# Using skin conductance to evaluate the effect of music silence to relieve and intensify arousal

Simon Lui
*Information Systems Technology and Design Pillar*
*Singapore University of Technology and Design*
*Singapore*
*simon_lui@sutd.edu.sg*

David Grunberg
*Information Systems Technology and Design Pillar*
*Singapore University of Technology and Design*
*Singapore*
*david_grunberg@sutd.edu.sg*

***Abstract*—Music and sound affect human emotion. There are many previous studies into the effect of music and sound on humans, but no work has yet studied the effect of silence. However, during silent performances such as John Cages 4'33", audiences are often observed to be aroused during the performance and relieved afterwards. In this paper we investigated the power of silence. Our hypothesis is that silence can change the physiological arousal, depending on the nature and perception of silence. We measured arousal by heart rate, respiration rate and skin conductance. We found that skin conductance was the most effective biofeedback to measure arousal induced by silence. The experimental results suggested that there were two kinds of silence. Intensifying silence increased the physiological arousal, and Relieving silence reduced physiological arousal. The experimental outcome can be potentially useful for music therapy and in stress relieving exercises.**

***Keywords*-Affective, biofeedback, silence, physiological arousal, music perception, skin conductance, relaxation, therapy.**

## I. Introduction

Music enhances human performance. Previous works showed that various music components can reduce body discomfort [1], induce positive emotion [2], and change the step size of walking [3]. However musical notes are not the only components in a musical work; there are also *rests*, or periods of silence. There are many previous works that discuss the importance of musical notes, but no work has yet studied silence. The silent period is an important component in music. We are inspired by the composition 433 by John Cage. This composition is three movements long. The music score instructs the orchestra not to play their instruments for 4 minutes and 33 seconds. The conductor, orchestra and audiences can not do anything else during the performance. Their arousals were highly intensified by the silent atmosphere. At the end of each movement, audiences immediately made noise and cough since they were relieved after the long silence. We hypothesize that silence can change arousal, where the change depends on the nature of the silence. In this work, we compared the effect of intensifying silence and relieving silence on physiological arousal.

## II. Background

### A. Biofeedback measures and arousal

Skin conductance (SC), also commonly known as electrodermal activity (EDA) or Galvanic skin response (GSR), is the resistance that causes variation in the electrical characteristics of skin. Arousal is one of the most important elements in studying emotion, concentration and stress. It has been proven that arousal can be studied with skin conductance. Khalfa [4] used skin conductance to classify among four emotions of various arousal levels. They found that skin conductance is very effective in measuring arousal. Another study used electromyography (EMG) and skin conductance to determine human emotion in real time when a user is playing a card game [2]. This work used the ProComp Infiniti system that is also used in this study.

### B. Relationship between music and arousal

Music and sound can affect arousal and hence performance. Lim [1] investigated the effect of synchronized music on cycling performance. They concluded that synchronizing music is better than non-synchronising music, metronome, and no music in enhancing cycling performance. In particular, synchronized music can reduce limb discomfort and enhance arousal. Styns [3] reported that synchronized music can increase walking speed. At 120 beat per minutes (bpm), walkers tend to take wider steps. There was a peak near 120 bpm in the step size versus tempo graph for all 20 participants. They found that synchronizing music enhances physiological arousal and strength such that the walker tends to walk with wider steps.

Ichihashi [5] illustrated that music arrangements such as dynamic change and octave change can affect the skin conductance of a professional pianist. Different sounds can induce different human emotions, and emotion is strongly related to physiological arousal [6]. Parsons [7] showed that the infant crying sound can induce higher pressure than the adult crying sound, and that the crying sound has higher arousal than bird sounds.

### C. Relationship between arousal and silence

People have been using music to change arousal and hence enhance performance of tasks. However no previous work has yet studied the direct relationship between silence and arousal. Silence was only used as a baseline to demonstrate the arousing effect of music on arousal. All these previous works reported that music was more arousing than silence. This is traditionally known as the

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Mozart effect [8]. People perform differently after listening to music composed by Mozart than the silent condition [9]. Clair showed that the alert response of persons with late stage dementia under silence was significantly lower than under music or reading [10]. Dousty showed that the heart rate and blood pressure of test subjects were higher when listening to music than silence [11]. However, previous studies only defined one single silence type. Instead, we defined two kinds of silence: intensifying silence and relieving silence. Our results contradict these prior studies and show that intensifying silence can be even more arousing than music.

