# Sodium Amytal Testing and Language

**A I Tröster and T D Parsons**, University of North Carolina, Chapel Hill, NC, USA



## Overview of the Intracarotid Amobarbital Procedure

The intracarotid amobarbital test (IAT) was first described by Juhn Wada and thus is often referred to as the 'Wada test.' Wada originally developed this technique to study the interhemispheric spread of epileptiform discharges in patients undergoing unilateral electroconvulsive therapy. Based on his observation that an expressive aphasia resulted when the language dominant hemisphere was injected with amobarbital, he reasoned that this technique might be useful in determining hemispheric language dominance in neurosurgical candidates (and thus minimize speech and language dysfunction in patients undergoing dominant hemisphere surgery).

Since the exact nature of the amobarbital procedure varies from center to center (and some centers perform injections of vessels other than, or in addition to, the internal carotid artery that can also inform about language), this article restricts itself to a general description of the practice of this procedure and its underlying assumptions. In general, the IAT involves invasive carotid arteriography. During the IAT procedure, a catheter is positioned within the internal carotid artery, and amobarbital then is injected to anesthetize the majority of one hemisphere of the brain. Such an injection leads to pharmacological inactivation of brain areas in the distribution of the ipsilateral anterior and middle cerebral arteries, and the anterior choroidal artery. That is, a great deal of the frontal and temporal cortices is deactivated. Following the infusion of amobarbital, the patient carries out multifarious memory and language tasks. Since it is assumed that disruptions of language and memory during IAT are a consequence of the temporary 'lesioning' of the injected hemisphere, and that IAT mimics the effects that surgery on the injected hemisphere might have, the IAT allows one to predict the effect that surgery would have on each hemisphere. Of course, what is at issue is whether the uninjected ('intact') hemisphere could adequately support language and memory were the other hemisphere to be operated on. Although some centers inject only the hemisphere to be operated on, most centers also carry out the procedure on the other hemisphere to establish the extent of lateralization of function.

## The Wada Test's Contribution to Neurolinguistics

The IAT bears several advantages as a research tool relative to traditional lesion studies. Specifically, it is possible to obtain baseline data in the individual to be studied, meaning language and memory performance is known in the 'prelesion' state; to compare lesion effects on both hemispheres in the same individual; and gather group data where the 'lesion'-to-assessment interval is relatively homogenous, thus minimizing maturational confounds, and the lesion is fully reversible. The disadvantages of the IAT entail the brevity of the drug effect and the possibly limited generalizability of findings. When gathering clinically relevant information is of paramount importance, there is, within the time constraints of the IAT, little opportunity to manipulate the nature of stimuli. Furthermore, because the IAT is carried out in individuals with typically chronic cerebral dysfunction (epilepsy), it is unclear whether findings obtained apply also to normal populations or even to groups with other neurological conditions. Nonetheless, the IAT has enabled researchers to explore not only intra- and interhemispheric differences in language representation and their correlates, but also, by looking at individuals with brain injury, the functional resiliency and plasticity of brain structures.

One domain of inquiry richly informed by IAT studies is the relationship between handedness and hemispheric language dominance. In most people, the left hemisphere is language dominant, but occasionally the right hemisphere is dominant or both hemispheres may participate in language on more equal footing. Although right-handedness is highly correlated with left hemisphere speech dominance in the population at large, brain abnormalities may interfere with the normal neuroanatomical organization of cognitive functions and involve reorganization. Specifically, IAT studies have shown that early brain injury is often associated with a shift in language dominance, but a shift in language dominance does not necessarily entail a shift in handedness, or vice versa.

Several studies have identified factors associated with shifts in language and handedness. Left hemisphere injuries sufficient to cause hemiparesis have been found to be associated with both left-handedness and right or bilateral speech representation. Among patients without hemiparesis, sinistrality and right or bilateral language representation were associated with the existence of extratemporal pathology. Left-handers with left hemisphere speech dominance have also been found to be less likely to have had hemiparesis or extratemporal injuries. Extratemporal lesions and multiple or bilateral seizure foci have been found to be related to atypical speech representation. In addition, among left mesial temporal lobe epilepsy patients, atypical language lateralization has been found to be associated with higher spiking frequency on EEG. Thus, the location and extent of injury may be factors related to language shifts.

