Theory of Individual Preference for Health and Peace

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In order to make balance in our life the two opposite poles such that 1) male and female, 2) left and right cerebral hemispheres, 3) sympathetic and parasympathetic systems, and 4) excitatory and inhibitory endocrine systems. In 1950, Selye published stress theory, it is normative that human life is so occupied by a wide range of stressors. There is great risk associated with ignoring the reality of life that could otherwise flourish, the one often subdued by the various stressors throughout the world. Environmental disorder caused by mass production and speedy transportation norms geared toward profit create an environment of unnatural rhythms which causes humans to lose much of their survival power, resulting in heightened vulnerability to serious cancers, kidney disease cognitive impairment, and pathogenesis by coronavirus. This paper introduces opposite pole of stress, i.e., preference. There is a natural underlying relationship connecting individual preference (selection) that enhances our survival power – with health and peace. It is especially those preferred individual creative expressions that play the most important role for blossoming future societies. It is at this conjunction that we should remember – the number of unknowns in the universe is infinite. Every one of us has the capacity to reveal possibilities that have lain hidden or latent in the vastness of the universe for millennia or even longer cycles of time. This paper suggests that ideas may first represent themselves in non-verbal manner, which is a type of communication associated with the right human cerebral hemisphere. Almost all expressions of verbal communication that we know to be associated with the left hemisphere are inherently limited and some of them are already well studied. A healthy life can be realized by incorporating preferred elements of temporal design into an individual's life and environment. Temporal design is a conceptual framework that encompasses all rhythmic events on all levels, of which those between the microscopic of about 0.8 s (the firing rate of neuron) to the macroscopic of the order of millennium are considered in this paper. Awareness of a unique personality encoded in our deoxyribonucleic acid (DNA), capable of realizing itself through unique creations to be integrated into the everyday, is fundamental to survival and the enjoyment of life, skipping stress- and illness-related suffering – and keeping health and peace.

Keywords: stress, preference, left and right hemispheres, temporal design

1 INTRODUCTION

The word "stress" was never used before the 1950s, and the number of operating central hospitals was considerably lower. Nowadays, it is normative for human life to be 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 other illnesses spread across the world due to various stressors [1, 2]. Treatment of these diseases requires tremendous amounts of money, resulting in a negatively spiraling society throughout the world. It is worth noticing that wars occur parallel to a standard of lack of life goods and financial economy, as well as a rich variety of stressors stemming from the ill concept "Time is Money." The mentioned conditions are symptoms of a majority-based society model.

We emphasize here the concept of original ideas and creativity, realized as preferred individual activity resonating with personality that is based on a person's unique deoxyribonucleic acid (DNA), and with the left and right cerebral hemispheres, associated with temporal and spatial aspects, respectively. Most generally, subjective preference is regarded as a primitive response of living creatures that entails judgments that steer an organism in the direction of maintaining life, to enhance its prospects for survival. It is worth noticing that preference is not a fleeting luxury, but rather an underlying mechanism that may be deeply associated with the base, and our sense of, aesthetics.

Let us focus our attention on the third stage of life (as shown in Figure 1) for an individual through the human-brain-grounded theory of temporal and spatial design in architecture and the environment [3] as a most effective stage for the expression of life-preference resonating with personality and directly related to DNA.

To exert healthy creations by living in a preferred environment, avoiding ill treatment of self and others and further wars, this paper introduces our inherent, built-in survival power through a theory of individual preference amid various stressors of life as mentioned above. First of all, we shall describe noisy environment affects prenatal and postnatal children on development of the first through third stages of life.

2 MATERNAL STRESS OF NOISE ON UNBORN BABIES AND CHILDREN

Our brain vividly and instantly responds to changes in environmental noise within a period of less than about 1.0 s. We should, however, be aware of the "long-term integrated effects" on unborn babies through maternal placenta over the course of about one year. Exposure to noise qualifies as a psychophysiological stressor; on the other hand, environmental noise is a representative measure of quality

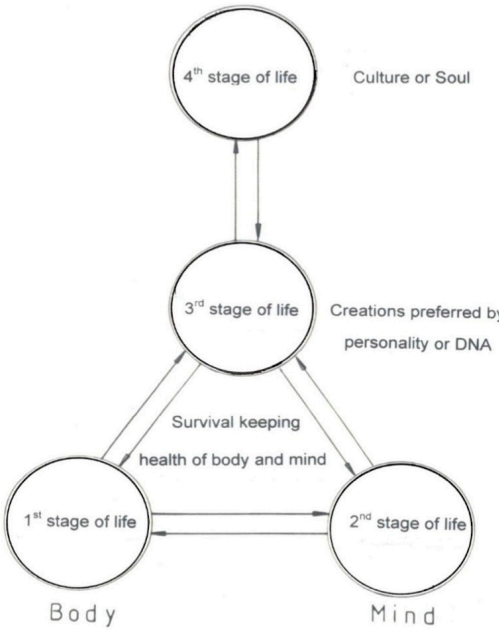

Figure 1: Human life with preference and stress is represented in four stages [3]. Note that each of four stage of life includes stress and preference. The strongest preference is resonating with personality or DNA. If a creation is accepted by future generations, it may become a culture, so that its lifespan may exceed well over millennium (ex. Figure 37, which are shown at the end of this paper).

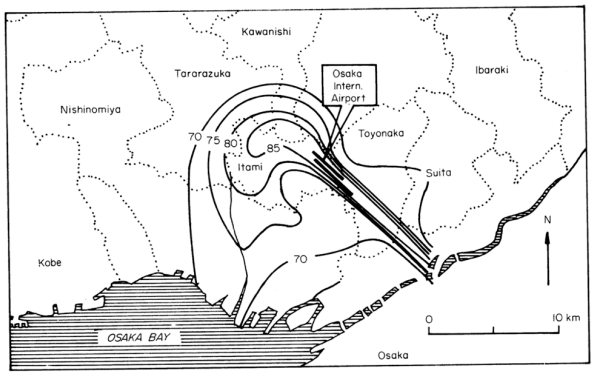

Figure 2: Aircraft noise level in the weighted equivalent continuous noise level (WECPNL) around Osaka International Airport. All living area in Itami City was $WECPLN > 70$.

of an urban environment. Investigations were performed around Osaka International Airport and the contour lines indicating noise levels are shown in Figure 2.

2.1 Human Placental Lactogen (HPL) in Maternal Plasma and Birth Weight

Evidence clearly indicated that due to noise stress, survival power in the body was lost during fetal life. Stress in pregnant mothers particularly after 30 weeks of pregnancy as shown in Figures 3 and 4 [4] was expressed in the fetal danger zone, F.D. Zone [5]. The number of children with birth weight less than 3000g in the noisy environment created by jet planes flying regularly over Itami City increased rapidly from 1964 onwards compared to the neighboring quiet towns as indicated in Figure 5.

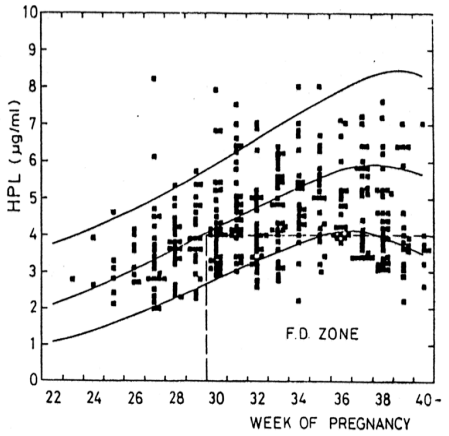

Figure 3: HPL levels of 343 mothers in the noise area (Itami City) by stage of pregnancy [4]. Three lines show the 2SD and mean values for normal HPL levels [5].

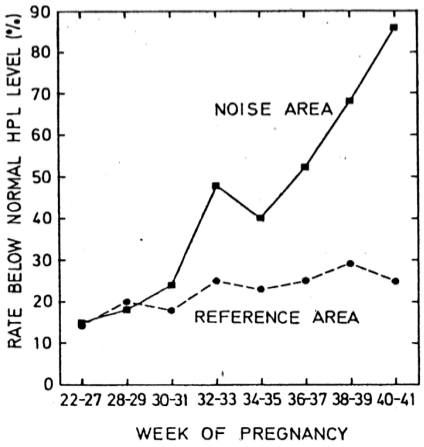

Figure 4: The percentage of mothers with HPL level more than 1SD below the mean in the stage of pregnancy [4]. Samples from the noise area were collected at Itami City Hospital in Itami City, and the reference area was collected at the Kanebo Hospital in Kobe and Kobe University Hospital.

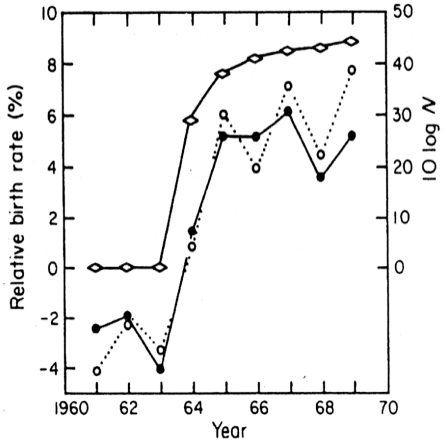

Figure 5: Relative birthrate under 3000 g in the noisy area (Itami City) and in reference to the neighboring low noise area, which relates to the number of jet planes using Osaka International Airport. Filled circle: Male. Open circle: Female. Open diamond: Number of jet planes parameter $10logN$, N being the number of jet planes using the airport.

2.2 Reaction in sleeping Babies

Effects of aircraft noise on reaction of sleeping babies (2-4 months old) were investigated by means of elec-

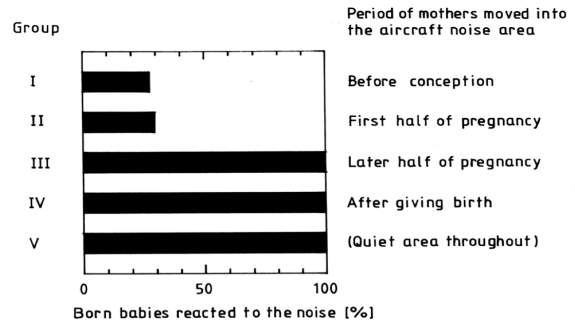

Figure 6: Percentage of plethysmogragh (PLG) reactions of each group (I-V) during sleep in response to the jet plane noise at peak levels 70 and 80 dBA.

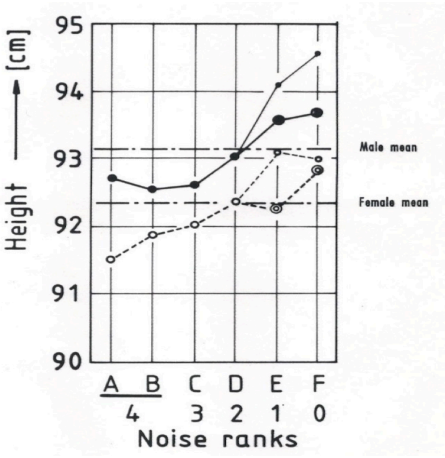

Figure 7: Mean height of boys (filled circles) and girls (open circles) investigated at three years of age according to noise ranks of living area classified by (4: $WECPNL > 85$, 3: WECPNL 80-84.9; 2: WECPNL 75-79.9; 1: WECPNL 70-74.9; 0: $WECPNL < 69.9$). Smaller circles denote means of Kawanishi children, while enclosed circles denote means of Toyonaka children [8].

troplethysmography (PLG) in relation to the pregnancy-periods when the mothers had moved into the noisy area. Results are shown in Figure 6. Most of the sleeping babies were tested in their own home environments. Groups were formed based on the time when the mother had started living in the noisy area. Those babies whose mothers had moved to the noisy area before conception or during the first five months of pregnancy did not react to daily aircraft noise presumably due to "prenatal adaptability," however, they did react to "unusual music" stimuli, which was accredited to "selective adaptation". These postnatal effects of aircraft noise on the sleep of babies were shown to depend on the pregnancy-period when their mothers had moved into the noise area [6]; 1% significance level between Group (I & II) and Group (III & IV) was achieved. The majority of babies in Groups (I & II) did not react to jet noise at peak levels of 70-90 dBA and they continued to sleep, however, babies in Groups (III, IV and V) reacted at 70-80 dBA, and some of them were afflicted enough to wake up and cry. Thus, about 70% of babies fewer than 4 months of age whose mother had moved into the noisy area before the first half of pregnancy were already adapted to the noise. But, the babies who had been subjected to noise in the later part of pregnancy were not more adapted to the noise, i.e., 100% of the babies reacted to the noise at 80-90 dBA.

