

Stimulus Versus Response Competition and Ear Asymmetry in Dichotic Listening

C.J. Darwin*

Haskins Laboratories, New Haven

The origin of the ear asymmetry effect in dichotic listening has been attributed to a number of factors: perception (Kimura 1961a,b), memory (Inglis, 1962; Oxbury, Oxbury, and Gardiner, 1967) and attention (Treisman and Geffen, 1968) all being espoused as candidates. Recent work on the recall of dichotically presented nonsense syllables has reinforced Kimura's original hypothesis that the effect originates in a difference in the efficiency with which the two hemispheres perceive auditory material (Darwin, 1971a; Haggard, 1971; Studdert-Kennedy and Shankweiler, 1970). Whether or not a right-ear advantage appears is not entirely predictable simply in terms either of the acoustic features in the stimulus presented to the subject or of the phonetic response category to whose perception they contribute, but rather in the relationship between the two (Darwin, 1971a). If short-term memory variables were paramount in determining the ear difference effect, we would expect the phonetic category to be the only relevant variable. This paper looks at the question of stimulus and response factors as determinants of the right-ear advantage from a slightly different angle, that of determining the conditions of contralateral stimulation under which the effect occurs.

It is generally true that ear differences are obtained more readily under conditions of dichotic presentation than monotic. The most convincing evidence of this comes from work on commissurotomed patients who can report perfectly digits presented to the left ear when only the left ear is stimulated but can report very little from the left ear when different digits are played simultaneously to the opposite ear (Milner, Taylor and Sperry, 1968). The extent of the suppression of the left ear depends on the clarity of the signal on the right ear; the greater the distortion, the less from the left ear is recalled (Sparks and Geschwind, 1968).

Work with normal subjects also shows that the nature of the competing stimulus is important. In otherwise similar paradigms, Kirstein and Shankweiler (1969) find a reliable right-ear advantage for stop-vowel syllables when they are opposed by another stop-vowel syllable, whereas Corsi (1967) failed to find any right-ear advantage for nonsense syllables opposed by white noise. Darwin (1971b) also found no right-ear advantage for stop-vowel syllables opposed by a random noise. Contralateral white noise, however, can enhance the ear difference for a two-click threshold task (Murphy and Venables, 1970). The relationship between the signals on the two ears, rather than the absolute nature of the signal, thus appears to be the important variable.

For ear differences to be revealed there must be both a relevant difference between the hemispheres and sufficient functional decussation to ensure

* Now at the University of Sussex.

that each ear is projected predominantly to the opposite hemisphere. Without a competing stimulus, that is, under monaural stimulation, the latter condition is presumably not satisfied (Kimura, 1961a,b). If such competition is necessary to ensure adequate functional decussation, we might presume that this competition is only necessary in principle up to the stage of processing at which the hemispheres become functionally distinct, since after this stage the two input signals can be distinguished by this treatment rather than simply by their ear of arrival. If decussation were not sufficient up to this first stage of hemispheric differentiation, no distinction between the hemispheres at this or any subsequent stage would be detectable in the response.

If, indeed, differences between the hemispheres first appear at some perceptual level, rather than at a level associated with the organization of the response, we might expect that, for ear differences to be obtained, the competing stimulus need only be in the same perceptual class as the stimulus on the other ear, rather than actually in the response class used in the experiment.

Method

The response set for this experiment consisted of the stop consonant syllables /ba, pa, ga, ka/. One of these sounds was always present on the ear which the subject attended and was asked to report. The other ear received one from a set of sounds. Which set was used constituted the experimental condition. The three sets were

1. /ba, pa, ga, ka/ (same as response set)
2. /ba, pa/ (two sounds from response set)
3. /da, ta/ (two sounds not in response set but in same perceptual class).

In the first set each sound on the attended ear was paired with every other sound in the response set except itself an equal number of times. The second and third sets, however, were restricted so that the two sounds in a dichotic pair always differed in voicing. The sounds used were prepared on the Haskins parallel formant synthesizer and assembled into a dichotic tape using a special computer program (Mattingly, 1968).

