inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 6.3

PSYCHOLOGICAL EFFECTS OF LIGHTING AND TEMPERATURE ON NOISE ANNOYANCE WITH NOISE SOURCE SIMULATOR

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Keywords:
ANNOYANCE, AUDIO-VISUAL INTERACTION, ILLUMINATION, SEASON

ABSTRACT
Light and temperature have a psycho-physical influence on people. They can soothe or excite, stimulate or depress. From the aspect, this paper discusses how degree the annoyance on various kinds of noises is influenced by the following factors: illumination (0lx, 30lx, 200lx, 2000lx), hues (red, purple, yellow, green, blue), flickering (welding simulated) and temperature (about 30°C in summer, about 18°C in winter). As the main results, it can be said as follows: (a) The relation between "annoyance" under normal lighting (30lx) and $L_{\mathrm{Aeq(5min)}}$ corresponds to the standard noise-rating scale based on judgment of residents in and around Nagano city. (b) The relation between "annoyance" under night simulated (0lx) and $L_{\mathrm{Aeq(5min)}}$ is parallel (-7dB) to the standard noise-rating scale. (c) The effects of audio-visual interaction between noise and light-hues can bring about annoyance in the following order: blue, green, yellow, purple and red.

1 - INTRODUCTION
The effect of noise, as one of the undesirable forms of sound, can be controlled by different engineering methods or its effects on people can be soothed by one of alternative methods, for example by the effects of illumination, temperature and background music. Using a brightness and hue of illumination to soothe or excite the effect of noise is based on the changing of perception in brain or method of turning away the attention of the subject from the noise.
In this paper the effect of interaction among the senses of sight, hearing and heat on noise annoyance is experimentally discussed.

2 - OUR STANDARD NOISE-RATING SCALE
There is no general model that relates physical measures of sound to auditory experiences (e.g., loudness) and, in turn, to annoyance (or noisiness) levels of community noises. Words representing the degree of annoyance vary with region and other factors. In many papers published up to date, however, the factors above were not all considered during selection of the rating words. Based on fundamental field experiments in and around Nagano City [1], [2], seven typical words to represent the level of "annoyance" were selected from 684 words collected. The noise-rating scale was composed using the method of successive categories [3]. The "annoyance" scale obtained has good correlation with $L_{\mathrm{Aeq(5min)}}$[dB] regardless of the kinds of noise sources (vehicles, machine shops, saw mills, trains, ironworks, construction equipment, etc.). It can be said that: "extremely annoying (3.19)" corresponds to 86dB, "very annoying (2.06)" to 74dB, "annoying (1.15)" to 64dB, "a little annoying (0)" to 52dB, "not too bothersome (-0.91)" to 43dB, "not bothersome (-1.81)" to 33dB and "not at all bothersome (-3.06)" to 20dB (see Table 3).

3 - PSYCHOLOGICAL EXPERIMENT
As the noise sources selected, the details (recording conditions and playback level) are listed in Table 1. The playback locations are an anechoic room (4×5×3 m) and a reverberation room (68m^3, room constant=15.8, reverberation time 3.0sec at 500Hz) of Shinshu University. Each noise was played back

in stereo from two loudspeakers (ONKYO D-77 FX) placed on one side (2m) of an equilateral triangle containing a subject being tested. In the case of aircraft noise, two loudspeakers (PIONEER S-55 TSD) suspended from the ceiling were used for playback. Table 2 shows our experimental conditions (room, illumination, season, noise etc.).

Class	Sources		Distance [m]	Recording level [dB] $L_{\mathrm{Aeq(5min)}}$	Background noise level	Playback level [dB] $L_{\mathrm{Aeq(5min)}}$
Vehicles	(a) National route 18 with average flow; 128/5min (Nagano City)					
	Large vehicles mixed at:	16%	2	72.9		72.9
		24%	30	62.2		62.2
		11%	60	50.8		50.8
		13%	120	45.5		45.5
						35.5
	(b) Tomei Express with average flow; 240/5min (Numazu City)					
	Large vehicles mixed at:	32%	5	68.7		68.7
		39%	50	60.2		60.2
		32%	50	59.2		49.2
		39%	71	58.1		38.1
						28.1
Trains	(c) JR conventional	3	3	69.3	35	69.3
	Limited express	2	10	65.2	34	65.2
	Local:	3	20	54.6	37	54.6
	(Nagano City)	1	50	51.1	39	41.1
						31.1
	(d) Tokaido Shinkansen:	3	5	69.8	44	59.8
	(Numazu City)	3	5	71.9	42	71.9
		3	6	70.9	41	50.9
		2	50	59.5	39	39.5
						29.5
Airplanes	(e) Haneda Airport (various jets)					
	Above the head:	3		76.3	39	71.3
		2		62.3	38	62.3
		3		77.4	42	77.4
		3		80.1	38	80.1
	Landing on opposite direction:					
		2		56.5	44	41.5
		3		65.1	45	31.5
		3		62.5	44	55.1
		3		59.3	47	52.5
						39.5
						29.3

