[5] Table 1 summarizes the characteristics of the 12 trials included in the above-mentioned two meta-analyses. [4]-[17]

Until recently, the types of music used to improve sleep quality have been those that are categorized as "sedative". Gaston described the characteristics of sedative music in 1968. Gaston claimed that the music that has minimal rhythmic activity, no percussive characteristics, and more legato melodic motives modulates responses in a direction opposite to that associated with rhythmic dance music. [18] Although several studies have been carried out to date on "sedative music", the term "sedative" has not yet been clearly defined. This is due to several reasons. Firstly, the distinction of what makes music sedative likely varies with culture, age, and various other factors. Secondly, people’s perception of what

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"sedative" means, has a unique qualifier, which is individualized to them. Thirdly, the expressions used to define sedative music (for example, "melodic", "gentle", etc.) are generally unclear. There could be some objective similarities among the sedative music pieces used in the above-mentioned two meta-analyses that demonstrated beneficial effects of music on sleep quality in sleep disorder patients. Unfortunately, however, we were unable to find any studies assessing similarities across sedative music pieces by using objective measures. What are the characteristics of the types of music that improve sleep quality? The purpose of the present study was to elucidate this research question.

Table 1. ***Features of the research included in the two meta-analyses.***

Author	Age (mean)	Males (%)	N	Country	Participants	Duration of intervention period	Length of sessions (min.)	Music selection	Rationale for music selection	Outcomes	Result	2014 Wang C.F.et.al	2015 Jespersen KV,et. al
Zimmerman,L. et.al 1996	67	68	96	USA	Patients who underwent coronary artery bypass graft surgery	2 consecutive days	30	Subjects selected from the pieces presented by the experimenter	"All of these musicul tapes consisted of a soothing type of music that facilitates relaxation."	RCSQ	On the third day after surgery, the music video group showed significantly better sleep score (RCSQ) than the control group (p <0.05).	○	
Richards,K.C. 1998	66	100	69	USA	Patients with cardiovascular disease admitted to CCU	1 day	7.5	The experimenter chose	It is because in a previous research (Aubuchon, 1990) this song helped to sleep.	PSG	The sleeping efficiency of the massage group (back massage group and music group) was 14.7% higher than that of the control group.	○	
Renzi,C.et.al 2000	46	60	86	Italy	Patients who had an operation on anorectum	1 day	30	The experimenter chose	Not described.	VAS	The quality of sleep score was lower in guided imaging (GI) patients then in controls.	○	
Kullich,W.et.al 2003	48	63	65	Austria	Adults with low back pain and sleep difficulties (PSQI scores>5)	3 weeks	25	The experimenter chose	"An especially produced music for application with pain"	PSQI	PSQI total score of the music group remarkably decreased.	○	○
Hernandez-Ruiz,E. 2005	35	0	28	USA	Women in DV shelters	5 consecutive days	20	Subjects chose	Not described.	PSQI	Significant effect on the sleep quality of the experimental group.	○	
Lai,H.L.et.al 2005	67	/*	60	Taiwan	Older adults with sleep problems documented by PSQI score>5	3 weeks	45	Subjects selected from the pieces presented by the experimenter	"The tempo of the sedative music was 60-80 beats/minute without accented beats, percussive characteristics, or syncopation," according to Gaston(1951, 1968).	PSQI	Music significantly resulted in better sleep quality and better sleep quality components (p = 0.04 - 0.001).	○	○
Harmat,L.et.al 2008	23	22	94	Hungary	Students with poor sleep documented by PSQI score>5	3 weeks	45	The experimenter chose	"The music was a collection of relaxing classical music including some popular pieces from Baroque to Romantic."	PSQI	Music improves sleep quality significantly (p <0.0001).	○	○
Chan,M.F.et.al 2010	76	45	42	Hong Kong	Older adults with sleep probrems and depression	4 weeks	30	Subjects selected from the pieces presented by the experimenter	"All were slow and flowing pieces, approximately 60-80 beats min, instrumental, and 30 min in length," according to several previous studies1).	PSQI	A statistically significant decrease in the PSQI score of the experimental group was seen at 4 weeks. There was no improvement in sleep quality in the control group.	○	
Chang,E.T.et.al 2012	32	6	50	Taiwan	Adults who experienced insomnia for at least 1 month, documented by PSQI score>5	3 consecutive days	45	Subjects chose or selected from the pieces presented by the experimente	"All the tracks had tempos ranging from 60 to 85 beats/ min (slow), minor tonalities, smooth melodies, and no dramatic change in volume or rhythm to achieve a relaxing effect," according to Nilsson (2010).	PSG	In the music group the evaluation of rest was significantly improved. Compared to the control group, shortening of sleep stage 2 and prolongation of REM sleep were observed, but music had little effect on sleep quality.	○	○
Ryu,M.J.et.al 2012	61	66	58	South Korea	Patients admitted to CCU after PTCA	1 day	52	The experimenter chose	"The sleep-inducing music (δ-wave music, which stimulates sleep waves in the brain)" was developed by Park(2008).	VSH	In the experimental group, sleeping quantity was significantly higher (p <0.05) than the control group, and the sleeping quality was significantly higher (p <0.001).	○	
Jespersen,KV. 2012	37	40	15	Denmark	Traumatised refugees with sleep problems documented by PSQI score>5	3 weeks	60	The experimenter chose	These pieces of music were chosen based on feedback from the participants in studies examining effect of music in Danish hospitals.	PSQI	Statistical comparison showed a significant improvement in sleep quality in the music group but not in the control group.		○
Shum,A.et.al 2014	64	33	60	Singapore	Older adults with poor sleep quality, documented by PSQI score>5	5 weeks	40	Subjects selected from the pieces presented by the experimenter	"All music compositions were soft, instrumental, slow music without lyrics, of approximately 60-80 beats per minute, for 40 min duration," according to several previous studies2).	PSQI	Significant reductions in PSQI scores were found in the intervention group from baseline to week 6, while there were no changes in the control group from baseline to week 6.		○

