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Individual Preference for Health, Recovering Environments and Keeping Peace

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ABSTRACT

Health and peace as well as environment are most concerned with individuals, and who should be responsible, because we have been directly suffered by damages. Unfortunately it has been unexpected to solve, at all, basically such a global problems by political and enterprise people. It is obvious that such a global approach by, for example, exercising-power-of-veto should be changed before dying environments that has been developed for hundreds of millions of years by nature. Now, we wonder we will be able to see 2100. It is now turnings point from the first and second stages of life same as animals, to the third stage of human life. Human life consists of 1) life of body; 2) life of mind, and 3) life of original idea and creation are based on a unique individual personality called the third stage of life that may persist long after the individual has passed on. Thus, the individual is called primate of all things and the lord of creation. The third stage of life is the most unique and preferred to individuals that makes lives longer than the first and second stages of life (Ando, 2016. Brain-Grounded Theory of Temporal and Spatial Design in Architecture and the Environment. Springer Tokyo). The Industrial revolution was occurred in the eighteenth century with speedy transportations supporting mass industrial productions has resulted environmental disorder represented by such as restraining the discharge of carbon dioxide which is one cause of global warming and is the most influential in greenhouse gasses. Also, ill concept of "time is money" that brought various stressors and related serious illnesses occupied throughout the world. At the same time by ever-increasing number of excellent economic people with high education, unfortunately they subject to unable to perform any creation toward the third stage of life.

1. INTRODUCTION

1.1. From Majority Based Society to Individual Based Society

The word "stress" was never used before the 1950s, and the number of operating central hospitals was considerably lower. Nowadays, it is normative that human life is so occupied by a wide range of stressors including ill human relations that the pleasure derived from the process of living is regretfully often drained away by stress. Serious illness such as cancer, kidney disease, dementia, intractable pain disease and others due to various stressors spread around the world (Ando, 2018b). These need tremendous amount of money resulting into negative spiral of society throughout the world. It is worth noticing that wars occurred according to lack of life goods and financial economy as well as varieties of stressors due to ill concept "Time is Money." These were resulted by majority-based society.

We emphasize here original idea and creativity, realized as preferred individual activity resonating with personality associated DNA, and with the left and right cerebral hemispheres, respectively, temporal and spatial aspects (Sections 3.2 – 3.4). Most generally, subjective preference is regarded as a primitive response of living creatures that entail judgments that steer an organism in the direction of maintaining life, so as to enhance its prospects for survival. It is worth noticing that preferece is not luxurious, therefore, it may deeply be associated with base of aethetics. Let us focus our attention on the third stage of life for each individual through the human-brain grounded theory of temporal and spatial design in architecture and the environment (Ando, 2016) as a most effective channel for the expression of life-preference resonating with personality related to DNA.

In order to attain healthy creations by living in a preferred environment, avoiding ill treatment of the self and others, and further wars. This paper introduces our inherent, built-in survival power by means of a dynamical theory of individual preference amid various stressors of life as mentioned in Section 3.1 (Ando and Jõgi, 2019).

1.2 Individual Based Society

For temporal design of the human environment, three stages of life are considered here, which is granted to each individual person at birth. The first is the physical life, the second is the spiritual and mind life. These two are in common to animals; only differences are just degrees. The third is very human as shown in Figure 1.1; the noblest among the three is “the third stage of life”.

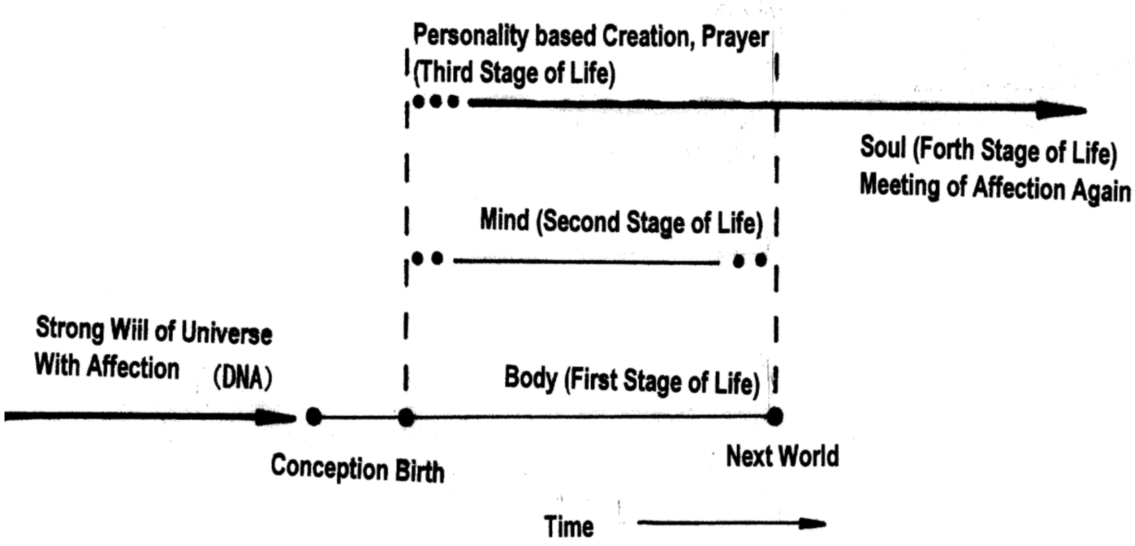

Figure 1.1 Three stages of human life defined that are taken into consideration in designing the temporal and spatial environment (Ando, 2016).
Human life consists of 1) life of body; 2) life of mind, and 3) life of original idea and creation is based on a unique individual personality that may persist long after the individual has passed on possibly as culture. The third stage of life is the most unique and joyful to human that makes philosophically wider and lives longer than the first and second stages of life. The third stage of life could be outgrown to the forth stage of life (Danjo, 2014).

According to different DNA and environment of each individual in which one grow up, each of us may have a unique purpose to be found and work on throughout the lifetime. At the same time, individual healthy life could be realized in all of three levels of life by the temporal and spatial design of environment (Ando, 2016). Particularly, if one awares the personality realizing unique creations to be integrated as culture, then one can enjoy every time till the end of healthy life.

It is worth noticing that all of people may cover together all of fields needed for health, maintaining environments and keeping peace in the whole world. It is lucky and wonderful facts to have all individuals born in different DNA or different personality availabile for original idea and creations throughout time and place (Figure 1.1). Only need is to educate individuals finding the wonderful personality for different creations, instead of so called "artificial interigence."

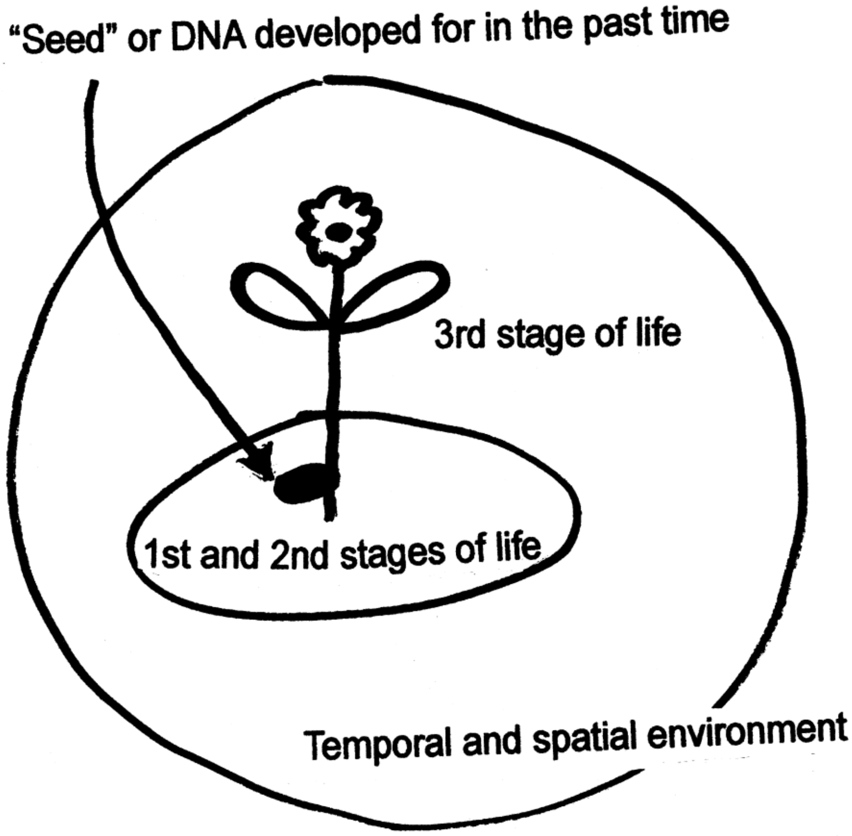

Figure 1.2 Development of the third stage of human life originated from individual personality (DNA) "seed" that is nurtured in preferred or esthetic temporal and spatial environment (Ando, 2016). Everyone is a genius because of different DNA given by Nature. Personality (DNA) for unique idea and creation may be well developed and effloresced like a flower of plant. This is the third stage of life and great possibility to remain as a parting gift to be the forth stage of life (Danjo, 2014). There are huge numbers or rather infinite countable number of fields are unknown to be clarified by individuals who are existing over the earth, about 7.55 x 10^9 at present time.

It goes without saying that science and art are always immature, because these are limited and ever under developing. They say that the 19th and 20th centuries were the era, in which technology made rapid progress. However, there existed all sorts of destructions behind such progress as a result. Those were namely environmental destructions and wars. It was probably because we were overconfident about science and technology, which was merely a tool for mankind. In order to make a coming age of human life into reality, it is desired to understand mankind itself better with the third stage of life. On this account, we should prepare an environment where every man's sensitivity, which do not incline to science but include art that can be enhanced.

The question of how many years mankind will be able to survive is the primary factor of individuals and social concern. There have been major wars under the plea of the racial liberation, religious liberation or the liberation of a state, and such possibility cannot be denial at present. Therefore, we hope to make "liberation of unique individuality (the third life)" one of ultimate objective of this paper. The liberation of individuality here means to accept diverse valuable individualities of yours and others, and cultivate creativity, which can only be achieved by each individual potential (Figure 1.2).

A well-designed environment would be a meeting place for art (aesthetic) and science (Sections 3.2-3.4), and, in turn, may help to discover the individual personality as the minimum unit of society. Everyone is a genius because of different DNA given by Nature. Temporal and spatial factors associated with the left and right cerebral hemispheres, respectively, may be well designed blending of a built environment and the Nature (Ando, 2009, 2016). Such environments, in turn, may help for development of human cerebral hemispheres, especially for the period during from the very beginning of life to about three years of age. It is said that the soul of a child of three is the same at 100.

Space (land) was thought to be a personal possession, and time was thought to be equal in the past. But in fact space including environment is something common to all mankind from generation to generation, and time does belong basically to individuals. It is ideal to build environment as well as a society where people can enjoy healthy physical, spiritual and individual time for assisting original idea and creation, ex. Creartive Work Space, CWS (Ando, 2016).

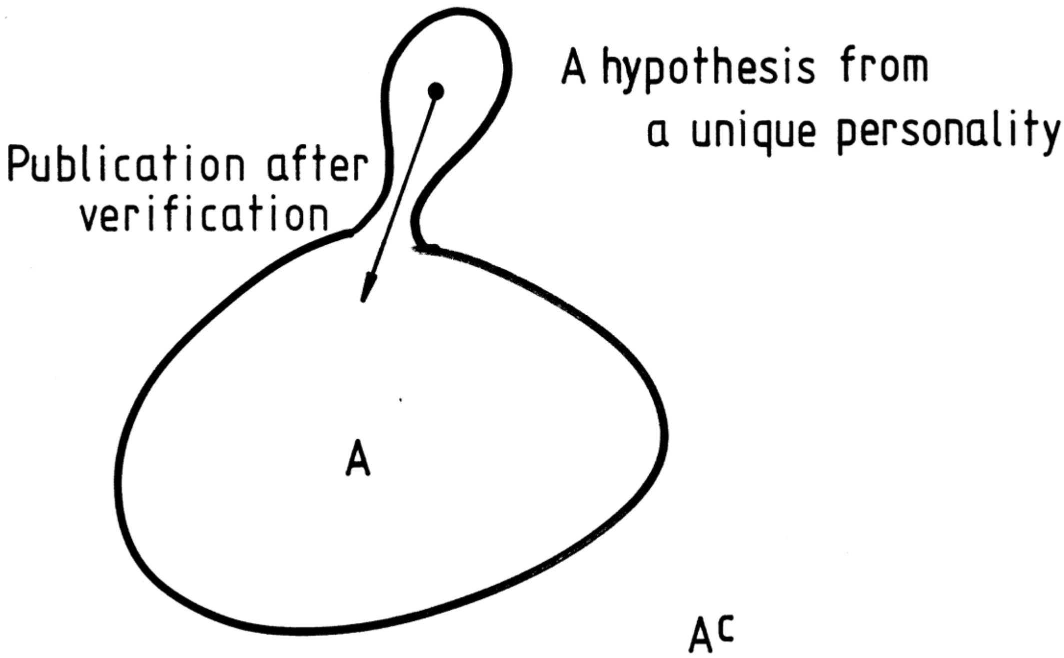

Figure 1.3 Sets of known A and unknown A^C. Creations start to have a hypothesis from a unique personality. After verification of the hypothesis, it may be published. This is a process of the third stage of life. When this kind of creations is integrated, then we call it "culture" (Ando, 2016).

Above all, we would like to define the nurture of creativity (making a contribution generation after generation) originating in individual time, which is unique to mankind, as the liberation of individuality. In other words, there are mysteries solvable only by each person's individuality due to different personality (DNA) and different viewpoint, which will never be generated again. Such a solution may only gain its eternal value once it is unveiled, but it is no exaggeration to say that those mysteries remain unsolved if solutions were unfound as a result of uniform education (Figure 1.3).

Mysteries of this sort exist in a place of every human activity, and providing a place for each individual to nurture a task, given to him/her and sprout out at their heart shall be the starting point of education and creation. We believe that this kind of education will be ultimately established, so that human and global environment (time and space) contributes to a healthy development of culture and science. For above reasons, it is ideal to liberate the original individuality from all idol worships of mere economic efficiency, status, reputation and so forth. Such idea of an individual liberation will not only be a process towards peace as it entails mutual respects but also hold hidden potential of becoming the path to protect all lives from environmental destructions. In order to develop individual personality and creation and any activity, we are attempting to provide a temporal design of our environment for the third stage of life as a hope for living, in addition to the first and second lives. That might be a base of each individual and development of healthy society and environment (Figure 1.4).

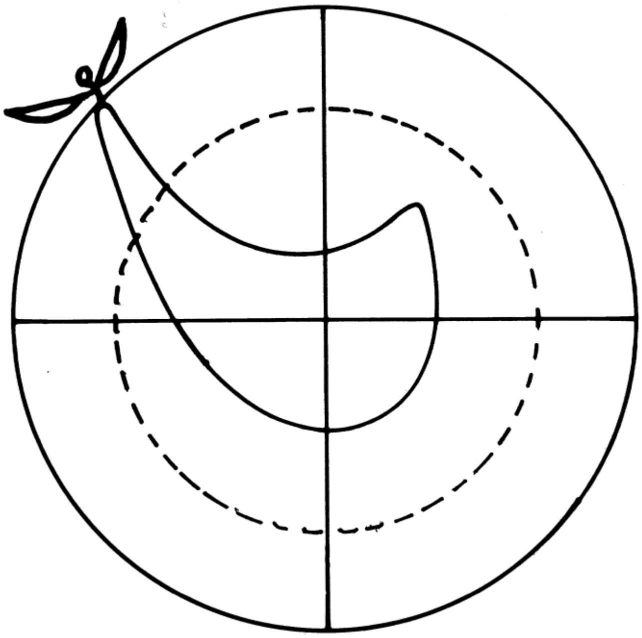

Figure 1.4 Individual potentiality to a particular direction due to the personality (DNA seed) and discover something originals that have not previously known because of unique DNA (Ando, 2016). There are infinite countable number of unknown fields, which individuals should be tackled. For example, the typical directions are music, pictorial art, formative arts, athletics, mathematics, science, engineering, literature, medicine, history, geophysics, agriculture, economics, business, and others that should be proposed by individuals. Dotted line is a record of an honor student, who is always high records in all of fields; however, they subject to never produce real creations from the bottom of personality.

It is worth noticing that the dimension of the head of newborn babies is relatively large because this part is initially developed in the body. If we consider analogy of this, it is highly recommended that the facilities related to human brain should be the first designed in house and urban, such as a museum, a concert hall, a library, a church and an institution, which may act as an important role for developing the third life of the individual. The arms and legs, corresponding to the highways and communication systems, may be designed later on.

2. Dynamical Theory of Preference of Life Amid Various Stressors

2.1. Previous Stress Theory in Life

It is well known that variety of "stressors" set into motion defense reactions mediated through the nervous and the hormonal systems (Selye, 1950). Introduction of the concept of stress in the 1950-ies coincided with avarice in economical pursuits and the idea that, "time is money". As a result, an ever-increasing number of people suffer from kidney disease, cancers, intractable pain disease and cognitive impairment as shown in Figure 2.1. The word "stress" has never used before 1950s, and the number of existing central hospitals was considerably lower.

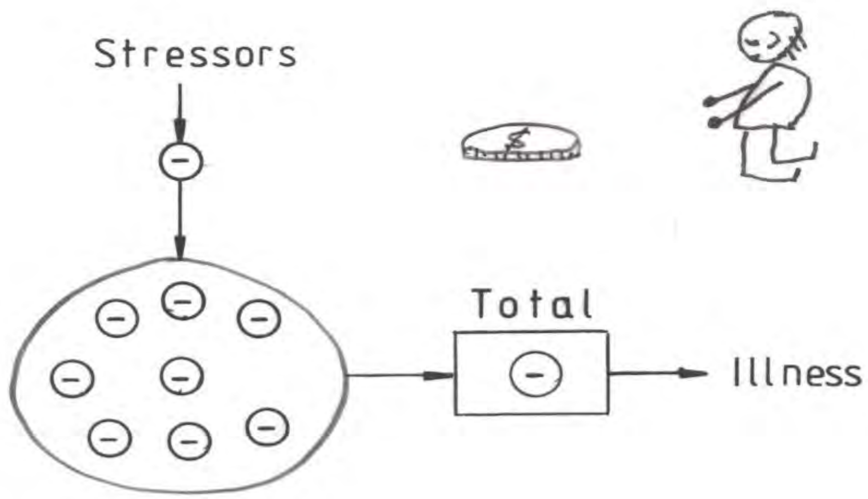

Figure 2.1 Stress theory losing survival power suffering diseases due to a certain limited survival power of individuals (Selye, 1950). The total score is always minus. This means diminish vital power for younger age and subjects to be illness for senior who are decreasing survival power.

Examples of stress are:

(1) It is normative that human life is so occupied by a wide range of stressors including due to ill human relations that the pleasure derived from the process of living is regretfully often drained away by stress.
(2) The most serious stressor is ill human relation that caused by communicating verbal communication with the left hemisphere only, so that before we know such relation is happened typically bullying. It is worth noticing that affection expressing by non-verbal communication with the right hemisphere. The most powerful and simple method is "fist bump" with only 0.1 s an international non-verbal language. But, doing shake hands need longer time and may subjects to convey bacteria.
(3) Stressors are competitions attaining business chance for getting money as typically as trade war.
(4) Global warming due to the most influential in greenhouse gasses. This is one of serious stress that is the environmental termination.
(5) There are many environmental stressors, such as noise pollutions, bad odorous.
(6) Also, there are ugly environmental designs including overcrowded city without any shelter.
(7) Educations avoiding individual creations preferred and only using standard textbooks and manuals. Also, Ill entrance examinations without asking any purpose of individual studies preferred.

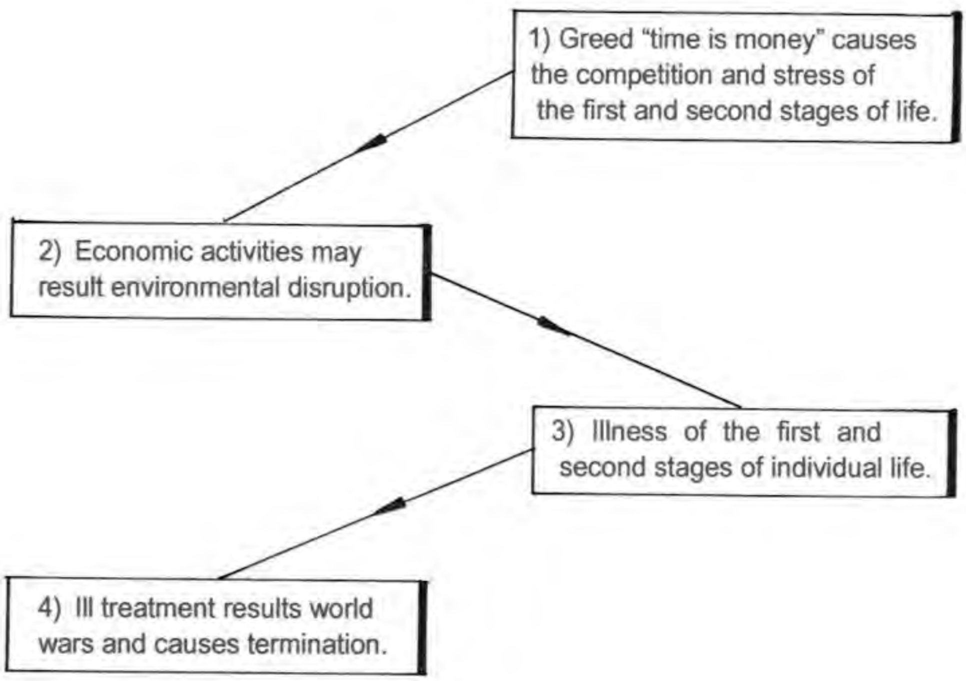

Figure 2.2 The stress of life caused by typically ill concept of "time is money," potentially resulting in world wars and thus causes termination.

As shown in Figure 2.2, greed "time is money" causes stresses. Economic and industrial activities resulted environmental disruption. These stresses cause serious illness, and ill treatments resulting wars toward termination. In order to avoid such termination it is proposed here a dynamical theory of individual preference in creations (Section 3.1).

2.2. Effects of Aircraft Noise on Development of Unborn Babies

Long-time integrated effects of environmental noise over a year on unborn babies and children are discussed here as the most typical and serious stressor for whole human society. The environmental noise is a representative measure for quality of environment in urban life. Our brain vividly responses to instantaneous change of the environmental noise with the period less about 1 s. The auditory-temporal window (2T) listening music is usually short period of order 40 ms (Ando, 1998). In other words, the temporal sensations for a very slow change with the long-term period more than several minutes are very weak on brain. However, we should aware the long-time integrated effects of environmental noise over a year on development of unborn babies and children. Since 1968, investigations were conducted around the Osaka international airport in Japan (Figure 2.3).

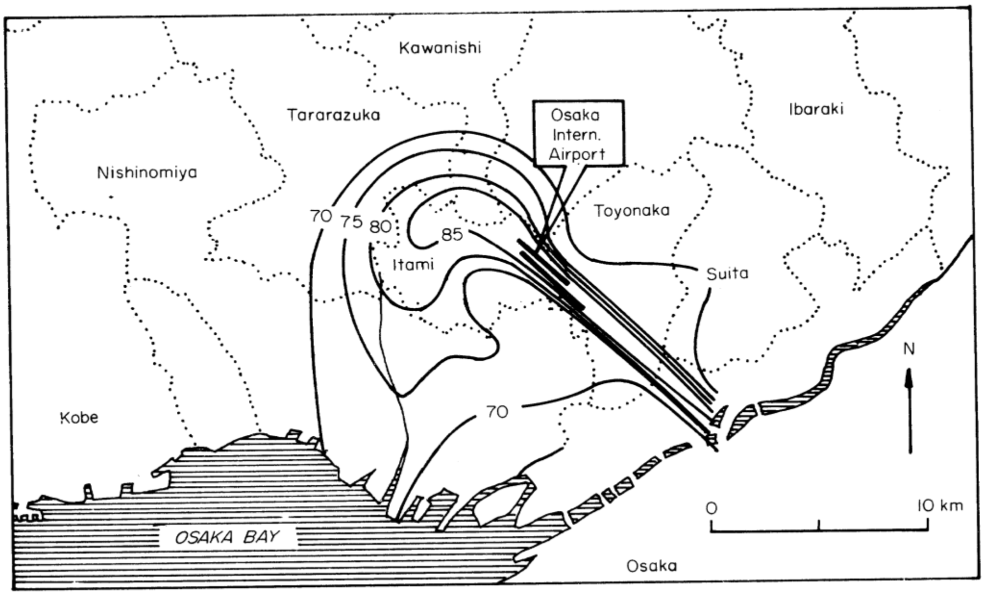

Figure 2.3 Contour lines of equal WECPNL around the Osaka International Airport. WECPNL in most of area of Itami City was in the range of 85 < WCPNL < 70.

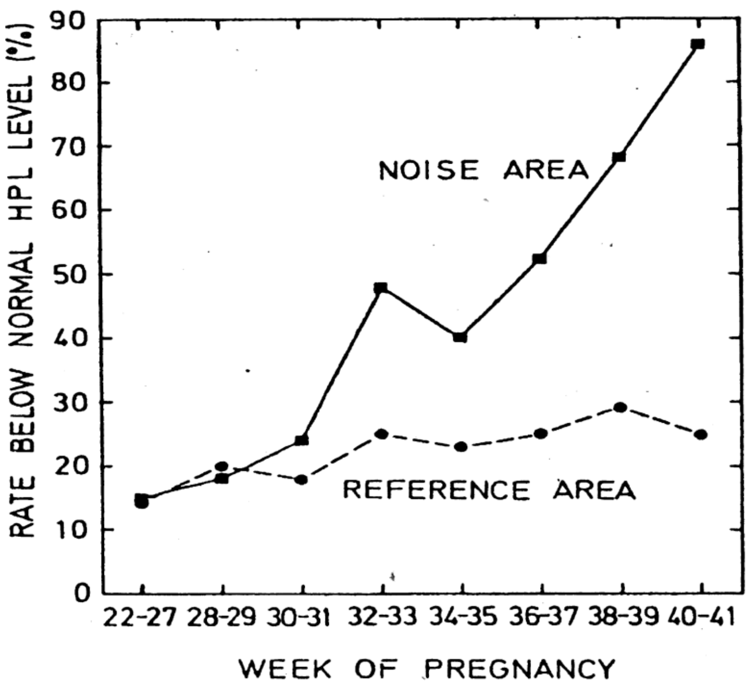

Figure 2.4 Percentage of subjects with HPL levels more than 1SD below the mean by stage of pregnancy (Ando and Hattori, 1977b).

We found in the investigation for about 10 years that:

1) Effects on the body (the firsr life): Intgreated effects of aircraft noise living area have described in terms of human placental lactogen (HPL) as shown in Figure 2.4 (Ando and Hattori, 1977b),

2) Thus in turn the development of unborn babies as demonstrated by number of the low birth weight babies in relation to number of jetplanes as shown in Figure 2.5 (Ando, 1988). After the birth, effects of the noise stress are discussed on development of the height (Schell and Ando, 1991).

3) Effects on the mind (the second life): Postnatal effects of aircraft noise on sleep of babies are depend on the period when their mother came into the noise area in reference to the period pregnancy (Ando and Hattori, 1977a). Also, developments of hemisphere specialization of children over the long period noise were clearly described by results of testing two different types of mental work associated with the left and the right hemispheres (Ando, Nakane and Egawa, 1975, Ando, 1988).

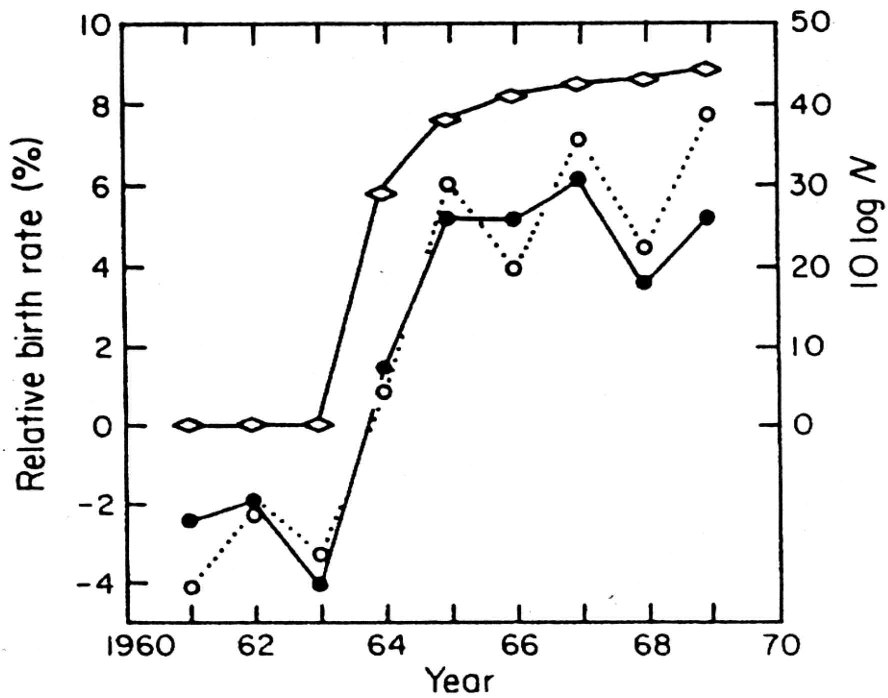

Figure 2.5 Birth rates below 3000 g as a function of year of living in Itami City, in reference to neighboring cities without aircraft noise shown in Figure 2.3.: Male. ○: Female.
Rhomb: Number N of aircrafts flew over Itami City plotted in a scale of 10logN.

3) Effects on creation (the third life): It is not yet clear, however, such an integrated effects of environmental noise on specialization of cerebral hemisphere, in turn, may influence on development of personality as a source of creation.

3. Role of Preference in Life

3.1. Dynamical Theory of Preference of Life Amid Various Stressors

In order to attain healthy living avoiding ill treatment of human and further wars, this paper proposes to attain survival power by means of dynamical theory of preference amid various stressors of life as indicated in Figure 3.1. We shall emphasize the most powerful preference, the one that, in terms of establishing a life based on the unique personality (DNA) of each individual. It should be founded on nourishing creativity associated with both cerebral hemispheres, and knowledge may be integrated as a culture for longer after the end of life in the society (the third stage of individual life).

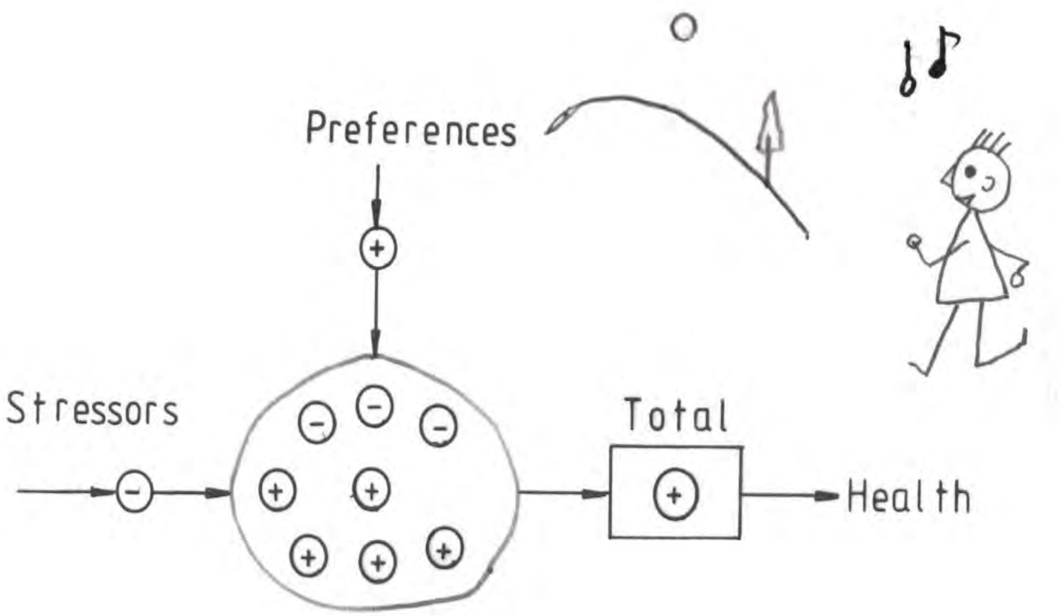

Figure 3.1 Dynamical theory of preference of life maintaining survival power amidst various stressors. Preference is what we want to be sincere gaining life force (Ando and Jõgi, 2019).

This theory supports and maintains survival power – health – even within such a vast variety of stressors. The most survival preference related to the unique personality (DNA) is, first of all, to select a field or a direction to live. At the same time, we may aware personality driven creations. Other wonderful things are existing in nature provided by the affection power such as, for example fresh air, green leaves, water stream may attain survival power due to the affection of nature. As well as music and drawing preferred which have been created by individuals. Non-verbal communications with living creatures typically babies less than one or two years of age, that may be performed by associated with the right hemisphere of individuals. Also, it is interested that with animals and plants we may perform non-verbal communications. This might be realized with all of creatures on the earth before communicating with space creatures.

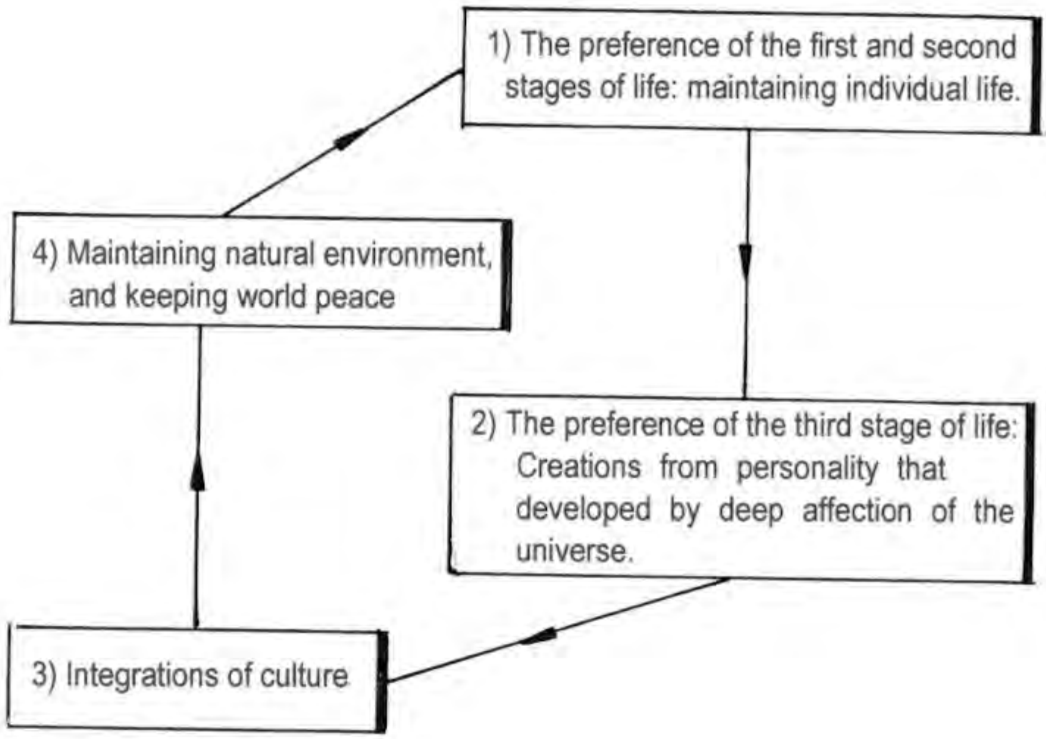

Figure 3.2 The preference for life in the first and second stages of life normally leads to maintaining individual life, and preference-based creations in the third stage of life that integrate with culture hopefully maintain the environment and support peace *ad aeternum* (Ando, 2018b).

Again, any creative activities preferred resonating with personality (DNA) may attain the most survival power, because that are possible being integrated in social culture for more longer life than the individual life time (third stage of life). In other words, as shown in Figure 3.2 the third stage of life may continue to culture even after the end of individual life, i.e., the fourth stage of life (Danjo, 2014). That is a kind of eternal life of an individual.

3.2. Subjective Preference (Aesthetic) of the Sound Field found in Alpha Wave

Before 1975, it was mysterious what is the excellent sound field in a concert hall. Design of concert halls have been performed based on experiences, for example, it is well known that in September 1962, at the opening concert of the New York Philharmonic Hall in the Lincoln Center for the Performing Arts and in the presence of Jacqueline Kennedy, acoustic expectations were soaring. The same evening, however, the New York Times reported in surprise of the recent acoustic outcome: "what happened in the Hall?" This hall had been designed according to acoustic data collected from concert halls throughout the world by Beranek (1962) who had conducted his studies by means of absolute quality judgments rating: 0, 1, 2, …and 10.

Instead of absolute quality judgments, a relative method such as the paired comparison test (PCT), which may be simply performed by even inexperienced subjects, because they may select more preferred sound field in the pair. This method is reproducible to be integrated and further the same is true to found scientific evidences in "the inner universe" (Ando, 1985, 1998). In fact, it has been discovered that alpha wave activities in the slow-vertex response (SVR), electroencephalographic (EEG) and magneto encephalographic (MEG) that are all well corresponded to subjective preference (Ando, 2009).

It is found that the two temporal factors (the initial delay time of reflection, Δt_1 and the subsequent reverberation time, T_{sub}) are associated with the left cerebral hemisphere, and the two spatial factors (the listening level, LL and the magnitude of the inter-aural cross-correlation function (IACC) for the sound signals arriving at two ear-entrances) in an enclosure are associated with the right hemisphere. It has been clarified that the whole brain was filled by the alpha wave only when both of the temporal factors and the spatial factors are satisfied by the preferred conditions. Subjective preference well correspond to the maximum of the effective duration of autocorrelation function of the alpha wave, $(\tau_e)_{max}$ (Ando, 2009, 2016).

Table 3.1 summarizes hemispheric dominance results obtained by analysis of the effective durations τ_e of α-rhythms, with respect to changes of each of four orthogonal factors namely the listening level LL, the first reflection time Δt_1, the reverberation time T_{sub}, and the magnitude of inter-aural cross-correlation IACC. This finding suggests also that the value of τ_e in the α-wave is an objective index for designing excellent acoustic environments. The activities of a longer value of τ_e in the α-wave may transfer to the hormone system to attain the survival power eliminating stresses.

Table 3.1 Hemispheric specializations of temporal and spatial factors observed by analyses of SVR, EEG and MEG. Here, it was obviously found that the two temporal factors were associated with the left hemisphere and the two spatial factors were associated with the right, without any exception.

Four Orthogonal Factors of the Sound Field Changed	AEP (SVR) $A(P_1 - N_1)$	EEG, ratio of ACF τ_e values of α-wave	AEP (MEG) N1m	MEG, ACF τ_e value of α-wave
Temporal				
Δt_1	**L > R** (speech)[1]	**L > R** (music)		**L > R** (speech)
T_{sub}	---	**L > R** (music)	---	
Spatial				
LL	**R > L** (speech)	---	---	
IACC	**R > L** (vowel /*a*/) **R > L** (band noise)	**R > L** (music)[2]	**R > L** (band noise)	

[1] Sound source used in experiments is indicated in the bracket.

From brain grounded theory of design based on subjective preference of the sound field in concert hall (Ando, 1985, 1998, 2007) to a brain-grounded theory of temporal and spatial design in architecture and the environment satisfying each individual, in order to cherish up personality enhancing creations (Ando, 2016).

3.2.1 Temporal Aesthetics Associated with the Left Hemisphere

(a) Initial Time Delay Gap between the Direct Sound and the First Refection (Δt_1)

When the time delay between the direct sound and the single reflection, Δt_1, i.e., the typical temporal factor of the sound filed was changed applying the speech signal, an almost direct relationship between individual scale values of subjective preference and the τ_e values of MEG □-wave over the left hemisphere was found in each of the eight subjects. Results for each of 4 subjects in the total 8 are demonstrated in Figure 3.1 (Soeta et al, 2002). Remarkably, the correlation coefficient, □, reached more than 0.94 for all of 8 subjects. The MEG was measured by SQUID as shown in PHOTO 3.1.

PHOTO 3.1 Magnetometer in recording the magneto encephalogram (MEG).

Most remarkably, however, there was weak correlation between the scale values of subjective preference and the amplitude of the α-wave, $\Phi(0)$, in both hemispheres ($r < 0.37$). Thus, it is emphasized that the amplitude of the □-wave **cannot be the measure** of subjective preference.

The value of τ_e represents the degree of repetitive features in the alpha waves that the brain repeats in a similar low frequency rhythm under the preferred conditions. This tendency for a larger value of τ_e under the preferred condition was much more significant than the results from the EEG α-waves mentioned above.

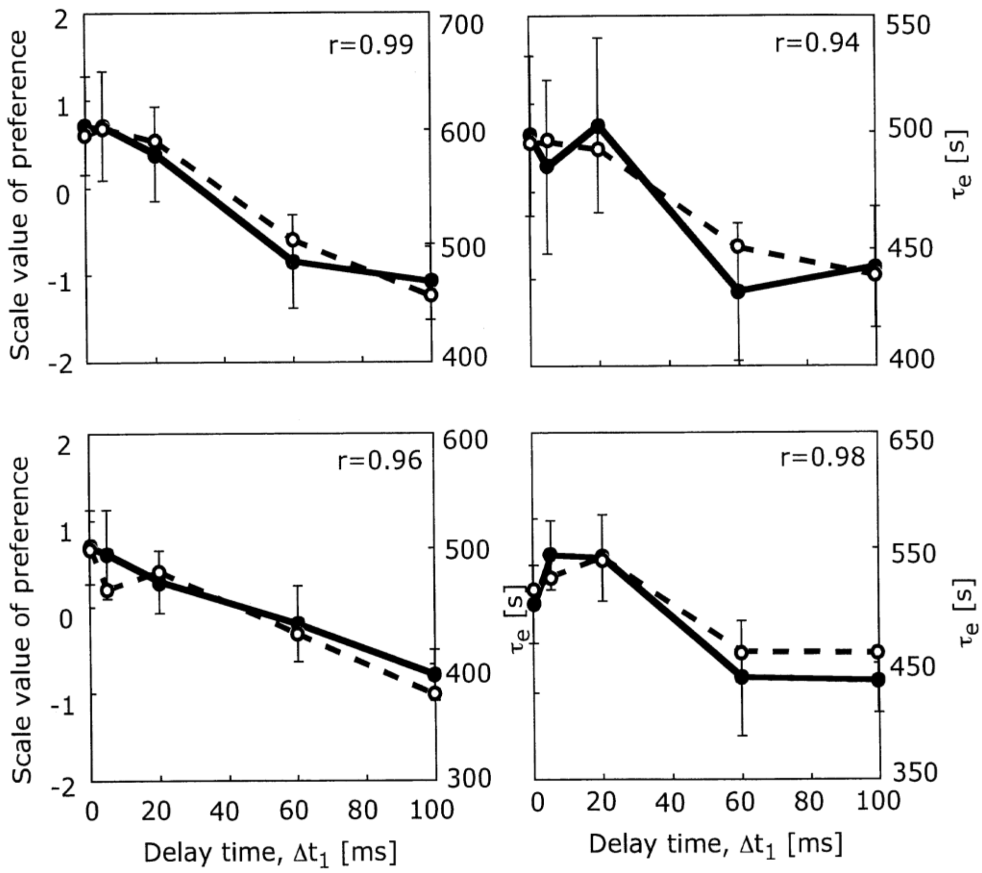

Figure 3.1 Good correspondences between the scale value of subjective preference and the averaged ACF τ_e value of the MEG α-wave over the left hemisphere of each of 4 individual subjects (in total 8 subjects). The averaged τ_e value and the scale value of preference are in the highest correlation over the eight channels (Soeta et al, 2002). ○: scale values of subjective preference; ●: averaged τ_e values of MEG α-wave, error bars being standard errors.

(b) Subsequent Reverberation Time (T_{sub})

Now, let us examine values of τ_e in the□□□wave with changes to the subsequent reverberation time (T_{sub}) relative to the scale values of subjective preference. Ten student subjects participated in the experiment (Chen and Ando, 1996). The sound source used was music motif B (Ando, 1985). Ten, 25-to 33-years old subjects participated in the experiment. The EEG from the left- and right-hemisphere was recorded. Values of τ_e of the α□wave, for the duration, 2T = 2.5 s, were also analyzed here.

First consider the averaged values of τ_e of the□□ wave, shown in Figure 3.2. Clearly, the values of τ_e are much longer at the preferred condition T_{sub} = 1.2 s than those at T_{sub} = 0.2 s in the left hemisphere, while the values of□τ_e are longer at T_{sub} = 1.2 s than those at T_{sub} = 6.4 s, also in the left hemisphere. However, this is not true for the right hemisphere; rather, the contrary is true.

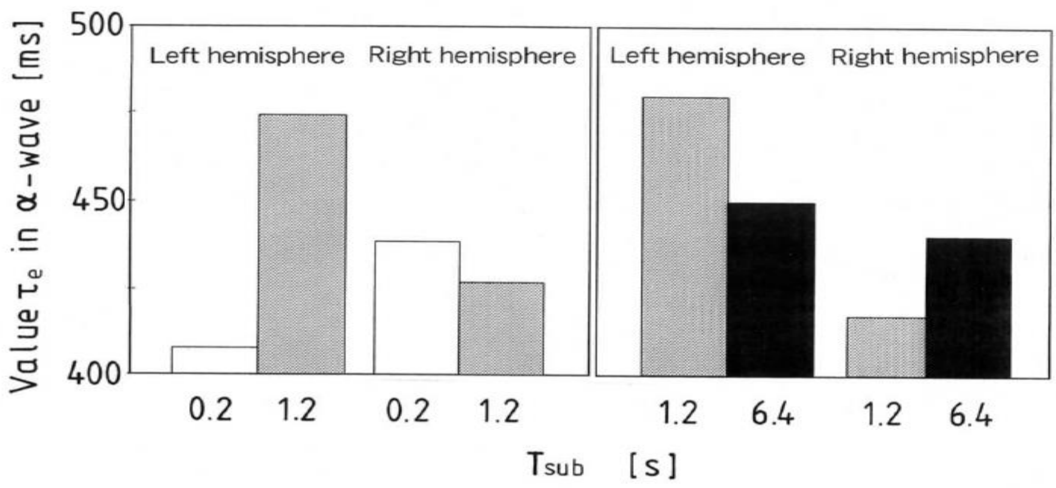

Figure 3.2 Averaged value of ACF τ_e of the EEG-alpha wave in change of T_{sub}: 0.2 s and 1.2 s; 1.2 s and 6.4 s for 10 subjects. Left: Left hemisphere. Right: Right hemisphere (Ando, 2009).

Further analyses indicated that the ratio of values for τ_e of the α□wave at 1.2 s and 6.4s is well correlated to the difference of the scale values of subjective preference for each individual (Ando, 2009).

3.2.2 Spatial Aesthetics Associated with the Right Hemisphere

(c) Listening Level (LL)

Since our environment always consists of the temporal factor and the spatial factor, it is assumed that different inter-hemispheric responses have been found according to the two major factors classified as listed in Table 3.1.

