ACALCULIA: ACQUIRED ANARITHMETIA

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Acalculia is a descriptive term used originally by Henschen (1920) to designate an acquired disorder of calculating ability. He specified that acalculia resulted from focal damage to the brain and collected all the cases of computational disorder which fulfilled these requirements available in the medical literature to that date. From this survey Henschen concluded that a distinct and independent cortical network existed for arithmetic functioning and therefore acalculia could exist as an entirely independent finding of brain damage or could be coupled with other symptomatology.

No cases of "pure" acalculia are recorded and even case reports in which computation defect is the major or outstanding feature are uncommon (Lewandowsky and Stadelman, 1908; Singer and Low, 1933; Lindquist, 1935; Cohn, 1961; Benson and Denckla, 1969). Most often, calculation defect is mentioned as one of several behavioral symptoms. This has led some investigators to classify acalculia by the signs and symptoms which accompany it or by the suspected site(s) of pathology. While the literature shows the usual variation in such classifications (Berger, 1926; Goldstein, 1948; Grewel, 1952; Critchley, 1953; Isham, 1970) there appears to be a basic agreement. If one excludes, by definition, calculating defects based on low intelligence or developmental problems, the following classification may be offered as a composite (after Hecaen, 1962):

1. Aphasic acalculia (figure or number alexia) - An inability to handle numbers as words produces the calculation errors.
2. Visuo-spatial acalculia (either unilateral neglect or mispositioning of figures) - An inability to align problems or to maintain place holding values produces computational errors.
3. Anarithmetia (true loss of computational ability) - An inability to retrieve learned arithmetic values and/or manipulate these values.

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Examples of the first two varieties are seen with reasonable frequency in clinical practice. Certainly disability in handling number language to a degree sufficient to interfere with arithmetic skill is common in cases of aphasia. There are several reports (Poeck and Orgass, 1966; Benson and Denckla, 1969) which suggest that the acalculia reported as a feature of the Gerstmann syndrome is truly a result of aphasia. The visuo-spatial form of acalculia is less common but clear cut examples have been reported (Cohn, 1961; Hécaen, 1962). Cases of aphasic acalculia almost always occur as a result of left hemisphere damage while right hemisphere involvement is most common in cases of visuo-spatial acalculia (Hécaen, 1962).

Most investigators agree that a third variety, anarithmetia, does exist and that it usually is a general intellectual impairment (Grewel, 1952), or disturbance of memory, or both (Cohn, 1961). Thus anarithmetia is frequently associated with bilateral (or "diffuse") brain damage. In particular, this type of acalculia is reported in the degenerative cerebral disorders such as Alzheimer's or senile dementia (Cohn, 1961; Hécaen, 1962). Hécaen does list a number of cases of anarithmetia occurring with either right or left unilateral brain damage but he presents no description of the calculating disturbance to substantiate this diagnosis. We would like to report an unusual case of calculating disturbance, apparently caused by focal brain damage, which we believe deserves to be called anarithmetia.

**Case Report**

A 42-year old industrial relations officer was admitted to the Aphasia Research Section of the Boston Veterans Administration Hospital in January of 1971 for evaluation and treatment of a reading disturbance. He was in normal health until August, 1968, when he was involved in a minor automobile accident. He sustained a small bruise on his head but there was no loss of consciousness. Later that day he noted some numbness of the right hand which progressed in intensity. That evening he read his newspaper as usual. By the next morning he noted increased numbness which now involved the right face, arm and leg. At this time he found that he could not read and later, when asked to do a simple addition problem for his 9-year old daughter, could not perform the mathematical operation. Headache was present, localised to the right supraorbital and forehead regions. Several days after the accident he was hospitalised.

