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Equating Individual Differences For Auditory Input

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ABSTRACT

While the level of intensity of a stimulus is highly controlled in most psychological experiments, there has never been a corresponding demonstration that the level of stimulus intensity is perceived by different subjects as being equivalent. That this is not the case has been demonstrated here. Both individual differences and a strong effect of sex were observed. A formula is given whereby control of input can be related to perceived loudness.

DESCRIPTORS: Sensation level, Sound pressure level, Orienting response, Startle response, Uncomfortable loudness level.

An unwritten assumption in much psychological literature is that objective standardization of input to the subject implies a correspondingly standardized subjective reaction, in that fixed levels of stimulation will be perceived as equivalent between subjects. Because of this assumption, conclusions regarding subject differences in response to stimuli are often attributed to such phenomena as personality (Spence & Farber, 1953; Eysenck, 1967), cognitive style (Silverman, Buchsbaum, & Henkin, 1969), but almost never to basic differences in enduring levels of sensitivity. With respect to such differences it is interesting that the sex variable is consistently found to affect both hearing thresholds at frequencies above 4000 Hz (Corso, 1959) and visual acuity (Roberts, 1964). A more sensitive auditory or visual system could relate to a more sensitive response to loudness or brightness. However, experiments on hearing tend to be negative in this respect. Barbenza, Bryan, and Tempest (1970) have found no correlation between threshold for hearing and loudness scaling, whereas Hood (1968) and Stephens (1970) suggest that there may be a negative relationship between the two when sensation level (SL) is the criterion.

This poses a problem. How can one ensure that different subjects perceive the stimulus administered in a comparable fashion? If a correlation exists between threshold and intensity judgments then the most straightforward solution to ensure equivalent input would be to fix levels at a certain number of decibels above threshold (sensation level) as was done by Keefe (1970). If no correlation exists then an adjustment or ratio score must be derived which includes subject differences in judgment of intensity.

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The problem of equating input for subjects becomes particularly critical for experiments in psychophysiology where autonomic responses to startle are presumed to differ from those to the orienting response. Graham and Clifton (1966) in their review of the literature report that the startle response can occur from about 70–75 decibels (dB) as measured by heart rate acceleration, whereas the orienting response producing deceleration is found to stimuli below this level. Uno and Grings (1965) found a uniphasic deceleration only, to tones of 60 dB or less. A similar problem arises when magnitude changes of vegetative responses such as the galvanic skin response and blood flow are the dependent variables. As the startle response or defensive reflex has non-habituating properties, while the orienting response habituates (Sokolov, 1963), then an accurate assessment of the level which produces startle in any individual is imperative.

This paper reports on data from a general study on individual differences in perception which are used to investigate the relationship between threshold and perceived loudness (McGuinness, 1972). The threshold measure was carried out in line with the normal audiometry procedures using the Method of Limits in order that the results could be compared directly with the available normative data. The tests for loudness intensity judgment employed a modified technique to that normally used for experiments on "uncomfortable" or "unpleasant" loudness levels (ULL) (Hood, 1968; Stephens, 1971). In the current experiment the subject was asked for a loudness judgment based upon a hypothetical scale of loudness levels. This was done both as an attempt to eliminate any interaction of fear with loudness judgment and to ensure greater reliability between subjects.

To measure factors of personality which might be expected to relate to responses to sensory input, the IPAT Contact Personality, Neuroticism, and Anxiety Questionnaires were employed (Cattell, King, & Schuettler, 1954; Scheier & Cattell, 1961; Cattell & Scheier, 1963).

Method

Subjects

Fifty students participated in the experiment (25 males and 25 females). They were first and second year psychology undergraduates. The age range was from 18–26, with a mean age of 20.6 yrs.

Apparatus

The experiment employed a Peter's SPD 5 Clinical Audiometer, with TDH-39 earphones and MX-41/AR cushions. The audiometer was checked for calibration using an artificial ear prior to the experiment, and also immediately after the experiment was completed. Calibration was found to be satisfactory at the conclusion of the experiment. Due to the available calibration figures, the frequencies of 10,000 and 12,000 Hz could only be checked for relative accuracy. The data recorded at these frequencies was reported for threshold, but no analysis was carried out above 8000 Hz.

The experiment was carried out in a semi-soundproofed windowless acoustically tiled room.