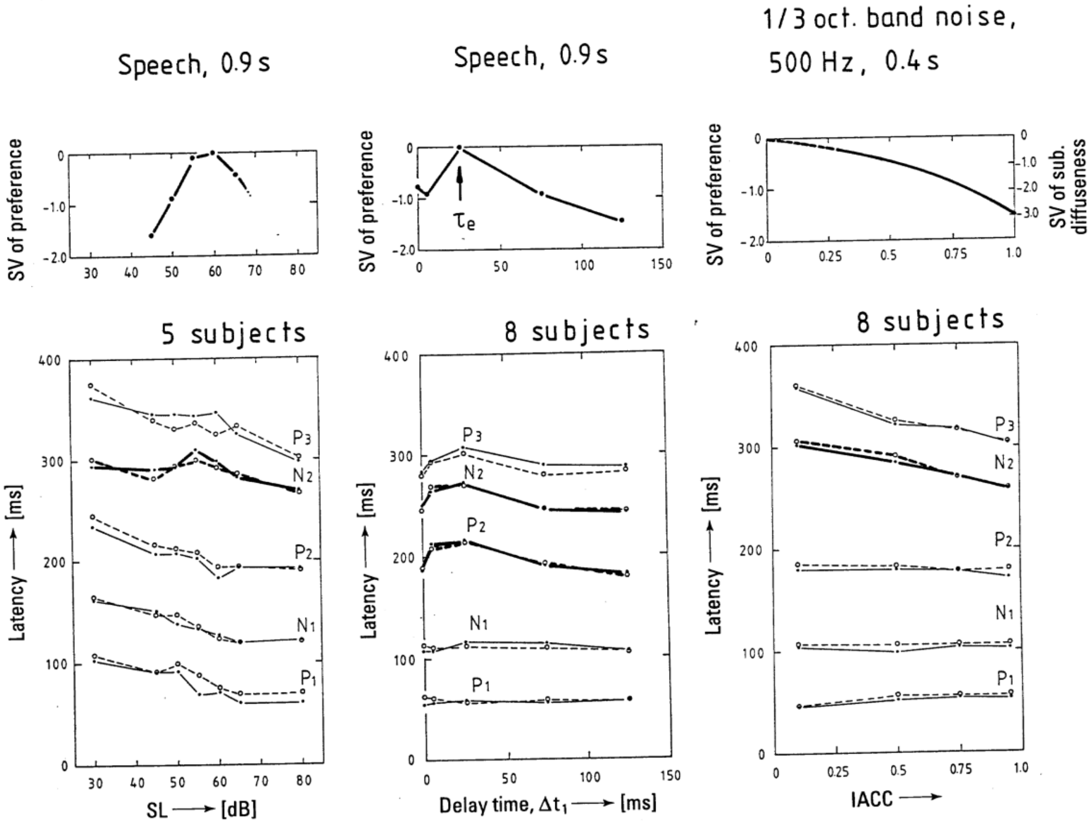

Figure 3.3 Relationships between averaged latencies of SVR and subjective preference for three factors of the sound field (Ando, 2009).

(____): Left hemisphere; (------): Right hemisphere. (a) As a function of the SL. (b) As a function of the delay time of reflection, Δt_1. (c) As a function of the IACC.

The amplitude of the first wave in the SVR as a function of the delay time is plotted in Figure 3.3. This value of $A(P_1 - N_1)$ is the difference in amplitude between the first (P_1) and (N_1). Values for relative height $A(P_1 - N_1)$ from 8 normal subjects who were presented the 0.9 s "ZOKI-BAYASHI" speech fragment were averaged together. The solid line indicates the initial SVR amplitude obtained from electrodes situated over the left hemisphere and the dashed line from over the right hemisphere. The amplitude from the left is clearly greater than that from the right ($p < 0.01$), possibly implying a left hemisphere dominance or specialization in the processing of changes in the delay time with speech (Table 3.1) (Ando, 1992).

Analogous hemispheric differences in the initial SVR amplitude were observed as a function of sensation level (SL) and the magnitude of interaural cross-correlation (IACC). For all levels above 30 dB SL, the initial SVR amplitude from the right hemisphere was greater than that from the left, $p < 0.01$ (Figure 3.3) (Nagamatsu, Kasai and Ando, 1989). We used 1/3-octave-band noise with the center frequency of 500 Hz to examine the response correlates of sound direction. For all IACC values from 0.1 to 1.0 in the paired stimuli, the amplitude from the right hemisphere was always greater than that of the left, $p < 0.01$ (Ando, Kang and Nagamatsu, 1987). By assembling the data (Table 3.1), one can see that hemispheric dominance of the SVR responses can change as a function of the variation of the acoustic parameter. It is remarkable when the IACC was varied in the paired stimuli; the right hemisphere was highly activated, because of its spatial factor. Also, the right hemisphere was dominant under the condition of varying the SL, even if the continuous speech signal /a/ was used as the source signal. On the other hand, the left hemisphere was dominant under the condition of varying Δt_1, which is the temporal factor of the sound field. From classic studies, the left hemisphere appears to be more highly involved with processing speech and temporal sequences, while the right is concerned with nonverbal and spatial identifications (Kimura, 1973, Sperry, 1974). In light of our results, some aspects of hemispheric dominance may be relative to the phenomena that depend on what is changed in the pair of stimuli, i.e., temporal vs. spatial factors, rather than absolute ones.

We found neural response correlates of subjective preference in the latency of SVR waves. The top plots of Figure 3.3 summarize the relationship between subjective preference scale values and three acoustic parameters (LL, Δt_1, and IACC). Applying the paired method of stimuli, both SVR and the subjective preference for sounds fields were investigated as functions of SL and Δt_1. The source signal was the 0.9 s speech segment. The lower part of this figure indicates the appearance of latency components. As shown in the left and center columns in this figure, the neural information related to subjective preference appeared typically in an N_2-latency of 250-300 ms, when SL and Δt_1 were changed.

Further details of the latencies for both the test sound field and the reference sound field, when Δt_1 was changed. The parallel latencies at P_2, N_2 and P_3, were clearly observed as functions of the delay time Δt_1. However, latencies for the reference sound field ($\Delta t_1 = 0$) in the paired stimuli are found to be relatively shorter, while the latencies for the test sound field with $\Delta t_1 = 25$ ms, the most preferred delay become longest. This may indicate a kind of relative behavior of the brain, underestimating the reference sound field when the test sound field in the pair is the most preferred condition (Ando, 2009).

Relatively long-latency responses are always observed in the subjectively preferred range of each factor. Thus, the difference of N_2-latencies over both hemispheres in response to a pair of sound fields contains almost the same information obtained from paired-comparison tests for the subjective preference. In general, the subjective preference may be judged in the direction of maintaining life; therefore, it may appear in neuronal response as a primitive response.

The right column of Figure 3.3 shows the effects of varying the IACC using the 1/3-octave-band noise (500 Hz) (Ando, Kang and Nagamatsu, l987). At the upper part, the scale value of the subjective diffuseness is indicated as a function of IACC. The scale value of the subjective preference also has a similar behavior plotted against the IACC, when speech or music signals are presented (Ando, 2009). The information related to subjective diffuseness or subjective preference, therefore, appears in the N_2-latency, ranging from 260 - 310 ms, in which a tendency for an increasing latency while decreasing the IACC was observed for eight subjects (except for the left hemisphere of one subject).

(d) Magnitude of Interaural Crosscorrelation (IACC)

In order to find first of all, the electroencephalogragy (EEG) response correlating to subjective preference for paired changes in the typical spatial factor that has been newly discovered, the magnitude of inter-aural cross-correlation function (IACC) of the sound field was investigated. Eight student subjects participated in the paired-comparison experiment (Sato et al, 2003). Music motif B (Sinfonietta by Arnold) was applied as the stimulus. Changes in IACC reflected clearly in right hemisphere dominance. The effective duration τ_e of α-band activity was found to be substantially longer in the preferred condition with a small magnitude of the inter-aural cross-correlation (IACC = 0.30). A significant difference was achieved in the right hemisphere for the pair of sound fields with IACC = 0.95 and 0.30 ($p < 0.01$) as shown in Figure 3.4.

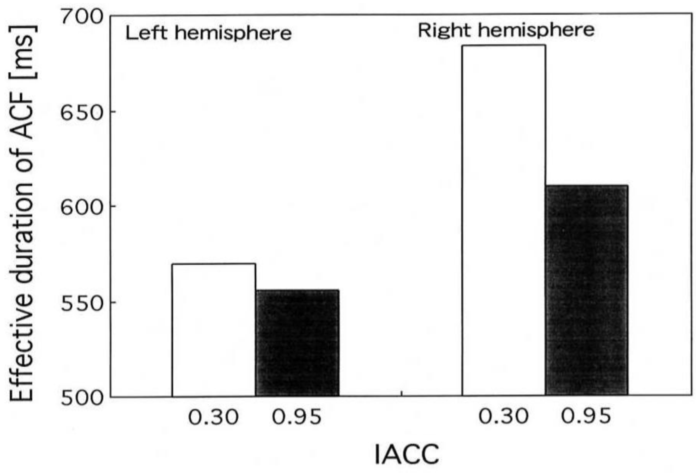

Figure 3.4 Averaged values of ACF τ_e of the EEG-alpha wave in change of the IACC for the pair of IACC = 0.30 and 0.95.

Results are summarized as below:

1) In seven of eight subjects except for Subject B, the ratios of effective durations τ_e for α-band responses to IACC change, [τ_e (IACC = 0.3) / τ_e (IACC = 0.95)], in the right hemisphere were greater than in the left hemisphere except for subject B (Figure 3.4). Thus, as far as the IACC is concerned, the more preferred condition with a smaller IACC is related to longer α-rhythm effective durations in the right hemisphere in most of subjects tested.
2) As shown the most clearly in Figure 3.5, the α-wave of alpha rhythm activity in the right hemisphere (T4) at IACC = 0.3 later propagates toward the left hemisphere (T3). In other words, the α-wave of alpha rhythm activity occupies whole brain and may transfer to the hormonal system resulting survival power in the body. This is what surprising activity of stressors.

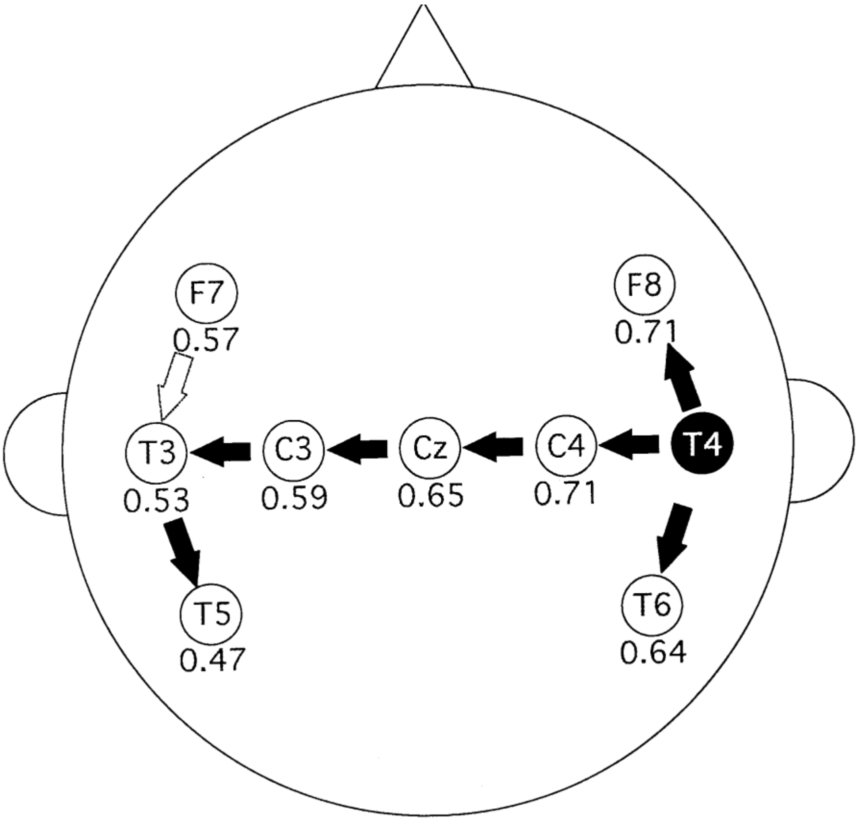

Figure 3.5 The EEG-alpha wave flow from the right hemisphere to the left in change of the IACC. Real numbers indicate the median (50%) values of the maximum absolute value in the CCF of the alpha wave.

Additionally, experiments using magenetoencephalography (MEG) measurements tested the effects of a speech signal that was altered by changes to the IACC (0.27, 0.61 and 0.90). The results reconfirmed that the effective duration τ_e in □-wave range of all of individuals increased when the IACC decreased in the right hemisphere (Soeta et al, 2003).

Applications designing concert halls and opera houses are well described maximizing subjective preference at each seat (Ando, 1998, 2009, 2015, 2016, Suzumura, and Ando, 2018),.

3.3 Visual Temporal Aesthetics Associated with the Left Hemisphere

3.3.1 Flickering Light in Vision

In rational design of landscape architecture, or any other visual object or space for that matter, conscious consideration of not only the spatial but also the temporal aspects ("temporal design") of the visual field may strongly affect how the design is later perceived. A series of experiments was carried out to probe the subjective preferences for temporal and spatial factors in vision. These factors are extracted respectively from the temporal ACF associated with the left hemisphere (Table 3.2) and the spatial ACF associated with the right hemisphere of the visual field (Sperry, 1974).

Table 3.2 Left hemisphere specialization observed in EEG and MEG alpha waves in relation to the temporal factors of the visual field (Ando, 2009).

Temporal factor	EEG, ACF τ_e-value of α-wave	EEG, CCF $\|\phi(\tau)\|_{max}$ of α-wave	MEG, ACF τ_e value of α-wave
Period of the flickering light, T	**L > R**[1] (SW)[3]	**L & R**[2] (SW)	**L > R** (SW)
Period of the horizontal movement of target	**L > R** (SW)	---	---

[1] The ratio of τ_e-values of α-wave in EEG increased significantly in the left hemisphere.

[2] The $\phi(\tau)|_{max}$-value of α-wave in MEG increased over a wide area of both hemispheres, when the scale value of subjective preference was high. A similar repetitive feature in the α-wave over a wide brain area relates to the preferred condition of vision.

[3] Sinusoidal waves used to control the period, T.

In order to obtain basic data for the temporal aesthetics of flickering light, PCTs were conducted. Subjective preference for a flickering light in terms of the ACF factors of the stimulus signal were also conducted (Soeta, Uetani and Ando, 2002b). It was found that the preferred sinusoidal period $[T]_p$ of the flickering light is roughly

$$[T]_p \sim 1.0 \text{ s.} \qquad (3.1)$$

To attain more representations of subjectively preferred conditions in addition to the sinusoidal signal given by Equation (3.1), a fluctuation was introduced to the preferred sinusoidal flickering light centered on 1 Hz. In this procedure, the amplitude of the first maximum peak extracted from the temporal ACF of the flickering light stimulus was the fluctuation factor ϕ_1 shown in Figure 3.4, which was controlled by changing the bandwidth of the noise (1, 2, 4, 8 and 16 Hz) over the period of 1 Hz.. In the natural environment we perceive many visual aspects in temporal fluctuation, from twinkling stars to leaves in the wind and flows of water in a river.

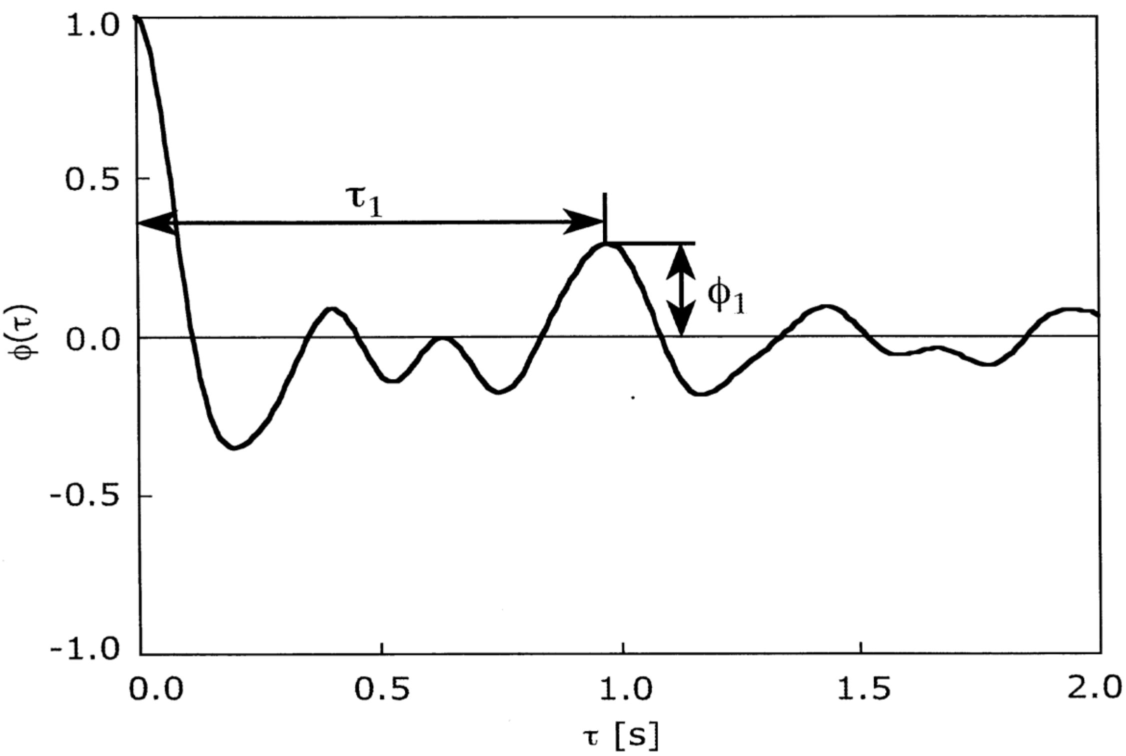

Figure 3.6 Definitions of the degree of fluctuation ϕ_1 and the period τ_1 extracted from the temporal ACF of the stimulus.

Subjective preferences of individual differences was rather wide ranging between $[\phi_1]_p = 0.27 – 0.90$. The averaged value for the participating subjects was $[\phi_1]_p$ » 0.46 (Soeta, et al., 2005). Individual results of the most preferred fluctuation factors $[\phi_1]_p$ are listed in Table 3.3.

Remarkably, the resulting preferred fluctuation expressed by ϕ_1 (Figure 3.6) is an intermediate of the values between those of a perfectly periodic sine wave ($[\phi_1]_p = 1.0$) and a perfectly random wave ($\phi_1 = 0$). The value of ϕ_1 is the degree of fluctuation that corresponds to “pitch strength” in sound signals. In music performance, it is a kind of artistic expression in the temporal domain.

Table 3.3. The most preferred fluctuations of flickering light $[\phi_1]_p$ for each observer and the averaged value.

Observer	$[\phi_1]_p$
A	0.51
B	0.50
C	0.47
D	0.58
E	0.45
F	0.90
G	0.27
H	0.33
I	0.33
J	0.31
Averaged	0.46

After obtaining the most preferred conditions for individual observers, the scale value of subjective preference could be obtained as a function of the normalized factor $\phi_1/[\phi_1]_p$ as shown in Figure 3.7 Thus, the preference evaluation curve for both individual observers and for an average of all of the observers can be expressed as

$$S \approx -\alpha|x|^{3/2} \tag{3.2}$$

where $x = \log\phi_1 - \log[\phi_1]_p$. The averaged weighting coefficient has been obtained with a number of subjects, $\alpha \approx 11.0$.

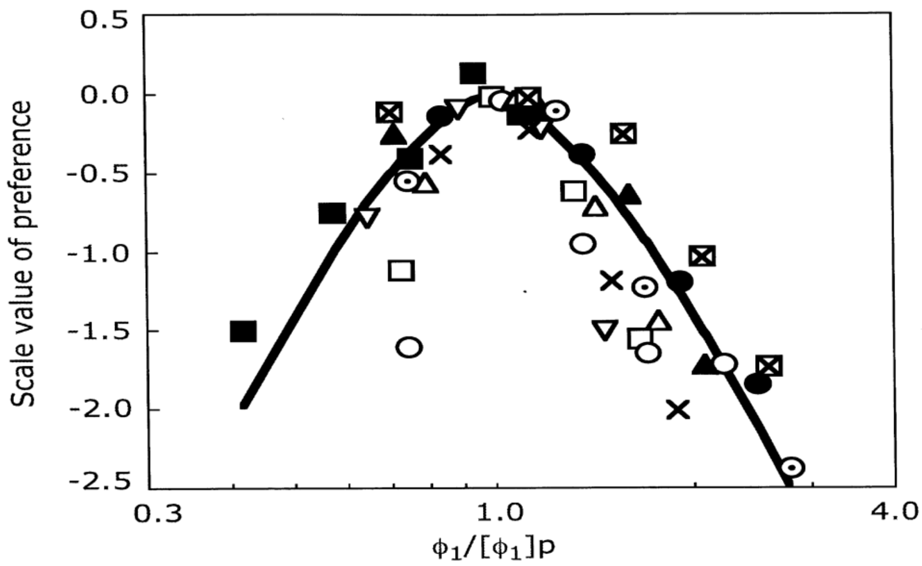

Figure 3.7 The normalized scale value of preference for all subjects. The solid curve is a value calculated by Equation (3.2) with constants $\alpha = 10.98$ and $\beta = 3/2$. Different symbols indicate the scale values obtained by different subjects. The abscissa is normalized by $[\phi_1]_p$, i.e., $\phi_1/[\phi_1]_p$. The scale value at the most preferred condition $[\phi_1]_p$ is adjusted to zero, without loss of any generality. Different symbols are the scale values obtained by different subjects.

Considering the thermal environment, the effects of a "breeze" could be described by applying the factors ϕ_1 and τ_1, which are extracted from the ACF of wind speed.

3.3.2 Oscillatory Movements of a Target in Vision

A good visual example of oscillatory movement of a target as shown in Figure 3.8 is a wall clock. Results of preference judgments applying the PCT for sinusoidal movements of a single circular target without any fluctuation on a monitor screen are mentioned in this section. The period of stimulus movements was varied separately in the vertical or horizontal direction.

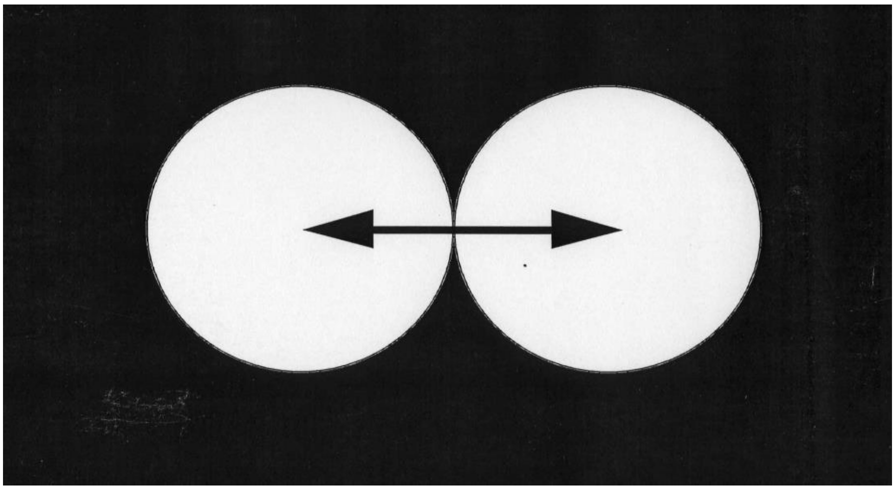

Figure 3.8 Stimulus target applied for the experiment showing an example of the horizontal movement.

The stimuli were displayed on a CRT monitor presenting 30 frames per second – a single white circular target moving sinusoidally (Soeta, Ohtori and Ando, 2003). The diameter of the target was subtended 1° of the visual angle (1.22 cm). The movement of the stimulus is expressed as:

$$h(t) = A \cos(\square\square t/T) \qquad (3.3)$$

where A is the amplitude and T is the period of the stimulus. In all experiments, the amplitude A was fixed at 0.61 cm on the monitor screen, corresponding to 0.5° of the visual angle. The white target and black background corresponded with gray levels 40 and 0.5 cd/m^2, respectively. The monitor presenting the stimuli was placed in a dark room 0.7 m away from the subject's eye position to maintain natural binocular vision.

Subjective preference for the period of movements in the horizontal and vertical directions was examined separately. The period of stimulus movement T in Equation (3.3) was varied at six levels: T = 0.6, 0.8, 1.2, 1.6, 2.0, and 2.4 s. Thirty pairs combining six different periods constituted each series, and 10 series were conducted for all 10 subjects in the experiments by the PCT.

The individual values of preference for movement oscillation periods in the vertical and horizontal directions are listed in Table 3.4. Results indicate that the most preferred periods ($[T]_p$) for all subjects are about 1.26 s in the horizontal direction and about 0.97 s in the vertical direction ($p < 0.01$).

As far as the author knows, typical clock periods are rather fast so that people living in houses would feel rather busy and get unconsciously "stressed".

Table 3.4 The most preferred periods $[T]_p$ of vertical and horizontal movements of the target for each subject and the averaged values.

Subject	Vertical [s]	Horizontal [s]
A	1.15	1.28
B	1.05	1.82
C	0.78	1.31
D	1.16	1.79
E	0.85	0.91
F	0.83	1.05
G	1.08	1.31
H	0.81	1.04
I	0.93	0.98
J	1.10	1.13
Averaged	0.97	1.26

3.4 Visual Spatial Aesthetics: Associated with the Right Hemisphere

Four factors were extracted from the two-dimensional ACF (Fujii and Ando, unpublished). To compare the degree of periodicity, the amplitude of the first peak in the ACF, ϕ_1 was considered under the condition of a roughly constant value, δ_1 being defined as distance from the origin 0 to the first peak. As the first approximation from the previous section, the fluctuation factor ϕ_1 could represent perceived regularity of texture (Figure 3.9). If the size and shape of the materials, and the spacing between the objects in the pattern are completely equal, the calculated ACF does not decay. This means that such a texture is, theoretically, perfectly regular. However, if the material contains a kind of fluctuation of the object size and spacing, and non-uniformity of the light reflection, then the ACF gradually decays, and the value of ϕ_1, which is a measure of perceived regularity, is considered as the measure for the degree of fluctuation in texture (Ando, 2009).

Next, 8 subjects between 22 to 24 years of age participated in the experiment. All had normal or corrected to normal visual acuity. Stimuli were presented on a display under dark conditions. The display was set at a distance of 1.5 m from the subjects. Subjects were presented pairs of two stimuli and asked to judge, which they preferred (PCT). All possible pairs from the five selected stimuli as shown in Figure 3.7 were presented in a random order in one session. All subjects conducted ten series of sessions, giving a total of 100 judgments.

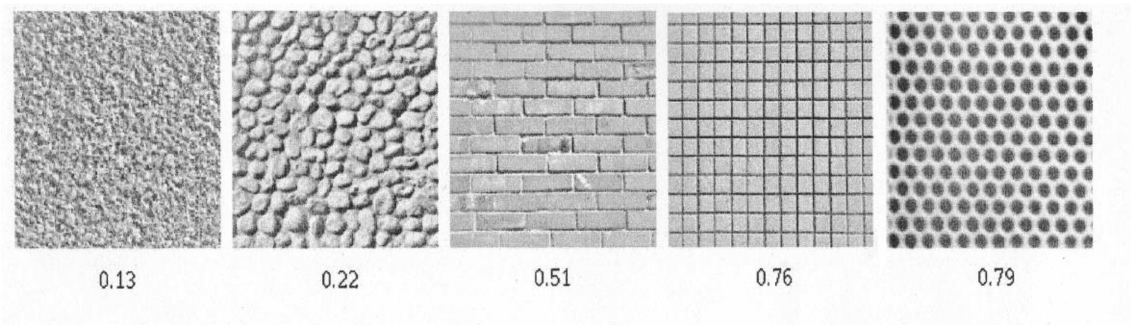

Figure 3.9 Two-dimensional spatial textures used with a changing value of ϕ_1 for the subjective preference judgment.

Results for all subjects are shown in Figure 3.10. The scale value of subjective preference has a single peak value for each subject, even allowing some individual differences. The most preferred range was found in the value of □$_1$ for each subject. Subjects did not prefer textures which had too high or too low a value of ϕ_1. By averaging the scale values of all subjects, $[\phi_1]_p$ » 0.41 was found to be the most preferred value for texture regularity. The coefficients in Equation (3.2) with the number of subjects was α » 3.9.

It is worth noticing that the most preferred subjective preference for flickering light with fluctuation is $[\phi_1]_p$ » 0.46 as well. We may therefore consider that a certain degree of fluctuation in both temporal and spatial factors is a visual property affecting subjective preference. In conditions $\phi_1 > 0.79$, all participating subjects showed low scale values for subjective preference, indicating an experience of "unconscious stress".

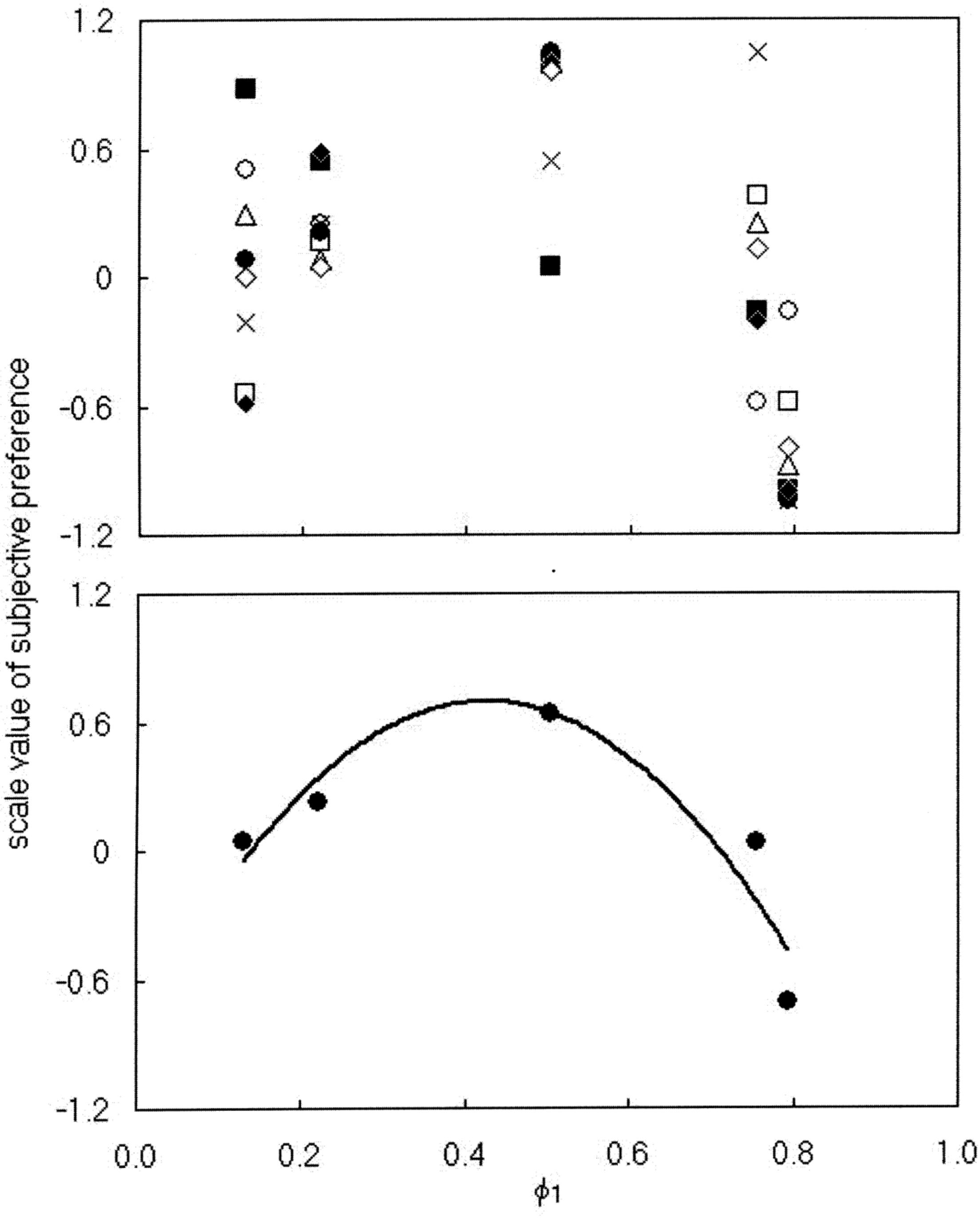

Figure 3.10 Above: Scale values of preference for 8 individual subjects.

Below: Averaged preference values for 8 subjects, and a fitting curve with the 3/2 power of ϕ_1 in Equation (3.2).

3.4. Effects of Preference and Stress on Dialysis Introduction Age (DIA)

In order to examine Dynamical Theory of Preference of Life Amid Various Stressors, this section shows stressors and preference factors that determine the dialysis introduction age (DIA) based on analyzing questionnaire distributed to patients attending a hospital in Kobe, Japan (Ando, 2018a, 2018b). To predict the DIA according to 16 factors of stress and preference in addition to factors of environment of dwelling as well as clinical history obtained by questionnaire, the mathematical quantification theory (Hayashi, 1950) was applied. All questionnaire data collected was 34 but valid data was 30 without lack of data, which were unanswered. The DIA data were rearranged by rounding, for example, 55 is 50 and 68 is 60.

It is remarkable that individual clinical history of past high blood pressure and proteinuria records was unexpectedly insignificant. But, the following eight effective factors were found significant to describe the DIA, 1) human relations; 2) worked hard in years; 3) alcoholic beverage; 4) noise pollution at the dwelling; 5) other pollutions; 6) smoking; 7) number of hospitalizations; 8) number of times moving house. Other factors such as sex, pets, bad odors, past noise pollution.

Troubled inter-human relations are potential accelerators of the dialysis introduction age (DIA), caused by the severe stress ($P < 0.01$) as indicated top of Figure 3.11. On the contrary, the preference factor of drinking socially ($p < 0.05$) as indicated the third line of the table, as it has been said to be the best of all medicine, postponed the DIA. As indicated the second line of the table, “worked hard” for more than 30 years postponed DIA due to habituation effects relative to shorter category than 29 years ($p = 0.05$). As indicated forth line, noise pollutions was acted the stress factor accelerating DIA ($p < 0.1$).

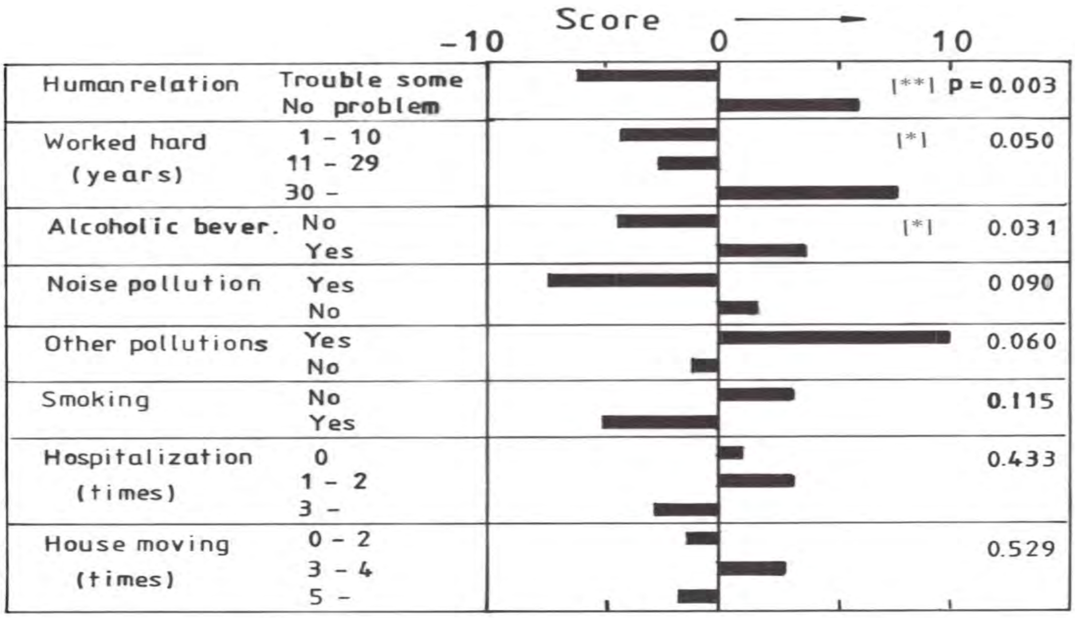

Figure 3.11 Results of each category of eight factors in calculating DIA by the analysis. Symbols [**] and [*] signify significant levels 0.01 and 0.05, respectively.

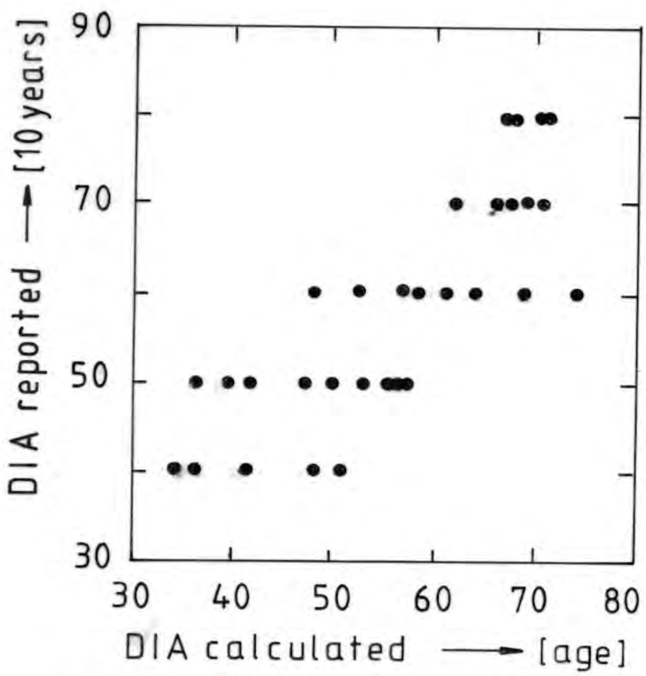

Figure 3.12 Relationship between DIA calculated utilizing results of analysis and DIA (10 years as round number) reported in the questionnaire by each patient. Remarkably, the DIA may be roughly described by eight factors indicated in Figure 3.11.

As shown in Figure 3.12, DIA calculated with the 8 factors is roughly agreed with

DIA reported by patients. The coefficient determination was 0.59 i.e., high enough. It is remarkable that the second significant factor was preferred alcoholic beverage, i.e., a glass of wine is to be the best of all medicines to postpone the DIA eliminating any kind of stress.

In fact, after a series of investigations on the effects of aircraft noise on unborn babies conducted near the Osaka International Airport (Section 2.2), the author experienced the beginning of his kidney disease due to work-related stress and additional stress from the Japanese authorities. At that time he had good luck mediated by the Alexander von Humboldt Foundation, West Germany, where he studied German at the Goethe-Institute in Boppard near the Rhine and could enjoy a glass of well-cooled white wine after lunch looking over wonderful water flows. Two months later, the research work on subjective preference of sound fields intended to take place in Gottingen for about one year and 8 months conducted (Ando, 1983, 1985). After these experiences, the author's DIA postponed for about 34 years due to manifest life preferences.

4. Third Stage of Healthy Life Recovering Environments and Keeping Peace

We aim to forward a hope for each individual to be surrounded by their preferred environment so that the three stages of life according to the theory of preference (Ando, 2016) could flourish. The development of original idea and creation and sustainable personality can be realized by the dynamical theory of preference life amid various stressors (Section 3.1),

1) Individual Power of Survival (Maximizing Preference – Minimizing Stress)
Maintaining our environments in the long haul can be achieved by a variety of creations preferred springing from the actions of a variety of unique personalities based on DNA, which ultimately integrate as culture. So that minimizing stresses are realized.

2) Individual Power of Affection (Maximizing Affection – Minimizing Avarice)
Individuals endorsing a particular affection value may play important role recovering environments and keeping peace. On the other hand, a nation with highly valuing idolatry such as money of status might result in being terminated for goobal

environments and even subject to occurring nuclear war.

3) Entrance Examination of Universities and Colleges (Maximizing Asking a Purpose of Studies – Minimizing Testing Knowledge)

In order to ask individual purpose of students together with its originality and creation to be performed after entrance, which is far more important than testing just knowledge. In other words, a universal education and a globalization based upon the concept of “time is money” is subject to suffering stress and consecutive illnesses and ill human relation.

Objectives of shifting to the third stage of human life from animal stages of body and mind, so that avoid any ill treatment between individuals are health and maintaining environments and also keeping peace. As is discussed here, any original idea and creative activities resonating with personality (DNA) may attain the most survival power according to creations that being integrated in social culture for more longer life than then the individual life time. Note that the third stage of life may continueto fourth stage of life in culture even after the end of individual life (Danjo, 2014).

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Origami Space-Time: Folding in Art and Science

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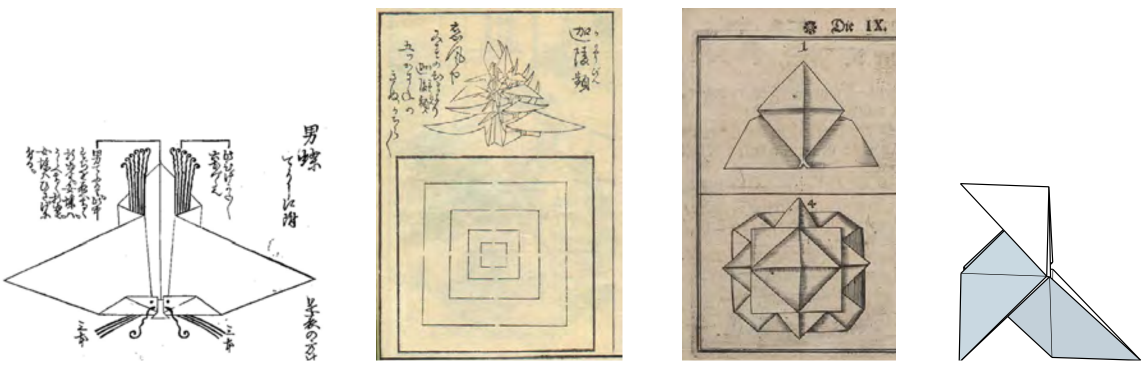
ABSTRACT

After the 2010s, the science of origami has extended its disciplines rapidly. One of the origins of the trend was the first international conference on origami science held at the University of Ferrara in 1989. It evolved to the 7OSME (the 7th international conference for Origami Science, Mathematics, and Education) at the University of Oxford in 2018. For the past 30 years, the art and science of origami made remarkable developments and its principles and concepts are adapted to the various fields such as mathematics, physics, chemistry, architecture, products, fashion, and engineering. Firstly, we give a historical overview of origami in both the East and the West. Secondly, we review the representative highlights of the recent researches. Thirdly, we offer a hands-on workshop to demonstrate Rotational Erection System(RES) as an example of the new types of the origami design method.

1. INTRODUCTION

The Japanese word “Origami” is now commonly used for the art of folding internationally. However the art of folding is ubiquitous to many cultures historically. It is a misconception that the art of folding is an ancient culture unique to Japan. We would like to show the overview of the art through non-ethnocentric observation to historic literatures.
The non-biased view would leads us the richer and innovative development of the art for the future.

2. HISTORY OF FOLDING (TIME)



a) Male Butterfly [2] b) Stacking Crane [5] c) Napkin Folding [6] d) Spanish Pajarita

Figure 1. Historic Examples of Folding in the East and the West.

The East: Traditional Paper Folding Art in Japan
The word Origami originally used for letter formats in 12th century. The words Orisue and Orikata were used for the art of paper folding for entertainment[1]. A comprehensive reference book for ceremonial paper wrapping was published around 1750s[2]. The oldest evidence of origami crane was recently found in the ornament on Samurai's knife made in 1590s by the artisan Eijyou Goto(1577-1617)[3]. Japanese woodblock print artist based in Kyoto Sukenobu Nishikawa(1671-1750) depicted how the paper fold toys were enjoyed by ladies and girls[4]. The book of linked origami cranes published in 1797 shows origami had developed to highly crafted art for the intellectuals[5].

The West: Europe
The book on artistic napkin folding was published in Italy in 1639[6]. The lost art of napkin folding was revived by the Spanish artist Joan Sallas[7] with his crafting skill and in-depth research on the old literatures. Independent of the oriental culture, several paper folding models unique to Europe were recorded in prints and paints. Pajarita (little bird, Figure 1. d) originated in Spain was used in other part of the West as Cocotte in France, Hobby Horse in England, and Crow in Germany[10]. The recent research by the historian in mathematics and philosophy provided a lucid exposition on the history of the mathematical concept of folding starting from the 16th century[8].

Comparison between the East and the West
Origami history researcher Koshiro Hatori concluded that the difference in European and Japanese origami models has its roots in the origin--ceremonial wrappers of the fourteenth century in Japan and baptismal certificates of the sixteenth century in Europe[9]. The some of the latter models(Figure 1. c) were also found in napkin folding in Europe[7].

USA and Britain After WWII ended in 1945, Japanese Origami was brought from the occupied Japan to USA and Britain by the soldiers and their families. Translated books of Japanese Origami became popular in those countries. Paper folding society in New York City used the word Origami first in 1950 for its society name and then British society adopted the term[11]. This naming strategy in the influential communities in English speaking world made the word Origami an universal word.

Word Trend 1860 to 2000 Google Books Ngram Viewer displays a graph showing how words or phrases have occurred in a corpus of books over years. The graph for "origami" in Figure. 1 shows the inflection points around 1950 and 1980. The first corresponds to the growth of entertainment origami and the second to the rise of scientific and technological interests on origami.

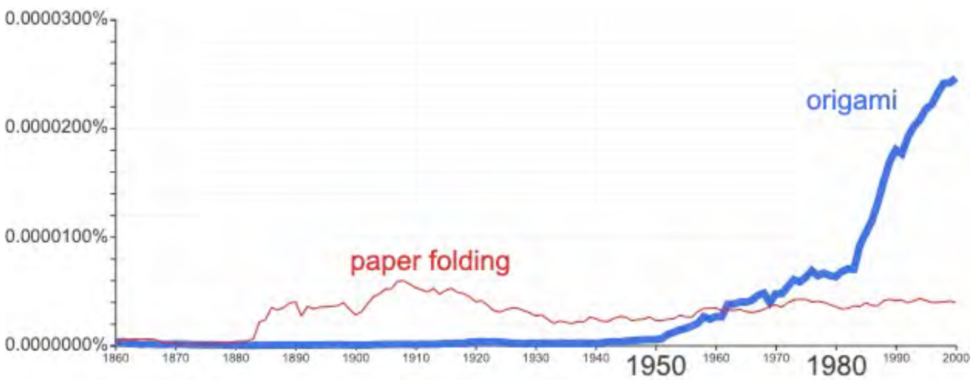


Figure 2. "Origami" in Google N-gram Viewer.

3. MODERN DEVELOPMENTS (SPACE)

OSME Conferences

The First International Meeting of Origami Science and Technology was organized by Professor Humiaki Huzita at Ferrara, Italy. It has been held in every four to five years since. The number of talks and participants for the conference increased significantly after the fourth meeting as shown in Table 1. The second meeting extended its range of interest from mathematics and science to art, history, education, and technology.