The experimental tape contained one block of forty-eight trials for each stimulus condition. One ear was attended for half a block and then the other ear for the remainder of the block. Each block was taken twice in each of two headphone orientations by each subject. The ordering of the blocks and which ear was attended was approximately counterbalanced over subjects (four of the six block orderings had six subjects and two had four). Thirty right-handed undergraduates, none of whom had previously taken part in a dichotic listening experiment, participated in the experiment.

The subjects were introduced to the sounds of the response set and given some practice at identifying them singly. Only those who did better than 75 percent correct on the single sound identification were allowed to proceed to the dichotic test. For the dichotic test subjects were told that they would get two different sounds, one in each ear, that they were to attend to

a given ear for a sequence of twenty-four trials, and that the sound in that ear would always be one of /ba, pa, ga, ka/, although the sound in the other ear might be something else. They were not told which stimulus condition they would receive nor that the sounds /da, ta/ were also being used in the experiment.

Results

Because of the restriction on the voicing dimension for stimulus conditions 2 and 3, the results were scored only for place of articulation; voicing of both the stimulus and the response was made irrelevant. Confusion matrices (2x2) were constructed for each subject and each stimulus condition, and from these matrices simple percent correct scores were calculated along with a measure of the discriminability of place of articulation untainted by variations in response bias between stimulus conditions. The measure used is derived from Luce (1959) and is

$$\log_e \alpha = \frac{1}{2} [p(R1/S1)p(R2/S2) / p(R2/S1)p(R1/S2)].$$

This measure is almost identical to the d' of signal detection theory but is more readily applicable to larger matrices and is computationally more convenient (Haggard, 1968).

The percent correct values appear in Table 1 and the $\log_e \alpha$ in Table 2.

Table 1. Percent correct for recall of place of articulation of the stops /b,p,g,k/ when opposed by different stimulus sets.

| <u>Ear</u> | <u>Opposing Set</u> | | | |
|--------------|---------------------|------|------|------|
| | bpgk | bp | dt | Mean |
| left | 64.6 | 86.0 | 69.7 | 73.4 |
| right | 71.9 | 90.7 | 74.0 | 78.9 |
| left + right | 68.3 | 88.3 | 71.9 | 76.1 |
| right - left | 7.4 | 4.7 | 4.2 | 5.4 |

Table 2. Mean $\log_e \alpha$ for recall of place of articulation of the stops /b,p,g,k/ when opposed by different stimulus sets.

| <u>Ear</u> | <u>Opposing Set</u> | | | |
|--------------|---------------------|-------|------|------|
| | bpgk | bp | dt | Mean |
| left | .366 | 1.238 | .670 | .758 |
| right | .586 | 1.420 | .822 | .942 |
| right + left | .476 | 1.329 | .746 | .850 |
| right - left | .220 | .182 | .152 | .184 |

Friedman two-way analyses of variance across all three stimulus conditions were not significant for right minus left ear scores either for the percent correct ($p > .2$) or for $\log_e \alpha$ ($p > .1$). There was thus no significant variation in ear advantage over the three stimulus conditions. Combining the data from all three conditions gave a significant right-ear advantage for the percent correct score ($p < .01$; 1-tailed Wilcoxon) and for the $\log_e \alpha$ ($p < .005$; 1-tailed Wilcoxon). The performance level (right plus left ear scores), however, showed highly significant variation on a Friedman test between the three stimulus conditions on $\log_e \alpha$ ($p < .001$). There was a significant difference in right plus left ear scores between stimulus condition 2 and both 1 and 3 ($p < .001$). The subjects are thus reflecting some aspect of the change in stimulus condition.