An extensive evaluation was performed; this included lumbar puncture, EEG, isotope brain scan, arteriogram and pneumoencephalogram, all of which were normal. Following the air study he was nauseated, his speech became garbled and it was several weeks before he or his wife felt that he could speak properly. Because of the persistent speech difficulty a second brain scan was performed ten days after admission. This revealed a small, discrete area of increased uptake in the left posterior parietal
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A second lumbar puncture was normal except for protein of 72 mg%. Repeat EEG was normal and he was released from the hospital.

Several months later a third brain scan showed persistence of parietal uptake plus a questionable left occipital abnormality. He was re-hospitalised to rule out metastatic disease. Repeat left carotid arteriogram was reported as showing equivocal evidence of posterior inferior parietal abnormality. Two “hot” areas were noted on another brain scan, a 2.5-3.0 cm area in the left posterior parietal region and a 3 cm area in the left occipital region. At this time the lumbar CSF protein was 55 mg%. Other laboratory studies, including a metastatic bone series, were normal, and he was again discharged.

A brain scan performed several months later showed no abnormalities. There was slow improvement and he returned to work in July, 1969, eleven months after the onset. He worked only half time, however, and was unable to perform even this portion of his regular job without fatigue.

In December 1969, while on the job, he suffered a syncopal episode lasting between one and two minutes and was re-admitted to the local hospital. Again, a large number of tests were within normal limits. The pneumoencephalogram was repeated as part of this evaluation and again produced a severe reaction. He ate poorly, had insomnia, was listless and apathetic and was referred to a psychiatric hospital for management. By that time he was demonstrating behavior disturbances which included amnesia, hallucinations and ideas of persecution. There was no past history of significant psychiatric disturbance. In the mental hospital he made a rapid and uneventful recovery and was discharged in one month. He had not felt able to return to work in the subsequent nine months and sought further evaluation and treatment for his reading difficulty.

Past history was non-contributory except that in March 1968, he had sustained a left fronto-parietal hairline fracture in an auto accident; there was no loss of consciousness with this injury. There was no other significant medical history. He was a college graduate (A. B. in English) and had served in the Army as a radar officer. He had studied algebra and geometry in high school and had constantly performed calculations, both on paper and in his head, as a routine part of his work. He had always been right handed and there was no family history of left handedness.

On admission to the Boston Veterans Administration Hospital, no abnormalities were noted on general physical examination. Careful neurological examination revealed an asymmetry of optokinetie nystagmus (decreased amplitude and frequency of the fast component when the test object moved from the patient’s right to left side). There was a small but homonymous visual field cut involving the right temporal area: visual acuity was 20/20. A slight right central facial weakness was noted. Finger to nose movements were performed better with the left extremity and there was a fine, fast bilateral terminal tremor. The right
extremity was slightly clumsy in performing rapid alternating motions. No motor weakness was exhibited. There was a mild deficit of position sense in the fingers on the right and a severe right astereognosis (to the extent that he could not identify by palpation a watch or cork in his right hand though he rapidly did so with his left). Two point discrimination was distinctly poor on the right hand, but not elsewhere. The remainder of the general neurological examination revealed no abnormalities.

*Aphasia and related disturbances*

Spontaneous speech was fluent and no defects were noted in comprehension or repetition. He displayed no obvious word finding problem in conversation but with confrontation naming occasionally showed some hesitation. Serial speech and singing were done without difficulty. Initially, reading accuracy and speed were normal only for single letters, digits and very short words. Simple sentences could be read but took a tremendous amount of time; for instance, it took him 22 seconds to read aloud, "Football is an eleven man game." His reading ability did improve with therapy but remained slow at time of discharge. Writing was characterised by slowness and frequent errors in spelling. Oral spelling was also incorrect; in contrast, he easily recognised words that were spelled out loud. His ability to draw and to copy drawings was always good but map localisation was slower than expected. Clock setting and the reading of time were slow and often inaccurate. Apraxia was not demonstrable. At no time did he display right-left confusion or finger agnosia, and he readily recognised faces. In no way did he show defective memory for remote knowledge and his manipulation of data other than in arithmetic (such as proverb interpretation, similarities and differences, etc.) was good.