*Not listed

1)Nilsson, 2008; Arslan,Ozer, & Ozyurt, 2008; Twiss, Seaver, & McCaffrey, 2006; Yung, Szeto, Lau, & Chan, 2003; Lee, Chung, Chan, & Chan, 2005
2)Chan, Chan, & Mok, 2010; Lai, & Good, 2005; Gaston, 1951.

Methods

We listened to, transcribed, and analyzed each of the 25 music pieces (Table 2) used in 5 of the previous studies [4,5] for which sound sources were available.

Music consists of 3 main elements: melody, rhythm and harmony. In this time, we have adopted measurable indices for music analysis in 2 of these 3 areas. As for melody, the scaling exponent of the spectrum of its zero-crossings was calculated in order to show its smoothness objectively. As for rhythm, the density of notes was calculated to show its "rhythm is at a minimum", and the redundancy of note values to show its "gentle movement". Four indices were used, including tempo, which were collectively considered for analysis of the characteristics of sedative music.

All analysis of all indications was carried out by two music experts with > 15 years of music performing experience.

Song No.	Song name	Study	Song No.	Song name	Study
1	♪Water Spirit	1)	14	♪Clair de lune	3)
2	♪You Deserve Love	2)	15	♪Violin Concert in E minor	3)
3	♪Gnossienne #5	2)	16	♪The Swan	3)
4	♪Gigi	2)	17	♪Going Home	4)
5	♪When Joanna Loved Me	2)	18	♪Memory	4)
6	♪Air 'on the G string'	3)	19	♪Romance from Eine kleine Nachtmusik	5)
7	♪Morning	3)	20	♪Nocturne2/ Chopin	5)
8	♪Canon in D	3)	21	♪Variation on Yang Pass	5)
9	♪Jesu,Joy of Man's Desiring v	3)	22	♪Shizuku	5)
10	♪Gymnopedie No.1	3)	23	♪Lord of Wind	5)
11	♪Piano Concerto No.21 in C 'Elvira Madigan'	3)	24	♪Winter Wonderland	5)
12	♪Viens, Mallika (from Lakme)/Leo Delibes	3)	25	♪In Love in Vain	5)
13	♪In Paradisum	3)			5)

1)Richards,K.C.et.al1998 2)Lai,H.L.et.al2005 3)Harmat,L.et.al2008 4)Chang,E.T.et.al2012 5)Shum,A.et.al2014

Table 2. *Music List for Analysis*

Scaling exponent of the spectrum of melody's zero-crossings

The scaling exponent of the spectrum of melody's zero-crossings (hereafter abbreviated as "scaling exponent of the melody") was calculated to assess the smoothness of melodies.

