The Effect of Music on the Level of Mental Concentration and its Temporal Change

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Abstract: Concentration is one of the most important factor in determining the efficiency of learning. There has not been, however, much systematic research on controlling the level of concentration. We therefore examined the effect of an external factor, namely playing music, on the performance on a task that requires much attention. We compared three conditions: music that the subject likes, music that the subject is not familiar with, and silence. The result showed that listening to music that the subject likes do increase the performance level. Also, we discovered that there exist different temporal patterns in the change of performance. The result also indicated a relationship between the temporal pattern in concentration and the external factor.

1 INTRODUCTION

The efficiency of learning is highly dependent on the mental state that the person is in. When the person is highly concentrated, he can understand and memorize many complicated concepts in a short period of time, whereas when he is not concentrated, he cannot learn as effectively.

Although the change in the level of concentration is in part a spontaneous process, it is nevertheless affected by external factors as well. The effect is evident when one considers how productive he can be when the deadline is approaching. Surprisingly, there has not been much work in changing the environmental factors to create higher performance in learning.

Various books describing techniques to enhance concentration have been published, but most of them are solely based on personal experiences rather than objective experiments. For example, many students listen to music while they study at home. They seem to have learned from their experience that music increases their level of concentration. There has not been, however, much work on evaluating if music could be used to control the level of concentration.

In contrast to education, there is an extensive amount of research in the field of sports science, where all efforts are put to win a competition (Katch and Katch 1999). Physical and mental quantities of athletes are measured and analyzed to reach highest performance. The approach here is more objective and quantitative. If such approach was successfully applied to education the effect would be tremendous.

One of the ways to measure the effect of music on learning is to measure how concentrated the subject is. In this paper, we describe a system aimed at measuring the level of concentration based on the performance of the subject. We compare three conditions, namely playing music that the subject likes, playing music that the subject is not familiar with, and silence. The overall performance of the subject and the temporal change in the performance level will be compared and analyzed, to objectively evaluate if music have positive or negative effect on concentration.

The rest of the paper is organized as follows. In Section 2 we describe our model of concentration, and factors that would affect it. Section 3 is on implementation of our system. It is followed by Section 4 where we illustrates the design and the result of the experiment. Section 5 is on related work. Finally, Section 6 concludes the paper.

2 MODEL

For a person to learn something new, he/she has to be attentive to the content of learning. When a certain amount of contents are to be learned, sustaining at-

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tention for a certain amount of time is a requirement.

In this paper, we define concentration as a sustained high level of attention to the task. In order to measure it, we therefore employ a task that requires attention. Figure 1 illustrates the overall construction of our model. Arrows indicate causal relationships. Concentration is determined by internal parameters, which is affected by external factors. By changing the external factors, we assume it possible to change the level of concentration (or attention).

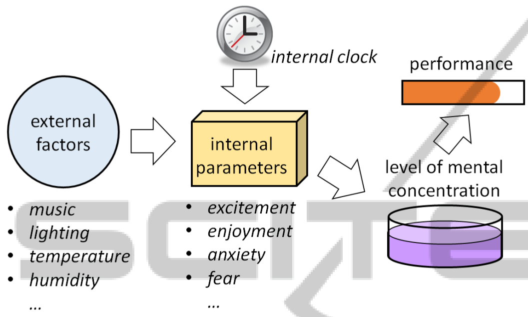

Figure 1: External factors and internal parameters.

In this paper, we mainly focus on how music and time affect the performance level on a task that requires concentration. We discuss the model in more detail in the following subsections.

2.1 Attention and Learning

In cognitive science, much work has been done to explain how attention affects different aspects of learning. The main position is even stated that there is no learning without attention (Schmidt 1995). A number of researchers have argued that different types of learning (e.g., explicit and implicit) depend on attention (Tomlin and Villa 1994).

