
Hemispheric lateralization of singing after intracarotid sodium amylobarbitone

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SYNOPSIS Hemispheric lateralization of singing was investigated in patients who had transient hemiplegia after intracarotid injection of sodium amylobarbitone. It was found that after right carotid injection singing was markedly deficient, whereas speech remained relatively intact. Songs were sung in a monotone, devoid of correct pitch rendering; rhythm was much less affected. By contrast, singing was less disturbed than speech after left carotid injection. The observations indicated a double dissociation; the right hemisphere contributed more for singing, whereas the left demonstrated its usual dominance for speech. A model is proposed that encompasses audible stimuli as well as tactual or visual into a scheme of functional lateralization wherein the right hemisphere specializes in processing a complete, time-independent stimulus configuration and the left in a series of successive, time-dependent units.

Musical expression in patients with cerebral lesions has been discussed in a number of clinical reports (Jackson, 1871; Gowers, 1875; Edgren, 1895; Probst, 1899; Head, 1926; Souques and Baruk, 1926, 1930; Alajouanine, 1948; Critchley, 1953; Luria et al., 1965). Typical accounts, though largely anecdotal, describe left hemisphere damage which produces severe deficits in speech but leaves capacity for singing, instrument playing, or other musical abilities. Lesions in the right hemisphere have conversely produced major deficits in music skills while speech was largely unaffected (Würten, 1903; Jossmann, 1927; Brain, 1941; Jellinek, 1956; Botez and Wertheim, 1959; Spreen et al., 1965).

Although lateralization of musical functions has been studied systematically by various means (Milner, 1962; Kimura, 1964; Gordon, 1970), investigations of musical expression after left hemisphere damage have been reported rarely. Of particular interest are cases of complete left (dominant) hemisphere ablation in whom any expression can be ascribed entirely to the right hemisphere. For example, singing was preserved in the case of a 46 year old man whose dominant hemisphere was surgically removed because of a recurrent tumour (Smith and Burklund, 1966; Smith, 1966; Burklund, 1972). In this patient, melodic quality and word articulation seemed about normal for singing, while speech was limited to a few automatic words and phrases, and some repetition. Another case of a young adolescent female whose dominant hemisphere was excised for a recurrent tumour resulted in markedly impaired speech (Gott, 1973; Zaidel, 1973), but at the same time did not significantly affect her singing ability (Gordon, 1973).

Some of the uncertainties surrounding the data from surgical hemispherectomies, or lateralized ablation in general, can be circumvented by a systematic study of patients with transient, reversible inactivation of one cerebral hemisphere. This condition is induced by intracarotid injections of sodium amylobarbitone (amobarbital) in order to determine hemispheric

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\(^3\) A film of this patient that demonstrates both poverty of speech and preservation of singing was loaned to us by C. W. Burklund, M.D., Veterans Administration Hospital, Omaha, Nebraska, U.S.A.
lateralization of speech in presurgical patients whose left–right contributions are in doubt (Wada and Rasmussen, 1960; Branch et al., 1964). The amylobarbitone acts almost instantaneously to depress hemispheric functions unilaterally for a period of three to five minutes, during which time the non-injected hemisphere functions independently—seeing, hearing, and feeling, as well as controlling the limbs of the contralateral side of the body—not unlike the usual behaviour after surgical hemispherectomy. Speech lateralization is inferred if, after injection into one carotid artery, the patient continues to speak, whereas injection into the other artery produces speech arrest.

While speech lateralization is being established, there is usually some time available during which one can examine other functions including singing (Bogen and Gordon, 1971). If the observations from the surgical hemispherectomy cases are indicative, one would expect to observe major disturbances in singing and mild disturbances in speech after right hemisphere depression and the reverse after left depression. Our results followed these expectations, but with some unexpected qualifications.

METHOD

PATIENTS The subjects were eight epileptic patients who were being considered for cerebral commissurotomy (Bogen and Vogel, 1962) and for whom it was necessary to determine the contribution of the cerebral hemispheres to speech. At the time of injection, all subjects were moderately sedated with anticonvulsants. Their ages, neurological findings and other pertinent information are presented in the Table.

PROCEDURE All patients had right carotid artery injections of sodium amylobarbitone which maximally depressed the right hemisphere but not the left. Five were also injected in the left carotid artery at least two days before or after the right-sided injection. Each test session commenced after injection of sodium amylobarbitone and terminated several minutes later after the patient's recovery from hemiplegia. Hemispheric depression after drug injection was indicated by flaccidity and lack of any response in the contralateral limbs. The unilateral hemiplegia was also accompanied by eye deviation toward the injected side and by moderate drowsiness.