When $-\alpha$ is the scaling exponent of the power spectrum of a fluctuation, the power can be inversely proportional to the α-th power of the frequency. The majority of the fluctuations observed in the natural world fall within the range of $0 \leq \alpha \leq 2$. In terms of melody, the closer α is to 0, the more drastically the pitch varies, and the closer α is to 2, the less drastically (and thus the smoother the melody becomes).[19]

To prepare each music piece for analysis, the melody line was firstly separated from the rest of musical information and was coded in a MIDI file, which was automatically converted into a WAV file to remove inter-individual variability in musical performance. Zero-crossings were then extracted from the WAV file, which were used to calculate their power spectrum. Linear approximation was subsequently applied to the results plotted in a double-logarithmic axis to calculate its slope. Mathematica programming was used for the series of analyses performed.

Redundancy of note values

To calculate the redundancy of note values for each music piece, the average information in the music piece was firstly calculated based on the types of notes and the frequency of their appearances, and the redundancy of note values in each music piece was subsequently estimated, assuming that the appearance of 45 types of notes (which is the sum of all types of notes found in the music pieces analyzed, where the value of a quarter note is 1, the minimum value is 0.083, and the maximum value is "4 or greater") with equal probability is the highest possible redundancy. In principle, the lower the redundancy of note values, the greater the rhythmic variations, and the higher the redundancy of note values, the more subdued the rhythmic variations. Agrement, glissando, and other very small note values were collectively regarded as having a minimum note value of 0.083.

Density of notes

The density of notes was determined by the total number of notes constituting the melody line, regardless of the note values of the individual notes. The number of notes per second was calculated by dividing the total number of notes in the melody line by the playing time (in seconds) of the music. In principle, the higher the density of notes, the faster the rhythm, and the lower the density of notes, the slower the rhythm.

Density of notes (number of notes per second) = total number of notes / playing time [in seconds]

Glissando and other similar notes were treated in the same manner as described above under *2) Redundancy of note values*.

Tempo

The total number of beats in each music piece was divided by the playing time (in minutes) of the music to calculate beats per minute (BPM). Although changes in tempo were observed in some of the 25 music pieces analyzed, pace was more or less the same between the first and second half of each music piece, and any of the tempo changes recorded were only temporary. Thus, even when there was an accelerando or ritardando or other change in tempo during the music, we simply counted the number of beats as we could hear them, and then divided the total number of beats by the total playing time to calculate a tempo. In this sense, the tempo mentioned herein actually refers to the average tempo in a single music piece.

Tempo (BPM) = total number of beats / playing time [in minutes]

Methods of statistical analysis

The results obtained for the 4 indicators from 25 music pieces were evaluated with cluster analysis. To compare each of these 4 indicators across the 3 groups identified by cluster analysis, significance probabilities were calculated by using Kruskal-Wallis test and multiple comparisons were performed by using Mann-Whitney U test.

Of the various methods that have been proposed for cluster analysis to suit a specific purpose or use, aggregative hierarchical clustering was applied, which is the most widely used form of cluster analysis. The first stage of aggregative hierarchical clustering involved defining similarities; quantifying similarities between samples; and calculating the distance between the samples. The most common distance measure called the Euclidean distance was used to measure the distance between samples. The last stage of analysis involved grouping (clustering) samples together based on distance and calculating the distance between clusters. Ward's method was used for clustering, which is the most widely used clustering method that is known to have a high classification sensitivity.[20]

Results

Measured values for each indicator

Table 3 summarizes the values measured, means, and standard deviations (SD) calculated for the 4 indicators based on 25 music pieces.

