*Journal of Neurology, Neurosurgery, and Psychiatry*, 1976, **39**, 1001–1007

# Cognitive recovery after severe head injury

## 3. WAIS Verbal and Performance IQs as a function of post-traumatic amnesia duration and time from injury

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SYNOPSIS Two studies are reported in which severely head-injured patients were followed up and Verbal (VIQ) and Performance (PIQ) IQs obtained on the Wechsler Adult Intelligence Scale at four intervals after injury. In the first study 51 patients were systematically followed, and results were based upon serial testing. In the second study results were based on the earliest data available from an additional 98 patients who had not been followed so systematically, in order to introduce a control for the effects of practice. Patients in both studies were categorised into four groups of the severity of head injury based upon duration of post-traumatic amnesia (PTA). In both studies, VIQ level was found to be related to PTA duration at three months after injury, while PIQ was related to PTA duration at both three and six months. No such relationships were found at 12 and 30 months after injury. Results are discussed in the context of previous studies relating the outcome of head injury to the duration of PTA.

Post-traumatic amnesia (PTA) is a period of confusion and disorientation occurring after a head injury. While it is characterised primarily by a failure of mnestic processes, a recent study (Mandleberg, 1975) has demonstrated a more general cognitive disability during this period, particularly for non-verbal task-skills; in consequence, the suggestion has been made that PTA represents a qualitatively, and not merely quantitatively, distinct phase of recovery.

The duration of PTA, which may range from minutes to months, is commonly accepted as the best available index of the severity of the head injury, particularly in cases where the absence of fracture, haematoma, or other neurological signs makes it difficult for the clinician to assess the degree of brain injury which has been sustained. As such, PTA duration has been found to be related to a number of outcome parameters, including psychiatric sequelae (Lishman, 1968; Bond, 1975); neurological signs and symptoms (Russell, 1932; Russell and Smith, 1961; Smith, 1961); and memory deficit (Brooks, 1972, 1974). PTA duration has also been related to eventual cognitive status (Tooth, 1947; Russell and Smith, 1961; Lishman, 1968), though other investigators found no such relationship (Dencker and Löfving, 1958; Dencker, 1958). The latter, indeed, concluded that although 'some cognitive functions deteriorated after head injury . . . the impairment was of subtle nature and of no practical importance' (Dencker, 1958, p. 119). In that study, however, 117 of the 128 patients had PTA of less than 24 hours and it is not entirely surprising that with such mild injuries no substantial effects due to PTA were observed.

Yet, the question of the relation between PTA duration and cognitive recovery cannot be regarded as entirely settled. Indirect evidence suggesting that in the relatively long term PTA duration may be of little value in predicting cognitive status is seen in the finding of Mandleberg and Brooks (1975) that a group of *severely* injured patients eventually reached average levels of ability on the Wechsler Adult Intelligence Scale (WAIS). At the same time, Mandleberg (1975) reported that by about 18 months after injury a group of more severely injured patients (mean PTA = 110 days) had essentially 'caught up' cognitively with an otherwise comparable, though less severely injured, group (mean PTA = 19 days). Moreover, preliminary data presented by Bond (1975), though not subjected to statistical analysis, suggested that PTA duration did not appear to affect cognitive level in the longer term.

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(Accepted 20 May 1976.)

The present paper is, therefore, devoted primarily to two parallel studies in which the relationship between PTA duration and cognitive level is assessed more directly, and in which time from injury is regarded as an important independent variable. The indices of cognitive status are the Verbal IQ (VIQ) and Performance IQ (PIQ) of the WAIS, a widely used and very well standardised psychometric instrument (Wechsler, 1955).

## METHOD

A prospective study of severe head injuries was initiated in 1968 at the Institute of Neurological Sciences, Southern General Hospital, Glasgow. Data were collected on a wide variety of clinical and pathological features, and survivors were recalled at intervals for follow-up psychometric and other tests. The Institute serves as the major neurosurgical centre for a very large catchment area, a fact which had important consequences both for the kind of case admitted and the design of the present studies. With regard to the first of these, it should be pointed out that those admitted to the Institute were in a sense preselected as being likely to require neurosurgical intervention. Thus, while the patients may be representative of those referred for special care, the sample probably includes a disproportionate number with intracranial haematoma.