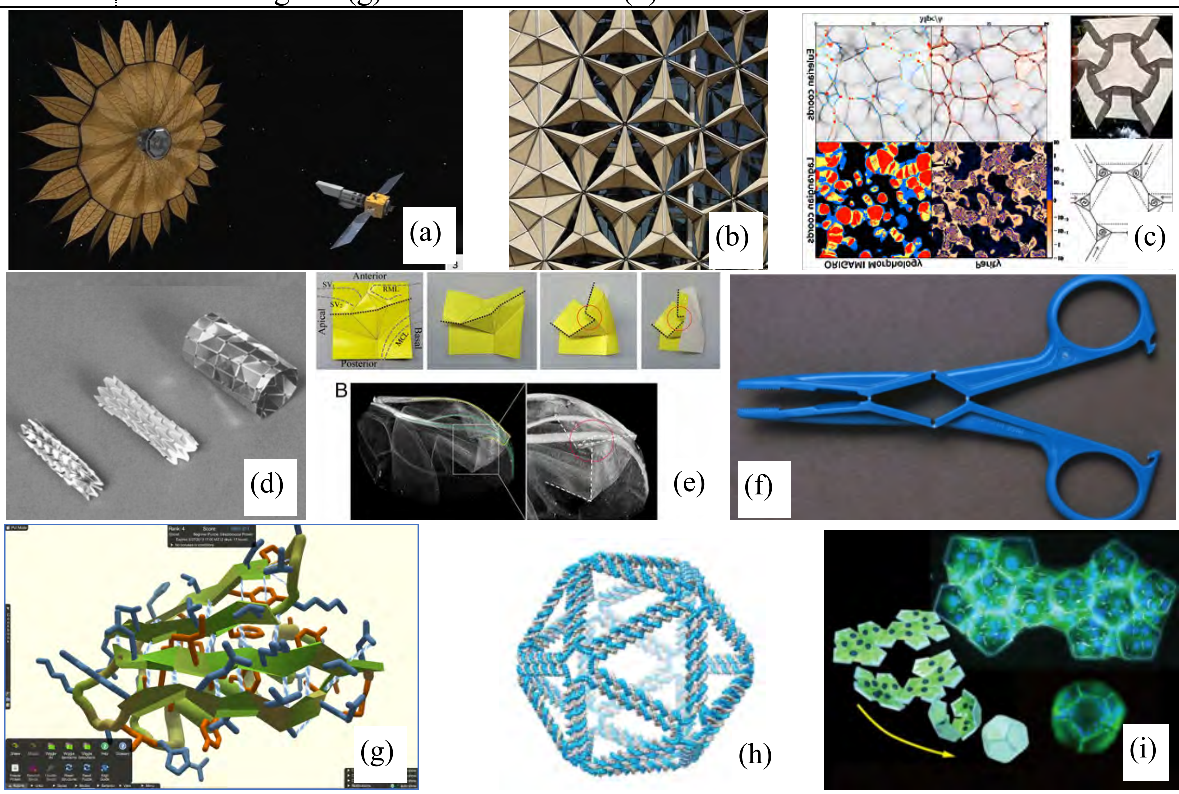
Table 1. OSME (International conference for Origami Science, Mathematics, and Education)

	1) 1989	**2)** 1994	**3)** 2001	**4)** 2006	**5)** 2010	**6)** 2014	**7)** 2018
Venue	Ferrara	Shiga	Asilomar	Pasadena	Singapore	Tokyo	Oxford
Country	Italy	Japan	USA	USA	Singapore	Japan	UK
Talks	17	49	31	80	61	137	110

Expanding Origami Research fields in Recent Years after 2000

The word Origami in science and technology today is used for the term for geometric manipulation of almost anything not restricted to folding sheet materials. The researches titled as DNA Origami is more like knitting strings of molecules. Figure 2 shows the broad range of Origami research at one glance in "Powers of Ten" format.

n	-9	-6	-5	-3	-2	-1	2	3	25
10^n [m]							Starshade(a)	Buildings(b)	Galaxy(c)
				Cell Origami (i)		Compliant Mechanisms (f)			
			DNA Origami (h)			Insect Wings (e)			
	Protein Origami (g)					SMA Stent (d)			

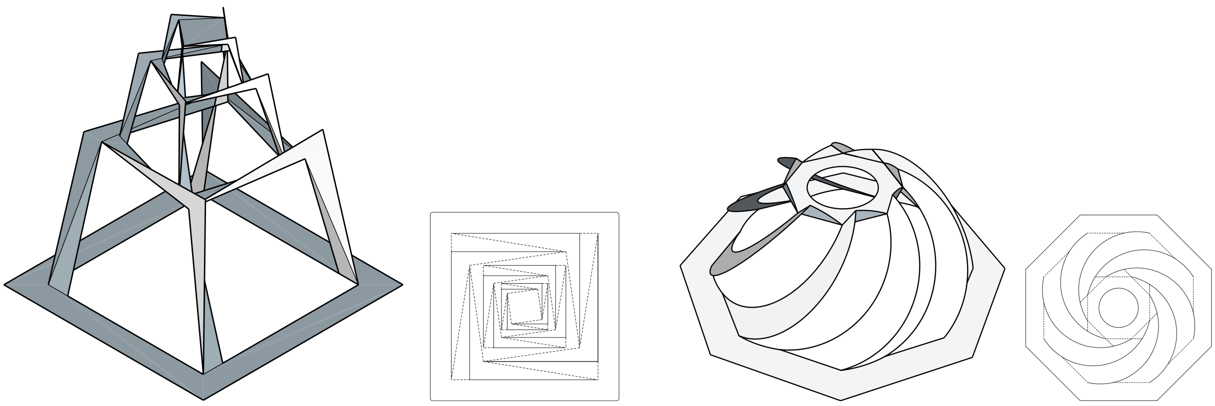


(a)[12], (b)[13], (c)[14], (d)[15], (e)[16], (f)[17], (g)[18], (h)[19], (i)[20]

Figure 3. Origami Powers of Ten

4. RES: ORIGAMI EXTENDED

In this chapter, we explain RES(Rotational Erection System) that we developed in 2011 as a recent example in Origami engineering science. RES is a design method to make 3D structure from a single sheet with systematic cuts and folds. It is Origami extended with cuts or Kirigami (Japanese: kiri = cut + gami = paper) folded into 3D shapes. RES would be an efficient production method for both artistic and industrial uses. Figure 4 shows a RES models and its cut & crease patterns. Figure 5 shows proposed architectural applications with use of cast-in-situ UHPC(Ultra High Performance Concrete) with the cable stay structure in Tilt-Up construction method.[21][22][23]



a) Tower: Isometric and Cut & Crease Pattern   b) Dome: Isometric and Cut & Crease Pattern

Figure 4. Rotational Erection System (RES):

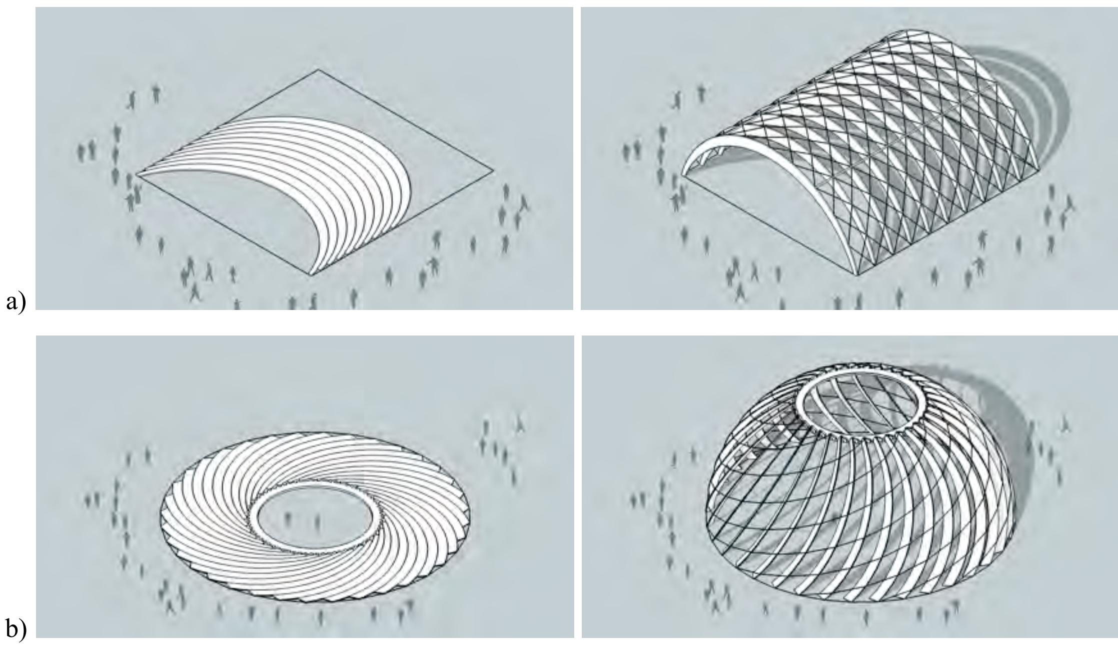


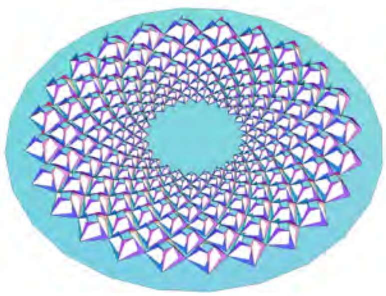
Figure 5. Construction of tilt-up UHPC with stay cables: a) vault, b) RES dome.

Significances of RES as a digital fabrication method are summarized in the Table 2.[21][24]

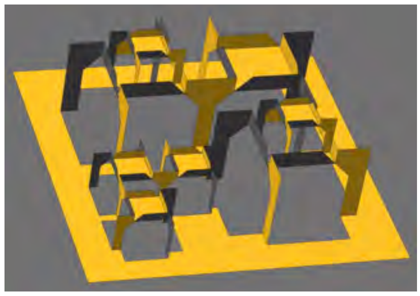
Table 2. Significances of RES

Concept	Integrated Cuts and Folds
Manipulation	Local and partial
Stability in Motion	Bi-stable or Tri-stable
Fabrication tools	Photo Etchings, CNC
Application	Machines and Building Elements
Assembly	Self-Assemble
Rigid Foldability	Modifiable with additional creases

We recently are exploring the tessellation methods of RES units on a sheet material. There are two strategy for RES tessellations: one is local manipulation and the other is inter-linked one.



a) Local manipulation



b) Inter-linked fractal pattern

Figure 6. RES tessellations

5. CONCLUSIONS

The art of Origami is an example of Temporal Design because the forms of Origami are generated by folding action in time. The forms in folded Origami carry the procedure of folding from a sheet of material. The beauty of Origami exists both in the process of folding and the folded state. The Origami or the art of folding became popular not because of its Japanese cultural background but because of its universal property that anyone can observe in the various phenomena in the Nature and cultures all over the world through the human history.

ACKNOWLEDGMENTS

Some parts of this talk were presented first as the invited keynote speech at the 2019 annual convention for Research Institute of Environmental Management, Administration and Maintenance of Japan.

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9th INTERNATIONAL SYMPOSIUM ON TEMPORAL DESIGN
OSAKA, 2-3 DECEMBER 2019

The attentional effect by temporal change of luminance

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ABSTRACT

This study aimed to examine how attentional effects were modulated by luminance levels of flickering light. In the experiment 1, subjects performed visual search tasks, in which visual distractors had an equal luminance level. The luminance of visual target was temporally modulated at 20 Hz in a flickering condition and temporally steady in a non-flickering condition. Results showed that averaged detection time for the target decreased with increasing luminance of the target in both conditions. In the experiment 2, visual search tasks, in which visual distractors had different luminance levels, were conducted. Results showed that detection time for the target decreased with increasing the luminance range of flicker. Results of both experiments suggest that the visual target can be found rapidly when the target has the temporal change of the luminance. Furthermore, the attentional effect is improved with the increase of the luminance range of flicker, but a certain degree of effect can be obtained even in a small luminance range of flicker.

1. INTRODUCTION

It is known that flickering light (i.e. a rapid and repeated change of luminance over time) with a relatively high temporal frequency capture more visual attention, compared with non-flickering light (i.e. light with stationary luminance) [1]. However, more information about how much attentional effect is obtained by amount of luminance change of flicker is needed to utilize flickering light for the purpose of improving attractiveness. This study focused on luminance of light, attentional effects of flickering light were examined. The time it takes to find out the visual target (detection time) was measured when visual distractors an equal luminance level and distractors had different luminance levels in the experiment 1 and 2, respectively. The detection time obtained for flickering targets and that for non-flickering targets were compared.

2. METHODS

Visual stimuli

<u>The experiment 1:</u> One target stimulus and fifteen distractors were presented on the liquid crystal display placed in front of the subject's eyes. The luminance of each distractor was fixed at 70 cd/m^2 in both of the flickering and non-flickering conditions. In the flickering condition, the luminance of the target stimulus changed temporally with a shape of rectangular wave and a temporal frequency of 20 Hz. The mean luminance of the flickering target was set at 70 cd/m^2, and the maximum luminance was changed at 5 levels. In the non-flickering condition, the luminance of the target was also changed at 5 levels. The background was black and the target and distractors were gray. The shape of stimuli was unified to square; however, the size of each stimulus was randomly varied.

The experiment 2: One target stimulus and fifteen distractors were also presented on the display. The shape of stimuli was unified to square, and lines overlay the stimuli. Line orientations on the distractors were randomly varied but line on the target was vertical. The luminance of each distractor was varied randomly between 20 to 120 cd/m^2. The target stimulus flickered at 20 Hz and its mean luminance was varied randomly between 20 to 120 cd/m^2 in each session. Luminance range of flicker was varied at 6 levels: from 0 to 7.5 % for the mean luminance.
Procedures: In the visual search task, a fixation mark was presented at the center of the display and then the target and distractors were appeared in each session. Subjects were instructed to press the button as soon as they find out the target. In total of 50 sessions were conducted for each luminance level in both of the flickering and non-flickering conditions of the experiment 1, and 40 sessions were conducted for each luminance range in the experiment 2.

3. RESULTS

The experiment 1: The averaged detection time became shorter as the maximum luminance of the target stimulus increased in flickering condition as shown in Fig. 1. As a result of one-way repeated measures ANOVA and multiple comparisons, significant differences were found between the higher two luminance levels and the lower two luminance levels ($p < 0.01$). Also in the non-flickering condition, the detection time became shorter as the luminance increased.
The experiment 2: The averaged detection time was the longest when luminance range of flicker was 0 % (i.e. non-flickering condition), and it became shorter as the range of luminance change increased as shown in Fig. 2. Significant differences were found among almost all luminance levels ($p < 0.01$).

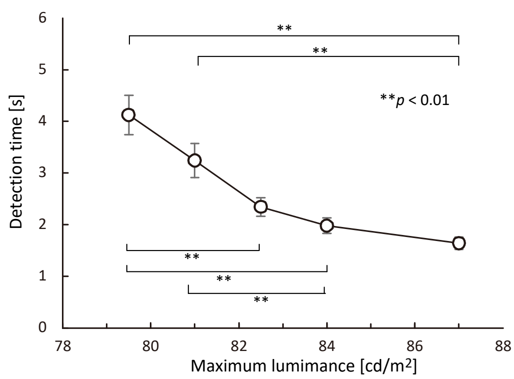

Fig.1. Detection time in Experiment 1 (flicker)

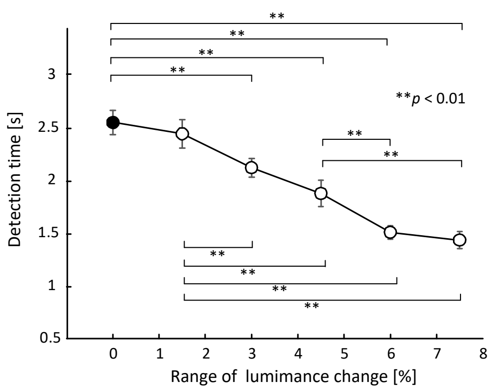

Fig.2. Detection time in Experiment 2

4. DISCUSSION

In the experiment 1, the detection time became shorter as the luminance of the target increased when the target stimulus to be detected was flickering and not flickering. However, the luminance of the target required for the same detection time was much lower for the flickering target. In the experiment 2, the detection time became shorter as the luminance range of flicker increased. Moreover, flicker with luminance range of only 3 % showed a significant effect in detection time, compared to non-flicker. These results suggest that the visual target can be found rapidly when the target has the temporal change of the luminance. Furthermore, such an attentional effect is improved with the increase of the luminance range of flicker, but a certain degree of effect can be obtained even in a small range of luminance change.

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Dance motion analysis by *Kinect* and dance-to-rhythm conversion algorithm

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ABSTRACT

Visually impaired people cannot check their movement visually, and then cannot understand whether their dance skill is good or not. The purpose of this research is to develop a system that the visually impaired dancers can grasp their performance level by hearing. We considered three elements related to dance proficiency "steady rhythm", "magnitude of movement" and "sharpness of movement". The steady rhythm and magnitude of movement were evaluated sufficiently by a first maximum peak of the normalized autocorrelation function (ϕ_1) and dynamic range of the coordinates, respectively. While, for the sharpness of movement, the corresponding factors were not able to be found at this moment.

We generated 8th-note drumbeats which were deteriorated depending on the ϕ_1 and the dynamic range of movement variation, and the psycho-acoustical experiments were conducted to judge the subjective distance from the original uniform drumbeats before the deterioration. As results, 97% subjects judged that the rhythm arranged in based only on the ϕ_1 is closer to the original one, and 93.8% subjects judged to be closer for the rhythm arranged by the both ϕ_1 and the dynamic range. This dance-to-rhythm conversion system would help to convey the performance level to visually impaired dancers.

1. INTRODUCTION

Although various barrier-free services for visually impaired people become popular such as Braille blocks and voice guidance, they are not promoted enough in the form of a hobby. For example, a ballroom dance can support them by pairing with healthy people (blind dance); however, dances by oneself (e.g., hip-hop and break dances) do not allow to check their movement visually, and then cannot understand whether their dance skill is improved or not.

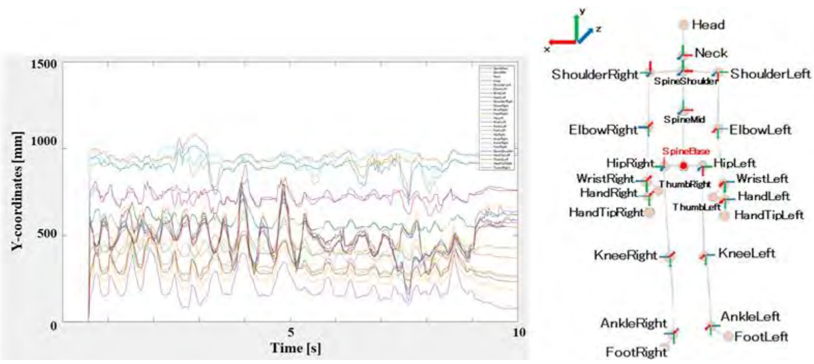

Figure 1. Y-coordinates of dance movement (left) and movable points (right) obtained by *Kinect*

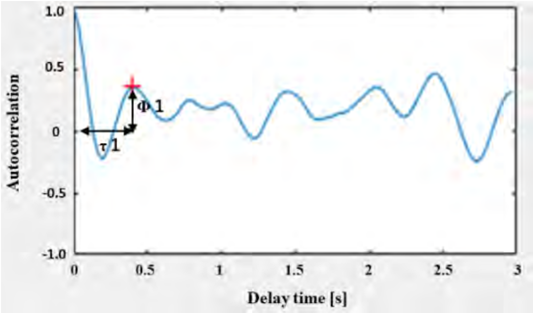

Figure 2. Normalized ACF of dance movement and the ACF factors (τ_1 and ϕ_1)

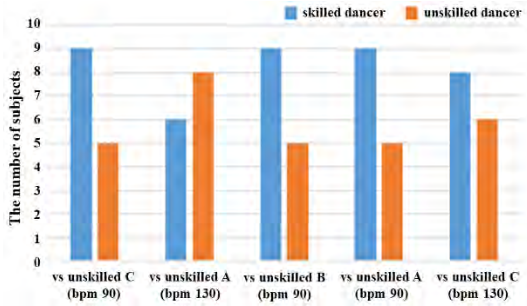

Figure 3. The result of the psycho-acoustical experiments in previous research [1]

The purpose of this research is to develop a system that the visually impaired dancers can grasp their performance level by hearing.

A previous research observed up-and-down movement of dance by acquisition of time sequence y-coordinates (Figure 1. left) using a *Kinect*, and that reconstructed the obtained movement into drum rhythm for the purpose to convey the image to the visually impaired dancers [1]. *Kinect* is motion capture device made by Microsoft and measures the distance to the body and obtains its 3D coordinate data with the motion of the skeleton reversed [2]. In the research, 25 movable points (Figure 1. right) of the body were recognized by *Kinect* in a sampling rate of 30 Hz, and an autocorrelation function (ACF) [3] was used to evaluate periodicity of movement. ACF is a measure of how well a signal $p(t)$ over time t matches itself with a time-shifted signal. The autocorrelation function $\Phi(\tau)$ is defined as

$$\Phi(\tau) = \lim_{T\to\infty} \frac{1}{T} \int_{-\frac{T}{2}}^{+\frac{T}{2}} p(t)p(t+\tau)dt \qquad (1)$$

where τ is delay time [s] and T is integration interval [s]. The drum rhythm was generated by a first maximum peak of the normalized ACF (ϕ_1) at a delay time of τ_1 as shown in Figure 2 (position: Spine Base in Figure 1. left). The research used data from the four points (Spine Base, Neck, Wrist Right, and Knee Left), and made these four data were assigned to different four drum sounds (bass drum, tom, cymbal, and hi-hat). One drum hit was arranged at equal intervals of τ_1, and then the arranged sounds were randomly shifted in the range of $(1 - \phi_1) \times weight$ (in this case: $weight = 0.1$). Because lower ϕ_1 indicates the irregularity of tempo in the dance, the reconstructed drum rhythm impairs the periodicity more largely by the process of the shifting. After passing this process for all four drum rhythm, the consequent rhythm were synthesized into one.

In the psycho-acoustical experiments, four dancers (one skilled dancers and three unskilled dancers) performed dance in the same choreography, which consisted of symmetrical movement in 10 s but in slow (beats per minutes (BPM): 90) and fast (BPM: 130) runs. Figure 3 compares the subjective evaluations (accuracy of rhythm) of 14 participants (male: 10, female: 4. Age: 20s – 30s) for the rhythms synthesized by the skilled and unskilled dances. Although the skilled dancer's rhythm was appreciated highly in almost pairs, the unskilled dancer's rhythm was accidentally chosen in some pairs especially for the fast run (BPM: 130).

Although the previous study focused only on the accuracy of periodical rhythm as a criterion [1], the performance of dance should be evaluated not only 1) the steady rhythm but also the 2) magnitude and 3) sharpness of movements. So, the aim of our study is to improve the affinity between the dance and the reconstructed rhythm by considering three elements related to dance proficiency. As shown in the previous study [1], the steady rhythm appeared in ϕ_1 and we confirmed that skilled dancer's ϕ_1 was higher than the unskilled dancer' one.

Figure 4. 8th-note drumbeats score (from the top, hi-hat, snare, bass drum, and up arrow is cymbal)

To evaluate the magnitude of movement, the dynamic range in the x- and y- coordinates was taken into our procedure. Finally, the sharpness of movement was evaluated using the speed of the movement.

2. METHODS

Synthesized algorithm from dance to drumbeat

To define an ideal rhythm clearly, we downloaded 8th-note drumbeats from free materials (Figure 4). For controlling the steady rhythm, the time intervals among drum hits were deteriorated depending on the shifting procedure described above. Therefore, the higher ϕ_1 of the up-to-down movement makes the drumbeat closer to the original one. For adding the magnitude of movement in the drumbeat, each drum hit was attenuated by 20 dB when the dynamic range was less than 5 mm. The attenuation value (20 dB) was determined not to hear it easily. For the sharpness of movement, we analyzed the speed and the acceleration of movement, but we could not obtained the correlative factors to sharpness of movement.

We reconsidered four suitable points of the body based on standard deviation, and then we determined to use Spine Base (bass drum), Knee Right (snare drum), Neck (cymbal), and Elbow Left (hi-hat). Since the bass drum and cymbal are noticeable even for a small shift, the points in the center of body were assigned to the two drum sounds.

The psycho-acoustical experiments

The psycho-acoustical experiments were conducted for 20 participants (male: 13, female: 7. Age: 19 – 53) to judge the subjective difference from the original 8th-note drumbeats. First, they listened to the original drumbeats and then answered which was subjectively closer to it among the skilled and unskilled dancer's rhythm presented by a loudspeaker mounted in a PC (made by NEC Personal Computers, Ltd., model number: PC-HZ750GAG) soon after listening to the original one. For the purpose to confirm the improvement from the previous study [1], the comparison test has five patterns for the algorithm controlling only ϕ_1 and four patterns for the algorithm controlling both ϕ_1 and the dynamic range of movement variation. For the sharpness of movement, we could not adopt the method to incorporate it into the rhythm quantitatively, so we used only two elements in these experiments.

3. RESULTS

Figure 5 shows the rate of participants who choose the skilled dancer's rhythm in the psycho-acoustical experiments. In Figure 5 left, the rhythm was arranged only by the ϕ_1, and 97% subjects judged to be closer to the original one on average. In Figure 5 right, the rhythm was arranged by the ϕ_1 and the dynamic range of movement variation, and 93.8% subjects judged to be closer on average.

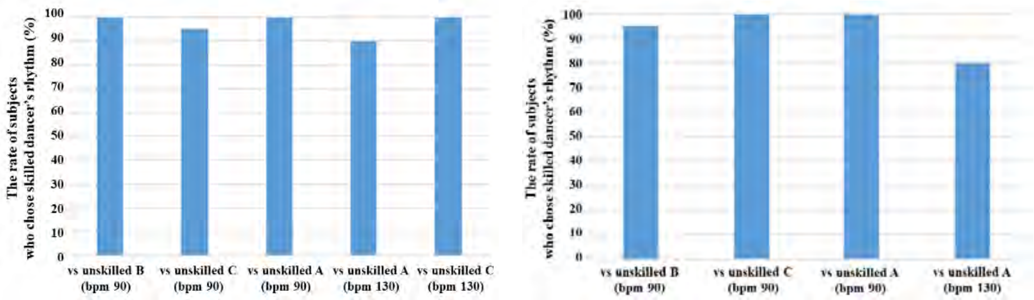

Figure 5. Rate of judgments that the skilled dancer's rhythm was closer to the original one
The reconstruction algorithm had a variable of only ϕ_1 (left) and both ϕ_1 and the dynamic range of movement variation (right).

4. DISCUSSION

After the experiments, most participants answered that they did not hesitate to choose which rhythm was closer to original one. By defining the ideal rhythm clearly, psycho-acoustical experiments became more reliable. However, by adding the magnitude of movement on the rhythm, the correct judgments decreased especially in the fast rhythm (BPM: 130) dance (Figure 5 left). In this algorithm, the constant attenuation (20 dB) of the drum sound was introduced at the border of one dynamic range (on-off action). For applying the magnitude of movement to the rhythm in a continuous manner, we have to consider a gradational methodology.

5. CONCLUSIONS

In this paper, we converted dance movement into drum rhythm by the algorithm using two elements related to steady rhythm (ϕ_1) and magnitude of movement (dynamic range). The algorithm deteriorated the original 8^{th}-note drumbeats depending on variables of the ϕ_1 and the dynamic range calculated from the dance movement captured by Kinect. As results, the rate of participants who judged the skilled dancer's rhythm better became lower for the improved algorithm. The problem have to be solved by improving the methodology to reflect the magnitude of movement to the rhythm. And we tried to improve the accuracy by considering the two elements, while the corresponding factors to "sharpness of movement" were not able to be found at this moment.

In further studies, we will try to quantify "sharpness of movement" of dance and we expect a gradual quantification for the proficiency level.

ACKNOWLEDGMENTS

We gratefully acknowledge dancers who cooperated in obtaining coordinates of movement and subjects of the psycho-acoustical experiments.

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Acoustic Design of Concert Halls

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ABSTRACT

This paper describes important considerations to design the acoustics of concert halls. After explaining the behavior of sounds in concert halls, the requirements for the reflections arriving at audience area are discussed in terms of the room shape design. Typical room shapes of concert halls are also introduced. Then, the requirements for the stage and the seat arrangement are explained. The reverberation design is discussed regarding the absorption of the seats, audience and the other surface materials. Finally, the methods to evaluate the acoustic design are briefly mentioned.

1. INTRODUCTION

During the music listening in concert halls, audience appreciates the musical performance fused with the acoustics of the hall. Therefore, not only the performance by musicians and conductor but also the hall acoustics is important. The acoustics from a sound source to a listener position is expressed by the impulse responses arriving at both ears. Each reflection arriving at a listener position has different amplitude, delay time and directions. The acoustic design is to form the structure of reflections. Fundamental acoustics of the hall are formed by the room shape and its materials. The following sections discuss the requirements for the room shape and surface materials to design the reflections and reverberations with regard to positive and negative acoustic effects on music listening.

2. BEHAVIOR OF SOUNDS IN CONCERT HALLS

Sounds radiated from sound source on the stage are expressed as a ray since the room size of concert halls is usually enough large in relation to the wavelength of the frequencies of interest. When a sound hits to a boundary, specular reflection, scattered reflections, and absorption happen. The specular reflection follows Snell’s law, in which the angles of sound incidence and reflection are the same. The order of reflection expresses how many times sound is reflected when a sound travels from a source to a listener position. At early design stage, the first order reflections can be used to determine the plan and cross-section shapes, reflector arrangement, and where to put diffusers and absorbers. Higher order reflections can trace the multiple reflections causing long-path echo, flutter echo, and creeping reflection. Scattering is expressed as non-specular reflections [1]. Sound attenuates by the traveling distance, boundary absorption, and air absorption. Sounds arriving at a listener position have attributes of amplitude, delay time, and incident direction, which determine the acoustic quality of sound field. Wave nature of sound becomes also important to consider the room modes, diffractions, interference between the direct sound and reflections.

3. REFRECTIONS AND DIFFUSIONS

Reflections with enough short delay time can support the direct sound to enhance the loudness and clarity. Furthermore, if early reflections come from lateral directions, they can enhance the spatial impression. It is inversely correlated with the interaural cross-correlation coefficient (IACC) between the signals arriving at the ears [2,3]. Lateral reflections can make the difference between the binaural signals regarding sound level, arrival time and spectrum. Effective incident angle for the reflection to minimize the IACC depends on the frequency [4]. For low frequencies below 500 Hz, the incident angle of 90° is the most effective. This is because the wavelength is much longer than the head and ear dimensions and the interaural phase difference is the factor to differentiate the binaural signals. For higher frequencies, smaller incidence angle can minimize the IACC. The main sound energy of music and speech signals appears at 1 kHz and the incident angle of reflection around 55° is the most effective.

To provide early reflections, proximity of boundaries is important. Narrow hall width and high ceiling can provide the early lateral reflections. Since the frontal central audience receives strong direct sound and the effect of reflections is relatively small, the side walls of the stage and frontal audience area are important to provide early lateral reflections. Leaf shape or saw tooth side walls whose surfaces are facing to the stage can provide more lateral reflections to the frontal central audience area. Side balconies can also provide early lateral reflections.

If the proximity of boundaries cannot be achieved, additional reflectors can be installed. The arrangement of the reflector panels should be partly open (say 50 %) to realize good balance between early reflections and reverberation [5]. Triangular panel is the optimum reflector shape since it makes incoherent boundary waves from each edge. Thus, it can reduce the excessive peak and dips on the spectrum [6]. Curved or bended surface of reflectors can enhance the lateral reflections and diffusion.

Too short delay time of reflection causes a tone coloration producing a comb filter effect due to the interference between the direct sound and the reflection. It may happen if the seat is placed directly on a side wall. Introducing side corridors between the wall and seat can easily avoid it. Multiple reflections causing long-path echo, flutter echo, and creeping reflection can be treated by appropriate placing of absorptive or diffusive materials. Rear wall of the audience area should be diffusive or absorptive if the wall directly sends back the reflection to the stage with long delay time (long-path echo).

Reflections should include diffusive components. When the side walls and the reflectors do not have sufficient diffusion, “acoustic glare” is perceived as a negative quality of the hall acoustics [7]. The specular reflection interferes with the direct sound and perceived as severe spectral modification with regular peaks and dips (comb-filter effects). Flutter echo, caused by multiple reflections between flat parallel walls, is a similar distortion. Also, the diffusion of a sound field affects the reverberation process. Irregular battens and blocks, semi-cylinder, pyramid, prism, wedges, and coffered wells can form diffusing surfaces.

4. ROOM SHAPE

Simple proportion of room dimensions must be avoided to prevent the room mode. Round, oval, and elliptic plan shapes make focusing of sounds to focal points and cause uneven distribution of the sound energy. Dome ceiling also make focusing. Any convex shape can scatter sounds to wider area than incident angle.

There are some typical room shapes of concert halls. Shoebox shape is a traditional and one of the best room plans. Its narrow hall width and high ceiling provide earlier lateral reflections, followed by ceiling reflections [8]. Shoebox shape itself is not only the key for good acoustics. Ornaments, statues, chandeliers, and coffers on the walls and ceilings can create diffusions. Fan shape is also common plan shape especially for multi-purpose halls since more audience can accommodate closer to the stage. Visual condition is also important for audience. Since the angled side walls send the reflections to rear audience area, additional reflectors or diffusers on the frontal side walls are needed to provide reflections to the frontal central audience area. Ceiling reflectors can also compensate the lack of lateral reflections. In vineyard or terrace type hall, level differences between the audience blocks produce vertical walls to reflect sounds to each audience area. Arena hall has the audience areas surrounding the stage. The audience at the sides and the rear of the stage can have intimate visual experience of musicians on the stage. The balcony fronts and ceilings can be designed to provide the lateral reflections to main audience area. In some recent auditoriums, interior surfaces consist of organic curves.

5. STAGE AND AUDIENCE AREA

The stage should be enough large to accommodate a group of orchestra members. The required area is 1.9 m^2 per musician. Regarding the floor shape, stage rear wall is usually narrower than the frontal width to provide reflections to both musicians on the stage and the audience in the frontal area. The stage size is crucial to design the delay time and amplitude of reflections, which relate to ease of ensemble or hearing each other. Stage volume affects the reverberance for musicians on the stage. Diffusion can be created by irregularities on the stage walls. Since the presence of musicians affects the strength of reflections, reflections and diffusions from upper walls are more effective. The angled stage rear wall can decrease the IACC in audience area [9].

In the audience area, the floor is usually sloped to provide better sightlines. It also contributes to reduce the seat-dip effect, that is, the attenuation of the sound energy at low-frequencies by the phase cancellation between the direct sound and grazing reflection from the floor [10]. The seats are arranged to comply with the building code which ensures the safety of evacuation in case of emergency. Items usually included in the code are the seat dimensions, row-to-row distance, limitation of the continuous seat numbers in each row, floor slope, corridor width, specification of exit doors, etc. The seat arrangement can also provide better sightlines. The staggered seat arrangement has advantage over grid arrangement, regarding better sightlines. Too wide fan shape is not preferable due to the limited sight of the stage from the most lateral seats.

Balconies are introduced to increase the capacity. Under balcony space should not be deep to avoid lower SPL, lower reverberation energy, and less diffusion. The recommendation for under balcony space is that the depth should be less than the opening height [7] or the furthest audience row should have at least 40° of vertical visual angle [11].

6. REVERBERATION AND ABSORPTION

The reverberation time is one of essential factors of the concert hall acoustics. As the management of musical event, greater capacity is preferable for more ticket sales. But it conflicts with the better acoustic condition, that is, longer reverberation time by greater room volume. Thus, the design should find the point of compromise. At early design stage, the room volume per seat number (V/N) is often used to achieve appropriate reverberation time. For concert halls, the V/N around 10 m^3 is recommended. More recent recommendation uses the ratio of the room volume to the area of the seating [11] or the area of both seating and orchestra [12].

Considering the fact that seats and audience are the major absorptions in concert halls, their precise absorption coefficients are necessary. Beranek and Hidaka made the absorption measurement in several concert halls by obtaining the reverberation times before and after installing the seats [13]. Although concert hall is not perfect diffusive sound field, huge seating blocks can be treated as surfaces like other boundary materials. The edges of the seating blocks exposed should be counted as an additional absorption area (acoustic seating area). The seats are classified by the degree of upholstery according to the thickness of absorptive materials. The absorption of the seats should be comparable to that of person so that the reverberation time does not greatly change according to the occupancy.

The absorption except for the seat and audience (residual absorption coefficient) should be kept low even for the low frequencies [13]. Although there is wide variation regarding surface materials of concert halls, plaster and gypsum boards are often used for side walls, ceiling, and balcony surfaces [14]. Wood is another frequently used material. Typical materials for the audience floor are concrete and wood, sometimes with carpet or cork/vinyl tiles. Reflector panels are often made of plywood or acrylic.

The Sabine's equation is a good approximation to predict the reverberation time with enough accuracy [15]. Due to a great room volume of concert hall, the calculation of the reverberation time needs to include the air absorption, which is significant at frequencies above 1 kHz [16]. Due to the absorption by seats and audience as porous material and the air absorption, the frequency characteristics of the reverberation time shows natural decrease from low to high frequencies.

Since the target reverberation time depends on performance program, variable acoustic system can be used in multi-purpose halls. The simplest variable acoustics use drapes. The reversible panels with reflective and absorptive faces are also used. Several halls equip the reverberation chambers around the original room volume. By opening and closing the doors to the chambers, the room volume can be varied and thus the reverberation time can be varied.

7. PREDICTION AND EVALUATION OF ACOUSTICS IN CONCERT HALLS

Thanks to the developments of simulation algorithms and computation power, the computer simulation is widely used to predict the acoustics at design stage. It can trace a number of reflections and can calculate impulse responses (thus, a set of acoustic parameters) at a number of listening positions. The reflection patterns in 3D spaces can be visualized. Immediate change of the surface absorption and scattering is also the advantage.

From simulation results, spatial distribution of a set of acoustic parameters can be examined. The Barron's revised theory is a reference to check if the sound energy distribution throughout the audience area is appropriate [17]. Since multiple reflections with higher reflection order can be traced, the entire process of reverberation delay can also be simulated. The observation of the initial reverberation decay can check if the early reflections and diffusions are appropriate [18].

Since the accuracy of the acoustic simulation is still not enough to predict reflections and diffusion from curved surfaces precisely, the scale model measurement is also used. The simulated and the measured impulse responses can be used for auralization, convolved with anechoic music signals.

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Dynamic Theory of Preference: Maintaining Survival Power Amid Various Stressors

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ABSTRACT

Subjective preference is the most fundamental requirement for the design of architecture and the environment, responsible for maintaining health in individuals and supporting individual creativity toward the third stage of life (the creative legacy). A sustainable third stage of life can only spring from a sustainable first and second stage of life (mind and body), keeping in mind both temporal and spatial aspects of the physical world at large, and our living environment in particular. The left hemisphere of our brain is always reacting to temporal stimuli, and the right hemisphere is constantly reacting to spatial stimuli, be they perceived physically or imagined during study. Visuality and spatiality are normally considered the main foci in architectural and creative expressions. Yet, there are other senses that can mediate to us affection from the surrounding world. Through a dynamic theory of preference, the authors would like to invite specialists from respective fields to study thermal preferences of individuals whilst listening to different types of music in concert halls that have been optimized according to the subjective preference theory.

1. INTRODUCTION

Lack of knowledge of what an excellent sound field should sound like once left one of the authors stressed when listening to music in a concert hall. The experience served as an impetus to understand human preferences for sound fields. The subjective preference theory of the sound field with temporal and spatial factors associated with the left and right cerebral hemispheres, respectively, was established in 1983 (Ando, 1983, 1985, 1998, 2007, Suzumura and Ando, 2018). Sound fields with echo or too long a reverberation when listening to vocal music, also those without clear spatial impressions, are not pleasantly perceived. Despite expensive tickets, the opening concert of the New York Philharmonic Hall in 1962 was a disappointment acoustically because the project had forgotten to consider one spatial factor, i.e., the IACC, the most powerful spatial factor that influences incipient subjective judgments.

Environmental noise from outside an enclosure can have extreme effects on preference judgments. An interesting experience was when at times, the temperature would feel too cold in the foot and leg area during the performances. This prompted the question – can thermal comfort or discomfort influence acoustic experiences and if so, to what degree? To begin with, inverting natural thermal stratification by cooling from overhead and warming from underneath could create the conditions for "positive alliesthesia", or a pleasure sensation, which is caused by different thermal sensitivities along the body's vertical axis – the foot and calf area prefers warmth while the head area prefers a cooler environment (Parkinson and de Dear, 2015). It is well-recognized across disciplines that physical environments are ready to adopt more progressive solutions such as PCE (personally controlled environments). Among these approaches is a place for not only visual and acoustic aesthetics, but also thermal aesthetics. Our perceived physical fields exhibit both temporal and spatial properties on all scales, and therefore, temporal and spatial factors of physical environments should be well designed (Ando, 2016).

Most generally, among the daily preferences in life is to listen to selected music in a well-designed concert hall like the Kirishima International Music Hall, which opened in 1994. The international symposium on music and concert hall acoustics (MCHA) and concert halls was held in 1995 for which we published a proceedings paper (Ando and Noson, 1997). We strove to maximize individuals' preference by using the seat selection system. A number of participants were tested for their preference of a simulated sound field in a specially provided listening room and the most preferred seating positions were found based on the results.

It is natural to want to feel good and it is therefore highly recommended to maximize preferences and minimize stress of life to maintain our survival power, keep in good health without suffering from disease (Ando, 2018). Finding preferences daily from natural phenomena such as rivers, brooklets, wind blowing through a mill, trees, and moonlight all continue to be expressions of the universe's affection to this end.

2. DYNAMIC THEORY OF PREFERENCE: MAINTAINING SURVIVAL POWER AMID VARIOUS STRESSORS

It is well known that variety of "stressors" set into motion defense reactions mediated through the nervous and the hormonal systems (Selye, 1950). Introduction of the concept of stress in the 1950s coincided with avarice in economical pursuits and the idea that, "time is money". As a result, an ever-increasing number of people suffer from kidney disease, cancers, intractable pain disease and cognitive impairment as shown in Figure 1. The word "stress" was not often used before the 1950s, and the number of existing central hospitals was considerably lower. Nowadays, it is normative that human life is so occupied by a wide range of stressors including ill human relations that the pleasure derived from the process of living is regretfully often drained away by stress.

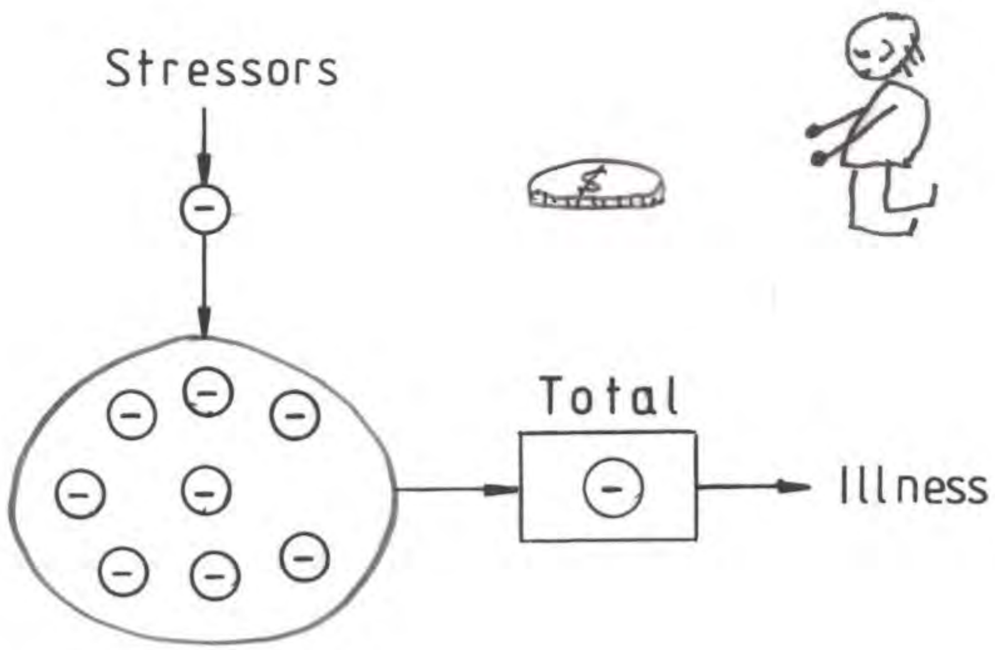

Figure 1 Stress theory that causes loss of survival power, leading to suffering from disease due to a certain limited total amount of survival power attributed to each individual (Selye, 1950).

In order to attain healthy living, avoid ill treatment of fellow humans and further wars, this paper proposes achieving high survival power by means of a dynamic theory of preference amid various stressors of life as indicated in Figure 2. We would like to emphasize the most powerful preference, the one which, in terms of establishing a life based on the unique DNA of each individual, should be nourished through creativity. Knowledge of our own creativity which is associated with both cerebral hemispheres may later integrate into culture and persist long after the end of our life in a society (the third stage of individual life).

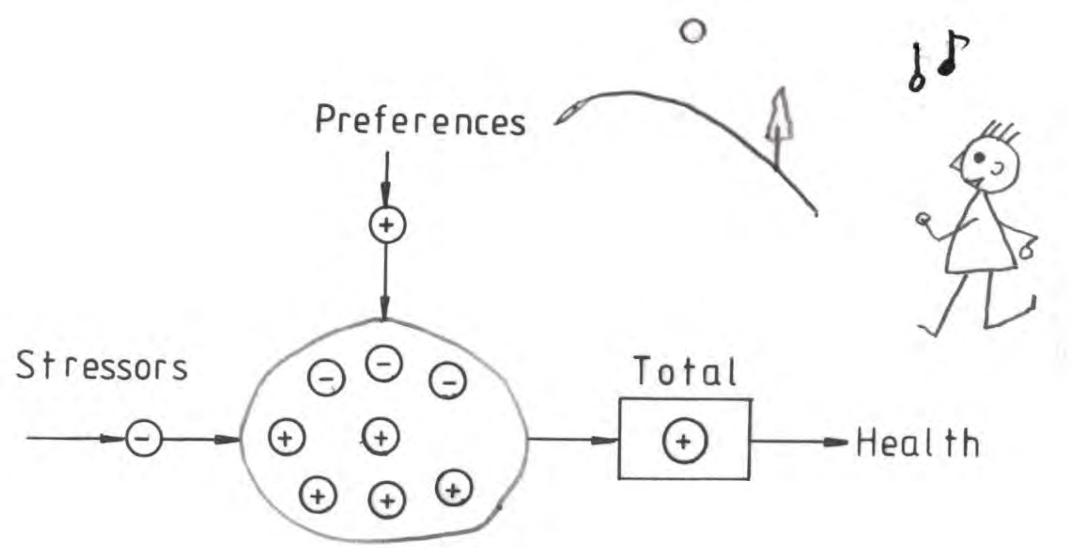

Figure 2 Dynamic theory of preference of life: maintaining survival power amid various stressors. Supporting and maintaining survival power – health – even within such a vast variety of stressors.

3. Application of the Dynamic Theory for Calculating Dialysis Introduction Age (DIA)

In order to apply the dynamic theory, factors of preference and stress usually present in human life thus influencing the dialysis introduction age (DIA) were studied. An investigation was conducted based on a questionnaire distributed to patients attending a hospital in Kobe, Japan, where one of the authors was a patient. Results show that the most stressful factors causing earlier DIA are troubled inter-human relations and environmental noise. The preference factor postponing DIA was found in social drinking.

3.1 Factor Analysis

In order to predict DIA, factor analysis based on the mathematical quantification theory (Hayashi, 1950) was carried out. 16 factors of stress and preference, in addition to dwelling environment factors as well as clinical history obtained by questionnaire, were analyzed. Total questionnaire data collected was 34 but valid data was 30 without lack of data (unanswered). DIA data were rearranged by rounding, for example, 55 is 50 (fifties) and 68 is 60 (sixties).

In order to calculate DIA, factors of individual clinical history of past high blood pressure and proteinuria records as well as factors 1) ill human relations; 2) worked hard in years; 3) consumption of alcoholic beverage; 4) noise pollution at the dwelling; 5) other pollutions; 6) smoking; 7) number of times hospitalized; 8) number of times moving house. Other factors such as gender, pets, bad odors, past noise pollution and preference for future life from first to third stages were insignificant for DIA also.

3.2 Results

As shown in Figure 3, the most significant factor predicting DIA was ill human relations as a negative factor ($p < 0.01$), thus DIA at younger age. The second significant factor was preferred alcoholic beverage as positive factor ($p < 0.05$), thus DIA at older age. The third was working hard as negative factor ($p = 0.05$), thus DIA at younger age. As indicated on the second line of the figure, “worked hard” for more than 30 years postponed DIA due to habituation effects relative to shorter category than 29 years ($p = 0.05$). As indicated on the fourth line, noise pollutions acted as a stress factor, leading to DIA at younger age ($p < 0.1$).

However, individual clinical history of past high blood pressure and proteinuria records did not affect DIA.