A practice period began just before testing with amylobarbitone but subsequent to insertion of the injection needle into the carotid artery. During this time, the patient became acquainted with the test material. He was asked to state his name, the date, and to repeat several words and sentences. These were recorded on audio tape and used as baseline speech samples to which performance during hemispheric depression could be compared. The patient then sang songs with which he was familiar; these were also recorded for later comparison. The practice session terminated when the patient was reasonably comfortable with the test situation and acquainted with the test material.

At the time of injection, the patient was supine with his knees drawn up and arms extended above his chest. He started to count aloud slowly (1, 2, 3... ) and, at the same time, to clench and unclench his fists. The sodium amylobarbitone (usually 200 mg in 10% solution) was injected into the common carotid artery through a no. 19 percutaneous needle in a period of one to two seconds. Almost immediately the contralateral arm and leg relaxed to a flaccid state while the ipsilateral limbs remained elevated and active.

The behavioural testing procedure described for the pre-examination was repeated during the depressed state of one hemisphere. The patient was asked to state his name, the date, and to repeat a few words and phrases. Acts such as ‘make a fist’, ‘wiggle your toes’, or ‘stick out your thumb’, were requested verbally or by demonstration and were designed to test comprehension and motor control through use of limb movements. To test singing, the examiner stated the title or sang a few bars of the songs that were practised during the pre-injection period. The patient was usually encouraged to complete the song using only ‘La, la, la...’ instead of words, concentrating mainly on the melody.

Repeated checking of the responsiveness of the flaccid limbs provided an indication of the level of hemispheric dysfunction. Once the previously paralysed limbs could move, either spontaneously or to command, the final examples of speaking and singing were recorded and the examination was terminated. The time course of events during the session was subsequently transcribed and analysed.

OBSERVATIONS

GENERAL RIGHT–LEFT CONTRASTS Singing was more impaired than speech after depression of the right hemisphere. Melodic deficits were characterized by striking absence of tonal con-

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4 All injections were done by J.E.B. and/or residents of the White Memorial Medical Center, Los Angeles, U.S.A.
### TABLE
#### SUMMARY DATA OF SUBJECTS