Moreover, the development of unborn babies as demonstrated by the number of low-birth-weight-babies in relation to the number of jet planes is shown in Figure 5 [7]. A detrimental postnatal effect on the development of height of children (Figure 7) has been discussed [8].

Postnatal effects of aircraft noise on the sleep of newborns are dependent on the period during which their mothers entered the noise area in reference to the period of pregnancy as shown in Figure 6 [6, 7, 9]. It is remarkable that only less than 30% of the babies whose mothers had moved into the aircraft noise area before conception or during the first half of pregnancy reacted to noise during their sleep, even though the peak level was 80 dBA. On the contrary, of the babies whose mothers had moved into the noise area in the later half of pregnancy or after giving birth, as well as those living in a quiet area throughout, 100% reacted to 80-dBA-noise level.

2.3 Developments of Specializations of Cerebral Hemisphere

Development of hemispheric specialization in children living in noisy areas was clearly different upon testing for two different types of mental work: an adding task associated with the left hemisphere, and identifying lack of visual patterns – a task associated with the right hemisphere [10, 11]. Tests were carried out in classrooms of two primary schools in a noisy area near Osaka International Airport, and in two primary schools in a quiet area. The total number of participants (TNP) was 1,286. The no-stimulus group was tested in a normal classroom without any reproduced sound ($NP = 572$). The noise group was tested while being exposed to jet plane noise at 90-100 dBA peak ($NP = 572$). The music group was tested while listening to an excerpt from the fourth movement of Beethoven's Ninth Symphony at 80-90 dBA peak ($NP = 142$).

The time pattern and spectrum of the music were similar to the jet noise. The sound stimulus was reproduced from two loudspeakers set at the front of the classroom during every alternative period, during the tasks given by

$$i = 2n \tag{1}$$

where $n = 1, 2, \cdots 7$ for the adding task, and $n = 1, 2, \cdots 5$ for the search task.

A "work amount curve" of individual work produced in each period was drawn for all test results. The mean work performance is not discussed here, because there were no significant differences between different conditions. Of particular importance in evaluating the test results is the rate of "V-type relaxation." This type of relaxation is thought to be caused by an abandonment of effort when mental functions are disturbed.

This score is classified into two categories according to the occurrence of a sudden large drop in the work amount curve during each task. This was assessed by $M_i < M - (3/2)W$, $i = 1, 2, \cdots N$, where M is the mean work performance and W is average variation of the curve excluding an initial effect in the first period, $i = 1$.

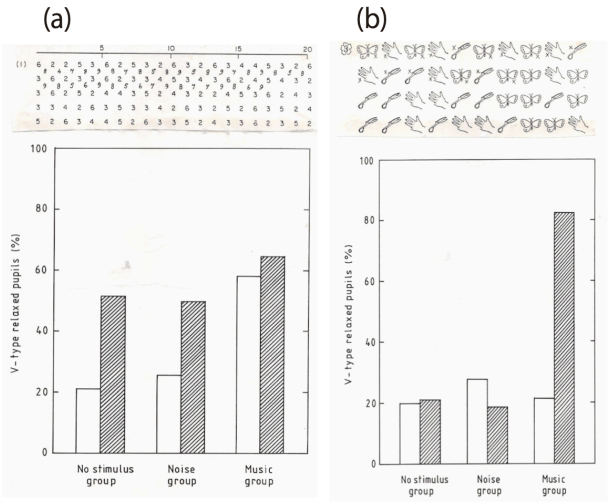

Figure 8: (a) Proportion of V-type relaxed children during adding task (9-10 years old). Unshaded bars are results from children from quiet living areas; Shaded bars show results for children from noisy areas. Upper part indicates an example of adding task of a period (60 s/period) in N (= 15). (b) Proportion of V-type relaxed children (7-8 years old) during the search (for lack of visual patterns) task. Unshaded bars are results from children from quiet living areas; Shaded bars show results for children from noisy areas. Upper part indicates an example of task of a period (30 s/period) in N (= 10).

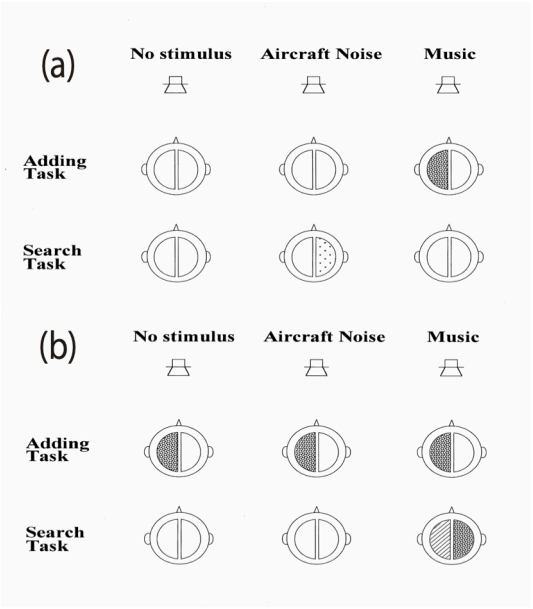

Figure 9: (a) Children from a quiet living area: Interference between mental tasks and sound stimuli. (b) Children from a noisy living area: Interference between mental tasks and sound stimuli. Interference effects are quite different for children from a quiet living area.

As shown in Figure 9(a), in a quiet living area, the percentage of V-relaxed children who had been given the adding task ($N = 15$) was much greater in the music group than in either the no-stimulus group or the noise group ($p < 0.01$). In the noisy living area, however, the percentage of relaxed children was always greater than in the quiet living area, particularly in the no-stimulus group ($p < 0.01$). Looking at the no-stimulus group and the noise group, we are seeing the long-term integrated effects of living in a noisy area, and no significant effects were observed either with or without noise reproduction. In the music group, interference effects could be observed between music and the adding task, because hearing music and performing an adding task are both associated with the left cerebral hemisphere.

As shown in Figure 9(b), concerning the pattern search the task ($N = 10$), the only significant difference between participants from different living areas was found in the music group ($p < 0.01$). Thus, development of cerebral hemispheres was greatly affected by the noisy living area. Results of the mental task were not dependent on gender, birth-order or birth-weight of the child, the working status of the mother, whether or not the mother had suffered from toxicosis during pregnancy, the child's gestational age when the mother moved into the noisy area, or the child's feelings about jet plane noise [10]. It is clear, therefore, that integrated effects of environmental noise on the specialization of cerebral hemispheres may strongly influence the development of personality as a source of creation.

The author wished to proceed with further investigations on the effects of jet plane noise around Osaka International Airport on miscarriages, deformed children and stillbirth. Over 13,000 babies a year were born into the noisy living area altogether around 1975. However, his kidney was beginning to weaken, hindering his daily routine considerably to a point where he could not get out of bed. Thereafter, he decided to give up on further investigations on noise stress on unborn and born babies, and work on studying subjective preference of the sound field of concert halls.

So far, we discussed the negative effects of noise, but if pregnant mothers and born babies listened to preferred music, then survival power might be greatly enhanced according to the following theory.

3 DESIGN THEORY OF SOUND FIELDS BASED ON SUBJECTIVE PREFERENCE

The design theory for the sound fields has been established in term of specialization of the cerebral hemisphere specialization due to the temporal and spatial factors of the field recording electroencephalogram (EEG) and magnetoencephalogram (MEG). Concerning the visual field we described in Appendix.

3.1 Factors Extracted from the Normalized Autocorrelation Function (ACF) of Sound Fields

3.1.1 Initial time delay gap between the direct sound and the first reflection (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 field was changed upon applying a speech signal, an almost direct relationship between individual scale values of subjective preference obtained by the paired-comparison test (PCT) and τ_e values extracted from autocorrelation function (ACF) of α-wave of the MEG recorded over the left hemisphere was found in each of the eight subjects, as shown in Figure 11 [23]. Remarkably, the correlation coefficient between them, p, reached more than

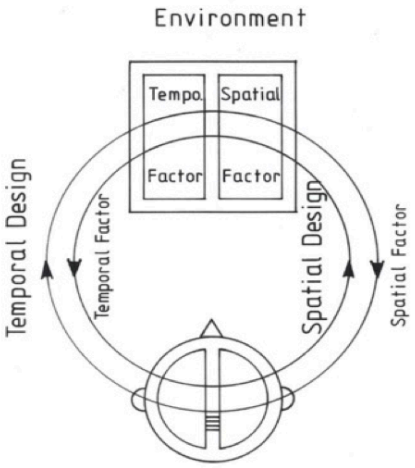

Figure 10: Brain-grounded theory of temporal and spatial design of the sound field and the visual field [3].

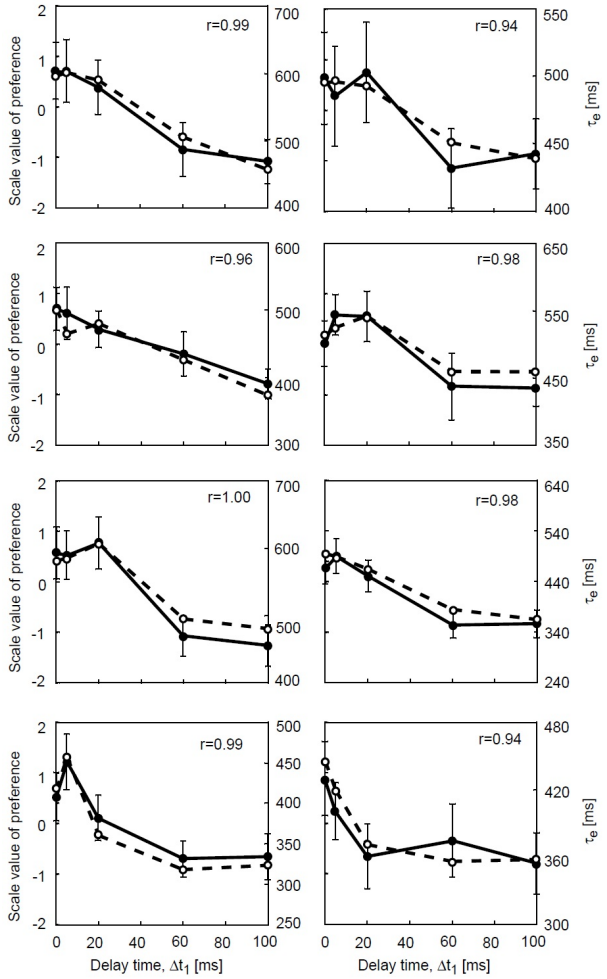

Figure 11: Good correspondence between the scale value of subjective preference and the averaged ACF τ_e value of the MEG α-wave over the left hemisphere for each of 8 individual subjects. Remarkably, the averaged τ_e value and the scale value of preference were in high correlation in all cases: $r > 0.9$ [23, 24]. ○: scale values of subjective preference; ●: averaged τ_e values of MEG α-wave, error bars as standard errors.

0.94 for all of 8 subjects. SQUID used recording MEG is shown in Figure 12.

Most remarkably, however, there was weak correlation between the scale values of subjective preference and the

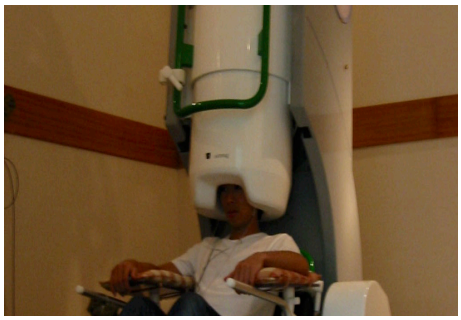

Figure 12: Magnetometer in recording the magnetoencephalogram (MEG).

amplitude of the α-wave, $\Phi(0)$, in both hemispheres ($p < 0.37$). Thus, the amplitude of the α-wave itself cannot be the measure of subjective preference.

