



**Music as Medicine:
A Mathematical Analysis of
Science, Art, and Literature**

A Sample Submission for the Inaugural
Math eXpressions™ 2009

by Tracey T. Meilander, MEd, PhD

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Part 1: Music as Medicine: Data Re-Analysis (Science)

A Sample Analysis for the Inaugural Math eXpressions™
For Research Poster, see Appendix A

Format: Data Analysis

by Tracey T. Meilander, MEd, PhD

Nurses of the Future Intern, Anne Marie O'Toole along with Cleveland Clinic staff members, investigated the effects of music intervention on patients during epidural block procedures. In her study, forty patients were divided into two equal groups that received different drugs, Diprivan or Versed, for an epidural block procedure. In each of these groups, patients were further divided into a Music or No Music treatment group. The drug dosage required for the epidural block was recorded for each patient in each treatment group for Diprivan and Versed. Anne Marie's results showed that patients receiving music intervention during the epidural block required less procedural sedation; however, the average dosages were not determined for each group.

In this analysis, the data from Anne Marie's study were restructured to illustrate the dramatic effects of music on pain management. By pooling the number of patients and their respective dosage, in the No Music and Music groups for each type of medicine (Diprivan or Versed), summative and average dosages were calculated (Table 1.). The summation (SUM) is calculated by adding all the dosages for each drug and treatment separately. Patients in the Music treatment group were administered less Diprivan and Versed (40 mg and 10 mg) than those in the non-treatment groups (185 mg and 22 mg), respectively. Both groups incorporated the same number of participants (sample size, n =10).

The average (AVG) dosage for each group was calculated as AVG/n . The standard error (SE) was calculated as the standard deviation (SD) from the mean (AVG) divided by the square root of the sample size (n) minus one ($SE = SD/(\text{SQRT}(n-1))$). The means were expressed as $AVG \pm 1 SE$ to graphically inspect for significance. The participants in the Diprivan group receiving music intervention required 78% less medicine (4.0 ± 2.2 mg) than those without music intervention (18.5 ± 2.7 mg) (Figure 1). The participants in the Versed group receiving music intervention required 55% less medicine (1.0 ± 0.2 mg) than those without music intervention (2.2 ± 0.2 mg) (Figure 2). In analyzing both graphs, no overlap exists between the standard error bars of the music vs. non-treatment groups. This visual rule-of-thumb can be used to identify significant differences between the two treatment groups. With both drug groups, it appears that music had a significant impact on reducing the dosage required for the epidural block. The addition of these findings to Anne Marie's study strengthens her research results.

Table 1. Dosages of Diprivan and Versed required by patients in no music (control) group versus music treatment group.

DIPRIVAN				VERSED			
No Music		Music		No Music		Music	
Patient #	Dose (mg)	Patient #	Dose (mg)	Patient #	Dose (mg)	Patient #	Dose (mg)
1	0	1	0	1	2	1	0
2	10	2	0	2	2	2	0.5
3	20	3	0	3	2	3	1
4	20	4	0	4	2	4	1
5	20	5	0	5	2	5	1
6	20	6	0	6	2	6	1
7	20	7	0	7	2	7	1
8	20	8	10	8	2	8	1
9	25	9	15	9	2	9	1
10	30	10	15	10	4	10	2
SUM	185	SUM	40	SUM	22	SUM	9.5
AVG	18.5	AVG	4.0	AVG	2.2	AVG	1.0
SD	8.2	SD	6.6	SD	0.6	SD	0.5
SE	2.7	SE	2.2	SE	0.2	SE	0.2
VAR	66.9	VAR	43.3	VAR	0.4	VAR	0.2
MEDIAN	20	MEDIAN	0	MEDIAN	2	MEDIAN	1
MODE	20	MODE	0	MODE	2	MODE	1