<table>
<thead>
<tr>
<th>Subject (sex)</th>
<th>M.K. (F)</th>
<th>N.F. (F)</th>
<th>C.B. (F)</th>
<th>D.M. (M)</th>
<th>P.D. (M)</th>
<th>P.E. (F)</th>
<th>L.H. (F)</th>
<th>B.K. (F)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>W.M. Hosp. no.</strong></td>
<td>48-72-14</td>
<td>50-31-61</td>
<td>KPH</td>
<td>49-28-00</td>
<td>RIAH</td>
<td>50-06-22</td>
<td>51-96-22</td>
<td>55-62-36</td>
</tr>
<tr>
<td><strong>Date(s) of injection</strong></td>
<td></td>
<td></td>
<td>7 Jan. '69</td>
<td>14 June '68</td>
<td>23 Oct. '69</td>
<td>4 Nov. '70</td>
<td>4 May '70</td>
<td>15 Sept. '72</td>
</tr>
<tr>
<td><strong>Right</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td><strong>Left</strong></td>
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<td></td>
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<tr>
<td><strong>Age at injection (yr)</strong></td>
<td>29</td>
<td>26</td>
<td>28</td>
<td>24</td>
<td>27</td>
<td>20</td>
<td>6</td>
<td>50</td>
</tr>
<tr>
<td><strong>Age at onset of seizures (yr)</strong></td>
<td>9</td>
<td>14</td>
<td>22</td>
<td>11</td>
<td>2</td>
<td>16</td>
<td>5</td>
<td>42</td>
</tr>
<tr>
<td><strong>Handedness (writing, eating, all tool use, preferred foot)</strong></td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>R</td>
<td>L</td>
<td>R</td>
<td>Ambi.</td>
<td>R</td>
</tr>
<tr>
<td><strong>Pre-op. WAIS IQ (while sedated)</strong></td>
<td>83</td>
<td>83</td>
<td>83</td>
<td>76</td>
<td>80</td>
<td>80</td>
<td>89</td>
<td>89</td>
</tr>
<tr>
<td><strong>Neurological examination</strong></td>
<td>Spastic L leg with foot drop since acute illness at age 4</td>
<td>Left Wartenberg thumb sign, mild. High fever at age 3</td>
<td>Non-contributory</td>
<td>Spastic R leg with foot drop since acute illness in infancy</td>
<td>Violent automatisms; abrupt falls</td>
<td>Dreamy states. Tonic spasms</td>
<td>Generalized automatisms</td>
<td>Nystagmus on lateral gaze, bilaterally</td>
</tr>
<tr>
<td><strong>Seizures</strong></td>
<td>Generalized convulsions, early history of left clonics</td>
<td>Violent automatisms</td>
<td></td>
<td>Generalized convulsions without warning</td>
<td></td>
<td></td>
<td>Generalized convulsions without warning</td>
<td>Adversive automatisms (toward the right)</td>
</tr>
<tr>
<td><strong>Other evidence of brain injury</strong></td>
<td>Multiple concussions</td>
<td>Multiple concussions</td>
<td>Multiple concussions</td>
<td>Multiple concussions</td>
<td>Multiple concussions</td>
<td>Multiple concussions</td>
<td>Multiple concussions</td>
<td>Nil</td>
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<tr>
<td><strong>EEG abnormalities</strong></td>
<td>Multiple concussions with occasional L reflection</td>
<td>Bitemporal</td>
<td>Bitemporal R &gt; L</td>
<td>Multiple concussions</td>
<td>Diffuse dysrhythmia with intermittent 3/sec spike and wave bilat.</td>
<td></td>
<td></td>
<td>Bilateral sharp and slow, more in left temporal region</td>
</tr>
<tr>
<td><strong>Skull X-ray and brain scan</strong></td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
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<tr>
<td><strong>Pneumoencephalogram</strong></td>
<td>Mild R ventricular enlargement</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal</td>
<td>Mild diffuse atrophy</td>
<td>Mild diffuse atrophy</td>
<td>Mild diffuse atrophy</td>
<td>Normal</td>
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<tr>
<td><strong>Arterial filling on angiography:</strong></td>
<td>Middle, posterior, and one pericallosal</td>
<td>Middle and posterior and one pericallosal</td>
<td>None (iodine sensitivity)</td>
<td>Middle only</td>
<td>Middle and one pericallosal</td>
<td>Middle and one pericallosal</td>
<td>Middle and one pericallosal</td>
<td>Middle and one pericallosal</td>
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<td><strong>Right</strong></td>
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<td><strong>Left</strong></td>
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**Hemispheric lateralization of singing after intracarotid sodium amylobarbitone**
trol resulting in monotonic renderings of the songs. Appropriately timed changes of pitch were present as singing improved, but these were grossly inaccurate. This latter phenomenon suggests that the patients knew when pitch changes should occur but lacked sufficient control. Rhythm, on the other hand, was much less affected and songs could usually be recognized on the basis of their musical cadence. The patients were also able to recognize the songs sung by the examiner and, in addition, hear the results of their own poor efforts. One patient, when asked how his singing sounded, replied, ‘Very groggy’. Another complained after her performance that her ‘...throat feels like a watermelon’.

In contrast with the impairment in singing, speech production, and language comprehension were preserved. The patients could recite the days of the week, make up novel sentences using a key word suggested by the examiner, or answer questions such as ‘What day is today?’ or ‘What is three plus five?’. The patients spoke not only with clarity but also with correct phonetic pitch and stress. The only consistent deficit was a slurring of words and thickening of speech as would be seen with an intravenous dosage of amylobarbitone.

After left carotid injection, speech was considerably more affected than singing. At a time when only single words could be spoken, songs could be sung with clearly recognizable pitch and rhythm qualities. Although not perfect, these samples were noticeably better than singing at comparable times after right carotid injection. The relatively small loss in singing ability compared with major impairments of speech after left carotid injection stands in marked contrast to a great loss of singing and mild disturbances of speech after right injection. This double dissociation argues against the idea that the effect of unilaterally injected amylobarbitone is simply a general impairment of the neural control of the vocal apparatus.

An unexpected observation was that no recognizable singing samples could be obtained before at least one word was elicited. Since the patients were mute after left carotid amylobarbitone injection, neither speech nor singing was heard for several minutes. However, as soon as a single word was spoken, singing rapidly improved. In contrast, speech recovery was slow, requiring an additional one to three minutes before any more words were uttered. (See Appendix for a sample protocol for one subject, B.K., in which the session for the left carotid injection and for the right injection were combined on one time scale.)