Class	Sources	Distance [m]	Recording level [dB] $L_{Aeq(5min)}$	Background noise level	Playback level [dB] $L_{Aeq(5min)}$
Steady Noise	(f) (Nagano City)				
	Air-conditioner fan (factory)	25	54.2		54.2
	Air-compressor and fan	12	65.8		34.2
	Stone-crusher for concrete	10	74.6		65.8
	Stone-crusher and polisher	34	63.9		45.8
	Table saw	5	68.2		74.6
	Plane	8	61.5		63.9
					43.9
					68.2
					51.5
					31.5
Intermittent Noise	(g) (Nagano City)				
	Scrap metal crusher/collector	13	65.4		45.4
	Press machine	23	56.8		26.8
	Press machine	2	75.6		75.6
	Crane, frame assembly	16	65.2		55.2
	Concrete breaker	23	62.4		62.4
	(h) (Haneda Steel Works area) (Tokyo)				
	Metal works	3	67.3		52.3
	Grinder	5	62.0		32.0
	Press machine	5	70.8		60.8
	Press and air-compressor	2	79.0		74.0
	Press and fan	5	64.9		44.9

Table 1: Selected noise sources.

Test	Room	Illumination				Season	Noise	Subjects
No.		Brightness (lx)		Hue	Flickering	(Temperature)	sources	
1	Anechoic	50		White	-	Spring (20°C)	Table 1	A group
	Room					Fall (20°C)	Table 1	(7 men)
	Background Music (Tatsuro Yamashita "Get back in love") $L_{Aeq(5min)}$=52.5 dB							
2	Reverberation room		45	White	-	Fall (20°C)	Table 1	B group (9 men)
3	Anechoic	0, 30, 2000		White	-			
	Room	200	Red, Purple, Yellow, Green, Blue		-	Winter (18°C)	Table 1	C group (7 men)
		200		Purple	Controlled		1/1 octave band	
		by M-sequence signal (n=7)				noise ($f0$=250, 1k, 4kHz)		
4	Anechoic	0, 30, 2000		White	-			
	Room	200	Red, Purple, Yellow, Green, Blue		-	Summer (30°C)	Table 1	D group (9 men)
		200		Purple	Controlled		1/1 octave band	
		by M-sequence signal (n=7)				noise ($f0$=250, 1k, 4kHz)		

Table 2: Experimental conditions in our laboratory.

Factors (No. of test)	Correlation coefficient	Constant: α	Slope: β	Standard deviation of residual
		Confidence limits (Lower limit, Upper limit) at level 95%	Confidence limits (Lower limit, Upper limit) at level 95%	
Field tests	0.792	-4.96 (-5.25, -4.67)	0.95 (0.90, 1.00)	0.98
Anechoic room test (No.1)	0.849	-4.83 (-5.04, -4.62)	0.95 (0.91, 0.98)	0.83
Reverberation room test (No.2)	0.876	-4.96 (-5.26, -4.67)	1.00 (0.95, 1.06)	0.78
Effect of background music (No.1)	0.864	-6.69 (-7.24, -6.13)**	1.25 (1.14, 1.35)**	1.01
(a): Vehicles (see Table 1) (No.1)	0.912	-5.07 (-5.56, -4.58)	0.99 (0.90, 1.08)	0.63
(b): Vehicles (see Table 1) (No.1)	0.823	-4.56 (-5.24, -3.89)	0.89 (0.77, 1.02)	0.87
(c): Trains (see Table 1) (No.1)	0.860	-6.07 (-6.79, -5.35)**	1.11 (0.98, 1.25)*	0.93
(d): Trains (see Table 1) (No.1)	0.887	-5.84 (-6.44, -5.24)*	1.06 (0.95, 1.17)*	0.78
(e): Airplanes (see Table 1) (No.1)	0.869	-4.61 (-5.18, -4.04)	0.91 (0.82, 1.01)	0.89
(f): Steady noise (see Table 1) (No.1)	0.883	-4.72 (-5.18, -4.28)	0.95 (0.86, 1.03)	0.72
(g): Intermittent noise (Table 1) (No.1)	0.851	-3.76 (-4.22, -3.30)**	0.82 (0.73, 0.90)*	0.71
(h): Intermittent noise (Table 1) (No.1)	0.836	-4.28 (-4.87, -3.70)*	0.82 (0.71, 0.93)*	0.76
0 lx, 18°C (No.3)	0.838	-4.40 (-5.11, -3.70)**	1.00 (0.87, 1.13)	0.92
30 lx, 18°C (No.3)	0.848	-4.67 (-5.31, -4.04)	0.93 (0.81, 1.04)	0.82
2000 lx, 18°C (No.3)	0.832	-4.36 (-5.04, -3.67)*	0.94 (0.82, 1.07)	0.89
0 lx, 30°C (No.4)	0.848	-3.86 (-4.47, -3.25)**	0.90 (0.79, 1.01)	0.79
30 lx, 30°C (No.4)	0.833	-3.81 (-4.42, -3.20)**	0.84 (0.73, 0.95)	0.79
2000 lx, 30°C (No.4)	0.849	-3.81 (-4.41, -3.21)**	0.89 (0.77, 1.00)	0.78
200 lx, Red, 18°C (No.3)	0.800	-3.78 (-4.49, -3.07)**	0.87 (0.74, 1.00)	0.92
200 lx, Purple, 18°C (No.3)	0.839	-4.14 (-4.79, -3.50)**	0.91 (0.79, 1.03)	0.84
200 lx, Yellow, 18°C (No.3)	0.841	-4.34 (-4.98, -3.69)**	0.92 (0.81, 1.04)	0.84
200 lx, Green, 18°C (No.3)	0.787	-3.96 (-4.67, -3.24)**	0.85 (0.72, 0.99)	0.95
200 lx, Blue, 18°C (No.3)	0.770	-4.43 (-5.24, -3.62)	0.89 (0.74, 1.04)	1.05
200 lx, Red, 30°C (No.4)	0.780	-3.22 (-3.88, -2.56)**	0.75 (0.63, 0.87)**	0.85

