Reviews on the Temporal Design for Three Stages of Human Life. *Most unlikely "time is money," but "time is life."* [a)]

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It has been discussed that auditory and visual sensations, in terms of the temporal and spatial factors, are associated with the left and the right human cerebral hemispheres, respectively (Ando, Auditory and Visual Sensations, to be published). The purpose of this paper is to apply this type of concept to general environmental design. An approach is made here, emphasizing the temporal design in architecture and in the environment. All healthy ideas, creations, and discoveries that have contributed to human life for thousands of years, have been based on the unique personality of the individual. Therefore, it is highly recommended that the environment be designed for three parallel stages of time, 1. the time of body, 2. the time of mind, and 3. the time of creation based on a unique personality. A well-designed environment would be a meeting place for the arts and sciences associated with both hemispheres, and in turn, might help further the discovery of the individual's personality as a minimum unit of society. A typical example can be seen in the Kirishima International Music Hall, which opened in 1994. The acoustic design together with the seat selection system is made to the subjective preference judgments of each individual [Ando, Architectural Acoustics, Blending Sound Sources, Sound Fields, and Listeners, Springer-Verlag, New York, 1998]. Similarly, to develop a healthy personality in children, temporal and spatial design should be considered in their environment because such an environment is an essential element for the development of the brain through the temporal and spatial information it receives. To activate both cerebral hemispheres for finding individual personality, a creative working space (CWS) in the home plays an important role [Bosworth and Ando, Journal of Temporal Design in Architecture and the Environment, 6, 18-25, 2006]. In addition, through the internet and company information systems, employees can work and study from home, thus realizing the maximum effects with the minimum of effort for both time and energy. Development of the left and right cerebral hemispheres begins in the early stages of pregnancy even before the development of the arms and legs. Therefore, the environments associated with the development of the brain, such as museums, libraries, opera houses and concert halls should be constructed during the early stages of a new city. It is worth noticing that environmental noise, for example, critically affects the development of specialization in both hemispheres [Ando, Journal of Sound and Vibration, 241, 129-140, 2001].

Keywords: development of cerebral hemispheres, design theory of environment, temporal and spatial factors, design studies of concert hall, creative work space (CWS)

1. INTRODUCTION - THREE STAGES OF TIME TO BE DESIGNED

Our rapidly changing environment is causing people to wonder how long this environment will remain suitable for living. To present, knowledge has been limited (Fig. 1) and unable to resolve this anxiety. To begin addressing this question from the temporal perspective, attempts are made here for temporal design in architecture and in the environment. This is made possible by addressing three stages of an individual's life (Fig 2):

1. the life of the body,
2. the life of the mind (for duration experience for every three year period below 18 years of age, see APPENDIX I), and
3. the life of ideas, creations and findings based on unique personalities.

The third life is the source of creation and the most unique to man. All healthy creations that have contributed to human life have been based on the unique personalities of the individual.

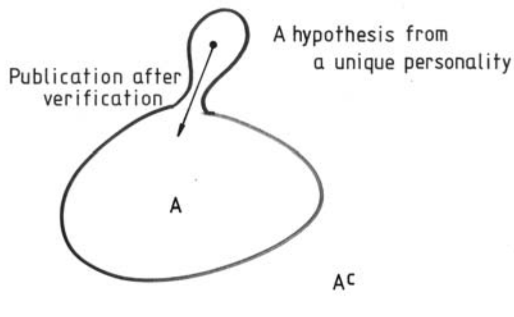

Fig. 1. A set of known limited, A, and an infinite number of unknown, A^C (Ando, 2004).

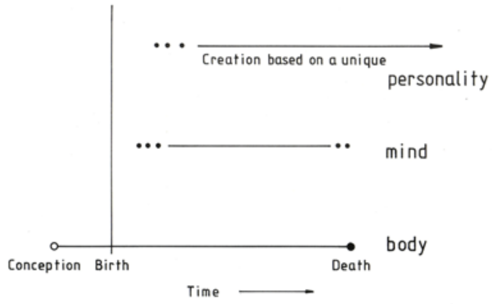

Fig. 2. Three-time stages of human life to be considered in the temporal design (Ando, 2004). Findings and creations based on a unique personality may contribute to society even after the end of life, body, and mind.

Thus, the environment should be designed for the three stages of life of the individual. A well-designed environment would be a meeting place for the arts and sciences, and in turn, may further the discovery of the individual's personality. While animals posses the first and second lives, they lack the third life, because they have no systems for integrating knowledge over time.

In the early stage of human life, environments containing temporal and spatial information are the most important for babies. Temporal information from the environment as well as maternal talks, play important roles in the development of the left hemisphere in babies. Spatial and nonverbal information-containing environment, such as art and space forms, may help in the right hemisphere development. The theory of designing sound fields that takes into account temporal factors together with spatial factors based on brain activities has been described (Ando, 1985; 1998; 2003). The sound field in a room can be altered with careful manipulation of four orthogonal factors describing subjective preference. These factors comprise two temporal factors, associated with the left hemisphere, and two spatial factors, associated with the right hemisphere. The spatial factors (IACC and LL) can determine the architectural form of the hall. The temporal factors are closely related to the design of a specific concert hall, which can be altered to showcase specific types of music, such as organ music, chamber music or choral works. It is worth noticing that generally, subjective preference itself is regarded as a primitive response of the living creature that entails judgments that steer an organism in the direction of maintaining life, so as to enhance prospects for survival. Compare this to the effects of long-term environmental noise on the three stages of life in the fetus and children that are discussed in APPENDIX II.

The purpose of this article is to apply such design theory in which temporal factors and spatial factors are explicitly considered for general environmental planning and design (Ando, Johnson and Bosworth, 1996). Reviews of the temporal design for the three area of human life are made here. It is hoped that the survey presented here, “taking temporal factors in design of architecture and the environmental into account,” can suggest a suitable line for further investigations for each person of about 6.3 billion existing on the earth as of 2005 for a lasting peace.

2. MODEL OF BRAIN SYSTEM FOR THE TEMPORAL AND SPATIAL FACTORS

2.1. Specialization of cerebral hemispheres for the sound field

The temporal factors associated with the left cerebral hemisphere may be extracted from the autocorrelation function (ACF) processors. And, the spatial factors associated with the right hemisphere may be extracted from the interaural crosscorrelation function (IACF) processor for the signal arriving at the two ear entrances. Any subjective attribute has been described by the use of these temporal and the spatial factors as well as the specialization of human cerebral hemispheres (Ando, 2002).

Independent influence of the above mentioned temporal and spatial factors subjective preference judgments have been achieved (Ando, 1983). Recordings over left and right hemispheres of the auditory brainstem response (ABR) as reflected activities from six nuclei in the auditory pathway (latency is observed at less than 10 ms), the slow vertex response (SVR) as reflected activities on the left and right hemispheres (latency is observed between 50 ms and 400 ms), the electroencephalogram (EEG) and the magnetoencephalogram (MEG) have revealed the following evidence (Table 1).

1) The left and right amplitudes of the early SVR, $A(P_1 – N_1)$ indicate that the left and right hemispheric dominance are due to the temporal factor (initial delay gap between the direct sound and the first reflection, Δt_1) and spatial factors (listening level, LL, and magnitude of IACF, IACC), respectively. From a physical point of view depending on the time, the sensation level (SL) or LL was first thought to be classified as a temporal-monaural factor. However, the results of SVR indicate that the sound level is right hemisphere dominant. Thus, SL or LL should be classified as a spatial factor, which is measured by the geometric average value of the binaural sound energies arriving at both ears (Ando Kang and Morita, l987; Ando, Kang and Nagamatsu, 1987; Ando, 1992).