One of the most important factors underlying atypical language representation is the age at which brain injury occurs. Since the resiliency of the brain is maximal during the early years of life, it makes sense that injury at a very early age might induce either the intact or the damaged hemisphere to reorganize (i.e., accommodate speech and language zones) so as to compensate for functional losses. Intrahemispheric language reorganization has been found to be more likely than interhemispheric reorganization after the age of 6 years. Interhemispheric language reorganization is more likely to occur at earlier ages, but unfortunately, not without possible cost to nonverbal functions. Specifically, patients may experience a 'crowding' of nonverbal function. Evaluation of verbal and nonverbal functions during IAT in epileptic patients with early onset of left hemisphere dysfunction has revealed that patients with atypical (right hemisphere) speech representation perform as well as patients with left hemisphere speech on most measures of language function. However, patients with atypical speech patterns perform more poorly than 'left hemisphere' patients on nonverbal tasks. Transfer of language may 'crowd out' functions normally under the mandate of the right hemisphere. Thus, a right–left maturation gradient, characterized by a slower development of the right than left hemisphere, might permit the still more plastic right hemisphere to assume language functions, but not without disturbing the typical organization of right hemisphere functions.

Amobarbital studies of patients with epilepsy have also challenged the notion that hemispheric language dominance falls into discrete categories. Rather, it is more likely that language representation falls on a continuum from strongly left hemisphere dominant to strongly right hemisphere dominant, just as handedness seems to fall on a continuum from strongly dextral to strongly sinistral. However, other data suggest that cases might not fall along all points of such a continuum. Specifically, there are four major patterns of hemispheric speech representation. Toward the left-dominant end of the spectrum, there are indeed several clusters representing degrees of left speech dominance. However, individuals with bilateral or right speech dominance tended to center at these respective points, without the gradation observed for left hemisphere representation.

A limited number of amobarbital studies have addressed two other important issues, namely, the intra- and interhemispheric organization of language in bilinguals and the organization of sign language. With respect to studies of bilinguals, studies have consistently shown that the interhemispheric organization of both languages is complementary; i.e., hemispheric dominance for the two languages is similar. However, the intrahemispheric organization of the native and second language is likely different. On the basis of the observation that the patient's second language recovered before the native language after left middle cerebral artery amobarbital injection, the second language might be organized within the central sylvian core, whereas the first language might be represented in more distant perisylvian areas. One might, however, find a diametrically opposing interpretation to be more plausible. Electrical stimulation studies show that object naming in the first and second languages is differentially represented within the language dominant hemisphere. According to these studies, the second language is represented in a larger area, more peripheral from the Sylvian fissure. Thus, one might conclude, assuming that the effects of amobarbital dissipate earlier in more distant areas, that the first language is more centrally represented.

Sign language studies in nondeaf individuals also indicate hemispheric organization of sign and spoken language to be similar, at least insofar as the same hemisphere is dominant for both forms of communication. The existence of subtle interhemispheric differences in the organization of signed and spoken language, however, is not settled by amobarbital studies. On the one hand, some studies have found that sign language is characterized by greater bilateral representation than spoken language. In contrast, several other studies have found the interhemispheric organization of signed and spoken language to be complementary and highly similar.

Because a substantial proportion of deaf individuals apparently have experienced some cortical reorganization, reports of IAT test results in a deaf individual are of particular significance. That is, such studies provide tentative data about whether findings from normal-hearing individuals concerning the organization of sign language apply to deaf individuals. Complete left-hemispheric dominance has been found in a right-handed individual for American Sign Language, signed English, and finger spelling. Thus, evidence of bilateral representation for sign language was not found.

Amobarbital studies have also indicated that crossed aphasia (the occurrence of aphasia in right-handed individuals after insult to the right hemisphere) should not necessarily be taken to imply right-hemispheric language dominance in these right-handers. Researchers have determined via IAT that their patients with crossed aphasia actually had bilateral language representation.

## Functional Magnetic Resonance Imaging and the Future of the Intracarotid Amobarbital Test

Even though IAT continues to be the standard presurgical means of assessing lateralization of language and memory, its invasiveness and attendant risks have caused many to search for a less invasive method. Researchers have begun using functional magnetic resonance imaging (fMRI) as a noninvasive alternative to the IAT. fMRI allows visualization of changes in the flow of fluids in brain areas that occur over time spans of seconds to minutes. In the brain, blood oxygen level is assumed to be related to neural activity, and consequently fMRI can be used to infer brain activity changes when images of the brain are obtained while persons are engaged in tasks and compared to images obtained during rest or a comparison task. A variety of language and memory activation paradigms have been described. In general, fMRI determines hemispheric dominance through the use of laterality indices that compare the ratio of activated pixels (small areas within an image) in one hemisphere to those in the other. Alternatively, hemispheric dominance for a function can be inferred from comparisons of the activation of specific, homologous regions in each hemisphere, which may yield results more consistent with those of the IAT than does the derivation of global lateralization indices. Despite the fact that fMRI shows promise as a noninvasive alternative to IAT, its reliability in predicting postoperative memory function has not been sufficiently investigated. It remains unclear whether removal of a region activated in an fMRI image necessarily leads to inability to perform the related task. Hence, additional studies are needed before fMRI can be trusted for surgical planning.