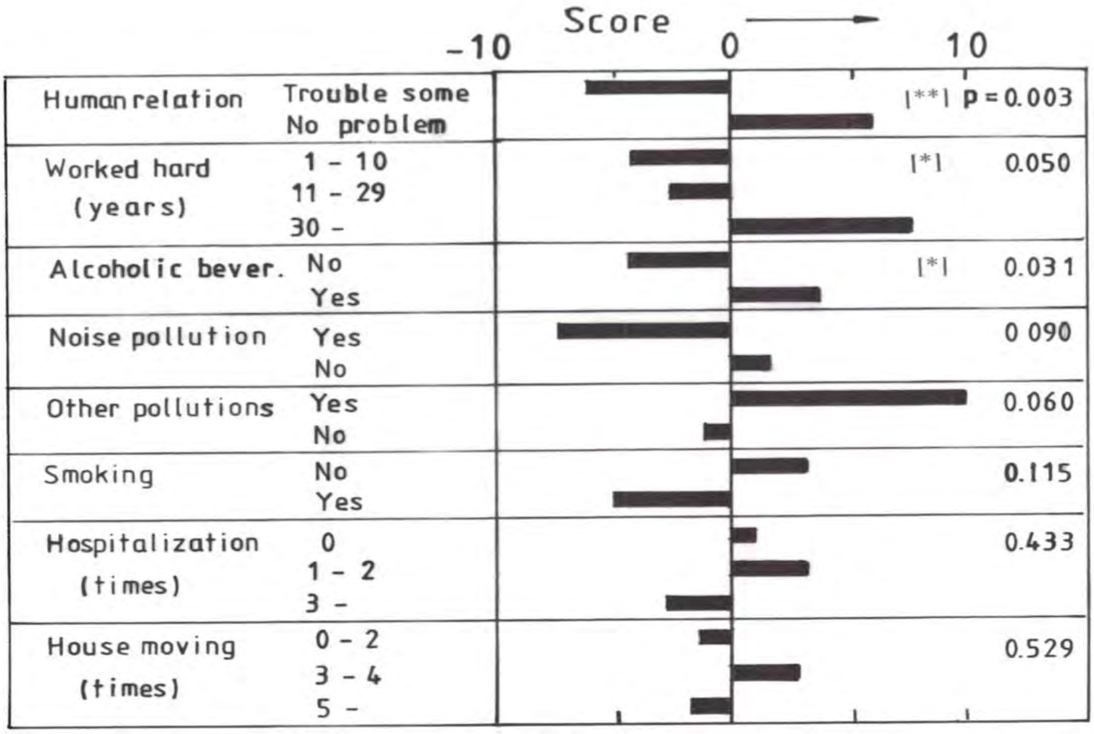

Figure 3 Resulting score of each category of eight factors in calculating DIA by analysis. Symbols [**] and [*] signify significant levels 0.01 and 0.05, respectively.

By applying these 8 factors the DIA is roughly described as shown in Figure 4. The total coefficient of determination was 0.59 (> 0.5), so that DIA was fairly described by the eight factors (Figure 4).

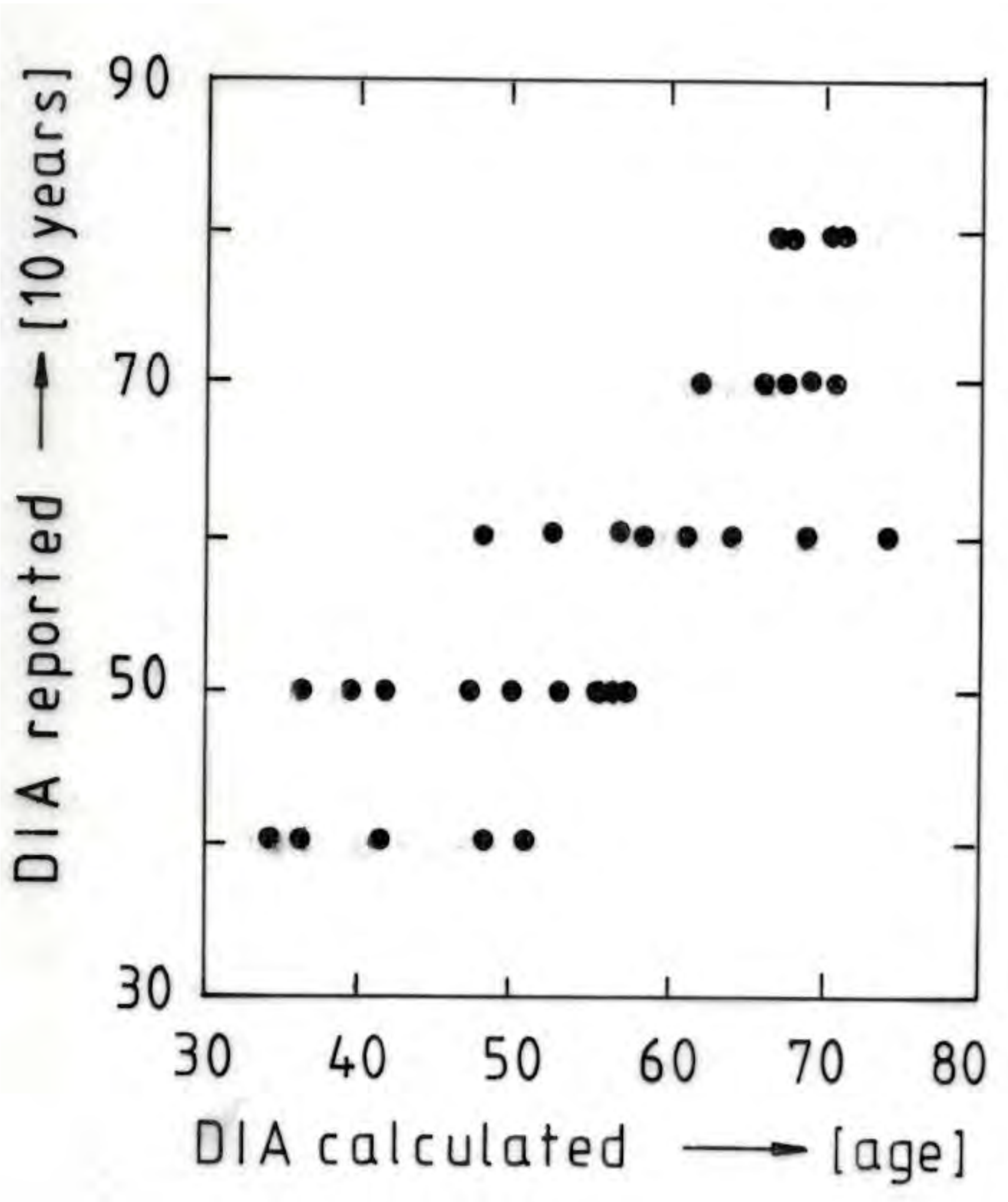

Figure 4 Relationship between DIA calculated utilizing results of analysis and DIA (10 years step as round number) reported in the questionnaire by each patient. The DIA may be roughly described by eight factors shown in Figure 3.

4. Third Stage of Healthy Life: Recovering Environments and Keeping Peace

We aim to forward a hope for each individual to be surrounded by their preferred environment so that the three stages of life according to the theory of preference (Ando, 2016) could flourish. The development of an original idea, creativity and a sustainable personality can be realized by the dynamic theory of preference of life amid various stressors (Section 3.1),

1) **Individual Power of Survival**

Maintaining our environments in the long haul can be achieved by creations springing from the actions of a variety of unique personalities. Uniqueness, encoded in each individual DNA, ultimately integrates into culture. We could say, our ecological footprint is in our DNA.

2) **Individual Power of Affection** (Maximizing Affection – Minimizing Avarice)

Individuals endorsing affection with value may play an important role for the future. On the other hand, a nation that highly values idolatry such as money or status might result in termination – environments are often secondary for such cultures, leaving them subject to catastrophic events such as nuclear war.

In other words, a universal education and globalization based on the concept of "time is money" is subject to producing individuals who suffer from stress, consecutive illnesses and ill human relations. The objective should be to shift to the third stage of human life from the animal stages of body and mind, so that from an early age we grow up learning to avoid ill treatment of others, maintain our health and environment, and keep peace.

As discussed previously, any original idea and creative activities that resonate with an individual's personality (DNA) may carry immense survival power in their personal life, and later as culture, traversing individual life span.

In other words, if survival power in the third stage (individual creativity) is strong enough, life as such may continue to the fourth stage (culture) and survive even after the end of an individual life (Danjo, 2014).

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Appropriate background music in coffee shop and autocorrelation analysis

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ABSTRACT

A coffee shop plays a role of social interaction in foreign countries, while, in Japan, it can be sometime a restful space enough to enter and spent a time even alone without doing anything. So the shop manager often plays relaxing and tranquil music in the background. Which kind of music is appropriate to the Japanese coffee shops? The author has gone around the 20 coffee shops in Matsue city and identified the titles and singers of the 76 background music (BGM). The categories were classic (26%), jazz (21%), pops (16%), rock (12%), the others (25%). To get the impression of the music, at first, I conducted a questionnaire (5-point scale) consisting of 25 adjectives. The 10 music were selected from the 76 music considering the balance of the categories, and they were presented to 22 participants (11 males and 11 females) by a headphone. At the same time, the participants judged the goodness for coffee shop by the same 5-point scale. As a result, the degree of fitting for coffee shop was related to the points in the items of "tender", "cheerful" and "tranquil." To examine the physical parameters seen in the appropriate BGM, an autocorrelation function (ACF) was carried out for the selected 10 music. As a result, the first maximum peak of ACF (ϕ_1) was highly correlated with the goodness for coffee shop ($r = 0.68$, $p < 0.01$). For music consisting of a number of musical instruments and singings, the ϕ_1 indicate the accessibility of the melody riding on the rhythm. Japanese people drinking in a coffee shop may spent a tranquil time unconsciously tracking melody of the BGM.

1. INTRODUCTION

In March 27th, 2013, a Seattle-based coffee chain STARBUCKS in Shimane was opened 46thly in the Japanese 47 prefectures. The reasons for the late debut are not only the depopulated region but also the rich coffee culture in Shimane. Shimane has many original coffee shops under small-scale management (e.g., Hattori coffee, Sawai coffee, Café Vita, etc.), so it was hard for major chains to eat away the share.

A background music (BGM) is indispensable to create some space to relax. Because the copyright protection is managed severely by Japanese Society for Rights of Authors, Composers and Publishers (JASRAC), almost shop managers use out-of-copyright music, such as classic and jazz music. Or music by cable broadcast and music free from copyright can be used in the public space.

BGM is music not aimed for appreciation but for half-listening while doing the other work. Based on this definition, previous studies for the BGM have focused on the working efficiency in the present and absence of BGM [1, 2]. However, the BGM plays the other role to guide

Table 1. Coffee shops' BGMs used for psycho-acoustical experiments

Jazz (3 music)	Classic (3 music)	Rock (3 music)	Pops (1 music)
Moving up	Tarantelle in A-Flat Major, Op. 4	Guitar Man	Irregular Red
How Long Has This Been Going On	Suite for Cello Solo No.3 in C	Moment by Moment	
Ballad of Hix Blewitt	III Menuetto + Tiro	Brown Eyed Handsome Man	

image (e.g., soft or premium) and feeling (calm and sense of safety) for the space, and the role is dominant for the BGM in the coffee shops.

Therefore, the aim of this study is to survey the BGM used by 20 coffee shops in Matsue (Shimane) and evaluate the feeling induced by it using an affective scale value during listening to music. The affective scale value is determined by five-point scale for 24 adjective items (e.g., tender, strong, melancholy, etc.) which express the impression of the music [3]. The participants of this psycho-acoustical experiment judged the impression of the BGM according to the adjective items, and judged goodness for the BGM heard in a coffee shop by the same five-point scale. Adding the psycho-acoustical experiment, an autocorrelation function (ACF) of the BGM was carried out to capture physical characteristics. The factors extracted from the ACF of music indicate pitch, tempo, clarity of melody, and so on. The goal of this study is to explain the fitting BGM for coffee shops by the adjective items and ACF factors.

2. SURVEY OF BACKGROUND MUSIC IN COFFEE SHOPS

From October to November 2016, we went around 20 coffee shops in Matsue (including major coffee chains) and identified the title and player of 76 BGM using app in Android, SHAZAM. The categories of music were followed by the same categories in iTunes (Apple Inc.). Many coffee shops use the BGM in same category to set the uniform atmosphere. For example, *Starbucks* and *Café Blanc* used music in classic and jazz, respectively. In the 76 BGM, the 20 music were classic (26%), 16 music were jazz (21%), 12 music were pops (16%), 9 music were rock (12%), and 19 music were the others (25%). As described above, classic and jazz (out-of-copyright music) were used mainly.

3. PSYCHO-ACOUSTICAL EXPERIMENTS

In the 76 BGM surveyed, the following 10 music were bought and downloaded (Table 1). For the 10 music, an affective scale value were measured to examine the impressions of them. Three music were chosen in one category, and one music was chosen in the pops as shown in Table 1. In addition to the 10 BGM, following five music used in stores excepting a coffee shop were downloaded; 1) BGM of LAMU (Supermarket), 2) Music of YAMADA DENKI Co., LTD. (Electric mass retailer), 3) BGM of HARD-OFF (Recycle store), 4) Theme of Don Quixote (Discount store), 5) BGM of MISHIMAYA (Supermarket).

In the above 15 music, representative 20 s was cut off, and the short music intervals (stereo source) were presented to the both ears of 22 participants (11 male and 11 female, age: 21 to 39 years old) by a headphone (HD 595, SENNHEISER) in a silent room (background noise: below 30 dB). The output level of the headphone was 70 dB.

The participants answered a questionnaire (24 items in five-point scale) according to the affective scale value after listening to each BGM of 20 s. The 24 items were expressed by adjectives, and the 25th item asked a degree of fitting for the BGM heard in a coffee shop in the same five-point scale.

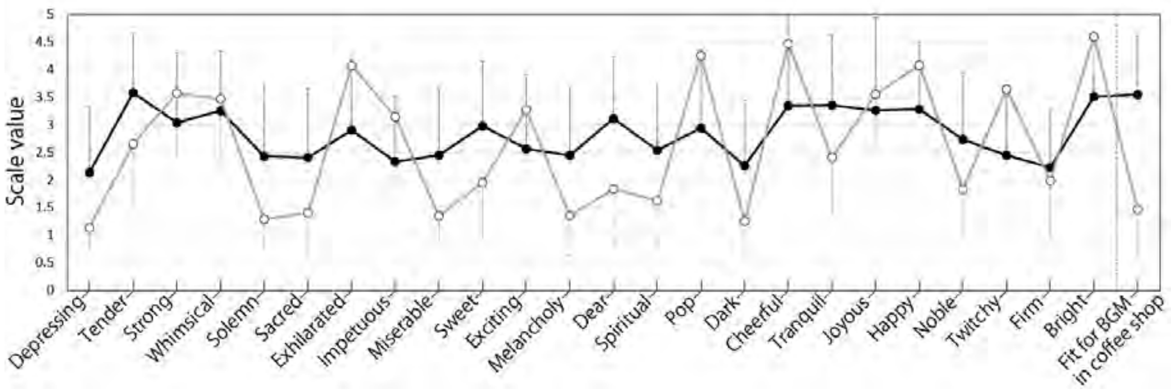

Figure 1. Affective scale values for each 24 adjectives and 1 degree of fitting for coffee shop's BGM according to the BGMs used in 10 coffee shops (○) and 5 other shops (●) (Error bar: SD)

As results, the obtained affective scale value and the degree of fitting were averaged in the 10 coffee shops and the 5 other shops (Figure 1). A larger value means to be more applicable for the adjective. The participants got "tender", "cheerful" and "tranquil" impressions from the BGMs in the coffee shops. These impressions creates comfortable and relaxed atmosphere. On the other hand, they got "exhilarated", "pop" and "cheerful" impressions from the other shops. These impressions fuels the customers' motivation to buy something. Naturally, the degree of fitting to the coffee shop was much larger for the BGM actually used in it than the BGM in the other shops. The high scale values for the fitting BGM got centered on the two categories, jazz and classic music: "Moving Up (jazz)" (averaged value: 4.36), "How Long Has This Been Going On (jazz)" (3.86), "Suite for Cello Solo No. 3 in C (classic)" (3.82) and "Ballad of Hix Blewitt (jazz)" (3.77).

4. AUTOCORRELATION FUNCTION (ACF) OF BGM

In next step, using the ACF of the BGM, we tried to extract a physical factor to explain why these music fitted to the coffee shop. ACF is the correlation of a signal with a delayed copy of itself as a function of delay, and is a mathematical tool for finding repeating patterns, such as the presence of a periodic signal, or identifying the missing fundamental frequency in a signal implied by its harmonic frequencies. The normalized ACF of a signal $P(t)$ is defined by

$$\emptyset(\tau) = \frac{\Phi(\tau)}{\Phi(0)} \quad (1)$$

where

$$\Phi(\tau) = \frac{1}{2T}\int_{-T}^{T} P'(t)P'(t+\tau)dt \quad (2)$$

and where $2T$ is the integral interval, τ is the time delay, and $P'(t)$ is the signal after passing through the A-weighting filter. Because ACF factors in music vary as a function of time, they were calculated in the integral interval ($2T$) that moves along with the duration of music. In this study, the running ACF using a $2T$ of 0.5 s, with 0.1 s sliding steps was calculated.

From the normalized ACF, the following factors were extracted as shown in Figure 2 [4, 5].

1. delay time of the maximum peak (τ_1): comprehensive pitch in music
2. amplitude of the first maximum peak (ϕ_1): clarity of melody
3. effective duration (τ_e): tempo, tone or number of musical instruments
4. width of the peak at $\tau = 0$ ($W_{\Phi(0)}$): spectral center of music

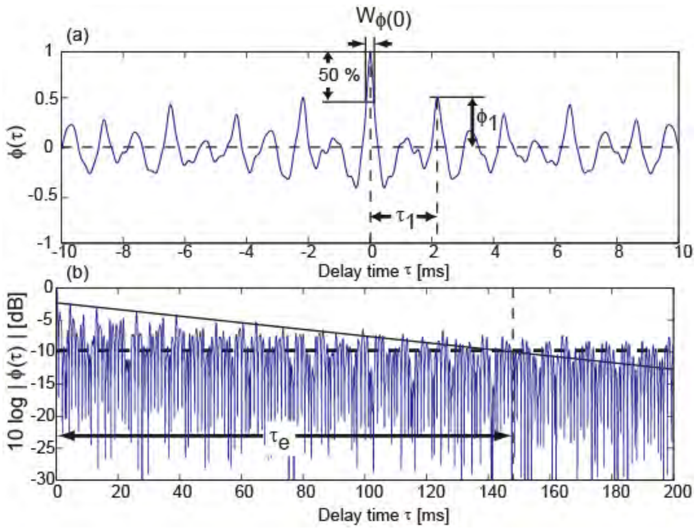

Figure 2. Definitions of ACF factors in (a) normal and (b) logarithmic scales of $\phi(\tau)$

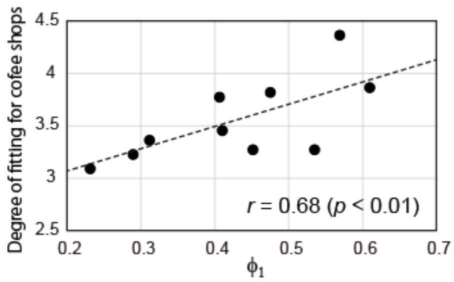

Figure 3. Relationship between ϕ_1 and degree of fitting for coffee shops

As results of running ACF along the music interval (20 s), 200 values of each factor could be obtained, so the represented value for a music was determined by the averaged one. When the averaged ACF factors were examined to find the relationship with the scale value of fitting for the coffee shop's BGM, the ϕ_1 had a high correlation with it (r = 0.68) as shown in Figure 3. In other words, the suitable BGM for coffee shop is a music which melody can be tracked clearly. The melodies of "Moving Up" and "How Long Has This Been Going On" are played by piano, and the melody of "Suite for Cello Solo No. 3 in C" is played by cello. The both melody lines could be picked up easily. On the contrary, a music with ambiguous melody (e.g., contemporary music) or music based on rhythm (e.g., dance music) are inadequate for the BGM in coffee shop.

5. CONCLUSION

As results of the affective scale value, the fitting BGMs to coffee shops are "tender", "cheerful" and "tranquil" music. As results of the ACF factors, music with higher ϕ_1 is adequate for the coffee shops, so the simple and clear melodies are preferred for the customers. Maybe they enjoy the comfortable and relaxed time following the melody lines unconsciously.

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Cortical magnetic activities induced by salient birdsong in noisy conditions

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ABSTRACT

To clarify brain activities related to salience of birdsong in noisy environments, magnetoencephalographic (MEG) activities and subjective salience induced by 6 birdsongs in 3 noisy environments were measured. The scale values of subjective salience of birdsongs in noisy conditions were also measured using the paired-comparison tests. The sparse regression analysis revealed that the power of the induced alpha (8–13 Hz) in the frontal region, and induced gamma (30–50 Hz) in the parietal region. The power of the frontal alpha and parietal gamma activities significantly changed across birds and noise conditions, respectively. These results indicate that the induced frontal alpha and parietal gamma activities are related to salience of birdsong and environmental noise, respectively.

1. INTRODUCTION

Birdsongs are often used in public space in Japan to inform visually-challenged people about presence of basic infrastructure, such as stairs in train station and traffic signals. Such birdsongs are required to be identified easily in urban noisy environments. Neurophysiological measurements e.g. magnetoencephalographic (MEG) measurements can reveal how salient sounds were processed in the human brain, and can facilitate us to find the optimal birdsong for conveyance of information in urban noisy environment.

In the previous study, Soeta and Nakagawa investigated the auditory evoked fields (AEFs) elicited by some birdsongs in silent conditions [1]. They concluded that the birdsong eliciting a large N1m response and/or a large correlation between the temporal envelope of the birdsongs and AEFs was easily detected in terms of transmission of information in the human auditory cortex. However, their results did not indicate direct relations between brain activities and how salient each birdsong was actually perceived. AEFs are affected by acoustic characteristics of a stimulus, such as the loudness [2] and speech envelope [3]. The previous result on AEFs elicited by birdsongs that have different acoustic characteristics can include responses related to not only salience of birdsong, but also irrelevant acoustic feature.

On the other hand, oscillatory activities also reflect brain functions, e.g. attention and memory [4, 5]. Oscillatory activities non-phase-locked to an external stimulus are known as induced activity [6]. They can be less influenced by acoustic characteristics of stimulus unlike AEFs. In the present study, we investigated relations between subjective salience of birdsongs in noisy conditions and induced activities. Magnetic oscillatory activities and subjective salience of birdsongs in noisy conditions were measured in MEG Experiments and Evaluation Tests, respectively. Induced activities correlated with subjective salience were explored by the sparse regression analysis. Effects of the birdsongs and noisy conditions on induced activities were also investigated.

2. MATERIALS AND METHODS

Physiological and Psychological Measurements

Thirteen participants (7 males and 6 females, 20–53 years old) took part in MEG Experiment 1 and 2. Eleven participants took part in Evaluation Tests of subjective salience. All participants had normal hearing and no history of neurological disease. Informed consent was obtained from each participant. The study was approved by the Ethics Committee of the National Institute of Advanced Industrial Science and Technology (AIST).

Six kinds of the birdsongs: the Cuckoo (CC), Japanese Bush Warbler (JB), Japanese Grosbeak (JG), Japanese White-eye (JW), Jay (JY), and Oriental Cuckoo (OC), were used. Three noisy conditions in room, subway station, and car cabin were simulated by Hoth noise [7], stationary noise based on actual recordings in [8], and an actual recorded noise, respectively. Thus, the number of stimuli was 18. Each duration of birdsongs was in the range of 700–1700 ms. Each noise was presented from 250 ms before the birdsong onset to the birdsong offset. The A-weighted sound pressure level of the birdsongs and the noises were 60 dBA in all experiments.

Brain magnetic activities were measured using a 122-channel whole-head magnetometer (Neuromag-122™, Neuromag) in a magnetically shielded room. The songs of the CC, JW and JY, and the songs of the JG, JB, and OC were presented in MEG Experiment 1 and 2, respectively. Each stimulus was presented binaurally and approximately 100 times in random order through insert earphones (Etymotic Research ER-2, Elk Grove Village). To maintain a constant vigilance level, participants were instructed to ignore the stimuli and to concentrate on a self-selected silent movie which was projected on a screen in front of them. In Evaluation Test, paired-comparison tests were performed for all combinations of paired stimuli. Each participant sat in a soundproof room and heard stimuli through headphones (HD 800 S, Sennheiser). The scale values of salience were computed according to Scheffé's method [9].

Analyses

Artifacts, power-line noise, and cardiac and ocular activities were removed from MEG raw data by digital filtering and the independent component analysis. The power of the induced theta (4–8 Hz), alpha (8–13 Hz), beta (13–30 Hz), gamma (30–50 Hz), and high-gamma (50–70 Hz) was computed from preprocessed MEG data based on the inter-trial variance for each stimulus [6]. The power of induced activities was averaged over the time samples during presentation of each birdsong, and over channels covering the left temporal, right temporal, frontal, parietal, or occipital lobes. The averaged power was divided by the averaged power for 200 ms before presentation of noise, and was log-transformed before statistical analyses.

We estimated sparse regression coefficients between scale value of salience and the power indices of induced activities using the least absolute shrinkage and selection operator (LASSO) [10]. The effects of the birdsongs and noise conditions on the induced activities selected by the LASSO were statistically analyzed using the two-way repeated-measures analysis of variance (ANOVA). Violations of sphericity were adjusted by the Greenhouse-Geisser correction. Post-hoc comparisons were conducted using Holm's method.

3. RESULTS AND DISCUSSION

Table 1 shows the nonzero regression coefficients obtained by the LASSO. The averaged scale values were explained by four power indices of the frontal alpha, occipital beta, parietal gamma, and left temporal high-gamma. The correlation coefficient between the averaged scale values and scale values predicted by the LASSO model was r=0.89. The ANOVA results showed the significant main effect of the birds on the power of the frontal alpha activity [$F(5,10)=2.49$, $P<0.05$] and the parietal gamma activity [$F(1.62,19.46)=6.56$, $P<0.01$]. Any effects on the occipital beta and left temporal high-gamma activities were not significant.

Table 1. Explanatory variables with nonzero regression coefficients obtained by the LASSO

Variables	Frontal alpha	Occipital beta	Parietal gamma	Left temporal high-gamma
Coefficient	0.21	−0.13	0.31	0.04

The power indices of the frontal alpha, and the parietal gamma for each combination of bird and noise condition were shown in Fig. 1 (a) and (b), respectively. The power of the frontal alpha changed between the bird conditions rather than within each bird condition. In the post-hoc comparison, however, no significant difference between bird conditions was found at the significance level of α=0.05. On the other hand, the power of the parietal gamma changed between noise conditions rather than between bird conditions. It increased when the songs of JY, CC, JW, and JB in the car cabin were presented, and decreased when these birdsongs in the station were presented. The post-hoc comparison revealed a significant difference between station and car cabin conditions [$P<0.01$].

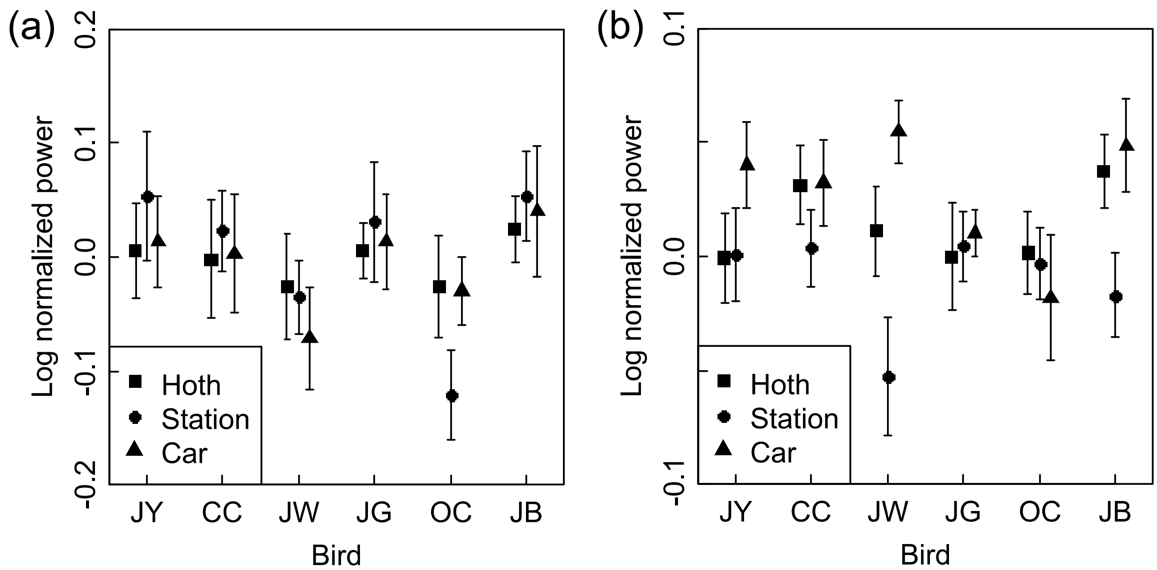

Figure 1. The log normalized power of (a) the frontal alpha activity and (b) the parietal gamma activity. Each symbol indicates noise condition. Error bars indicate the standard error of the mean.

The result regarding the frontal alpha shows a correlation between the frontal alpha activity and salience of birdsong. The previous study reported relation between the induced upper alpha band in the frontal region and the semantic memory [11], which is a sort of the long-term memory. Salience of birdsong is possibly affected by whether retrieval of birdsong in memory succeeded or did not. Also, familiarity of birdsong is possibly related to the frontal alpha and salience of birdsong. In contrast to the frontal alpha, the result regarding the parietal gamma activity indicates that the parietal gamma activity reflects the effect of environmental noise on salience of birdsong. While relation between the induced gamma activity and the auditory long-term memory was also reported [12], the induced gamma activity might be affected by another brain function associated with the processing of background sound. Despite a negative contribution of the occipital beta to salience, no significant effect was found. The beta activity in the occipital region is related to visual attention [5]. Participant's visual concentration on a silent movie was possibly modulated by salient birdsongs.

4. CONCLUSIONS

Our results indicate that the induced frontal alpha activity is related to salience of birdsong, and the parietal gamma activity reflects variation of salience caused by environmental noise.

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Sound exposure level and intelligibility of Japanese monosyllables in individuals with sensorineural hearing loss

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ABSTRACT

Although some Japanese monosyllables are hardly discernible for individuals with sensorineural hearing loss, it is not clear which acoustic features make these monosyllables difficult to discern. A previous study reported that the degree of periodicity is the significant factor influencing the speech intelligibility (Shimokura *et al.*, 2017); however, no studies have explained the role of acoustic energy in speech perception. In this study, to examine the effect of acoustic energy on the speech intelligibility, we focused on sound exposure level (SEL), which is the time-integrated value of squared sound pressure. The SEL can be expressed as a function of the time-interval of the integration, and we defined the time until the curves of SEL reach to a certain power level [dB] as *intelligibility onset time* (IOT), and compared the logarithmic IOT with the percentages of correctly perceived articulations obtained by 50 Japanese vowel and consonant-vowel monosyllables spoken by a female (Akasaka *et al.*, 2010). Results showed that the logarithmic IOT were strongly and negatively correlated with the percentages of correctly perceived articulations under the condition that voice onset times (VOTs) are non-negative (r = -0.70, p < 0.01). The monosyllables with non-negative VOTs are vowels, semi-vowels and voiceless consonant-vowel monosyllables. The tendency was observed more clearly for the group of individuals with severe hearing loss (r = -0.77, p < 0.01). In conclusion, as far as the monosyllables have non-negative VOTs, this study suggests that cumulative acoustic energy of the initial portion is an important clue to identify them as the sensorineural hearing loss becomes advanced, and it can be considered that the IOT may express an onset time to pay attention for them.

1. INTRODUCTION

It is known that patients with sensorineural hearing loss are not able to discern some Japanese monosyllables, even when they are presented at an optimal level for each patient. Akasaka *et al.* examined the percentages of articulations of 50 Japanese vowel and consonant-vowel monosyllables (Table 1) for 144 ears in three different cases (mild hearing loss: 50, moderate hearing loss: 51, severe hearing loss: 43) [1]. The most correctly and incorrectly heard syllables for all ears were /i/ (percent articulation: 92%) and /de/ (13%), respectively. However, it is not clear which acoustic features cause such differences.

A previous study used autocorrelation function (ACF) analysis to explain the difference of the speech intelligibility, and noted the relationship with the effective duration (τ_e), which is defined by the delay time at which the envelope along the early decay of the normalized ACF becomes -10 dB [2]. τ_e represents the degree of periodicity contained in signals. As a result, τ_e was highly correlated with the percent articulations among the different consonants ($r = 0.87$, $p < 0.01$); however, τ_e was not able to explain the differences in the intelligibility among the different vowels fully. So it means that there are other clues than the periodicity in the speech.

In this study, for the purpose of examining the effect of acoustic energy on the speech intelligibility, we calculated sound exposure level (SEL), which is the time-integrated value of squared A-weighted sound pressure. Elderly people have a difficulty in discerning an onset of speech; therefore, we focused on the initial rise of the acoustic energy.

2. METHODS

2.1. Calculation of SEL

SEL is the index of total energy of sounds, which is defined in ISO 1996-1 [3]. The SEL as a function of time can be expressed as

$$L_{AE}(t) = 10 \log \frac{1}{T_0} \int_0^t \frac{p_A^2(s)}{p_0^2} ds \tag{1}$$

where T_0 is the reference duration of one second, $p_A(s)$ is the A-weighted instantaneous sound pressure at running time s, and p_0 is the reference sound pressure (20 μPa).

In this study, we calculated the $L_{AE}(t)$ of the 50 Japanese monosyllables (Table 1). All of the monosyllables were spoken by a single female speaker. The monosyllables varied in duration from 0.19 s (/a/) to 0.45 s (/su/).

2.2. Finding Relationship between Intelligibility and SEL

The $L_{AE}(t)$ of the monosyllables underwent step-like changes as time proceeds (Figure 1). Since it was difficult to apply the single regression to the $L_{AE}(t)$ for evaluating the sharpness of initial rise, we determined the times until the $L_{AE}(t)$ reach to a certain power level (L [dB]). Hagiwara reported that the loudness of noise was integrated logarithmically in short-term less than or equal to 100 ms [4]. Hence, we calculated a correlation between the reaching times in the logarithmic scale and the percent articulations for the every values of L, and finally we determined the L which provided the highest correlation for each degree of hearing loss.

The initial rise of the $L_{AE}(t)$ was varied whether its voice onset time (VOT) is negative or not. VOT is the time between the release of a consonantal constriction and the onset of vocal-fold vibration. In the case of the monosyllables with non-negative VOTs (VOT > 0 and VOT = 0 in Table 1), the initial rises of the $L_{AE}(t)$ were various (Figure 1a). On the other hand, the monosyllables with negative VOTs (VOT < 0 in Table 1) raised the SEL similarly (Figure 1b), because such monosyllables have vocal-fold vibrations before the release point commonly (Figure 2). Consequently, we separated 50 monosyllables into the two groups (non-negative VOTs and negative VOTs), and examined the highest correlations for each group. The former consists of vowels, semi-vowels and voiceless consonant-vowel monosyllables, and the latter consists of voiced consonant-vowel monosyllables except for semi-vowels.

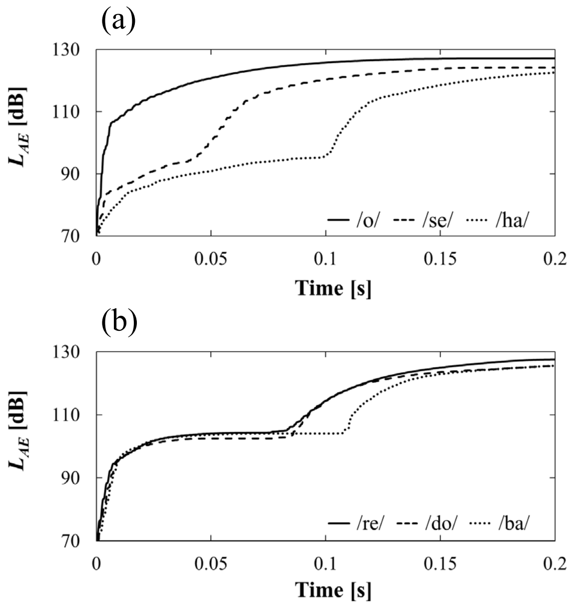

Figure 1. The curves of SEL of the monosyllables with (a) non-negative VOTs and (b) negative VOTs

Table 1. List of 50 Japanese monosyllables

	Consonant row													
	VOT > 0				VOT = 0			VOT < 0						
Vowel row	ka	sa	ta	ha	a	ya	wa	na	ma	ra	ga		da	ba
	ki	shi	chi	hi	i			ni	mi	ri		ji		
	ku	su	tsu	fu	u	yu			mu	ru		zu		
	ke	se	te		e			ne	me	re			de	
	ko	so	to	ho	o	yo		no	mo	ro	go		do	

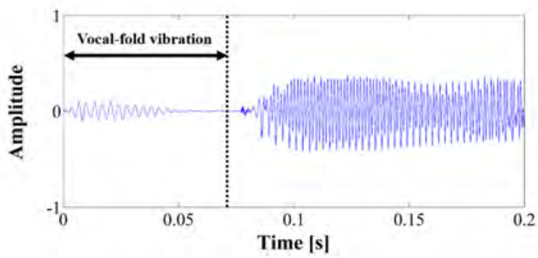

Figure 2. Waveform of /do/ (VOT < 0)

3. RESULTS

Table 2 shows the values of the highest correlation coefficients and L in all cases. The logarithmic times leading to $L_{AE}(t) = L$ were highly and negatively correlated with the percent articulations of the monosyllables with VOTs ≥ 0 in all individuals with sensorineural hearing loss ($r = -0.70$, $p < 0.01$). Additionally, the tendency was observed more clearly as hearing loss was advanced (mild: $r = -0.46$, $p < 0.05$, moderate: $r = -0.70$, $p < 0.01$, severe: $r = -0.77$, $p < 0.01$), as shown in Figures 3a to 3c. By contrast, there was no correlation in the monosyllables with VOTs < 0.

4. DISCUSSION

Under the VOTs ≥ 0 condition, the highly correlations indicate that cumulative acoustic energy of the initial portion is an important clue to identify the monosyllables as the sensorineural hearing loss becomes advanced. Differently from the previous study [2], the SEL is explicable for the differences in the intelligibility order also among vowel rows.

The negative correlations mean that more sharply rise of $L_{AE}(t)$ makes the monosyllable perceived more correctly. It seems that patients with sensorineural hearing loss begin detecting the acoustical information included in the monosyllable when the $L_{AE}(t)$ is filled to the L dB. Thus, we define the times as *intelligibility onset times* (IOTs).

When the IOT is short, individuals with sensorineural hearing loss may notice it soon and listen to it in the remained long term enough to discern. In addition, we believe that controlling the IOT using digital signal processing leads to improved speech intelligibility for individuals with sensorineural hearing loss, as far as the monosyllables have non-negative VOTs.

On the other hand, IOT was unlikely to explain the differences in the intelligibility of the monosyllables for the VOTs < 0 condition. The $L_{AE}(t)$ was filled to the L dB at the same time because of common preceding vocal-fold vibrations, and the IOTs, which range from -2.03 to -1.05 in all patients, are not much scattered in contrast with the VOTs ≥ 0 condition. We assume that there are other explanatory variables for identifying them than energy.

Table 2. Values of the highest correlation coefficients and L in all cases

	VOT ≥ 0		VOT < 0	
	r	L [dB]	r	L [dB]
Mild	-0.46*	92.0	-0.23	98.8
Moderate	-0.70**	92.4	-0.17	99.2
Severe	-0.77**	95.5	-0.02	103.3
All patients	-0.70**	93.5	-0.16	100.3

** $p < 0.01$, * $p < 0.05$

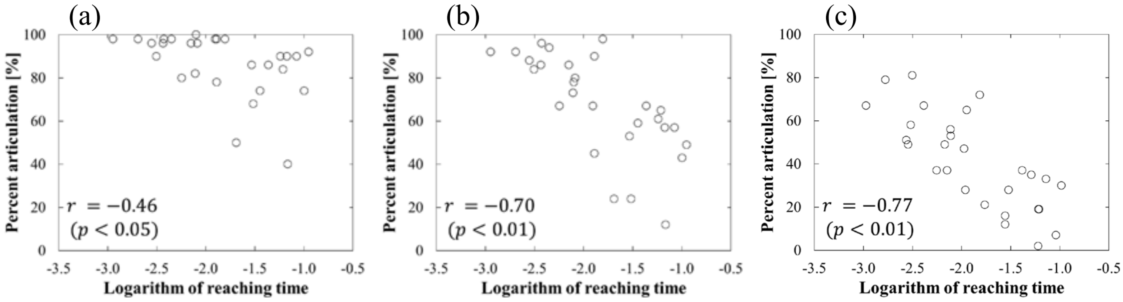

Figure 3. Relationships between percent articulations and the logarithmic times until the $L_{AE}(t)$ reach to the 92.0 dB for (a) mild, 92.4 dB for (b) moderate and 95.5 dB for (c) severe hearing loss. Note that they are for case of VOTs ≥ 0.

5. CONCLUSIONS

In this study, we examined the effect of SEL on the speech intelligibility in individuals with sensorineural hearing loss. We defined the time until the logarithmic rise of SEL as a function of the integration time reach to a certain power level as IOT. We found that the IOT had highly negative correlation with the percentages of correctly perceived articulations under the condition that VOTs are non-negative (all patients: $r = -0.70$, $p < 0.01$). Furthermore, we found that the correlations became higher as sensorineural hearing loss was advanced. Thus, cumulative acoustic energy of the initial portion may be used as an important clue to identify the monosyllables with non-negative VOTs.

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OSAKA, 2-3 DECEMBER 2019

Implementation of active noise control on cartilage conduction hearing devices

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ABSTRACT

Active noise control techniques are often used in various industrial fields. One of the technologies most familiar to us is noise canceling earphones. But, it remains one problem that it occludes user's ear canal by an earplug and the desired sound (speech, alarm, noise from approaching vehicle and so on) can't be heard. To solve this problem, cartilage conduction devices have received an attention in recent years. Cartilage conduction is a third auditory pathway different from air and bone conductions in which the vibrations of air and skull bones are perceived as sound, respectively. The aim of this study is to implement the active noise control on the cartilage conduction device and realize the noise canceling even if both of the ear canals remain to be opened. In this study, pure tones (250, 500, 750, 1000, 1250, and 1500 Hz) were presented in 74 dB as environmental noises, and the sound in the ear canal was compared before and after the noise cancelling onset. As a result, averaged 10dB decay was confirmed for the pure tones below 1250 Hz. Further study will try the sound deadening for noise signals distributing in broad frequency range.

1. INTRODUCTION

With the recent development of digital signal processing technology, active noise control technology is used in various scenes [1-3]. Active noise control (ANC) is a noise control technique that uses phase interference to mute a noise (primary source) by generating the opposite-phased noise from a separately prepared sound source (secondary source). Since this technique uses phase interference, it has been found to be effective sound attenuation for low-frequency sounds with long wavelengths. The device most familiar to us in this technology would be the ANC earphone. Although this audio device can quietly present speech and music, it remains a problem that the sound reduction is limited when the secondary sound source is out of phase from the primary source.

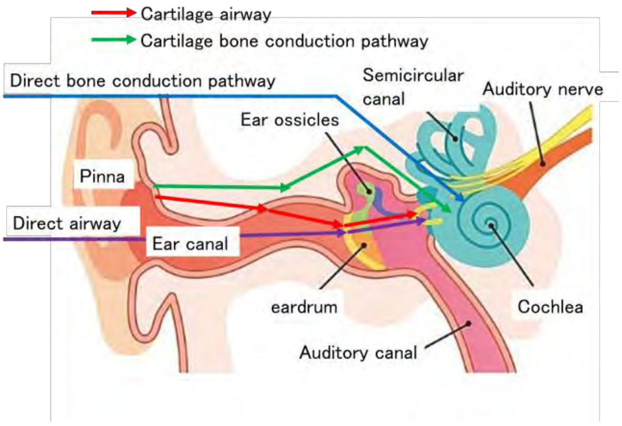

Figure 1. Cartilage transmission pathway

The phase shift occurs because of unstable position of the secondary source mounted on the earphone. Since the waveform generated from the secondary source has to cancel just at the control point (eardrum), it is important to fix it in the same position in any time when it is worn on the ear.

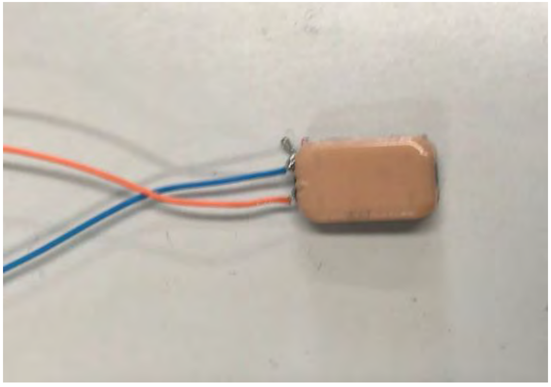

Figure 2. Cartilage conduction vibrator

To fix the secondary source position, we focus on a new sound transmission path called *cartilage conduction* discovered by Hosoi in 2004. Our outer ear and external auditory canal are formed by aural cartilage, and the oscillated cartilage by a transducer generates sound directly in the canal (red arrows in Figure 1). By applying the cartilage conduction to the secondary sound source, the ANC could be archived in the high quality comparable to existing ANC earphones [5]. Because the output position is always our own cartilage, the secondary sound source can be fixed regardless of the mounting position of the transducer. In addition, it has been found that cartilage conduction can amplify the sound especially in a band of 1000 Hz or less. The attribute is suitable to cancel the environment noise (e.g., traffic noise) that has usually sound energy in the low frequency. Therefore, this research aims to realize the ANC based on the cartilage conduction using a least mean square (LMS) adaptive filter technique. The LMS filter mimics a desired filter by finding the filter coefficients that relate to producing the least mean square of the error signal (difference between the desired and the actual signal). The LMS filter is introduced in the calculation algorithm of the existing ANC earphones, so it is likely to work well also for the ANC based on the cartilage conduction. Since the cartilage conduction can behave as long as the transducer contacts in some place of aural cartilage, the generated sound can be heard without occluding the ear canal. It means that the ANC based on the cartilage conduction will enable to perceive only the desired sound without occluding the ear canal, and the user does not suffer unpleasant sensation such as a feeling of fullness.

2. METHOD

2.1. Cartilage conduction transducer

In this study, we experiment by attaching an electromagnetic transducer (Figure 2) to the aural cartilage behind the ear concha, because the spectral shape of generated sound in the ear canal was flatter especially in the low frequency range than the other stimulating positions. And the position has another merit not to occlude the ear canal perfectly. A double-faced tape was used to fix the position.

2.2. Filtered-X LMS algorithm

Phase and amplitude of a processed signal by the ANC are modified until it reaches the eardrum, so we need to consider the transfer function of the path. In this experiment, the transfer function is corresponding to the cartilage conduction path, and the control target noise is transmitted from the air conduction path. Filtered-X Least Mean Square (FXLMS) algorithm is an approximate minimization method taking into account the secondary transfer function by keeping updating the optimum filter coefficients sequentially [6]. So, in our algorithm, the cartilage conduction path was estimated as shown in Figure 3. The update formula of the filter is as follows,

$$h(n+1) = h(n) - \mu * e * \hat{S} * x \tag{1}$$

where h is filter coefficient vector, n is update count,μ is step-size-parameter, e is error signal, $\hat{S}$ is estimated cartilage pathway, and x is reference signal. The μ is a variable that decides a magnitude of updating the coefficient vector. When the error signal value is small, the coefficient vector update amount is also small.

2.3. Procedure

First, the transfer function of the cartilage conduction pathway was estimated by LMS using white noise. White noise was outputted using the vibrator and recorded near the eardrum. Reference signal was this white noise, and target signal was recorded signal. And using estimated filter (ŝ in Figure 3), the FX LMS was performed estimating the filter coefficients for the primary path (P), because the transfer function of the cartilage conduction path does not change largely. In this experiment, the cartilage vibrator was attached to a silicon-based ear model. The ear model is guaranteed to match the transfer function of real human cartilage [7]. For signal acquisition, a probe microphone (type 4182; Bruel & Kjaer) recorded an error signal (e) near the eardrum and a 1/4-inch microphone (type 2669; Bruel & Kjaer) recorded the reference signal (x). By updating the filter coefficients of the air path function (P) and outputting the control signal (y) from the transducer, the error signal (e) was minimized. This algorithm was programed by a Simlink in Matlab. The target signal for muting (d) was five kinds of pure tones (250, 500, 750, 1000, 1250 Hz), and pure tones were outputted in 74 dB from the loudspeaker (type 6301; FOSTEX), apart from the ear model in 50 cm. The experiment was conducted in a silent room (background noise: below 60 dB).