The value of τ_e represents the degree of repetitive features in the α-waves that the brain repeats in a similar low frequency rhythm 8-13 Hz under the preferred conditions. This tendency for a higher value of τ_e MEG α-waves under the preferred condition was much more significant than the results from the EEG α-waves mentioned above. Thus, the temporal factor Δt_1 of the sound field is the left hemisphere specialization.

3.1.2 Subsequent reverberation time (T_{sub}) of sound fields

Now, let us examine values of τ_e in the α-wave with changes to subsequent reverberation time (T_{sub}) relating to the scale values of subjective preference. Ten student subjects participated in the experiment [25]. The sound source used was music motif B [17]. Ten subjects between 25–33 years old participated in the experiment. EEG from the left and right hemisphere were recorded. Values of τ_e of the α-wave, for the duration, $2T = 2.5$ s, were also analyzed here.

The averaged values of τ_e of the α-wave are shown in Figure 11. Clearly, the values of τ_e are much higher 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 higher 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 in both figures so that the left hemisphere specialization for the temporal factor of the sound field, reverberation time T_{sub}.

3.2 Spatial Factors Associated with the Right Hemisphere

3.2.1 Sensation level (SL)

Subjective preference in relation to sound level has been described by means of the slow vertex response (SVR) with the right hemisphere, but the details are not reviewed here, due to the different method in EEG and MEG [26].

3.2.2 Magnitude of interaural cross-correlation (IACC)

To find the EEG response correlating to subjective preference for paired changes in the spatial factor, i.e., the mag-

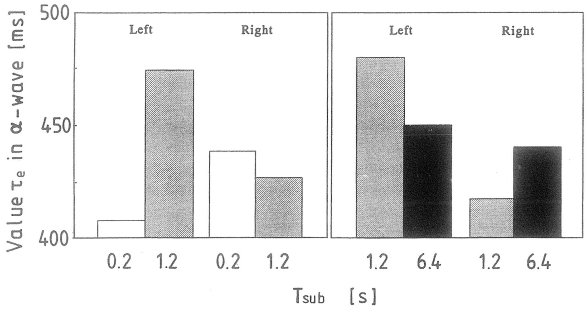

Figure 13: Averaged value of ACF τ_e of the EEG alpha wave upon change of pair $T_{sub} = 0.2$ s and 1.2 s (left figure); 1.2 s and 6.4 s (right figure) obtained by 10 subjects [26]. Note that the most preferred reverberation time for music motif B is $[T_{sub}]_p \approx 1.2$ s, so that the values τ_e in α-wave were much longer than $T_{sub} \approx 0.2$ s and 6.4 s.

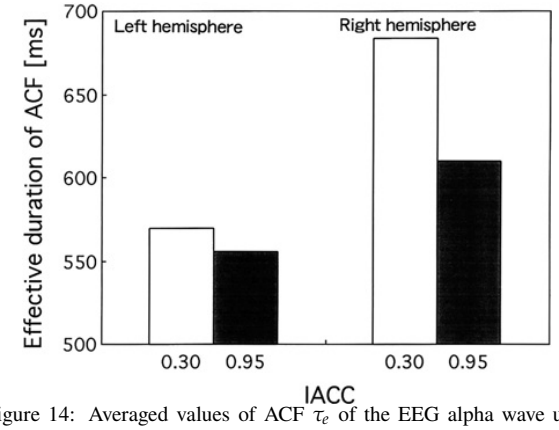

Figure 14: Averaged values of ACF τ_e of the EEG alpha wave upon change of IACC, for the pair of $IACC = 0.30$ and 0.95. Note that the smaller value of IACC is always preferred, since we prefer difference between the sound signals arriving at the two ears.

nitude of the interaural cross-correlation function (IACC) of the sound field was investigated. Eight student subjects participated in the paired-comparison experiment [53]. Music motif B (Sinfonietta by Arnold) was applied as stimulus. Changes in IACC reflected clearly in right hemispheric dominance. The effective duration τ_e extracted from ACF of α-wave ($2T = 2.5$ s) was found to be substantially longer in the preferred condition with a small magnitude of IACC ($IACC = 0.30$). 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 14.

The ratios of effective durations τ_e for α-band responses to IACC change, $[\tau_e(IACC = 0.3)/\tau_e(IACC = 0.95)]$, in the right hemisphere were more evident than in the left hemisphere except for one subject 14. Thus, as far as 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.

Additionally, experiments using MEG measurements tested the effects of a speech signal that was altered by changes to IACC (0.27, 0.61 and 0.90). Results reconfirmed that effective duration τ_e in the α-wave range of all of individuals increased at the preferred condition when IACC decreased [24].

As summary of hemispheric specializations of temporal and spatial factors of sound fields is listed in Table 1.

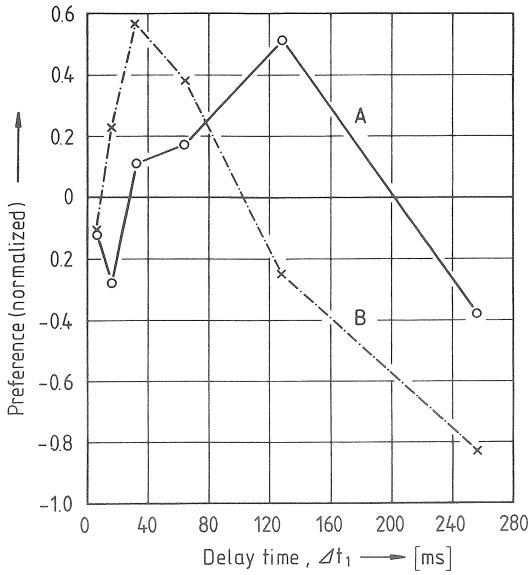

Figure 15: Results of subjective preference for different sound sources as a function of the delay time of single reflection obtained by the PCT giving $+1$ and -1, corresponding to the positive and negative judgment, respectively. The normalized score is obtained by the factor $S(F-1)$, S being the number of sound field and F is number of subjects (6 sound fields and 13 subjects). Normalized preference score for music motif A ($\tau_e \approx 127$ ms) and music motif B ($\tau_e \approx 35$ ms) [16].

4 SUBJECTIVE PREFERENCE IN RELATION TO THE ORTHOGONAL FACTORS OF THE SOUND FIELD

Subjective preference judgment is the most primitive response and the overall response. It is regarded as a living creatures that entail judgments that steer an organism in the direction of maintaining life, so as to enhance its prospects for survival. Also, it is interesting that the preference judgments is deeply related to aesthetic issue. The method of obtaining the linear scale value of stimuli by applying the law of comparative judgment is well known [12, 13, 14, 15]. The PCT is the simplest method, so that any person may be participated and results may be integrated and utilized in the wide range of applications. From results of subjective preference studies in relation to temporal factors and spatial factors of the sound field, the theory of subjective preference is derived. Based on the theory, an example of calculating subjective preference at each listener's position can be demonstrated.

4.1 Sound Fields with a Single Reflection and Multiple Reflections

Obviously, the most preferred delay time, with the maximum score, differs greatly between the two motifs and the speech signal. When the amplitude of reflection $A_1 = 1$, the most preferred delays are around 130 ms for music motif A, 35 ms for music motif B (Figure 15). It was found that these correspond well to the effective duration of the ACF, $(\tau_e)_{min}$, of source signals of 125 ms (motif A), 40 ms (motif B) and 10 ms (Speech) as indicated in Table 2. After inspection, the preferred delay was found roughly at a certain duration of ACF, defined by τ_p, such that the envelope of ACF becomes $0.1A_1$. Thus, $\tau_p = (\tau_e)_{min}$ only when $A_1 = 1$. The data collected as a function

Table 1: Hemispheric specializations of temporal and spatial factors observed by analyses of SVR, EEG and MEG.

Factors changed	AEP (SVR) $A(P_1 - N_1)$	EEG, ratio of ACF τ_e values of α-wave	AEP (MEG) N_{1m}	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)[3]	

[1] Sound source used in experiments is indicated in the bracket.
[2] The flow of EEG α-wave from the right hemisphere to the left hemisphere for music stimulus in change of the IACC was determined by the maximum value of the cross-correlation function $|\Phi_{lr}(\tau)|_{max}$ between α-waves recorded at different electrodes.
[3] [27, 28]

Table 2: Music and speech source signals and their minimum effective duration of the running ACF, $(\tau_e)_{min}$.

Sound source	Title	Composer or writer	$(\tau_e)_{min}$ [ms][1)]
Music motif A	Royal Pavane	Orlando Gibbons	125
Music motif B	Sinfonietta, Opus 48; IV movement	Malcolm Arnold	40
Speech S	Poem read by a female	Doppo Kunikida	10

[1] The value of $(\tau_e)_{min}$ is the minimum value extracted from the running ACF, $2T = 2$ s, with a running interval of 100 ms.

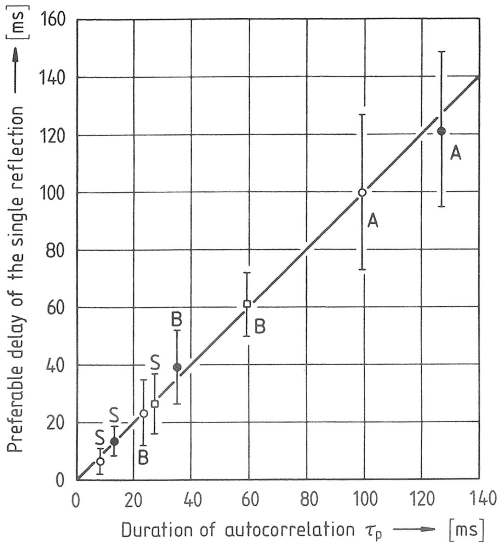

Figure 16: The most preferred delay time of the single reflection as a function of the duration of the autocorrelation function of source signals, τ_p given by Equation 2.

The most preferred delay time of the duration τ_p are shown in Figure 16, where data from a continuous speech signal are also plotted. When the envelope of the ACF is exponential, then it is expressed approximately by [11]

$$\tau_p = [\Delta t_1]_p = (1 - \log_{10} A_1)(\tau_e)_{min} \qquad (2)$$

Two reasons can be given for explaining why the preference decreases for the short delay range of reflection, $0 < \Delta t_1 < \tau_p = [\Delta t_1]_p$ as shown in Figure 17:

1. Tone coloration effects occur because of the interference phenomenon in the coherent time region.
2. The IACC increases when Δt_1 is near 0.

On the other hand, echo disturbance effects can be observed when Δt_1 is greater than τ_p.

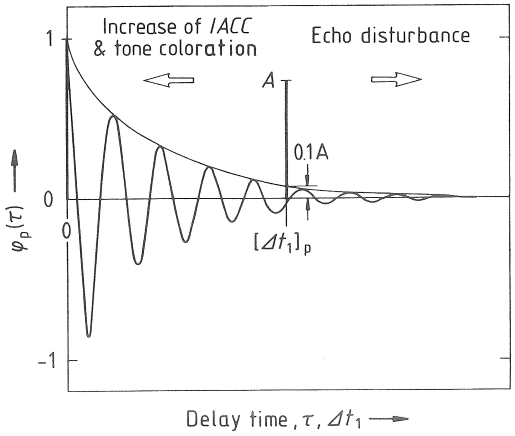

Figure 17: Subjective attributes before and after the most preferred delay time of the reflection, $[\Delta t_1]_p = \tau_p$ [11].

4.2 Preferred Horizontal Direction of a Single Reflection to a Listener

Applying music motif A and B, the delay time of the reflection, in the experiment showing the preferred direction of a single reflection, was fixed at 32 ms. The direction was specified by loudspeakers located at

$$\xi_1 = 0°(\eta_1 = 27°), \xi_1 = 18, 39, \cdots 90° \ (\eta_1 = 9°) \quad (3)$$

Results of the preference tests are shown in Figure 18. No fundamental differences are observed between the curves of the two motifs in spite of the great difference of $(\tau_e)_{min}$. The preferred score increases roughly with decreasing IACC. The correlation coefficient between the score and the IACC is –0.8 ($p < 0.01$).