**Detailed Observations: Right Carotid Injection**

Right carotid injection of sodium amylobarbitone produced severely deficient singing in seven of the eight patients considered in this report. Three of these, M.K., C.B., and D.M., sang upon request within the first 90 seconds of hemispheric depression, but their performances were characteristically monotonic. C.B. was allowed to use words instead of ‘La, la, la...’ with the result that she sang without melody but said every word correctly. It was apparent, however, that the patients had some general idea of how the melody of the songs should sound. Some would try to change the pitch of their voice at appropriate times, but would not succeed in giving a correct rendering of successive tone intervals. Rhythm, on the other hand, seemed unaffected though somewhat slowed. Verbal comprehension in these three patients was excellent. Each could follow spoken instructions or answer questions with relative ease. Speech was generally intelligible in spite of some dysarthria. Prosody and phonetic stress were within normal limits.

Four patients, N.F., P.E., L.H., and B.K., did not sing at all for several minutes after right amylobarbitone injection in spite of repeated requests and singing demonstrations. Two of these, N.F. and P.E., were talking and answering questions, but when asked to sing P.E. said she could not, inappropriately remarking how nervous she had been all day; N.F. similarly ignored the request. It was not until two-and-a-half to three minutes after onset of hemiplegia that any singing could be elicited from either patient. By this time the melody was fairly good but, at the same time, voluntary movement in the affected limbs was observed indicating recovery of the depressed right hemisphere.

L.H. and B.K. were neither responsive to singing nor to verbal command for several minutes. B.K. spoke her first word five minutes after right injection, but would not sing in spite
of repeated requests to do so, until an additional five minutes had passed (see Appendix). Her renditions of 'Happy Birthday' and the 'Merry Widow Waltz', at this time, were completely devoid of melodic quality. There was little or no variation in pitch, although she produced generally correct rhythmic patterns. Speech, on the other hand, had pretty well returned to normal so that B.K. was capable of maintaining a meaningful conversation, easily answering questions, and carrying out verbal commands with the non-paralysed limbs. After another two minutes, singing returned to normal along with recovery from left hemiparesis.

L.H. performed correct limb movements to verbal command but did not say her first word until four minutes after injection. Once she started to speak, however, she was able to carry on a conversation quite well. Singing was amelodic at first but slowly improved until six-and-a-half minutes after injection when she sang fairly well in spite of a flaccid left arm.

The one patient, P.D., whose singing was not impaired after right carotid injection was strongly left-handed. Also, the usual amount of amylobarbitone failed to produce complete depression of the right hemisphere as evidenced by persisting movements of the left limbs. Therefore, it was difficult to draw conclusions from this session.

**Detailed Observations: Left Carotid Injection**

Speech could not be obtained for several minutes in four of the five patients injected with amylobarbitone in the left carotid artery. It was also true that singing did not occur during the entire period of speech arrest. However, in one case, P.E., indications of what appeared to be singing were present at least two minutes before similar attempts to speak. She made vocal efforts to mimic the examiner's demonstration of singing. This was notable since she exhibited no visible or audible reaction to repeated requests to say 'yes' or 'hello' during the same period of time. Her 'singing' improved to a level that could be vaguely recognized as a specific song, just before she was able to say her name. But it was not before she could repeat another word or two that a clearly recognizable melody was produced. Speech continued to return slowly while singing recovered more rapidly. It was not until well after her singing returned to pre-injection levels that P.E. was able to converse comfortably.

B.K. was unresponsive for an unusually long time, showing little behaviour beyond wincing and withdrawing from painful stimuli (see Appendix). The first sign of recovery was repetition, upon request, of the word 'yes', eight-and-one-half minutes after injection of amylobarbitone. Almost immediately she sang two songs with clearly recognizable melody. Additional speech could not be elicited. When asked the date after singing the second song she could only mumble. In answer to another question, she said something like 'seven-dovey' or perhaps 'seventy-three'. She still could repeat the word 'yes', but it was a full two minutes after singing the second song before she repeated additional words on request. In fact, word repetition was all she could do for another two minutes. When asked a question, she would repeat part of the question rather than answer it. It was not until 14 minutes after injection or more than five minutes after she spoke her first word that speech approached normality.