As to the second consequence, problems of transportation often meant that patients could not be followed up at regularly spaced intervals. Accordingly, data were blocked in relation to time elapsed from injury. Four such time blocks were employed: (1) 0–three months (mean = approximately six weeks); (2) four to six months (mean = approximately 5½ months); (3) seven–12 months (mean = approximately 11½ months); and (4) 13 months or more (mean = approximately 29 months; upper limit of range = six years). For convenience these will sometimes be referred to as the three-month, six-month, 12-month, and 30-month evaluations respectively.

Even with the blocking of data, however, not all patients could be followed systematically. Some postponed appointments to times more convenient to themselves. Thus, a patient who postponed his six-month appointment to (say) eight months, would have a data gap for the four to six month period. If he subsequently kept his 12-month appointment, he would have two sets of data for the seven to 12 month period. Other patients inevitably dropped out of sight after one or two follow-ups ('early dropouts'), while others, on the contrary, after failing to respond to early follow-up requests, appeared unexpectedly for later ones ('late returnees').

It was to make use of the maximum amount of data that the present investigation was conceived of as two parallel studies, the first making use of data gathered from 'systematic returnees'—that is, those who responded to all follow-up requests, and the second utilising data from 'non-systematic returnees'. The second study may thus be thought of as a replication of the first and, moreover, as one which presented an unique opportunity for controlling for the possible effects of practice which might have artificially inflated the later scores of the systematic returnees. These potential practice effects were also investigated.

It should be pointed out that there were probably consistent differences between the systematic and non-systematic returnees. Some of these—for example, distance of residence from Glasgow—may be of little relevance to the present investigation. Others, however—for example, differences in motivation—may be reflected to a certain extent in the data. Thus, it may be the case that 'early dropouts' regard themselves (correctly) as being 'back to normal', while 'late returnees' on the other hand are aware (equally correctly) of *not* being back to normal. Both these groups may differ from the systematic returnees, who presumably return for follow-up evaluation for other reasons. It is not entirely clear, however, whether the systematic or non-systematic returnees should be regarded as more representative of head injured patients as a whole.

## MEASUREMENT OF PTA DURATION

Duration of PTA was defined as the time from injury to return of continuous awareness for at least 24 hours. Patients with relatively short PTA were followed up daily on the ward and questioned about names, addresses, visitors, and the activities of the previous day. In this manner it was possible to establish PTA duration directly. Patients with relatively long PTA posed a problem, however, in so far as they were frequently transferred to other in stitutions after their condition had stabilised but while remaining amnesic. Such patients, in addition, often appear to slip in and out of the amnesic state, seeming to be oriented one day, but disoriented the next. In these patients PTA duration had to be established retrospectively by questioning the patient and his relatives along the lines suggested by Russell and Smith (1961). With the longer PTA patients it is therefore likely that some error has inadvertently occurred in estimates of duration, though it is hoped that these have been minimised by the choice in the following studies of relatively broad PTA categories.

*Study 1*

PATIENTS

These were 51 adults (47 male; four female) admitted to the Division of Neurosurgery, Institute of Neurological Sciences, Southern General Hospital, Glasgow, after head injury. The mean age of the group was 28.96 years (SD = 13.14). Most patients had left school at age 15 or 16 years. Mean PTA duration for the group as a whole was approximately six weeks (range = two days to approximately 10 months).

Patients were classified into four groups on the basis of PTA duration as follows: group I (N = seven): PTA less than one week; group II (N = 21): PTA one to three weeks; group III (N = 14): PTA four to seven weeks; group IV (N = 9): PTA eight weeks or more. *F* tests comparing age and years of education for the four PTA groups were non-significant. Table 1 describes the groups on three further clinical indices.