The score with motif A at ξ drops to a negative value, indicating that the lateral reflections, coming only from around ξ are not always preferred. The figure shows that there is a preference for angles less than ξ, and on average there may be an optimum range centered on about $\xi = 55°$,

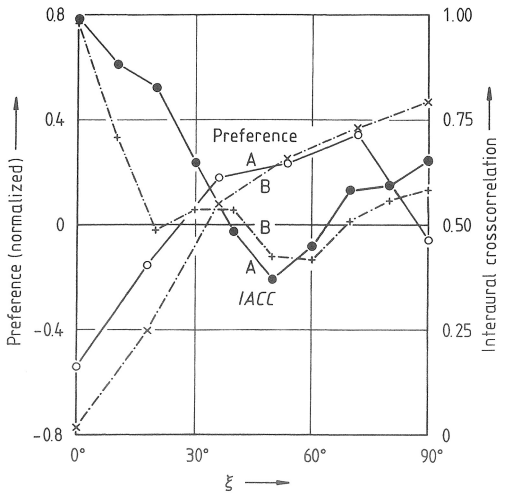

Figure 18: Normalized preference score and the IACC for music motif A ($\tau_e \approx 127$ ms) and music motif B ($\tau_e \approx 35$ ms) as a function of the horizontal angle of incidence of the single reflection, ξ [16]. The negative strong correlation between subjective preference and the IACC may be found. The most effective horizontal angle minimizing the IACC may be found commonly around $\xi = 55°$ regardless of sound source or the value of τ_e.

Similar results can be seen in the data from speech signals [18].

4.3 Conditions Maximizing Subjective Preference

4.3.1 Listening Level (LL)

The listening level is, of course, the primary criterion for listening to vocal and orchestra music in the sound field of concert hall. The preferred listening level (LL) depends upon the music and the particular passage being performed. For example, the gross preferred levels obtained by 16 subjects are in peak ranges of 77-79 dBA for two different musical sound sources, i.e., music motif A (Royal Pavane by Gibbons) with a slow tempo, and 79-80 dBA for music motif B (Sinfonietta by Arnold) with a fast tempo.

4.3.2 Early Reflections After the Direct Sound (Δt_1)

An approximate relationship for the most preferred delay time $[\Delta t_1]_p$ has been discovered in terms of the envelope of autocorrelation function of source signals and the total amplitude of reflections, A [17]. Generally, it is expressed by

$$|\phi_p(\tau)|_{envelope} \approx kA^c, \, at \, \tau = [\Delta t_1]_p \tag{4}$$

where k and c are constants, which depend on the subjective attributes (TABLE 6.2 in [11]). When the envelope of ACF is exponential as indicated for most of music and speech signals, then

$$[\Delta t_1]_p \approx (\log_{10} \frac{1}{k} - c \log_{10} A)(\tau_e)_{min} \tag{5}$$

where the total pressure amplitude of reflection is given by

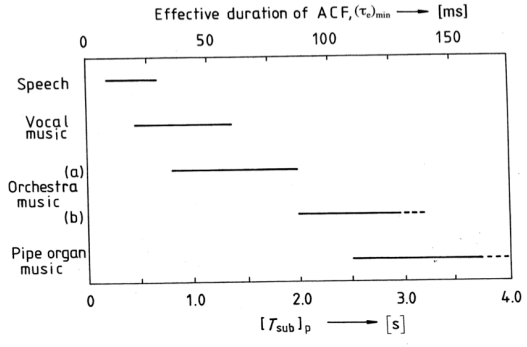

Figure 19: Reverberation time recommended for each sound source that related to the value of $(\tau_e)_{min}$.

$$A = (A_1^2 + A_2^2 + A_3^2 + \cdots)^{1/2} \tag{6}$$

The relationship of Equation 5 for a single reflection may be obtained by putting $A = A_1$, $k = 0.1$ and $c = 1$ so that

$$[\Delta t_1]_p \approx (1 - \log_{10} A_1)\tau_e \tag{7}$$

Later, it has been accurately expressed that the value of τ_e in Equation 7 is replaced by the minimum value of τ_e of the running ACF [19, 20], so that

$$[\Delta t_1]_p \approx (1 - \log_{10} A_1)(\tau_e)_{min} = \tau_p \tag{8}$$

The value of $(\tau_e)_{min}$ is observed at the music piece of the most active part containing the most "artistic" information like a "vibrato", a "quick" in the music flow and/or a very sharp sound signal like attack. The echo disturbance, therefore, may perceive at the signal piece occurring $(\tau_e)_{min}$.

Even for a long music composition, the music flow might be divided into such a short piece, so that the most minimum part of $(\tau_e)_{min}$ of the running ACF in the whole music, which determine the preferred temporal conditions, may be taken into consideration for the choice of music program to be performed in a given concert hall. A method of controlling the minimum value $(\tau_e)_{min}$, which determines the preferred temporal conditions for vocal music has been discussed [21, 22]. If the vibrato is introduced during singing, then it makes effectively decrease of $(\tau_e)_{min}$.

4.3.3 Subsequent Reverberation Time after the Early Reflections (T_{sub})

It has been examined that the most preferred conditions of frequency response to the reverberation time is just flat [19]. The preferred subsequent reverberation time is expressed approximately by

$$[T_{sub}]_p \approx 23(\tau_e)_{min} \tag{9}$$

The values A given by Equation 6 tested were 1.1 and 4.1, which cover the usual conditions of sound fields in a room.

Recommended reverberation times for several sound sources are shown in Figure 19. A lecture and conference room must be designed for speech, and an opera

house for two greatly different sources, i.e.,vocal music and orchestra music.

4.3.4 Magnitude of the Inter-Aural Crosscorrelation Function (IACC)

All available data over 500 listeners indicate a negative correlation between the magnitude of the IACC and subjective preference, i.e., dissimilarity of signals arriving at the two ears is preferred [29, 30]. This holds only under the condition that the maximum value of the IACC is maintained at the origin of the time delay keeping balance of sound field for two ears. If not, then an image shift of the source may occur. To obtain a small magnitude of IACC in the directions from which the early reflections arrive at the listener should be kept within a certain range of angles $\pm 55°$ from the median plane for usual sound sources consisting main frequency range centered on 1.0 kHz is It is obvious that the sound arriving from the median plane $\pm 0°$ makes the IACC greater. Sound arriving from $\pm 90°$ in the horizontal plane is not always advantageous, because the similar "detour" paths around the head to both ears cannot decrease the IACC effectively, particularly for frequency ranges higher than 500 Hz. For example, the most effective angles for the frequency ranges of 1 kHz and 2 kHz are about centered on $\pm 55°$, respectively.

In order to realize these conditions simultaneously, a geometrical uneven surface has been proposed [31].

4.3.5 Theory of Subjective Preference for the Sound Field

Let us now these results with the temporal factors extracted from the running ACF and the spatial factors extracted from the interaural cross-correlation function, associated with the left and the right human cerebral hemispheres, respectively, put into a theory of subjective preference.

Since the numbers of orthogonal acoustic factors, which are included in the sound signals at both ears, are limited to four as mentioned in Section 4.3 [17, 32, 33], the scale value of any one-dimensional subjective response may be expressed by

$$S = g(x_1, x_2, \cdots x_I) \equiv g_L + g_R \tag{10}$$

where according to the specialization of human cerebral hemisphere. It has been verified by a series of experiments that four objective factors act independently of the scale value when changing two of four factors simultaneously. Results indicate that the units of scale values are considered to be almost constant, so that we may add scale values to obtain the total scale value [32],

$$\begin{aligned} S \equiv g_L + g_R &= g(x_1) + g(x_2) + g(x_3) + g(x_4) \\ &= S_1 + S_2 + S_3 + S_4 \end{aligned} \tag{11}$$

where $g_L = S_2 + S_3$ and $g_R = S_1 + S_4$ and $S_i, i = 1, 2, 3, 4$ is the scale value obtained relative to each objective parameter. Equation 11 indicates a four-dimensional continuity. The scale value is relative and only addition and subtract operations may allowed.

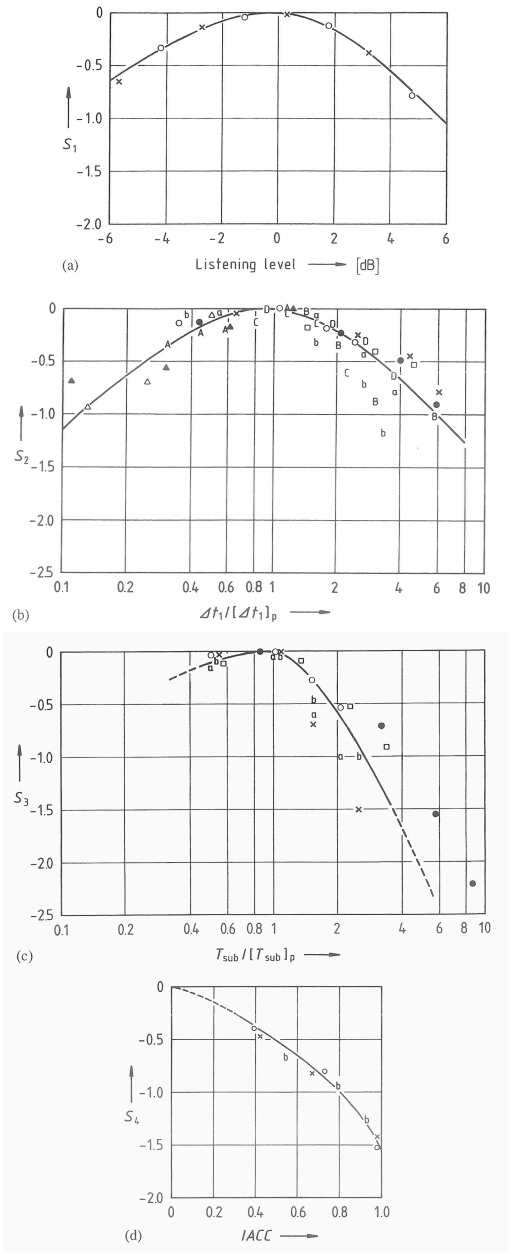

Figure 20: The scale value of subjective preference as a function of each of four orthogonal factors of the sound field obtained with a number of subjects difference symbols indicated difference music motifs. Solid lines are averaged values and utilized for acoustic design of sound field at each seating position by Equation 11 by use of architectural shape o in design stage. The maximum scale value is adjusted zero at the most preferred condition of each factor. (a) Scale value S_1 as a function of the LL. (b) Scale value S_2 as a function of the Δt_1 normalized by $[\Delta t_1]_p$ calculated by Equation 7. (c) Scale value S_3 as a function of the T_{sub} normalized by $[T_{sub}]_p$ calculated by Equation 9. (d) Scale value S_4 as a function of the IACC.

The dependence of the scale values on each of four orthogonal factors is shown graphically in Figure 20. From the nature of the scale value, it is convenient to put a zero value at the most preferred conditions, as shown in these figures. These results of the scale value of subjective preference obtained from the different test series; using different music programs, yield the following common formula as indicated by solid lines in Figure 20:

$$S_i \approx -\alpha_i |x_i|^{\frac{2}{3}}, \quad i = 1, 2, 3, 4 \tag{12}$$

where x_i is, and the values of α_i are weighting coefficients as listed in Table 3. If α_i is close to zero, then a lesser contribution of the factor x_i on subjective preference is signified.

The factor x_1 is given by the sound pressure level difference, measured by the A-weighted network, so that

$$x_1 = 20 \log P - 20 \log [P]_p \tag{13}$$

P and $[P]_p$ being the sound pressure at a specific seat and the most preferred sound pressure that may be assumed at a particular seat position in the room under investigation;

$$x_2 = log(\Delta t_1 / [\Delta t_1]_p) \tag{14}$$

$$x_3 = \log (T_{sub} / [T_{sub}]_p) \tag{15}$$

$$x_4 = IACC \tag{16}$$

Thus, the scale values of preference have been formulated approximately in terms of the 3/2 power of the normalized objective parameters, expressed in the logarithm for the parameters, x_1, x_2 and x_3. The remarkable fact is that the spatial binaural parameter x_4 is expressed in terms of the 3/2 powers of its "real values," indicating a greater contribution than those of the temporal parameters are. Thus, the scale values are not greatly changed in the neighborhood of the most preferred conditions, but decrease rapidly outside of this range. Since the experiments were conducted to find the optimal conditions, this theory holds in the range of preferred conditions tested for the four factors. This theory has been well based on neural activities in the auditory-brain system that is deeply related to subjective preference of the sound field. It has been clearly shown the two temporal factors the initial time delay gap between the direct sound and the first reflection Δt_1 and the subsequent reverberation time T_{sub} are associated with the left cerebral hemisphere, and the two spatial factors the IACC and the LL are associated with the right.