Procedure

Threshold measures were carried out in accordance with the recommended audiometric technique. The *S* was told that he would be presented with a series of continuous tones of different frequencies and each ear was to be stimulated separately. The frequencies employed were 125, 250, 500, 1000, 2000, 3000, 4000, 6000, 8000, 10,000, and 12,000 Hz. All *Ss* had 2 descending and 2 ascending trials for each ear at each frequency. Thresholds were measured to the nearest dB.

In the loudness test the *S* was seated facing the audiometer and was asked to adjust the attenuator to a decibel level which he felt was "too loud." This was based on a verbal rating sequence: Inaudible, faintly audible, distinct, fairly loud, too loud, uncomfortably loud, pain. At the point where a "fairly loud" tone became "too loud" the *S* was asked to stop the attenuator and his response was recorded. Each *S* had 3 trials at all the frequencies in the range 250–8000 in random order and had his eyes closed throughout the trials. All tones were presented monaurally to the ear with the best overall threshold. If this could not be determined, *S* received left ear presentations. Each *S* was asked to fill in three personality questionnaires: The Cattell Anxiety, Neuroticism, and CPT (Extravert-Introvert) scales.

Results

Part 1

Threshold curves are presented in Fig. 1 and illustrate the sex differences normally found at higher frequencies, although these differences are less marked than those usually recorded and do not appear until 6000 Hz.

No analysis was carried out on any part of these curves, as they represent typical threshold curves for this age group (Corso, 1959; Eagles, Wishik, Doerfler, Melnick, & Levine, 1963; Hull, Mielke, Timmons, & Willeford, 1971).

Part 2

Loudness estimations were remarkably consistent within *Ss*, seldom varying more than 5 dB across the frequency range. Distributions showed only a marginal leptokurtosis, mainly for women, with the tendency for scores to fall further below than above the mean. The standard deviation for the men was 13.45 (range 60–115 dB), and for the women, 15.72 (range 40–100 dB). The

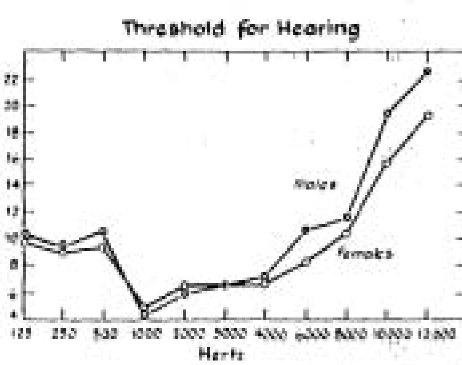

Fig. 1. Threshold levels in dB (.0002 dyne/cm²) for males and females over 11 frequencies.

plot of loudness estimates across the frequency range is illustrated in Fig. 2 and shows a striking effect of sex.

An analysis of variance showed that the sex difference was significant at $p < .001$, with no significant effect of frequency, and no interaction F, 7 and 368 = 28, < 1, < 1). The audiometer had an automatic cut-out device for the frequencies 125, 10,000, and 12,000 Hz, hence the analysis was performed only on the scores in the range 250–8000 Hz. The mean loudness levels for each sex were as follows: Men, 83.30 dB, Women, 75.50 dB.

Correlations were carried out for frequencies at threshold and levels of loudness estimation in the range 250–8000 Hz. An additional correlation was computed for threshold at 10,000 against the mean overall tolerance for each *S*. All other correlations were computed using the scores for each frequency level.

Table 1 shows that for males the correlations tend to be negative, with significant negative correlations occurring across the frequency range 2000–4000 Hz ($p < .05$). For the women the correlations are positive, with only one positive correlation which reached significance ($p < .05$). In view of the fact that most correlations are not significant and none were strong enough to suggest that there was a fixed relationship between threshold and loudness, it was concluded that a lawful relationship between threshold and loudness at all frequency levels does not exist. This confirms the findings of both Barbenza et al. (1970) and Stephens (1970) using sound pressure levels.

TABLE 1

Correlations for threshold and loudness estimation levels

Sex Groups	Correlation								
	250[a]	500	1000	2000	3000	4000	6000	8000	10,000
Females	.11	.13	.23	.14	.14	.21	.19	.36*	.30
Males	−.12	−.09	−.10	−.45*	−.49*	−.43*	.11	.12	−.08

[a]Hz, throughout.
*$p < .05$.