Studies have inferred that attentional mechanisms is essential for all learning even for simple perceptual task (Ahissar and Hochstein 2002) and that more complex learning requires more attention (Schmidt 1995). One established principle of visual attention is that the harder a task is, the more attentional resources are used to perform the task and the smaller amount of attention is allocated to peripheral processing because of limited attention capacity (Huang and Watanabe 2012).

2.2 The Effect of Emotion on Attention

Some researchers have discussed that excitement may enhance attention and facilitate flexibility. On the other hand, it has been pointed out that positive mood may reduce the subject's performance (Schwarz and Clore 1983, Schwarz and Clore 1988, Rank and Frese 2008). When a subject experiences positive affective states, he assumes he is performing sufficiently well thus he withdraws effort. Also, in Cerin et al.'s model predicts that, in general, an affective profile characterized by mild to moderate intensity levels of threat-related affects (e.g. fear and apprehension) and affects conducive to or associated with approach behavior and task-focused attention (e.g. interest, excitement and enjoyment) will be perceived as facilitating performance (Cerin et al. 2000).

We however consider that the balance between excitement and calmness is important. If a person is overexcited, it often happens that he is distracted by any small stimuli and cannot concentrate on the task. On the other hand, if one's mind is too calm or relaxed, he would not feel like doing anything. The level most appropriate for a task lies somewhere in between excited and relaxed. We assume that listening to music that one likes has a modulating effect, with excitatory and inhibitory factors, helps achieve the best performance. Some music excites and other music calms. We assume that people know from experience which music is best for them to modulate music to sustain his/her level of attention. We test this hypothesis through experiments described in this paper.

2.3 Temporal Change in the Level of Attention

Time has various effects on cognitive performance (Grondin 2008). For example, it has been pointed out that attention is limited in time (Nobre and Coull 2010). Humans cannot sustain a high level of concentration for a long period of time. Learning is no exception. In practice, it is important to know how the level of attention changes, how it can be recovered, in order to make humans more productive.

It is also known that there are various rhythms in mental processes, from short ones to long ones (Buzsaki 2006). The level of concentration does not monotonically decreases either. It may have some rhythm, or it may rise as the end of the task approaches. It may follow different patterns other than rhythms, for example constant decrease in performance. By measuring the temporal change in performance, we try to uncover the temporal change of concentration. In this paper, we try to uncover such different patterns through experiments.

3 IMPLEMENTATION

We implemented a system aimed at controlling the level of concentration. In this section, we first describe a way to measure it, then describe the actual implementation.

3.1 Measurement of Mental Concentration

Our system measures the level of concentration using the amount of time required to perform a task that requires attention. It is based on a "conjunction search" task, where the subject is presented with signs that have combinations of features, such as shape, color, and orientation (Bergen and Julesz 1983). Figure 2 shows an example of the image presented to the subject when using our system.

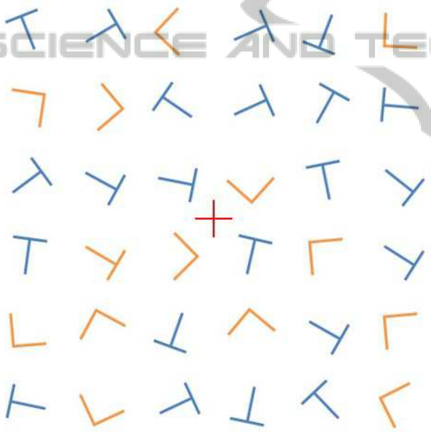

Figure 2: Conjunction search task.

The subject is presented with 100 signs, aligned into 10 rows and 10 columns, shown on a computer screen. Signs are in two types, namely T and L, and in two colors, blue and orange. The subject is asked to find a sign that is different from the rest in two aspects. For example, about half of the signs are blue T, and about the half are orange L, but there is one exception, either orange T or blue L. Once the subject finds it, he presses a key, and then the next trial starts. The exceptional sign is presented at different location each trial.