It should be emphasized that speech in this patient started to return only five minutes after right carotid injection, while attempts at singing did not appear until 10 minutes. In contrast, she sang less than nine minutes after left carotid injection, but did not speak a word besides 'yes' until 12 minutes after injection. Detectable signs of voluntary movement of the right limbs occurred about the time of the first signs of speech (10–12 minutes) but good control did not occur until minutes later. It is notable that general recovery, including speech, was longer after left-sided injection than after right in this patient, but recovery of singing was strikingly shorter.

No singing or speech was elicited from L.H. immediately after left injection, although her left limbs seemed strong and able to move spontaneously in a coordinated manner. The movements were not performed either to verbal command or to demonstration, even though the patient was looking at the examiner's hand. She said her first word almost seven minutes after injection and did not sing until just after that time. Her one attempt to sing was as good as her pre-examination sample and far superior to her first attempt to sing after right carotid
injection. This one attempt was also slightly better than her last singing attempt after right injection even though the two occurred during the same six-and-a-half to seven minute time-period in their respective sessions.

The one patient who continued talking after left-sided injection was P.D., the left-hander. His singing ability was hard to assess because baseline performances were quite poor. The only evidence of asymmetry in musical performance was a lesser degree of confusion after right-carotid injection, although it should be remembered that hemispheric depression had not been complete. Observations of singing in this patient hint at a reversed dominance although amylobarbitone testing failed to lateralize speech conclusively. Postoperative evidence confirmed that speech was controlled from the right hemisphere (Levy et al., 1972).

DISCUSSION

The most notable finding was that singing was more impaired than speech when the right hemisphere was depressed, but less impaired than speech during left hemisphere depression. A similar left–right dissociation between the two functions was implied in previous case studies but none was able to exclude the possibility of functional compensation by the intact hemisphere between the time of injury and the time of tests. Furthermore, only a few accounts have compared musical ability before and after cerebral injury. The present study avoids both of these weaknesses. The singing dysfunction is measured in the present patients before, during, and after a ‘reversible hemispherectomy’ where typical symptoms of unilateral hemispheric ablation are temporarily induced only to disappear some minutes later. Consequently, the performance of either hemisphere can be directly compared with the normal functioning of both, in the same individual. Not only does the rapid reversal obviate the possibility of compensatory learning, it also provides critical ‘preinjury’ data.

Therefore, we conclude from our observations that these right-handed (except P.D.) patients normally depend more upon the right hemisphere for singing than upon the left hemisphere.

It is emphasized that the major deficit in sing-

ing after right carotid injection was the production of correct pitch. Rhythm was hardly affected at a time when singing was either monotonic or markedly off-key. Rhythm was also not affected during left hemisphere depression. Apparently, rhythmic production is possible by either the left or right hemisphere alone, independent of the ability to sing on pitch. Lack of hemispheric specialization of rhythmic aspects of music has been implied in previous studies (Milner, 1962; Gordon, 1970).

Whereas tonal control was the characteristic deficiency of singing after right carotid injection of amylobarbitone, there was no evidence of similar tonal defects in speech. The patients did not speak in a monotone; they maintained natural voice inflections in spite of the dysarthria associated with the systemic distribution of the barbiturate. It can be concluded that pitch control for singing is a function separate from pitch control for propositional speech, and that it is better represented in the right hemisphere. Furthermore, it can be inferred, though not directly observed, that tone control for speech is better represented in the left hemisphere. This conclusion is consistent with the results of a recent dichotic listening experiment using a tone language (Thai), showing right ear (left hemisphere) dominance in native speakers for detection of pairs of words whose meanings depended only on differences in pitch (Van Lancker and Fromkin, 1973). The importance of the left hemisphere for pitch in language was seen in another recent dichotic study where a right ear dominance for nonsense sentences disappeared when the original phonetic pitch contours were reduced to a monotone (Zurif and Mendelsohn, 1972).