2) Both left and right latencies of N_2 correspond well to the

Table 1. Hemispheric specialization determined by analyses of AEP (SVR), EEG and MEG determined hemispheric specializations.

Factors changed	AEP(SVR) $A(P_1 - N_1)$	EEG ratio of ACF τ_e values of α-wave	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 (music)[2]	---
	R > L (band noise)		

[1]Sound source used in experiments is indicated in parenthesis.
[2]The flow of EEG α-waves from the dominant right hemisphere to the left hemisphere for music stimuli in change of the IACC was determined by the CCF $|\phi(\tau)|_{max}$ between α-waves recorded at different electrodes.

IACC (Ando, Kang and Nagamatsu, 1987).
3) Results of EEG for the cerebral hemispheric specialization of the temporal factors, i.e., Δt_1 and the subsequent reverberation time (T_{sub}) indicated left hemisphere dominance, and the IACC was the right hemispheric factor. Thus, a high degree of independence between the left and right hemispheric factors may be achieved (Ando and Chen, 1996; Chen and Ando, 1996).
4) The scale value of subjective preference is well corresponded to the value of τ_e of extracted from ACF of the α-wave over the left hemisphere and the right hemisphere according to the change of temporal and spatial factors of sound fields, respectively (Ando and Chen, 1996; Chen and Ando, 1996).
5) Amplitudes of MEG recorded when Δt_1 was changed reconfirms the left hemisphere specialization (Soeta, Nakagawa, Tonoike and Ando, 2002).
6) The scale values of individual subjective preference relate directly to the value of τ_e extracted from the ACF of the α-wave of the MEG. It is worth noticing that the amplitudes of the α-wave in the EEG and the MEG do not correspond well to the scale value of subjective preference (Soeta, Nakagawa, Tonoike and Ando, 2002).

In addition to above mentioned temporal activities both on the left and right hemispheres, spatial activities on the brain were analyzed by the cross-correlation function of alpha waves of EEG and MEG. The results show that a large area of the brain is activated, when the preferred sound fields are presented (Okamoto, Soeta and Ando, 2003; Sato, Nishio, and Ando, 2003; Soeta, Nakagawa, Tonoike, and Ando, 2003). These imply that the brain repeats a similar temporal rhythm in the alpha-wave range over such a wider area over the scalp under preferred sound fields.

Previously, it has been found that the left hemisphere is mainly associated with time-sequential identification (Zatorre and Belin, 2001, Wong, 2002), and the right hemisphere is fundamentally concerned with spatial identifications. The left-hemispheric specialization of speech signals has been reported by a number of authors using EEG and MEG (For example, Eulitz, et al, 1995, Naatanen, et al, 1997, Alho, et al, 1998). By records of functional magnetic resonance imaging (FMRI or fMRI), it has been shown that left hemisphere specialization for verbal and right hemisphere for nonverbal corded information (Opitz, Mecklinger and Friederici, 2000). The left hemisphere is mainly associated with speech and time-sequential identifications, and the right is concerned with nonverbal and spatial identification (Kimura, 1973; Sperry, 1974). However, when the IACC was changed using speech and music signals, the right hemisphere dominance was observed as indicated in Table 1. Therefore, hemispheric dominance is relative depending on which factor is changed in the comparison pair and no absolute behavior could be observed.

2.2. Specialization of cerebral hemispheres for the visual field

Here, we summarize factors in the alpha wave corresponding to subjective preference, and the specialization of human cerebral hemispheres for the temporal factors of the visual field.

Next, we have investigated activities on both the EEG and the MEG, which correspond to subjective preference for the visual field. Results revealed are:
1. The ACF τ_e value of the alpha wave range at the preferred period of the flickering light was longer than those for the less preferred one for all subjects ($p < 0.01$).
2. Remarkably, averaged values of τ_e and ϕ_1 extracted from the ACF of the MEG alpha wave from the left hemisphere area were significantly greater than those from the central and right areas ($p < 0.01$).
3. The values of τ_e (and ϕ_1) for the preferred stimuli were greater than those for the less preferred stimuli ($p < 0.01$). It is obvious that the value of τ_e correlated to the value of ϕ_1 ($r = 0.72$, $p < 0.01$), but not to the value of $\Phi(0)$ ($r = 0.23$).
4. It is concluded that averaged values of τ_e and ϕ_1 from the left (O1) area were significantly longer than those from the central and right stages (O2).
5. We found in the MEG study that the values of τ_e (and ϕ_1)

from the left occipital area were significantly greater than those from the central and right occipital stages, but such tendencies were not found on our EEG study. So far, it is reconfirmed that the left hemisphere is mainly associated with temporal factors of the visual fields.

The study on the relationship between the EEG response and the subjective preference by varying the period of horizontal movement of the single target showed:

6. The value of τ_e of alpha waves for stimulus in the most preferred condition was longer than that for stimulus in the less preferred conditions ($p < 0.01$).

7. This tendency was the maximum at O1 in the left hemisphere.

8. The value of $|\phi(\tau)|_{max}$ of alpha waves for stimulus in the most preferred was greater than that for the stimulus in the less preferred conditions ($p < 0.01$). Considering this fact together with the similar repetitive feature in the alpha wave increased, thus the brain repeats the "alpha rhythm" in the time domain, and that this activity spreads wider area over the cerebral cortex.

Table 2 summarizes the cerebral hemisphere specialization to visual temporal factors observed here that indicates left hemisphere dominance. In most subjects, the left cerebral hemisphere is much concerned with linear, sequential modes of thinking, such as speech and calculation. The right hemisphere tends to perceive space in multiple-dimensional and non-temporal terms for visual field (Sperry, 1974; Davis and Wada, 1974; Galin and Ellis, 1975; Levy and Trevarthen, 1976). We have clearly shown as mentioned in Section 2.1, subjective preference about time-factored experience for the sound field

Table 2. Cerebral hemisphere specializations relating to visual temporal factors.

Factors changed	EEG ACF τ_e value of α-wave	MEG ACF τ_e value of α-wave
Period of flickering light, T	L > R (sinusoidal wave)[1, 2]	L > R (sinusoidal wave, $p < 0.01$)
Period of moving target, T	L > R (sinusoidal wave, $p < 0.01$)[1]	---

[1] A flow of EEG α-waves from the left hemisphere to the right hemisphere for stimuli of both flickering light and moving target in change of the period was observed by the CCF $|\phi(\tau)|_{max}$ between α-waves recorded at different electrodes.

[2] A significant difference was not achieved.

takes place in the left hemisphere, and the spatial factored experience in the right hemisphere.

3. A DESIGN STUDY OF THE KIRISHIMA INTERNATIONAL CONCERT HALL

According to the above-mentioned results and preference theory (Ando, 1985; 1998), design objectives generally are classified by two categories; two temporal factors associated with the left hemisphere and two spatial factors associated with the right hemisphere. Using the optimal values in the four orthogonal factors of the sound field obtained by a number of listeners, the "principle of superposition" can be applied for calculation of the scale value of preference at each seat. Comparison of the total preference values for different configurations of the concert hall allows a designer to choose the best one for a range of specific music programs.

3.1. Theory of subjective preference for the sound field

Since the numbers of orthogonal acoustic factors, which are included in the sound signals at both ears, are limited (Ando, 1983), the scale value of any one-dimensional subjective response may be expressed by

$$S = g(x_1, x_2, \dots x_I) \quad (1)$$

where x_i is an orthogonal factor ($i = 1, 2, \dots I$), and I being the number of orthogonal factors of the sound field. In this study, the linear scale value of preference obtained by the law of comparative judgment is applied. 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, such that

$$S = g(x_1) + g(x_2) + g(x_3) + g(x_4)$$

$$= S_1 + S_2 + S_3 + S_4 \quad (2)$$

where S_i, $i = 1, 2, 3, 4$ is the scale value obtained in relation to each objective parameter. Thus, Equation (2) indicates a four-dimensional continuity.