Usually, it is easy for a subject to find an exceptional sign when there is only one feature involved (Duncan and Humphreys 1989). It is an unconscious process, and the exceptional sign "pops out". In other words, the subject notices the exception without paying much mental effort.

On the other hand, one that is exceptional because of a combination of features, it requires much more time to find it. Usually, it requires conscious process for searching it. It means that consciousness is involved in the combinatorial search process. Considering the usual assumption that consciousness is closely related to attention, the task requires much attention, or concentration. By measuring the time required to find the exception, we can quantitatively evaluate the level of concentration. This type of test is widely used in psychology to measure the level of attention put by the subject.

In our system, the subject can click a sign by moving a pointer using the mouse. If the clicked sing is not the exceptional one, it is recorded as a mistake. By a preliminary experiment, we checked that time required for moving the pointer to the exceptional sign is negligible compared to time necessary for finding the sign.

3.2 Environmental Factors

As a control factor to affect the internal parameters, we chose to focus on music. Music affects emotion, making a person feel happy or sad. It is natural to think that it may affect internal parameters mentioned above. It has already been pointed out that it improves performance on spatial tasks (Schellenberg et al. 2007). Our experiments are to see if this is also true for tasks that involve concentration, and see if it can be quantitatively and systematically measured with an aid of a computer program.

In our experiments, we compared 3 conditions listed below.

1. Silence.
2. Music that the subject likes.
3. Music that the subject is unfamiliar with.

We chose to compare between music that are liked by the subject and that the subject is unfamiliar with. We assume that when the subject is listening to the music that he likes, performing the task becomes more enjoyable.

We asked the subjects to name a song that he/she likes, and used it in the experiment. For unfamiliar music, subjects were provided with music liked by other subjects, after checking that he/she is actually unfamiliar with it.

Using music that the subject likes is to determine the effect of enjoyment on concentration. The goal of our experiment is to determine whether the effect comes directly from the music itself, or is strongly influenced by the subject's liking to it.

3.3 Software

For implementing our system, we used PsychToolbox (Brainard 1997, Kleiner, Brainard and Pelli 2007), which is a set of functions run on Matlab, aimed at vision research. PsychToolbox contains various functions that could be used for creating psychological tests. For implementation, we used Octave, a Matlab compatible software.

4 EXPERIMENTS

We performed experiments on 12 subjects. All of them were undergraduate and graduate students, ranging from a freshman to 1st year in master's course. Using our system, we measured the number of trials each subject could perform during a set amount of time (15 minutes), under different conditions. Subjects were asked to perform trials as many times as possible. In other words, they were asked to find exceptional signs as fast as possible.

The types of music that were played were mostly pop music, with lyrics. There were up-tempo ones and slow-tempo ones, depending on the preference of each subject. When we could, we chose unfamiliar music from those that were liked by other subjects. This was to avoid the effect that comes from the types of music, for example the positive effect on concentration that may arise from listening to up-tempo music.

4.1 Comparison among Subjects

The numbers of trials that the subjects could perform under three conditions mentioned in the previous section is indicated in Table 1. The three conditions were silence, playing music that the subject likes, and playing music that the subject is unfamiliar with.

It shows scores for each condition, which are the numbers of trials that the subject succeeded within the time limit of 15 minutes. If the subject could complete each trial in a shorter time, he gets a higher score.

To avoid the effect from the subject getting used to the task and performing better in the latter part of the experiment, we arranged the conditions in different orders. The order of conditions the experiment was carried out for each subject is indicated by the second column of Table 1, using order IDs. The order is explained using Table 2.

The result shows that the average score were highest when the subject was listening to the music that he likes. The second highest was when he listened to the music that he is unfamiliar with, and the lowest was for the silence condition. It indicates that performance can be improved using music.

Table 1: Scores of subjects under different conditions.