TABLE 1

DISTRIBUTION OF CLINICAL FEATURES IN 51 'SYSTEMATIC RETURNEE' HEAD INJURIES

| | *Fracture* | *Haematoma* | *Motor abnormality* |
|---|---|---|---|
| PTA Group I (N = 7) (PTA < 1 week) | | | |
| R only | 0 | 1 | 3 |
| L only | 4 | 2 | 1 |
| Bilateral | 1 | 0 | 0 |
| None | 2 | 4 | 3 |
| PTA group II (N = 21) (PTA 1–3 weeks) | | | |
| R only | 4 | 4 | 6 |
| L only | 8 | 2 | 5 |
| Bilateral | 1 | 0 | 0 |
| None | 8 | 15 | 10 |
| PTA group III (N = 14) (PTA 4–7 weeks) | | | |
| R only | 2 | 4 | 6 |
| L only | 6 | 2 | 4 |
| Bilateral | 0 | 0 | 0 |
| None | 6 | 8 | 4 |
| PTA group IV (N = 9) (PTA ⩾8 weeks) | | | |
| R only | 4 | 2 | 2 |
| L only | 2 | 3 | 5 |
| Bilateral | 0 | 0 | 0 |
| None | 3 | 4 | 2 |

RESULTS

Figures 1 and 2 present mean recovery curves for the four PTA groups for VIQ and PIQ respectively. As patients were all systematic returnees who had been tested in each of the four time blocks, data were analysed by means of a split-plot factorial analysis of variance, with simple effects also being computed (Table 2). In the event of an overall significant *F* ratio for the main groups' effect, the major question of interest was to determine from the simple effects the time after injury at which the distribution of WAIS IQs for the four PTA groups was no longer significantly different. The question of where precisely the significant differences occurred between the groups was regarded as of secondary interest only, and no *t* tests were performed.

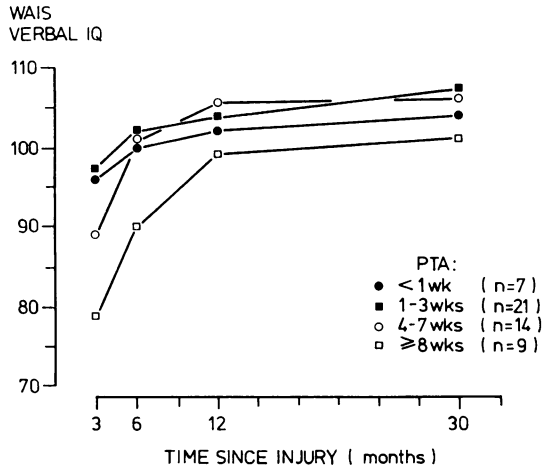


FIG. 1 *Recovery of WAIS Verbal IQ in 51 systematic returnee head injuries.*

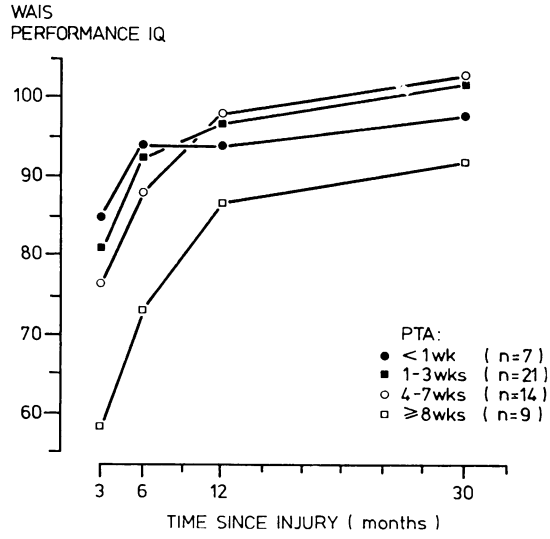


FIG. 2 *Recovery of WAIS Performance IQ in 51 systematic returnee head injuries.*

TABLE 2

SUMMARY OF ANALYSIS OF VARIANCE RESULTS FOR STUDIES 1 AND 2: (*F* RATIOS ONLY)