*Calculation and number language*

He could rapidly count both forward and backward without error; he could count in series (i.e., by 3's) and by discontinuous groups. He could read, write or recognise any number presented at random. His digit span was normal. He could identify or produce on command calculation signs (plus, divide, etc.) without error. Minor defects in learned quantities were observed, however (e.g., when asked how many feet in a yard he delayed eleven seconds and then stated "36 feet").

As a formal test of computation ability problems of addition, subtraction, multiplication and division were presented in two different forms, verbally and written; responses were requested by three different means, verbal, written and multiple choice. With each combination of testing, the results were similar. He performed the addition and subtraction problems accurately and only moderately slow but had almost total failure with problems in multiplication and division. He performed complex and difficult addition and subtraction problems, not only when
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using paper and pencil or with multiple choice responses but even when the problems were presented verbally, and he gave verbal responses. In sharp contrast, he failed frequently on comparatively simple multiplication and division problems. Figure 1 shows examples which demonstrate his
difficulty with multiplication. These problems were dictated to the patient who wrote the numbers correctly, aligned the problem and proceeded to carry out the computation. In the first and in the final examples, where knowledge of multiplication tables alone was demanded, he gave correct responses. Note that where the number one was the multiplicand (problems 2, 3, 4, 5, 8 and 9), he was invariably correct; when two was the multiplicand (problems 4, 6 and 7), he was often but not always correct. Only occasionally was he correct when using other numbers as multiplicand. In the problems in Figure 1 he made many errors in the multiplication process but was always correct with the addition portion. Exactly similar difficulties were demonstrated in division problems. (Only multiplication will be described or discussed as failure to multiply correctly was also significant in all attempts at complex division). From the examples (Figure 1) it is difficult to decide whether individual errors were based on inability to remember the multiplication tables, to handle the carrying process or to retain the basic process of computation. It can be noted that he used appropriate form, maintained correct place holding

Fig. 1 — Multiplication problems dictated to patient. Note errors in problems 2, 3, 6, 7 and 8. Also note correct alignment and addition of intermediate products.
values and that addition of his own figures was invariably correct. There was no evidence of paraphasic or perseverative errors. Each time he was tested the patient complained that prior to the onset of the present difficulty he had regularly performed similar multiplication and division problems easily and accurately.

**DISCUSSION**

The major clinical findings demonstrated in this case are not uncommon in neurological practice. These included partial alexia and agraphia, a mild word finding defect, cortical sensory disturbance involving the right hand and a right inferior quadrantopsia. All findings suggested dominant (left) parietal lobe pathology and this localisation was confirmed by three positive isotope brain scans. The presence of calculating disturbances (acalculia) following dominant parietal pathology is not unexpected; the characteristics of the calculation defect in this case, however, appear unique and are the focus of this report.

Careful testing failed to demonstrate any aphasic disturbance which involved number language. The patient could read, write, recite, repeat and accurately verbalize numbers. There was neither paraphasia nor perseveration to account for the disturbance of computation. Similarly, clinical testing did not reveal evidence of visuo-spatial disorientation and in actual performance, the patient had no difficulty in aligning problems nor in assigning and maintaining place-holding values. Thus this patient had an acquired disorder in calculating ability (acalculia) which cannot be considered as belonging to either the aphasic or the visuo-spatial varieties described above. We believe this case is best described under the term, anarithmetia, proposed by Hécaen.

In discussing anarithmetia, Hécaen noted considerable heterogeneity and suggested that a number of different mechanisms could produce this disturbance. Among the potential mechanisms he stressed intellectual deficit, spatial agnosia and the disautomatisation of the reading of figures. Our patient suffered none of these defects, at least not in sufficient degree to offer an explanation for his calculating problem.