Subject	Order	Silence	Like	Unfam.
A	I	98	89	113
B	I	86	84	84
C	II	119	119	96
D	II	54	61	69
E	III	71	72	62
F	III	106	132	109
G	IV	88	96	93
H	IV	109	105	105
I	V	116	131	138
J	V	115	110	112
K	VI	54	51	43
L	VI	40	56	53
Total		1056	1106	1077
Avg		88	92.17	89.75

Table 2: Order of testing.

Order	Silence	Like	Unfam.
I	1st	2nd	3rd
II	3rd	2nd	1st
III	2nd	3rd	1st
IV	2nd	1st	3rd
V	1st	3rd	2nd
IV	3rd	1st	2nd

Table 3 shows the number of mistakes made by the subjects when carrying out the test. It shows that the number of mistakes was least when the subject was listening to the music he likes. Figure 3 illustrates the same information as a graph.

Table 3: The number of mistakes made by subjects.

Subject	Silence	Like	Unfam.	Total
A	0	1	1	2
B	1	0	0	1
C	0	0	0	0
D	2	0	2	4
E	0	2	2	4
F	0	0	0	0
G	0	0	0	0
H	1	0	0	1
I	0	0	0	0
J	3	1	1	5
K	0	1	1	2
L	2	0	0	2
Total	9	5	7	21

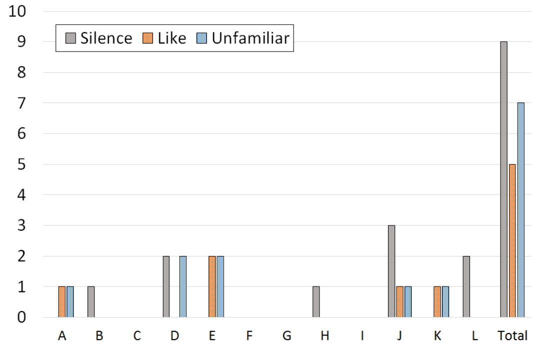

Figure 3: The number of mistakes made by subjects.

4.2 Temporal Change in Performance

In the experiment, each subject was asked to perform the task for 15 minutes, for each condition. After performing a task under one condition, the subject takes 5 minutes break.

Since the task is rather simple, so it is assumed that the subjects get tired with the task, or bored, which would lower the performance. Unless a high level of concentration is maintained, the performance level of the subject is unlikely to be constant.

Figure 4-9 shows one example of the change in the performance level as a subject did a sequence of trials. The x-axis indicates the trial ID and the y-axis indicates the time it took for the subject to complete that trial, i.e. to find the exceptional sign and click it.

The sequence of the times taken for finishing trials was considered as a function of sample points in time. We applied second order polynomial fitting to this function. The polynomials are also shown in the figures. They show the gradual changes of the performance levels.

Based on an observation, we grouped the result into three types. Type 1 is the case when the performance level does not change much. In this case, the polynomial is nearly constant. Type 2 is that the performance worsens as the time passes. In this case, the polynomial is a nearly linear increasing function. Type 3 is when the performance is best near the beginning and near the end, and worse in the middle. In this case, the polynomial is a convex function with its maximum in the middle part of the trial sequence. This is summarized in Table 4. In the table, a_2 is the coefficient of the quadratic term and a_1 is the coefficient for the linear term, for the second order polynomial fitting. Note that the performance is better when the y-value is lower.

The frequent appearance of Type 3 (high in the middle) was interesting, possibly indicating the rise in the performance level when the deadline is approaching.

In general, the overall performance level (the score the subject obtained) was highest for Type 1 and lowest for Type 3. Also, Type 1 was most frequent when the subject was listening to the music that he liked. On the other hand, Type 3 was most frequent when the subject was in the silence condition.

The result indicates that listening to preferred music condition raises the overall performance because it reduces occasions where the subject cannot find the exceptional sign and takes unusually longer time to finish the trial.

Table 4: Types in the temporal change of performance.