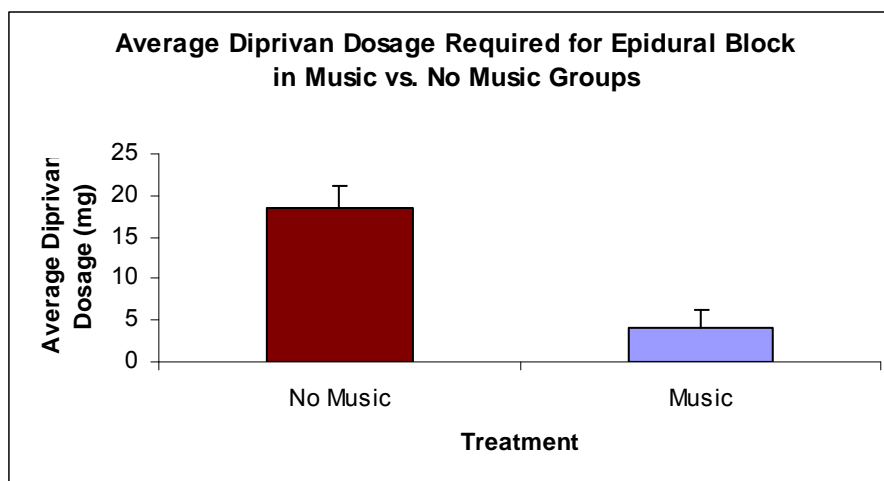


Figure 1: Average Diprivan dosage (mg) required for epidural block in music (control) group versus no music (treatment) group.

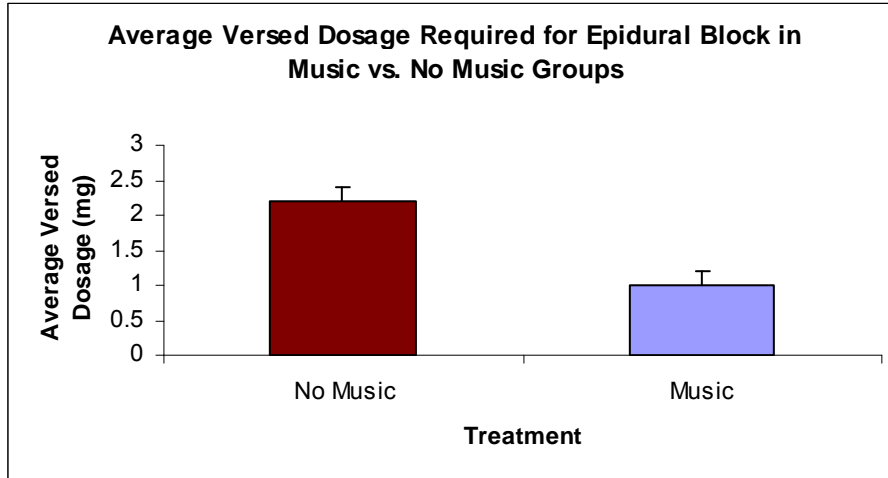


Figure 2: Average Versed dosage (mg) required for epidural block in music (control) group versus no music (treatment) group.

Part 2: Is *Dealing Melodic Medicine* Golden?: A Mathematical Analysis (Art)

A Sample Analysis for the Inaugural Math eXpressions™ 2009

Format: Essay

by Tracey T. Meilander, MEd, PhD

The Golden Ratio is one of the most pleasing and beautiful shapes in art, architecture, and nature. It is also known as the Golden Number, the Golden Mean, the Golden Rectangle, phi (Φ) or 1.61803398874989... (PhiPoint Solutions, LLC 1997). The ratio of a rectangle is calculated as length divided by width. If this ratio is approximately 1.6, then the rectangle is considered to be “Golden.” Examples of the Golden Ratio are abundant in art, architecture, and nature (Queens College 2001). The face of the *Mona Lisa*, by Leonardo da Vinci, approximates the Golden Ratio. Many works by the Dutch Modernist Piet Mondrian exhibit multiple iterations of the Golden Ratio. Both the Parthenon in Athens, Greece, and Notre Dame Cathedral in Paris, France, demonstrate the use of the Golden Ratio in architecture. In nature, the shell of the nautilus and the patterns of flowers also exhibit the Golden Ratio.

