Subjective Preference for Movements of a Visual Circular Stimulus: A Case of Sinusoidal Movement in Vertical and Horizontal Directions

Yoshiharu Soeta[a)], Keisaku Ohtori and Yoichi Ando
Graduate School of Science and Technology, Kobe University, Rokkodai, Nada, Kobe, 657-8501, Japan

(Received 10 February 2002; accepted 2 May 2002)

Preference judgments using the paired-comparison method for sinusoidal movements of a single circular target in vertical and horizontal directions on a monitor screen were performed. To examine which period of movement is preferred, the period of stimulus movements was varied separately in vertical or horizontal direction in Experiment 1. To examine which direction of movement is preferred in preferable period range, the direction and the period of stimulus movements were varied simultaneously in Experiment 2. Results show that the periods preferred ($[T]_p$) by the subjects for both directional stimuli are observed to be roughly 1.0 s. However, the significant difference is found in that the preferred period averaged about 0.97 s for the vertical direction and about 1.26 s for the horizontal direction. All observers participating in the vertical direction series showed that the curves for scale value of preference are significantly sharper in the fast-moving range in reference to $[T]_p$ than those in the slow-moving range in Experiment 1. Scale values of preference at the most preferred periods for both horizontal and vertical movement are nearly equal, however, sharp decline of subjective preference in the fast-moving range are found for the vertical direction in Experiment 2.

Keywords: subjective preference, movement of a visual stimulus, paired-comparison method

1.INTRODUCTION

It is believed that humans have a preferred amount of stimulus variation in their perceptual environment. Some research even argues that an organism has an optimal level of stimulus variation [1-5]. As a basic auditory stimulus, Chen et al. showed that the preferred tempo for a noise burst occurred approximately 0.55 s [4]. In vision, Soeta et al. examined subjective preference for a flickering light, and showed that the preferred period was approximately 1.27-1.75 s [5].

There are many studies on subjective preference as an overall impression of sound fields in a concert hall [6-8]. Based on the linear scale values of preference to the following four factors: (1) level of listening; (2) initial time-delay gap of the first reflection and the direct sound; (3) subsequent reverberation time; (4) magnitude of interaural cross-correlation, which is obtained by applying the law of comparative judgment [9], a total preference can be calculated according to the principle of superposition,

$$S = S_1 + S_2 + S_3 + S_4, \tag{1}$$

where S_i, i = 1, 2, 3, 4, is the scale value obtained relative to each four factor. From the nature of the scale value, it is convenient to put a zero at the most preferred conditions. The results of scale value of subjective preference from the different test series, using different music programs, yield the following common formula:

$$S_i \approx -\alpha_i |x_i|^{3/2}, \qquad i = 1, 2, 3, 4, \tag{2}$$

where the values of α_i are weighting coefficients and i corresponds to each four factor above-mentioned. The scale value of preference have been formulated approximately in terms of the 3/2 power of the normalized objective parameters, expressed in logarithm for the parameters, x_1, x_2, and x_3. The spatial binaural parameter x_4 is expressed in terms of the 3/2 power of its real values. For example, the factor is given by the

$$x_1 = 20\log P - 20\log [P]_p \tag{3}$$

sound pressure level difference, so that P and $[P]_p$ being the sound pressure level and the most preferred sound pressure

a)Now at Life Electronics Laboratory, National Institute of Advanced Industrial Science and Technology (AIST), Midorigaoka, Ikeda, Osaka, 563-8577 Japan level. These theories on subjective preference of sound fields have an important influence on the way that concert halls are designed and built [10].

To create pleasing sequences in the visual fields, an optimal level of stimulus variation should be investigated. We chose preference as a primitive subjective response, so that observers would make judgments rapidly and easily. It would lead the individual away from inappropriate environments and toward desirable ones [11]. To investigate how the periodical movement of a target is preferred, preference judgments for a single circular target moving sinusoidally in vertical and horizontal movements were conducted individually in Experiment 1. Experiment 2 was intended to investigate which directional movement of a target is preferred in preferable period range.