Applying the theory of subjective preference, we demonstrate the quality of the sound field at each seating position in a concert hall with a shape similar to that of Symphony Hall in Boston. Suppose that a single source is located at the center, 1.2 m above the stage floor. Receiving points at a height of 1.1 m above the floor level correspond to the ear positions. Reflections with their amplitudes, delay times, and directions of arrival at the listeners are taken into account using the image method.

Contour lines of the total scale value of preference calculated for Music Motif B are shown in Figure 21. This figure shows effects of the reflection from the side reflections on the stage. The sidewalls on the stage may produce decreasing values of IACC for the audience area. Thus, the preference value at each seat is increased, as shown in Figure 21(b) in comparison with that in Figure 21(a). In this calculation, the reverberation time is assumed to be 1.8 s throughout the hall and the most preferred listening level, $[LL]_p = 20 \log [P]_p$ in Equation 13, is assumed for a point on the center line 20 m from the source position

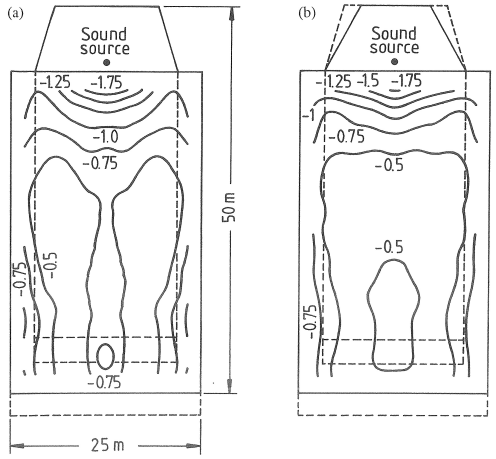

Figure 21: Examples of calculating the total scale value after obtaining the four orthogonal factors at each seating position. (a) The original room shape of the Boston Symphony Hall. (b) Modified stage enclosure of the Boston Symphony Hall.

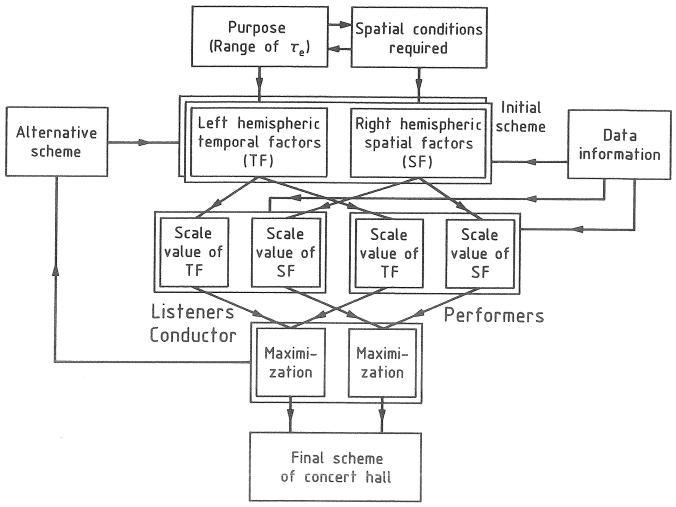

Figure 22: Acoustic-design procedure maximizing the scale value of both temporal factors (TF) and spatial factors (SF) for the sound field in a concert hall, enhancing the satisfaction for both human cerebral hemispheres for each listener, conductor and performer are taken into consideration.

4.4 A Case Study of the Kirishima International Music Hall

The principle of superposition of the scale value of subjective preference, with the optimal values of the four objective acoustic factors, can be applied to determine the total preference value at each seat. Comparison of the total preference values for different configurations of a concert hall allows us to choose the best design for a specific performance space, as well as for a certain music program.

Procedures for designing sound fields in a concert hall are illustrated in Figure 22. The purpose of this section is to demonstrate by means of a case studies how the acoustical design of a concert hall.

4.4.1 Temporal factors for listeners

First of all, the purpose of a concert hall undergoing planning is determined by the classification of the music to be

Table 3: Four orthogonal factors or design criteria of the sound field and its weighting coefficients α_i in Equation 12, which were obtained by a series of experiments (the paired-comparison test) on subjective preference with a number of subjects [32, 33].

i	x_i	α_i	
		$x_i < 0$	$x_i > 0$
1	$20\log P - 20\log [P]_p$ (dB)	0.07	0.04
2	$\log(\Delta t_1 / [\Delta t_1]_p)$	1.42	1.11
3	$\log(T_{sub} / [T_{sub}]_p)$	0.45 + 0.75A	2.36 - 0.42A
4	IACC	1.45	-

performed, with respect to a range of τ_e. The planning is associated with other facilities existing near the site, and with the location of the concert hall under design. If the space is designed for pipe organ performance, the temporal factors Δt_1 and T_{sub} are determined by the range of τ_e, which may be selected to be, say, centered about 200 ms ($T_{sub} \approx 4.6$ s). When designed for the performance of chamber-music, the range of τ_e is selected near the value of 65 ms ($T_{sub} \approx 1.5$ s). The conductor or the sound coordinator selects suitable music motifs with a satisfactory range of τ_e of ACF to achieve a music performance that blends the music and the sound field in the hall. The information for the ACF of music signals, and related subjective attributes are integrated. Moreover, in order to adjust the preferred initial time delay gap for each music performance location, the position of each instrument is carefully selected on the stage. For instance, if the values of τ_e for violins is shorter than that of contrabasses with mainly the low frequency ranges, the position of violins are shifted closer to the left wall on the stage and the positions of contrabasses are shifted closer to the center as viewed from the audience [33].

4.4.2 Spatial factors for listeners

As is discussed, the IACC should be kept as small as possible, maintaining $\tau_{IACC} = 0$. This is realized by suppressing the strong reflection from the ceiling, and by appropriate reflections from the side walls at particular angles. If the source signal contains mainly the frequency components around 1 kHz, the reflections from the side walls are adjusted to be centered at roughly 55 degrees to each listener, measured from the median plane of the listener. Under actual hearing conditions in an existing hall, the perceived IACC depends on whether or not the amplitudes of reflection exceed the hearing threshold level. Thus, a more diffuse sound field may be perceived with increasing power of the sound source. For example, Keet reported the apparent source width increases with increased listening levels [34]. While the source is weak enough, hearing only the direct sound, the actual IACC being processed in the auditory-brain system approaches unity, resulting in no diffuse sound impression. In general, small values of IACC can be realized by early strong reflections only. If the sound source is located in the center line on the stage, then coherent signals arrive at the same time from the both side walls. From this point of view, acoustical-asymmetric properties in shaping the hall may create further advantages.

As an initial design sketch of the Miyama concert hall, Kagoshima, Japan, a plan shape like a leaf (Figure 23) was presented at the first meeting for further discussion with the architect, Fumihiko Maki, with the explanation

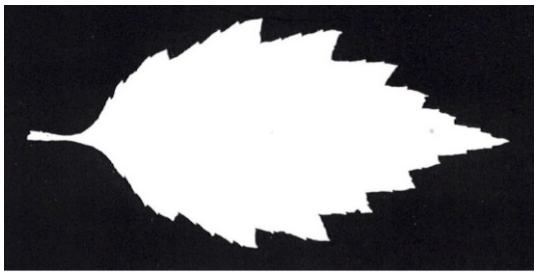

Figure 23: Leaf presented at Maki's office

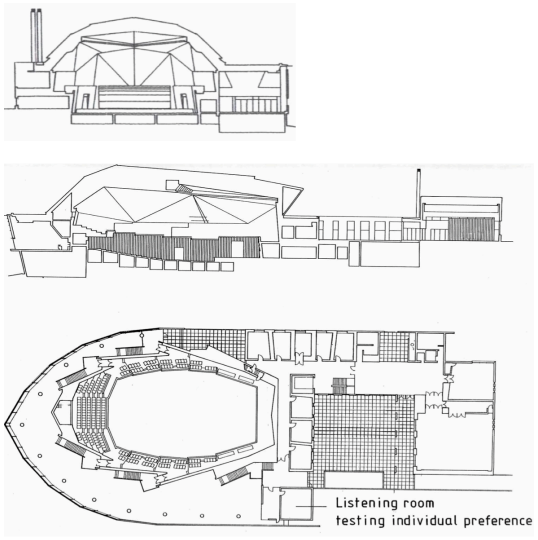

Figure 24: Longitudinal section and plane of balcony level of Kirishima International Music Hall (Miyama Conceru) designed by architect [35] as a leaf type.

of temporal and spatial factors of the sound field [33].

After some weeks, Maki indicated a revised scheme of the concert hall as shown in Figure 24 [35, 36]. Without any change of plan and cross sections, the calculated results for music motifs A and B indicated performed on τ_e stage are shown in Figure 25 [37]. Relatively, the total scale value for Music B performed in this hall much greater than than that for Music A, because of the effective duration τ_e of ACF for Music B is much more fitted with temporal factor of the sound field.

4.5 Design Study of Kirishima International Music Hall

Scale values of subjective preference for the four orthogonal factors were calculated at each seating position on an architectural scheme under work, the total scale values were obtained, inserted, resulting in a cyclically altered scheme. The process was repeated until satisfactory results were attained. Music performers are advised to blend the temporal factors of the sound fields with their musical program. To obtain an excellent sound field, the genetic

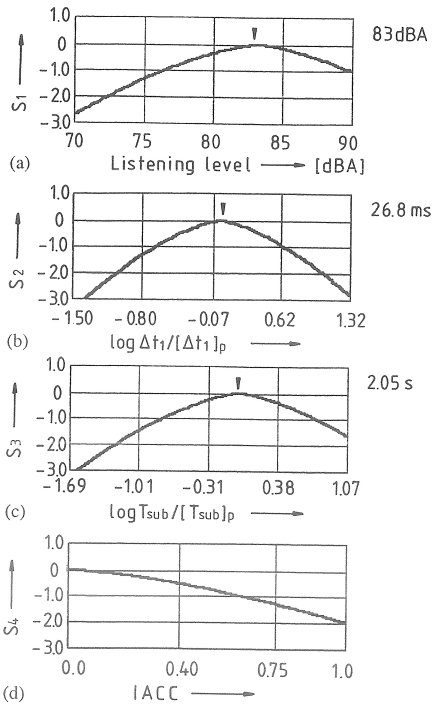

Figure 25: An examples of the scale value of individual subjective preference obtained by the paired comparison test for each of the four orthogonal factors of the sound field (subject BL). (a) The most preferred listening level was 83 dB A. (b) The preferred initial time delay gap between the direct sound and first reflection was 26.8 ms. (c) The preferred subsequent reverberation time was 2.05 s. (d) The scale value of subjective preference as a function of IACC. This tendency is the same for all of listeners, so that IACC is called the consensus factor.

algorithm (GA) operation has been executed on a shape modified from the Shoebox [26, 52]. The initial shape was a shoebox; 14 m wide, the stage was 9 m deep, the room was 27 m long, and the ceiling was 15 m above the stage floor. The sound source was 4.0 m from the front of the stage, but was 0.5 m to one side of the centerline and 1.5 m above the stage floor.

A practical application of this design theory was done for Kirishima International Concert Hall (Miyama Conceru) as shown in Figure 24, which was characterized as a "leaf shape." To enhance individual satisfaction for each listener, a special facility for seat selection, testing each listener's own subjective preference was first introduced in this hall [39].

4.6 Seat Selection System Enhancing Individual Preference

The listening room testing individual preference was utilized for maximize individual subjective preference for each listener a seat selection system was introduced as shown in Figure 26 [33, 38]. The music source was orchestral, "Water Music" by Handel. Typical examples of the test results as a function of each of the four orthogonal factors for listener BL are demonstrated in Figure 27.

The scale value of this listener BL was close to the average for subjects previously collected: the most preferred $[LL]_p$ is 83 dBA, $[\Delta t_1]_p$ is 26.8 ms (the averaged preferred value calculated was 24.8 ms, where $[\Delta t_1]_p = (1 - \log_{10} A)\tau_e, A = 4$), and the most preferred reverberation time was 2.05 s (the averaged preferred value obtained with a number of listeners was 1.43 s). Thus, the center area of seats was preferred for listener BL similar to the calculated value at the design stage (Figure 22). For all listeners, the scale value of preference increased with decreasing IACC value, thus it is called consensus factor.