The dependence of the scale value on each objective parameter is shown graphically in Fig. 3. From the nature of the scale value, it is convenient to put a zero value at the most preferred conditions, as shown in this figure. These results of the scale value of subjective preference obtained from the different test series; using different music programs, yield the following

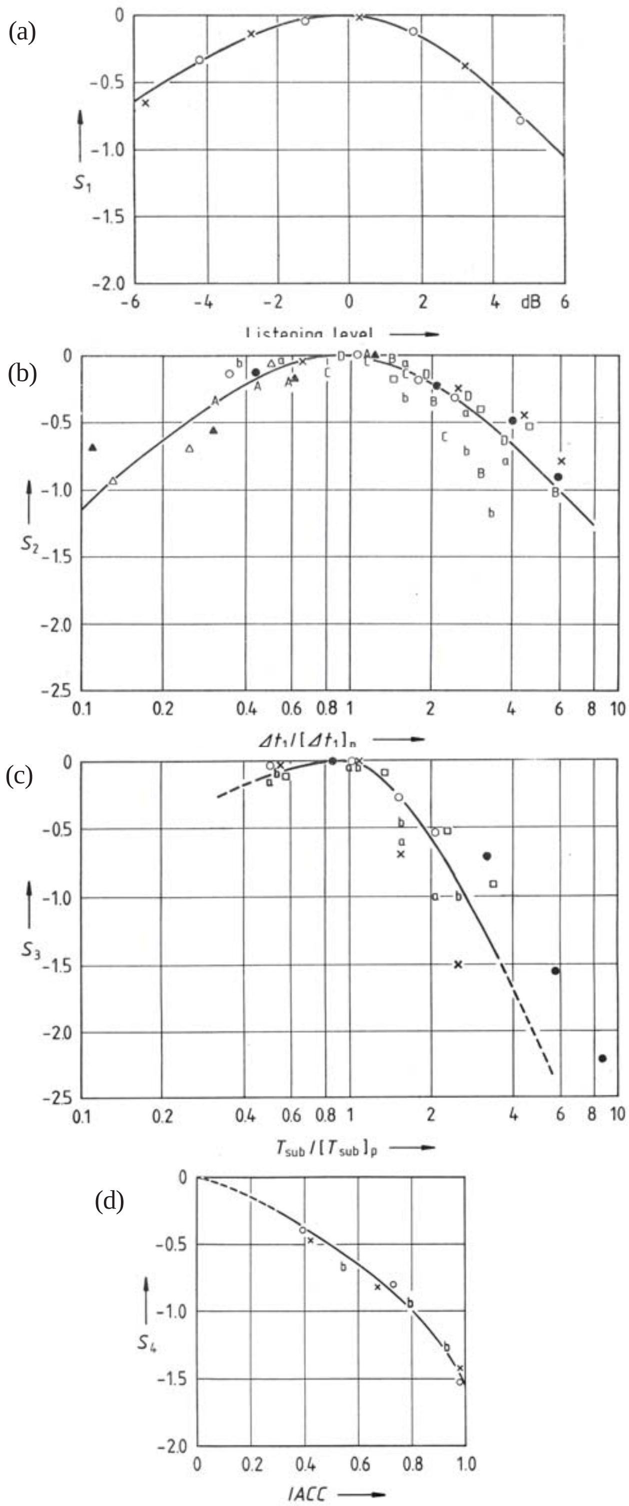

Fig. 3. Scale values of subjective preference obtained for simulated sound fields in an anechoic chamber. Different symbols indicate scale values obtained from different source signals (Ando, 1983). Even if different signals are used, a consistency of scale values as a function of each factor is observed, fitting a single curve.(a) As a function of listening level, LL. The most preferred listening level, $[LL]_p = 0$ dB. (b) As a function of $\Delta t_1/[\Delta t_1]_p$. (c) As a function of $T_{sub}/[T_{sub}]_p$. (d) As a function of IACC.

common formula:

$$S_i \approx -\alpha_i |x_i|^{3/2},\ i = 1, 2, 3, 4 \quad (3)$$

where 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 x1 is given by the sound pressure level difference, measured by the A-weighted network, so that

$$x_1 = 20\log P - 20\log[P]_p \quad (4)$$

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;

$$x_2 = \log(\Delta t_1 / [\Delta t_1]_p) \quad (5)$$

$$x_3 = \log(T_{sub} / [T_{sub}]_p) \quad (6)$$

$$x_4 = IACC \quad (7)$$

where the preferred condition of the temporal factor in Equation (5) is given by

$$[\Delta t_1]_p \approx (1 - \log10\, A)\tau_e \quad (8)$$

the value A being the total pressure amplitude of reflections, and τ_e is the effective duration of autocorrelation function of the source signal (Ando, 1998).

$$A = [A_1^{\,2} + A_2^{\,2} + A_3^{\,2} + \ ...]^{1/2} \quad (9)$$

A_n (n = 1, 2, ...) is the pressure amplitude of each reflection. And, the preferred reverberation time $[T_{sub}]_p$ in Equation (5) may be given by

Table 3. Four orthogonal factors of sound fields and its weighting coefficients α_i obtained with a number of subjects in the condition of $\tau_{IACC} = 0$.

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	---

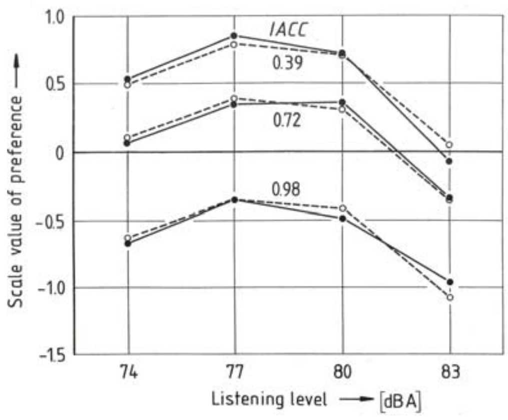

Fig. 4. Scale values of subjective preference for the sound field with music motif A, as a function of listening level and as a parameter of the IACC (Ando, Kang and Morita, l987). ----- : Calculated values based on Equation (2) taking the two factors into consideration; ____: measured values.

$$[T_{sub}]_p \approx 23(\tau_e)_{min} \quad (10)$$

Thus, the scale values of preference have been formulated approximately in terms of the 3/2 powers 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. 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. Under the conditions of fixing Δt_1 and T_{sub} around the preferred conditions, for example, scale values of subjective preference calculated by Equation (2) for the LL and the IACC with constants listed in Table 3 are demonstrated in Fig. 4. Agreement between calculated values and observed ones are satisfactory (Ando, 1985).

As a typical example, first of all, we shall discuss the quality of the sound field at each seating position in a concert hall with a shape similar to that of the 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 Fig. 5a. The results shown in Fig. 5b demonstrate effects of the reflection from the sidewalls adjusted on the stage, which produce decreasing values of IACC for the audience area. The preference value at each seat is increased, as shown in Fig. 5b in comparison with that in Fig. 5a. In this calculation, the reverberation time is assumed to be fixed at 1.8 s throughout the hall and the most preferred listening level, $[LL]_p = 20\log[P]_p$ in Equation (4), is set for a point on the center line 20 m from the source position.

In order to examine above mentioned subjective preference theory, the subjective preference judgments changing source locations on the stage in an existing hall were performed by the paired-comparison tests at each set of seats. Calculated scale values of subjective preference were reconfirmed in the real hall (Sato, Mori and Ando, 1997).