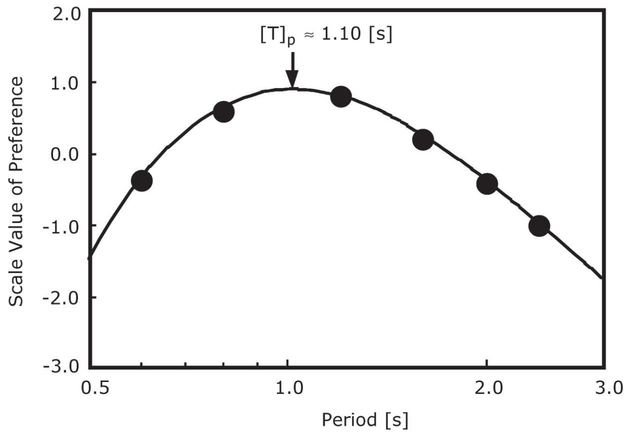

Fig. 2 An example of obtaining the most preferred period $[T]_p$ (subject B, vertical direction).

2.METHODS

Ten observers (nine males and one female) participated in Experiment 1. Their ages ranged from 21 to 26 years. Ten observers (eight males and two females) participated in Experiment 2. Their ages ranged from 22 to 26 years. All subjects had normal or correct-to-normal binocular vision.

The stimuli were generated by a computer, and displayed on a CRT monitor presenting 30 frames per second. Fig. 1 shows a stimulus used in the experiment. Although many vision researchers use gratings or dots moving at a constant velocity as visual stimuli, our study used a single, white, circular target moving sinusoidally. The diameter of the target was subtended 1 deg of the visual angle (1.22 cm). The movement of the stimulus is expressed as:

$$h(t) = A\cos(2\pi t/T), \tag{4}$$

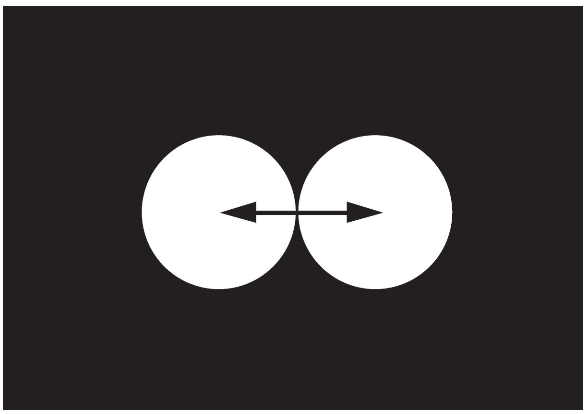

Fig. 1 A stimulus target used in the experiment, here showing an example of horizontal movement.

where A is the amplitude and T is the period of the stimulus. In all experiments, the amplitude was fixed at 0.61 cm on the monitor screen, corresponding to 0.5 deg of visual angle. The white target and black background corresponded to gray levels 1 and 0, and their respective luminance was 40 and 0.5 cd/m^2.

The monitor presenting the stimuli was placed in a dark room 70 cm away from the subject's eye position to maintain foveal fixation (natural binocular). Subjective preference tests were conducted by the paired-comparison method by varying the period and the direction of movement. Trials started with a first interval lasting 5.0 s, followed by a blank duration of 1.0 s and a second interval lasting 5.0 s. During the subsequent blank duration of 4.0 s, the subjects judged which interval contained the subjectively preferred stimulus movement. The paired-comparison method is considered to be the most effective method for examining subjective preferences because the subjects are not required to make absolute judgments. The scale values of the subjective judgments of each subject were calculated according to Case V of Thurstone's theory [9, 12].

Subjective preference for the period of movements in horizontal and vertical directions was examined separately in Experiment 1. The period of stimulus movement T in equation (4) was varied at six levels: T = 0.6, 0.8, 1.2, 1.6, 2.0, and 2.4 s. The direction of stimulus movement was constant. Thirty pairs combining six different periods constituted a series, and ten series were conducted for all ten subjects in experiments respectively presenting vertically and horizontally moving stimuli.

To examine which direction of movement is preferred in preferable period range, the direction and the period of stimulus movements were varied simultaneously in Experiment 2. The period of stimulus movement T in equation (4) was varied at three levels: $T = 0.8$, 1.2, and 1.6 s. Thirty pairs combining three different periods and both vertical and horizontal directions constituted a series, and ten series were conducted for all ten subjects.

2.3 Results

3.1 Experiment 1: Preferred period in each direction

The model of Case V for all data was reconfirmed by a goodness of fit test [13]. The results of the goodness of fit indicated the model had a good match between fitted and the observed values.