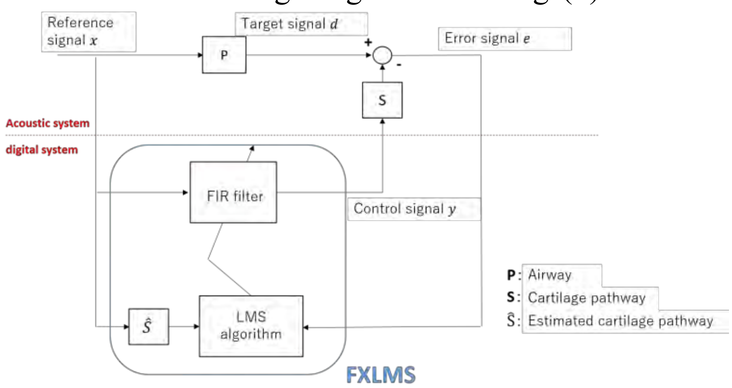

Figure 3. Overview of the filtered-X LMS

3. RESULTS

The sound pressure levels (SPLs) recorded by the probe microphone in the ear canal was compared before and after running the algorithm, and a sound attenuation was defined by the difference of the SPLs when they were in steady state (Figure 4). When SPL values are large, the data shows the strong silencing effect. In this experiment, we compared proposed system with an ANC earphone currently on the market (type 3123729; BOSE). Because the sound attenuations of the

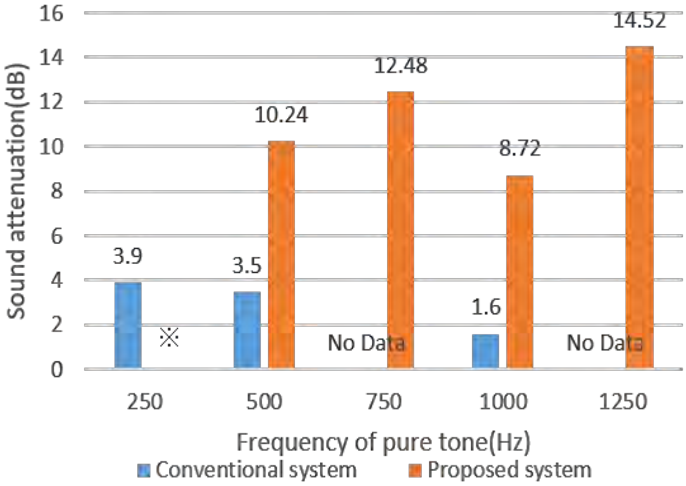

Figure 4. Silence effect at each frequency

earphone were quoted from another paper [8], some pure tones did not have the data ("No Data" in Figure 4). As results, a large silencing effect was confirmed in four frequency bands (500 to 1250 Hz). On the other hand, the output from the cartilage vibrator continues to increase at 250 Hz, so I can't get a data (* in Figure 4).

4. DISCUSSION AND CONCLUSION

Introducing the FXLMS, we proposed a noise reduction method using a cartilage conduction. As results of the experiment, we were able to obtain large silencing effect (approximately 10 dB) for the pure tones in the bands below 1250 Hz. However, it behaved unstably for the 250Hz pure tone. It might be caused by the inadequate parameter settings in FXLMS. The most important parameter is μ. When the value of μis large, although the silencing effect is increased, the possibility of the system becoming unstable is increased. When the value of μis small, although the silencing effect is decreased, the system is stable. I try to decide the best setting in FXLMS and make the stable system.

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Case studies of acoustical examinations of room which is consisted of diffusers

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ABSTRACT

In recent years, music halls, practice rooms and studios using diffusion materials tend to be constructed. Regarding the acoustic performance of the diffusing material, evaluation methods such as the scattering coefficient are defined, but they are often adopted without confirmation in actual design and construction. On the other hand, the client specifies a numerical target such as reverberation time and demand no acoustic disturbance such as flatter echo at the contract. This time, we will report on the cases studied in several projects related to music halls using diffuser materials. Finally, suggestions for understanding the acoustic effects and cost-effectiveness of diffuser materials based on failure cases are presented.

1. Music hall with diffuser[1)]

This music hall was planned as the first classical hall in Vietnam. Dang Thai Son, who is the first Asian pianist to win the Chopin Competition, was deeply involved in the construction, and the basic design was completed on the Vietnamese side and followed the image of his concert hall.

We were involved as an acoustic consultant, and the client demands a target reverberation time was 1.8 Sec (500Hz). In order to satisfy the target acoustical conditions and share the image of acoustic conditions, we ask Mr Dang Thai Son, which halls (around 1,000 seats) in Japan are impressed in Japan. Table 1 shows impressive halls in Japan by Dang Thai Son.

It was considered that the acoustic performance of the diffuser which was installed in most areas of the walls was important. Reverberation time was predicted by evaluating the absorption coefficient and the oblique incident sound absorption coefficient.

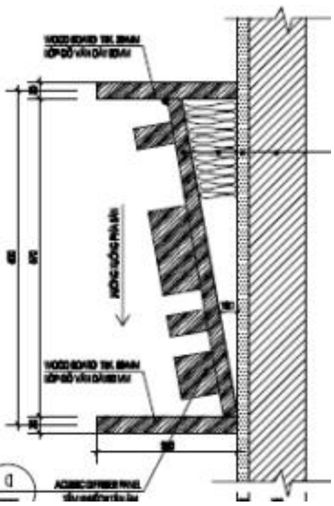
The reverberation time was predicted from the reverberation time without seat, and it can be adjusted at the finishing material. As a result, we could satisfy the acoustical conditions without any adjustments.

Mr. Dan Tai Sung gave us a kudo for our acoustic consulting. But since the acoustic performance of the diffusing material was unclear, we spent uneasy days until the hall was completed.

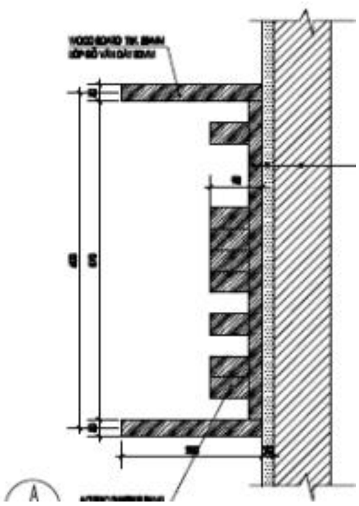
Table 1. Impressive halls in Japan by hearing from Dang. Thai. Son.

	Hanoi national concert hall	H hall	K hall	I hall	KM hall	M hall	S hall
Volume (m³)	11,970	9,100	9,216	9,659	5,690	8,475	21,000
Surface area (m²)	4,219	2,930	2,752	3,728	2,220	3,338	6,674
Stage area (m²)	351	210	162		225	134	209
W (m)	24.0	21.0	18.0		14～16	14.0	19.0
D (m)	12.5	10.0	9.0		11～16	9.0	11.0
H (m)	15.4	15.7	15.3		7～9.5	12.3	17.5
V/S (m)	2.8	3.1	3.3	2.6	2.6	2.5	3.1
Number of seat	900	750	800	821	480	770	2006
V/N	13.3	12.1	11.5	11.8	11.9	11.0	10.5
RT at 500Hz(s)	2.0	2.0	2.1	2.1	1.9	2.0	2.6
Occupied	**1.8±0.1**	**1.7**	**1.9**	**1.9**		**…..1.6**	**2.1**

Figure 1. Inside view from stage

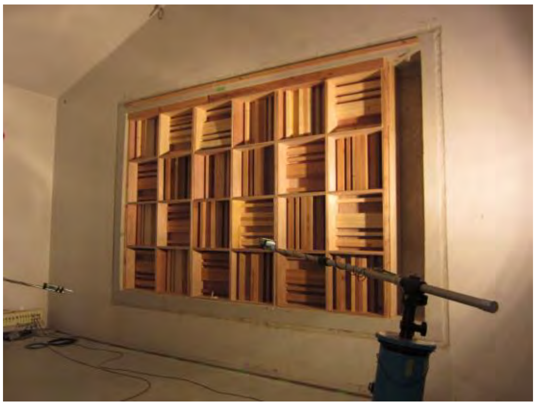


Type 1



Type 2

Figure 2. Detail of cross section of wall diffusers, (600×600)



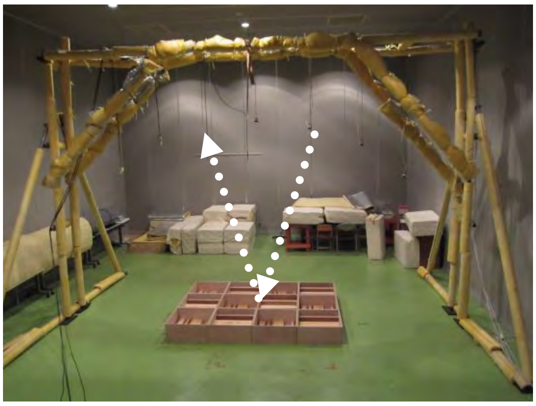


Figure 3. Measurement setups for absorption and oblique incidence absorption coefficient

Figure 4. Inside view of the hall, left: without seats condition

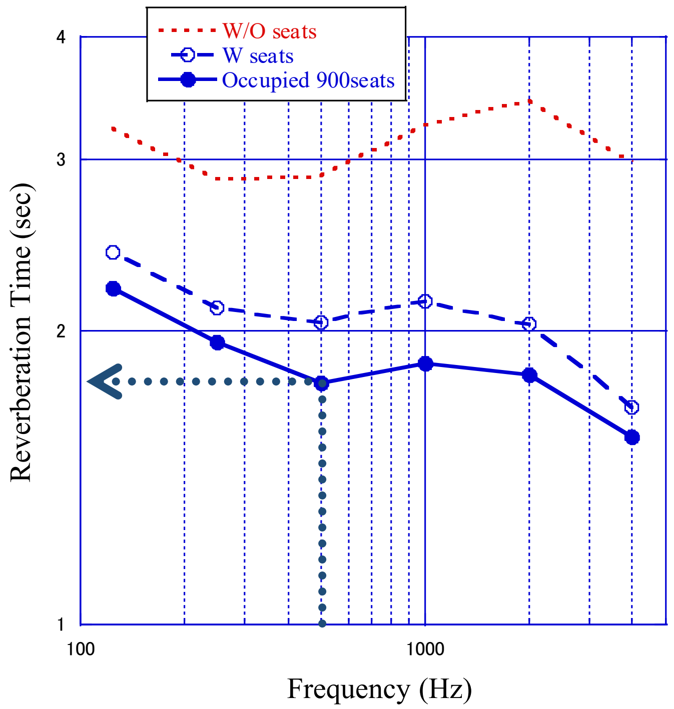


Figure 5. Reverberation time after the completion

2. Practice room with diffuser[2)]

The next case is about the music practice room attached to the main hall (2,000 seats) at the local city. Acoustic design was made by a major design office, and diffusers were installed on the walls and ceiling of this room. After evaluating the sound absorption coefficient and the scattering coefficient of the diffusers by 1/5 scale model at the reverberant chamber, and 1/10 scale acoustic model experiment was conducted.

Acoustical conditions between with and without diffusers were compared at the 1/10 scale model. It was confirmed that the diffusing material effect on reverberation time and clarity, and maintain roundness. The effect of the diffusing material was also visually expressed by using 3D microphone.

It was confirmed that the reverberation time could be satisfied even if the sound absorption layer behind the diffusion material was removed by the sound absorption coefficient obtained in the process of evaluating the scattering coefficient of the diffusion material. Sound absorbing layer was canceled at the construction stage. In addition, the gap between the slits of the diffuser was also adjusted. At the completion measurement, despite the rectangular room, it was confirmed that an ideal echo time pattern was obtained at any position in the room, it was easy to use as a practice room.

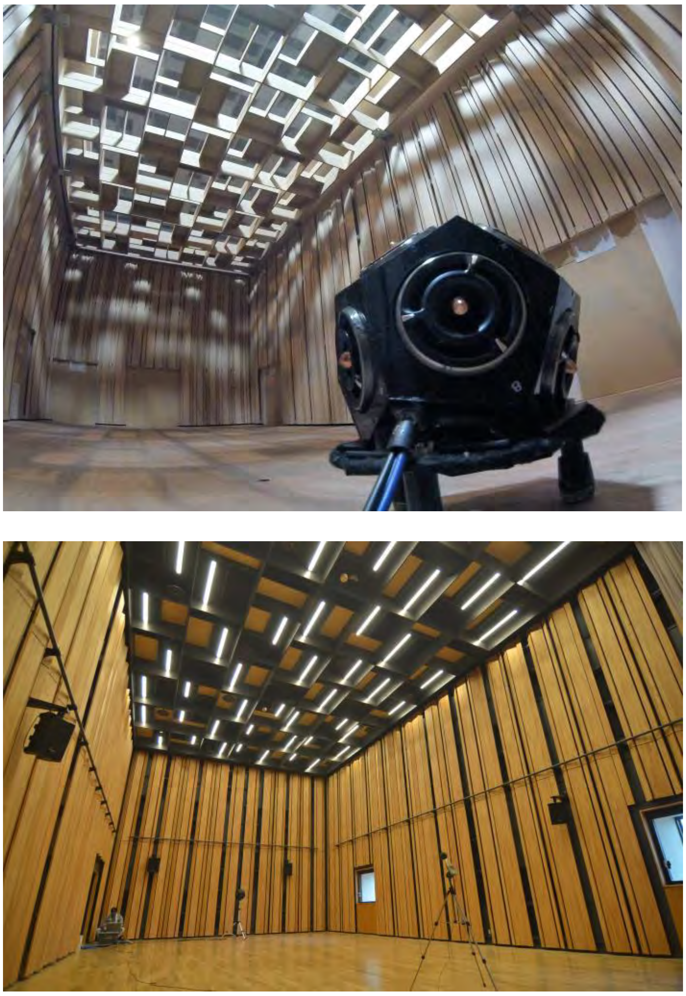


Figure 6. Inside view of rehearsal room (upper: 1/10 scale model, lower: real scale)

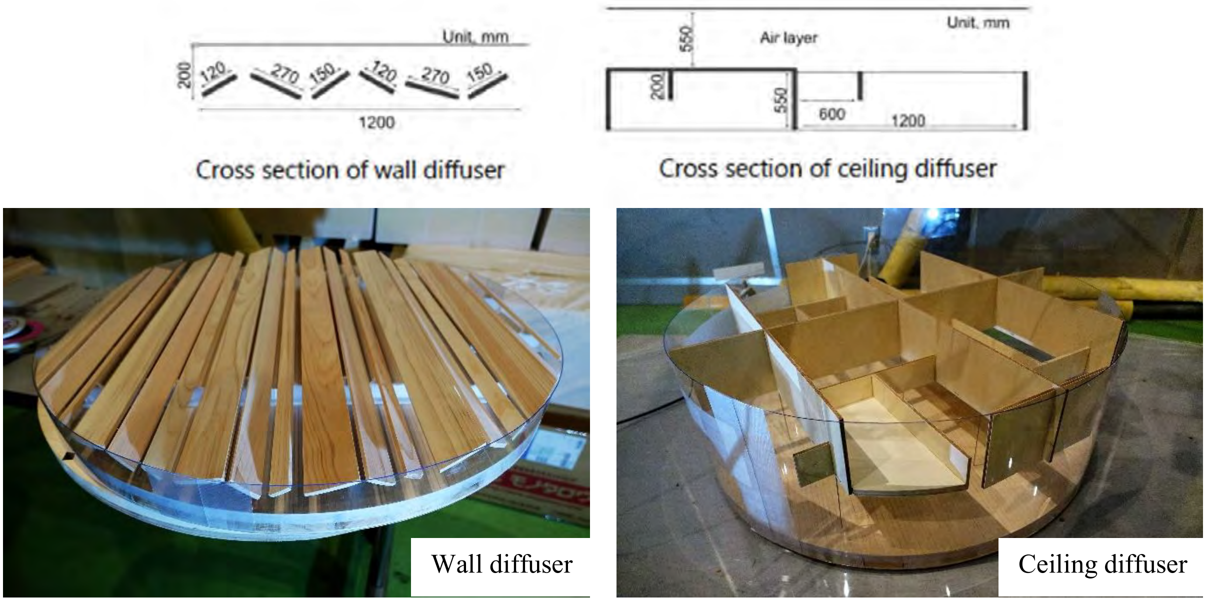


Figure 7. **Acoustical measurement setup of material**

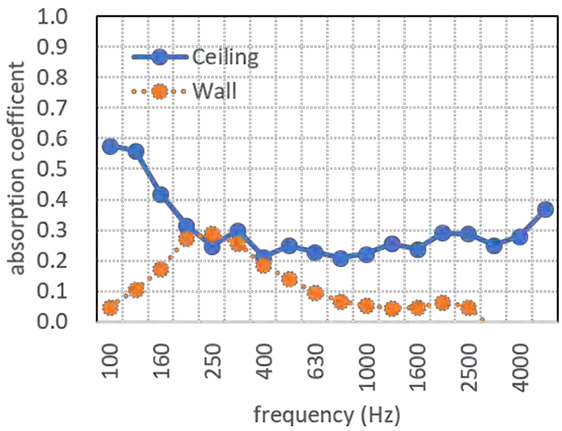


Figure 8. Absorption coefficient of materials

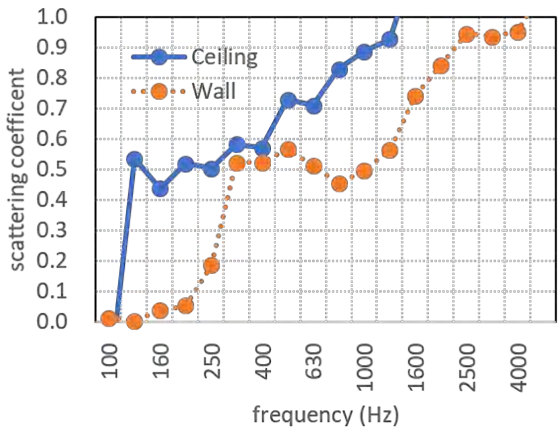


Figure 9. Scattering coefficient of materials

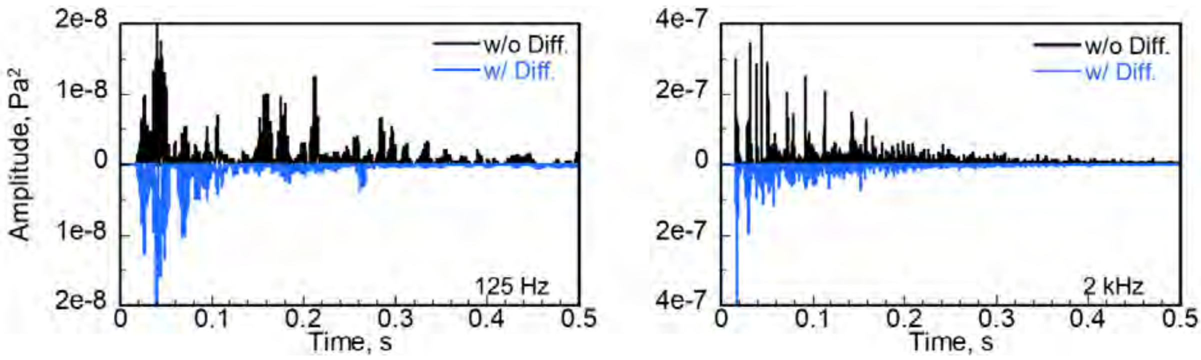


Figure 10. Square values of impulses responses at 125 Hz & 2 kHz : w/o Diffuser VS w/ Diffuser

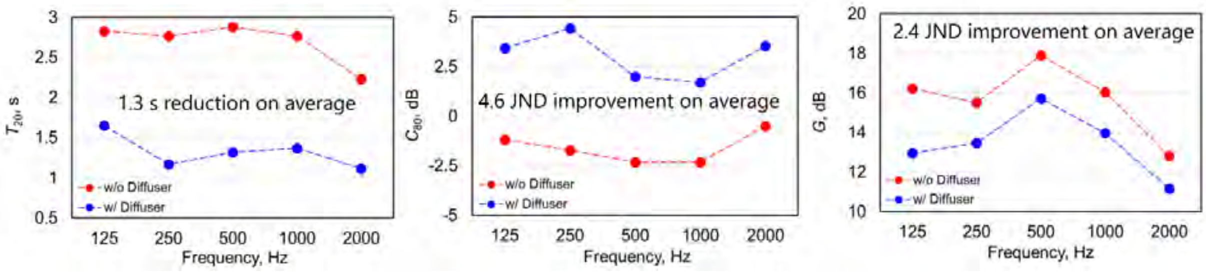


Figure 11. Comparisons of acoustic parameters: w/o Diffuser VS w/ Diffuser

3. Lecture room without diffuser

Finally the school auditorium which is used as a lecture and brass band practice is shown (surface area:2,000㎡, Room volume: 4,590 ㎥, 500 seats, 9㎥/seat). We strongly suggested whether incline side walls nor diffuse installed the flutter echo would be occurred by flat and parallel side wall, but our suggestion wasn't accepted and lecture room was built just as it is. After one year later from the completion, the client insisted that the speech intelligibility was low for lecture using the electro acoustic, and brass band members felt the unusual acoustic condition for the practice. The pictures were attached in the email. Flatter echoes might be occurred by flat side walls, (44ms ≒ width 15m / 340 m/sec). Impulse response was measured on the condition that two absorbing curtains were hanged on one side wall. Figure 14 shows the difference of echo time pattern between with and without curtains. Figure 15 shows the ACF of with and without and shown second peak[3)] was observed at around 44ms. From Figure 16, RT was shortened by absorbing curtains above 500 Hz and flatter echo has disappeared.

Brass band club supervisor confirmed he could not felt coloration by flatter echo after hanging curtain. He also commented that it was difficult to hear speech by through the speaker for who was low hearing. Although it is easy to suppress the flutter echo of the mid-high range by the sound absorbing curtain, it was imagined that the improvement would not enough for the low frequency range such as a male voice. The application of the diffuser, especially for low frequency is still desired.

Figure 12. Situation of brass band practice

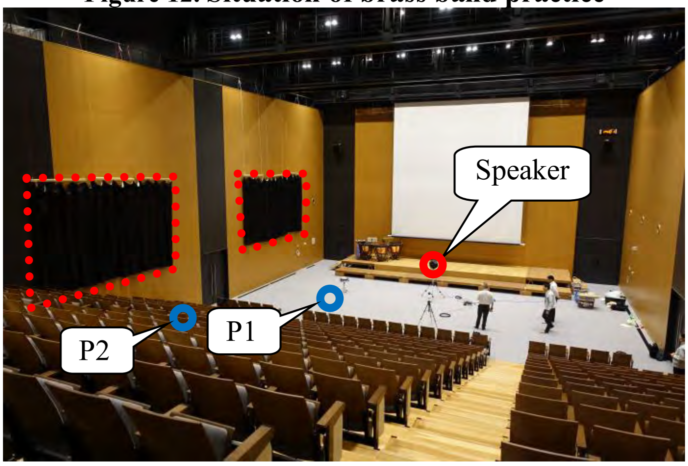


Figure 13. Eliminate flatter echo by using the absorption curtain (red square)

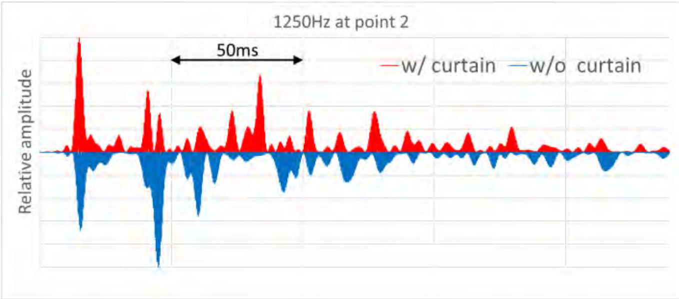


Figure 14. Echo time pattern of w/ and w/o curtain.

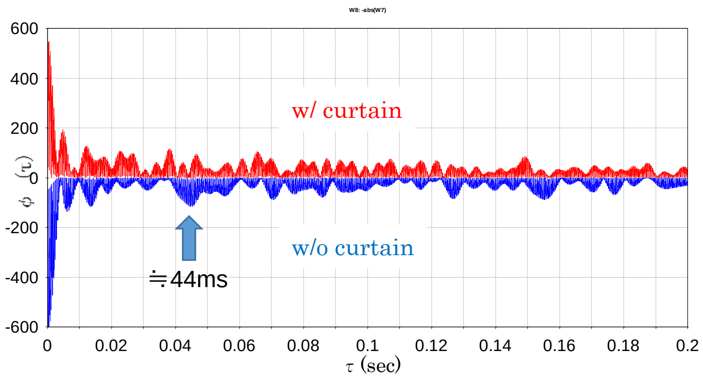


Figure 15. ACF of w/ and w/o curtain.

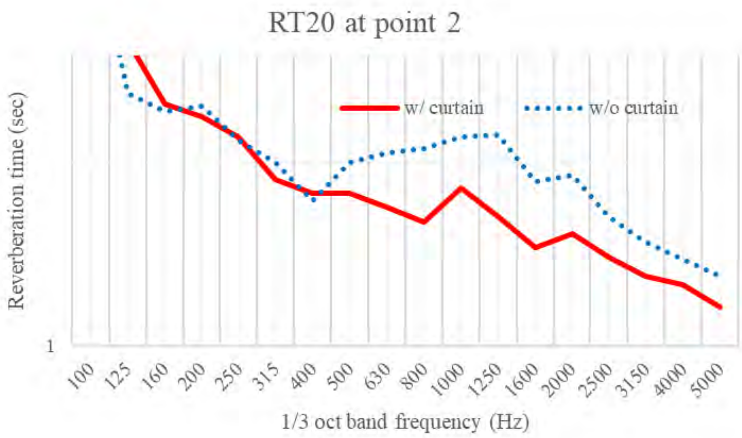


Figure 16. RT20 of w/ and w/o curtain.

4. CONCLUSIONS

I had opportunities to work on some concert halls where diffuser materials were installed. However, even big projects have been adopted without a basic study of the acoustic characteristics of diffuser (evaluation of sound absorption and scattering coefficient).

As introduced in the second case, it is a useful method to evaluate and confirm the sound absorption and scattering coefficient on 1/4 or 1/5 scale model measurement, and it would be a standard study method before construction.

Small projects, such as the last failure case, have limited budgets, so if the reason is not clear, a cost-free design will be adopted. Therefore, we educate designers to understand the sound effects such as diffusion materials, and It is important to explain its importance to the client. For example, it is also necessary to show the auditory effect of diffusers.

Therefore, it is necessary to carry out acoustic studies on reflection characteristics as well as reverberation time and other acoustical conditions. In the future, I hope that the design guidelines[4),5)] will include specific measures in the future.

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News about musical Spaces in Italy

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ABSTRACT

The authors are now involved in designing an Auditorium to be built in Ozzano, a place near Bologna, to be utilized for conferences, soloist music, modern and ancient singing, didactical activities. The space they proposed to us has an elliptical shape so there will be some possible focusing problems; thus we have studied and proposed a particular multi-functional panel to be displayed along the lateral walls; these panels will both diffuse the sound rays toward the seating area and furnish a surface with variable absorption.

The modular panel made almost entirely of wood will supply three different acoustic functions: absorption, diffusion and variable absorption; furthermore, we have proposed a sort of shell above the small stage enable to project the sound till to the last seating position and thus having as focus a better distribution of acoustic energy within a space.

In the city of Novara there is an ancient Opera House with some acoustic problem: in occasion of refurbishing for safety works, an Author was initially involved in finding acoustical opportunities to take on.

This paper refers the more recent advances at Symposium time.

1. INTRODUCTION

There are two schools to face acoustic problems in a space devoted to music and Opera exhibitions.

Some time ago, Leo Beranek [1] proposed an all experimental approach, based on acoustic measurements and correlated interviews collected among a selected public, among which many conductors and executers, to be utilized in determining correlations among acoustic parameters and quality indexes; from his correlating diagrams, Beranek derived also some criteria to help the design phase of new concert halls and Opera Houses. This original work was then improved till near his one hundred years life.

Some year after, Yoiki Ando [2] proposed a different approach, based on both mathematical evaluations about the independence among acoustical parameters and experimental data based directly on human brain reactions, aimed to correlate acoustic preference and a combination of four independent parameters. Even this proposal was improved during the following years till the publication [3] and opened the way towards the more recent publication on temporal design [4].

The first Author of this paper is particularly grateful to Prof. Ando for its invitation to a seminar in Kirishima [5] where he met both and was called to give his personal contribution to the evaluation of local preference in various places of the Kirishima auditorium: this was the beginning of a structured activity on the subject at the Engineering Faculty in Bologna, in which the second Author formed and actively contributed with his former professional experience of architect, see for instance [6, 7].

2. OZZANO AUDITORIUM

Near Bologna there is, among the others, a developed industrial site, where a local industrial firm is planning some new buildings devoted to support various activities; one of them will be equipped for cultural activities like conferences, permanent schools to prepare new personnel for the firm, public library, musical performances.
The auditorium will be erected inside the whole building, in a position particularly protected from external (for instance traffic) and internal (for instance air conditioning apparatus) noise sources: as quite usual, the staff of architects who designed the whole provided also to the design of the auditorium building so, when we were called for acoustical support, we found the shape already designed.
This is an usual problem in Italy, reminding the period when famous Architects fully designed shining Opera Houses having in mind also the acoustic problem.
But now the acoustic of an auditorium needs a particular attention as quite always it is necessary a wide flexibility in use, so also an electronic diffusion plant must be available for some kind of performance, obviously not required for some soloist of classical music who like to play live.
The proposed shape was elliptical, so it was necessary to diffuse the sound, avoiding any focusing effect; at the same time, it was necessary to arrange some kind of variable absorption, to get a low reverberation time when the electronic support was in use.
The system for natural diffusion in the hall was then structured in two elements, of which the first consisted in some kind of shell to project the sound source till to the end of the hall and, at the same time, to reduce the spread of sound towards the nearer concave surfaces (fig. 1).

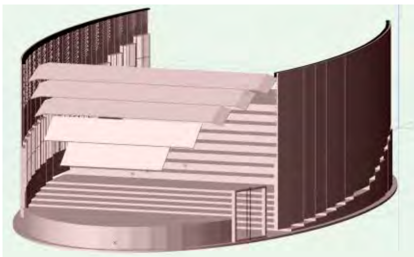

Figure 1. The acoustical shell to be placed up to the performer and panels to lean on the lateral walls

To obtain the expected result, presented at the firm by computer simulation (fig. 2), a special composed lateral panel was studied and tested (fig. 3).

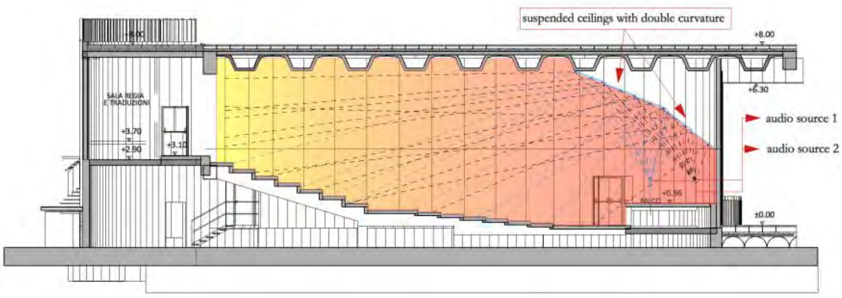

Figure 2. A computer simulation of the expected sound field

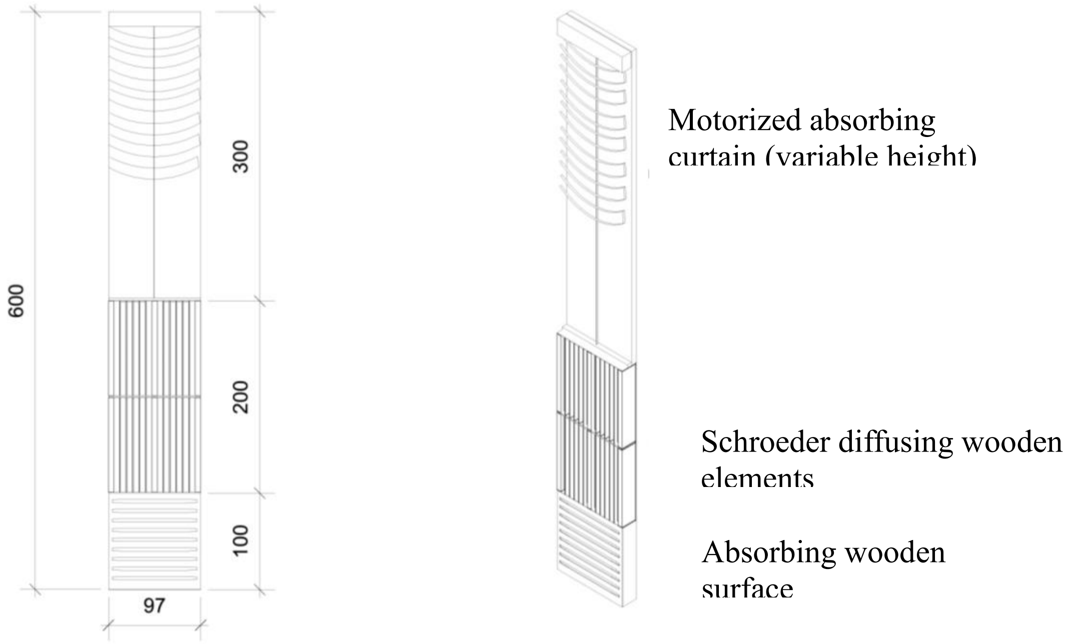

Figure 3. Lateral elements of fixed base but with variable height along the slope (see fig.1)

3. COCCIA OPERA HOUSE

In Novara there is an old lyrical hall built in years 1886-'88 following the classical style of the most celebrated Italian Opera Houses: at the moment the Hall is utilized to perform some selected Opera' texts, as its stage allow to manage only not too complex sceneries.

Figure 4. An inside view of Coccia from the stalls

Now it is necessary to modify many arrangements for security reasons, so Cocchi was asked to present some idea with the goal of improving the acoustic quality of the theatre.
As the request was, till now, only formal, it was decided to abandon at the moment the idea of make measurements, necessaries to test preferences, and to make an unusual audio test based only on preference judgements derived during some performances of the same opera but utilizing different positions of two qualified spectators; as the following week the same opera

was performed also at the Municipal theatre of Bologna, utilizing one of the selected locations in both theatres, records of the same musical passages were compared.
From these comparative tests it resulted that it must be reduced the absorption of the hall, working on seats and floor on the stalls, reducing the number of spectators (at the moment the value of the volume/spectators ratio is about five and we appreciated some difference between the first and the second performance, when some usual spectator was absent), and modifying the balconies' sills of the boxes.
It resulted also some lack of balance between singer and orchestra, the late being too strong when the singer performs soft passages: this parameter must be eventually verified with G measurements having the source placed either in the pit or in the stage.
At the moment we are waiting for reverberation time measurements to be taken before and after the seat replacement in the stalls.
We hope we can relate more experiences at the next edition of this Symposium.

4. CONCLUSIONS

As the works are in progress, at the moment it is not possible to get conclusions other than to put in evidence the importance that in a new project the presence of a specialist in acoustics would be useful already at the beginning of the projecting process. Facing the refurbishment of opera halls, one can take advantage of both the results finally presented by Beranek and Ando, taking all the possible measurements of acoustic parameters and comparing them with any suggested value for good preference: if they result good enough for preference, it is necessary to pay attention to not modify anything that could influence them, otherwise if some preference is not attained some change to the original structure must be adopted.

ACKNOWLEDGMENTS

We are grateful to Y. Ando and L. Beranek for their useful teachings, ant to R. Shimokura for his active and appreciated care during the long stay with us in Bologna.

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Psychological and physiological evaluations of building noise

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ABSTRACT

This paper deals with a series of field and laboratory studies concerning the impact of building noise on health and well-being. In particular, floor impact noise produced by footsteps in apartment buildings was chosen as a major noise source. Firstly, 24-hour noise measurements in 32 real houses in apartment buildings were carried out in order to identify dominant noise sources and their levels. Next, a series of laboratory experiments were conducted to measure psychological and physiological responses to floor impact noise. Participants were asked to evaluate the noticeability and annoyance of sound stimuli. Also, heart rate, electrodermal activity, and respiration rate were measured. It was found that noticeability and annoyance increased as the noise level increased. The noise exposure evoked the significant changes in the physiological responses. Another laboratory experiment examined the effect of self-reported noise sensitivity on the psycho-physiological responses. Thirty-four participants were grouped into low and high noise-sensitivity groups. The results showed greater responses from the high noise-sensitivity group.

1. INTRODUCTION

Multi-family housing is one of dominant housing types in many countries. For example, one in seven (14%) would live in a flat or maisonette in the UK [1] and Statistics Korea [2] reported that such type of housing with reinforced concrete structure accounted for over 60.1 % of the whole housing units. Residents in this type of buildings are easily exposed to numerous noise from their neighbours which leads to a large number of noise complaints [3]. The majority of the complaints are associated with footstep noise such as adult walking and child running. Therefore, a number of studies [4-6] have investigated the perception of impact noise caused by footsteps. However, very little is known about how the residents psycho-physiologically react to the floor impact noise. This paper summarises several recent studies about psychophysiological evaluations of floor impact noise.

2. CHARACTERISTICS OF NOISE EVENTS CAUSED BY UPSTAIRS NEIGHBOURS

Sites

Thirty-two residences in multi-family housing buildings were recruited for the measurements. Net floor area of the sites ranged from 42 to 212.5 m^2. The oldest site was built in 1984 and the latest one was built in 2013. The number of bedrooms in each home varied from one to five. The number of bathrooms ranged from one to three. Slab thickness of each site ranged from 135 to 210 mm. Since Korean domestic regulation was strengthened in 2005, many of the sites built earlier had slab thickness of 135 and 150 mm. Most sites were built with slabs thicker than 150 mm since then.

Procedure
The noise measurements were carried out in either living rooms or bedrooms under unoccupied conditions. The recording location of each site was chosen depending on the report of the residents living in each site that they could hear the most noise from upstairs. The measurements were conducted from the morning to the following morning for 24 hours while the residents vacated the site.

Data analysis
All data were exported from the noise monitoring system as one-minute interval noise levels. The 24-hour period was classified into the day (07:00 ~ 19:00), evening (19:00 ~ 23:00), and night (23:00 ~ 07:00) according to ISO 1996-2. In order to identify noise sources, noise events exceeding threshold noise levels were identified. The threshold noise levels were set as 35 dBA (L_{Aeq}) for daytime, and 30 dBA (L_{Aeq}) and 45 dBA (L_{AFmax}) for night-time.

Results
The overall noise levels
Among the three time-periods (day, evening, and night), L_{Aeq} in the evening had the widest variation, while median L_{Aeq} was the lowest at night. It was found that six sites exceeded the threshold levels in the daytime or evening (35 dBA, L_{Aeq}) and eight sites exceeded that of the night-time (30 dBA, L_{Aeq}). Three sites exceeded all the threshold levels for day, evening, and night. Regarding L_{AFmax}, the evening presented the widest variation and most of the sites exceeded the threshold levels in the daytime or evening (50 dBA, L_{AFmax}).

The Noise levels of each noise source
Figure 1 shows the box-plots of the noise levels of each noise source in terms of L_{AFmax}. In general, airborne noise sources presented larger variations than structure-borne sources. Among the airborne noise sources, the noise from the PA system showed the highest median values followed by the voice of children; however, the PA system was not frequently heard.

3. PSYCHOPHYSIOLOGICAL EVALUATIONS OF FLOOR IMPACT NOISE

This study examined psychological and physiological responses evoked by floor impact noise stimuli. It was carried out in a laboratory setting in which two psychological responses (annoyance and noticeability) and three physiological measures (heart rate, electrodermal activity, and respiration rate) were investigated. A total of 21 participants took part in the experiment. During the measurements, the participants were exposed to floor impact noise stimuli generated by either real impact sources (e.g. footsteps and scraping of furniture) or the standard impact source (impact ball). Each noise source was presented at different ranges of noise levels.

Noise stimuli
A total of six different noise sources were used to represent a majority of the impact noises in residential buildings in the previous study. Five real sources were used with a standard heavyweight impact source (impact ball) adopted in ISO 10140-5. The real sources were classified into two groups based on their physical characteristics; (1) heavyweight impact sources and (2) lightweight impact sources. All the stimuli had similar frequency

characteristics with dominant sound pressure levels at low frequencies, especially at 63 and 125 Hz.

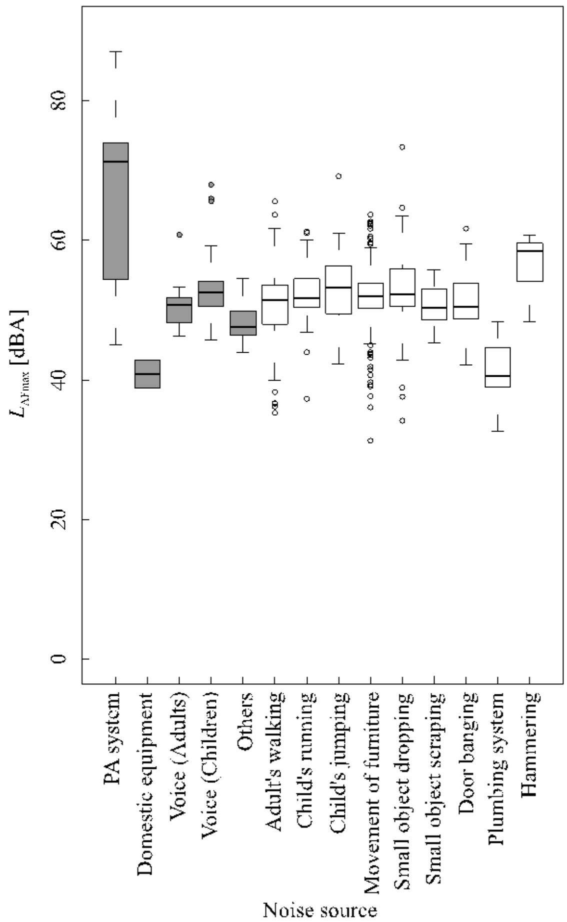

Figure 1. L_{AFmax} for the noise sources; the airborne noise sources are shown with grey boxes and the structure-borne noise sources are shown with white boxes.

Response measurements

Psychological responses were assessed in terms of noticeability and annoyance. The participants were asked to press the response button when they heard the noise stimuli during the experiment. At the end of each of session, the participants were also asked to rate their annoyance using 11-point scales (0 = 'Not at all' to 10 = 'Extremely'). Annoyance caused by each noise stimulus was evaluated using a magnitude estimation technique. Three physiological responses were measured for the entire duration of each session: heart rate (HR), electrodermal activity (EDA), and respiration rate (RR). All the physiological responses were measured using the MP 150 WSW digital acquisition system (BIOPAC Systems), recorded and analysed via a data acquisition/analysis software (AcqKnowledge 4.4, BIOPAC Systems).

Results

<u>Subjective responses</u>

Figure 2(a) shows the noticeability as a function of L_{AFmax} across the different sources. For both real and standard impact noise sources, the noticeability increased as the noise level increased. Correlations between noticeability and L_{AFmax} were statistically significant (r = .62 for the whole stimuli; r = .61 for the real impact noise; r = .64 for the standard impact noise; $p < 0.01$ for all correlations). Figure 2(b) describes the mean magnitude estimates of noise annoyance for each noise stimulus. It was found that annoyance increased as the noise level increased for both real and standard impact noises. The correlations between the annoyance ratings and L_{AFmax} were greater than 0.9 for both sources ($r = .95$ for the whole stimuli; $r = .95$ for the real impact noise; $r = .93$ for the standard impact noise; $p < 0.01$ for all correlations). The annoyance ratings of each stimulus also correlated with noticeability for both sources ($r = .47$ for the real impact noise; $r = .43$ for the standard impact noise; $p < 0.01$ for all correlations).

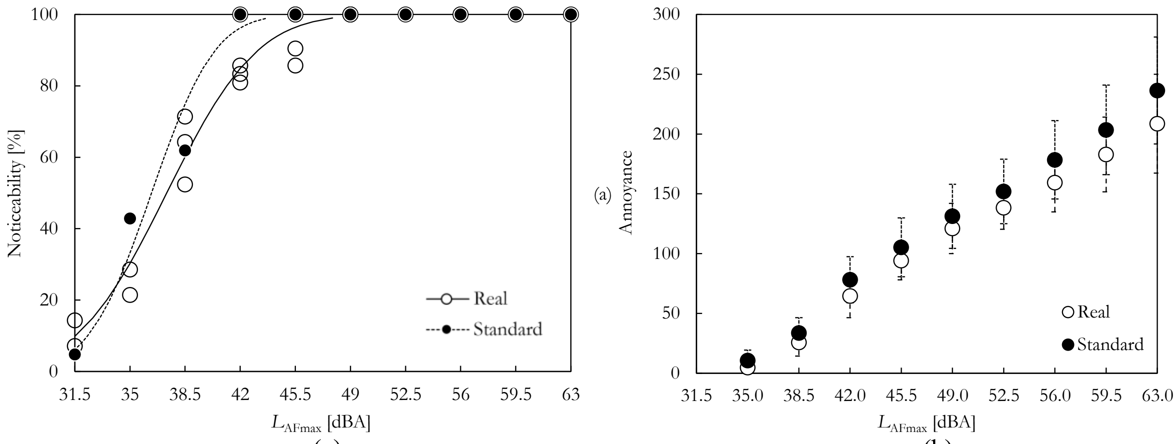

Figure 2. Subjective responses to floor impact noise: (a) noticeability and (b) annoyance.

Physiological responses

Error! Reference source not found.3 shows the mean changes were presented for the real and standard impact noise stimuli. The mean HR decreased by more than 1 % for both sources and the difference between the baseline and the noise exposure was statistically significant ($p < 0.05$). HR response to the standard impact noise decreased slightly more than that of the real impact noise but there was no significant difference between the sources. EDA increased significantly due to noise exposure ($p < 0.05$). The mean EDA changes were more than 2 % for the standard impact noise and 1 % for the real impact noise; the standard impact noise resulted in a higher increase than the real impact noise but the difference between the two types of the source was not statistically significant. Similarly, significant RR increases (more than 3 % for both sources) were recorded when participants listened to floor impact noise ($p < 0.05$).

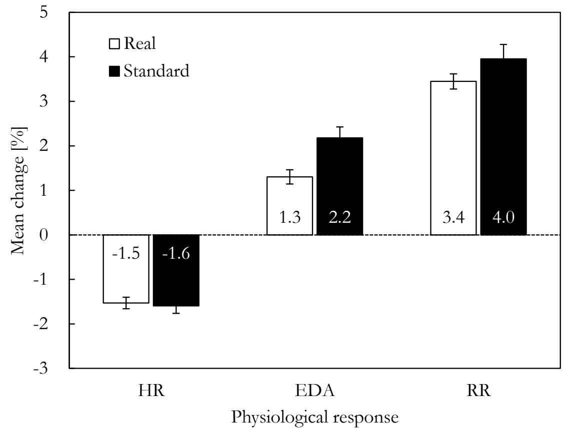

Figure 3. Mean percentage changes of the physiological responses.

4. EFFECTS OF NOISE SENSITIVITY

This study assessed the effect of noise sensitivity on psychological and physiological responses to floor impact noise stimuli which lasted longer than those in the previous study. A total of 34 participants were chosen based on their responses to the screening survey. Noises generated by a standard impact source (impact ball) and two real impact sources (an adult's walking and a child's running) were used as the floor impact noise stimuli and one road traffic noise stimulus was used in order to compare the responses to indoor and outdoor noises.