Since the first stimulus condition is somewhat peripheral to the main question asked by this experiment, a Wilcoxon T-test was used to test whether the ear difference is any larger for condition 2 than for condition 3. This showed a quite insignificant trend in the opposite direction. Combining conditions 2 and 3 gave a significant right-ear advantage on the $\log_e \alpha$ scores ($p < .02$; 1-tailed Wilcoxon) and on percent correct ($p < .05$; 1-tailed Wilcoxon).

Discussion

This experiment certainly gives no support to the hypothesis that the competing stimulus must be part of the response set for a right-ear advantage to be obtained. Provided that the competing stimulus is from the same perceptual class, it need not be part of the response set. Thus a plosive can be an effective competing stimulus to another plosive even if it is not in the response set; by contrast, noise is not a sufficient competing stimulus. This result does not, of course, say at what level between these two extremes competition is effective. The result is quite compatible with the view that the ear difference effect is primarily a perceptual phenomenon but is not so readily explained by a view maintaining that only processes subsequent to phonetic categorization are pertinent.

The significantly greater performance on condition 2 (two sounds from the response set) than on either of the other two conditions suggests that a more predictable stimulus is more readily ignored than a less predictable one. This is, of course, confounded in the present experiment partly by the particular consonants used and partly by the voicing restriction in stimulus conditions 2 and 3. However, the effect is a large one, has implications for theories of attention, and warrants further research.

REFERENCES

- Corsi, P.M. (1967) The effects of contralateral noise upon the perception and immediate recall of monaurally-presented verbal material. Unpublished M.A. thesis, McGill University, Montreal.
- Darwin, C.J. (1971a) Ear differences in the recall of fricatives and vowels. *Quart. J. Exp. Psychol.* 23, 46-62.
- Darwin, C.J. (1971b) Dichotic forward and backward masking of speech and non-speech sounds. Paper presented to Acoust. Soc. of Amer., Washington, April 1971.
- Haggard, M.P. (1968) Selectivity in speech perception models. *Z. Phonetik* 21, 70-73.

- Haggard, M.P. (1971) Encoding and the REA for speech signals. *Quart. J. Exp. Psychol.* 23, 34-45.
- Inglis, J. (1962) Dichotic stimulation, temporal lobe damage and the perception and storage of auditory stimuli: A note on Kimura's findings. *Canad. J. Psychol.* 16, 11.
- Kimura, D. (1961a) Some effects of temporal lobe damage on auditory perception. *Canad. J. Psychol.* 15, 156-165.
- Kimura, D. (1961b) Cerebral dominance and the perception of verbal stimuli. *Canad. J. Psychol.* 15, 166-171.
- Kirstein, E. and Shankweiler, D.P. (1969) Selective listening for dichotically presented stop consonants and vowels. Paper read at Eastern Psych. Assoc. Meeting, Philadelphia, April 1969.
- Luce, R.D. (1959) Individual Choice Behavior. New York: Wiley.
- Mattingly, I.G. (1968) Experimental methods for speech synthesis by rule. *IEEE Trans. AU-16*, 198-202.
- Milner, B., Taylor, L. and Sperry, R.W. (1968) Lateralized suppression of dichotically presented digits after commissural section in man. *Science* 161, 184-186.
- Murphy, E.H. and Venables, P.H. (1970) Ear asymmetry in the threshold of fusion of two clicks: A signal detection analysis. *Quart. J. Exp. Psychol.* 22, 288-300.
- Oxbury, S., Oxbury, J., and Gardiner, J. (1967) Laterality effects in dichotic listening. *Nature* 214, 742-743.
- Sparks, R., and Geschwind, N. (1968) Dichotic listening in man after section of neocortical commissures. *Cortex* 4, 3-16.
- Studdert-Kennedy, M. and Shankweiler, D.P. (1970) Hemispheric specialization for speech. *J. Acoust. Soc. Amer.* 48, 579-594.
- Treisman, A.M. and Geffen, G. (1968) Selective attention and cerebral dominance in perceiving and responding to speech messages. *Quart. J. Exp. Psychol.* 20, 139-150.