The most preferred period $[T]_p$ for each subject was estimated by fitting a suitable polynomial curve to a graph on which scale values were plotted. Fig. 2 shows an example of the method used for estimating $[T]_p$. The peak of this curve denotes the subject's most preferred value. Table 1 shows the results of the most preferred periods for each subject for both vertical and horizontal directional stimuli. The global value of the most preferred period was about 0.97 s for vertical movement, and about 1.26 s for horizontal movement. Results from all subjects indicated that preferred periods in the vertical direction were shorter than that of those in the horizontal direction. The t-test on the most preferred periods in the two directions was significant ($t = 3.47$, $P < 0.01$).

Table 1. The most preferred periods $[T]_p$ for each subject and the averaged values in vertical and horizontal directions

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

We also attempted to determine the characteristics of the preference evaluation curve in more detail. As shown in Fig. 2, the preference evaluation curve can generally be expressed as:

$$S \approx -\alpha |x|^{\beta}, \quad (5)$$

where α and β are the weighting coefficients and $x = \log_{10}T - \log_{10}[T]_p$. To simplify equation (5), the coefficient β may be fixed at a certain value so that the preference evaluation curve can be expressed by a sole coefficient α. After obtaining the most preferred period for each subject, we identified values of α and β for the period in the fast-moving range in reference to $[T]_p$, and also in the slow-moving range (Table 2). The values of α and β in the fast-moving range in reference to $[T]_p$ for the

Table 2. The values of a and b for each subject as calculated by Equation (5)

	Vertical direction				Horizontal direction			
	$T \le [T]_p$		$T \ge [T]_p$		$T \le [T]_p$		$T \ge [T]_p$	
Subject	α	β	α	β	α	β	α	β
A	–	–	11.12	1.33	21.86	1.89	9.08	1.19
B	–	–	8.84	1.49	7.00	1.39	–	–
C	–	–	8.26	1.41	16.03	1.57	17.62	1.54
D	–	–	8.17	1.41	6.20	1.56	–	–
E	–	–	5.53	0.93	–	–	7.68	1.16
F	–	–	8.33	1.28	–	–	10.74	1.60
G	–	–	12.75	1.62	13.03	1.52	14.81	1.53
H	–	–	4.91	0.86	–	–	11.24	1.56
I	–	–	6.57	1.15	–	–	9.41	1.72
J	–	–	15.55	1.72	–	–	11.84	1.54
Averaged		–		1.32		1.59		1.48

Table 3 The values of $\alpha_f(\leq[T]_p)$ and $\alpha_s(\geq[T]_p)$ for each subject and averaged values when the value of β was fixed at 1.5

	Vertical direction		Horizontal direction	
Subject	$\alpha_f(\leq[T]_p)$	$\alpha_s(\geq[T]_p)$	$\alpha_f(\leq[T]_p)$	$\alpha_s(\geq[T]_p)$
A	20.73	13.74	13.55	13.81
B	10.45	8.93	7.68	7.71
C	19.44	8.92	14.69	16.58
D	15.05	9.23	5.89	7.88
E	25.19	9.51	29.80	10.87
F	29.21	10.20	14.30	9.60
G	16.46	11.04	12.74	14.10
H	22.04	8.80	13.07	10.49
I	20.02	9.42	11.37	7.44
J	11.84	11.95	13.30	11.09
Averaged	19.04	10.17	13.64	10.96