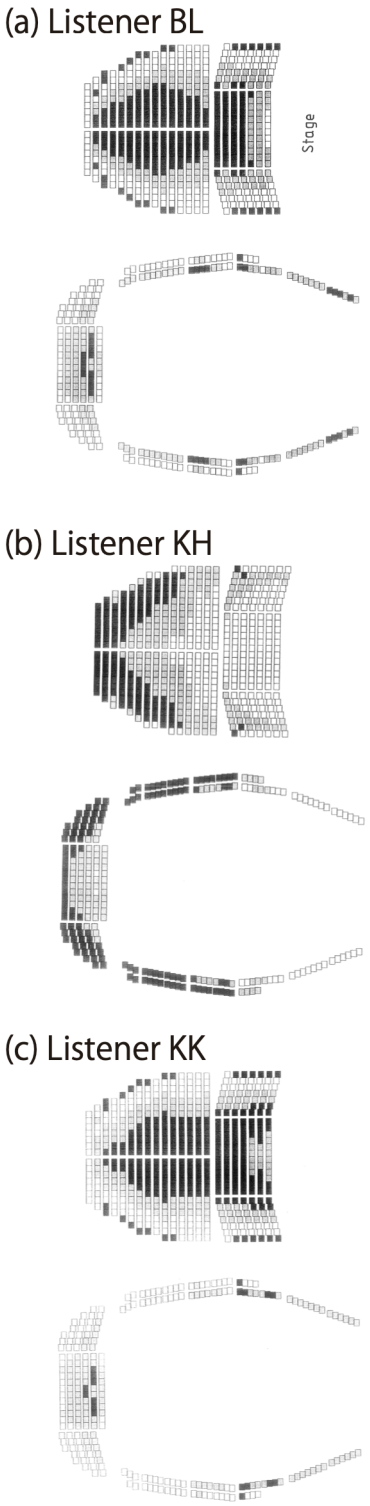

Figure 26: An example of Seat selection at Kirishima International Music Hall based on the four orthogonal factors (two temporal and two spatial associating, respectively, with the left cerebral hemisphere and the right hemisphere) of the sound field.

It is worth noticing that the most effective factor is IACC

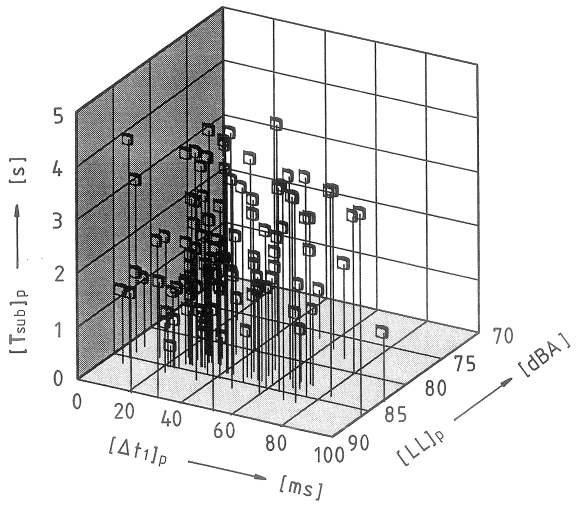

Figure 27: Individual difference of the most preferred values plotted in a three-dimensional grid ($[T_{sub}]_p$, $[\Delta t_1]_p$. and ($[LL]_p$.) factors obtained from 106 individuals other than one consensus factor: IACC [33].

so that smaller values are preferred for all of listeners. It is suggested that we need other three factors to be tested for future seat selection systems. We can use simple headphone systems for seat selection at any concert hall.

Since listener KH preferred a very short delay time of the initial reflection, his preferred seats were located close to the boundary walls as shown in Figure 26(b).

Listener KK indicated a preferred listening level exceeding 90 dBA. For this listener, the front seating areas close to the stage were preferable, as shown in Figure 26(c).

It has been shown that for all listeners, the smaller the IACC is preferred that is, so the sound waves arriving at both ears are different [33]. The sound field simulation system with distributed loudspeakers [38, 39] is no longer necessary.

Therefore, the following three faculties require testing for each individual.

1. The delay time (Δt_1) of early reflected sound varies greatly depending on individual preference.

2. Listening sound pressure level (LL) is also related to individual hearing ability, and there are large differences in preferences.

3. Reverberation time (T_{sub}) also varies greatly depending on individual preference. However, the reverberation time (T_{sub}) is almost the same for all seats in the hall.

Therefore, the music conductor should be carefully select according to type of music.

It is possible to test 1) to 3) by testing a large number of people at the same time using a headphone system before selecting seats together with for your accompanying persons being seated near to you. For example, the musical motif to be used may be just one, Royal Pavane composed by Gibbons, and then an average curve is applied based on the $(\tau_e)_{min}$ value of the music.

5 SUBJECTIVE PREFERENCE OF THE VISUAL FIELD, IN RELATION TO TEMPORAL AND SPATIAL FACTORS

Subjective preference for a flickering light obtained by the paired comparison test (PCT) was investigated in terms of the ACF factors of the signal in the time domain. It has been found that the preferred period of the flickering light with a sinusoidal signal is approximately 1 Hz [40]. The purpose of this study is to find more preferred conditions introducing a fluctuation to the flickering light. For this purpose, the bandwidth of the noise centered on 1 Hz, was varied at five levels (1, 2, 4, 8, and 16 Hz) by the use of the second-order Chebyshev filter. A remarkable finding is that the most preferred value of $[\phi_1]_p$ is about 0.46, where ϕ_1 can be extracted from the temporal ACF of the stimulus signal. The scale value of preference is formulated approximately in terms of the 3/2 power of the normalized ϕ_1 of a flickering light by the most preferred value, $[\phi_1]_p$. This result may suggest a reason, for example, why does one like the twinkling star. Further, we may produce a visual light and even a music signal based on this temporal factor, "vibrato," and also blending together.

5.1 Subjective Preference of a Flickering Light

In the natural environment there are plenty of visual aspects in wonderful temporal fluctuation, such as leaves in the wind and clouds in the sky, starlight twinkling to air currents, fire flames and water flowing in a river. Flames in a bonfire and gleaming or glittering sunlight reflecting off the surface of a waterbody provide us with a lively and splendid environment.

Although a number of studies have dealt with sensitivity to flickering stimuli, this section is concerned with subjective preference in time-varying light. Subjective preference is chosen as a primitive and overall response relating to aesthetics.

The preferred period for flickering light as a sinusoidal signal has been found to be approximately 1 Hz. To obtain a more preferred condition, we introduced a fluctuation to the sinusoidal flickering light centered on 1 Hz [41]. The amplitude of the first maximum peak of the ACF, ϕ_1 (vibrato), was controlled by changing the bandwidth of the white noise (1, 2, 4, 8, and 16 Hz), which corresponds to pitch strength. An 8-mm-diameter green light-emitting diode (LED), set at a distance of 1.0 m from the subject in dark surroundings, was the light source. The stimulus field from the LED was spatially uniform and its size corresponded to 0.46 of the visual angle. The mean luminance was set to 30 cd/m^2 and kept constant during the sessions.

The source signal was characterized by the ACF factors, $\Phi(0)$, ϕ_1, and τ_1 (Figure 28, the short duration $2T = 4.0$ s). The value of $\Phi(0)$, representing average power, was set constant. The τ_1 corresponding to the center frequency of the band-pass noise, fixed at 1.0 s.

Ten, 20–23-year-old subjects participated in the experiment. All had normal or corrected-to-normal vision. They adapted to the dark and watched the LED stimulus. Then, the PCT was performed for all combinations of the pairs,

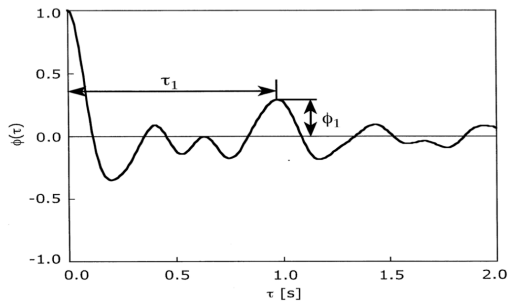

Figure 28: Definition of temporal factors τ_1 (pitch) and ϕ_1 (vibrato or pitch strength) extracted from the autocorrelation function of the fluctuation to the sinusoidal flickering light centered on 1 Hz.

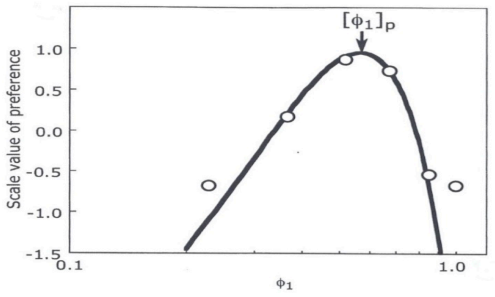

Figure 29: An example of obtaining the most preferred, $[\phi_1]_p (\approx 0.58)$, for a single subject. The scale value at $\phi_1 = 1$ is not taken into consideration in the fitted curve, because the decline of preference saturated already at $\phi_1 = 0.85$ in this case.

Table 4: The most preferred fluctuations in 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

i.e., 15 pairs of stimuli, interchanging the order in each pair per session, and the pairs were presented in random order. A total of ten sessions were conducted for each individual subject. The subjects were asked which stimulus they preferred to watch.

The most preferred, $[\phi_1]_p$, for each subject was obtained by fitting a suitable polynomial curve to a graph on which scale values were plotted. Figure 29 shows an example of the method used for finding $[\phi_1]_p$. The peak of this curve denotes the subject's most preferred value. Table 4 shows the results of $[\phi_1]_p$ for the 10 subjects, where the average value of $[\phi_1]_p$ was 0.46.

We attempted to determine the characteristics of the preference evaluation curve in more detail, in a manner similar to Equation 17. The preference evaluation curve can be expressed broadly by,

$$S = S_L \approx -\alpha[x]_p^{3/2} \tag{17}$$

Table 5: Values of α and β for each observer obtained for Equation 17. It is worth noticing that the average value of $\beta \approx 3/2$, so that the individual differences may be expressed by a single value alpha as indicated in Table 6.

Observer	α	β
A	9.16	1.17
B	4.98	0.72
C	7.98	1.28
D	11.98	1.39
E	11.42	1.36
F	5.53	1.36
G	6.94	1.46
H	24.72	2.37
I	14.93	2.41
J	6.57	1.23
Averaged		1.47

Table 6: The value of α obtained for each observer representing individual difference and the averaged value; when the value of β is fixed at 3/2 in Equation 17, then individual differences may be expressed by the single constant α.

Observer	α
A	15.99
B	18.00
C	11.02
D	14.45
E	13.82
F	6.49
G	7.27
H	8.32
I	5.88
J	8.53
Averaged	10.98

where α and β are the weighting coefficients and $x = \log\phi_1 - \log[\phi_1]_p$. After obtaining the most preferred value $[\phi_1]_p$ for each subject, values of α and β were obtained. To simplify Equation 17, the coefficient β may be fixed at a certain value so that the individual preference curve can be expressed by the sole coefficient α. The average value of β, estimated by a quasi-Newton numerical method, was approximately 1.47, as shown in Table 5. As discussed below, the scale value of preference for the period of a flickering light and circular stimulus moving in vertical and horizontal directions is also formulated approximately in terms of the 3/2 power of the normalized period [42]. Thus, the value of β was fixed at 3/2 here again, so that the coefficient α represents individual difference in subjective preference. The values obtained by a quasi-Newton numerical method, are listed in Table 6. The weighting coefficient α describes the sharpness of the preference curve with respect to ϕ_1.

Consequently, if the value of β is fixed at 3/2 in Equation 17, then individual differences may be expressed by the solo constant α only.

Figure 30 shows scale values for all of the subjects and the preference evaluation curve calculated by Equation 17. The correlation coefficient between scale values of preference and calculated values by Equation 17 is 0.92 ($p < 0.01$). Remarkably, as indicated in Table 5, the most preferred fluctuation expressed by $\phi_1 = 0.46$. This value is an intermediate value between those of sinusoidal wave $\phi_1 = 1$ and the perfectly random wave, $\phi_1 = 0$.