| *Source of variation* | *Study 1 (Split plot factorial)* | | | *Study 2 (Randomised blocks factorial)* | | |
|---|---|---|---|---|---|---|
| | *df* | *VIQ* | *PIQ* | *df* | *VIQ* | *PIQ* |
| Main effects | | | | | | |
| Between subjects | 50 | — | — | — | — | — |
| Groups | 3 | 1.02 | 3.17* | 3 | 8.02‡ | 8.20‡ |
| Subjects w. groups | 47 | — | — | — | — | — |
| Within subjects | 153 | — | — | — | — | — |
| Trials | 3 | 75.87‡ | 95.56‡ | 3 | 5.81‡ | 6.22‡ |
| Groups × Trials | 9 | 1.79 | 3.32† | 9 | 0.65 | 0.80 |
| Simple group effects | | | | | | |
| 3 months | 3 | 2.19* | 6.50† | 3 | 3.20* | 4.17† |
| 6 months | 3 | 1.42 | 4.22† | 3 | 1.61 | 3.01* |
| 12 months | 3 | 0.49 | 1.11 | 3 | 1.30 | 2.37 |
| 30 months | 3 | 0.37 | 0.95 | 3 | 1.07 | 0.81 |

* $P < .05$; † $P < .01$; ‡ $P < .005$.
Fuller tables of results available from author on request.

For PIQ, significant *F* ratios were observed for simple group effects at the three-month and six-month evaluations. For VIQ, on the other hand, a significant *F* ratio was observed only at the three-month evaluation. In view of the lack of significance of the main VIQ groups' effect the latter result would not ordinarily be remarked upon were it not for the parallel with study 2 below. Consideration of results from VIQ and PIQ together suggests a somewhat slower recovery rate for the latter than for the former, consistent with earlier findings (Mandleberg and Brooks, 1975). Of particular interest is the finding that, in the longer term, IQ levels were indistinguishable on the basis of PTA duration alone, though a trend was apparent for the longer PTA groups to score slightly less well than the shorter PTA groups. This too is consistent with earlier findings (Mandleberg, 1975).

## *Study 2*

### PATIENTS

These were a further 98 severely head injured adults (86 males; 12 females) admitted to the Division of Neurosurgery, INS. The mean age of this group was 34.75 years (SD = 15.11), and mean PTA duration for the group as a whole was approximately five weeks (range = four days to approximately six months). The majority of the patients had left school at ages 15 or 16 years.

Patients were again categorised into four groups on the basis of PTA duration, using the same categories as in study 1. The distribution of patients was as follows: group I, N = 18; group II, N = 33; group III N = 30; group IV, N = 17. Age and educational levels of the four PTA groups were not significantly different (*F* tests). Table 3 describes the groups on three further clinical indices.

TABLE 3

DISTRIBUTION OF CLINICAL FEATURES IN 98 'NON-SYSTEMATIC RETURNEE' HEAD INJURIES

| | *Fracture* | *Haematoma* | *Motor abnormality* |
|---|---|---|---|
| PTA group I (N = 18) (PTA < 1 week ) | | | |
| R only | 2 | 2 | 1 |
| L only | 3 | 3 | 2 |
| Bilateral | 1 | 0 | 1 |
| None | 12 | 13 | 14 |
| PTA group II (N = 33) (PTA 1–3 weeks) | | | |
| R only | 8 | 6 | 10 |
| L only | 12 | 9 | 8 |
| Bilateral | 1 | 2 | 0 |
| None | 12 | 16 | 15 |
| PTA group III (N = 30) (PTA 4–7 weeks) | | | |
| R only | 5 | 6 | 11 |
| L only | 8 | 7 | 10 |
| Bilateral | 2 | 1 | 0 |
| None | 15 | 15 | 9 |
| PTA group IV (N = 17) (PTA ⩾8 weeks) | | | |
| R only | 0 | 5 | 4 |
| L only | 6 | 3 | 8 |
| Bilateral | 3 | 2 | 0 |
| None | 8 | 7 | 5 |

### PROCEDURE

The patients in this study were all non-systematic returnees. Approximately half had been tested only once on the WAIS; of the remainder, all but four had been tested twice at irregular intervals. The remaining four had been tested three times at irregular intervals. Of those tested more than once on the WAIS, only the *earliest* available set of scores was utilised. Thus, at the cost of losing a certain amount of data, it was possible to ensure for the group as a whole that only IQ scores uninfluenced by previous experience of the WAIS were included in the analysis.