*See also:* Anatomical Asymmetries versus Variability of Language Areas of the Brain; fMRI Studies of Language; Imaging Brain Lateralization; Mapping Syntax Using Imaging: Problems and Prospects for the Study of Neurolinguistic Computation.

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# Sogdian

**P O Skjærvø**, Harvard University, Cambridge, MA, USA



Sogdian, an Eastern Middle Iranian language, was spoken at least up to the 8th century in Sogdiana, the area of modern Uzbekistan that includes the cities of Samarkand and Bukhara. Many Sogdians were merchants, however, and traveled east as far as China, bringing with them the Sogdian language. The Manicheans and Christians, as they fled from persecutions from the 3rd century on, took the Sogdian language with them to the farthest reaches of Chinese Turkestan and beyond, into Mongolia, where the Sogdian alphabet was adopted by the local Turks and the Mongolians, who still use it. The Sogdian written remains consist of religious and nonreligious texts. Most of the religious texts are translations, the Buddhist texts from Chinese, the Manichean ones from Persian and Parthian, and the Christian ones from Syriac.

We have Sogdian texts in five different alphabets: Old Sogdian Aramaic, Sogdian-Uighur (Uyghur), Manichean, Nestorian Christian, and Northern Brahmi. The Sogdian Aramaic script is used in the *Ancient letters* (see below) and in graffiti on rocks along the Karakorum Highway in northern Pakistan. The Sogdian-Uighur script is the most common, being used for secular documents, as well as for Buddhist and Manichean texts. The Manichean and Nestorian scripts were used for Manichean and Christian texts, respectively. There are a small number of late Sogdian manuscripts from Turfan written in Northern Brahmi script.

In early times, the Sogdians must have been the neighbors of the Tocharians (*see* **Tocharian**), who borrowed numerous (proto-)Sogdian words. The modern Iranian language Yaghnobi is the descendant of a Sogdian dialect different from the known Sogdian.

The oldest Sogdian texts are the *Ancient letters*, written on paper and discovered by the British-Hungarian discoverer and archeologist Marc Aurel Stein in eastern Chinese Turkestan (now in The British Library). The letters can be dated to the early 4th century by references to current events.

From the 8th century, we have a collection of letters and administrative, economic, and legal documents written in the Sogdian script from the archives of King Dhewastich found at Mount Mug east of Samarkand.

The largest corpus of Sogdian texts are the Buddhist texts removed from a cave at Dunhuang in eastern Xinjiang by Aurel Stein and the French scholar and archeologist Paul Pelliot (now in The British Library and the Bibliothèque Nationale). Numerous Sogdian Manichean and Christian texts were discovered at Turfan in northeastern Xinjiang by German archeologists (now in the Brandenburgische Akademie der Wissenschaften in Berlin).

Sogdian phonology and morphology are both conservative and innovative. The most important innovation is the 'rhythmic law,' by which words with long vowels before the endings ('heavy' stems), lose final short vowels. Thus, OIran. SING NOM **wrk-ah* and ACC **wrk-am* 'wolf' are Sogd. *wərk-í* and *wərk-ú* ('light' stem), while OIran. **daiw-ah* and **daiw-am* and **daiw-am* 'demon' are both *δḗw*. Sogdian shares with Ossetic the plural suffix *-t-* (originally a collective noun, hence declined like a feminine singular), for instance, *δḗw-t* 'demons'; forms of *δβar-* 'door': SING NOM *δβar-í*, LOC *δβar-yá*, PLUR NOM-ACC *δβar-t-á*, GEN-DAT, LOC *δβar-t-yá* 'at the doors'. Sogdian uses demonstrative pronouns as definite articles (*xō mártī* 'the man', *xā strīš-t* 'the women' [< *strīč-*], *uya kánθ-ī* 'in the city' [LOC]).