3.2. Design studies

Since a small value of IACC as the typical spatial factor, which corresponds to different sound signals arriving at two ears, is preferred for every individual without any exception, the space form of the hall is the major importance. An example of applying this design theory was performed in the Kirishima International Concert Hall with the architect Fumihiko Maki as shown in Fig. 6 (Maki, 1997, Ando, et al, 1997; Nakajima and Ando, 1997; Ando, 1998). Plan of a leaf-shape and ceiling with triangular plates realized a small value of IACC for most of the seats (Photo 1).

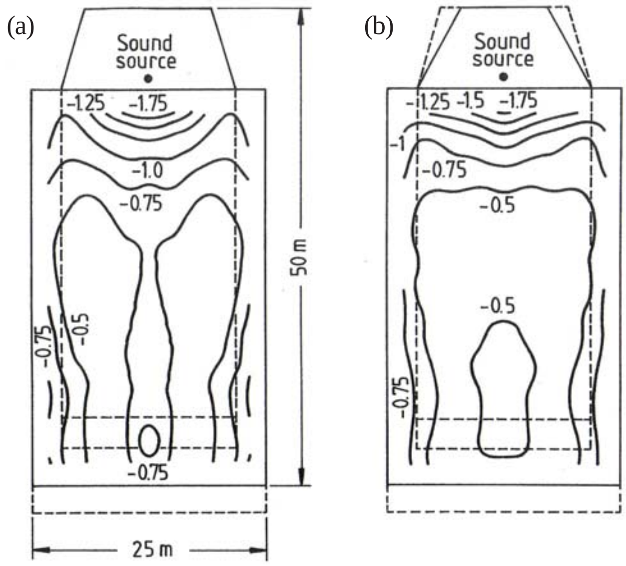

Fig. 5. An example of calculating scale values with the four factors using Equations (2) through (10). (a) Contour lines of the total scale value for Boston Symphony Hall, with the original side reflectors on stage. (b) Contour lines of the total scale values for the optimized side reflectors.

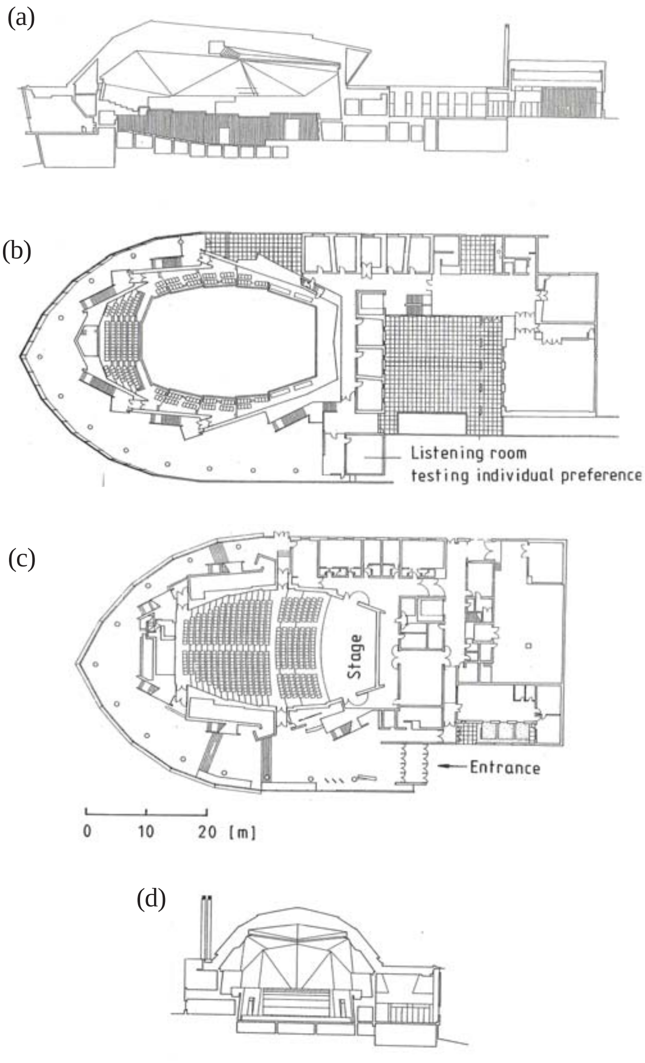

Fig. 6. Scheme of the Kirishima International Concert Hall, Kagoshima, Japan designed by the architect Maki (1997) and associates, Ikeda, (1997). (a) Longitudinal section. (b) Floor plan of balcony level. (c) Floor plan of audience level. (d) Cross-section.

Photo 1. The Kirishima International Concert Hall, Kagoshima with tilt sidewalls and triangular ceilings.

Another example is Tsuyama Music Cultural Hall (Suzumura, et al, 2000) with the similar shape of Kirishima Hall. Additional design introduced 52 columns (30-cm diameters) as a design element in the hall. The columns provide surfaces for scattering reflected sound waves for the higher frequency range above 1 kHz. This brought about a small value of IACC for the frequency range near the columns and at the seating-center area close to the stage. As a temporal design, the height of triangular reflectors installed above the stage may be adjusted for performers, according to the effective duration τ_e of the ACF for music in a program. The acoustic environment inside the hall is well suited to chamber music, with a $(\tau_e)_{min}$ in the range of 50 - 90 ms, because the subsequent reverberation time T_{sub} measured was about 1.7 s with audience. This canopy also plays an important role in decreasing the IACC at the seating area close to the stage.

3.3. Seat selection enhancing individual preference

In order to maximize individual subjective preference for each listener, a special facility for seat selection, testing each listener's own subjective preference, was first introduced in use at the Kirishima International Concert Hall in 1994. The system used arrows for testing subjective preference of sound fields four listeners at the same time. Since the four orthogonal factors of the sound field influence the preference judgments almost independently, each single factor is varied, while the other three are fixed at the most preferred condition for the average listener. Results of testing acousticians who participated in the First International Symposium on "Music and Concert Hall Acoustics" (MCHA95), which was held in Kirishima, in May 1995, are presented here.

3.3.1. Individual subjective preference

The music source was orchestral, the "Water Music" by Handel; the effective duration of the ACF, τ_e, was 62 ms (Ando, 1998). The total number of listeners participating was 106. Typical examples of the test results, as a function of each factor, for listener BL are shown in Fig. 7. Scale values of this listener were close to the averages for subjects previously collected: the most preferred $[LL]_p$ is 83 dBA, $[\Delta t_1]_p$ is 26.8 ms (the preferred value calculated by Equation (8) was 24.8 ms, where $[\Delta t_1]_p \approx (1 - \log10A)\, \tau_e$, A = 4), and the most preferred reverberation time was 2.05 s (the preferred value calculated by Equation (10) is 1.43 s). Thus, the center area of seats was preferred for listener BL, as shown in Fig. 8. With regard to the IACC, it was the result for all listeners that the scale value of preference increased with decreasing IACC value. Since listener KH preferred a very short delay time of the initial reflec-