## III. Experiment and Discussion

### A. Experiment 1: Procedure

We invited 15 males and 15 females from 16 to 35 years old with normal hearing to participate in our first experiment (mean age = 26.50, SD = 6.21). We used the ProComp Infiniti system to measure the participants heart rate, respiration rate and skin conductance while they were watching a music video. These biofeedback measures were widely used to represent the level of anxiety [12] and arousal [13] in response to stress [14]. We used the T9307M wrist strap sensor to measure the heart rate. The signal was recorded with three electrodes attached to the participants wrist. We used the SA9311M waist belt sensor to measure the respiration rate. The signal was recorded by strapping the belt around the chest just below the pectoral. We used the SA9309M finger band sensor to measure skin conductance. The signal was measured on two fingers (index, ring) of their non-dominant hand (25 of 30 participants chose the left hand).

The participants sat inside a quiet room during the experiment. We then attached sensors to their wrist/waist/finger. We measured each biofeedback measure separately so only one kind of sensor was attached at one time. Participants put on the Sony MDR-7506 headphones after the sensor was comfortably installed. Three example stimuli (10 s; silence, noise, and music) were presented to the subjects. This reduced the orienting response evoked by the first trial. Subjects were then asked to relax for 3 minutes. The baseline biofeedback was then measured and the actual experiment began.

Each participant watched two silent videos (30 db), two human noise videos taken of an audience chatting before a concert (40 db) and two music videos (70 db) in random order for each of the three biofeedback measures. The performances used for the music videos were excerpts of the 1st movement of Beethoven's 5th Symphony, Bach's Sonata No. 2 in A. Minor, Gilberto's "The Girl from Ipanema", Benoit's "Right Here, Right Now", Queen's "We Will Rock You", and Dion's "My Heart Will Go On". Thus, each participant watched 18 total videos. Each video was exactly 60 seconds long. There was at least 20 seconds of break between each video. We played the next video after the biofeedback measurement returned to the baseline level.

### B. Experiment 1: Analysis

Biofeedback measures were recorded continuously during the experiment, and we calculated the average value every 10 to 15 seconds. All signals were filtered to remove noise and unrelated information. The heart signal was band-pass filtered by 1-35 Hz. The skin conductance signal and respiration signal were low-pass filtered by 0.3 Hz and 1 Hz respectively. We performed two-way analysis of variance (ANOVA) with JMP and Statplus to analyze the significance of TIME x TYPE (silent, noise, music) interaction as well as the significance of the TIME differences on the biofeedback measurements.

The skin conductance showed a significant TYPE difference ($F_{2,501}=50.2423$, $p<0.0001$) and a significant TIME x TYPE interaction ($F_{5,498}=31.4335$, $p<0.0001$). Post hoc analysis showed that the skin conductance under music was significantly higher than under silence ($p<0.001$). The skin conductance under silence was significantly higher than under noise ($p<0.001$). Figure 1a shows the mean (and standard error) changes of the skin conductance.

The respiration rate also showed a significant TYPE difference ($F_{2,501}=22.7306$, $p<0.0001$) and a significant TIME x TYPE interaction ($F_{5,498}=12.4818$, $p<0.0001$). Post hoc analysis demonstrated that the respiration rate under music was significantly higher than under silence and under noise ($p<0.05$). However, there was no significant difference between silence and noise. Figure 1b shows the mean (and standard error) changes of the respiration rate. Although both skin conductance and respiration rate were significant, the F values of the respiration rate were less than the skin conductance.

The heart rate data showed no significant differences.

### C. Experiment 1: Discussion

Experiment one clearly showed that both skin conductance and respiration rate were significant in telling the difference among music, noise, and silence-induced arousal. In particular, skin conductance performed better than respiration rate. Heart rate showed no meaningful effect.

The outcome also showed that physiological arousal was different when listening to music, noise, or silence. In experiment one, music was more arousing than noise and silence in general. This matched the outcome of previous works [8], [9], [10], [11]. However, no previous works studied the effect of relative silence in the same piece of music. In experiment one, silence was less arousing than music because we measured the biofeedback when participants watched the same type of video for 60 s. There was no relative change during the 60 s of playback. There was only one category of silence. It was not clear if the silence was relieving or intensifying in nature. Thus, we investigated this in experiment two.