The verb system is complex. There are three stems: present, past, and perfect (perfect participle = past stem + suffix-*ē*, FEM-*č-a*; e.g., PRES *pətsā́č-* 'fit', PAST *pətsaγt-*, PERF MASC *pətsaγt-ē*, FEM *pətsay-čá-* [*-γt-č-*> *-γ-č-*]). It has all the Old Iranian moods (indicative, imperative, subjunctive, optative, injunctive), as well as active and middle. It has, in modified form, the old imperfect, for instance, PRES *βar-ám*, IMPERF *βar-ú* 'I carry, carried', PRES *wḗn-am*, IMPERF *wḗn* 'I see, saw', PRES *θaβr-ám*, IMPERF *θā́βr-u* 'I give, gave'. Progressive tenses are formed with the suffix *-skun* (*-sk*) and the future with the suffix *-kām* (*-kan*, *-k*) from a noun meaning 'wish' (IMPERF PROG *βar-á-skun* 'he was carrying', FUT *βar-ám-kām* 'I shall carry'; Christian Sogd. PRES PROG *γərb-ám-sk* 'I am seizing', FUT *wā́b-t-kan* 'he shall say').

There is a large range of past tense forms built on the remade Old Iranian perfect system: transitive active tenses with past stem plus the verb *δār-* 'hold, have' (e.g., *uγt-u-δā́r-t* 'he has said'), but intransitive and passive tenses with past stem plus copula (e.g., *tγat-ḗš* 'you entered', *ā́žit-əsθa* 'you were born').

The perfect is made with the perfect participle in the same way (e.g., *βast-ḗ δārand* 'bind-PERF.MASC hold.PRES-3RD.PLUR' = 'they hold/keep bound,' *βast-č-á astí* 'bind-PERF.FEM COP.3RD SING' = 'she is (now) bound'). The passive is made with the perfect participle plus 'be, become' (e.g., *βast-ḗ-t uβ-and* 'bind-PERF.MASC.PL become.PRES-3RD.PLUR' = 'they are being bound', *ánxast-ē əkt-ēm* 'goad-PERF.MASC become.PAST-COP.1ST SING' = 'I was goaded').

Among special formations, note the 'potentialis,' formed with a past participle with the ending (light) -*a* and the verbs *kun-* 'to do' (active) and *β-* 'become' (passive), by which possibility and completion of action are expressed (e.g., *nē žayd-á kun-am* 'NEG uphold.PART do.PRES-1ST.SING' = 'I cannot uphold', *nē āpāt βō-t* 'NEG reach.PART become.PRES-3RD.SING' = 'it cannot be reached', *čānō xwart xurt kun-and* 'when food eat.PART do.IMPERF-3RD.PL' = 'when they had eaten').

There are minor dialect differences between texts written in the Sogdian, Manichean, and Nestorian scripts (e.g., Sogd. *wan-*, *kwn-* 'to do', Man., Chr. *kun-*). Christian Sogdian also has phonetically more developed forms (see also on the progressive and future above), e.g., **kərtu-δār-am* 'I did, I have done' > Buddhist Sogdian *əktu-δār-am* > Christian Sogdian *k-θār-am*.

*See also:* Iran: Scripts, Old Persian, Aramaic, Avestan; Iranian Languages; Old Church Slavonic.

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# Solomon Islands: Language Situation

**B Palmer**, University of Surrey, Guildford, UK



The Solomon Islands (SI) is a former British colony bordering Papua New Guinea (PNG) in the southwest Pacific. Despite a population of only about 400 000, the country has 63 vernacular languages, many with several dialects. Seven are Papuan; the rest belong to the Oceanic branch of Austronesian.

Most of the country's languages belong to two separate branches of Oceanic: Southeast-Solomonic (SES) and Northwest-Solomonic (NWS).

SES is the largest group, with 26 languages accounting for 65.5% of the vernacular-speaking population. It is a conservative and clearly defined subgroup within Central/Eastern Oceanic, more closely related to the languages of Fiji, Polynesia, and Micronesia than to NWS. SES has two main branches, one centered on Guadalcanal and Gela, the other on Malaita and Makira.

NWS is a more complex group extending across the PNG border into Bougainville, with close links to languages farther west in PNG. Accounting for 22.5% of the population, SI's 19 NWS languages comprise three branches centered on Choiseul, Santa Isabel, and New Georgia, plus Mono-Alu, from a Bougainville-based branch.