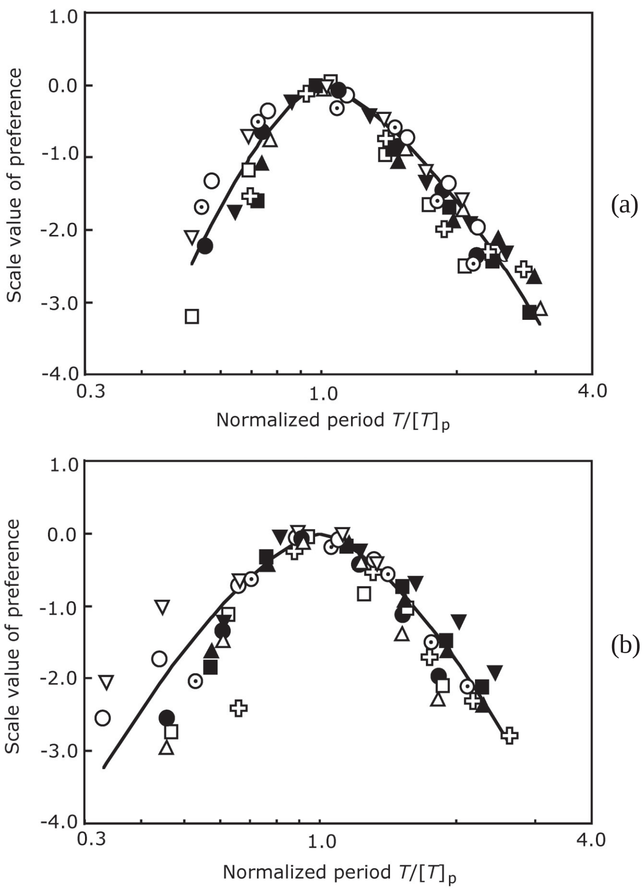

Fig. 3 The scale values of preference for all subjects in vertical (a) and horizontal directions (b). The abscissa is normalized by the most preferred period $[T]_p$.

vertical direction couldn't be calculated because there are only two scale values. The average value of β, estimated by a quasi-Newton numerical method, was approximately 1.43. Thus, the value of β was fixed at 3/2 [6-8]. Taking into consideration the coefficients α_f and α_s, which respectively describe α_f values for both the fast-moving and the slow-moving ranges, equation (5) may be rewritten as:

$$\begin{cases} S \approx -\alpha_f |x|^{3/2} & x \leq 0 \\ S \approx -\alpha_s |x|^{3/2} & x > 0 \end{cases} \quad (6)$$

The weighting coefficient α describes the sharpness of the preference curve with respect to the normalized period. The large α value signifies that the subject clearly differentiates the level of preference. Table 3 lists values of α_f and α_s for all subjects and the averaged α_f and α_s values.

Fig. 3 shows scale values for all of the subjects and the preference evaluation curve calculated by Equation (6). It is clear that in the vertical direction, the sharpness of the preference curve in the fast-moving range in reference to $[T]_p$ differs from that in the slow-moving range. However, such a tendency was not observed in the horizontal direction. The t-test on the α_f and α_s values for the horizontal direction was not significant (t = 1.37). However, for the vertical movement stimuli, α_f values were significantly larger than α_s values (t = 4.61, $P < 0.005$).

3.2 Experiment 2: Preferred direction in preferred period

The model of Case V for all data was reconfirmed by a

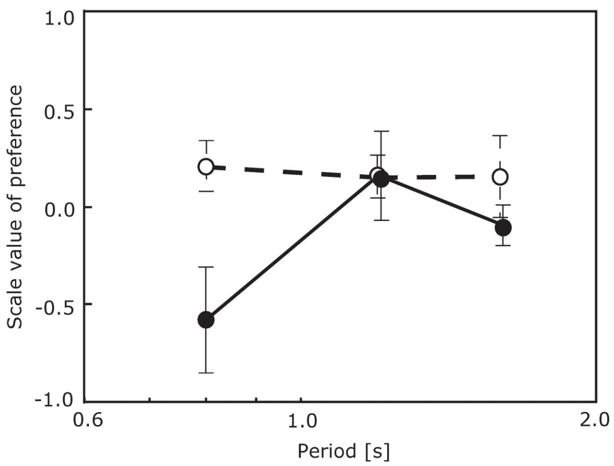

Fig. 4 Scale values of preference as a function of periods: filled circle and thick line show the vertical direction results; open circle and broken line show the horizontal direction results. Error bars are standard error.

Table 4 *F*-values of the analysis of variance for scale value of preference

		Vertical direrction			Horizontal direrction		
	Period	0.8	1.2	1.6	0.8	1.2	1.6
Vertical direrction	0.8	–	5.70*	4.05	9.55*	8.76*	6.20*
	1.2	–	–	1.12	0.10	0.01	0.01
	1.6	–	–	–	4.40	3.58	1.35
Horizontal direrction	0.8	–	–	–	–	0.16	0.09
	1.2	–	–	–	–	–	0.01
	1.6	–	–	–	–	–	–

goodness of fit test [13]. Three of the ten subjects did not conform to the acceptance criteria of a chi-squared test.