Table 3. *Analysis results of 25 pieces*

Song No.	Melody	Redundancy	Density	Tempo
1	1.111	55.9	2.179	76
2	1.322	60.0	1.274	49
3	0.718	46.9	1.649	46
4	1.196	50.5	1.725	45
5	0.796	48.2	1.926	90
6	1.109	66.0	1.276	55
7	1.089	66.4	3.186	61
8	1.027	60.1	2.044	79
9	0.908	96.4	2.807	63
10	1.163	81.9	0.738	84
11	0.949	45.9	1.543	63
12	0.965	67.1	1.369	52
13	0.925	52.1	0.464	48
14	1.183	57.3	1.153	66
15	1.219	56.9	1.026	37
16	1.225	58.2	0.824	58
17	1.030	51.5	0.715	39
18	1.113	60.0	1.184	80
19	0.790	62.8	2.832	69
20	1.212	52.4	2.055	53
21	1.118	77.9	4.250	81
22	1.203	48.5	1.056	64
23	1.355	42.8	0.685	86
24	0.670	78.0	1.378	80
25	0.986	50.2	0.764	62
Mean	1.055	59.76	1.604	63.44
S.D.	0.181	12.81	0.905	15.37

Scaling exponent of the melody

The mean scaling exponent of the melody (absolute value) for the 25 music pieces was 1.055 (SD: 0.181), the minimum value being 0.67 and the maximum value being 1.355.

Redundancy of note values

The mean redundancy of note values for the 25 music pieces was 59.76% (SD: 12.81%), the minimum value being 42.8% and the maximum value being 96.4%.

Density of notes

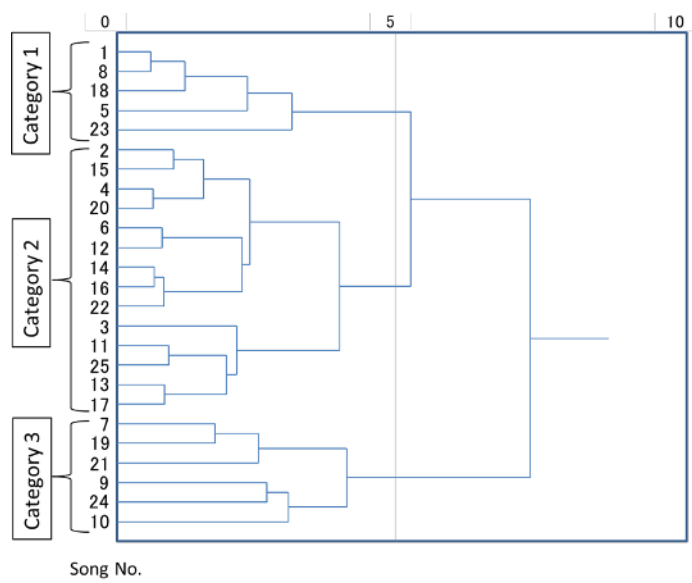
The mean density of notes for the 25 music pieces was 1.604 per second (SD: 0.905 per second), the minimum value (the lowest density of notes) being 0.464 per second and the maximum value (the highest density) being 4.25 per second.

Tempo

The mean tempo for the 25 music pieces was 63.44 BPM (SD: 15.37 BPM), the minimum value being 37 BPM and the maximum value being 90 BPM. This finding is more or less in line with the reference BPM used in a previous study to select sedative music pieces, which was "60-85 BPM". In our study, 10 music pieces had 59 BPM or less, 13 had 60-85 BMP, and only 2 had 86 BPM or more.

Cluster Analysis

Based on the findings of the cluster analysis performed on the results obtained for the 4 indicators from 25 music pieces, the



music pieces were largely categorized into 3 groups (namely Category 1, Category 2, and Category 3, see Figure 1). Category 1 included 5 music pieces, Category 2 included 14, and Category 3 included 6.

Figure 1. *Dendrogram of cluster analysis results of 4 indices of all 25 music pieces.*

Category 1

In this category, the mean scaling exponent of the melody was 1.08 (SD: 0.201), the mean redundancy of note values was 53.4% (SD: 7.7%), the mean density of notes was 1.604 per second (SD: 0.642 per second), and the mean tempo was 82.2 BPM (SD: 5.67 BPM).

Category 2

In this category, the mean scaling exponent of the melody was 1.089 (SD: 0.165), the mean redundancy of note values was 54.5% (SD: 6.6%), the mean density of notes was 1.207 per second (SD: 0.441 per second), and the mean tempo was 52.64 BPM (SD: 9.22 BPM).