The dichotomy between language and speech on the one hand, and singing on the other, may be differentiated on a level related to their construction. For example, a sentence, paragraph, phrase or, in short, speech is composed from several morpheme units which are retrieved from memory according to grammatical rules and are ordered into a specified temporal arrangement. In contrast, songs, melodies, as well as many everyday prosaic passages are remembered and produced as intact wholes. The parts of these units are not pieced together tone by tone, word by word, but rather are recalled all at once.
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as a complete unit. The ability to store and recall intact such large units may be an important aspect of those tasks for which the right hemispheres of most individuals are dominant (Zangwill, 1961; Hécaen and Angelergues, 1963; Bogen and Gazzaniga, 1965; Levy-Agresti and Sperry, 1968; Bogen, 1969a, b; Milner, 1971; Sperry and Levy, 1971; Sperry, 1972). It is convenient to suppose that these tasks have some underlying process in common. We may call this common process, ‘appositional’ (Bogen, 1969b), a usage parallel with Jackson’s use of the word ‘propositional’ to encompass the left hemisphere’s dominance for speaking, writing, calculation, and related tasks including what he called ‘internal speech’ (Jackson, 1878). Although it would be premature at this time to believe that we know in any final way of what appositionality consists, we would like to introduce a preliminary hypothesis based on our observations and those of others that absence versus presence of the dimension of time is instrumental in distinguishing appositionality from propositional.

The emphasis on time is not a new description of cerebral function (Efron, 1963). It is related to the simultaneous-successive (or sequential) dichotomy discussed by Luria (1966) and of the different but interactive temporal-spatial mechanisms of Lashley (1951). While both authors discuss speech as an example of successive or serial order, and both suggest that two functions of different types—for example, simultaneous vs. sequential—do not coexist in the same cortical areas, neither Luria nor Lashley differentiates between right and left cerebral functions. We propose, as others have suggested (Levy-Agresti and Sperry, 1969) that these simultaneous and sequential functions, described by us as time-independent—that is, complete units unrelated to others—and time-dependent—that is, units related to others successively in time—are specialized abilities of the right and left hemispheres, respectively. Previous characterizations of the right hemisphere’s ability as ‘spatial’ is ill-applied to audible stimuli, unless ‘spatial’ is understood to mean ‘having no time dimension’. Reliance upon ‘time’ as a principle of organization may better distinguish the left from the right hemisphere: the left is crucially concerned with it, whereas the right is not.

We wish to thank Professor R. W. Sperry and Dr. Charles R. Hamilton and Dr. Eran Zaidel for their helpful criticisms in preparation of this manuscript.

REFERENCES


Kimura, D. (1964). Left-right differences in the perception of


### APPENDIX

The time sequences during intracarotid injection of amylobarbitone are presented for right injection (left hemisphere intact) on the left of the time line and for left injection (right hemisphere intact) on the right of the time line. Words that are in bold type are utterances by the patient, words in parentheses are editorial comments, and roman type indicates examiners’ utterances.

This patient displayed an unusually long period of non-responsiveness after both right and left carotid injections. Subsequent to this period the vastly different pattern of recovery after left injection than after right injection is illustrative of the typical double dissociation between singing and speech seen in the other patients.

The patient showed an unusual lack of response to all but painful stimuli during this period after intracarotid injection to either the right or left side.

<table>
<thead>
<tr>
<th>Protocol of intracarotid injections of amylobarbitone for patient B.K.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Right carotid injection</strong> (Left hemisphere ‘intact’)</td>
</tr>
<tr>
<td>15 September 1972</td>
</tr>
<tr>
<td><strong>One</strong>, <strong>two</strong>, <strong>three</strong>, <strong>four</strong>, <strong>five</strong>, <strong>six</strong>, <strong>seven</strong>, <strong>eight</strong>, <strong>nine</strong>, <strong>ten</strong></td>
</tr>
<tr>
<td>—</td>
</tr>
<tr>
<td><strong>0:00</strong></td>
</tr>
<tr>
<td><strong>(RIGHT INJECTION OF SODIUM AMYLOBARBITONE)</strong></td>
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<tr>
<td><strong>0:00</strong></td>
</tr>
<tr>
<td><strong>One</strong>, <strong>two</strong>, <strong>three</strong>, <strong>four</strong>, <strong>five</strong>, <strong>six</strong>, <strong>seven</strong>, <strong>eight</strong>, <strong>nine</strong>, <strong>ten</strong></td>
</tr>
<tr>
<td>Can you keep going?</td>
</tr>
<tr>
<td>Your hand is going, but I don’t hear you talking.</td>
</tr>
<tr>
<td>Sigh (HEAVY BREATHING)</td>
</tr>
<tr>
<td>The patient showed an unusual lack of response to all but painful stimuli during this period after intracarotid injection to either the right or left side.</td>
</tr>
<tr>
<td>4:00</td>
</tr>
<tr>
<td><strong>Happy birthday.</strong></td>
</tr>
<tr>
<td><strong>Wake up and say, ‘hello’;</strong></td>
</tr>
<tr>
<td>Can you say something Mrs. K—?</td>
</tr>
</tbody>
</table>
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Bernice say, 'yes'.