### D. Experiment 2: Hypothesis

We hypothesize that there are two kinds of silence: relieving silence, which has a relaxing effect, and 'intensifying silence', which has an intensifying effect. Intensifying

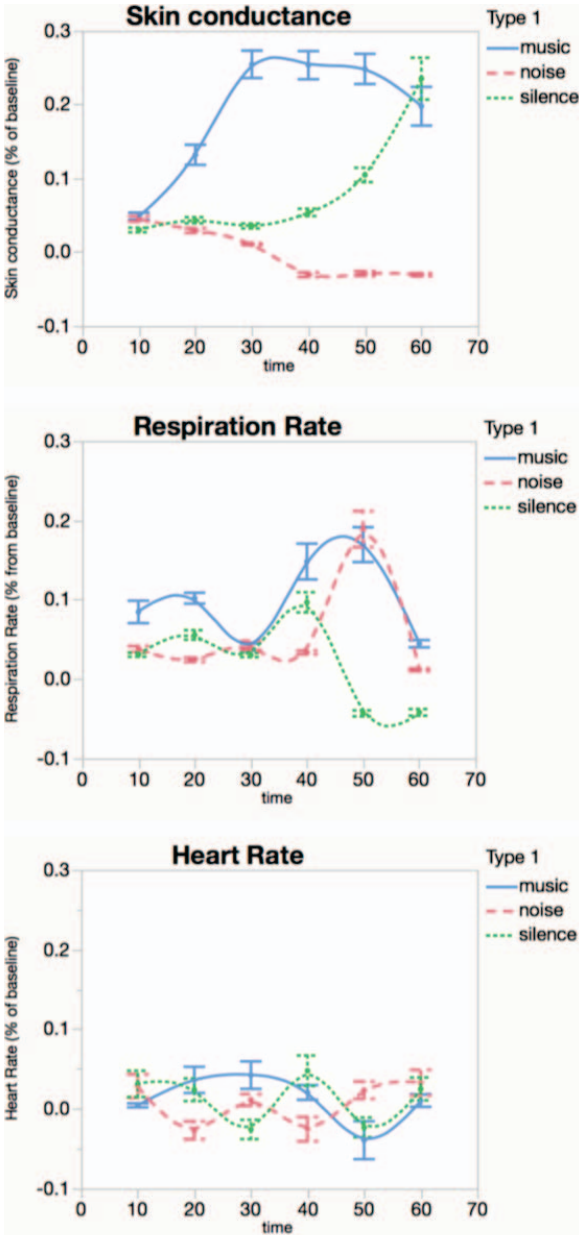


Figure 1. The mean (and standard error) changes in skin conductance a), respiration rate b), and heart rate c) from the pre-stimulus baseline (time = 0) during a successive 60 s of video playback.

silence often occurs suddenly, such as when a conductor freezes his baton before counting off and the audience quiets in anticipation. Relaxing silence is more natural.

### *E. Experiment 2: Procedure*

We re-invited 28 of the participants from Experiment 1, excluding 2 people who had not shown detectable skin conductance. Each participant was equipped with a finger band sensor to measure skin conductance. Respiration and heart rate were not measured since the first experiment showed skin conductance to better measure arousal derived from music, silence, and noise. Each participant then

| Sequence | Part I (20 seconds) | Part II (30 seconds) | Part III (30 seconds) |
|---|---|---|---|
| A | Audience noise (60 db) | Intensifying silence (<30 db) | |
| B | Audience noise (60 db) | Intensifying silence (<30 db) | Relieving silence (40 db) |
| C | Audience noise (60 db) | Intensifying silence (<30 db) | Relieving music (70 db) |
| D | Audience noise enhanced (65 db) | Intensifying silence with noise enhanced (40 db) | |
| E | Normal silence (<30 db) | | |

Figure 2. The 5 video sequences used in Experiment 2.

watched five music video sequences in random order. The duration of each music video sequence was 80 s. Each music video sequence can be divided into three parts as shown in Figure 2. In all videos, part I refers to 0-20 s, part II refers to 21-50 s, and part III refers to 51-80 s. 'Intensifying silence' was taken from the moments when a conductor raised his baton just before a music performance started, 'relieving silence' was taken from just after the performance ended, and 'normal silence' was taken from a silent nature video. The 'relieving music' was taken from the 2nd Movement of Mozart's Piano Sonata K332, a slow and gentle piano piece. Noise enhancement was performed in Audacity. There was at least 20 s of silence between each video, and we only played the next video when the measurement of the participant returned to baseline.