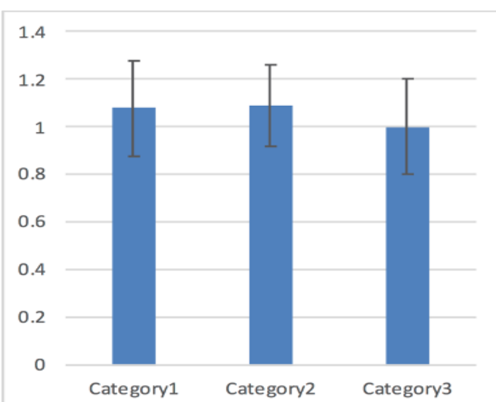
Category 3

In this category, the mean scaling exponent of the melody was 0.956 (SD: 0.199), the mean redundancy of note values was 77.2% (SD: 12.0%), the mean density of notes was 2.532 per second (SD: 1.272 per second), and the mean tempo was 73 BPM (SD: 9.94 BPM).

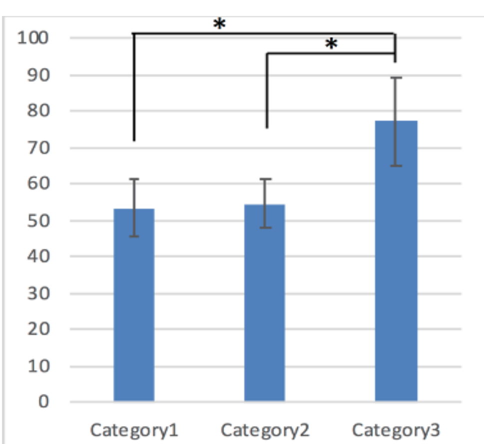
Comparison across categories

Figure 2 compares the results that correspond to the 4 indicators across categories.

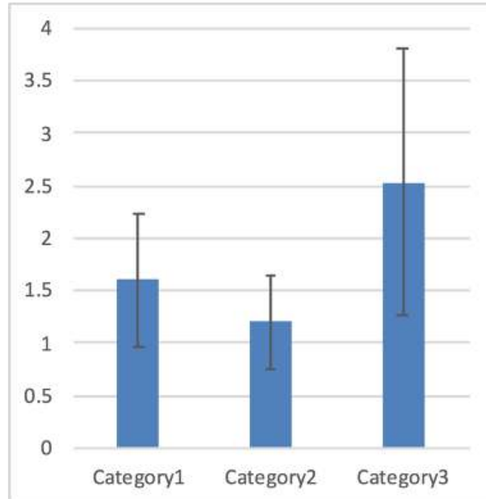
Figure 2. *Means and standard deviations of 4 indices in each category. (*: p<0.01)*



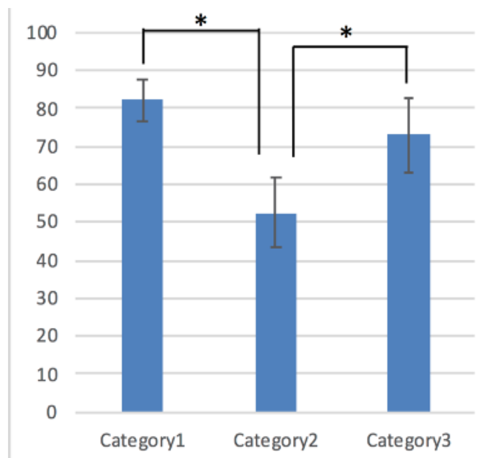
Scaling exponent of the melody



Redundancy of note values



Density of notes



Tempo

Scaling exponent of the melody

The mean scaling exponent of the melody was 1.08 (SD: 0.201) for Category 1, 1.089 (SD: 0.165) for Category 2, and 0.956 (SD: 0.199) for Category 3. Kruskal-Wallis test showed no significant differences across the 3 groups (X^2 = 2.3871, degree of freedom = 2, p = 0.3031).