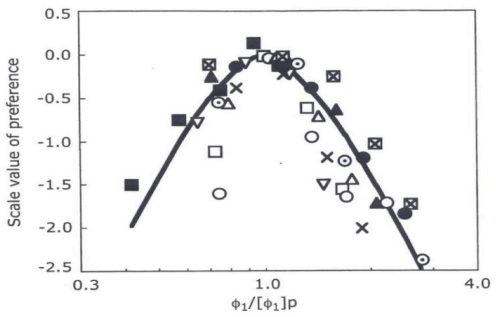

Figure 30: The normalized scale value of preference for all subjects. The solid curve is calculated value by Equation 17 with constants $\alpha = 10.98$ and $\beta = 3/2$ (Table 5). Different symbols indicate scale values obtained by different subjects. The abscissa is ϕ_1 normalized by $[\phi_1]_p$. The scale value at $[\phi_1]_p$ is adjusted to zero, without loss of any generality.

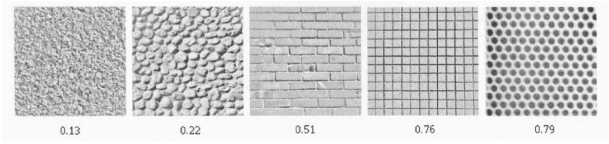

Figure 31: Two-dimensional spatial and significant textures by value of ϕ_1 (pitch strength) extracted from the normalized ACF as defined by Figure 28 used for subjective preference judgment by the PCT.

The scale value of preference is formulated commonly in terms of the 3/2 power of x of the flickering light. Thus, Equation 17 represents the preference evaluation curve, similarly to that of the sound field.

Many representations have been traditionally based on the spectral patterns, however, pitch of complex tones and timbre, for example, can be well described by temporal factors extracted from the ACF [1, 2].

5.2 Subjective Preference for Vertical and Horizontal Movements of a Target

Preference judgments using the PCT for sinusoidal movements of a single circular target without any fluctuation on a monitor screen were performed. The period of stimulus movements was varied separately in the vertical or horizontal direction.

Results show that the most preferred periods ($[T]_p$) for all subjects are about 1.0 s in the vertical direction and about 1.3 s in the horizontal direction. The curve of the scale values of preference may be commonly expressed by Equation 17 with $x = \log_{10} T - \log_{10} [T]_p$ and $\beta = 3/2$. All observers participated in the vertical direction series showed that the curves for the scale value of preference are significantly steeper in the fast-moving range in reference to $[T]_p$, than those in the slow-moving range.

5.3 Subjective Preference for Textures

To determine if temporal fluctuation applies to spatial fluctuation in texture [26], a subjective preference test for textures as shown in Figure 31 was conducted by changing the factor ϕ_1 (pitch strength) as defined in Figure 28.

Results of subjective preference SV with ten subjects are shown in Figure 32. The upper figure shows a degree of individual differences. The scale values of all individuals

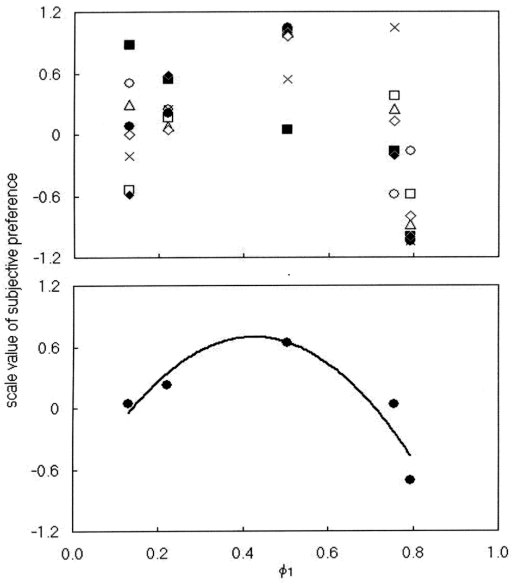

Figure 32: Above: Scale values of preference obtained from ten individual subjects. Below: Averaged preference values and a curve fitted with Equation 17.

and number of subjects, the scale value of preference can be approximately expressed by

$$S \approx -\alpha [x]_p^{3/2} \tag{18}$$

where x is $\phi_1 / [\phi_1]_p$, the averaged weighting coefficient α, and the most preferred value for texture regularity was found $[\phi_1]_p \approx 0.41$.

It is worth noticing that subjective preference for flickering light was obtained by the PCT, which was investigated in terms of ACF factors of the signal in the time domain. The most preferred degree of fluctuation was found around $[\phi_1]_p \approx 0.46$, and the scale value of preference was formulated approximately in terms of the 3/2 power of the normalized ϕ_1 of flickering light by the most preferred value, $[\phi_1]_p$ similar to Equation 18. Thus, a certain degree of fluctuation in both temporal and spatial factors is a visual property maximizing subjective preference [26, 41]. The same formula with 3/2 power of four normalized orthogonal factors given in Equation 18 is true in preference theory of the sound field [11, 17].

6 THEORY OF PREFERENCE OF LIFE MAINTAINING SURVIVAL POWER AMID VARIOUS STRESSORS

The theory of preference amid various stressors of life as shown in Figure 33 is a general theory of continuance to the well-known stress theory [43], which connected mainly with symptomatic therapy. It emphasizes the most powerful preference for a life based on the unique personality (DNA) of an individual – life that should be founded on nourishing creativity associated with both cerebral hemispheres. Knowledge gained may integrate with and become culture, crossing the boundary of physical time associated with individual life in society (the third stage of individual life).

The theory supports to maintain survival power and health even within a vast variety of stressors (Figure 33).

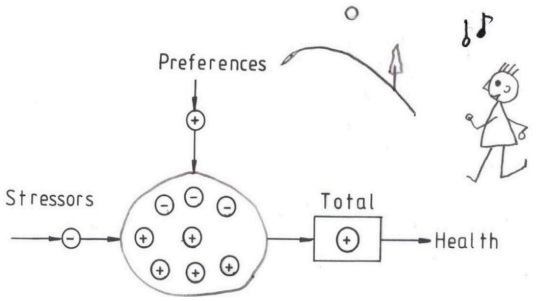

Figure 33: Theory of preference of life maintaining survival power amidst various stressors. Innocence in preferences increases life force, so that deeply connected with preventive medicine [44].

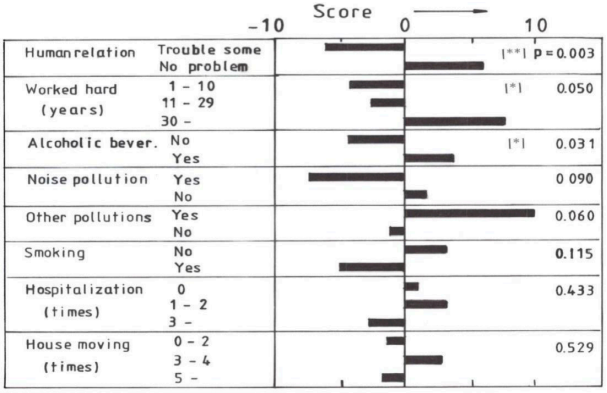

Figure 34: Results of each category of eight factors in calculating DIA by the analysis. Symbols [**] and [*] mark significance levels 0.01 and 0.05, respectively.

The most survival power is directly related to a person' s unique preference originating in their DNA when she chooses her field of practice or life direction, which is intertwined with personality-driven creations. Other wonderful things exist in nature that are the source of universal affection, for example fresh air, green leaves, a water stream. Sometimes, music or a drawing by may provide an impetus for further exploration.

Before verbal communication begins to show at around age two, nonverbal communications associated with the right human cerebral hemisphere are present in babies less than one year of age. It is interesting to note that with animals and plants, nonverbal cues are the primary communication channel. The breadth of nonverbal communication may easily reach all creatures on earth and perhaps even beyond. The survival power associated with deeply preferred creative activities that resonate with unique personality (DNA) might be strongest because of the potential for integration with social culture even after the individual lifetime has ended (third stage of life). In other words, as shown in Figure 1, the third stage of life may continue as culture even after the end of individual life, that is, as the fourth stage of life [45], provided future generations accept the creation. Creativity, handled properly, can thus be a doorway to an eternal life for an individual.

7 AN INVESTIGATION ON EFFECTS OF PREFERENCE AND STRESS ON DIALYSIS INTRODUCTION AGE (DIA)

To examine the theory of preference of life amid various stressors, this section shows stressors and preference factors that determine dialysis introduction age (DIA) or onset age of dialysis, which was conducted by analyzing a questionnaire distributed to patients attending a hospital in Kobe, Japan [1, 2]. To predict DIA according to 16 factors of stress and preference in addition to factors of dwelling environment as well as clinical history obtained by questionnaire, the mathematical quantification theory [46] was applied. The total questionnaire data collected were 34 but valid data were 30 without lack of data, which were unanswered. The DIA data were rearranged by rounding, for example, 55 to 50 and 68 to 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 to describe DIA:

1) Human relations, 2) hard work over the years, 3) consumption of alcoholic beverages, 4) noise pollution at the dwelling, 5) other pollutions, 6) smoking, 7) number of hospitalizations, 8) number of times moving house.

Note that other factors including gender, pets, bad odors, past noise pollution was insignificant. Remarkably, results showed that troubled inter-human relations (the first step toward wars) are potential accelerators of DIA, caused by severe stress ($p < 0.01$) as shown at the top of Figure 34. On the contrary, the preference factor of social drinking ($p < 0.05$) in an amount less than 180 cc of Japanese Sake as well as wine as indicated on the third row of Figure 34, as it has been said to be the best of all medicine, postponed DIA. As indicated on the second row of the figure, "hard work" for less than 29 years acted as stressor, but for more than 30 years postponed DIA due to habituation effects relative to a period shorter than 29 years ($p = 0.05$). As indicated on the fourth row, noise pollution acted as a stress factor ($p < 0.1$). DIA calculated with 8 factors is roughly agreeable with the DIA reported by the participating patients. The coefficient determination was 0.59, that is, high enough in this kind of investigation with the questionnaire. It is remarkable that the second significant factor to postpone DIA was preferred alcoholic beverage. It is said, therefore that head of 100 medicines due to few side effects.

Noise affecting unborn babies and children [4, 6, 7, 9, 11, 47], ugly visual design without knowing or applying the preference theory [3], and troubled human relations are all factors that form a considerable part of our everyday environment, causing a situation where the pleasure derived from the process of living is regretfully often drained away by stress. Losing individual survival power may cause serious illness such as cancer, kidney disease, dementia, intractable disease, various infections and complications from the corona virus. However, the possibility to enhance our natural survival mechanism exists which is considered in the dynamical theory of preference of life amid various stressors and by the preference factors that determine onset age of disease as discussed above.

Clearly, the survival power of all individuals in the whole world was relatively less than that of the coronavirus. Thus, a negative spiral of society throughout the

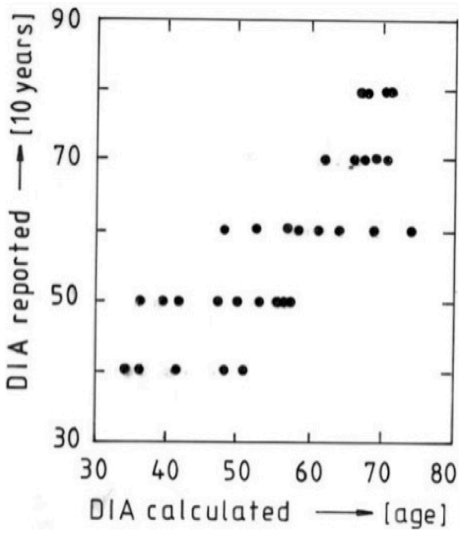

Figure 35: Relationship between DIA calculated utilizing results of analysis, and DIA (10 years as round number) reported in the questionnaire by each patient. Remarkably, DIA may be roughly described by eight factors indicated in Figure 34.

world will occur, if globalization of majority-based society will not change into individual based society. For example, to reduce greenhouse gas by temporal design, stopping global warming is one of the main challenges.