Type	**Polynomial fitting**	a_2	a_1
Type 1	Roughly constant	$a_2 \approx 0$	$a_1 \approx 0$
Type 2	Increasing	$a_2 \approx 0$	$a_1 > 0$
Type 3	High middle, low ends	$a_2 > 0$	

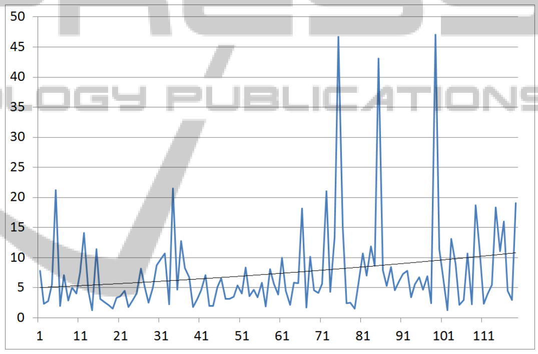

Figure 4: Temporal change under the silence condition (Subject C, Type 2).

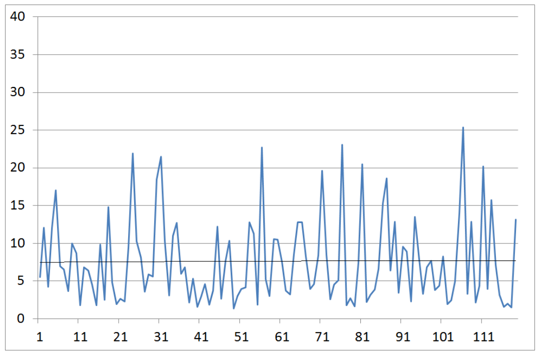

Figure 5: Temporal change under the liking music condition (Subject C, Type 1).

The regression curve may seem to be dependent on large values that intermittently occurs. However, since one of the aims of our experiment was to see the lack of attention, the fact that the subject took a long time to find the exceptional sign does carry information. We did not consider them as outliers.

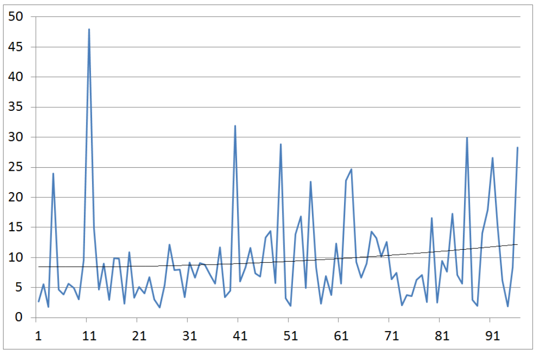

Figure 6: Temporal change under the unfamiliar music condition (Subject C, Type 2).

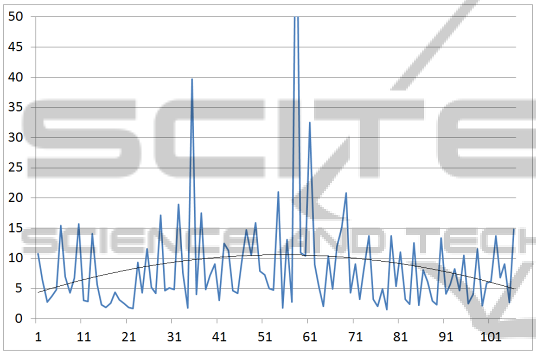

Figure 7: Temporal change under the silence condition (Subject F, Type 3).

4.3 Discussion

Our result that music affects the level of concentration have various application in the daily practicality of learning. When doing self-study, selecting appropriate music would help raise the performance. Even in a classroom, when it is not a lecture-style class but is a practice-style, it might help students by allowing them to listen to music while solving problems.

Teachers may even advice students to try out different types of music while studying, since our result indicates that familiarity to music may affect the temporal change in the level of concentration.