Redundancy of note values

The mean redundancy of note values was 53.4% (SD: 7.7%) for Category 1, 54.5% (SD: 6.6%) for Category 2, and 77.2% (SD: 12.0%) for Category 3. Because Kruskal-Wallis test showed significant differences across the 3 groups (X^2 = 11.8365, degree of freedom = 2, p = 0.0027), Mann-Whitney U test was also performed, which revealed significant differences between Category 1 and Category 3 and between Category 2 and Category 3 (Category 1 vs. Category 3: Z = 2.7386, p = 0.0062, Category 2 vs. Category 3: Z = 3.2167, p = 0.0013).

Density of notes

The mean density of notes was 1.604 per second (SD: 0.642 per second) for Category 1, 1.207 per second (SD: 0.441 per second) for Category 2, and 2.532 per second (SD: 1.272 per second) for Category 3. Kruskal-Wallis test showed no significant differences across the 3 groups (X^2 = 5.6549, degree of freedom = 2, p = 0.0592).

Tempo

The mean tempo was 82.2 BPM (SD: 5.67 BPM) for Category 1, 52.64 BPM (SD: 9.22 BPM) for Category 2, and 73 BPM (SD: 9.94 BPM) for Category 3. Because Kruskal-Wallis test showed significant differences across the 3 groups (X^2 = 15.5129, degree of freedom = 2, p = 0.0004), Mann-Whitney U test was performed, which revealed significant differences between Category 1 and Category 2 and between Category 2 and Category 3 (Category 1 vs. Category 2: Z = 3.2404, p = 0.0012, Category 2 vs. Category 3: Z = 2.9291, p = 0.0034).

Discussion

In this study, music analysis was carried out to elucidate the characteristics of the types of music that improve sleep quality. The following results were collected: (1) The spectrum of melody's zero-crossings was close to -1 for most music pieces, the redundancy of note values varied across music pieces with the mean being 59.76% (SD: 12.81%), the densities of notes were generally low, and the tempos of the 25 music pieces were generally a bit slower than those of typical sedative music reported in previous studies. (2) Based on the findings of the cluster analysis performed, the music pieces studied were largely categorized into 3 groups. Although no significant differences were found across these groups with respect to the spectrum of melody's zero-crossings and the density of notes, significant differences were found across the 3 groups with respect to the redundancy of note values and the tempo.

Previous research was carried out in Japan on the frequency distribution of the scaling exponents for different genres of music (the study focused on the entire music piece, instead of just the melody line). According to this study, the most frequent class was 1.01-1.25 (approximately 55%) for classical music, 1.01-1.25 (approximately 50%) for some typical music used for music therapy (e.g. Schubert's "Serenade", Beethoven's "Fur Elise", Teiichi Okano's "Harugakita" (Japanese song), Kengyou Yatuhashi's "Rokudan", according to Watanabe, 1987) 0.51-0.75 (approximately 55%) for popular music (hit songs from 1945-1970), and 0.26-0.50 (approximately 60%) for rock music.[21] A comparison of these findings with our results reveals that the scaling exponents of the melodies of the music pieces selected in our study are closer to those of classical music and some typical music used for music therapy than to those of rock music and pop music. A scaling exponent of approximately 1 corresponds to the so-called "1/*f* noise or fluctuation". The scaling exponents of the melodies of all 25 music pieces used in the present study were close to 1 (1.05±0.18), which means that these melodies have pitch variations resembling that of 1/*f* noise or fluctuation.

To our knowledge, no study has been conducted to date on the redundancy of note values, and therefore there is no data available with which to compare our findings on this particular indicator. The redundancy of note values reflects the rhythmic element of music, and in principle, the lower the redundancy of note values, the greater the rhythmic variations, and the higher the redundancy of note values, the more subdued the rhythmic variations. Gentle rhythm is known as one of the typical characteristics of sedative music. Although gentle rhythm usually refers to subtle rhythmic variations, the redundancy of note values varied across the music pieces analyzed in the present study, with the maximum redundancy of note values exceeding 90% and the mean redundancy of note values being 59.76% (SD: 12.81%).

The density of notes is another indicator that has very seldom been addressed in previous studies, and we could find no data with which to compare our findings. Typical sedative music has, in general, minimal rhythmic activity.[18] Although there was a slight variation in the density of notes across the 25 music pieces analyzed, 84% of them had a note density of 2.5 per second or less (and 92% of them had a note density of 2.99 per second or less), which indicates that the type of music that is known to improve sleep quality tends to have a low number of notes per second.