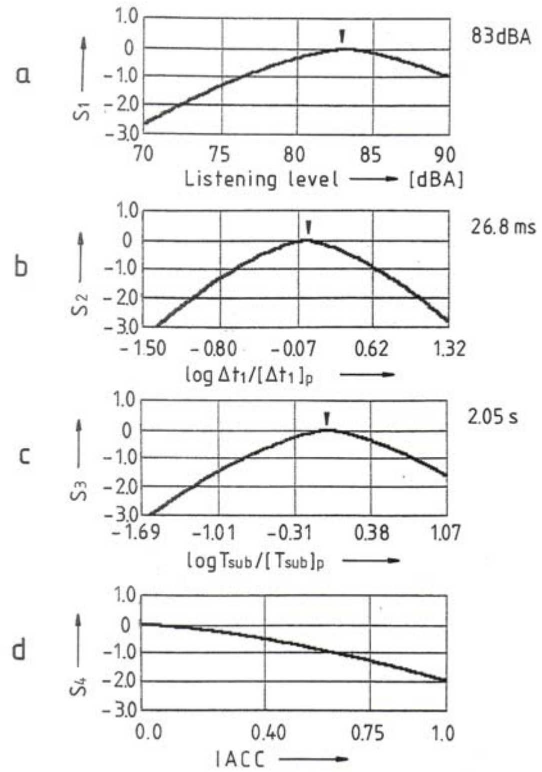

Fig. 7. Scale values of preference obtained by tests for four factors, subject BL. (a) The most preferred listening level is 83 dBA, the individual weighting coefficient in Equation (3): $\alpha_1 = 0.06$. (b) The preferred initial time delay gap between the direct sound and first reflection is 26.8 ms, the individual weighting coefficient in Equation (3): $\alpha_2 = 1.86$, where $[\Delta t_1]_p$ calculated by Equation (3) with $\tau_e = 62$ ms for the music used (A = 4) is 24.8 ms. (c) The preferred subsequent reverberation time is 2.05 s, the individual weighting coefficient in Equation (3): $\alpha_3 = 1.46$, where $[T_{sub}]_p$, calculated by Equation (10) with $\tau_e = 62$ ms for the music used, is 1.43 s. (d) The individual weighting coefficient in Equation (3): $\alpha_4 = 1.96$.

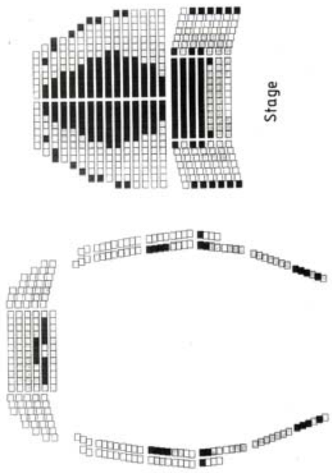

Fig. 8. Preferred seating area calculated for subject BL. The seats are classified in three parts according to the scale values of preference calculated by the summation S_1 through S_4. Black seats indicate preferred stages, about one third of all seats in this concert hall, for subject BL.

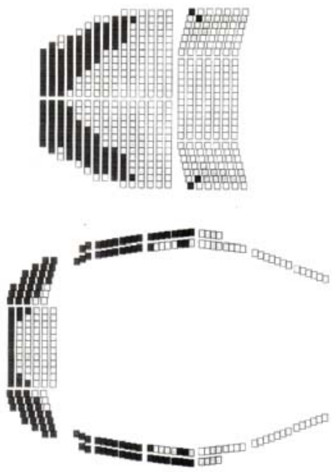

Fig. 9. Preferred seat area calculated for subject KH.

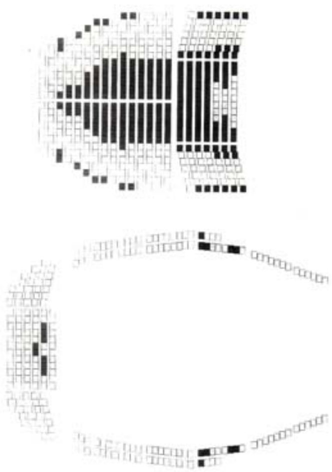

Fig. 10. Preferred seat area calculated for subject KK.

tion, his preferred seats were located close to the boundary walls as shown in Fig. 9. Listener KK indicated a preferred listening level exceeding 90 dBA. For this listener, the front seating stages close to the stage were preferable, as shown in Fig. 10. For listener DP, whose preferred listening level was a rather weak (76.0 dBA) and preferred initial delay time short (15.0 ms), so that the preferred seats are in the rear part of the hall as shown in Fig. 11. The preferred initial time delay gap for listener AC exceeds 100.0 ms, but was not critical. Thus, any initial delay times are acceptable, but the IACC is critical. Therefore, the preferred area of seats was located only in the rear part, as is shown in Fig. 12.

3.3.2. Preferred conditions for each individual

Cumulative frequencies of the preferred values with 106 lis-

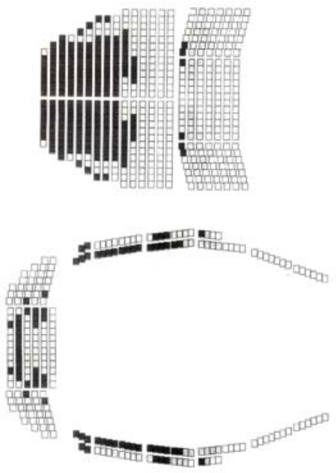

Fig. 11. Preferred seat area calculated for subject DP.

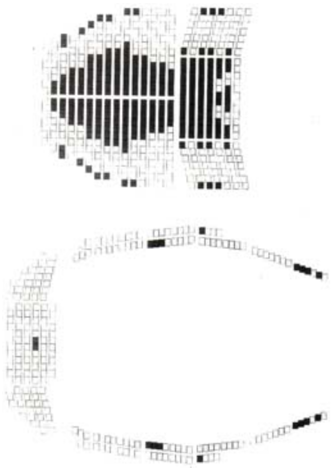

Fig. 12. Preferred seat area calculated for subject CA.

teners are shown in Fig. 13 through Fig. 15 for three factors. As indicated in Fig. 13, about 60 % of listeners preferred the range of 80 to 84.9 dBA in listening to music, but some of listeners indicated that the most preferred LL was above 90 dBA, and the total range of the preferred LL was scattered, exceeding a 20 dB range. As shown in Fig. 14, about 45 % of listeners preferred the initial delay times 20 to 39 ms, which were around the calculated preference of 24.8 ms due to Equation (8); some of listeners indicated 0 to 9 ms and others more than 80 ms. With regard to the reverberation time, as shown in Fig. 15, about 45 % of listeners preferred 1.0 to1.9 s which are centered on the calculated preferred value of 1.43 s, but some listeners indicated preferences less than 0.9 s or more than 4.0 s.

It was thought that both the initial delay time and the subsequent reverberation time appear to be related to a kind of "liveness" of the sound field. And, it was assumed that there

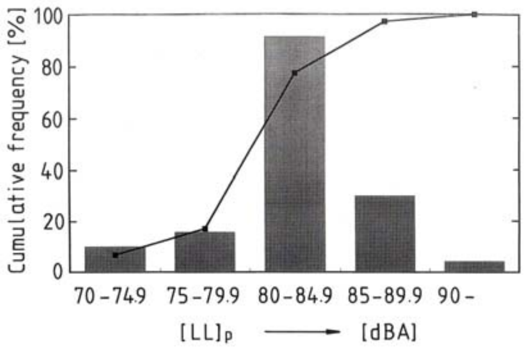

Fig. 13. Cumulative frequency of preferred listening level $[LL]_p$ (106 subjects). About 60 % of subjects preferred the range of 80 - 84.9 dBA. Three-time stages of human life to be considered in the temporal design (Ando, 2004). Findings and creations based on a unique personality may contribute to society even after the end of life, body, and mind.

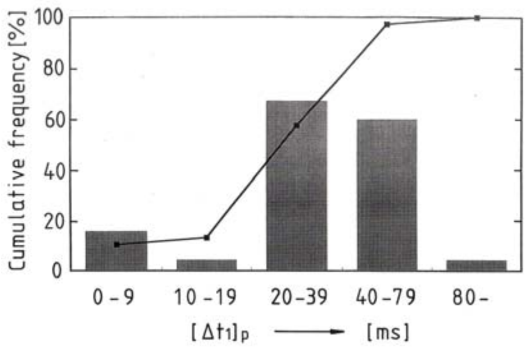

Fig. 14. Cumulative frequency of the preferred initial time delay gap between the direct sound and the first reflection $[\Delta t_1]_p$ (106 subjects). About 45 % of subjects preferred the range of 20-39 ms. The calculated value of $[\Delta t_1]_p$ by Equation (8) is 24.8 ms.