### *F. Experiment 2: Analysis and Discussion*

There was a significant TIME X TYPE interaction ($F_{3,164}=21.4595$, $p<0.0001$) and a significant TYPE difference ($F_{1,167}=45.4356$, $p<0.0001$) between sequences A and B in part III (51-80 s). Sequence A was more arousing than sequence B in part III ($p<0.001$). Because part III of sequence A is an intensifying silence and part III of sequence B is a relieving silence, this supported our hypothesis that there are two kinds of silence. Figure 3 illustrated how the relieving silence resolved the intensifying silence by comparing sequence A and B.

There was a significant TIME X TYPE interaction ($F_{3,164}=27.7307$, $p<0.0001$) and a significant TYPE difference ($F_{1,167}=39.1740$, $p<0.0001$) between sequences B and C at part III. Sequence C was significantly more arousing than sequence B in part III ($p<0.001$). In sequence B, the intensifying silence in part II was resolved by the relieving silence in part III. In sequence C, the intensifying silence was resolved by a relieving music. While either relieving music or relieving silence can resolve an intensifying silence, the arousal during music playback is higher than the arousal during relieving silence playback. Figure 3 shows how music and relieving silence resolved the intensifying silence in different way by comparing sequence B and C.

There was a significant TIME X TYPE interaction ($F_{3,165}=9.2144$, $p<0.0001$) between sequences A and C at part III. However the TYPE difference between sequences A and C was not significant without the TIME interaction ($F_{1,167}=1.8163$, $p=0.1796$). No post hoc comparison tests were significant. Figure 3 compares the effect of relieving music (sequence C, part III) with intensifying silence (sequence A, part III). At the end of the video,

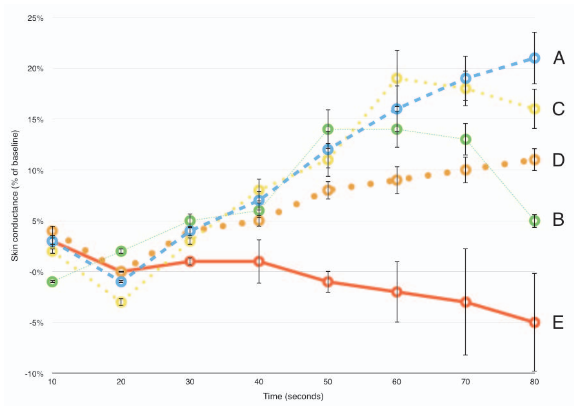


Figure 3. The mean (and standard error) changes in skin conductance that occurred during the video playback of sequences.

the skin conductance induced by silence (sequence) is higher than by music (sequence C). This contradicts the traditional understanding that music always has a higher arousal than silence. This is because the arousal induced by silence actually depends on the nature of the silence.

There was a significant TIME X TYPE interaction ($F_{1,166}$=133.7720, $p<0.0001$) and a significant TYPE difference ($F_{1,334}$=42.1668, $p<0.0001$) at part II (21-50 s) and part III (51-80 s) between sequences A and D. Sequence A was more arousing than sequence D in part II and III ($p<0.001$). This showed that a cleaner silence (hence a sharper relative change) generates higher arousal. Figure 3 shows that noise can reduce the intensifying power of silence by comparing sequence A and D.

Sequence E is a normal silence. The TIME X TYPE interaction and TYPE difference between sequences AE, BE, CE, and DE are all significant ($p<0.001$). Figure 3 shows the differences between normal silence (sequence E) and all the other sequences. Because both sequence A and E are silent in part II and III but A is significantly more arousing than E ($p<0.001$), the comparison between sequences A and E further supported the existence of intensifying silence.

## IV. Conclusion and Future Works

It was traditionally believed that music was always more arousing than silence. We illustrated with an experiment and statistics that a relative silence can actually intensify the physiological arousal. People were alerted when it suddenly became quiet. We are the first one in the current state-of-the-art who has investigated the effect of relative silence on physiological arousal. This outcome is potentially useful for music therapy, relaxation exercise, emotion training exercise, psychiatric rehabilitation, workplace safety, and human performance enhancement. In particular, previous work has shown that both caffeine and music can increase the alertness of a tired drive, but music also risks distracting a driver. Because physiological arousal is strongly related to alertness and silence is not as distracting as music, our work can be potentially extended to solve the driving safety problem. Our next step for this project is to quantify the arousing effect of silence during playback as well as the noise level and decibel change. This will involve a much larger testing scale with more participants and a more extensive set of parameters.

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