Noise stimuli

Both floor impact noise and road traffic noise were used as noise stimuli. Floor impact noise was generated by real human footsteps (‘Real’) and a standard impact source, impact ball (‘Standard’). Road traffic noise (‘Traffic’) was recorded in the suburb of Liverpool, UK. L_{AFmax} of the floor impact noise stimuli were fixed at 40, 50, and 60 dBA. The road traffic noise was set to be played at 40 and 60 dBA (L_{Aeq}).

Response measurements

After each noise exposure for five minutes, the participant was asked to rate their annoyance using an 11-point scale (0 = ‘Not at all’ to 10 = ‘Extremely’). Three physiological responses were measured for the entire duration of each session: heart rate (HR), electrodermal activity (EDA), and respiration rate (RR).

Results

Subjective responses

As presented in Figure 4, the high noise-sensitivity group reported higher annoyance ratings than the low noise-sensitivity group when the [illegible] ted. The differences between the two groups increase [illegible] gnificant differences were found at 50 and 60 dBA. A [illegible] d traffic noise, with a significant difference betwee [illegible] noise-sensitivity group, correlations between anno [illegible] istically significant (r = .71, $p < 0.01$ for the real imp [illegible] standard impact noise).

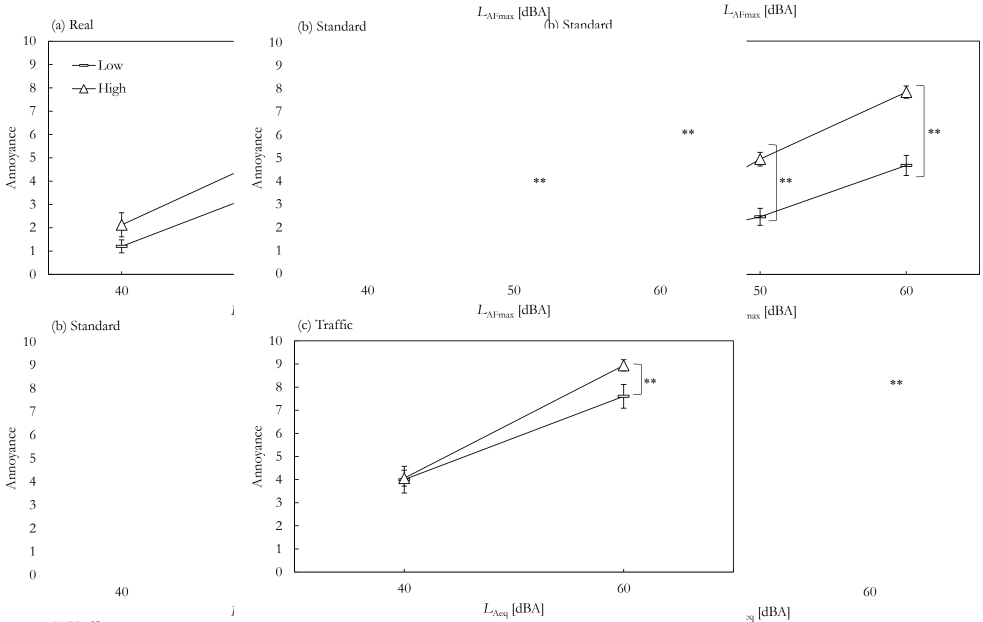

Figure 4. Annoyance compared between the low and high noise-sensitivity groups as a function of L_{AFmax}: (a) Real, (b) Standard, and (c) Traffic.

Physiological responses

As shown in Figure 5, HR decreased when the noise was played for 30 seconds, whereas EDA and RR increased. Differences between baselines and noise exposures were statistically significant for all the noise sources and all the physiological measures ($p < 0.01$). Responses of the high noise-sensitivity group were consistently greater than those of the low noise-sensitivity group across all noise sources and all the physiological measures. The two noise-sensitivity groups' HR were significantly different when the standard impact noise and road traffic noise were heard. EDA were significantly different when the standard impact noise was heard. RR were not significantly different for all noise sources. There was no significant difference between the two noise-sensitivity groups when the real impact noise was presented.

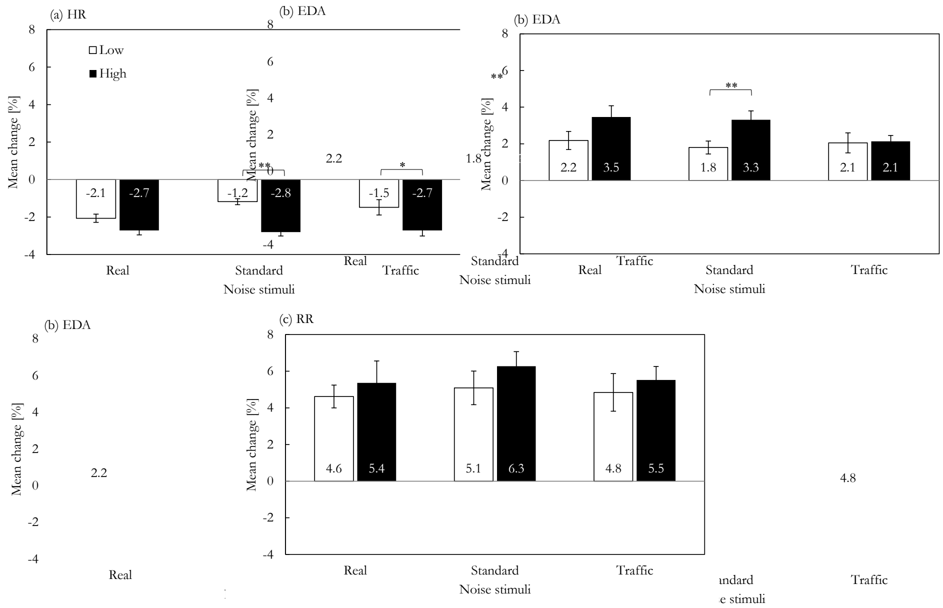

Figure 5. Mean percentage changes of the physiological responses for 30 seconds compared between the low and high noise-sensitivity groups (* $p < 0.05$, ** $p < 0.01$).

5. CONCLUSION

The noise measurements showed that the overall L_{Aeq} ranged from 20.8 to 45.7 dBA for 24 hours and the overall L_{AFmax} ranged from 48.8 to 87.1 dBA for 24 hours. Neighbour noise included different airborne and structure-borne noises. The highest and lowest L_{AFmax} of structure-borne noise sources were generated by hammering and plumbing system, respectively. Laboratory experiments indicated that the noise stimuli presentation had significant impacts on all the subjective and physiological responses. As noise levels increase, noticeability and annoyance increased, heart rate decelerated, electrodermal activity increased, and respiration rate accelerated. A clearer difference between the noise-sensitivity groups was found when the floor impact noise stimuli were presented compared with the road traffic noise stimuli exposure. Furthermore, the participants with higher noise sensitivity presented greater changes in heart rate, electrodermal activity, and respiration rate.

Given that there are a number of different sources of neighbour noise, future research may examine emotions evoked by different noise sources. Future research could adopt various airborne and structure-borne noise sources to study emotional changes. Future research could also examine the cultural differences in emotional changes caused by neighbour noise. Since neighbour noise is not a social problem only in South Korea, research on emotions in different cultures using different languages would be helpful to understand the issue more generally. Moreover, future research may involve the study settings in which performance tasks and physiological measurements are involved in so that it could evaluate the emotional states more broadly along with the use of emotion lexicons.

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OSAKA, 2-3 DECEMBER 2019

Mental Health of Inhabitances in High-rise Building Relating to Traffic Noise

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ABSTRACT

A study was carried out to measure traffic noises at each floor of the high-rise building and simultaneously to assess the annoyance and mental health status of its inhabitances. The final aim was to testify the relationship between the mental health status and annoyance status with the level of the road-side traffic noise SPL. Two high-rise roadside residential buildings (busy and quiet) were selected in which peoples are living for longer time. The SPL were measured at the door positions of the veranda in rush hour. The annoyance of the inhabitances towards the road-side traffic noises were also measured by using questionnaire. The two-component mental health status was measured by two different scales (Anxiety and Depression). Results for a single building (beside busy-traffic road) showed that the levels of road-side noises were found curvature form vertically, which leads similar curvature form of annoyance level of the inhabitances. Mental health status was found up to half way similar curvature form of annoyance but dissimilar for the rest half. Another result showed comparing two buildings that the inhabitances have much better mental health in the high-rise building ($p < 0.5$) with quite-traffic than that of those living in the high-rise building with busy-traffic.

1. INTRODUCTION

Noise Effects

Dhaka, presently with around 16 million inhabitances is one of the biggest cities in the world. It has high density population and very high traffic noises on the street. Here, pollution means the above of the standard level (Bangladesh Gadget, 2006) of sound level. Many inhabitances of high-rise buildings in Dhaka City don't like to stay for longer time when the building is beside the busy road. That's why the price rate of flat houses is generally lower. The question is why people don't like to live in the high-rise buildings beside higher traffic road. Very little literature, as one research found which describes the physical risk of noise effect in high-rise building (Barkokébas, B. Jr. *et* al., 2012). Another study indicates slight health effects of noise in high-rise building (Pieter-Paul, V. *et* al., 2016). The polluted traffic noises can be the effective causes of the degradations of physical and mental health was found indirectly (Caerphilly, S., 1993; Hellman, C. J. *et* al., 1982; Mathews, Jr., K. E. *et* al., 1975; Saifuddin, K. *et* al., 2010). Therefore, a study was designed to investigate the effects of traffic noise on mental health of the inhabitances of high-rise building. Mental health is defined here by two components: Anxiety and Depression.

Purpose of Study

The main purpose of this study was to investigate the relationships between the levels of traffic noise vertically each floors of the high-rise building and level of annoyance of the inhabitance vertically for each floor, respectively. Another purpose was to investigate the relationship between the noise level and annoyance level and the level of mental health status of the inhabitances of the same high-rise building.

Hypothesis

Traffic noise increases the level of annoyances of the inhabitances of high-rise building which affects the level of their mental health status.

2. METHODS

A survey type of research was conducted where purposive sampling design was followed. Noise levels were measured by a digital SPL meter. On the other hand, levels of annoyance and mental health were measured by using two questionnaires. Two high-rise buildings (12 floors) were selected where, one was beside the road with very high-traffic and another one beside the road with very low-traffic. The methods of physical and subjective measurements for both building were kept constant. Noise levels were measured at the door positions of the veranda of all floors of the two buildings. One questionnaire has measured annoyance level on the 10-points scale and some demographic information. Another questionnaire has measured the levels of anxiety (36 items) and depression (30 items) which had five answering options and their own cut-off points for both. The anxiety and depression both have its four steps/levels (Mild < Moderate < Sever < Profound). The ages of the respondents were ranged between 20 to 45 years old (N = 200). A five member's research team has collected the data by SPL meter and applying questionnaires.

3. RESULTS AND DISCUSSIONS

The Figures 1(a, b, c, d) showed noise levels (SPL) at the peak-time of the working day. The graphs symbol meaning, ▲: noise levels under very-noisy road traffic, and ♦: noise levels under very-quite road traffic for two different buildings, respectively.

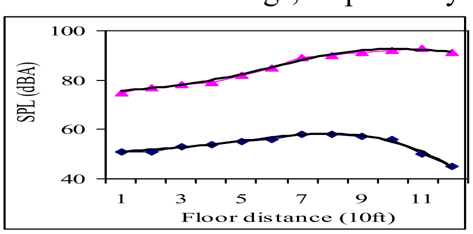

Figure 1(a). Road side (0ft from road) for each floor (12floors)

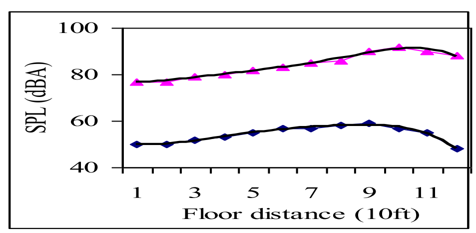

Figure 1(b). House side (15ft from road) for each floor (12floors)

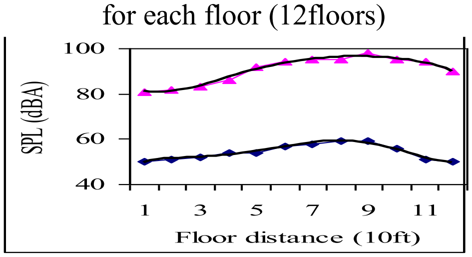

Figure 1(c). Veranda side (2ft from building) for each floor (12floors)

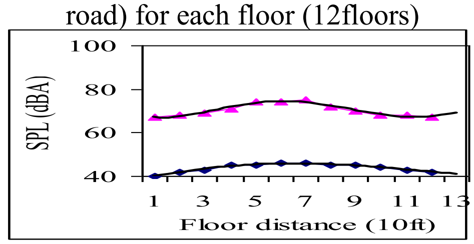

Figure 1(d). In house (5ft from inside wall) for each floor (12floors)

The perceived annoyance of the inhabitances of two buildings towards the traffic noises as per higher floors is shown in the Figure 2.

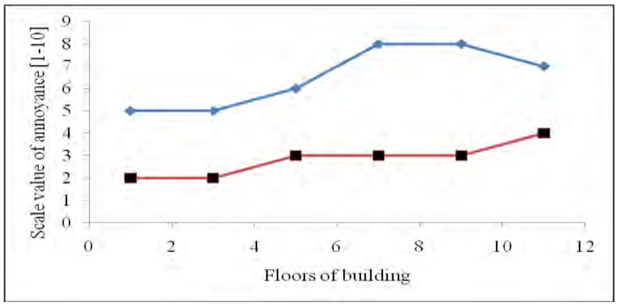

Figure 2. Magnitude of perceived annoyance based on each floor of the building,
♦ = Noisy area, ■ = Quite area.

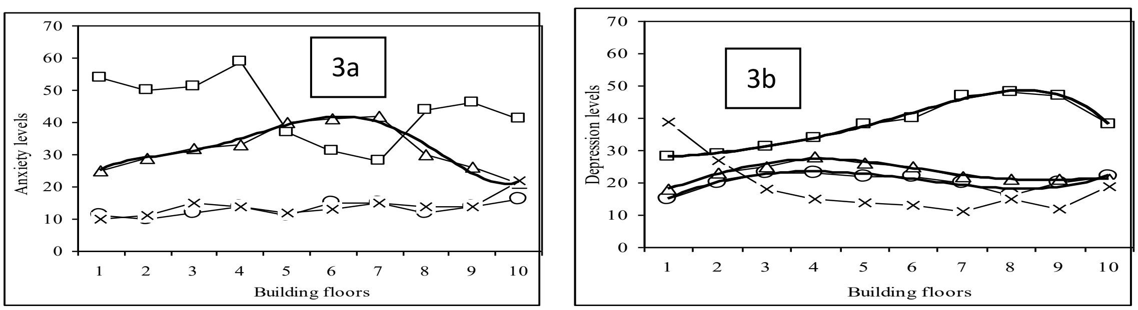

Figure 3(a, b). Building with noisy traffic, O: Mild, □: Moderate, Δ: Sever, ×: Profound (Figure 3a: Anxiety, and Figure 3b: Depression).

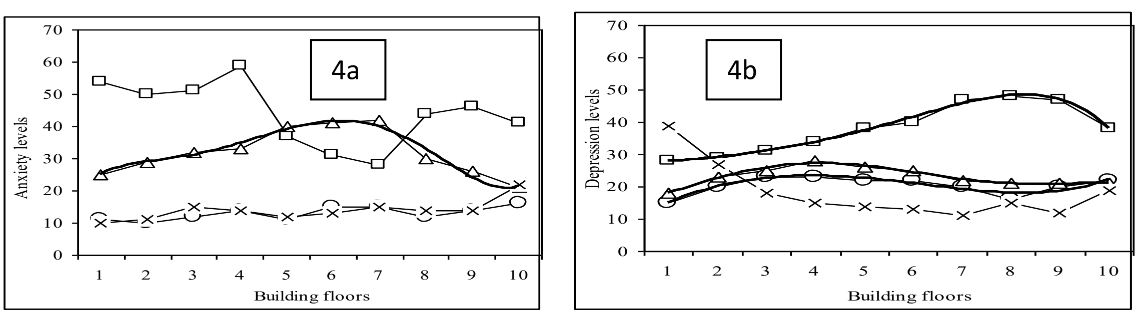

Figure 4(a, b). Building with quite traffic, O: Mild, □: Moderate, Δ: Sever, ×: Profound (Figure 4a: Anxiety, and Figure 4b: Depression).

Figure 2 expresses the annoyance levels towards road-side traffic noises of those inhabitances that are living in the high-rise buildings (noise and quiet areas) based on different floors (1st to 12th). Figure 3(a, b) and Figure 4(a, b) express the found anxiety and depression levels with their four categories under noisy and quiet conditions, respectively.

4. CONCLUSIONS

According to the purpose and hypothesis of this study the physical and subjective studies were conducted in the two different phases. The levels of annoyance, anxiety and depression of the adult inhabitances of two high-rise buildings were measured. The levels of road side traffic noises were also measured of those two buildings in where one building was beside the very noisy road and another was beside the quiet road. Results revealed that there is relation between the road-side traffic noise and the annoyance. Relations also found between the road-side traffic noise and mental health (anxiety and depression) of the inhabitances of high-rise buildings. It also found significant that the floors as means of height of building is a parameter of producing the annoyance, anxiety and depression as a result of the psychophysical reaction towards the road side traffic noises. Therefore, the results of this study suggest that the road site traffic noise should be considered when the high rise building is designed for the sake of the mental health conditions of the inhabitances.

ACKNOWDGEMENTS

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The impact of demographic and residential factors on aircraft noise-induced health effects at Noi Bai International Airport

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ABSTRACT

Surveys on health effects of aircraft noise were conducted at thirteen residential areas around Noi Bai International Airport in November 2017 and August 2018. The residents' general noise annoyance, health consequences such as insomnia, body mass index (BIM), high blood pressure, and their associations with aircraft noise exposure were investigated. Social and health data were obtained by interview method with questionnaire content about living environment, housing factors, and respondents' health status. Day-evening-night noise level (L_{den}) and nighttime equivalent noise level ($L_{night(22:00-6:00)}$) were obtained from the field measurement in the first survey and noise map in the second survey. In the second survey, in addition to the self-reported data, blood pressure data were collected by measurement using blood pressure meters. Comparisons of respondents with high blood pressure and insomnia ratios at different noise exposure level ranges showed that there is no significant association between ratios of hypertension and noise exposure levels but a significant exposure-response relationship was found between night-time noise exposure levels and insomnia. Non-acoustical factors such as the usage of air conditioner, direction of a bedroom to the main road, sound insulation ability of the house, length of residence, floor area are found to moderate the respondents' annoyance and insomnia. and high blood pressure. These study results suggested that improvement of residence quality and a restriction on nighttime flight operation should be considered to protect the health of the residents living around airports in Vietnam.
Key words: aircraft noise, noise annoyance, insomnia, high blood pressure

1. INTRODUCTION

After the newly-built terminal was opened and went into full operation at the end of December 2014, Noi Bai International Airport's capacity had been boosted by 10 million passengers a year and had increased the ability to serve more flights a day. This led to health consequences caused by increasing aircraft noise levels for residents living around HNBIA. By conducting two surveys in November 2017 and August 2018, in addition to researching the community responses, the impacts of noise on residents' health were assessed. This study is expected to provide practical investigation methods and knowledge about the impact of noise on public health, especially those living around airports in developing countries.

2. METHODS

2.1. Survey sites

Six sites were selected under the major arrival route (A1-A6), and five sites were selected under the major departure route (A7-A11). Two control sites, A12 and A13, which were assumed to be little affected by aircraft noise in the same living conditions as the others, are located in the northeast direction of the airport [3]

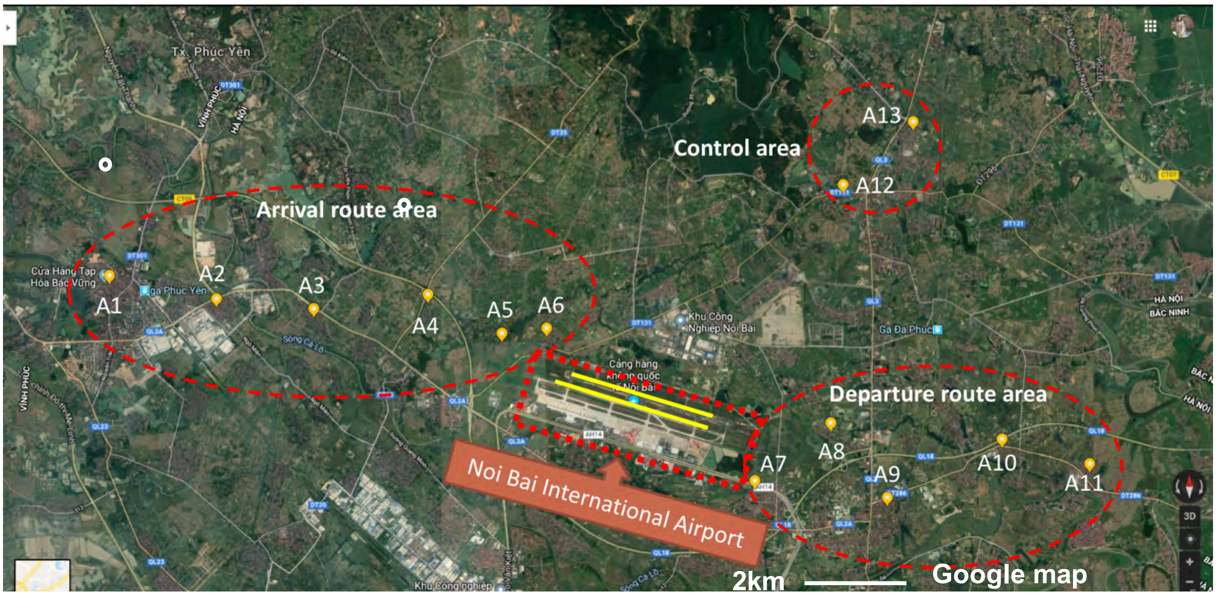

Figure 1. Map of survey sites

2.2. Socio-acoustic and health surveys

This research was conducted in 2 rounds in 2017 and 2018 to collect noise exposure levels and community responses.

The health surveys were conducted around HNBIA in November 2017 (Round 1) and August 2018 (Round 2). In Round 1, face-to-face interviews were conducted to obtain data of community responses and health. In Round 2, interview was still conducted in the same way as in Round 1, but the questionnaire was changed by adding more health related questions instead of questions on attitudes and housing factors, etc. In Round 2, a blood pressure measurement (OMRON HEM-6324T) was performed after the interview was completed.

In Round 2, instead of field measurement, noise levels were obtained from a noise contour map calculated with measured ADS-B data and operation data provided by the airtport managers.

3. RESULTS

3.1. Demographic data

There are differences in demographic data between Round 1 and Round 2. More respondents of "Student, housewife, retired, unemployed" in Round 2 than Round 1. The proportion of respondent living in the area for more than 10 years in Round 2 is less than that of Round 1.

Table 1. Demographic data of two rounds

		Round 1	Round 2
Number of respondents		623	130
Response rate (%)		95.8	83.3
Gender	Male	47.7	40.9
	Female	52.3	59.1
Age	20s-50s	75.5	71.2
	≥60s	24.5	28.8
Length of residence	0-9 years	14.3	75.0
	10 years or more	85.7	25.0
Occupation	Employment	51.4	15.2
	Student, housewife, retired, unemployed	48.6	79.5

3.2. Average daily noise exposure levels

Table 2 shows noise exposure levels measured at the survey in 2017 and estimated for the survey in 2018. Sites A5 and A8 have the highest average noise levels.

Table 2. Average daily noise levels in Rounds 1 and 2

	Round	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13
$L_{night(22:00\text{-}6:00)}$ (dB)	1	47	47	54	55	69	55	57	59	58	53	52	30	29
	2	45	48	53	54	64	57	59	58	58	52	50		
L_{den} (dB)	1	55	54	62	63	76	64	65	66	65	60	59	38	38
	2	52	55	60	61	71	64	65	65	65	58	57	40	37

3.3. Changes in sleep effects and general annoyance

Figures 2 and 3 show the logistic regression relationship between the noise levels and the percentage of highly annoyed respondents and the percentage of respondents suffering from insomnia of the two surveys. The relationships between the percentage of highly annoyed and L_{den} of the two survey are consistent. However, the relationship for percentage of insomnia and $L_{Aeq,night}$ of Round 2 is significantly higher than that of Round 1.

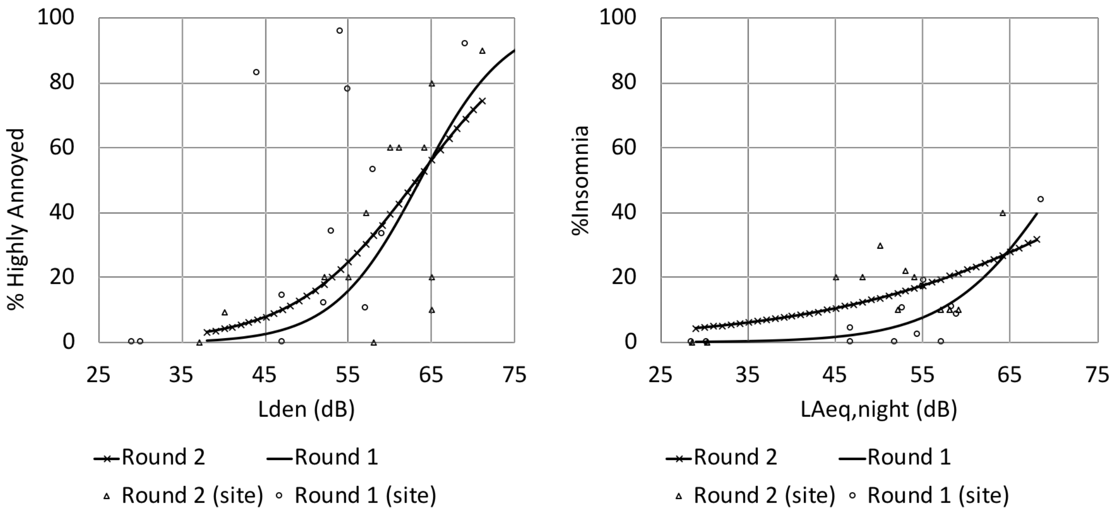

Figure 2 and 3. The relationship between noise exposure levels and the percentage of highly annoyed, between noise exposure levels and the percentage of insomnia

3.4. Combined effects of acoustic and residential factors

The bedroom which has air conditioner or not, whether faces to the main road, uses sound insulation, people who living in those areas less than 5 years, the house area which less than 100m2 are the residential factors considering effects to local living quality.
Table 3 and 4 show that sound insulation, air conditioner and bedroom direction are the residential factors related to locals' annoyance and sleep disturbance.

Table 3. Nominal logistic fit for Annoyance

Source	LogWorth	PValue
Lden	102.550	0.00000
Sound insulation	15.720	0.00000
Air conditioner	8.093	0.00000
Bedroom direction	2.649	0.00225
Live<5years	1.546	0.02847
S<100m2	0.998	0.10050

Table 4. Nominal logistic fit for Insomnia

Source	LogWorth	PValue
Lnight	12.156	0.00000
Air conditioner	8.167	0.00000
Bedroom direction	3.979	0.00010
Sound insulation	3.519	0.00030
Live<5years	0.302	0.49835
S<100m2	0.067	0.85698

4. CONCLUSIONS

The higher rate of insomnia was found with the survey period when night flight operation was enhanced. Not only the aircraft noise but also some residential factors affect to local life, especially their annoyance and sleep disturbance. For further studying the impact of noise on general health of resident living around the airport areas in Vietnam, investigation based on reliable method of collecting health data is needed

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Subjective evaluation of low-frequency noise from outdoor unit of air conditioner in residential building through auditory experiment

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ABSTRACT

This study conducted the subjective evaluation of low-frequency noise from outdoor unit of air conditioner in residential building through auditory experiment. Noises from several outdoor units of air conditioners were first recorded in the residential building, and their acoustical properties were analyzed. In the auditory experiment, the recorded noises were filtered out using sound insulation spectrum of wall. The noises were then presented from headphone and woofer, and subjects rated their annoyance due to the presented noises. Relationship between psycho-acoustical parameters (Zwicker and autocorrelation function parameters) of noise from outdoor unit of air conditioner and annoyance was analyzed. It was found that tonal component and its strength in the low-frequency range of outdoor unit noise mainly affect subjective perception of the outdoor unit noise.

1. INTRODUCTION

The split-type air conditioner has been widely used in the residential buildings. The split-type air conditioner consists of indoor unit and outdoor unit. Especially, outdoor unit produces considerable noise by operation of fan and compressor. In general, noise from outdoor unit has tonal components in the low frequency range and noise component in the middle and high frequency range. Sometimes, the noise from outdoor unit irritate residents inside the dwelling. There were several studies [1,2] on sound quality evaluation of noise from outdoor unit using Zwicker parameters [3] as psycho-acoustical metric. Several studies [4,5] tried to explain the subjective perception of air-conditioner and refrigerator using autocorrelation function (ACF) parameters [6]. This study investigated the relation between psycho-acoustical parameters (Zwicker and ACF parameters) and annoyance for noise from outdoor unit of air conditioner through auditory experiment.

2. METHODS

Stimuli

In the field measurement, four types of noise from outdoor unit of air conditioner in buildings were recorded. The noises were recorded on the condition of stationary state using a sound level meter (NL-52, Rion, IEC 61672-1: 2002 Class 1) with a condenser microphone (UC-59, Rion). The microphone was placed at 1 m from the outdoor unit and at height of the center of fan of outdoor unit. The original sound sources recorded outdoors were edited to have a duration of 10 s for the auditory experiment. Additional sound sources were then created by editing the original sound source in order to simulate the sound source for indoor spaces. This editing was

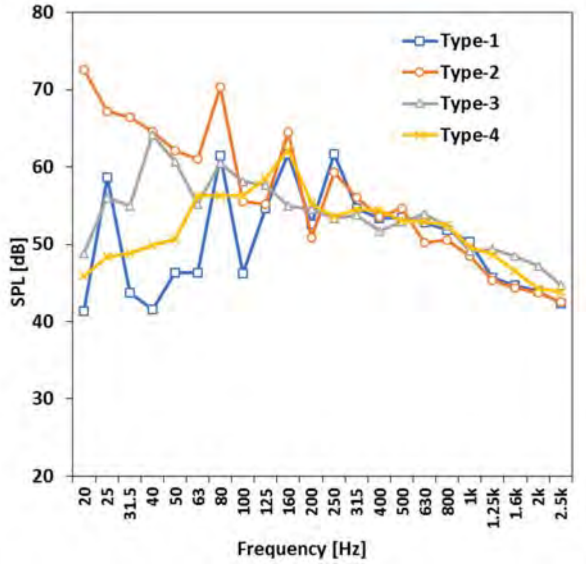

Figure 1. Frequency responses of stimuli of outdoor unit noise at 60 dB in L_{Aeq}

performed using a sound editing software (Adobe Audition) with filters having frequency responses that mimicked the effect of sound insulation averaged over fourteen façade on the original sound source. All the sound samples were then normalized to the same equivalent sound pressure level at 60 dBA. Figure 1 indicates the frequency responses of stimuli of outdoor unit noise, where the SPLs of all stimuli were adjusted to 60 dB in L_{Aeq} for the listening test. As shown in Figure 1, stimuli have large variation in SPL in low frequency range and several tonal components. Value of dBC-dBA of the stimuli ranged from 12 to 21.

Experimental procedure

A listening test to rate the annoyance due to the outdoor unit noises was conducted. The subjects rated their annoyance regarding the outdoor unit noises while imagining a specific hearing situations: Outdoor unit noise originating outside is heard when you are reading a book in your living room with the windows closed. Subjects rated their annoyance due to the presented sound using a numerical scale with eleven points (0 = 'not at all' and 10 = 'extremely') as recommended by the ICBEN team [27] and the ISO 15666 standard [28].

Subjects and Apparatus

Thirty subjects in their twenties with normal hearing participated in the auditory experiment. The subjects listened to the stimuli using an open-type headphone (Sennheiser HD 600) and a woofer speaker (Dynaudio BM14SII). The headphone and speaker produced sounds of over 100 Hz, and from 18 Hz to 250 Hz, respectively. All tests were conducted in a soundproof room, in which background noise level and reverberation times were approximately 15 dB in L_{Aeq} and 0.19 s in the middle frequency range (500 Hz and 1 kHz octave band), respectively.

3. RESULTS

Figure 2 shows relationship between Zwicker's parameters [3] and annoyance for outdoor unit noise including correlation coefficient (r-value) for outdoor unit noise. Zwicker's parameters were analyzed using sound analysis software (01dB-Matravib ver.4.9). As shown in Figure 2, loudness, sharpness, and roughness are highly correlated with annoyance, but sharpness had negative relation with annoyance. Roughness showed largest correlation coefficient with annoyance.

Figure 3 shows relationship between ACF parameters [4] and annoyance for outdoor unit noise including correlation coefficient (r-value) for outdoor unit noise. For ACF parameter analysis, integration time interval was 3 s and running step was 0.1 s. The values of ACF parameter in

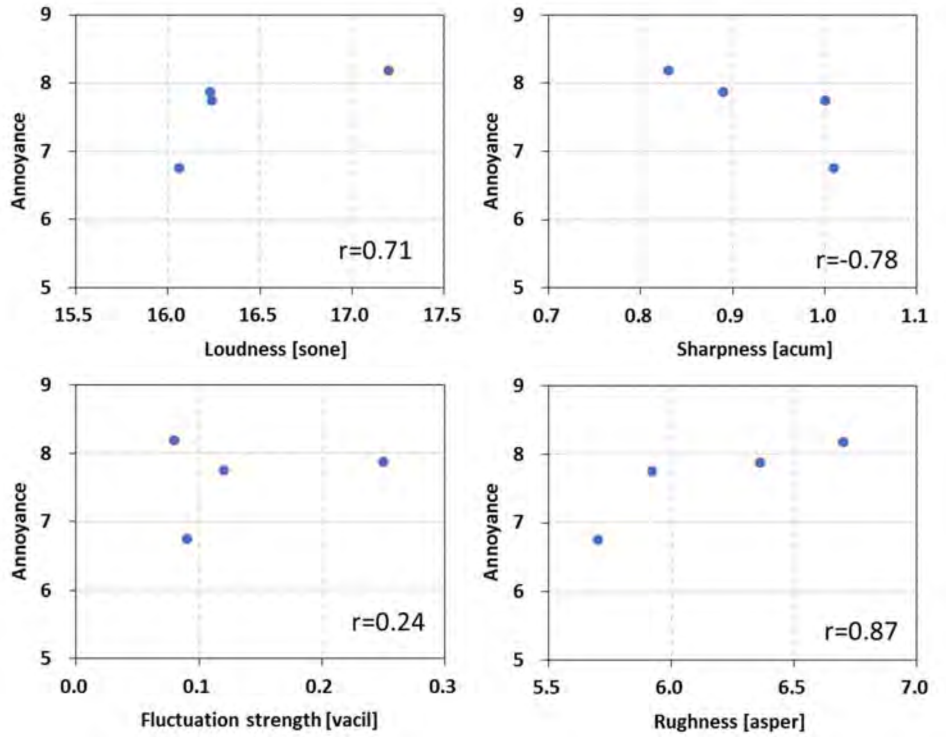

Figure 2. Relation between Zwicker's parameters and annoyance for outdoor unit noise; r-values indicate correlation coefficient

the Figure 3 indicate averaged value over each running step. As shown in Figure 3, it was observed that all ACF parameters are relatively well correlated with annoyance. τ_1 among the parameters had largest correlation coefficient with annoyance. Φ_0 and τ_1 showed negative relation with annoyance, while τ_e and ϕ_1 had positive relation with annoyance.

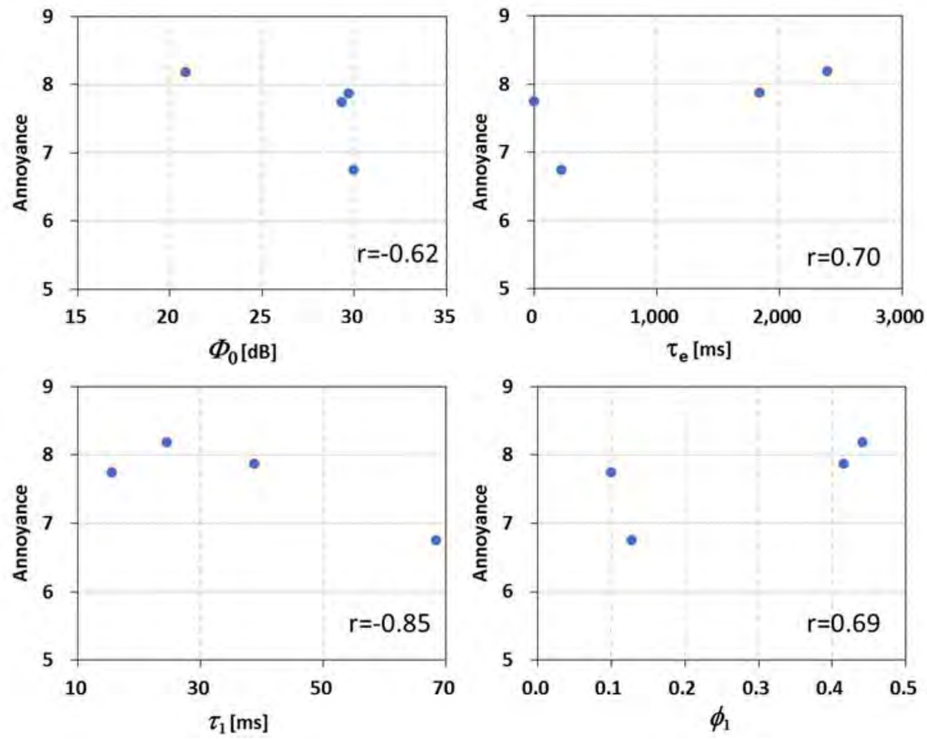

Figure 3. Relation between ACF parameters and annoyance; r-values indicate correlation coefficient

In addition, multiple regression analysis was conducted using Zwicker and ACF parameters as independent variables including annoyance score as dependent variable. Enter method in multiple regression analysis (SPSS ver. 23) was utilized. Result showed that annoyance due to outdoor noise can be explained by τ_1, ϕ_1 and fluctuation strength as shown in Equation 1.

$$\text{Annoyance}\,. \quad -0.02\ {}_1 + 1.82\emptyset_1 + 0.09\ \ .S. + 7.89 \qquad (1)$$

In the equation, loudness as a Zwicker's parameter was excluded because stimuli used in the auditory experiment has equal sound energy in terms of L_{Aeq} and small range of loudness. From the result of multiple regression analysis, annoyance due to noises from outdoor unit of air conditioner can be mainly affected by tonal component and its strength in the condition of equal sound energy of noises.

4. CONCLUDING REMARKS

This study investigated the relation between psycho-acoustical parameters and annoyance for noise from outdoor unit of air conditioner through auditory experiment. It was found that annoyance due to the outdoor unit noises with equal sound energy can be explained by τ_1, ϕ_1 and fluctuation strength. This result indicates that tonal component and its strength in the low-frequency range of outdoor unit noise mainly affect subjective perception of the outdoor unit noise.

ACKNOWLEDGMENTS

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Just noticeable difference of SPL in low-frequency range for heavyweight floor impact sound in residential building

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ABSTRACT

This study investigated just noticeable difference (JND) of SPL in low-frequency range of heavyweight floor impact sound through an auditory experiment. A floor impact sound for the auditory experiment were recorded in a reinforced concrete building using rubber ball. Two types of rubber sound with ordinary frequency responses were then edited as the reference sounds. The reference sounds were modified by amplifying SPL by 0 dB, 5 dB, 10 dB, and 15 dB in 32 Hz octave band. The reference and modified sounds were then presented to subjects using headphone and woofer. JND test was performed in terms of loudness and annoyance. It was found that JND of SPL in 32 Hz band was about 23 dB and 16 dB for loudness and annoyance, respectively.

1. INTRODUCTION

Heavyweight floor impact sound such as children's jumping has been widely perceived as most irritating noise source in the multi-story residential building. Especially, SPL in low-frequency range below 100 Hz of heavyweight floor impact sound largely depend on structural properties of the building. Because construction quality of structural components in building is not stable, SPL in low-frequency range below 100 Hz of heavyweight floor impact sound is varied even for same architectural and structural design. Meanwhile, rating method of heavyweight floor impact sound insulation was proposed in ISO 717-2 [1]. SPLs from 63 Hz and 500 Hz were employed for calculating the single number quantity in the standard. However, there is a need to confirm optimum frequency range (especially for lower frequency) for the single number quantity in terms of subjective aspects. There are several subjective studies [2-4] on annoyance evaluation for various frequency spectrum of rubber sound. This study investigated just noticeable difference (JND) of SPL in low-frequency range of heavyweight floor impact sound through an auditory experiment.

2. METHODS

Stimuli

A rubber sound as the heavyweight floor impact sound was recorded in a living room of the apartment building (area: 84 m^2) with box-frame type reinforced concrete structure (slab thickness: 180 mm). A microphone was positioned at center of room and at height of 1.2 m from the floor. Rubber ball was impacted at center position of living room of upper unit. A sound level meter (NL-52, Rion, IEC 61672-1: 2002 Class 1) with a condenser microphone (UC-59, Rion) was utilized for the recording. The original rubber ball sound sources with two impacts were edited to have a duration of 3 s for the auditory experiment. Additional sound sources were then created by editing the original sound source in order to simulate ordinary frequency responses of rubber ball sound as shown in Figure 1 (a). Two frequency responses (from 63 Hz to 500 Hz octave band) of rubber sound was derived from previous study [3], which suggested usual types of frequency response through investigation of 35 floors with 150 mm to 180 mm slab thickness in box frame type reinforced concrete apartments. Figure 1 (b) shows frequency responses of reference and test sound of rubber ball sound at 55 dB in $L_{iA,Fmax}$. SPL in 31.5 Hz octave band for reference sound was adjusted to equal SPL to 63 Hz octave band. SPL in 31.5 Hz octave band for test sound was amplified by 5 dB, 10 dB, and 15 dB.

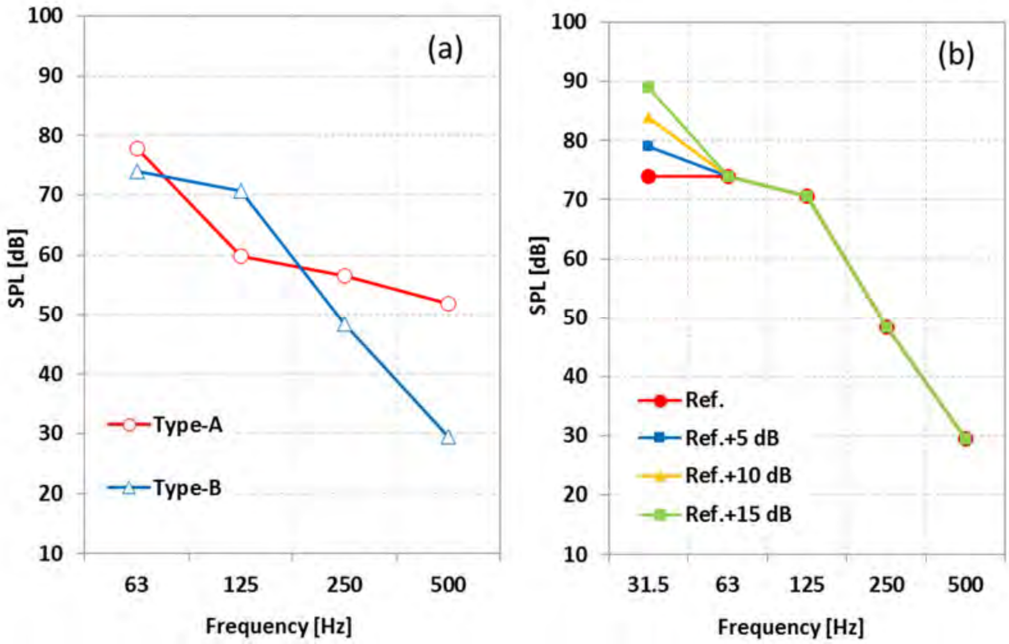

Figure 1. Frequency responses of (a) reference and (b) test sound (for type-A) of rubber ball sound at 55 dB in $L_{iA,Fmax}$

Experimental procedure
An auditory experiment for JND test was conducted using method of limit. Reference sound were paired with test sounds with interval of 2 s. Two ascending and descending series were completed by subjects. Subjects were asked to judge the differences in terms of subjective loudness and annoyance between reference and test sound.

Subjects and Apparatus
Thirty one subjects (male: 21; female: 10) in their twenties (mean: 25 years of age, standard deviation: 3 years) with normal hearing participated in the auditory experiment. The subjects listened to the stimuli using an open-type headphone (Sennheiser HD 600) and a woofer speaker (Dynaudio BM14SII). The headphone and speaker produced sounds of over 100 Hz, and from 18 Hz to 250 Hz, respectively. All tests were conducted in a soundproof room, in which background noise level and reverberation times were approximately 15 dB in L_{Aeq} and 0.19 s in the middle frequency range (500 Hz and 1 kHz octave band), respectively.

3. RESULTS

Figure 2 shows percentage of correct answer as a function of SPL difference in 32 octave band for each frequency response in terms of loudness and annoyance. As shown in Figure 2, percentage of correct answer increases steadily as SPL difference increases for both frequency types in terms of both subjective attributes. In particular, percentage of correct answer for type A was larger than that of type B for all cases.

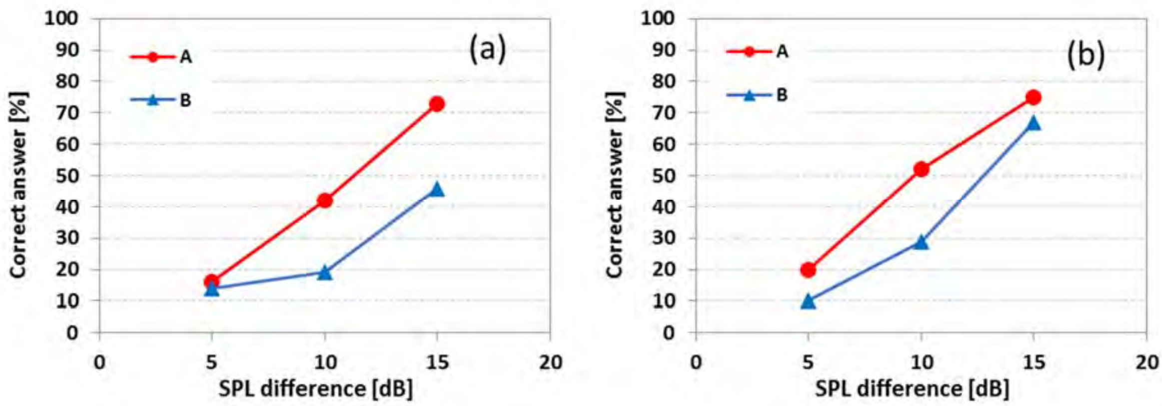

Figure 2. Percentage of correct answer as a function of SPL difference in 32 octave band for each frequency response; (a) loudness and (b) annoyance

Figure 3 shows the predicted percentage of correct answer as a function of SPL difference in 32 octave band for each frequency response in terms of loudness and annoyance. The prediction of the percentage was conducted by using sigmodal dose-response equation and maximum of least square (MLS) method for best fit curve. JND was obtained by calculating the SPL difference corresponding to 75 % of correct answer from the best fit curve. Table 1 indicates JND of SPL in 32 Hz octave band for rubber sound in terms of subjective loudness and annoyance. Result showed that JND of SPL in 32 Hz octave band for loudness and annoyance was 23 dB and 16 dB averaged over two types, respectively. Type B had lager JND of SPL in 32 Hz octave band than Type A for both loudness and annoyance.