The 18 patients of PTA group I were distributed across the time blocks as follows: 0–three months, n = four; four to six months, n = five; seven to 12 months, n = five; over 12 months, n = four. The 33 patients of group II were distributed: 0–three months, n = 12; four to six months, n = eight; seven to 12 months, n = four; over 12 months, n = nine. The 30 patients of group III were distributed: 0 to three months, n = six; four to six months, n = seven; seven to 12 months, n = eight; over 12 months,

n = nine. The 17 patients of group IV were distributed: 0 to three months, n = four; four to six months, n = four; seven to 12 months, n = three; over 12 months, n = six.

## RESULTS

Figures 3 and 4 present mean recovery curves for the four PTA groups for VIQ and PIQ respectively. Data were analysed by a randomised block factorial analysis of variance (unweighted means solution) using the procedure for unequal cell n's described by Kirk (1968). Main and simple effects were again computed (Table 2). With regard to the major question of when, if at all, IQ scores for the four PTA groups ceased to be significantly different, findings exactly replicated those of study 1. For PIQ, significant PTA group differences were observed at both the three-month and six-month evaluations. For VIQ, a significant $F$ ratio was observed only at three months. It is to be noted that the latter finding was, in this instance, associated with a significant $F$ ratio for the main groups' effect. As in study 1, PTA group differences in the longer term were not statistically significant, although again a trend was observed for the longer PTA groups to score slightly less well in the long term than the shorter PTA groups.

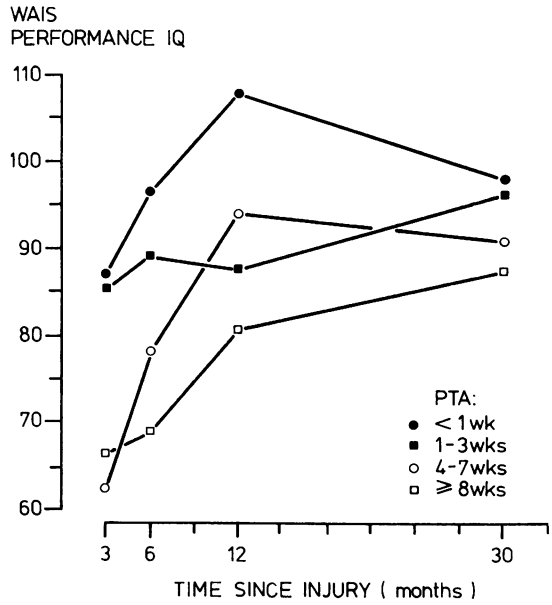


FIG. 4 *Recovery of WAIS Performance IQ in 98 non-systematic returnee head injuries.*

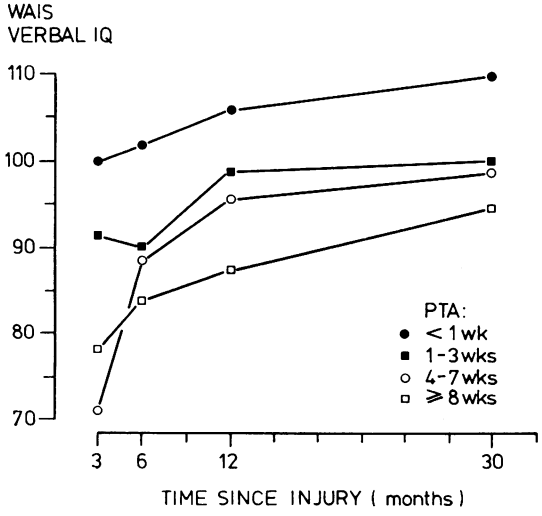


FIG. 3 *Recovery of WAIS Verbal IQ in 98 non-systematic returnee head injuries.*

## EFFECTS OF PRACTICE

It was hypothesised that practice effects, if they occurred, would be most noticeable at the 30-month evaluation, when the systematic returnees would have had three previous exposures to the WAIS, while the non-systematic returnees would have had no previous experience. The original PTA categories were retained, and the 30-month data were analysed by a four factor (PTA duration) by two treatment (previous experience *vs.* no previous experience) randomised blocks analysis of variance (unweighted means solution) for unequal cell n's. Main effects were computed, but no significant $F$ ratios were found. Thus, although visual inspection of the recovery data suggested a trend for the systematic returnees to score somewhat better at 30 months than the non-systematic returnees, especially with respect to PIQ, it appeared that previous exposure to the WAIS did not significantly enhance the IQ scores of the former group. Many psychologists, on the basis of reported practice effects of five to eight IQ points in normal subjects (Wechsler, 1958; Quereschi, 1968), have questioned the value of scores obtained by repeatedly testing organic patients on the WAIS. In view of the present results, one may wonder whether such caution is empirically justified.