4:10 How about this one.
— Can you squeeze it?
— Yes, now you're squeezing with the left hand.
— Okay, now that's it.
Can you say, 'yes'.

4:20 Let go with the left hand.
Can you say, 'ha'.

4:20 Let go with it.
— Can you let go?
— Let go.
Can you say, 'ah'.

4:20 No; she's doing rhythmic movements.
That's a little easier than saying yes.
Can you open your eyes?

4:30 Now squeeze—hard.
Open your eyes.

Make a fist over here with your right hand.

4:40 Let's see what happens if we rub the sternum. (Groan) (Heavy breathing)
(Keeps making fists and opening)
— (Makes a fist on the left)

Keep it open.

4:50 Well, you've got a good fist there, but you aren't keeping it open.
Can you keep it closed?

— Keep your fist closed.
— Can you move your feet?
— Let's see you wiggle your toes.
 (No)
Can you make a fist over here with the left one?

(Completely limp)

How about saying, 'yes'? 'Yes'.
Can you say, 'yes'? Huh? Say, 'yes'.

5:10 
(First word after right injection)

Yes
— (Positive right toe sign nothing on left)

There's a 'yes'.
— Say it again, say, 'yes'.
— Yeah. That's a girl.

5:20 Can you stick out your tongue?
(Trying unsuccessfully)
— (Withdrawal of left leg)

Can you say, 'today'?

5:30 Can you move a little bit of something?
— What can you move?
— Can you stick out your tongue?

La

5:40 All right now try (Happy birthday) La, la, la. (Heavy breathing)
(Happy Birthday) La, la, la...

5:50 Can you open your eyes?
Open your eyes.
(She seems to be going to sleep)
Can you raise up your hand?
Raise up your hand. Groan
— Keep it open.
— Can you say, 'yes'?
— Can you say, 'yes'?
— Can you say, 'yes'?

6:00 Keep your hand open.
— Can you lift your arm up?
Groan
— (Right arm very flaccid)
— How about this one?

6:10 Can you lift this one up?
Now squeeze my fingers.
Give it a good squeeze, squeeze it.
Hold it, hold it.
Groan
— You're squeezing rhythmically, but you're not holding, hold it, hold it.
Groan
— Moving left hand)
Can you make a fist with your other hand?
— Give me a squeeze.
May be she's singing.
Here, I'll hold on here.
— Now, you squeeze my fingers.
Okay let's try that.

6:20 You're not doing it.
(Happy birthday) La, la, la...
Oooh

6:30 You were doing it before.
— Can you squeeze that?

(Happy birthday) La, la, la...
Oooh

6:40 La, la, la . . . (Merry widow waltz)
— 

(Sodium amylobarbitone seemed to put her to sleep)
Can she say her name?
— 

(Sodium amylobarbitone seemed to put her to sleep)
That a girl, don't go to good, okay.

Can you stick out your tongue?

Now, can you say, 'yes'?

You're making a fist with either hand? Stick it out your tongue.

Okay, make a fist now. Hold my fingers. Don't let go. Don't let go. Hold it. All right, Sir.

No, you're doing very weak. Hold on tight. Now open it up.

Very good, open it the all way. Open it up. That a girl.

Open it all the way, that's fine. Can you open the other one? Open the other one. How about wiggling your toes? Wiggle your toes. Just the right ones. Can you wiggle the left ones? Wiggle all your toes.

That's pretty good though, you wiggled more. Can you stick your thumb out on this hand? Stick out your right thumb. Nope. Doesn't seem to work very well.

There you go, very good.

Open your eyes, Bernice.

Open 'em up.

Bernice, can you stick out your tongue?

Bernice, wake up Bernice. Bernice, wake up Bernice.

Bernice, can you stick out your tongue?

Bernice, can you stick out your tongue?

Bernice, can you stick out your tongue?

Bernice, can you stick out your tongue?

Bernice, can you stick out your tongue?

Bernice, can you stick out your tongue?
Hemispheric lateralization of singing after intracarotid sodium amylobarbitone

That's right.  
Now wake up a little bit.  
I've got a hard one for you.  
How much is five plus eight?  
F-F- Uh huh.  