Cheyenne Richmond from North Olmsted High School was a winner of an Honorable Mention prize at the 2008 eXpressions™ art exhibition. In her linoleum print on canvas, *Dealing Melodic Medicine* (Figure 3), she interpreted the scientific research of nursing intern Anne Marie O’Toole. The rectangular artwork is divided into four smaller rectangles with the same color scheme. Each of these rectangles is further subdivided into four rectangles with alternating patterns. The same two designs, an oval pill with a small treble clef and large patterned treble clef, are repeated as a pattern throughout each of the major rectangles. In her artist statement, Cheyenne shares that each rectangle represents a playing card “to symbolize that music and medicine are both in the same deck.”

A mathematical analysis of *Dealing Melodic Medicine* was completed to determine if Cheyenne’s artwork exhibited the Golden Ratio. Since the original artwork was not available, a digital image of the artwork was utilized. As long as the proportions of the image were not altered, the measurements of the image should be in constant proportion to the original artwork (retaining scale symmetry). The largest rectangle, encompassing the entire work of art, measured 7.6 cm (length) by 6.0 cm (width) with a ratio of 7.6/6.0 or 1.3. The four medium rectangles each measured 3.8 cm (length) by 3.0 cm (width) with a ratio of 3.8/3.0 or 1.3. Each of the smallest rectangles measured 2.0 cm (length) by 1.5 cm (width) with a ratio of 1.5. Each of these ratios deviated from the Golden Ratio by approximately 20% indicating that this ratio is not present in the art and is not directly responsible for its appeal.

All ratios remained constant (1.3) from the smallest to the largest rectangles. This phenomenon may demonstrate artistic symmetry as well as repetitive patterning in Cheyenne Richmond's artwork. Humans are inherently attracted to symmetry with infants being most attracted to checkered patterns and symmetrical faces; artists may either consciously or unconsciously preferentially utilize artistic techniques that stimulate areas of the brain that respond to symmetry and pattern (Ramachandran and Hirstein 1999). These authors also suggest that grouping of patterns may heighten neurological activity in the area of the brain that responds positively to symmetry. Even though *Dealing Melodic Medicine* does not illustrate the Golden Ratio as expected, its appeal may be directly related to symmetry, repetitive patterns, and grouping.

“Without mathematics there is no art.” - Pacioli.



Figure 3. *Dealing Melodic Medicine* by Cheyenne Richmond, North Olmsted High School, North Olmsted, Ohio.



References:

PhiPoint Solutions, LLC. 1997. Phi: the Golden Number.
<http://goldenumber.net/goldsect.htm>. Searched on April 28, 2008

Queens College. 2001. Math and art: the Golden Rectangle.
<http://educ.queensci.ca/~fmc/October2001/GoldenArt.htm> Searched on April 28, 2008.

Ramachandran, V.S. and Hirstein, W. 1999. The science of art: a neurological theory of aesthetic experience. *Journal of Consciousness Studies*, 6 (6-7): 15-51.

Part 3: Why was Brian Washburne's Ransom Note *Dear Toby Cosgrove* a Blue Ribbon Winner in Literary eXpressions™ 2008?: A Mathematical Analysis (Literature)

A Sample Analysis for the Inaugural Math eXpressions™ 2009

Format: Essay with supporting tables and graphs

by Tracey T. Meilander, MEd, PhD

Dear Toby Cosgrove, a ransom note written by Brian Washburne from James Ford Rhodes High School, was a Blue Ribbon winner in Literary eXpressions™ 2008. Why was Brian's ransom note selected by literary judges for a Blue Ribbon award over other entries? Why is *Dear Toby Cosgrove* an appealing literary work? The answer to these questions may be in the simplicity of the ransom note as well as its ability to convey the message of Anne Marie O'Toole's research "Music as Medicine."

The appealing qualities of Brian's ransom note were analyzed by breaking down his literary work mathematically into component parts. The entire note included 316 words in 21 sentences with an average word count of 15.0 ± 2.8 (± 1 standard error (SE)) words per sentence (Table 2a). The standard deviation (SD) was 12.7 indicating a wide range in the number of words per sentence. The calculated range was from 1 to 43 throughout the document with a median and mode of 12 and 3, respectively. Mathematical analysis of words per sentences illustrates the fact that long informative sentences were interspersed among short succinct sentences. When represented graphically, the Word Count per Sentence shows this pattern (Figure 4) indicated by three to four peaks in the number of words per sentences throughout the document. However, these peaks did not suggest any general trend or relationship throughout the ransom note as indicated by the regression line ($r^2 = 0.00$).