## DISCUSSION

It would appear that psychometric intelligence—and, in so far as the task-skills required for effective performance on the WAIS may represent a substantial subset of those abilities necessary in other spheres of daily life, cognitive level more generally—is related to severity of head injury only in the relatively early stages of recovery. The critical period at which PTA may cease to be a useful predictor of cognitive level is apparently between three to six months in the case of verbal skills, and seven to 12 months in the case of non-verbal ones. To the extent that PTA duration appears to have no implications for 'eventual' outcome cognitive level, the present results conform to the findings of Dencker and Löfving (1958)—this time, however, with a considerably more severely injured sample. Nevertheless, consideration of the recovery curves suggests that, while cognitive *outcome* may not be related to PTA duration, *rate* of cognitive recovery may yet be seen to exhibit such a relationship. It is hoped to investigate this possibility in a later paper.

The present results, in general, run contrary to previous claims that PTA duration does bear a relationship to various outcome parameters. Since, to the author's knowledge, this paper is the only one in which PTA duration has been related longitudinally to 'hard' psychometric data, it provides a contextual background against which earlier reports may be assessed. Even if all contrary reports are accepted at face value, a number of propositions may be advanced which may help harmonise earlier studies with the present findings.

First, there is no *a priori* reason to assume that results obtained for one class of parameter necessarily generalise to another class. Thus, for example, Lishman (1968) has found that longer PTA is associated with increased likelihood of psychiatric sequelae in head injuries. It is not legitimate to assume, however, that the brain damage which gives rise to the personality disorder *ipso facto* results in lowered intellectual competence. In the case where the personality change is of the frontal variety, with concomitant apathy, euphoria, disinhibition, etc., it may be that there are changes in levels of arousal and/or motivation which affect cognitive style rather than competence. This point will be further elaborated below. Similarly, long-term neurological deficit need not be associated with lowered cognitive ability: many clinicians will be familiar with the patient who, after prolonged PTA, eventually returns to an intellectually demanding occupation, albeit with the aid of cane or brace to overcome residual hemiparesis. Personality changes on the one hand, and long-term neurological deficit on the other, are not necessarily associated with cognitive deterioration.

Second, where it has been claimed that PTA duration *is* related to cognitive outcome, two questions must be asked: (1) what is the nature of the injuries which have been sustained? and (2) what cognitive indices are employed? With regard to the first we may note, for example, that Lishman's group was composed entirely of penetrating injuries; once again, it cannot be assumed that results from a focally injured group extend to patients with more diffuse lesions. As to the second, it is often the case that the cognitive indices tend to be of the 'soft' variety, such as evidence of poor concentration or attention, poor motivation, or general claims of 'disturbed memory'. This is not to denigrate the value of soft data, but merely to make the point that here, too, we may be dealing with changes of style rather than of competence. Stylistic changes might be reflected in speed of response, in persistence at a task, or in other variables responsive to changes in task strategy; but such changes do not necessarily impair achievement. Ben-Yishay *et al.* (1974) showed, for example, that hemiplegics who had been trained to average or better levels on a cognitive task (the WAIS Block Design test) retained the same 'brain-injured style' with raised competence as they had displayed before training. It is hoped to be able to examine this question, too, at a later date.

Third, where 'hard' cognitive indices have been employed, it is necessary to consider (1) the time from injury at which the results were obtained, and (2) the nature of the tasks, in particular their overt or latent verbal components. The importance of the first consideration is apparent from the present study; and in this connection it may be noted that where Lishman did employ psychometric data in categorising his patients, he made use of test results which had been obtained relatively soon after injury. With respect to the second point, the present paper suggests that the relationship between PTA and cognitive level attenuates more rapidly for verbal than for non-verbal abilities.