Fig. 4 shows the results of the scale values of preference for seven subjects. The effects of periods on the scale values of preference were examined using the one-way ANOVA. The effects are found to be significant ($F = 4.14$, $P < 0.05$) for vertical movement, however, the significant effects are not found for horizontal movement ($F = 0.07$). The results of ANOVA show significant effect for periods between 0.8 and 1.2 s in vertical direction ($P < 0.05$) as shown in Table 4. The scale values of preference at period of 0.8 s in the two directions was also significant ($P < 0.01$).

4. DISCUSSION

The results indicate that a sinusoidal period of about 1.26 s is preferred for horizontally moving stimuli. This period is approximately twice the period of the most preferred tempo for noise bursts [4], and the same as the period of the most preferred period of a flickering light [5]. For vertically moving stimuli, the most preferred period was about 0.97 s, which is a significantly faster period than that of horizontally moving stimuli and also a flickering light. Moreover, the values of α_f were significantly larger than those of α_s in regards to vertical movement. These results indicate that, for vertically moving stimuli, faster movement is more preferable than it is for horizontally moving stimuli, but that the scale values of subjective preference decrease more rapidly in the fast-moving range in reference to $[T]_p$ than in the slow-moving range.

Several investigators found that motion sensitivity to vertical and horizontal movement is isotropic [14-18]. Kinchla and Allan indicated that there is no difference in sensitivity to vertical and horizontal movement but that judgmental standards asymmetries exist [19]. Those sensitivity and judgmental standards respectively correspond to the α values and the most preferred period $[T]_p$ in this study, where preferred periods in the vertical direction are significantly shorter than those in the horizontal direction. It is also thought that the difference between the most preferred periods for vertical and horizontal movement appeared to be due to the judgmental standard of subjective preference for vertical and horizontal movement.

As shown in Fig. 4, subjective preference for vertical movement was more sensitive than that for horizontal movement, that is, asymmetry in the sensitivity of vertical and horizontal movement preference was detectable in the fast-moving range in Experiment 1. Scale value of preference at period of 0.8 s was significantly smaller than that of 1.2 s for vertical movement ($P < 0.05$) in Experiment 2. Breitmeyer et al. show anisotropy between the upper and lower hemifields with the use of dynamic random-dot stereograms [20]. In magnetoencephalographic studies, Portin et al. suggest that the human visual cortex close to the calcarine sulcus is more strongly activated by lower than upper visual field stimulus, however, such asymmetry doesn't exist in horizontal visual field stimulus [21, 22]. Naito et al. show that the amplitude of the magnetic responses to downward motion is larger than that to upward motion in the upper visual field [23]. Such asymmetries in cortical activation may effect the sensitivity of vertical and horizontal movement preference.

Scale values of preference at the most preferred periods for both horizontal and vertical movement are nearly equal in Experiment 2. This means that both movements are acceptable in pleasant sequential design. However, more attention to sensitivity is needed for the vertical direction because of sharp decline of subjective preference in the fast-moving range.

The weighting coefficient β in equation (5), estimated by a quasi-Newton numerical method, was nearly equal to 3/2. This is consistent with preference judgment for a flickering light [5], sound fields [6-8], and matching a tonal tempo with wind blown camphor leaves [24]. Equation (6), which represents the preference evaluation curve in the present study, corresponds to that of sound fields, which could mean that the theories on subjective preference of sound fields might also be applicable to studies such as this on visual fields. Theories on subjective preference of sound fields have an important influence on the way that concert halls are designed and built [10]. As for visual fields, theories on subjective preference can also be helpful in creating aesthetically pleasing sequences. In this paper, an example of subjective preference of a visual stimulus was showed. Clearly, such a sample is insufficient to serve as the basis of any form of proof. Further studies based on a much larger population of visual stimuli are necessary.

5. CONCLUSION

The results of this paper lead to the following conclusions:

1) The most preferred periods are approximately 0.97 s for vertical direction stimuli and approximately 1.26 s for horizontal direction stimuli. Thus, a shorter period is more preferable in the vertical direction than in the horizontal direction ($P < 0.01$).

2) For vertical direction stimuli, the values of the weighting coefficient α_f indicating sharpness of preference are significantly larger than the values of α_s ($P < 0.01$) when the period of stimulus movements is varied separately in vertical or horizontal direction. Scale value of preference at period of 0.8 s is significantly smaller than that of 1.2 s for vertical movement. ($P < 0.05$) and scale value of preference at period of 0.8 s for vertical movement is significantly smaller than that for horizontal movement ($P < 0.01$) when the direction and the period of stimulus movements are varied simultaneously.