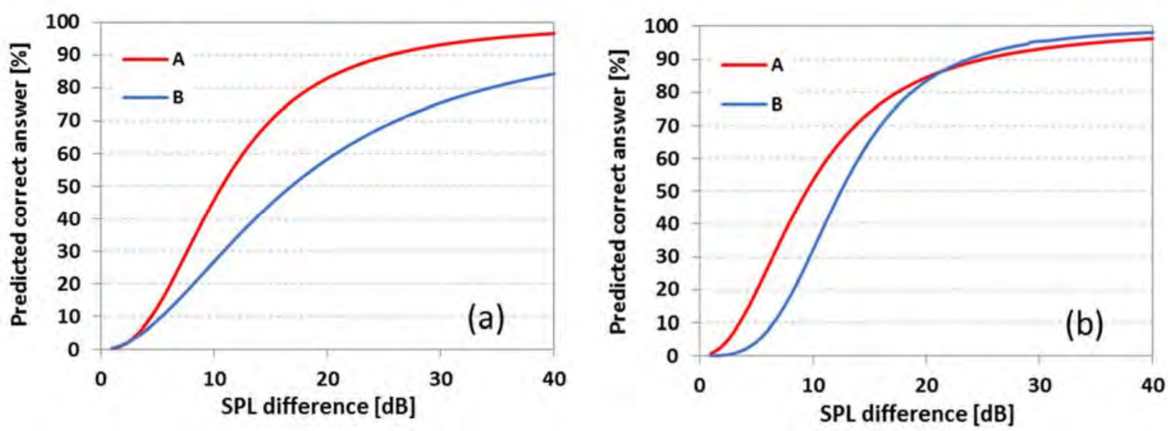

Figure 3. Predicted percentage of correct answer as a function of SPL difference in 32 octave band for each frequency response; (a) loudness and (b) annoyance

Table 1. Just noticeable difference (JND) of SPL in 32 octave band for rubber sound

	Type-A	*Type-B*
Loudness	16 dB	29 dB
Annoyance	15 dB	17 dB

4. CONCLUDING REMARKS

This study investigated the just noticeable difference (JND) of SPL in 32 Hz octave band for rubber sound through an auditory experiment based on method of limit. It was found that JND of SPL in 32 Hz band was about 23 dB and 16 dB for loudness and annoyance, respectively. It was also observed that JND varied with frequency response of rubber sound.

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Sound Quality Analysis Based on Correlation Mechanism

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ABSTRACT

With the development of noise control technology, the sound pressure level of noise sources has decreased and the importance of sound quality has increased. Factors extracted from the autocorrelation function (ACF) and the interaural cross-correlation function (IACF) has been used for sound quality evaluation. Sound quality is considered to be composed of multidimensional elements. Recently, three major perceptual dimensions of sound, *Evaluation*, *Potency*, and *Activity*, were derived. *Evaluation* refers to general human judgment. *Potency* is the sensitivity to the magnitude, and *Activity* is the sensation of the temporal and spectral compositions of the perceived sound. Therefore, it is necessary to evaluate three dimensions to understand sound quality of sound sources. In this study, three perceptual dimensions of sound, *Evaluation*, *Potency*, and *Activity*, for aircraft noises and noises in running cars were evaluated and the dominant physical factors that relate to the three perceptual dimensions were determined.

1. INTRODUCTION

A correlation is one of the most common and most useful statistics. It measures the strength and direction of a linear relationship between two variables. When a signal is a time series, it is characterized by periodicity or randomness as a function of time. The correlation coefficients between two time series data can change as a function of time and it can be observed by autocorrelation function (ACF). The ACF is a set of correlation coefficients between the series and lags of itself over time. The ACF is a time-domain function that is a measure of how much a signal shape, or waveform, resembles a delayed version of itself. For example, white noise is random, so the ACF has quite low value. Pure tone is completely periodic, so the ACF is also periodic.

In a similar way, the relationship between two time-series data is characterized by the correlation coefficient as a function of time, that is, cross-correlation function (CCF). The CCF is a measure of similarity of two waveforms as a function of a time-lag applied to one of them. The CCF between signals obtained from left and right ears is called interaural cross-correlation function (IACF).

The relationship between our sensations and physical characteristics of sounds has been examined. It has been found that our temporal and spatial sensations can be described by factors obtained from the ACF and IACF of sounds [1, 2]. For example, pitch and pitch strength can be characterized by delay time, τ_1, and amplitude, ϕ_1, of the maximum peak of the ACF. Apparent source width (ASW) can be characterized by the amplitude, IACC, and width, W_{IACC}, of the maximum peak of the IACF. Based on these findings, a model for environmental noise evaluation has been proposed [3]. It may also applicable to evaluation of sound quality.

As a result of determining a macroscopic structure of sound quality by sensory evaluations and multidimensional scaling method, three main dimensions, namely *Loudness*, *Pitch* and *Pleasantness*, for sound quality evaluation have been proposed [4]. Recently Ma et al. [5] undertook a systematic review of forty-five eligible studies on human perceptual dimensions of sounds. Three major perceptual dimensions of sound, *Evaluation*, *Potency*, and *Activity*, were derived. *Evaluation* refers to general human judgment. *Potency* is the sensitivity to the magnitude, and *Activity* is the sensation of the temporal and spectral compositions of the perceived sound. These suggests that at least three dimensions are necessary for psychological evaluation of sound quality.

Previous psychological evaluations of sound quality have focused on one psychological dimension, that is *Evaluation* or *Potency*, although three perceptual dimensions are proposed [4, 5]. It is necessary to evaluate all three dimensions to understand human perception of sound quality in more detail for designing better sound. The aim of this study was to clarify psychological responses to aircraft noise and noises in a running car by the three major perceptual dimensions of sound and to determine the dominant physical factors that relate to the three major perceptual dimensions.

2. METHODS

Measurements of aircraft noise were carried out at two locations under take-off and landing routes near Osaka International Airport in environments far from industrial or urban areas to avoid other noise sources. The distance between the runway and each measurement location was approximately 100 m. Aircraft noise was recorded using a binaural microphone (Type 4101, Brüel & Kjær). An experimenter positioned the binaural microphones next to his ears and stood at the location. The height of the experimenter's ears was 1.6 m above the ground. Aircraft noise was saved on a laptop computer via an AD converter at a sampling rate of 48 kHz and sampling resolution of 24 bits.

Two cars were chosen for the measurement. Car A was a sedan while car B was a small car. Noise in the running car cabins were recorded by a laptop computer via a head and torso simulator (HATS, Type 4128C, Brüel & Kjær) and an AD converter at a sampling rate of 48 kHz and a sampling resolution of 24 bits. The HATS was located on the passenger seat. The effect of the air conditioner was investigated by setting the air-conditioning mode to off, weak, and strong. The cars run on an express way at a speed from 70 to 90 kilometers-per-hour. All windows were closed during the measurement.

Factors extracted from ACF and IACF have been proposed for sound quality evaluation [3, 6]. To calculate ACF and IACF factors, the normalized ACF and IACF of the signals recorded at left and right ears from the microphones, $p_l(t)$ and $p_r(t)$, as a function of the running step, s, is defined by

$$\phi_{lr}(\tau) = \phi_{lr}(\tau; s, T) = \frac{\Phi_{lr}(\tau; s, T)}{\sqrt{\Phi_{ll}(0; s, T)\Phi_{rr}(0; s+\tau, T)}}, \quad (1)$$

where

$$\Phi_{lr}(\tau; s, T) = \frac{1}{2T}\int_{s-T}^{s+T} p_l^{'}(t)p_r^{'}(t+\tau)\,dt. \quad (2)$$

When only the signal recorded at the left, p_l(t) or right, p_r(t), ear, is used, the equation (1) shows the normalized ACF. Here, $2T$ is the integration interval and $p'(t) = p(t)*s_e(t)$, where s_e(t) is the ear sensitivity. s_e(t) represents the impulse response of an A-weighted network, including the transfer functions of the human outer and middle ear, for convenience [2, 6]. Then normalized ACF and IACF are carried out using the geometric mean of the energy at s and the energy at $s+\tau$. This ensures that the normalized ACF and IACF satisfy the condition $0 \le \phi_{lr}(\tau) \le 1$.

L_{Aeq} was determined from the A-weighted p(t) as a function of s. L_{Aeq} is calculated using

$$L_{Aeq}(s,T) = 10 \log \Phi(0; s,T). \qquad (3)$$

This means that the ACF includes L_{Aeq} as one of its factors. The other ACF factors are calculated from the normalized ACF as shown in Figure 1 (a). τ_1 and ϕ_1 are defined as the delay time and the amplitude of the first maximum peak. τ_1 and ϕ_1 are related to the perceived pitch and the pitch strength of sounds, respectively [2, 6]. Higher values of τ_1 and ϕ_1 mean that the sound has a lower or a stronger pitch, respectively. The effective duration of the envelope of the normalized ACF, τ_e, is defined by the ten-percentile delay and represents a repetitive feature containing the sound source itself [2]. The other ACF factor, the width of the first decay, $W_{\phi(0)}$, is defined using the delay time interval at a normalized ACF value of 0.5. $W_{\phi(0)}$ is equivalent to the spectral centroid [6]. Higher values of $W_{\phi(0)}$ indicate that the sound includes a higher proportion of low-frequency components.

The interaural cross-correlation coefficient (IACC) is related to the subjective diffuseness and ASW [2], and is defined by

$$\text{IACC}(s, T) = |\phi_{lr}(\tau; s, T)|_{\max}, |\tau| \leqslant 1 \text{ [ms]}. \qquad (4)$$

When the IACC is 1, a listener can clearly perceive the direction of the sound source. When IACC approaches 0, listeners can hear the sound, but it is diffused. The other IACF factors are calculated from the normalized IACF as shown in Figure 1 (b). The interaural delay time at which IACC is defined is τ_{IACC}, corresponding to the sense of direction at low frequency [2, 6]. W_{IACC} is the width of the IACF and is defined by the interval of delay time at a value of δ below the IACC. W_{IACC} mainly depends on the frequency component of the signals and is related to the ASW [2, 6].

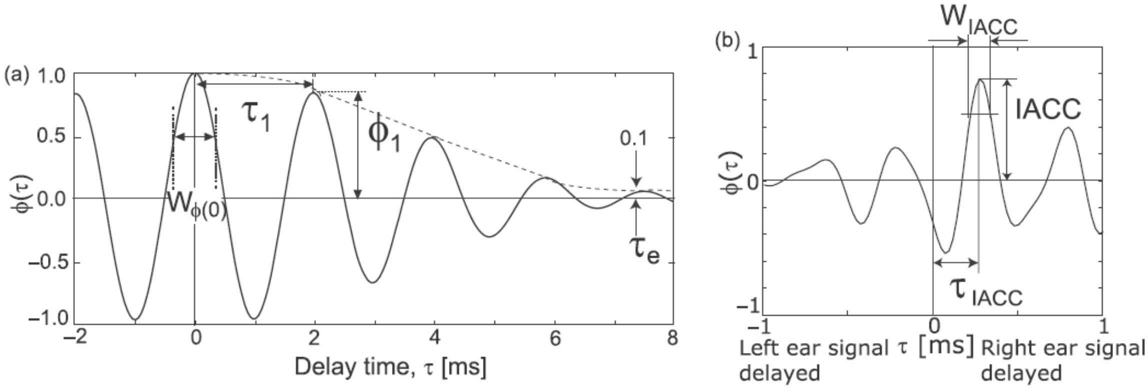

Figure 1. (a) The definition of the ACF factors, τ_1, ϕ_1, τ_e, and $W_{\phi(0)}$. (b) The definition of the IACF factors, IACC, τ_{IACC}, and W_{IACC}.

Sixteen stimuli with a mean L_{Aeq} below 80 dB were selected from the measured aircraft noise to avoid hearing impairment of the participants. Six of the sixteen stimuli were measured under the take-off route and ten were measured under the landing route. Twelve stimuli were selected from the measured noise in car cabins running on an express way to focus on the road and air-conditioner noises in running cars. The stimuli were presented binaurally through a headphone amplifier and headphones. The duration of each stimulus was 2.0 s, including rise and fall ramps of 0.1 s. The participants sat in a comfortable thermal environment in a soundproof room to listen to the stimuli. All stimuli were presented at the same L_{Aeq} ± 0.2 dB as the actual measured noises.

We selected annoyance as *Evaluation*, loudness as *Potency*, and pitch as *Activity* as the three perceptual dimensions [5]. Subjective annoyance, loudness, and pitch were evaluated to clarify the effects of the physical factors on each subjective response. Informed consent was obtained from each participant after the nature of the study was explained. The study was approved by the ethics committee of the National Institute of Advanced Industrial Science and Technology (AIST) of Japan. Scheffe's paired comparison tests [7] were carried out for all combinations of pairs of stimuli by interchanging the order in which the stimuli in each pair were presented and presenting the pairs in random order. The silent interval between stimuli was 1.0 s. Using a seven-point scale, the participants were asked to judge which stimulus from each pair was more annoying, louder, or higher following presentation of each pair. The averaged values of annoyance, loudness, and pitch according to each participant were calculated based on the modified Scheffe's method and were defined as the scale values (SVs) of annoyance, loudness, and pitch.

To calculate the effects of each objective factor on participant annoyance, loudness, and pitch, multiple regression analyses were conducted using a linear combination of the mean or median ACF factors and their standard deviations (SDs) or interquartile range (QR) as predictive variables:

$$SV \approx a_0 + a_1{*}L_{\mathrm{Aeq}} + a_2{*}\tau_1 + a_3{*}\phi_1 + a_4{*}\tau_{\mathrm{e}} + a_5{*}W_{\phi(0)} + a_6{*}\mathrm{IACC} + a_7{*}\tau_{\mathrm{IACC}} + a_8{*}W_{\mathrm{IACC}} + a_9{*}\mathrm{SD\_}L_{\mathrm{Aeq}} + a_{10}{*}\mathrm{QR\_}\tau_1 + a_{11}{*}\mathrm{SD\_}\phi_1 + a_{12}{*}\mathrm{SD\_}\tau_{\mathrm{e}} + a_{13}{*}\mathrm{SD\_}W_{\phi(0)} + a_{14}{*}\mathrm{SD\_IACC} + a_{15}{*}\mathrm{QR\_}\tau_{\mathrm{IACC}} + a_{16}{*}\mathrm{SD\_}W_{\mathrm{IACC}}. \qquad (5)$$

To identify and quantify the significant objective factors of participant annoyance, loudness and pitch, stepwise selection was carried out by successively adding or removing variables. The stepping criteria employed for entry and removal were based on the significance level of the *F*-value and set at 0.05 and 0.10, respectively. To avoid multicollinearity, factors with a variance inflation factor of 10 or more were excluded. The analyses were carried out using SPSS statistical analysis software (SPSS version 22.0, IBM).

3. RESULTS AND DISCUSSION

Figure 2 shows scale value of annoyance, loudness, and pitch. Roughly speaking, aircraft noise under the landing route was judged as more annoying, louder, and of a higher pitch than under the take-off route. Noises in the running car A with the strong air-conditioning mode was judged as more annoying, louder, and of a higher pitch than other conditions.

A multiple linear regression analysis was performed with the SVs of annoyance, loudness, and pitch for all participants as the outcome variable. The final model for airplane noises indicated that L_{Aeq}, $W_{\phi(0)}$, and the SD of L_{Aeq} were the significant factors:

$$SV_{annoyance} \approx a_0 + a_1 * L_{Aeq} + a_5 * W_{\phi(0)} + a_9 * SD\_L_{Aeq}, \quad (6)$$
$$SV_{loudness} \approx a_0 + a_1 * L_{Aeq} + a_5 * W_{\phi(0)} + a_9 * SD\_L_{Aeq}, \quad (7)$$
$$SV_{pitch} \approx a_0 + a_1 * L_{Aeq} + a_5 * W_{\phi(0)} + a_9 * SD\_L_{Aeq}. \quad (8)$$

The model was statistically significant ($F(15, 2135) = 120.65$, $p < 0.001$, for annoyance, $F(15, 2807) = 370.73$, $p < 0.001$, $p < 0.001$, for loudness, $F(15, 2807) = 281.84$, $p < 0.001$, for pitch), and the adjusted coefficient of determination, R^2, was 0.58 for annoyance, 0.78 for loudness, and 0.71 for pitch. The standardized partial regression coefficients in Equations (6), (7), and (8) are summarized in Table 1.

The final model for noise in running cars indicated that L_{Aeq}, ϕ_1, τ_e, $W_{\phi(0)}$, SD of L_{Aeq}, and the SD of ϕ_1 were the significant factors:

$$SV_{annoyance} \approx a_0 + a_1 * L_{Aeq} + a_5 * W_{\phi(0)} + a_9 * SD\_L_{Aeq}, \quad (9)$$
$$SV_{loudness} \approx a_0 + a_1 * L_{Aeq} + a_3 * \phi_1 + a_{11} * SD\_\phi_1, \quad (10)$$
$$SV_{pitch} \approx a_0 + a_3 * \phi_1 + a_4 * \tau_e + a_{11} * SD\_\phi_1. \quad (11)$$

The model was statistically significant ($F(11, 1505) = 240.92$, $p < 0.001$, for annoyance, $F(3, 204) = 244.88$, $p < 0.001$, for loudness, $F(11, 1505) = 168.64$, $p < 0.001$, for pitch), and the adjusted coefficient of determination, R^2, was 0.56 for annoyance, 0.76 for loudness, and 0.52 for pitch. The standardized partial regression coefficients in Equations (9), (10), and (11) are summarized in Table 1.

A multiple linear regression analysis showed that the energy-index of L_{Aeq} and the temporal variation of the sound level denoted as the SD of L_{Aeq} and SD are the significant factors for annoyance prediction. This is consistent with previous findings [8, 9] and confirms not only the sound level, but also the temporal variation of the level, has a large influence on subjective annoyance. The spectral content, denoted as $W_{\phi(0)}$, is also a significant factor for annoyance prediction, consistent with previous findings [8]. A negative regression coefficient of $W_{\phi(0)}$ means a higher noise component causes annoyance, i.e. sharper aircraft noise is perceived as annoying.

Table 1. Significant predictive variables and the standardized partial regression coefficients.

	Predictive variables (aircraft noise)	*Standardized coefficients (aircraft noise)*	*Predictive variables (noise in cars)*	*Standardized coefficients (noise in cars)*
Annoyance	a_1, L_{Aeq}**	0.49	a_1, L_{Aeq}**	0.50
	a_5, $W_{\phi(0)}$**	−0.22	a_5, $W_{\phi(0)}$**	−0.22
	a_9, SD_L_{Aeq}**	0.32	a_9, SD_L_{Aeq}**	0.48
Loudness	a_1, L_{Aeq}**	0.33	a_1, L_{Aeq}**	0.38
	a_5, $W_{\phi(0)}$**	−0.43	a_3, ϕ_1**	−1.42
	a_9, SD_L_{Aeq}**	0.37	a_{11}, SD_ ϕ_1**	−0.96
Pitch	a_1, L_{Aeq}**	0.22	a_3, ϕ_1**	−0.78
	a_5, $W_{\phi(0)}$**	−0.23	a_4, τ_e**	0.89
	a_9, SD_L_{Aeq}**	0.60	a_{11}, SD_ ϕ_1**	−0.53

As is the case with annoyance, a multiple linear regression analysis for airplane noises showed that the energy-index, L_{Aeq}, and the spectral content, $W_{\phi(0)}$, are the significant factors for subjective loudness prediction. This indicates that not only sound level but also spectral content has a key role in loudness perception. Negative regression coefficient of $W_{\phi(0)}$ suggests that sharper aircraft noise is perceived as louder. The largest standardized partial regression coefficient of $W_{\phi(0)}$ for predicting loudness was observed. The mean L_{Aeq} of the presented aircraft noises was in the range of 72.7–79.6 dB, which was narrow. Therefore, participants can judge loudness based more on the spectral content rather than actual sound level.

As for noises in running cars, the energy-index, L_{Aeq}, pitch strength, ϕ_1, and the temporal variation, the SD of ϕ_1, are the significant factors for subjective loudness prediction. Pitch strength, ϕ_1, and the temporal variation, the SD of ϕ_1, are the significant factors for subjective pitch prediction. A study on annoyance caused by refrigerator [10] and air-conditioner [11] noises indicated that the ϕ_1 is a significant factor in annoyance evaluation. Annoyance caused by floor impact sounds suggests that the SD of ϕ_1 is a significant factor [12]. These suggests that pitch strength is also key role on subjective perception on sounds.

The energy index, L_{Aeq}, and the variation, the SD of L_{Aeq}, were the significant factors for pitch prediction. This may be explained by the mechanism of pitch perception. Pitch is slightly influenced by sound level, that is, the pitch of high-frequency tones (> 4000 Hz) increases with increasing level while the pitch of low-frequency tones (< 500 Hz) decreases with increasing level [13, 14]. The airplane noise used in the experiment had high-frequency components (> 4000 Hz) and the sound levels increased over time in most of the cases. In addition, the systematic review of human perceptual dimensions of sound demonstrates that quiet/loud perception is related not only to *Potency* (loudness) but also *Activity* (pitch) [5].

In previous studies, psychoacoustic indices including loudness, sharpness, roughness, and fluctuation strength have been widely used as sound quality indices [15]. ACF factors are useful for *Evaluation* dimensions such as annoyance and preference [11, 16]. The present study confirmed that ACF factors are useful for three perceptual dimensions. The superiority of the ACF factors was that it was possible to predict three perceptual dimensions with a single formula with different coefficients, as shown in the results of airplane noises. In addition, model refinement is required to improve prediction accuracy for subjective responses because subjective annoyance and pitch cannot be explained well by the ACF factors.

4. CONCLUSIONS

We analyzed psychological responses, annoyance, loudness, and pitch of aircraft noises and noises in running cars to determine the factors that significantly influence subjective annoyance, loudness, and pitch caused by this noise. The results indicated that the sound level, the temporal variation of the sound level, the pitch strength, the temporal variation of the pitch strength, and spectral centroid are factors that significantly influence subjective annoyance and loudness. The temporal variation of the sound level, the pitch strength, the temporal variation of the pitch strength, effective duration of the ACF, and spectral centroid are factors that significantly influence subjective pitch.

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Sound Power Level of Construction Machinery in Open space and Construction site

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ABSTRACT

Construction noise can be divided into operation noise of construction equipment and working noise of the construction work. In particular, the construction noise is high sound level and large fluctuating. However, it is difficult to measure the sound power level because the construction equipment is large and dangerous during operation. Therefore, in this study, the sound power level measured that of six kinds of high noise generating construction machines which has no noise control standard in Korea. The maximum sound power level of the six construction machines is above 100 dB (A). It is necessary to develop a method for measuring the noise level of construction machinery.

1. INTRODUCTION

Construction noise is a major cause of frequent environmental disputes and has different characteristic from other general environmental noise.[1] Unlike general environmental noise, the noise vibration of construction works occur only during the construction period and disappears when the construction is completed. In addition, the noise level is relatively large and fluctuates. Most of construction noise comes from the construction machinery during construction, and can be divided into operation noise of construction machinery and working noise of construction. In 2000, the European Union enacted a Directive 2000/14 / EC on Directives for Mechanical Noise in the Field.[2] A mandatory noise labeling system (Article 13) was applied to 41 construction machinery, and a certification system (Article 12) was implemented by setting a noise limit for a total of 22 construction machinery.
The Ministry of Environment of Korea is operating a preliminary reporting system that includes noise and vibration reduction measures for certain constructions that generate noise and vibration during the construction period as a method of noise reduction under the public law. In order to expand the use of low noise construction machines, noise level indicators are mandatory for high noise construction machines such as excavators, compaction machines, loaders, air compressors, generators, breakers, concrete shearers, perforators, rudders and pilots. Among them, there are noise management standards for excavators, compaction machines, loaders, and air compressors, but there are no management standards for the rest of generators, breakers, concrete shearers, perforators, rudders and propellers. Therefore, in this

study, noise was measured at the site for six noise generating construction machines according to ISO that had no noise control standard set and compared with the existing measurement results.[3-4]

2. MEASUREMENTS

The six machinery were measured as Table 1. The equivalent noise level on the hemispherical surface was calculated after three consecutive measurements of the equivalent noise level for each measuring point. Then, the final sound power level was calculated by applying background noise and environmental correction. Background noise level during sound power level measurement was mostly less than 30 dB (A).

Table 1. Test condition of six construction machinery

Construction Machinery Type	*Number of measurement machinery*	*Measurement radius (m)*	*Measurement place*
Generator	4	10	Open space
Breaker	2	10	Construction site
Hand breaker	4	4	Open space
Concrete saw	3	4	Open space
Boring machine	3	10	Construction site
Pile driver	3	10	Construction site

3. TEST RESULTS

The maximum value of the generator's sound power level was 122 dB (A) and the minimum value was 82 dB (A). Most of them were small generators of 20kW, and large generators would be relatively easy to reduce noise by installing soundproof enclosures. The maximum value of the breaker's sound power level was 132 dB (A) and the minimum value was 100 dB (A). The sound level measured at 10 m distance was compared with the sound power level. The sound power level of the hand breaker was measured from 103 dB (A) to 108 dB (A). The weight range of the portable breaker used for the measurement ranged from 5.5 kg to 29.5 kg. Higher weight products tend to have higher noise levels. In addition to the noise level, the amount of vibration transmitted to the operator was very large. Concrete saws can be divided into portable cutters for hand cutting and road cutters used for floor cutting. The maximum sound power level of the concrete cutter at idle was 121 dB (A) and the minimum value was 100 dB (A). Portable cutters tended to have high noise levels even at relatively small outputs. The sound power level of the boring machine was 132 dB (A) maximum and 99 dB (A) minimum. In particular, the noise level occurred when excavating in hard ground according to the ground condition. The maximum value of the sound power level of the pile driver was 136 dB (A) and the minimum value was 87 dB (A). In particular, the noise level, like the perforator, produced a loud noise when driving in hard ground according to the ground conditions.

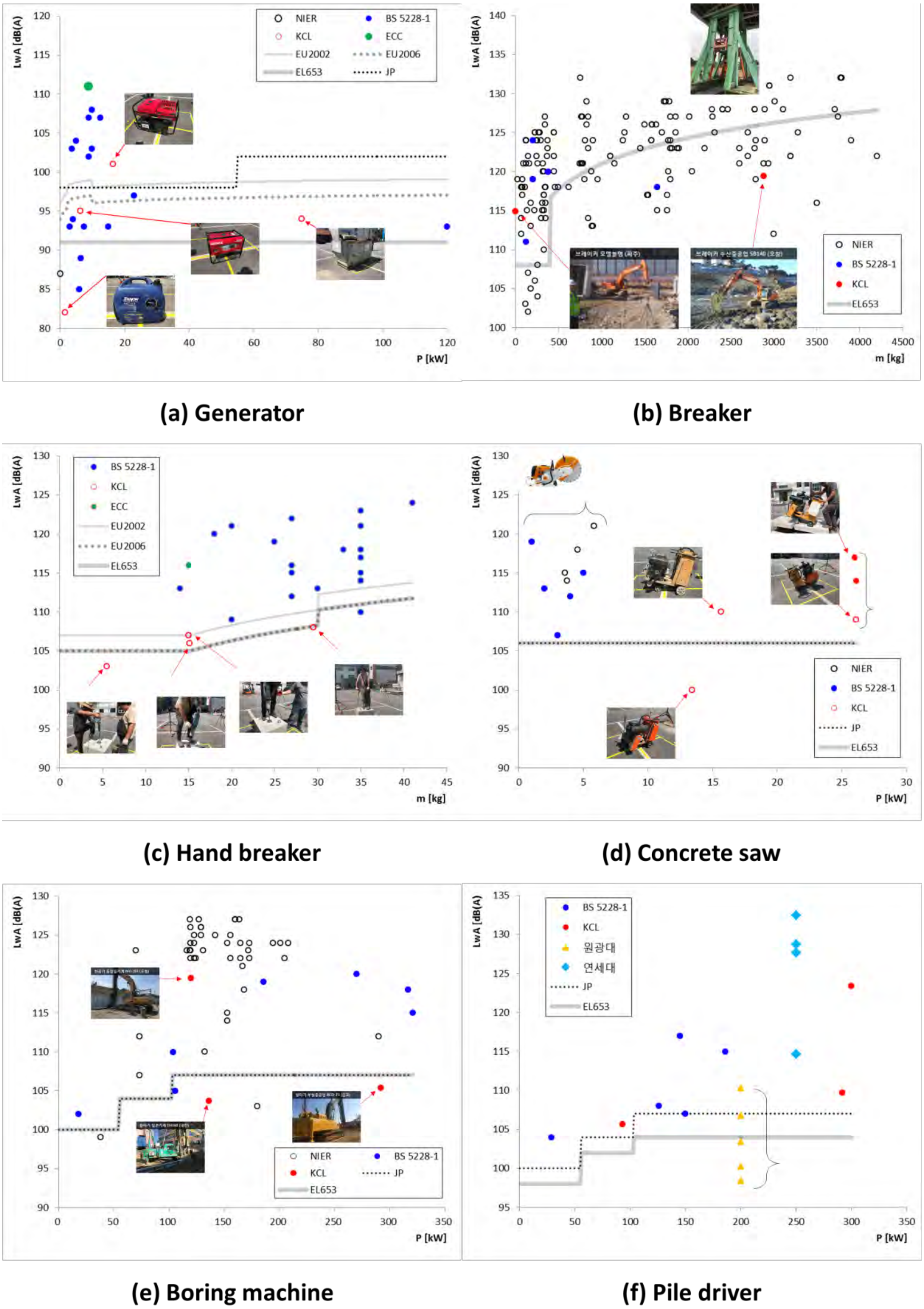

Figure 1. Sound power level of six construction machinery

4. CONCLUSIONS

In this study, six types of construction equipment noise levels were measured at open place and construction site. As a result of measurement, the maximum value of the six types of construction equipment noise exceeded 100dB(A). Breaker, boring machine and pile driver work noise is higher than the noise generated by the machine itself. In the case of boring machine and pile driver, it is impossible to measure in the laboratory, so it is necessary to develop the method for measuring the noise level in the construction site.

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Floor impact sound reduction performance according to dynamic stiffness of EPS resilient materials

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ABSTRACT

This paper investigated the reduction performance of floor impact sound according to dynamic stiffness of EPS resilient materials. 12 kinds of flat type EPS resilient materials were measured by designing different thickness and dynamic stiffness. The dynamic stiffness was measured in the laboratory by the pulse exciting method of KS F 2868 (modified ISO 9052-1). The floor impact sound reduction performance was measured after installing resilient materials on a concrete slab and loading 50 mm of cement mortar on the resilient materials under laboratory conditions. The relationship between the measured floor impact sound results and the dynamic stiffness and thickness of the resilient materials was analyzed. As a result, it was found that the higher dynamic stiffness of the resilient materials,the more effective to reduce the floor impact sound at 63 Hz or less. The floor impact sound at 125 Hz or more showed a higher reduction performance as the dynamic stiffness was lower. Thick resilient materials was more effective at 125 Hz or more, but not at low frequencies.

1. INTRODUCTION

In Korea, lots of researches have been conducted in various fields to reduce the floor impact sound of multi layer buildings [1]. Floating floor method using a resilient materials between concrete slab and upper layers is known to have the best price-performance ratio. Previous studies have shown that the lower dynamic stiffness of resilient materials show the lower floor impact sound not only the light weight floor impact but also heavy floor impact [2], [3]. But, the tendency between the two was very low. Because they used a lot of kinds materials have various range dynamic stiffness.

In this study, the relationship between the heavy weight floor impact sound level according to the dynamic stiffness and thickness was investigated using Expanded Poly-Styrene (EPS) resilient materials under limited experimental conditions.

2. DYNAMIC STIFFNESS MEASUREMENT

Measurement Method

The dynamic stiffness of resilient materials is measured according to KS F 2868 (modified ISO 9052-1). As shown in Figure 1, the resonance frequency is measured from the vibration propagation frequency characteristic of the vibration system by the pulse excitation method in the laboratory. From eqation (1), the apparent dynamic stiffness per unit area was calculated.

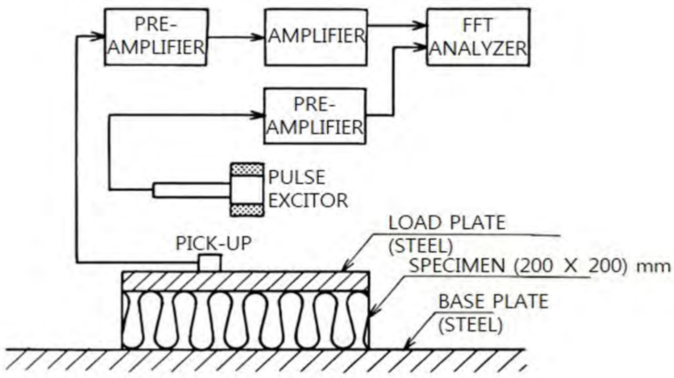

Figure 1. Pulse exciting method diagram (KS F 2868)

$$S'_t = (2\pi f_r)^2 \cdot m'_t \tag{1}$$

where f_r is resonance frequency of vibration system (Hz)

m'_t is mass per unit area of load plate (kg/m^2)

Results

In this study, 12-type-specimen were used to meausre the dynamic stiffness, the thickness and the floor impact sound insulation performance. The dynamic stiffness of the resilient material is severely changed at early time measurement and tends to increase continuously as the loading time increases as Table 1. So, the results of a 30-minute measurement that began to show a stable trend was compared with floor impact sound levle.

Table 1. Dynamic stiffness and thickness of EPS materials with loading times

No.	Dynamic stiffness with loading times (MN/m^3)					Thickness(mm)
	1 min	30 min	60 min	90 min	120 min	
1	9.05	10.40	10.51	10.68	10.68	10.7
2	10.91	11.61	11.73	11.79	11.90	20.1
3	9.63	10.34	10.46	10.46	10.57	29.4
4	14.29	16.11	16.46	16.46	16.53	10.1
5	12.45	13.19	13.45	13.51	13.83	21.5
6	18.34	20.09	20.24	20.17	20.56	30.6
7	21.03	23.57	24.42	25.11	25.28	10.2
8	20.24	22.24	22.24	23.57	22.90	21.0
9	15.42	16.46	16.74	17.10	17.03	30.0
10	20.79	24.67	25.63	26.34	27.33	10.8
11	19.09	21.19	21.59	21.83	22.32	21.4
12	20.71	23.15	23.74	24.42	24.50	29.6

3. FLOOR IMPACT SOUND MEASUREMENT

Measurement Method

As shown in Figure 2, the floor impact sound level was measured by loading a 50 mm cement mortar plate on a 150 mm concrete slab fixed laboratory for 12 types of resilient materials measured dynamic stiffness. The heavy weight floor impact sound level was measured according to KS F 2810-2 (Method for measuring floor impact sound using a standard heavy weight impact source).

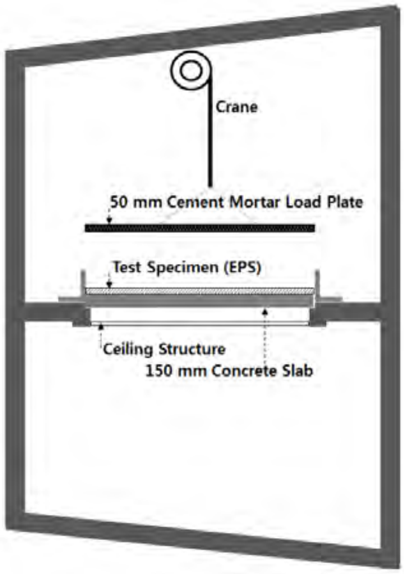

Figure 2. Impact sound test set-up diagram

Results

As a result of the floor impact sound measurement, the heavy weighted floor impact sound single-number-quantity evaluation values ($L_{i,\ Fmax,\ AW}$) were measured in samples 1, 2, and 3 with low dynamic stiffness. The lowest was measured in sample 9 with 30 mm thickness and have a dynamic stiffness of 16.46 MN/m^3.

In case of the dynamic stiffness is as low as 10 MN/m^3 such as sample 1, 2, and 3, the floor impact sound level is higher than that of other samples at 63 Hz, and the floor impact sound single-number quantity ($L_{i,\ Fmax,\ AW}$) by the bang machine tends to increase. This may be a characteristic of the floating floor structure, and it is estimated that the effect of resonance caused by the lower ceiling is complex.

It is assumed that this tendency is a characteristic of the floating floor structure, or the effect of resonance caused by the lower ceiling under the concrete slab.

Table 2. Floor impact sound measurement results with bang machine

No.	Dynamic Stiffnessat 30 min (MN/m^3)	Thickness (mm)	Floor impact sound level (dB)				$L_{i,Fmax,AW}$ (dB)
			63 Hz	125 Hz	250 Hz	500 Hz	
1	10.40	10.7	87.4	67.1	57.6	34.3	57
2	11.61	20.1	88.5	61.4	51.3	28.8	58
3	10.34	29.4	88.5	61.0	48.1	28.8	58
4	16.11	10.1	83.7	66.5	52.9	31.7	54
5	13.19	21.5	85.3	64.3	50.2	28.5	55
6	20.09	30.6	84.1	62.5	49.5	28.4	54
7	23.57	10.2	81.7	68.4	53.2	27.3	54
8	22.24	21.0	81.8	67.4	52.2	25.9	54

9	16.46	30.0	82.3	65.4	51.1	26.5	52
10	24.67	10.8	82.2	69.1	54.8	26.8	54
11	21.19	21.4	82.2	68.2	53.0	26.3	54
12	23.15	29.6	82.4	67.8	53.4	27.2	54

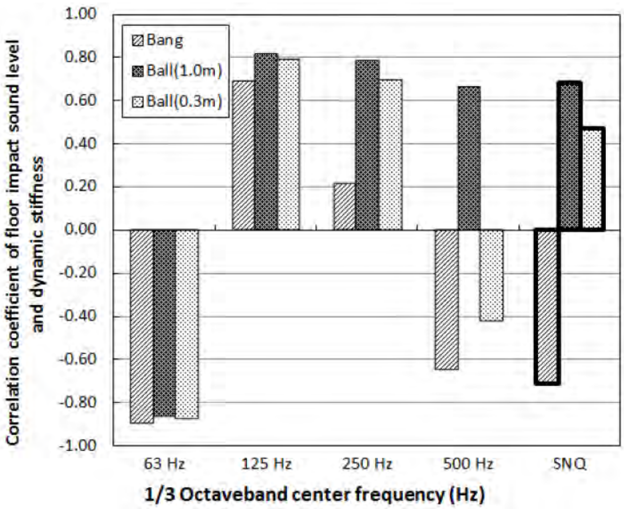

Figure 3. Correlation coefficient between floor impact sound level and dynamic stiffness

4. CONCLUSIONS

As a result of comparison between the floor impact sound level and the dynamic stiffness of the resilient materials, the lower the impact sound level was lower at 63 Hz and higher at 125 Hz and 250 Hz. This may be because the resonance frequency of the floor structure coincides with 63 Hz when the dynamic stiffness is low. The floor impact sound measurement result by the bang machine is measured lower as the dynamic stiffness is higher. Further experimentation with various materials and experimental conditions may be necessary.

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Effect of different noise-power-distance data on the validity of noise maps calculation for airports in Vietnam

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ABSTRACT

Noise map provides a basis for land-use and flight path planning to limit the noise impact on residents around airports. This study is one of the first attempts to access an appropriate method to create noise maps for airports in Vietnam. Field measurements were conducted at Noi Bai International Airport (HNBIA) and Da Nang International Airport (DNIA) in November 2017 and August 2018, respectively. In this study, the L_{den} were calculated using the Integrated Noise Model (INM) with available Noise-Power-Distance (NPD) data in INM and NPD data created based on the field measurement. Besides, to assess the validity of the prediction, the predicted L_{den} was compared with the measured L_{den}, which were defined by field measurements. Noise levels were estimated for HNBIA with 3 scenarios: (1) Civil aircraft only, using INM's NPD; (2) Civil aircraft & military aircraft, using INM's NPD for military aircraft; (3) Civil aircraft & military aircraft, using measurement-based NPD for military aircraft; and DNIA with 2 scenarios: (4) Civil aircraft only, by INM's NPD; (5) Civil aircraft only, by measurement-based NPD. By comparing the predicted and the measured values, it could be found that the estimation validity was improved by using measurement-based NPD of military aircraft.

1. INTRODUCTION

For better managing the noise environment around the airports while enhancing aviation traffic, the Vietnam government plans to produce noise maps for all 21 airports until 2020 based on the guideline of the International Civil Aviation Organization (ICAO) [1]. The noise map provides a basis for appropriate land-use and flight path planning to limit the noise impact on residents living in the vicinities of the airports. Many airports including major airports located near residential areas in Vietnam are used for both military and civil aircraft. Therefore, it is necessary to develop a prediction tool to produce an accurate noise map for the management of

current and future noise environment around airports, especially for civil-military mixed-used airports.
An estimation based on actual flight operation conditions is essential to precisely predict aircraft noise exposure around a specific airport. However, some information needed to make a noise map is not available due to technical and security issues. In particular, there is no data on the sound source of military aircraft.
To produce the accurate noise map in the vicinities of the airport, the purposes of this study are creating measurement-based Noise-Power-Distance (NPD) data for a military aircraft and improving the accuracy of noise prediction by using the INM and the NPD.

2. PROCEDURE OF THE PREDICTION

Outline of the prediction

Figure 1 shows a flow chart of the prediction method presented in this study. Single-event sound exposure levels (L_{AE}) in each aircraft noise event was decided by the NPD data of each aircraft model and by representative flight path. The value of NPD represents the relationship between the L_{AE} and distances from receiving points under the flight path to the aircraft. Day-evening-night equivalent sound level (L_{den}) was calculated from the L_{AE} values and the number of flight operation. To assess the validity of the predicted noise map, the estimated L_{den} by the INM was compared with the field measurement values.

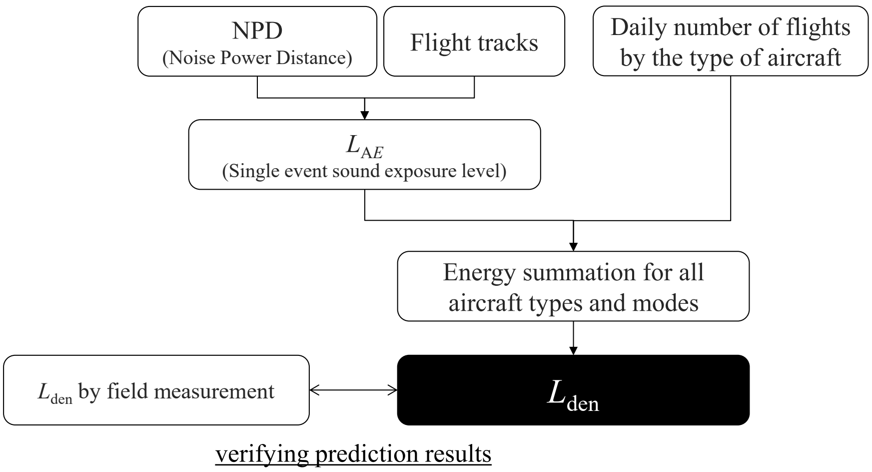


Figure 1. A flow chart of the prediction method presented in this study

NPD data

The NPD data pre-configured in INM software was used as noise source data of civil aircraft. For military aircraft, Sukhoi Su-22 has the highest noise level among the main military aircraft in operation in Vietnam. However, most of the NPD data of Russian-made military aircraft operated in Vietnam are not included in the INM software. Herein, the results in the case of using the NPD data of the alternative single-engine fighter aircraft model (Lockheed Martin F-16) included in INM and in the case of using the Su-22 NPD data based on field measurement were compared. It was assumed that F-16 has similar noise emission characteristics with Su-22 because both of them are the single-engine fighter aircraft. Measurement-based NPD data for Su-22 was created from a one-third octave band level obtained by field measurement. Figure 2 shows a diagram of the measurement process for establishing NPD data

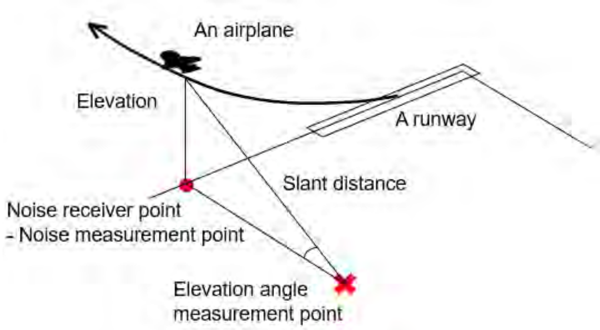


Figure 2. Diagram of elevation angle and noise measurement

The sound exposure level of a single aircraft noise event according to a distance to the noise source, $L_{\mathrm{AE,r}}$, was calculated based on a procedure described in a document of ECAC DOC.29 version 2 with β takes the value of 7.5 [2]:

$$L_{\mathrm{AE},r} = L_{\mathrm{AE},0} + \left(L_{\mathrm{A,Smax},r} - L_{\mathrm{A,Smax},0}\right) + \beta \log_{10}\left(\frac{D}{D_0}\right) \tag{1}$$

$L_{AE,0}$: A-weighted single event sound exposure level at the measurement point [dB]
$L_{\mathrm{A,Smax,r}}$: Maximum A-weighted sound pressure level according to the distance to the noise source [dB]
$L_{\mathrm{A,Smax,0}}$: Maximum A-weighted sound pressure level at the measurement point [dB]
D: the distance from the noise source to a given receiving point [m]
D_0: the distance from the noise source to the measurement point [m]

In which, $L_{\mathrm{A,Smax,r}}$ is calculated with the geometrical diffusive decay by the distance between D and D_0 and sound attenuation due to air absorption according to ISO 9613-1 [3]. The coefficient β is 7.5, which represents the distance duration effect, was assumed to be applied for civil aircraft. Because the flight speed of military aircraft is much higher than civil aircraft, the decay of sound by the slant distance to the sound source becomes much faster. In INM, it was decided that the 6-log relationship would be maintained since it represents a best-fit empirical relationship for millitary aircraft and were developed using simplified data adjustment procedure [4]. In this study, the coefficient β was changed from 1 to 15 in increments 0.5, and the value with the smallest difference from the measured value was examined to obtain the best fit for the military aircraft operating in Vietnam.

Flight operation

Flightpath. The flight paths of civil aircraft were set based on the field observation by Automatic Dependent Surveillance-Broadcast (ADS-B). ADS-B is a precise satellite-based surveillance system that continuously tracks the aircraft positions. The flight paths of take-off and landing were classified based on the collected ADS-B data during the measurement period. However, ADS-B cannot determine the flight path of military aircraft. Therefore, the flight path of the military aircraft was set to a straight line in the direction of the runway extension for take-off and landing based on the results of visual observation at the site.

The number of flights. Airport operation data including flight logs and weather conditions were provided by the airport managers. Although HNBIA is in northern Vietnam which has four seasons, the flight operation at HNBIA is categorized into winter (late October to late March) and summer (in the remaining period) schedules. Da Nang has a tropical monsoon climate with two seasons: wet season (September to December) and dry season (January to August). Runways and flight tracks usage depends on the operation modes and weather conditions, e.g., wind direction. According to the flight logs, the average arrivals and departures a day in HNBIA is approximately 400 flights and 250 flights for DNIA. The twin-engine jet airliner A320 and A321 occupied the majority of all the flights with a total of 64% for HNBIA and 80% for DNIA, as shown in Table 1. It is worth noting that 40 military flight events were measured and recorded during the field measurement conducted in two days at HNBIA. No military aircraft was operated during the measurement period at DNIA.