**POOR MELODY**  
13:00  
Twelve (or) (Fifteen) (?)  
Thirteen is correct.  
Now, can you sing Happy Birthday?  
Sing 'la la la ...'  
(HAPPY BIRTHDAY)  

7:40  
What day is today?  
—  
What day is today?  

(GOOD SPEECH)  
7:50  
What day of the week?  

(MARKEO)  
7:40  
What day of the week?  
—  
What's two plus two?  

(Poor MELODY —  
MORE SPOKEN THAN SUNG)  
8:00  
What's two plus two?  
—  
What day is today?  

(MARKEDLY DYSPHASIC SPEECH)  
8:00  
What day of the week?  
—  
What's two plus two?  

(MARKEDLY DYSPHASIC SPEECH)  
8:40  
What does it mean?  
—  
What day of the week?  

(CONTINUED)  
9:00  
What day of the week?  
—  
What day is today?  

(DYSPHASIC SPEECH)  
9:00  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
9:40  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
10:00  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
10:10  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
10:20  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
10:30  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
10:40  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
10:50  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
11:00  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
11:10  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
11:20  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
11:30  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
11:40  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)  
11:50  
What day of the week?  
—  
What day is today?  

DYSPHASIC SPEECH)
to drink?  12:00  (Slight grip on right hand for first time)
It doesn't matter, Doctor.
—  There's a little grip.
I'm just fine.
—  Let me see you wiggle your toes again.
Okay, sing Happy Birthday and then
—  Wake up and wiggle your toes.
we're all done.
—  Wiggle your toes.
I'm just very thirsty.
—  Say, 'yes'! Yes.
We're going to give you a drink of
—  Say, 'September'. September
water here in about three minutes.
—  That's quite good
You sing Happy Birthday.
—  What year is it?  September
Ooh
—  That's what month it is.
Why do you punish yourself, Doctor?
—  Why do you punish yourself, Doctor?
Because we like the pain.
—  No, what year is it?
Now, Happy Birthday
(sings) to you.
—  That's what month it is.
Happy birthday to you...
—  That's what month it is.
Happy birthday to you
—  (Continued dysphasic but improving)
Happy birthday to you...
—  Improving)
Happy birthday, dear Jennifer,
—  Improving)
happy birthday to you
Good.
—  Improving)
We are now going to pull out the needle
—  Improving)
and I have to press on your neck so it
won't bleed and that hurts a little bit.
—  Improving)
That's all right, Doctor.
—  Improving)
You been very kind.
—  Improving)
We're going to press on there.
—  Improving)
I don't think you'll like the pressing,
—  Improving)
... that I didn't—Mumble?
You've been very nice. Thank you.
—  Improving)
Yes ma'am, you're a super, super
—  Improving)
patient.
—  Improving)
Two and two  Yeah.
—  Improving)
—  Improving)
Two and two?
—  Improving)
Two and two
—  Improving)
Is?
—  Improving)
Are?
—  Improving)
Two and two equals what?
—  Improving)
Two and two  Yeah.
—  Improving)
—  Improving)
Two and two?
—  Improving)
Two and two
—  Improving)
Is?
—  Improving)
Are?
—  Improving)
Two and two equals what?
—  Improving)
Two and two  Yeah.
—  Improving)
—  Improving)
Two and two
—  Improving)
—  Improving)
Two and two?
—  Improving)
—  Improving)
—  Improving)
What's the name of this town we're in?
—  Improving)
Where are we?
—  Improving)
Can you tell us where we are?
—  Improving)
California
—  Improving)
That's the state, what's the city?
—  Improving)
Oh, I'm sorry.
—  Improving)
Uh uh
—  Improving)
What city, Uh
—  Improving)
Do you know the name of the hospital?
—  Improving)
Yes
—  Improving)
Um Mum Memorial?
—  Improving)
That's pretty good.
—  Improving)
What's my name?  Doctor Bogen.
—  Improving)
That's pretty good.
—  Improving)
What's your name?  Bernice K—
—  Improving)
What month is it?
—  Improving)
September sixteenth.
—  Improving)
Yeah, what, uh, what year?
—  Improving)
Can you tell me what year it is?
—  Improving)
Yes, I will.
—  Improving)
Uh
—  Improving)
—  Improving)
—  Improving)
—  Improving)
—  Improving)
14:30  I'm sorry.
—  Improving)
—  Improving)
—  Improving)
1972
(Motor control of the right limbs begins to return)
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