Singer and Low (1933) gave a detailed presentation and discussion of a single patient with severe acalculia and postulated several causative factors which could underly the calculation disturbance: (a) difficulty in constructing a continuous whole out of discontinuous parts, (b) difficulty in following a progression from a set point, (c) difficulty in grasping a whole without separation into component parts. The factors suggested by Singer and Low could be used to describe the present case. The process of multiplication is a continuous whole which is constructed from separate or discontinuous parts. The retrieval and utilisation of the multiplication tables could be described as following a progression from a set point. Finally, complex problems, particularly multiplication and division, are solved by dividing the whole into simpler component parts. Unfortunately,
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this description of calculation difficulty can be used just as accurately to characterize other varieties of acalculia. Thus it can only be considered a description, not an explanation of our patient's problem.

The possibility of an hysterical basis for the acalculia deserves consideration but seems rather unlikely. The presence of acalculia was an entirely inadvertent discovery. The patient had been hospitalized for study of reading disturbance and had not complained of calculation disturbance until specifically questioned. There was no evidence of secondary gain to be realized from this symptom. Calculating ability was not of significance to either his job or his personal life and had never received any interest or comment from his physicians prior to the evaluation on our unit.

In truth, we do not have a specific explanation for the calculating difficulty demonstrated by this patient. We do feel that aphasia, spatial agnosia, intellectual deficit, memory defect and hysteria can be ruled out as possible sources of acalculia. The patient demonstrated that he understood the basic processes of computation, even when he failed to carry out the process correctly. Evaluation of the errors in complex multiplication problems (Figure 1) suggests several possibilities: (1) inability to remember (retrieve) the multiplication tables; (2) inability to add the initial products; (3) difficulty with the process of carrying during multiplication or addition; (4) admixture of the processes of multiplication, addition and carrying. The first of these seems unlikely as he was consistently correct if he was asked only to multiply one number by another. Similarly, the portions of the multiplication problems consisting of addition alone (the final addition of the products) were always performed correctly, and with ease. The third possibility also appears unlikely; at least he did not show any difficulty in carrying when performing addition problems. The fourth possibility cannot be excluded so readily. Only during the operation of multidigit multiplication did he err. A number of steps are carried on simultaneously during this process; these include retrieval of the multiplication tables, appropriate spatial alignment of the digits and retention and appropriate use of any integers remaining from the previous product (carrying). These steps are performed almost simultaneously, essentially as a single step, by most educated individuals. Our patient could not introspectively separate the steps to discover where his prime difficulty lay. Similarly, observations by the examiners failed to isolate any single step as the source of the failure. Nonetheless, it would appear that a confusion of the processes (adding, multiplying and carrying) was the source of his consistent calculation disturbance.

Whether the variety of acalculia reported here is correctly labelled as anarithmetia is a moot question. Clinically, the calculating defects described are readily separated from those seen in the aphasic or visuo-spatial variations of acalculia. Most cases of anarithmetia described in the literature, however, are products of bilateral brain disease and occur in a different symptom setting. Bilateral pathology cannot be ruled out in the
present case but the available evidence implicates pathology involving only the left posterior parietal region. Therefore, we would like to present this as a case of partial calculating disturbance of the anarithmetic variety which appears to be the result of focal pathology in the dominant posterior parietal area. Quite possibly a similar calculating defect is present in many other cases of acalculia seen in clinical practice but remains hidden by the overwhelming presence of aphasia or visuo-spatial disorientation.

**Summary**

Traditionally, three varieties of acalculia are discussed: (1) aphasic acalculia, in which number language is disturbed; (2) visuo-spatial acalculia, in which alignment and place-holding values are abnormal; (3) anarithmetia, a disturbance of the basic ability to perform computations. A single case is presented which demonstrates a mild but significant calculating disorder. The incomplete nature of the calculating disturbance allows considerable analysis into the underlying disability and there is clear evidence that neither language nor visuo-spatial disability has produced this acalculia. A breakdown of the ability to perform higher computational processes is demonstrated, warrants use of the term anarithmetia and allows some conjecture concerning the source of this unusual problem.

**References**


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