Finally, it should be pointed out that the various indices of the severity of head injury may not be freely interchangeable, and that certain of these may yield results which stand in apparent contradiction to those obtained when PTA duration is the independent variable. Lishman also (indeed, primarily) employed depth of wound as an index of severity in his study; Dailey (1956) separated severe from less severe injuries on the basis of presence *vs.* absence of post-traumatic epilepsy. In both studies the more severely injured patients showed evidence of long-term cognitive deficit (soft in the former instance, hard in the latter). Such findings suggest that alterna-

tive indices of severity may well tell us more about the prospects for a satisfactory cognitive outcome than does PTA duration; and, as a corollary, they raise the question of precisely what it is that is measured by PTA duration. Unfortunately, the data from the present study supply too few clues for such speculation to be fruitful.

This research was supported by the National Fund for Research into Crippling Diseases, as part of a wider study of head injuries by Professor Bryan Jennett, Department of Neurosurgery, University of Glasgow. The author wishes to extend his thanks to the following: Professor Bryan Jennett, by whom clinical data on patients were collected and coded; Mr D. N. Brooks, for his advice in connection with the statistical analysis of the data; and the consultants of the Division of Neurosurgery, Institute of Neurological Sciences, for their assistance and co-operation.

REFERENCES

Ben-Yishay, Y., Diller, L., Mandleberg, I., Gordon, W., and Gerstman, L. J. (1974). Differences in matching persistence behavior during block design performance between older normal and brain-damaged persons: A process analysis. *Cortex*, **10**, 121–132.

Bond, M. R. (1975). Assessment of psychological outcome of severe head injuries. In *Outcome of Severe Damage to CNS: CIBA Foundation Symposium 34 (New Series)*, pp. 141–157. Elsevier: Amsterdam.

Brooks, D. N. (1972). Memory and head injury. *Journal of Nervous and Mental Diseases*, **155**, 350–355.

Brooks, D. N. (1974). Recognition memory after head injury. *Cortex*, **10**, 224–230.

Dailey, C. A. (1956). Psychologic findings five years after head injury. *Journal of Clinical Psychology*, **12**, 349–353.

Dencker, S. J. (1958). A follow-up of 128 closed head injuries in twins, using co-twins as controls. *Acta Psychiatrica et Neurologica*, **33**, suppl. 123.

Dencker, S. J., and Löfving, B. (1958). A psychometric study of identical twins discordant for closed head injury. *Acta Psychiatrica et Neurologica*, **33**, suppl. 122.

Kirk, R. E. (1968). *Experimental Design: Procedures for the Behavioral Sciences*. Brookes/Cole: Belmont, California.

Lishman, W. A. (1968). Brain damage in relation to psychiatric sequelae after head injury. *British Journal of Psychiatry*, **114**, 373–410.

Mandleberg, I. A. (1975). Cognitive recovery after severe head injury: 2. Wechsler Adult Intelligence Scale during post-traumatic amnesia. *Journal of Neurology, Neurosurgery, and Psychiatry*, **38**, 1127–1132.

Mandleberg, I. A., and Brooks, D. N. (1975). Cognitive recovery after severe head injury: 1. Serial testing on Wechsler Adult Intelligence Scale. *Journal of Neurology, Neurosurgery, and Psychiatry*, **38**, 1121–1126.

Quereschi, M. (1968). The comparability of WAIS and WISC subtest scores and IQ estimates. *Journal of Psychology*, **68**, 73–82.

Russell, W. R. (1932). Cerebral involvement in head injury. *Brain*, **55**, 549–603.

Russell, W. R., and Smith, A. (1961). Post-traumatic amnesia in closed head injury. *Archives of Neurology (Chic.)*, **5**, 16–29.

Smith, A. (1961). Duration of impaired consciousness as an index of severity in closed head injury. *Diseases of the Nervous System*, **2**, 1–6.

Tooth, G. (1947). On the use of mental tests for the measurement of disability after head injury. *Journal of Neurology, Neurosurgery, and Psychiatry*, **10**, 1–11.

Wechsler, D. (1955). *Manual for the Wechsler Adult Intelligence Scale* Psychological Corporation: New York.

Wechsler, D. (1958). *Measurement and Appraisal of Adult Intelligence*. Williams and Wilkins: Baltimore.