The first paragraph was also analyzed for letter count per word and syllables per word in an effort to calculate the reading level of the ransom note. In the first paragraph, 446 letters were counted in 96 words from five sentences (Table 2b). The average number of characters per word was 4.6 ± 0.2 (± 1 SE). A median and mode of 4 and 3, respectively, indicate that long and short words were rare in this document. Figure 5 graphically represents the letter count per word in the first paragraph and shows that no general trend or relationship was identified ($r^2 = 0.01$). Also in the first paragraph, 145 syllables were identified with an average of 1.5 ± 0.1 (± 1 SE) syllables per word (Table 2c). Both median and mode were one, suggesting that the majority of words in the first paragraph were of one syllable.

The average sentence length (ASL) and average syllable per word (ASW) were used to determine reading ease using the Flesch Reading Ease Formula. This formula is used by educators and the United States government as a standard test to determine the

reading level of a written document. In Washburne's ransom note, ASL was calculated as 15.0 while ASW was calculated as 1.5. The Flesh Reading Ease Readability Score (FRE) was calculated using the following formula:

$$\text{FRE} = 206.835 - (1.015 \times \text{ASL}) - (84.6 \times \text{ASW})$$

The FRE for this ransom note was calculated as 65.1 which lies within the standard reading level range of 60-69. The Flesh-Kincaid Grade Level Readability Score (FKRS) was calculated using the following formula:

$$\text{FKRS} = (0.39 \times \text{ASL}) + (11.8 \times \text{ASW}) - 15.59$$

The FKRS for this document was calculated as 7.9 which indicates that the ransom note was written for an eighth grade reading level. The standard reading level average is seventh to eighth grade and most writers aim for a general readability of 7.0 to 8.0. Washburne's ransom note falls within this range.

Perhaps it is the simplicity of *Dear Toby Cosgrove* that makes the literary work so appealing to both readers and judges. Mathematical analysis of the ransom note shows that the readability falls within the standard range and is geared towards a standard reading level.

Table 2. Word analysis of *Dear Toby Cosgrove* by Brian Washburne.

a) Document		b) First Paragraph		c) First Paragraph	
Sentence	Word Count	Word	Letter Count	Word	Syllables
1	3	1	5	1	2
2	18	2	1	2	1
3	12	3	8	3	2
4	28	4	3	4	1
5	35	5	3	5	1
6	11	6	8	6	3
7	3	7	1	7	1
8	13	8	7	8	2
9	12	9	6	9	2
10	37	10	4	10	1
11	3	11	6	11	2
12	9	12	3	12	1
13	11	13	6	13	1
14	15	14	4	14	1
15	43	15	3	15	1
16	9	16	9	16	2
17	32	17	6	17	2



18	16
19	3
20	1
21	2
Sum	316
Average	15.0
SD	12.7
SE	2.8
Median	12
Mode	3

18	6
19	1
20	6
21	10
22	3
23	3
24	7
25	8
26	2
27	1
28	8
29	6
30	6
31	5
32	2
33	8
34	6
35	3
36	4
37	3
38	6
39	2
40	3
41	9
Word	Letter Count
43	3
44	5
45	4
46	1
47	2
48	2
49	8
50	5
51	2
52	8
53	5
54	6
55	4
56	4
57	2
58	3
59	1

18	2
19	1
20	2
21	3
22	1
23	1
24	3
25	2
26	1
27	1
28	2
29	2
30	1
31	2
32	1
33	3
34	2
35	1
36	1
37	1
38	1
39	1
40	1
41	2
Word	Syllables
43	1
44	1
45	1
46	1
47	1
48	1
49	2
50	2
51	1
52	2
53	1
54	2
55	1
56	1
57	1
58	1
59	1



60	7
61	7
62	3
63	7
64	3
65	9
66	6
67	4
68	3
69	7
70	7
71	4
72	8
73	2
74	3
75	2
76	6
77	3
78	7
79	6
80	3
81	4
82	8
83	4
84	1
85	8
86	3
87	3
88	3
Word	Letter Count
89	6
90	2
91	3
92	2
93	6
94	3
95	4
96	7
Sum	446
Average	4.6