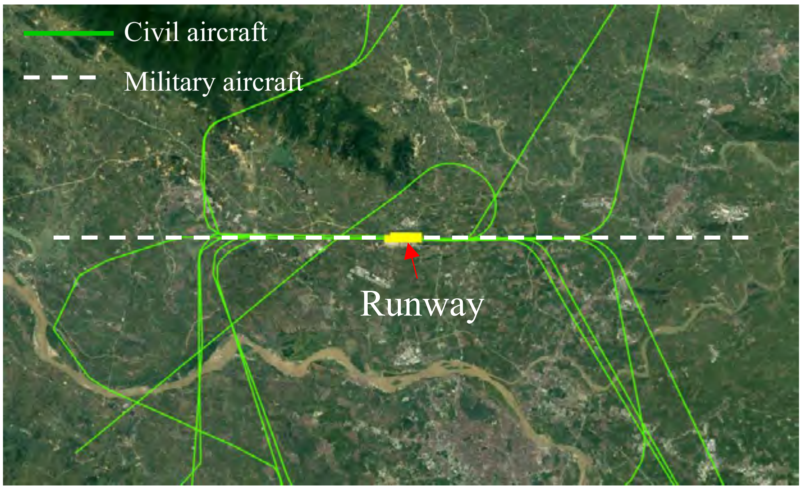


Figure 3. The representative flight paths around HNBIA

Table 1. Civil and military aircraft types operated in HNBIA and DNIA

HNBIA: Civil aircraft (November 14th, 2017)					
Type	Departures	Arrivals	Type	Departures	Arrivals
A321	75	71	A332	1	2
A320	53	55	A330	2	2
B789	11	11	B772	2	2
A359	10	10	B777	2	2
AT72	7	7	A319	1	2
A333	4	5	B747-800F	0	1
A332	4	4	E90	1	1
B738	4	4	A330F	1	1
B747	3	4	B777F	1	0
B747-400	3	2	B787	1	1
B773	2	2	B739	1	0
C208	2	2	PC12	0	1
			Total	191	192
Military aircrafts (November 14th, 2017)					
Type	Departures	Arrivals			
Su-22	8	11			
C17	1	2			
Total	9	13			
DNIA: Civil aircrafts (August 15th, 2018)					
Type	Departures	Arrivals	Type	Departures	Arrivals
A321	65	64	B772	2	2

A320	31	32	B744	1	1
B738	17	17	A319	1	1
AT72	2	2	A333	1	1
			Total	120	120

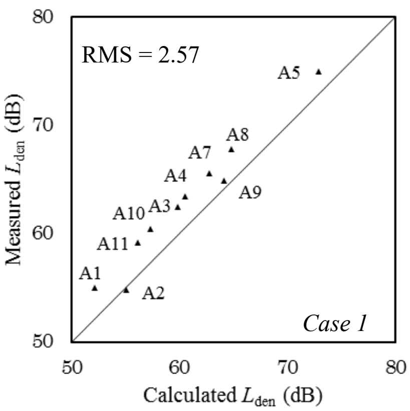
Data collection for result verification

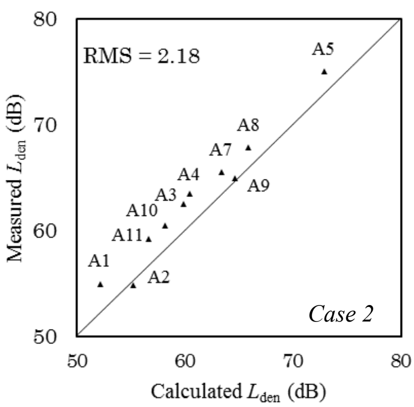
To assess the validity of the estimated noise level, field noise measurements were conducted at 11 sites around HNBIA and 6 sites around DNIA. A sound level meter (RION NL-42) was set up on the rooftop of a house located in each site. However, at site A6 in HNBIA and A4 in DNIA, the sound level meters were installed on the balcony since the rooftops were not accessible. As a result, the noise level considerably decreased, possible up to 10 dB, due to the building shielding effect. Therefore, they were excluded from the analysis in the next section.

The noise data at each site were compared with flight logs to identify the aircraft events. Then L_{AE} in each aircraft noise event was calculated from the A-weighted sound pressure levels L_{pA}, which were continuously recording every 0.1 s. After that, L_{den} at each site was calculated by using the L_{AE} values and the number of flights. The day, evening and night periods to calculate L_{den} are different between countries, depend on the daily activity pattern. In Vietnam, they are defined as the periods from 06:00 to 18:00, from 18:00 to 22:00, and from 22:00 to 06:00, respectively [5].

3. RESULTS

Figure 4 shows the results in HNBIA. The consistency between the predicted and the measured values were examined by comparing the root mean square error (RMS). Comparing the result in Case 1 (only civil aircraft) with those of in Case 2 (with military aircraft by INM's NPD: F-16), it can be seen that the correspondence with measured values is improved by considering military aircraft. For Case 3 (with military aircraft by field measured NPD: Su-22), the optimum value of the coefficient β in Eq. (1) was examined and it was found to have minimum RMS when β is 6.5 for take-off and 13.0 for landing, as shown in Figure 5. Therefore, the combination of these values was applied to calculated NPD for Su-22 in the analysis of Case 3. The prediction in this case is the most consistent with the field measured values.





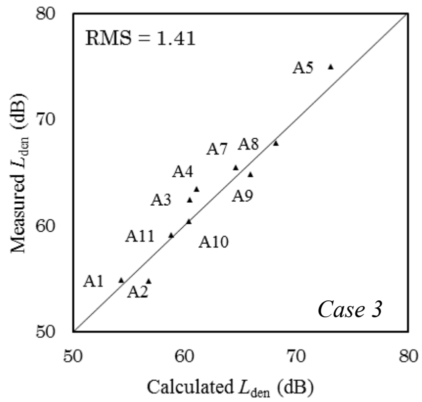


Figure 4. The comparison of L_{den} between prediction and measurement in HNBIA

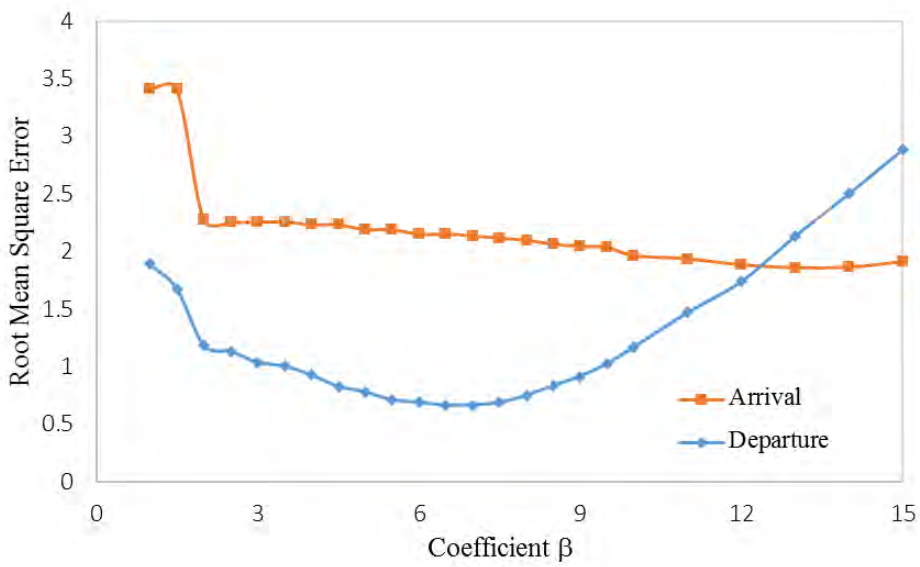


Figure 5. The result of the optimum coefficient value in Eq. (1) for Su-22 NPD data.

Figure 6 shows the results in Case 5 and 6, at DNIA. Estimated noise levels using measurement-based NPD data was found to be less correlated with measured L_{den} than that estimated with INM's NPD data.

From these results, the following can be said.

- It is important to include military aircraft in the prediction (Comparing Case 1 with Case 2 and 3).
- Because NPD of military aircraft operated in Vietnam is not included in INM, it is necessary to create NPD based on field measurement (Comparing Case 2 with Case 3).
- For civil aircraft, the prediction is not necessarily improved by creating the NPD from the results obtained by measurement. This suggests that it is required to consider the take-off weight, thrust setting, etc. (Comparing Case 5 with Case 6).

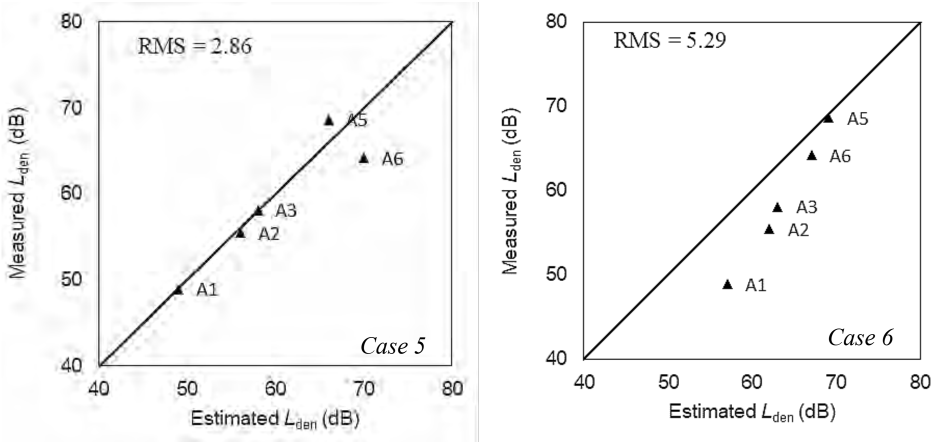


Figure 6. The comparison of L_{den} between prediction and measurement in DNIA

Two airports in this study are not the only airports which both civil and millitary aircraft are operated in Vietnam. Since the noise power level of fighter aircraft is much higher than that of civil aircraft, a noise map that reflects the contribution of fighter aircraft noises is necessary. In this study, the prediction result for civil aircraft only (Case 1) was about 5 dB smaller than the field measurement value and underestimate the effects of noise.

In Vietnam, there is no information on the noise of military aircraft, and tools to know the NPD, flight route, and the number of flights is required. In this survey, it was possible to collect Su-22 NPD, and it was confirmed that the consistency with the measured values was improved by reflecting them in the calculation of L_{den}. Therefore, in the future, it will be necessary to collect NPD data for other military aircraft models. Regarding the flight path, continuous tracking techniques with a camera might be applied for the identification [6]. As to the number of flights, it is possible to classify fighter aircraft noise and civil aircraft noise by using time-series data of noise levels. On the other hand, when more complicated classification is required, such as distinguishing military aircraft other than fighter aircraft, the aircraft model identification technique [7] based on a continuous recording of frequency characteristics should be considered.

In the document of INM, the coefficient β in Eq. (1) is set as 6.5 in the case of calculating NPD for military aircraft. In the present study, the same result was obtained for the take-off noise. However, for the landing noise, the smallest RMS was obtained when the coefficient is set as 13.0. This is thought to be based on the fact that the fighter planes also do not move at a particularly high speed when landing (The faster aircraft moves, the smaller the coefficient value is.). However, because the coefficient value for civil aircraft is 7.5 regardless of take-off and landing in INM, it remained unknown why is the RMS minimized when the coefficient is set to 13.0 for the landing of military aircraft. It is necessary to investigate various models and accumulate more data for gaining more concrete affirmation in the further phase of this study.

4. CONCLUSIONS

In this study, L_{den} was estimated for the two major airports in Vietnam. INM's existing NPD data was replaced by measurement-based NPD data for specific conditions of HNBIA and DNIA in the estimation. Applying the Russian military airplane Su-22's NPD data obtained from measurement improved the estimation of L_{den} at HNBIA. Furthermore, when creating the measured-based NPD for Su-22, the distance duration effect related to flight speed was also examined so that the difference between the measured and predicted L_{den} became minimum. To develop a reliable method of noise map estimation for aviation environment management in Vietnam and sustainable air traffic development in Vietnam and other Asian countries, further study is needed to improve the validity of the estimation. In particular, it is unclear whether it is necessary to use NPD based on field measurements for predicting civil aircraft noise level. It is necessary to examine using detailed information about the operation profile.

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A study on suitable noise metrics for aircraft noise policy-making in Vietnam

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ABSTRACT

There are many decibel-based noise metrics that are used in noise policy to describe aircraft sound in the environment. Among those, Day-evening-night-weighted sound pressure level (L_{den}), Day-night-weighted sound pressure level (L_{dn}), and Nighttime average sound pressure level (L_{night}) are the most widely-used noise metrics, but the designation of reference time intervals such as the day, evening and night in these noise metrics is different depending on the lifestyle and culture in each country. This paper discusses a result of a survey on life rhythm of Vietnamese, which was conducted as a part of Vietnam-Japan joint effort to develop aircraft noise guideline, referring to the questionnaire of the Basic Survey on Social Life in Japan and additional queries relating to living activities by the time intervals. The survey was performed via internet and about 120 responses were collected with participants from the north and south areas in Vietnam. These data together with those accumulated from socio-acoustic surveys conducted in Vietnam from 2007 to 2018 were analyzed to investigate time patterns of Vietnamese lifestyle and changes in L_{den}, L_{dn}, and L_{night} noise metrics when time interval segmentation in these metrics are adjusted. No significant difference in sleeping time, which means the nighttime interval, was found between Japanese and Vietnamese. However, the meal time was different between the two countries. According to the analysis of the socio-acoustic surveys, traffic congestion hours, bedtime and wake-up time in the southern city are approximately one hour later than those in the northern cities in Vietnam, while those in the central cities are in between the northern and southern. This study finally suggests appropriate noise metrics for aircraft noise policy in Vietnam, referring to the current national and international noise standards and regulations.

1. INTRODUCTION

Study Context

The growth of aviation has further enriched people's lives by connecting people and places but led to a new social problem called aircraft noise. Being one of the fastest-growing of the world's economies, Vietnam is planning many new airports and implementing airport expansion to handle the country's stressed aviation infrastructure. As a result, the impact of aircraft noise is becoming especially serious for residents living in areas close to expanded and new airports. However, Vietnam has no particular measure to manage the sound environment around its airports but only some regulations and standards on general environmental noise.

Like other developed countries, Japan has established various measures to limit or reduce the number of people affected by aircraft noise includes standards, and regulations for aviation operation and airport planning and expansion relating to noise abatement. Since the main target in any noise control program to keep the noise exposure of the population below an acceptable threshold level. This paper describes a trial process to develop an appropriate noise metric as the first step toward establishing environmental policy for the airport noise management in Vietnam by referring measures which are being implemented in Japan.

Noise Metrics

There are many decibel-based noise metrics that are used in noise policy to describe aircraft sound in the environment. Among those, Day-evening-night-weighted sound pressure level (L_{den}), Day-night-weighted sound pressure level (L_{dn}), and Nighttime average sound pressure level (L_{night}) are the most widely-used noise metrics; for example, all EU Member States have adopted L_{den} and L_{night} as noise indices for the EU strategic noise mapping [1]. The L_{dn} index calculated by dividing 24 hours into two parts (day and night) are used in the United States, Denmark, the Netherlands, Norway, etc. However, the designation of reference time intervals such as the day, evening and night in these noise metrics is different depending on the lifestyle and culture in each country.

Related Standards and Regulations of Vietnam and Japan

Currently, when studying about impacts of transportation noise in Vietnam, we use the following two ways of reference time intervals: (i) day-time of 6:00-22:00 and night-time of 22:00-6:00 in case of the day-night level (L_{dn}) and (ii) day-time of 6:00-18:00, evening-time of 18:00-22:00 and night-time of 22:00-6:00 in case of the day-evening-night level (L_{den})[2,3]. These time intervals are according to the Vietnamese Environmental Standard TCVN 5949-1998, issued in 1998 (Table 1), in which noise limits are respectively specified for the three reference time intervals of day-time (6:00-18:00), evening-time (18:00-22:00) and night-time (22:00-6:00).

Table 1. Vietnamese National Community Noise Standards "TCVN 5949-1998 - Acoustics - Noise in public and populated areas - Permitted maximum noise level"

Land Use in Receiving Area	dBA Time Period		
	0600-1800	**1800-2200**	**2200-0600**
1. Areas which need special quietness: Hospital, library, kindergarten, nursing houses, schools, church, temples	50	45	40
2. Residential areas, hotels, hostels, administrative offices	60	55	50
3. Residential areas which scatters in the areas of commerce, service and production	75	70	50

Since 2010, *TCVN 5949:1998* was superseded by a newer national technical regulation on noise *QCVN 26:2010/BTNMT*, issued by the Ministry of Natural Resources and Environment (Table 2). This regulation prescribes the maximum noise limits in areas where humans live and work. This regulation is aimed at all noise created by human, regardless of noise sources and their positions. In this standard, special areas are denoted as areas where there exist special facilities requiring exceptional quietness such as medical establishments, libraries, kindergartens, schools, churches, temples, pagodas, while usual areas are defined as areas where there exist apartment buildings, detached or terraced houses, hotels, guest houses, and administrative agencies. Dividing of a day into 3 intervals in *TCVN 5949:1998* was replaced by another dividing of a day into 2 intervals in *QCVN 26:2010/BTNMT*. Permissible noise limits in the day-time and the night-time are 55 and 45 in special areas and 70 and 55 in usual areas. The feasibility of this regulation is questionable because it seems to be difficult to cut down 25 dB of day-time noise level to meet the night-time noise limit considering the situation that the traffic volumes still stay high later than 21:00 in most cities in Vietnam.

Table 2. Vietnam's National Technical Regulation on Noise (QCVN 26:2010/BTNMT)-Permissible noise limits (in decibel), dBA

No.	Area	From 6:00 to 21:00	From 21:00 to 6:00
1	Special areas	55	45
2	Usual (General*) areas	70	55

*noted by the authors

Table 3 shows a comparison of noise limits for general environmental noise between Vietnam and Japan. Note here that we applied the definition of day-night level by neglecting the difference in time intervals: the night-time in Vietnam starts 1 hour earlier than Japan, resulting in the day-time interval of 1 hour longer in Vietnam. The day-time noise limit for general area in Vietnam almost equals to that in an area facing to trunk road in Japan, but night-time is 10dB stricter. As a result, in case of day-night level, Vietnam's regulation is slightly stricter than Japan for area facing to trunk road. The noise limit for special area in Vietnam is 5dB higher, or in other words, looser than that in Japan.

Table 3. Comparison of noise limits for general environmental noise between Vietnam and Japan

<table>
<tr><td rowspan="2">Type of Area</td><td colspan="3">Vietnam：QCVN26:2010</td><td colspan="2" rowspan="2">Type of Area</td><td colspan="3">Japan：Environmental Quality Standard for General Noise</td></tr>
<tr><td>0600-2100</td><td>2100-0600</td><td>L_{dn}</td><td>0600-2200</td><td>2200-0600</td><td>L_{dn}</td></tr>
<tr><td>Special</td><td>55</td><td>45</td><td>55</td><td colspan="2">Special AA</td><td>50</td><td>40</td><td>50</td></tr>
<tr><td rowspan="5">Usual (General)</td><td rowspan="5">70</td><td rowspan="5">55</td><td rowspan="5">69 (68.7)</td><td colspan="2">Exclusive dwelling use A/B</td><td>55</td><td>45</td><td>55</td></tr>
<tr><td colspan="2">Commerce & dwelling C</td><td>60</td><td>50</td><td>60</td></tr>
<tr><td rowspan="3">Area facing to road</td><td>A/2 lanes</td><td>60</td><td>55</td><td>62 (62.4)</td></tr>
<tr><td>B/2 lanes &C</td><td>65</td><td>60</td><td>67 (67.4)</td></tr>
<tr><td>Trunk road Indoor & closed window</td><td>70 (45)</td><td>65 (40)</td><td>72 (72.4)</td></tr>
</table>

Table 4 shows the noise guideline of "Environmental Quality Standards for Aircraft Noise" in Japan, which was notified in 1973 and was revised in 2007. In the revision, Japan adopted the day-evening-night level (L_{den}) as the rating index for aircraft noise. The reference time intervals are day-time (07:00 – 19:00), evening-time (19:00 – 22:00) and night-time (22:00 – 07:00) and a penalty of 5 dB and 10 dB applies to noise events occurring in the evening-time and night-time, respectively. This determination of time intervals is based on the result of the Basic Survey on Social Life in Japan, i.e., on the data of time intervals for various activities in the daily life of people of 15 years old and over [4].

Table 4. Japanese Environmental Quality Standards for Aircraft Noise, revised in 2007

Type of area	Limit value L_{den} in dB
I	57
II	62

Area category I refers to areas used exclusively for residential purpose
Area category II refers to other areas

$$L_{den} = 10log_{10}\frac{1}{24}\left(12 \times 10^{\frac{L_d}{10}} + 3 \times 10^{\frac{L_e+5}{10}} + 9 \times 10^{\frac{L_n+10}{10}}\right)$$

L_d, L_e, L_n: day, evening and night sound levels
d: day-time (07:00–19:00), e: evening-time (19:00–22:00), n: night-time (22:00–07:00)

This paper discusses a result of a survey on life rhythm of Vietnamese, which was conducted as a part of Vietnam-Japan joint effort to develop aircraft noise guideline, referring to the questionnaire of the Basic Survey on Social Life in Japan and additional queries relating to living activities by the time intervals.

2. DATA COLLETION

The Basic Survey on Social Life by the Statistics Bureau of Japan

Conducted for the first time in 1951, the Basic Survey on Social Life of Japan has been conducted every five years to obtain basic information on the actual social life of the population such as the status of main activities (study, training, volunteer activities, sports, hobbies, entertainment and travel or excursions, etc.) in the allocation of lifetime and leisure time. The survey provided important documents that are indispensable for various administrative measures related to the improvement of the social life such as the promotion of work-life balance and the formation of a gender-equal society. In this study, we extracted and analyzed data on the survey regarding Japanese daily behavior for each time period, and compared with those obtained in the survey conducted with Vietnamese respondents.

Questionnaire Survey of Vietnamese's Life Rhythms

There has been no survey on Vietnamese's life rhythms. In this study, the survey was conducted to examine the daily life behaviors and activity time zone of Vietnamese, referring to the survey form of the Basic Survey on Social Life in Japan. The information of the activities that are greatly involved in the consideration of the noise metrics such as sleep and meals as well as demographic information of the respondents were included in the questionnaire (Table 5). This questionnaire was composed in Vietnamese and created using the Google form. The respondents who are Vietnamese people living in Vietnam were contacted and responded via the Internet.

The participants were from the north and south areas in Vietnam. These data together with those accumulated from socio-acoustic surveys conducted in Vietnam from 2007 to 2018 [5] were analyzed to investigate temporal patterns of Vietnamese lifestyle and changes in L_{den}, L_{dn}, and L_{night} noise metrics when time interval segmentation in these metrics are adjusted.

Table 5. Questionnaire items of the surveys

No.	Questions	Answer formats
Q1	Respondent's gender	Male /Female/Others
Q2	Respondent's age	(1) Under 19; (2)20~30; (3)31~40 (4)41~50; (5)51~60; (6) Over 60
Q3	Respondent's occupation	·Student; Agriculture; Full-time job; Housewife;·Part-time job; ·Others
Q4	Number of working hours per week	(1) Under 15 hours; (2)15 to 29 hours; (3)30 to 34 hours; (4) 35 to 39 hours; (5) 40 to 48 hours; (6) 49 to 59 hours; (7) more than 60 hours; (8) not fixed
Q5	Time to wake up during weekdays	(0 ~ 23)
Q6	Time to wake up on Saturday and Sunday	(0 ~ 23)
Q7	Time to go to bed during weekdays	(0 ~ 23)
Q8	Time to go to bed on Saturdays and Sundays	(0 ~ 23)
Q9	Time to eat breakfast	(0 ~ 23)
Q10	Time to have lunch	(0 ~ 23)
Q11	Time to have dinner	(0 ~ 23)
Q12	Time and location of daily activities (for each of 30-minute time interval)	

Time	Activity content	Location			
		Home	Moving	Workplace	Others
0:00	··				
0:30	··				
~	··				
23:30	··				
00:00	··				

3. RESULTS

Demographic data of The Surveys

There is a total of 122 responses obtained from the survey. Table 6 shows the demographic data of the respondents. The percentage of the employed and unemployed respondents is 63.6% and 36.4%. This rate is close to the existing Vietnamese statistical data. The same consistency was found with data of other items such as male and female balance and age distribution between under 60 and over 60-year-old respondents.

Comparison of Time Pattern of Daily Activities between Japanese and Vietnamese

Sleeping time: As shown in Fig. 1, the sleeping time pattern of Vietnamese is considerably different between the weekdays and weekends. This discrepancy was found to be less noticeable with the data of Japanese. Both Vietnamese and Japanese respondents seem to maintain the same time for starting sleep but get up 30 mins to 2 hours later on the weekends. Vietnamese seems to start sleeping later but get up earlier than Japanese. This result means the nighttime interval in noise metrics of Vietnam may be different from that of Japan.

Table 6. Some demographic factors of the surveys

Items			This study		Demographics of Vietnam (%)
Gender	Male		43.8 (53)		49.5
	Female		56.2 (68)		50.5
Age	Under 19		10.7 (13)		
	20~30		30.6 (37)		
	31~40		27.3 (33)	81	84.3
	41~50		10.7 (13)		
	51~60		12.4 (15)		
	Over 60		8.3 (10)		15.7
Occupation	Employed		63.6 (77)		60.3
	Unemployed		36.4 (44)		39.7

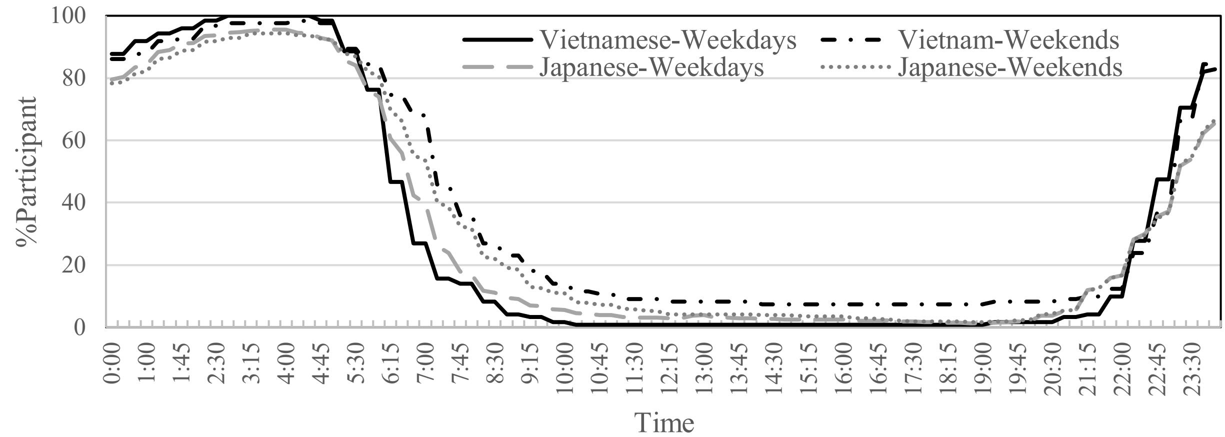

Figure 1. Comparison of **sleeping time pattern** between Japanese and Vietnamese

The data of the sleeping time of Vietnamese in weekdays were classified by three age groups, under 30, from 30 to 60 and over 60 (Figure 2). People under the age of 60 wake up later than those over the age of 60. The rate of wake-up after 7 am for people under 60 is from 10% to 50%. The rate of go-to-bed after midnight for people under 30 is about 30%, while from 30 to 100% of the respondents over 30-year-old start sleeping from 22:00 to 24:00.

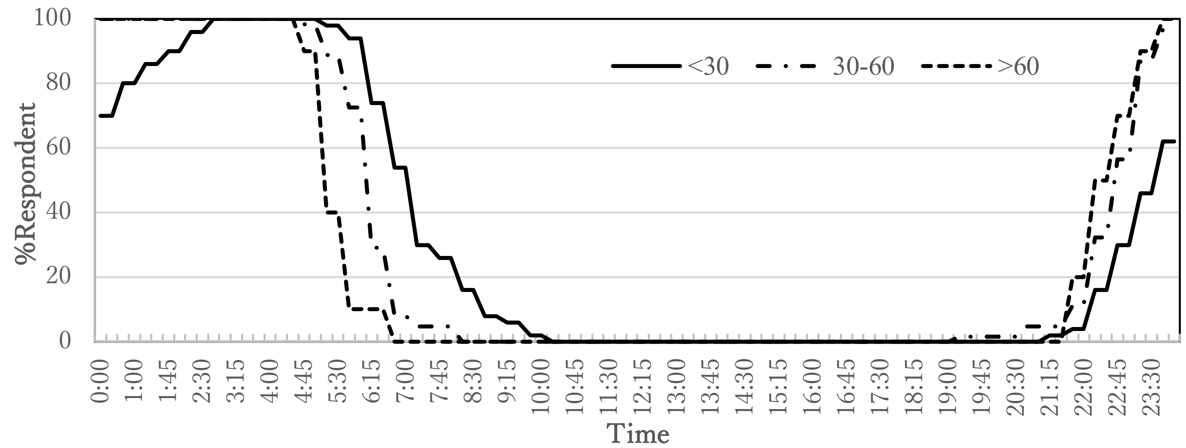

Figure 2. Comparison of **sleeping time** of Vietnamese in weekdays **divided by age categories**

<u>Mealtime:</u> The mealtime was found to be different between the respondents of the two countries (Figure 3). The breakfast and lunchtime are earlier in Vietnam. This result is consistent with the earlier get-up time of Vietnamese. The percentage of Japanese respondents having dinner after 19:00 is much higher than Vietnamese respondents

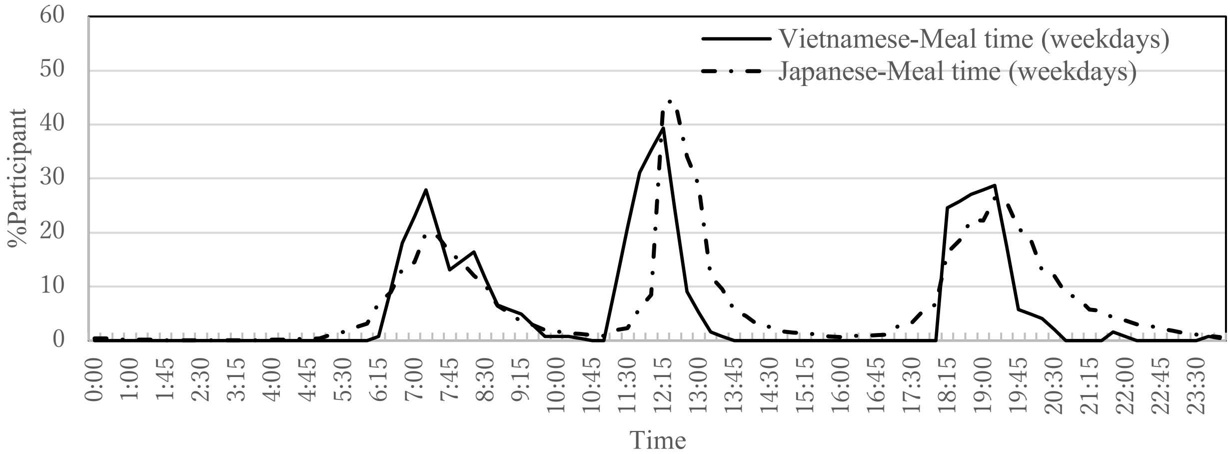

Figure 3. Comparison of **breakfast, lunch and dinner time pattern** between Japanese and Vietnamese

<u>Time spent at home, workplace and for moving:</u>

The time patterns of sleeping, staying at home and workplace and moving were shown in Fig.4. Two peak times in the morning and the evening indicate the time when residents leave homes for work and that when they come back home after work, respectively. Rush hours of moving can be judged as 7-8 am (7:00-8:00) and 5-6 pm (17:00-18:00). The peak of staying at home is coincident with the lowest percentage of the respondent being at the workplace. This indicates the routine of returning home for lunch and rest of the Vietnamese.

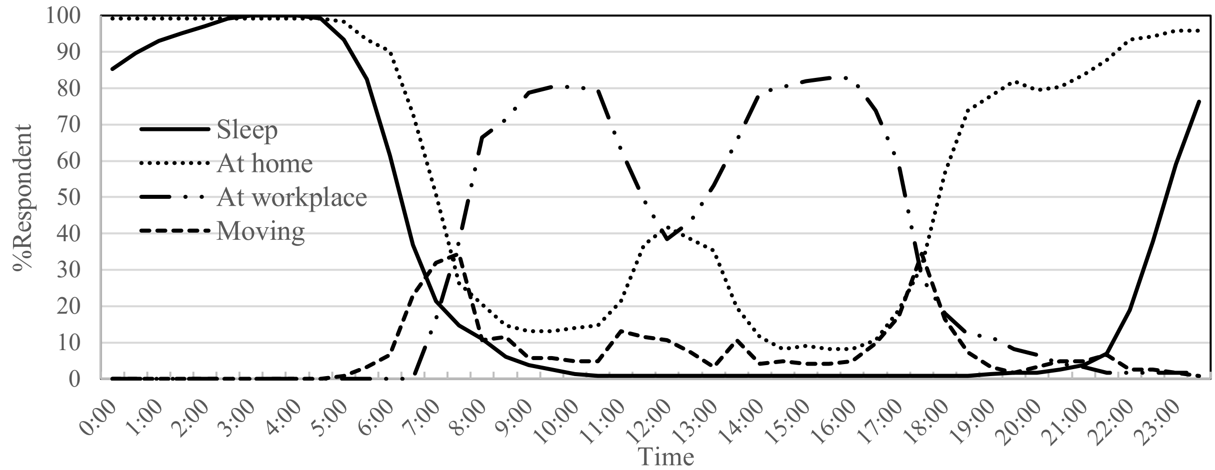

Figure 4. Comparison of **sleeping time pattern** and time **spent at home**, workplace and for moving of Vietnamese

Suitable Noise Metrics for Aircraft Noise Policy in Vietnam

Regarding the time break at the beginning and end of the day and nighttime division when calculating the Day-night-weighted sound pressure level L_{dn}, the daytime interval of 15 hours (07:00 to 22:00), the nighttime interval of 9 hours (00:00 to 07:00 and 22:00 to 24:00) shall be the standard. However, according to the results of the sleeping time of Vietnamese divided by age categories, because the wake-up time and bedtime of the elderly are about one hour earlier than the standard, it may be preferable to set the daytime and night time one hour earlier than the standard.

4. CONCLUSIONS

In this study, the time patterns and activities were considered for a thorough assessment of the appropriate noise rating indices. Time patterns of Vietnamese lifestyle were compared with those Japanese. A comparison was made for the noise metrics for noise evaluation in the relating current noise regulations of Vietnam and Japan. In summary, Vietnamese wake up in between 5-7 am and go to bed in between 9-11 pm. These results suggest that an appropriate noise metric for aircraft noise policy in Vietnam might be L_{dn} with the two reference time intervals of the day (06:00-21:00) and night (21:00-06:00), which is consistent with *QCVN 26:2010/BTNMT* for current use. The use of L_{den} with the three reference time intervals of day-time (6:00-18:00); evening-time (18:00-22:00); and night-time (22:00-6:00) is recommended for the next policy implementation phase.

ACKNOWLEDGMENTS

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[4] Survey on Japanese's social life demonstrated by type of activity and the percentage of activity participant and corresponding time period (for people of 15 years old and over) on weekdays (Homepage of Japan's Statistical Office, Ministry of Internal Affairs and Communications) in Japanese.

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Noise reduction performances of tunnel-shaped noise barriers

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ABSTRACT

This paper investigated noise reduction performances of tunnel-shaped noise barriers using ray-tracing simulation method. Several types of tunnel-shaped noise barriers were selected based on the actual designs. Estimation method of road traffic noise using ray-tracing algorithm was verified through comparison with normal noise mapping algorithm. After construction of the computer simulation model, parametric analysis was carried out with various width and length of road, sound absorption and transmission properties of barrier panel. Horizontal and vertical sound level distributions of each tunnel-shaped noise barriers were estimated. As results, more than 400 m is required for noise barrier length to secure enough noise reduction performances. As for sectional shape, corrugated or gable roof showed better noise reduction performances than flat roof. In addition, effectiveness of tunnel-shaped noise barriers was discussed in terms of noise reduction performances neighboring high-rise residential building in comparison with wall-shaped noise barriers.

1. INTRODUCTION

Near high-rise apartment buildings, tunnel-shaped noise barriers, so called soundproof tunnel, are often introduced since the limitation of stacking noise barrier panels not too high [1-2]. However, it is not easy to estimate noise propagation of tunnel-shaped noise barriers using the conventional noise mapping software. Therefore, it is needed to investigate effectiveness of tunnel-shaped noise barriers on reducing traffic noises to nearby residential area in comparison with wall-shaped noise barriers. In this study, sound fields characteristics of inside and outside of various shaped noise barriers were compared in terms of sound pressure level using ray-tracing computer simulation with sound absorption and transmission properties measured in laboratory condition.

2. METHODS

Simulation set-up

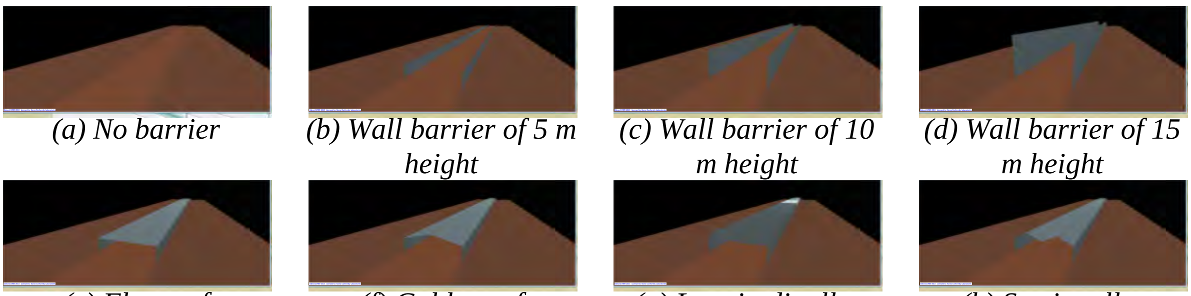
A conventional software using ray-tracing method (Odeon v.12) is employed. Boundary enclosure with 100% sound absorption was constructed with a dimension of width 100 m, length 500 m and height 50 m. Road of 6 lanes was modelled as width of 21 m (3.5 m for a lane) with the absorption characteristics of an asphalt pavement [3]. Ground except for road was assumed as rough soil field. Acryl panel of 10 mm thickness was selected for the material of noise barrier panel and roof. However, its sound absorption values were based on properties of paired glass because of the absence of relevant data. Line sound source characteristics at the height of 1.5 m were applied with a gain of 120 dB with frequency correction from the normalized road traffic noise spectrum [4]. Receivers at the height of 1.2 m were placed horizontally with spacing of 2.5 m. Sectional receiver grid with the same spacing was additionally considered at the middle of noise barrier. A-weighted sound pressure levels were derived with transition order of 2, number of early rays of 2,082 and number of late rays of 1,041 for survey purpose. Table 1 shows acoustical properties of the materials used in the computer simulation.

Table 1. Acoustical properties of the materials used in the computer simulation (A: Sound absorption coefficient, T: Sound reduction index in dB, W: correction level in dB)

Material names		*Sound absorption coefficients of 1/1 octave bands*					
		125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
A	*Asphalt pavement* [3]	0.05	0.07	0.31	0.59	0.60	0.60
	Rough soil (Odeon)	0.15	0.25	0.40	0.55	0.60	0.60
	Paired glass	0.20	0.10	0.08	0.06	0.04	0.02
T	*Acryl panel of 10 mm*	16.2	24.7	28.9	34.1	37.0	35.0
W	*Road traffic noise*	-19	-15	-12	-9	-11	-16

Simulation configuration

Based on the practical examples of tunnel-shaped noise barriers, 3D model of the eight simulation configurations with different shape of noise barriers were prepared: no barrier, wall-shaped barriers of various heights of 5 m, 10 m and 15 m, tunnel-shaped barriers of wall height of 5 m with various roof shape of flat, gable of 2.5 m additional height, longitudinally- and sectionally-corrugated with spacing of about 10.5 m (Figure 1). Basic length of noise barrier was 400 m.



(a) No barrier *(b) Wall barrier of 5 m height* *(c) Wall barrier of 10 m height* *(d) Wall barrier of 15 m height*

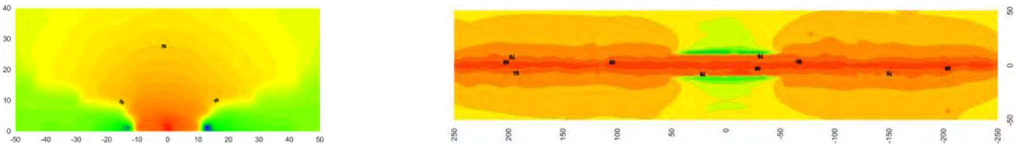
(e) Flat roof *(f) Gable roof* *(g) Longitudinally-corrugated roof* *(h) Sectionally-corrugated roof*

Figure 1. 3D models of various shapes of the simulated noise barriers

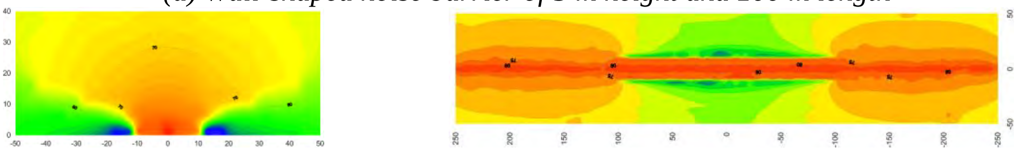
3. SIMULATION RESULTS

Length of noise barriers

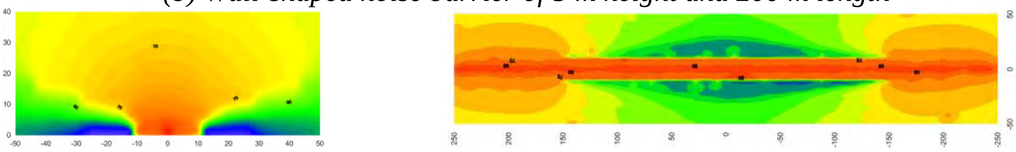
Figure 2 shows the simulation results for the wall-shaped noise barrier of 5 m height in accordance with various length of 100 m to 400 m. Acoustically-shadowed zone was vertically and horizontally changed in terms of barrier length. In case of the barrier length of 400 m, acoustically-shadowed zone was clearly observed.



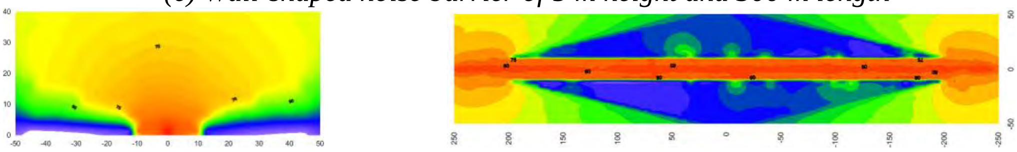
(a) Wall-shaped noise barrier of 5 m height and 100 m length



(b) Wall-shaped noise barrier of 5 m height and 200 m length



(c) Wall-shaped noise barrier of 5 m height and 300 m length

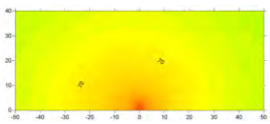


(d) Wall-shaped noise barrier of 5 m height and 400 m length

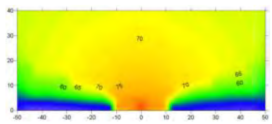
Figure 2. Horizontal distribution of overall sound pressure level at the same plane

Vertical and horizontal distributions of sound pressure levels

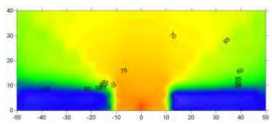
Figure 3 shows the simulation results of vertical distribution of sound pressure levels at the same section for each simulation configuration. In case of no barrier, sound pressure level was gradually decreased for all directions. In cases of wall-shaped barriers, sound pressure levels below the upper edge of barrier profile were dramatically decreased, but sound propagations at upper directions were similar to the case of no barrier. In cases of tunnel-shaped barriers, sound propagations at upper directions were also highly decreased in comparison with the cases of wall-shaped barriers. In consideration of nearby high-rise apartment building within 50 m from the centre lane of the road, gable of corrugated shaped roof showed better noise reduction than flat roof case. Figure 4 shows the simulation results of horizontal distribution of sound pressure levels at the same section for each simulation configuration. Middle area of outside of noise barriers in longitudinal direction showed the highest noise reduction. Wall-shaped noise barriers showed better noise reduction in terms of horizontal distribution at the height of 1.2 m. However, sound pressure levels on road area in cases of tunnel-shaped noise barriers were higher than those of wall-shaped noise barriers.



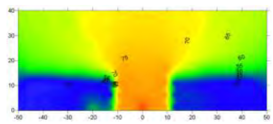
(a) No barrier



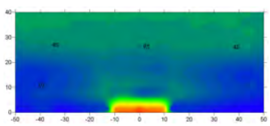
(b) Wall barrier of 5 m height



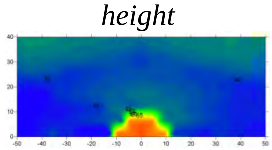
(c) Wall barrier of 10 m height



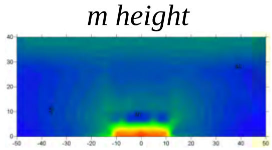
(d) Wall barrier of 15 m height



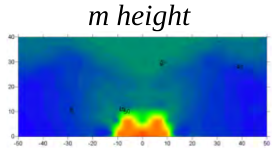
(e) Flat roof



(f) Gable roof

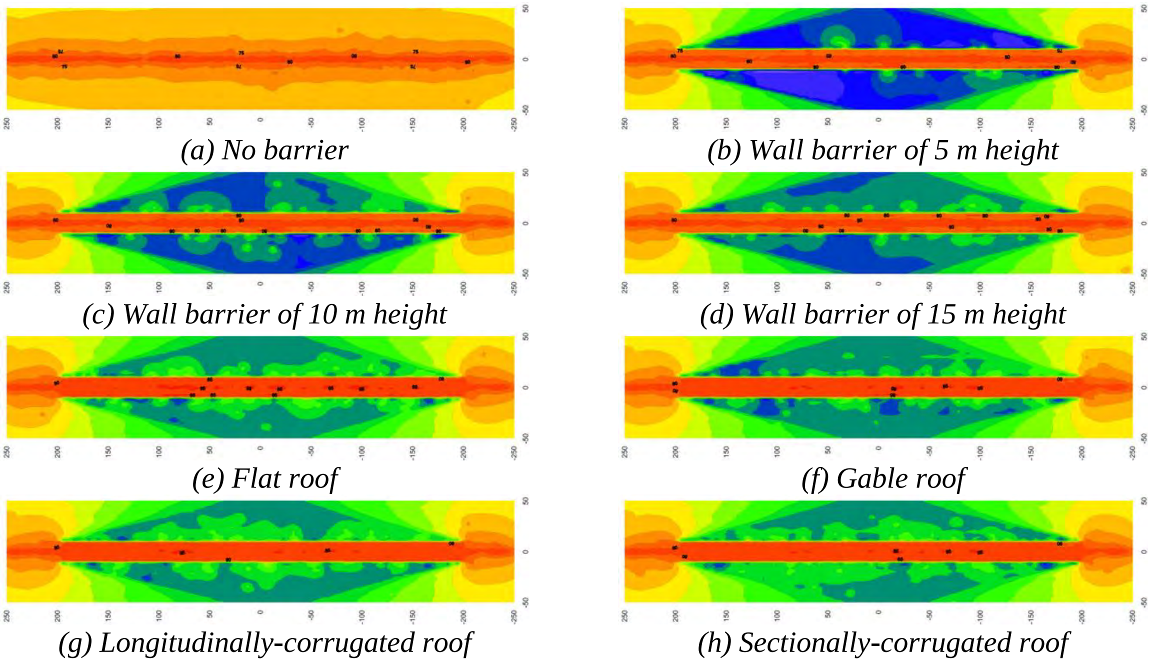


(g) Longitudinally-corrugated roof



(h) Sectionally-corrugated roof

Figure 3. Vertical distribution of overall sound pressure level at the same section



(a) No barrier *(b) Wall barrier of 5 m height*

(c) Wall barrier of 10 m height *(d) Wall barrier of 15 m height*

(e) Flat roof *(f) Gable roof*

(g) Longitudinally-corrugated roof *(h) Sectionally-corrugated roof*

Figure 4. Horizontal distribution of overall sound pressure level at the same plane

4. CONCLUSIONS

In this study, sound propagation properties of noise barriers were investigated using ray-tracing method. Differences between wall and tunnel shapes, and various sectional shapes were effectively compared. As a further study, acoustic fitting with field measurements and scale model testing is needed to improve the prediction method using ray-tracing.

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