Four further languages comprise Utupua-Vanikoro, a sister subgroup to SES within Central/Eastern Oceanic. Spoken in the remote Reefs-Santa Cruz islands, they account for 0.5% of the population. Another six languages, spoken on remote islands by 3.5% of the population, are Polynesian Outliers, the result of prehistoric back-migration from Polynesia. Finally, the Micronesian Kiribati language (Gilbertese) is spoken in several communities resettled from Kiribati in the 1950s (0.5% of the population).

The remaining seven languages divide into two possibly unrelated Papuan groups: Central Solomons and Reefs-Santa Cruz, each representing 4% of vernacular speakers.

This complex picture is the result of a complex linguistic history. At least 35 000 years ago the region was inhabited by Papuan speakers. As the easternmost limit of intervisible islands, SI probably represented the farthest reach of pre-Austronesian human settlement in the Pacific.

The first Oceanic settlement, around 1400 B.C., was rapid, probably giving rise to SES and Utupua-Vanikoro. A second, slower wave followed as Western Oceanic speakers spread into western SI, overlaying the earlier Oceanic stratum and giving rise to NWS. Over time, Oceanic languages largely displaced earlier Papuan languages. Contact between Oceanic and Papuan speakers brought lexical innovation in SES, and long periods of Oceanic/Papuan bilingualism contributed to grammatical innovation in NWS. In the Reefs-Santa Cruz islands, long coexistence between Papuan and Utupua-Vanikoro languages resulted in

**Table 1** Speaker numbers for Solomon Islands vernacular languages in 1998 (Ethnologue)

| | |
|---|---|
| More than 18 000 | 1 |
| 15 000–18 000 | 3 |
| 10 000–15 000 | 7 |
| 5000–10 000 | 15 |
| 1000–5000 | 25 |
| 500–1000 | 4 |
| 100–500 | 7 |
| Fewer than 100 | 1 |

considerable mutual influence. More recently, Polynesian back-migration brought Outlier languages to small islands away from the main group.

Most SI languages have hundreds or thousands of speakers rather than tens of thousands (see Table 1). With 40% of the population, the Malaitan group contains the seven largest, with Kwara'ae (33 600) the only language with more than 18 000 speakers.

Multilingualism is the norm and code-switching common. Intermarriage between speakers of different languages is widespread, with communication often in Solomon Islands Pijin (SIP). Many smaller languages are seriously endangered, most losing ground to a few increasingly dominant vernacular languages. At least one Papuan language and three Oceanic languages have disappeared during the last century, and one is moribund.

The largest indigenous lingua franca is Roviana, with 16 000 second-language users. Over the past century, the role of vernacular lingua francas has steadily decreased in favor of SIP. Today, over 300 000 Solomon Islanders speak SIP as a supplementary language, and 15 000 speak it as their first language, securing its creole status. SIP is mutually intelligible with Tok Pisin (TP) (PNG) and Bislama (Vanuatu), the three forming Melanesian Pidgin. SIP is closer to English than are the other dialects, lacking the French element in Bislama and the German component and extensive vernacular source of TP.

Although SIP is almost universal in intergroup communication, it is typically viewed as 'broken' English by many speakers. Unlike TP and Bislama, SIP has no official status and is not used in education beyond the earliest years. However, it is the only language known throughout the country and is the language of urban life and of an emerging urban culture. English is the official language, used in government, courts, education, and most media, although SIP does appear in some media.

*See also:* Austronesian Languages: Overview; Bislama; Central Solomon Languages; Language Education Policies in the Pacific; Malayo-Polynesian Languages; Papuan Languages; Pidgins and Creoles: Overview; Tok Pisin.

*Language Maps (Appendix 1):* Map 173.

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# Somali

**F Serzisko**, University of Cologne, Cologne, Germany



Somali is a Cushitic language of the Afro-Asiatic language family spoken by approximately 10 million speakers in and around Somalia. There are five major Somali dialects (Lamberti, 1986).

## Phonology

The following consonant phonemes are distinguished as shown in Table 1

There are five vowels: a, e, i, o, u and vowel length, in standard orthography indicated by doubling the vowels, is distinctive.

The following shows the letters used in Standard Somali orthography

| | | | | | | |
|---|---|---|---|---|---|---|
| IPA | ʔ | ʕ | ħ | ʃ | ɖ | x |
| Somali Orthography | ' | c | x | sh | dh | kh |

Tone appears to be distinctive in Somali both on the lexical level and on the grammatical level. It is, however, still a matter of debate whether this tonal distinction is really a tonal distinction or pitch accent (Hyman, 1981 for discussion).