60	2
61	3
62	1
63	2
64	1
65	4
66	1
67	1
68	1
69	2
70	2
71	1
72	2
73	1
74	1
75	1
76	2
77	1
78	3
79	2
80	1
81	1
82	3
83	1
84	1
85	2
86	1
87	1
88	1
Word	Syllables
89	2
90	1
91	1
92	1
93	2
94	1
95	1
96	3
Sum	145
Average	1.5

SD	2.3
SE	0.2
Median	4
Mode	3

SD	0.7
SE	0.1
Median	1
Mode	1

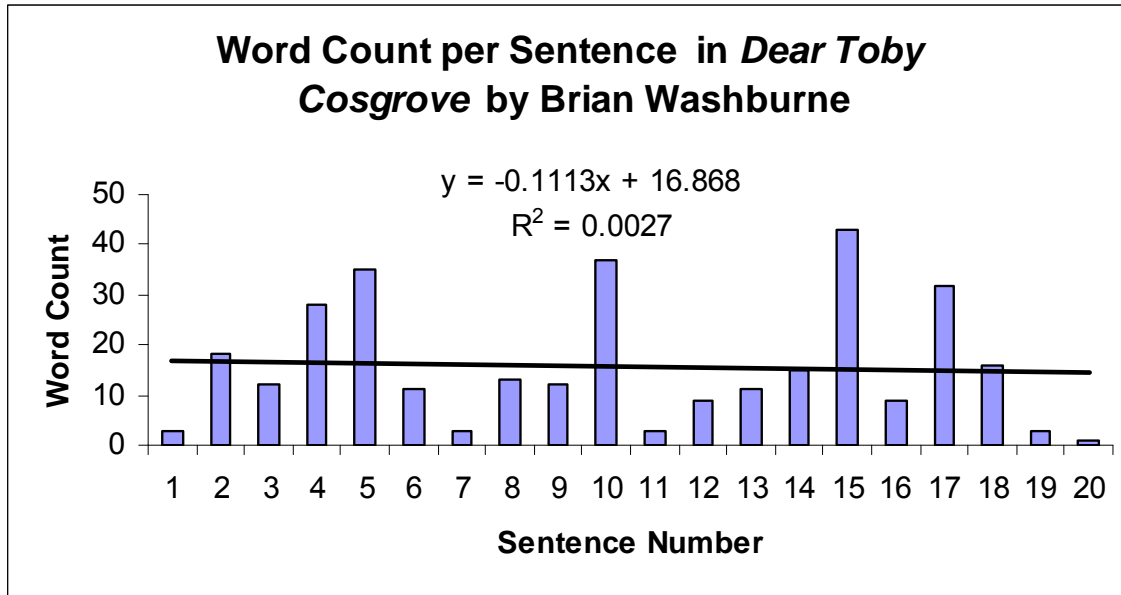


Figure 4. Word count per sentence in *Dear Toby Cosgrove* by Brian Washburne.