3) The scale value of preference is formulated approximately in terms of the 3/2 power of the normalized period of a circular stimulus moving in vertical and horizontal directions.

ACKNOWLEDGEMENTS

This research was supported by a Research Fellowship from the Japan Society for the Promotion of Science for Young.

REFERENCES

[1] Dember, W. N. and Earl, R. W. (1957). Analysis of exploratory, manipulatory, and curiosity behaviors. Psychol. Rev. 64, 91-96.

[2] Vitz, P. C. (1964). Preferences for rates of information presented by sequences of tones. J. Exp. Psychol. 68, 176-183.

[3] Vitz, P. C. (1966). Affect as a function of stimulus variation. J. Exp. Psychol. 71, 74-79.

[4] Chen, C., Ryugo, H., and Ando, Y. (1997). Relationship between subjective preference and the autocorrelation function of left and right cortical α-waves responding to the noise-burst tempo, J. Archi. Plann. Environ. Engng. AIJ. 497, 67-74.

[5] Soeta, Y., Uetani, S., and Ando, Y. (2002). Relationship between subjective preference and alpha-wave activity in relation to temporal frequency and mean luminance of a flickering light. J. Opt. Soc. Am. A 19, 289-294.

[6] Ando, Y. (1983). Calculation of subjective preference at each seat in a concert hall. J. Acoust. Soc. Am. 74, 873-887.

[7] Ando, Y. (1985). Concert Hall Acoustics. Springer-Verlag, Heidelberg.

[8] Ando, Y. (1998). Architectural Acoustics, Blending Sound Sources, Sound Fields, and Listeners. AIP Press Springer-Verlag, New York.

[9] Thurstone, L. L. (1927). A law of comparative judgment, Psychol. Rev. 34, 273-289.

[10] Ando, Y. and Noson, D. (1997). Music and Concert Hall Acoustics, conference proceedings of MCHA 1995. Academic Press, London.

[11] Kaplan, S. (1987). Aesthetics, affect and cognition: environmental preference from an evolutionary perspective. Environ. Behav. 19, 3-32.

[12] Gullikson, H. (1956). A least square solution for paired comparisons with incomplete data. Psychometrika 21, 125-134.

[13] Mosteller, F. (1951). Remarks on the method of paired comparisons III. Psychometrika 16, 207-218.

[14] Ball, K. and Sekuler, R. (1974). Masking of motion by broad-band and filtered directional noise. Percept. Psychophys. 26, 206-214.

[15] Levinson, E. and Sekuler, R. (1980). A two-dimensional analysis of direction-specific adaptation. Vis. Res. 20, 103-108.

[16] van de Grind, W. A., Koenderink, J. J., van Doorn, A. J., Milders, M. V., and Voerman, H. (1993). Inhomogeneity and anisotropies for motion detection in the monocular visual field of human observers. Vis. Res. 33, 1089-1107.

[17] Raymond, J. E., (1994). Directional anisotropy of motion sensitivity across the visual field. Vis. Res. 34, 1029-1038.

[18] Gros, B. L., Blake, R., and Hiris, E. (1998). Anisotropies in visual motion perception: a flesh look. J. Opt. Soc. Am. A, 15, 2003-2011.

[19] Kinchla, R. A. and. Allan, L. G. (1970). Visual movement perception: A comparison of sensitivity to vertical and horizontal movement. Percept. Psychophys. 8, 399-405.

[20] Breitmeyer, B., Julesz, B., and Kropfl, W. (1975). Dynamic random-dot stereograms reveal up-down anisotropy and left-right isotropy between cortical hemifields. Science 187, 269-270.

[21] Portin, K., Salenius, S., Salmelin, R. and Hari, R. (1998). stimuli. Neuromagnetic recordings. Exp. Brain Res. 124, 287-294.

[23] Naito, T., Kaneoke, Y., Osaka, N. and Kakigi, R. (2000). Asymmetry of the human visual field in magnetic response to apparent motion. Brain Res. 865, 221-226.

[24] Soeta, Y., Uchida, Y., and Ando, Y. (2001). Matching a tonal tempo with movement of camphor leaves in the wind. J. Temporal Des. Arch. Environ. 1, 21-26.