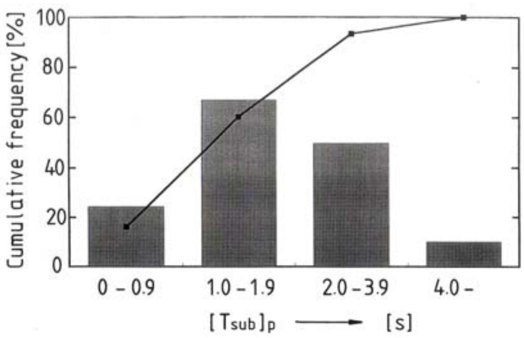

Fig. 15. Cumulative frequency of the preferred subsequent reverberation time $[T_{sub}]_p$ (106 subjects). About 45 % of subjects preferred the range of 1.0-1.9 s. The calculated value of $[T_{sub}]_p$ by Equation (10) is 1.43 s.

is a great interference effect between these factors for each individual. However, as shown in Fig. 16, there is little correlation between preference values of $[\Delta t_1]_p$ and $[T_{sub}]_p$ (correlation is 0.06). The same is true for the correlation between values of $[T_{sub}]_p$ and $[LL]_p$ and for that between values of $[LL]_p$ and $[\Delta t_1]_p$, a correlation of less than 0.11. Fig. 17 shows the three-dimensional plots of the preferred values of $[LL]_p$, $[\Delta t_1]_p$ and $[T_{sub}]_p$. Looking at a continuous distribution in preferred values, no specific groupings of individuals can be classified to emerge from the data.

The important fact is that there are no correlation between weighting coefficients α_i and α_j, $i \neq j$, (i and j = 1, 2, 3, 4) in Equation (3) (Ando, 1998). A listener indicating a relatively small value of one factor will not always indicate a relatively small value for another factor. Thus, a listener can be critical about preferred conditions as a function of some factors, while insensitive to other factors, resulting in a characteristic individual difference distinct from other listeners.

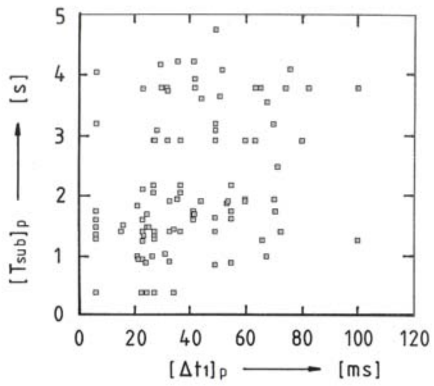

Fig. 16. Relationship between preferred values of $[\Delta t_1]_p$ and $[T_{sub}]_p$ for each subject. No significant correlation between values was achieved.

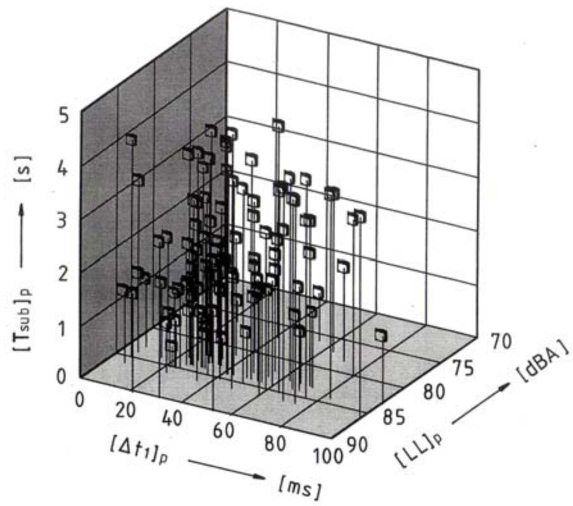

Fig. 17. Three-dimensional illustrations of preferred orthogonal factors of sound fields for individual subjects. Preferred conditions are distributed in a certain range for each factor, so that subjects could not be classified into any specific groups.

3.4. Subjective effects of sound fields on performers

The theory of subjective preference allows a conductor or a music director to chose a program of music to be performed that will yield the best sound in a given concert hall. Previously, we have described how music of rapid movement with a short τ_e fits a concert hall with a short initial time delay gap and a short subsequent reverberation time. Music of slow tempo with a long τ_e fuses in a hall with relatively long values for these two temporal factors. It is strongly recommended, therefore, that one choose music to be performed in a given concert hall to blend the music program with the sound field.

When music is performed with vibrato, then the value of τ_e subjects tends to be shorter than music without vibrato. Therefore, musician can blend music and hall acoustic by controlling the style of performance to a certain extent (Kato, et al, 2005).

4. DESIGN STUDY OF A HILLSIDE HOUSE WITH A SMALLOFFICE

In order to demonstrate the temporal design for the three stages of our lives, experiences of discrete periods for man and the natural environment should be blended as shown in Fig. 18. Remarkably, there are certain significant periodic eigen values in both human biological rhythms and physical environmental activities in the time domain to be designed. For this purpose, the hillside house was built in Kirishima in 2004.

Following musical tempo centered on 1 s, there are eigen values, such that about 90 minutes correspond to the rapid eye movement (REM) or period during sleep and wakefulness in man, one day, one week, one month, one year or four seasons, about 30 years as a generation change, about 90 years as a human life time and so on. Thus, we do not need to consider every "real" time period, or an infinite number of scales. Thus, a crucial factor in the temporal dimension of the environment related to man is cycles. Every aspect of the passage of time is bound up with cycles: birth and death, the changing of the seasons, sleeping and waking, work and leisure. The present theory suggests that these cycles should be explicitly recognized in design, and during the design process itself as well. The passage of time in the designed environment should be as consciously considered in addition to the three-dimensional organization of the space itself.

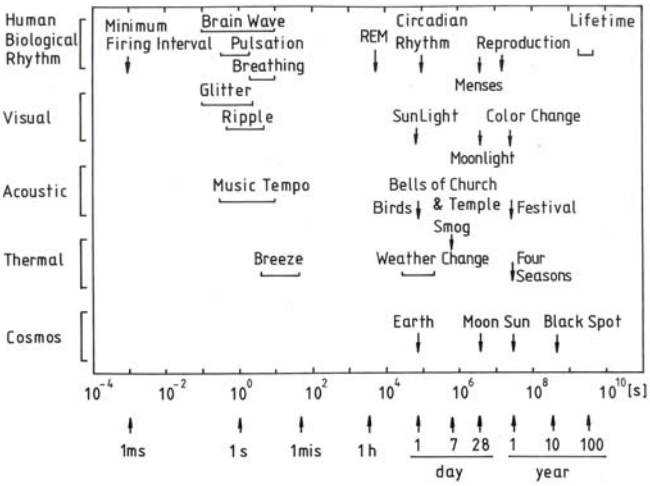

Fig. 18. Blending human biological rhythms and discrete periods of physical environments.

In order to realize these three stages of life, the hillside house was built in Kirishima, Kyushu, Japan about 700 m above sea level (Bosworth and Ando, 2005). For the first stage of time, for instance, the bedroom is designed with three parts of a small window, so that it resembles a cave with a small amount of natural light causing the body to relax. For the second stage of time particularly for the periods of day and four seasons, windows in the living room, kitchen and bathroom are carefully designed to have enough lights from outside and to allow viewing of trees and the large scale natural garden including Sakurajima, an active volcano, and the Kinko Bay. Skylights illuminate the hallway and table. The veranda is joyful space for tea and food in the morning and afternoon.