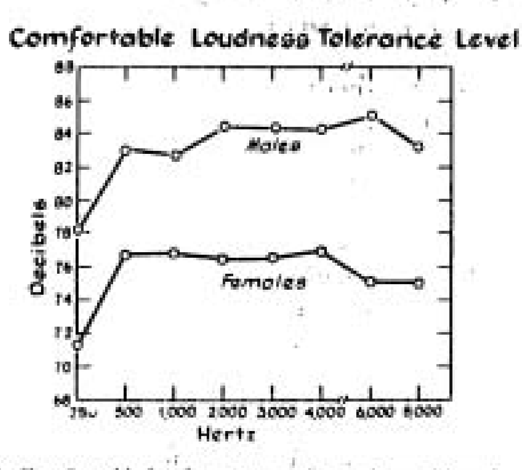

Fig. 2. Comfortable loudness curves for males and females.

Correlations were compiled for personality as related both to tolerance and to threshold. The highest correlation which occurred was for female extraversion showing a positive relationship to increased loudness tolerance. This was .23 and is not significant. Personality scores were also grouped into categories of high, medium, and low on each measure and tests for trend were carried out using the Jonckheere Trend Test. Again no significant trend was found for any personality factor with the exception of females showing a significant trend ($p < .03$) for extraversion to relate to high loudness judgment, and introversion to low.

Discussion

The most striking result to emerge from this study is the sex difference in loudness estimation. This confirms almost exactly the decibel differences found in children using white noise as the stimulus, and asking the children for a level of "loud enough" (Elliott, 1971). However, this does not imply that a simple answer to the problem of ensuring equivalent input to subjects is to fix an arbitrary difference level for males and females. The raw data showed that men were just as likely to have abnormally low loudness estimations as females were to have high estimations. So the problem is not a straightforward one.

The findings of this study relate to known psychometric and acoustic data as follows:

1. The tendency for negative correlations to occur between threshold and loudness estimation for men corresponds to Hood's (1968) finding where he found a significant negative correlation between the uncomfortable loudness level and threshold when using sensation levels, but not when using sound pressure levels. Hood only investigated responses at 1000 Hz, and it may be that the relationship between threshold and loudness is more complex than he suggests, although Stephens and Anderson (1971) also report a significant negative correlation between ULL and SL, using a wider range of frequencies. A negative correlation could suggest that a recruitment effect may be occurring for certain subjects, in that hearing loss beyond normal levels will be related to lower tolerance of loudness. Thus the correlations could well be elevated by a few subjects with abnormal hearing loss. Hood and Poole (1966) advocate the use of sound pressure levels for measurement within subjects, as it is far more consistent over time than results obtained using sensation levels. When comparing inter-ear correlations for each subject, Stephens and Anderson report consistently high positive correlations for SPL but not for SL. It does appear from all the evidence that some type of adjustment score would be preferable to the use of sensation levels.

2. The loudness curve appears flat over most frequencies (Fig. 2) which parallels the findings in psychophysics (Stevens & Davis, 1938). This indicates that the subjects were stable in their criterion levels throughout these trials. The descending limbs of the curve at either extreme do not agree with the data of Stevens and Davis who found that at either extreme of the frequency range the equal loudness contours tend to rise, only becoming flat at 100 dB. The opposite findings here could be related to harmonic distortion in the audiometer at both low and high frequencies. However, Stephens (1970) reports that the loudness slope in his experiment was steeper at 250 Hz than at 4000 Hz, which accords with the data reported here.

3. Experiments investigating the slope of the loudness function, or loudness scaling, have consistently demonstrated that magnitude estimations fall on a straight line when the subject's log score is plotted against dB. This indicates that there is a power function involved in the perception of intensity (Stevens, 1956; Barbenza et al., 1970; Stephens, 1970). Because this finding is almost universal it is possible to suggest that as the loudness estimation curve in this study accorded well with the equal loudness contour data, that the level "too loud" will correspond to some point along a power function of magnitude, e.g. a straight line. This would indicate that for women the slope of the loudness function would be steeper than that of men. This finding has been consistently noted in experiments, but has not been reported in the literature.[1] Because the threshold levels between the sexes were nearly identical, in contrast to the unequal loudness estimation levels, this would suggest, apart from individual differences, that a formula equating input to subjects should be derived using loudness estimation data.