The industrial revolution of 1830 brought about a shift to global activity and handling of issues, which is the overarching problem, we still face today in the form of industrial productions and related mass transportation. Our emphasis is on original creativity and its extensions into society through a person's third stage of life, which is preferred individual activity that resonates with a person's unique DNA, and on the temporal and spatial objectives for our physical environment, associated with the left and right human cerebral hemispheres, respectively, as expressed in the design theory of preference [3]. Most generally, in everyday life from the first to third stages, subjective preference is regarded as a primitive response of living creatures that entails judgments that steer an organism in the direction of maintaining life, to enhance its prospects for survival. Balance between creations and recreations in individual life are highly recommended. The nature of preference is not a thing of luxury, per se, it is rather an underlying mechanism that may be deeply associated with the base, and our sense of, aesthetics.

8 NEW CONCEPT OF TWO OPPOSITE POLES : GLOBALIZATION BASED SOCIETY AND INDIVIDUAL PREFERENCE BASED SOCIETY

We do not know that how many thousand years will the healthy sun continue to shine as before. And, how many thousands of years will healthy humanity be able to exist. There are unknown challenges beyond imagination. Concerning human being, all individuals may be satisfied as a minimum unit of society due to their preference driven by DNA maximizing unique creation and minimizing stress. Number of all of individuals existing in the world is a limited integer, and small enough from the viewpoint of computer memory and operation. Preference is the base of aesthetic issue. The temporal and spatial environmental design minimizing stress and realizing preventive medicine without drags and its side effects for thousands years. A societal model as such may enhance individual preference for realizing health and peace. The number of unknowns is infinite in the world to be discovered. Thus, education for creations based on individual personality (DNA) and preference [48] should be realized. On the other hand, economic resources are limited in the world, and we should have a better grasp of how to allocate resources to every individual.

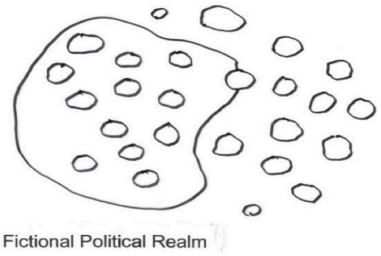

Figure 36: From globalization of a majority-based society to an individual-based society. A realm indicates globalization, however, there will always be preferences of individuals outside of the realm. All individuals with their preference may be satisfied as a minimum unit of society, as the number of individuals existing in this world is a limited integer. It is small enough from the viewpoint of computer memory and operation.

At present, however, it is normative that human life is overwhelmingly occupied by a wide variety of stressors. For example, environmental noise affecting unborn babies and children [4, 6, 7, 9, 11, 47], ugly visual design without knowing or applying the preference theory [3], and troubled human relations that have been covered above, all form a considerable part of our physical environment so that the pleasure derived from the process of living is regretfully often drained away by stress. Losing individual survival power may cause serious illness such as cancer, kidney disease, dementia, intractable disease, infections and complications from the coronavirus.

The study performed on DIA reveals the possible areas for application of the theory of preference of life amid various stressors. Preference and stress factors determine the onset age of the kidney disease. The problem was the survival power of individuals in the whole was subject to relatively less than that of the coronavirus. A negative spiral of society throughout the world will occur if globalization of the majority-based society will not change into individual-based society, as shown in Figure 36.

Globalized activities from industrial productions to related mass transportation have been causing environmental problems since the industrial revolution in 1830. Typical problems have been even more perplexing since the atomic the atomic weapons were dropped over Hiroshima and Nagasaki.

We hope, therefore, for adoption of a societal model that is based on original creativity that carries an individual through the third stage of life into positive integration with societal culture. This individual-based model of society is built on preferred individual activity that resonates with a person's unique DNA, and the temporal and spatial objectives associated with the left and right cerebral hemi-

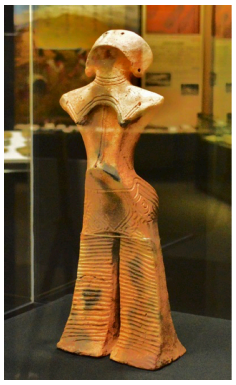

Figure 37: An example of the fourth stage of life: "Jomon Venus" about 4,500 years ago, 45cm height discovered in 1992, Nishinomae site, Funagata-machi, Yamagata, Japan.

spheres, respectively, [3] as framed by the design theory of preference. Most generally, in everyday life from the first to the third stages (Figure 1), subjective preference is regarded as a primitive response of living creatures that entails judgments that steer an organism in the direction of maintaining life, to enhance its prospects for survival. Balance between creations and recreations in individual life are highly recommended. Preference is not a thing of luxury; therefore, it is associated with the base of aesthetics (ex. Figure 37).

ACKNOWLEDGMENTS

Marianne Jogi improved English expressions.

Appendix

A Genetic Algorithms (GA) for Optimizing Room-Forms by the Spatial Factor

The theory of subjective preference in terms of the four orthogonal acoustical factors has been described [17, 33] allows us to evaluate at each seat of the sound field in an enclosure under design. The linear scale value of subjective preference has been obtained by using the law of comparative judgment. The units of the scale value derived from a series of experiments with different sound sources and different subjects were almost constant, so the scale values may be added as expressed by, Equation 9. Here, an application of the GA to the system for optimizing the shape of an enclosure is available with the spatial factor of sound fields, which is associated with the right hemisphere. The first model was an optimization of the proportions of a hall of the typical shoebox type. The results show that the optimized form is similar to the "Grosser Musikvereinssaal" in Vienna. The second model is the optimization of the shape with a number of portions of modification. A kind of the leaf-shaped plan is a typical result of the maximization of the scale values of subjective preference in relation to the IACC for the audience area.

The temporal and spatial factors are carefully designed, in order to satisfy both left and right human cerebral hemispheres for each listener, respectively. The GA [49], a form of evolutionary computing, has been applied to a variety of complex engineering problems.

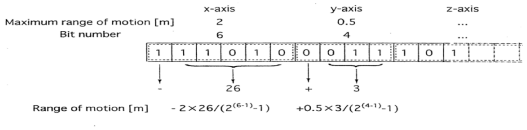

Figure A.1: An example of the binary strings used in encoding of the chromosome to represent modifications to the room shape.

The algorithm is started with a set of solutions (represented by "chromosomes") that is called a population shown in Figure A.1 Solutions from one population are selected to form a new population. This is repeated until a condition (for example, an improvement over a previous best solution) is satisfied.

A.1 GA operations

In this study, a GA system was applied to the design of enclosures [50]. The GA system was used to generate the alternative scheme. Those architectural schemes, which produce greater scale values of subjective preference, are selected in the process of evolution. We started by applying this technique to optimize the proportions of the most basic form that is a shoebox shape of enclosure. The scale value of subjective preference is employed as fitness function. Those enclosure shapes that produced greater scale values are selected as parent chromosomes. To create a new generation, the room shapes are modified and the corresponding movement of the vertices of the walls is encoded in chromosomes, i.e., binary strings. After GA operations that included crossover and mutation, new offspring were created. The fitness of the offspring was then evaluated in terms of the scale value of subjective preference. This process here was repeated until the end condition of about two thousand generations had been satisfied.

The typical spatial factor is IACC for a source on the stage were calculated at each of a set of seats. The single omni-directional source is located at the centre of the stage, 1.5 m above the stage floor. The receiving points that correspond to the ear positions were 1.1 m above the floor of the hall. The image method is applied to determine the amplitudes, delay times, and directions of arrival of reflections at these receiving points. Reflections were calculated up to the second order to reduce the calculation time. Note that second-order reflection is enough to provide convergence of the physical factors for a listening position near the stage. The averaged values of the IACC for five music motifs (Motifs A through E, in [17] were applied.

According to architectural scheme under design, the scale value in relation to each orthogonal factor $S_i (i = 1, 2, 3, 4)$ can be calculated by Equation 11. Here, the parameters x_i and coefficients α_i are in Equation 12 are listed in Table 3. In this calculation, the scale values of subjective preference due to IACC, i.e., S_4, are applied as the measure for the sake of simplicity, because the geometrical shape of a hall directly affects this spatial factor. Before going into GA operation, it is highly recommended to have a good initial shape of room so as to be small values of IACC due to recommended angles centered on 55

Table A.1: Comparison of proportions for the optimized by GA with the $\bar{S}_4$ (IACC) of "shoebox type," and the existing Grosser Musikvereinssaal.

	Length/widht	Height/width
Optimized for $\bar{S}_4$ for the IACC	2.57	1.43
Grosser Musikvereinssaal	2.55	0.93

left and right sides from the media plan for early reflections to each seating position that is important to obtain a final scheme of an enclosure without a lot of time in calculations.

The scale values of S_2 and S_3 were excluded, because due to the temporal factor that are much related to the value of $(\tau_e)_{min}$ of music signals (Figure 19). Changing the performance style of vocal sound on the stage. these temporal factors may be satisfied. It has been found that music and vocal sound with rapid movements sounds or vibrato are best fitted in an enclosure with a short initial time delay gap Δt_1, and a short subsequent reverberation time T_{sub}. A slow tempo music performed in the pit is blended by relatively long values for the factor Δt_1 and T_{sub} that is classified by the value of $(\tau_e)_{min}$.

A.2 Example of Designing a Shoebox-Type Enclosure

First of all, the proportion of the shoebox hall has been optimized by GA. The initial geometry was the hall with 20-m wide, the stage of 12-m deep, 30-m long, and the ceiling of 15 m above the floor. The point source was located at the centre of the stage and 4.0 m from the front of the stage and seventy-two listening positions were selected. The range adjusting each sidewall and the ceiling is ± 5 m from the respective initial positions, and the distance through, which each was moved, was coded on the chromosome of the GA. The scale value at the listening positions other than those within 1 m of the sidewalls were included in the average ($\bar{S}_4$). As is well known that all subjects tested, the preference increases with decreasing IACC [17, 51] commonly.

The result of GA operation is indicated in Table A.1. It is similar to the proportions of the "Grosser Musikvereinssaal," which was said the most excellent concert hall at that time. The length/width ratios resulted are almost the same as those of "Grosser Musikvereinssaal."

A.3 A Shape Improved from the Shoebox-Type Enclosure

The range of sidewall and ceiling variation was ± 5 m from the initial scheme. According to the above results an initial form was 14-m wide, the stage was 9-m deep, the room was 27-m long, and the ceiling was 15 m above the stage floor. The sound source was again 4.0 m from the front of the stage, but was 0.5 m to one side of the centerline and 1.5 m above the stage floor. The front and rear walls were vertically bisected to obtain two faces, and each stretch wall along the side of the seating area was divided into four faces. The walls were kept vertical (i.e., tilting was not allowed) to examine only the plan of the hall in terms of maximizing $\bar{S}_4$. Each wall was moved independently from other walls. In the acoustical simulation using image

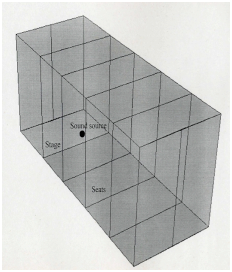

Figure A.2: The initial scheme of an enclosure.

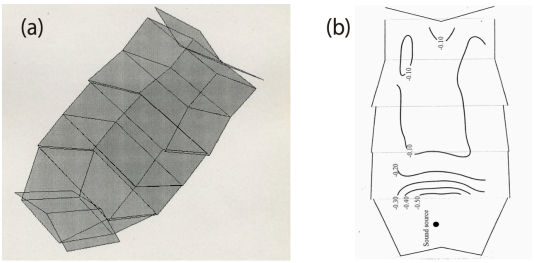

Figure A.3: A shape improved from the shoebox enclosure resulted by GA that likes the leaf type.

method, the openings between walls were assumed not to reflect the sound. Forty-nine listening positions distributing throughout the seating area on a 2×4 m grid were selected. In the GA operation, even though the sidewalls were moved, these forty-nine listening positions were all included. The moving range of each vertex was ± 2 m in the direction of the line normal to the surface. The coordinates of the two bottom vertices of each surface were encoded on the chromosomes for the GA. In this calculation, the most preferred listening level was assumed for a point on the hall's long axis (central line), 10 m from the source position for the sake of convenience.

The result of optimizing for $\bar{S}_4$ is shown in Figure A.3a and contour lines of equal $\bar{S}_4$ values are shown in Figure A.3b. To maximize $\bar{S}_4$, the rear wall of the stage and the rear wall of the audience area took on convex shapes that avoid reflections from near the median plane.

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