For the third stage of life, a proposal is being made a space for working at home with the office system. The temporal period of work must be about 90 – 120 min., which corresponds to the sleep and wakefulness (REM) period (Othmer, Haydn and Seglbaum, 1969). An example of the creative workspace (CWS), which fully activates both hemispheres, has been designed (Ando, 2000).

Previously, eight systems of the CWS have been introduced in March 2002 to Ando Laboratory, Kobe University. It consists of “three different panels” specialized for the left and right hemispheric tasks (Ando 1988, 2001) and for the integration of knowledge by an information-communication system. The left hemispheric task is the temporal processes, including writing, reading, speech hearing, calculation, and logical considerations. The right hemispheric task is including the spatial processes of pattern recognition, space forming, and drawing, painting and making of scale models. It is promising that multiple dimensional ideas might be created by such a multiple dimensional workspace. This quite differs from a usual one-dimensional working space, which subjected to create only “one-dimensional ideas”. As listed in Table 4, eight users were reported that the total qualities of this system were 2.5 – 15 times (mean value: 5 times) better than one-dimensional desks, which they had used, and efficiencies of work increased to 2 – 15 times (mean value: 3 times). All users, therefore, reported efficiencies that were more than 2 times at least ($p < 0.01$). Verbal and non-verbal materials previously created by a user, which are displayed on the walls around the three panels, may induce further creations. Photo 2 is an example of the CWS activating two cerebral hemispheres in the hillside house. Also, the networking system between home and office may realize the maximum effect with the minimum of effort for both time and energy, without attending work and study places everyday.

Table 4. Overall evaluations and work efficiencies judged by eight users for the CWS referring to those for the usual office desk.

User	Overall evaluation (Time)	Work efficiency (Time)
RS	5.0	3.0
YS	2.5	2.5
YO	10.0	5.0
TH	5.0	3.0
KK	15.0	15.0
KF	5.0	3.0
YA	3.0	3.0
SS	10.0	2.0
Average	6.9	4.6
Mean (50%)	5.0	3.0

5. REMARKS ON HUMAN BRAIN DEVELOPMENT AND THE ENVIRONMENT

It is worth mentioning that the physical dimensions of the head of newborn infants are relatively large suggesting that the head is initial developed in the body (Photo 3). If we consider an analogy of this, it is highly recommended that facilities associated with human brain development should be designed first when planning a new city. Examples in urban planning are churches, museums, concert halls, libraries and educational institutions, which may act as an important role for creation. Then the, arms and legs corresponding to highways and communication systems may be almost automatically developed later on.

Architecture corresponds to:

1) Style including hair, dress and its ornaments for the design department;

2) Structure including bony frameworks and muscles for the

Photo 2. CWS with a U-type panel in a hillside house. The left side of the panels is specialized for right hemispheric tasks so that one can use any tools for making a scale model and drawing figures and the center part of the panel is used for left hemispheric tasks. The right side of panels is used for left hemispheric tasks. The view from the south window of the office is designed to be relaxing for the brain.

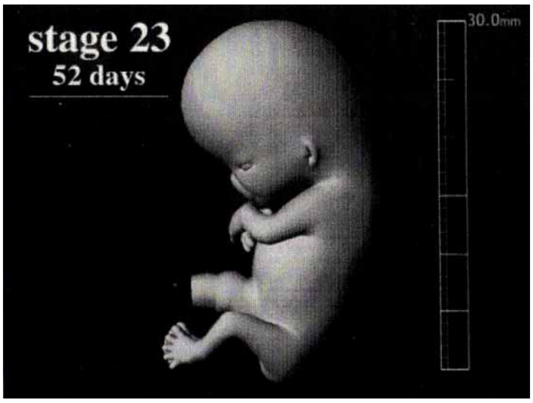

Photo 3. Fetus at 52 days.

structural technology department, and;
3) Sensory organs and circulation systems for the environmental technology department, respectively. However, there is no area in architecture corresponding to the "brain," for both the second stage of life (except for environmental physiology and psychology) and third stage of life. Each individual has his or her own DNA, and after birth, the living environment is different, therefore, each individual has a different personality and a different world point of view. This is a source of creation, and healthy creations will remain in the human society for a long time as the third stage of life even after the end of the first and second life. This process, in turn, plays an important role maintaining the environment for every living creature and then lasting peace.

It is strongly hoped that the concept developed here may allow one to design a delightful human environment for the both cerebral hemispheres by basing both temporal and spatial factors on a limited number of environmental variables. The sound field's variables, for example, comprise two temporal factors of the left hemisphere dominance, and two factors of the right hemisphere dominance that are related to spatial attributes. These are almost true for visual variables.

It is hoped that this article suggests a suitable line for further works in the temporal design of architecture and the environment.

APPENDIX I. DURATION EXPERIENCE FOR EACH THREE-SCHOOL YEAR

A tendency was found that subjective time duration of three years during the senior high school was much shorter than those during the junior high school and the elemental school.

In order to obtain the subjective impression of every three-year period for 15 years (about 3 through 18 years of age) of university students in the ocean navigation for 30 days between Kobe, Japan and Perth, Australia in a summer session in 1994 minimizing effects of difference of individual conditions were selected as subjects (Ando, et al, 1999). The total number of subjects participated for this investigation, performed in a large lecture room of a chartered boat, was 285 (female 81 % and male 19 %). Most of the students were junior and sophomore. Questionnaires were distributed during the voyage, and students were asked to carefully respond with their subjective impression on the following time durations:
Q1: A duration of three years before elementary school, in reference to that of the junior high school period of three years (JHSP);
Q2: A duration of three years of lower class elementary school in reference to JHSP;
Q3: A duration of three years of upper class elementary school in reference to JHSP;
Q4: A duration of three years senior high school in reference to JHSP.
Thus, this method is similar to the magnitude estimation. Subjective durations were answered choosing one of real numbers from 0.1 through 3.0 step 0.1, in addition they could answer other than these numbers.

For the subjective duration with (1) sex of subject; (2) experience of transfers of elemental school due to change in family residence; and (3) period of every three year, the analysis of variance was performed. The significant differences could be achieved in a period of every three-year and in experience of transfer of elemental school, but not for sex of the subject. Since the subjective duration estimated is well described by the time on the logarithmic scales, meaningful mean values may be found at the 50th percent of cumulative frequencies.

Figure A1 indicates the 50 percentile values, as a function of a period of a three-year range, for both subjects who moved and transferred elementary schools and subjects that did not.

For most subjects, who did not transfer elementary schools (238 subjects), results from Q1 (3-5 year of age) through Q3 (9-11 years of age) reveal that subjective durations are longer than unity, 1.2; and results from Q4 (15-17 years of age) indicate subjective impression for 15-17 years old are significantly shorter than unity, 0.8, in reference to JHSP ($p < 0.01$). For subjects who transferred elementary schools (47 subjects), the subjective durations for 3-5 and 6-8 years of age were significantly longer about 1.3 or more, than those for subjects who did not transfer schools ($p < 0.05$).

The remarkable finding of this investigation is that the 50 percentile mean values for the three-year periods below 11 years old in reference to JHSP are about 1.2, however, the mean value of subjective duration for the age of 15 -17 is dramatically shorter 0.8. If subjects transferred elementary schools, then the additional stress may create longer subjective durations for the corresponding period (6 - 8 years old) and the former period (3 -5 years old) than that of subjects who did not transfer their schools.