Factors (No. of test)	Correlation coefficient	Constant: α	Slope: β	Standard deviation of residual
		Confidence limits (Lower limit, Upper limit) at level 95%	Confidence limits (Lower limit, Upper limit) at level 95%	
200 lx, Green, 30°C (No.4)	0.822	-4.15 (-4.79, -3.50)**	0.85 (0.73, 0.97)*	0.84
200 lx, Purple, Flickering, 18°C (No.3)	0.559	-1.92 (-2.75, -1.10)**	0.51 (0.36, 0.66)**	1.07
200 lx, Purple, Flickering, 30°C (No.4)	0.664	-1.27 (-1.81, -0.74)**	0.44 (0.34, 0.54)**	0.70

Table 3: The correlation coefficient, the regression coefficients (constant and slope), each lower and upper limit of the 95%-confidence interval, and the standard deviation of residual for simple regression model (*: statistical significance at the level of p<0.05, **: statistical significance at the level of p<0.01).

Especially, the flickering condition was simulated with the working of welding.

4 - TEST RESULTS

Effects of secondary (i.e., noise sources, room, background music, illumination and season) factors are investigated by fitting coefficients in the following linear model through simple regression analysis:

$$A = \alpha + \beta \left(L_{\mathrm{Aeq(\ 5min)}} / 10 \right) \quad (1)$$

where A is the annoyance score; α is the constant (intercept); and β is the slope.
Table 3 gives the correlation coefficient for model (1), the regression coefficients (constant and slope), each lower and upper limit of the 95%-confidence interval, and the standard deviation of residual. The 95%-confidence interval of the regression coefficients can test for the significant difference between our standard noise-rating scale and each noise-rating scale obtained under the conditions shown in Table 1 and Table 2. An asterisk (*) indicates that a difference is significant at the level of p<0.05, and (**): at the level of p<0.01.

5 - CONCLUSIONS

From the experimental results on psychological effects of secondary physical factors (i.e., various kinds of noise sources, room, background music, illumination and season), several conclusions can be given in following:

- "A little annoying" corresponds to about 51dB of $L_{\mathrm{Aeq(5min)}}$ regardless of the kinds of noise sources except for trains (55dB) and intermittent noise ((g) see Table 1: 46dB).
- The annoyance scale is good correlative with $L_{\mathrm{Aeq(5min)}}$ regardless of experimental place.
- For soothing a noise background music proper to the occasion (above the same sound volume as noise level) is more suitable, because music can create a perception of a less noise.
- For nighttime simulated (0lx) "a little annoying" corresponds to 44.0 dB (winter) and 42.9dB (summer), because the utter darkness can create a perception of a more noise.
- Light-brightness (2000lx) is not suitable for soothing a noise. "A little annoying" corresponds to 46.4dB (winter) and 42.8dB (summer).
- Light-colors are not suitable for soothing a noise, because in fact they exacerbate it. "A little annoying" corresponds to 43.4dB (red), 45.5dB (purple), 46.6dB (yellow), 47.2dB (green) and 49.8dB (blue).
- Light-flickering simulated welding can create a perception of a more noise. "A little annoying" corresponds to 37.6dB (winter) and 28.9dB (summer).

ACKNOWLEDGEMENTS
This research was partially supported by the Ministry of Education, Science, Sports and Culture, Grant-in-Aid for Scientific Research C (2), 11832009, 1999.

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