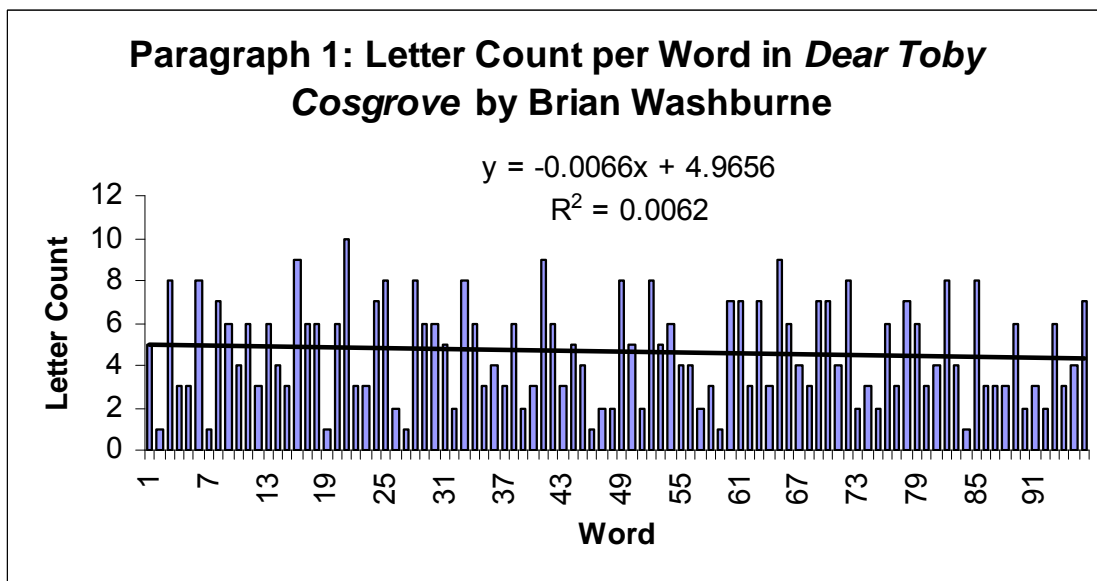


Figure 5. Letter count per word in the first paragraph of *Dear Toby Cosgrove* by Brian Washburne.



Dear Toby Cosgrove by Brian Washburne



1: Start out going WEST on EUCLID AVE / US-20 toward E 90TH ST. 0.1 miles

2: Turn RIGHT onto E 89TH ST. 0.1 miles

2.4 miles

W. 122

Delos M. Cosgrove:

You may remember a certain intern, Anne O'Toole, who worked with the Cleveland Clinic during a summer internship. She was heavily involved in a research project called "Music as Medicine." During the time she worked at the Cleveland Clinic she would play a CD of soothing music to patients right before they went in for a certain surgery. The results she cultivated showed that the average patient that listened to her CD before the surgery needed 50% less sedation than a patient who did not listen to the CD before the same surgery.

You may be wondering what this has to do with you. I will explain. Faculty in your clinic might have noticed that a certain CD went missing. Yes, the CD used in the "Music as Medicine" research is gone. You may think this is unimportant and another CD can be easily purchased, but in order to implement that change you would have to hire someone to complete the research all over again using the new CD. Why, you ask? O'Toole's research did not include other types of music. What if the new CD had a negative effect on patients? Is that a risk you, as the head of the clinic, are willing to take?

I have calculated approximately how much a new research project would cost and how much money the clinic would save on sedatives if the CD were still in the clinic's possession, and arrived at a fair price for the recovery of the CD. The cost will be ten thousand dollars in cash.

In the far right corner of the Memphis Kiddie Park's parking lot, see the directions, on the day 12/5/07 at 5:30 P.M. there will be a black briefcase, it contains the CD. Take the briefcase with the CD and in its place put a briefcase containing the money. That is all.

Sincerely,
CD Thief




Mr. Delos M. Cosgrove
c/o
Cleveland Clinic
9500 Euclid Ave., A-80
Cleveland, OH 44195



Writer Brian Washburne | Title *Dear Toby Cosgrove* | Genre Ransom Note | Award Blue Ribbon |
School James Ford Rhodes High School, Cleveland, Ohio | Teacher Audrey Schneider | Intern Anne Marie O'Toole |
Writer's Statement I wrote a ransom note for the stolen music CD used in the Music as Medicine research project.

APPENDIX A

The Effects of Music Intervention on Patients During Epidural Block Procedures

Anne Marie O'Toole, Nurse of the Future Intern
Carla Hart-Tyner RN, BSN
Carolyn Weikart RN, PhDc, Clinical Nurse Researcher
Cleveland Clinic



Hypothesis

- Listening to music during an epidural block will reduce the amount of sedation used by patients as compared to patients who did not listen to music during their procedure.

Methodology

Design

The design for this study is an experimental design that was used to examine the hypothesis that music therapy will reduce the amount of sedation utilized during an epidural block procedure. This design enabled the investigator to examine the potential cause and effect of music intervention on epidural block patients.

Procedures

Potential participants were asked to participate in the survey in the privacy of an exam room. A brief explanation of the project was given. If the subject agreed to participate, the survey was read to the participant and completed by the principle investigator. The subjects were randomized into the music intervention group or the control group, which received no music. The subjects randomized into the music intervention group then received a pair of headphones prior to administration of any sedation. They listened to music before and during the procedure. Subjects completed the survey during the following visit.