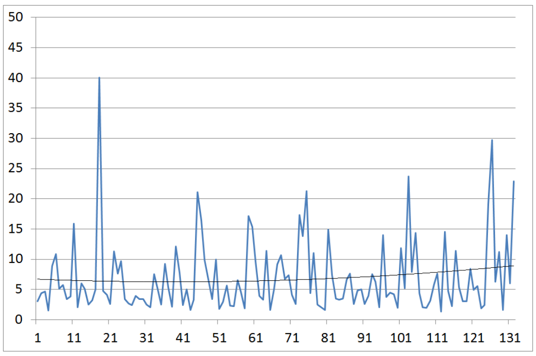

Figure 8: Temporal change under the liking music condition (Subject F, Type 1).

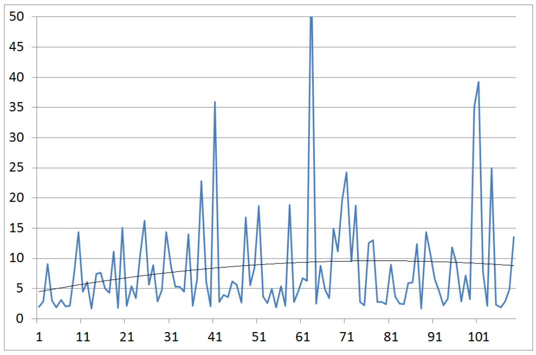

Figure 9: Temporal change under the unfamiliar music condition (Subject F, Type 3).

Also, the method proposed in this paper to measure the level of concentration may be used for other purposes too, for example to know how long a subject can stay concentrated in learning.

5 RELATED WORK

In this section, we discuss related work from different aspects.

5.1 Factors That May Affect Mental Concentration

Onyper et al. tested a group of subject to solve puzzles or memorize items, while chewing gum (Onyper et al. 2011). They were compared with another group that did not chew gum during the test. The result indicated that chewing gum has positive effect on the subjects' performance. They state that chewing gum may wake you up and increase the level of concentration.

Nittono et al. found out that when the subject is presented with a cute ("kawaii", in recent terminology) picture preceding a task, his performance increased (Nittono et al. 2012). Although they hypothesized that a cute picture makes the subject focus on the details of it and increase his performance, it could also be resulting from the increased level of concentration due to excitement or enjoyment.

Our work is different from existing work in that it focused on music among many possible factors. It is also different in that it intended to capture the temporal change in the level of concentration in a short time span, i.e. in the order of seconds, which is much shorter than usually considered.

5.2 Cognitive Performance While Listening to Music

Rauscher et al. reported the superior spatial abilities for participants who listened to a recording of music composed by Mozart compared to those who sat in silence or listened to relaxation instructions (Rauscher, Shaw and Ky 1993). Because the performance was better on the spatial tasks after listening to Mozart, this result became known as the Mozart effect (Schellenberg 2005). Reviewing studies that examined effects of listening to music on cognitive performance can be divided to two general group: performance after listening to music and performance while listening to music or background music. Despite the difference, it is pointed out that music influences a wide range of behaviors including cognitive performance (Schellenberg 2012). In these studies, however, it was not checked whether the subjects actually liked Mozart. In comparison, we made a distinction between music liked by the subject and the one that the subject is not familiar with. Our result showed that while music itself raises concentration, the one that is liked works even better.

Shih et al. compared how music with, and without, lyrics affects human attention (Shih, Huang and Chiang 2012). Background music with, and without lyrics, was tested for effects on listener concentration in attention testing using a RCT (randomized controlled trial) study. The findings revealed that, if background music is played in the work environment, music without lyrics is preferable because songs with lyrics are likely to have significant negative effects on the concentration and attention of worker.

Patston and Tippett examined the overlap between music and language processing in the brain and whether these processes are functionally independent in expert musicians (Patston and Tippett 2011). A language comprehension task and a visuospatial search task were performed under three conditions: music-correct, music-incorrect, and silence for expert musicians and non-musicians. The performance of musicians was negatively affected by the presence of background music compared to silence when performing a language comprehension task. In contrast, the performance of non-musicians was not affected on either the language task by the presence of music played either correctly or incorrectly.