The formula could take the initial form based upon the power law which states that:

$$\Psi = k\Phi^n$$

The complete form is:

$$\Psi = k(\Phi - \Phi_0)^n$$

where Φ is a "threshold" value of physical magnitude. Although no threshold value is absolute due to subject variability involved in the loudness scaling technique, for purposes of a simple approximation within a single experimental framework, it can be assumed that:

$$\Phi_0 = 0$$

K is a scaling parameter which relates to the unit measurement employed, and to the individual's sensory magnitude scale. Again for purposes of ease of computation, magnitude can be scaled so that:

$$k = 1$$

We then have:

$$\log \Psi = n \log \Phi$$

It could be the case that an affective component, such as fear, is involved in loudness estimation. However, the only affective personality variable known to be related to loudness or noise estimation is anxiety (Pearson & Hart, 1969; Stephens & Anderson, 1971), and this relationship has been eliminated by adopting the rating technique employed in this experiment. So we can assume that the estimation of "too loud" will correspond to a reasonably equal sensation value for all subjects. In any case it could be argued that some affective component would enter into any type of loudness estimation, whether it be loudness scaling, or estimation of a specific level; although this remains to be verified. We can therefore assume that Log Φ is given by the decibel measure.

Now let:

Dt_m = Log Φt_m (the measured mean tolerance for males)

Let Dt_i be the tolerance threshold for a given individual

Let n_m be the power law index for the average male

[1] D. W. Robinson, National Physical Laboratories, unpublished data.

Let n_i be the power law index for an individual S_i.
At the loudness threshold we then have:

$$n_m Dt_m = n_i DT_i$$

It will be noted that both male and female estimates of "too loud" fall in the range of intensity designated as startle (Graham & Clifton, 1966). Therefore an abrupt onset of tone at these levels will undoubtedly produce a startle response in many subjects. If this is not desired then the equation should thus be modified by altering Dt_m to some lower value: D_m. Dt_i would then change to D_i for a corresponding sensory magnitude given by:

$$nm\ Dm = ni\ Di$$

So:

$$\frac{D_i}{Dt_i} = \frac{D_m}{Dt_m}$$

In changing the standard Dt_m to avoid startle, one should take for a given subject a value D_i which bears the same ratio to Dt_i as D_m does to Dt_m. This gives the final working formula:

$$D_i = D_m \cdot \frac{Dt_i}{Dt_m}$$

The substitution in the formula of the female mean score should be done for female subjects, ensuring that the same ratio employed for D_m to Dt_m is used for D_f to Dt_f.

The formula above will give an approximate equivalence between subjects, and is certainly to be preferred over a purely arbitrary standard of input or to the use of sensation levels. It will be apparent that to find the best fitting $\Psi = k(\Phi - \Phi_0)^n$ for any individual a more complex technique would be required. This is clearly beyond the possibilities of many psychological laboratories both in terms of equipment and time. The equation above can be employed with an inexpensive audiometer, provided that all subjects within a given experiment are tested in the same manner.

The finding for extraversion in females relating to high tolerance of loudness is in line with that of Elliott (1971) on children, but the absence of any relationship in men is difficult to explain. Other findings illustrate certain inconsistencies in the data. Stephens (1971) reports that females show a bimodal distribution in noise annoyance scores, with high annoyance subjects being significantly more introverted. This was not observed for men. In the study by Stephens and Anderson (1971) they report a significant effect for extraversion in estimation of uncomfortable loudness levels in one study, but this relationship was not found in a subsequent experiment. The absence of a relationship between personality and threshold confirms the findings of Stephens (1969) but does not uphold the relationship to extraversion found by Smith (1968).

The lack of any significant effect of neuroticism or anxiety on hearing in this study tends to indicate that relatively pure sensitivity factors are involved. A study by Wilson and Zung (1966) also supports this view. They demonstrated that when a criterion to respond to specific auditory stimuli was established, sexes did not differ in EEG activation. However, significantly greater EEG desynchronization occurred in females at all levels of sleep, when the stimuli had no signal value. This strongly suggests that sensitivity rather than a response bias is responsible for sex differences in hearing.

This assumption is all the more compelling in view of the author's recent findings that men are significantly less tolerant of light than women. It becomes difficult to argue, therefore, that environmental or cultural factors could operate to oversensitize one modality in women, and a different modality in men.

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