Instruments and Measures

Music intervention was recorded as a "yes" or "no." The first sedation, versed, was recorded on a 0 to 5 scale. Zero represented no medication given, 1=0.5 mg, 2=1 mg, 3=2 mg, 4=3mg, and 5=4mg. The second sedation, diprivan, was recorded on a 0 to 5 scale. Zero represented no medication given, 1=10mg, 2=15mg, 3=20mg, 4=25mg, and 5=30mg.

Data

- Survey Source Sheet
 - ID number, age, BMI, and visit number were taken down on the survey as the actual number.
 - Pain disorders were recorded as 1=yes if the patient had the disorder and 0=no if the patient did not have the disorder.
 - Pain and anxiety levels were recorded on a scale where 0=no anxiety or pain, 1=mild, 2=moderate, 3=horrible, and 4=severe.

Survey Information

ID	gender	age	sex	height	weight	visits	visits	visits	visits	visits	visits	visits	visits	visits	visits
1	1	3	75	206	1	0	1	0	4	0	2	0	0	0	0
2	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
3	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
4	1	3	75	206	2	0	1	0	4	0	0	0	0	0	0
5	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
6	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
7	1	3	75	206	2	0	1	0	4	0	0	0	0	0	0
8	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
9	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
10	1	3	75	206	2	0	1	0	4	0	0	0	0	0	0
11	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
12	1	3	75	206	2	0	1	0	4	0	0	0	0	0	0
13	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
14	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
15	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
16	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
17	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
18	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
19	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0
20	1	1	48	202	3	1	0	1	4	0	0	0	0	0	0

music * versed Count

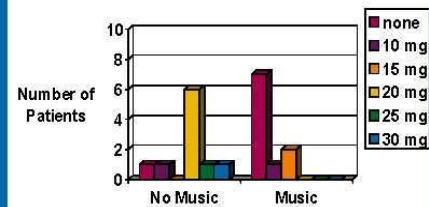
	none	versed				Total
		0.5 mg versed	1 mg versed	2 mg versed	4 mg versed	
music no	0	0	0	9	1	10
music yes	1	1	7	1	0	10
Total	1	1	7	10	1	20

music * diprivan Count

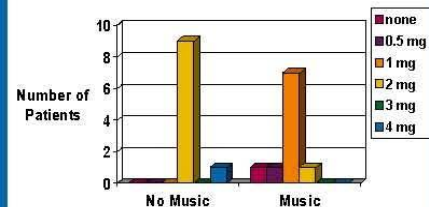
	none	diprivan					Total
		10 mg diprivan	15 mg diprivan	20 mg diprivan	25 mg diprivan	30 mg diprivan	
music no	1	1	0	6	1	1	10
music yes	7	1	2	0	0	0	10
Total	8	2	2	6	1	1	20

Results

Music Intervention and Diprivan

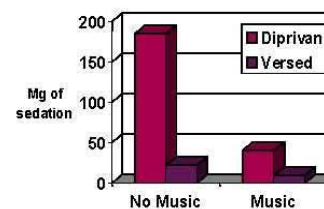


Music Intervention and Versed



These graphs compare the diprivan and versed levels of those patients who listened to music as to those who did not listen to music during their block procedure.

Total Sedation Levels



Conclusions

The hypothesis was proven correct. Patients who received music intervention required less procedural sedation during their epidural block than those patients who did not receive music intervention.

Recommendations

This study was not limited in either patient population or willing participants. The limitations imposed by the time constraints necessitated a pilot study. The pilot study showed significant results with a limited number of patients. Further investigation into musical interventions during epidural block procedure is warranted.

Patient Response

Patients who received music intervention during their epidural block responded positively to the research project. This was not only visible in the results but also in the feedback received following the blocks. Many patients requested to have music again on their following blocks. Patients are encouraged to bring their own relaxing music to listen to during their block. There were no negative responses to the music intervention, the only concern to some patients was the type of music. Overall, participants in the project were very satisfied with the effect of the music intervention.