Cassidy and MacDonald studied the effects of HA (music with high arousal potential and negative affect), LA (music with low arousal potential and positive affect), and everyday noise, on the cognitive task performance of introverts and extraverts (Cassidy and MacDonald 2007). Performance was decreased across all cognitive tasks in the presence of background sound compared to silence. HA and LA music produced differential distraction effects, with performance of all tasks being poorer in the presence of HA compared to LA and silence, in the presence of noise than silence across all tasks, and in the presence of noise than LA in three of the four tasks.

Furnham and Strbac examined whether background noise would be as distracting as music (Furnham and Strbac 2002). In the presence of silence, background garage music and office noise, subjects with introvert and extravert personalities carried out a reading comprehension task, a prose recall task and a mental arithmetic task. Results found a significant interaction between personality and background sound on comprehension task only, although a trend for this effect was clearly present on the other two tasks. Participants performed best in silence, background music was second best for performance, and background noise was lowest results.

The existing work mainly focused on making comparison among music, silence and noise, whereas in our work music liked by the subject is compared with unfamiliar one. In this sense, it is more related to the emotion of the subject. Also, the existing work has not discussed much on how listening to music may affect the temporal change in the level of concentration. We designed and carried out experiments to check this effect.

5.3 Music for Enhancing Learning

Researchers from psychology as well as sociology have attempted to explain the importance of music for intellectual development by focusing on a variety of cognitive ability. Singer (Singer 2008) and Barker (Barker 2008) reported that music increased the chance students remembered what they had learned, by assisting the recall of information. Binkiewicz discussed the idea that songs are powerful pedagogical tools that enliven a classroom and enhance student learning in an enjoyable manner (Binkiewicz 2006).

When music is utilized learning, positive results occurred in achievement. Music showed positive impacts on achievement as Southgate and Roscigno assessed three patterns of music participation: in school, outside of school, and parental involvement in the form of concert attendance and possible effects on math and reading performance for both elementary and high school students (Southgate and Roscigno 2009). Their study captured the significant influence of music involvement for both math and reading achievement.

Paquette and Rieg described the benefits of incorporating musical experiences into daily instruction and argued that integrating experiences with music in the childhood classroom supports English language learners' literacy development (Paquette and Rieg 2008). Sims examined the effects of high versus low teacher affect and active versus passive student activities during music listening on preschool children's attention (Sims 1986). Data obtained through observation indicated that children were most attentive during music listening activities when the teacher exhibited high magnitude nonverbal affect, and when they were given a hand-movement activity in which to participate.

Our paper focused on the effect of music on the level of concentration, which is related to performance in general, rather than specific tasks in learning. By focusing on a simple task rather than complicated ones, we believe that we could quantify more fundamental parameter that affect the level of performance.

6 CONCLUSION

In order to increase the concentration level and raise the performance in learning, we implemented a system for measuring it, and examined the effect of an external factor, namely playing music that the subject likes. The result showed that playing music does have positive effects on the level of concentration, which would contribute to the performance level.

In future work, we would like to carry out experiments using more subjects, to make our result more statistically reliable. We would also like to look at the temporal patterns of concentration in more detail. We would like to see if there is actually rhythms for concentration, as mentioned by Buzsaki for different mental processes (Buzsaki 2006). We would like to explore this, for example using frequency analysis. We also plan to carry out more controlled testing, using a larger number of subjects, to validate our hypothesis.

We also plan to explore modulation of the excitement level using music, and see if the concentration can be improved. When the subject is too relaxed, we make him listen to excitatory music, and while the subject is overexcited, we make him listen to inhibitory music. We would like to see if the concentration level can effectively controlled that way. We expect the result to provide a fundamental basis for creating the environment most suited for learning.

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