As for the tempo, typical sedative music is known to have 60 to 85 BPM. [11,13,14] The mean tempo of the 25 music pieces analyzed in the present study was 63.44 BPM (SD: 15.37 BPM). When the 25 music pieces were categorized into 3 groups based on their tempos (namely 59 BPM or less, 60-85 BPM, 86 BPM or greater), it could be observed that the largest number of the music pieces belonged to the "60-85 BPM" group, which is in line with the findings reported in previous studies. Because 92% of the music pieces belonged to either the "59 BPM or less" group or the "60-85 BPM" group, we can conclude that improvement of sleep quality can be achieved not only by music with a BPM range between 60 and 85 but also by any type of music with slow tempos (85 BPM or less). Taking into account the fact that most music has a tempo between 40 and 300 BPM[22], the tempos of the sedative music pieces analyzed in the present study are relatively slow (mean tempo: 63.44 BPM).

Based on the findings derived from our cluster analysis, the 25 music pieces analyzed were largely categorized into 3 groups. No significant differences were found across these groups with respect to the spectrum of melody's zero-crossings and the density of notes, which indicates that the music characteristics represented by these indicators could be a common factor present in the melodies that improve sleep quality. On the other hand, significant differences were recorded across groups with respect to the redundancy of note values and the tempo.

Category 1 showed faster tempos (mean tempo: 82.2 BPM, SD: 5.67 BPM) and lower densities of notes compared to other categories. Category 2 showed relatively low densities of notes and had a mean tempo of 52.6 BMP (SD: 9.22 BPM), which is slower than the average tempo observed in typical sedative music. Category 3 showed a mean density of notes of 2.532 per second (SD: 1.272 per second), which is slightly higher than that of the other two categories. On the other hand, it showed relatively high redundancy of note values, which indicates that music pieces belonging to this category have gentle rhythmic activity that is characteristic of typical sedative music. Overall, findings from these categories show that not all the results obtained for the 4 indicators are in line with the characteristics of typical sedative music. Each category exhibited, in fact, a distinct combination of music characteristics. Sedative music is typically known to have smooth melody lines, legato sounds, minimal rhythmic activity, gently rhythm, and slow tempos (60 to 85 BPM).[18] Findings from the present study suggest that assessing various combinations of music characteristics, instead of just focusing on the individual indicators of music characteristics, may provide greater insight into the effects of music on sleep quality.

In this time, we conducted this study under the hypothesis that the pieces of music which improve sleep quality haves common characteristics. The previous researches which we analyzed were of different ages, countries, cultures; however, the results showed some common characteristics as already mentioned. These results suggest that the pieces of music that improve sleep quality may have common characteristics in the world, even in different cultural backgrounds. The mechanism of action by which these characteristics of music affect sleep is a task to study in the future. In discussing the effects of music on sleep and sleep disturbance, the relationships between music and biological factors should be clarified. We would like to discuss how components of music are related to human living body during sleep (heart rate and tempo, brain wave and frequency, etc.),[23,24] and the entrainment by which the two autonomous rhythmic processes of music and human influence each other. [25]

Conclusions

Our study revealed several characteristics of the types of music that improve sleep quality. By analyzing other indicators of music characteristics (such as harmony, etc.) and by investigating how different combinations of music pieces or music categories can affect sleep in future studies, we should be able to gain a better understanding of the types of music that can improve sleep quality. Further identification of the characteristics of sedative music will greatly contribute to providing personalized music therapy to patients through careful consideration of their preferences.

Limitations of the study

1) Although we identified a total of 39 music pieces from previous studies on sedative music, sound sources were available for only some of the identified pieces. As a result, only 25 of the identified music pieces could be included in our analysis.

2) Because only certain aspects of each music piece were assessed in music analysis, our findings neither accurately reflect the characteristics of music in its entirety nor take into account the subtle differences that might be introduced to music by different musical performers.

3) This research evaluated several components of music, not all components of music could be analyzed. Other components of music such as harmony and timbre and the cultural elements of music may also be important factors in improving the quality of sleep. Therefore, there is the possibility that other clusters may be produced, taking into account some factors other than the four we used.

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