It is considered that the duration experience ΔT of time in the brain is such a way that:

1) If there is no activity of the brain, then $\Delta T = 0$.
2) When the brain is developed after birth, then the time may be perceived and the duration sensations emerge.
3) According to new experience and new information from the environment, ΔT is prolonged.
4) When the brain has become accustomed to the daily environment and life, then ΔT is shortened, as shown in Fig. A1.
5) When children transfer to other elementary schools from ages 6 to 11, the subjective duration was much longer than those who did not move at least partially caused by an additional stress on brain development.

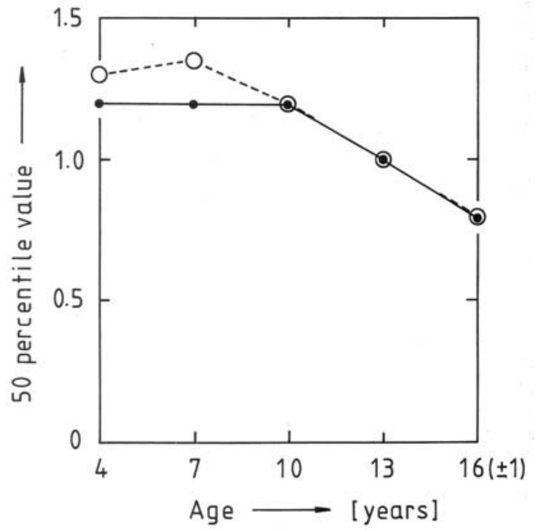

Fig. A1. Values of the 50 % of the time ratio of each three-year term in reference to the duration experience for the period of junior-high school (three years). ○ : Subjects who transferred elementary schools between ages 6-8 (47 subjects) or ages 9-12 (23 subjects). ●: Subjects who did not transferred elementary schools during their school periods (212 subjects). The varied data was 282.

APPENDIX II. LONG-TIME INTEGRATED EFFECTS OF NOISE ON DEVELOPMENT OF UNBORN BABIES AND ON CEREBRAL HEMISHPERE OF CHILDREN

The brain vividly responds to instantaneous changes to the environment in a period of less than several seconds, because the auditory-temporal window is usually less than about 2 s. On the contrary, the temporal sensation for stimuli with a long-term period more than several minutes is weak enough. Thus, we should be aware, not only of the effects of instantaneous noise such as annoyance and loudness, but also the long-time integrated effects of more than one year, on the development of the fetus and on the cerebral hemispheres of children.

Since 1968, these investigations were performed around an international airport in Japan. We found that:

1) Effects on the body: Time integrated effects of the aircraft noise on the developments of the body of the fetus are briefly reviewed. There are many unconscious physiological rhythms and subjective psychological attributes associated with environmental noise for long periods. Effects of environmental noise have been investigated in term of human placental lactogen (HPL) in the serum of expectant mothers both subjected to and not subjected to aircraft noise. As shown in Fig. A2, the HPL levels of subjects in the noise area tended to be lower than those in the reference area after the 30th week of pregnancy ($p < 0.01$). The lower HPL levels were associated with lower birth weight for infants of mothers who lived in the noise area (Ando and Hattori, 1977b). After birth, an effect of development of height has been discussed (Schell and Ando, 1991).

2) Effects on the mind: Postnatal effects of aircraft noise on the sleeping babies are dependant upon the period when their mothers came into the noise area in reference to the period of pregnancy (Ando and Hattori, 1977a). Also, time integrated effects on the development of the cerebral hemispheres of children were investigated. Developments of cerebral hemispheres of children over long periods of accumulation were

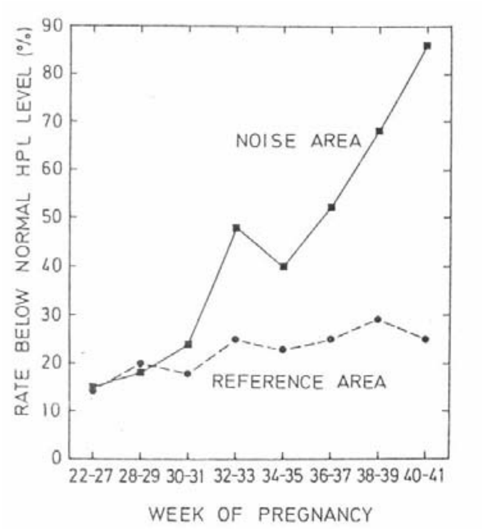

Fig. A2. Percentage of subjects with HPL levels more than 1SD below the mean by stage of pregnancy.

clearly discussed by the results of testing different mental processes associated with the left and the right hemispheres (see Fig. A3: Ando, Nakane and Egawa, 1975; Ando, 1988; Ando, 2001).

3) Effects on creation: This is not yet clarified, but integrated effects of environmental noise on body and mind (specialization of cerebral hemisphere), in turn, may influence the development of personality as a source of creation.

So far, the results indicate that from a number of investigations on effects of environmental noise that any environmental stress experienced by pregnant mothers may be may be passed on and affect the development of the fetus. Such stress may affect the development of individual personality as a source of creation contributing to any living creatures. It is strongly hoped, therefore, that the concept of design may allow one to realize the healthy human environment by basing temporal factors on a limited number of environmental variables.

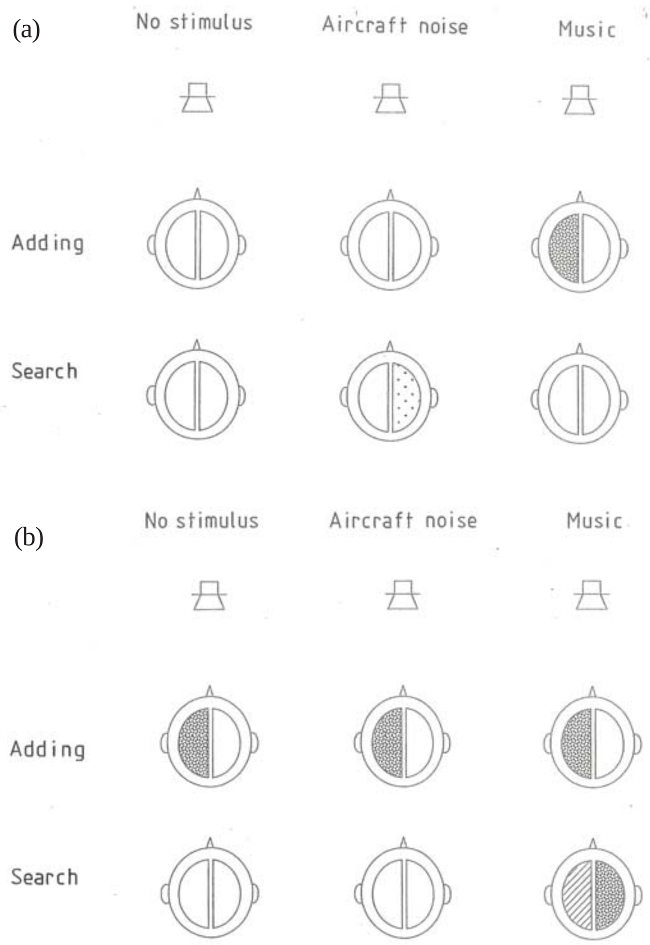

Fig. A3. Explanations of interference between mental tasks and sound stimuli, taking into the specialization of cerebral hemispheres are considered, and development of the hemispheres due to differences in noise levels in the living stages. The adding task and search respectively may be associated mainly with the left hemisphere and the right hemisphere. The effect of interference in the respective hemispheres, shown by shaded stages, differs remarkably between children from noisy and quiet living stages. (a) Children from a quiet living area. (b) Children from a noisy living area.

[a]This paper was presented as a Keynote Address at the 2nd ISTD opened for public in Kokubu City on 27 July 2005.

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