

TRAUMATIC AMNESIA

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INTRODUCTION

THE disturbances of memory associated with head injury are varied and worthy of special study. The most obvious clinical abnormality which accompanies many head injuries is an instantaneous paralysis of brain function—motor, sensory, reflex and mental. The term *concussion* is often used to describe this phenomenon. It is obvious that during the period of brain paralysis there can be no registration of surrounding incidents and accordingly there is subsequently a permanent amnesia for events occurring during this time. As consciousness returns the mental functions recover as after an anæsthetic, the more complex being the last to return to their normal state. While in slight injuries the stages of recovery occupy only a few minutes, after severe trauma recovery of brain function may occur very gradually during a period of several days or weeks. The stages of recovery, however, are often similar whether they run a brief or prolonged course. The function of memory is usually regained at about the same time as the last trace of confusion disappears, and the period of post-

traumatic amnesia (P.T.A.) is then at an end. The duration of the P.T.A. can be roughly ascertained, as Russell (1932) has pointed out, by asking the patient at any time *after* he has finally emerged from the state of confusion, when he "came to himself". This end-point, however, is sometimes ambiguous, for, as Symonds has emphasized, the patient's first memory after the injury, though clearly described, may be followed by a further period of amnesia for hours or days. In such cases the patient is usually able to record the time or date from which he has continuous memory, and this has been used by us for the measurement of the P.T.A. in the cases to be described. It is thus only in the later stages of mental recovery that the patient becomes sufficiently aware of his surroundings to commit them to memory and thus to end the period of post-traumatic amnesia.

POST-TRAUMATIC AMNESIA (P.T.A.)

The duration of post-traumatic amnesia (P.T.A.) can only be estimated with accuracy after the patient has recovered from even slight degrees of confusion. This duration of P.T.A. will then usually remain relatively constant and will form a permanent index of the duration, not of unconsciousness, but of impaired consciousness. The P.T.A. therefore provides a useful clinical guide for the physician who may enquire into the case for the first time long after the injury occurred. It is obvious that the duration of P.T.A. will provide some indication of the severity of the general brain commotion caused by the injury, and studies by Symonds and Russell (1943) indicated its usefulness in prognosis. We have again analysed these Service cases with reference to subsequent fitness for *full duty* in a series followed up successfully through the Unit medical officers. The results are given in Table I and indicate clearly that the prospects of good recovery of efficiency diminish rapidly as the P.T.A. lengthens.

TABLE I.—FOLLOW-UP.

Duration of Post-Traumatic Amnesia compared with future fitness for *full duty*—based on follow-up of surviving cases six to twenty-four months after discharge from hospital. Cases were those admitted in the acute stage and therefore relatively unselected. Only those followed-up successfully are considered.

Duration of P.T.A.	Total cases admitted to hospital	Ret. to duty from hospital	"Fully duty efficiently" on follow-up	Per cent. of total
Nil	29	28	25	86%
1 hour	92	90	80	87%
1-24 hours	73	70	54	74%
1-7 days	39	34	23	59%
7 days	41	26	7	17%
No record.. .. .	2	2	1	
	<hr/> 276	<hr/> 250	<hr/> 190	<hr/> 69%

Duration of P.T.A.—This analysis in Table I is concerned with accidental blunt injuries in which the rate of change of velocity to which the skull is subjected probably determines the degree of brain damage (Denny-Brown and Russell, 1941). In gunshot wounds, on the other hand, the brain is often submitted to little acceleration, and as in other penetrating injuries the damage is often quite local. Thus in Table II the

TABLE II.

Duration of Post-Traumatic Amnesia in a consecutive series of surviving "accidental" and gunshot wound cases admitted to a Military Hospital for head injuries.

	Total	Duration of Post-Traumatic Amnesia					No record
		Nil	< 1 hr.	1-24 hr.	1-7 days	> 7 days	
"Accidental" head injury.	1,022	99 10%	208 20%	312 31%	231 23%	167 16%	5 ½%
Gunshot wounds of the Brain.	200	64 32%	40 20%	22 11%	42 21%	24 12%	6 3%

duration of P.T.A. is compared in a series of accidental injuries and of gunshot wounds of the head with dural penetration or skull fracture. No less than 32 per cent. of the gunshot wound cases have no amnesia, and this must be due to a failure of many of these missiles (which include small bomb fragments) to concuss the brain as a whole. There is also a remarkably small proportion of cases of gunshot wound with P.T.A. of one to twenty-four hours. This is in striking contrast to the "accidental" group and indicates that when gunshot wounds do cause loss of consciousness the latter is likely to be either of very short or of much prolonged duration. This can probably be explained by the assumption that when such wounds are of sufficient severity to cause severe general commotion the associated brain destruction will ensure by its extent or its complications that the P.T.A. is prolonged.

TABLE III.

Duration of Post-Traumatic Amnesia in a series of surviving cases admitted to hospital in the acute stage and therefore relatively unselected.

	Total	Duration of P.T.A.					No record
		Nil	< 1 hr.	1-24 hr.	1-7 days	> 7 days	
Military Hospital cases	331	34	115	91	45	43	3
Per cent.		10%	35%	27%	14%	13%	1%
Russell's (1932) cases.							
Edinburgh	184	80		57		47	
		43%		31%		25%	
Gutmann's (1943) cases.							
Oxford	179	118		39	19	3	
Per cent.	—	66%		22%	11%	2%	

Table III gives the number of cases in the various P.T.A. groups in an unselected series of acute hospital admissions. The cases were admitted to a Military Hospital for Head Injuries, and were those admitted in the acute stage only; they are compared with figures for general hospitals published by one of us (W. R. R.) and also by Gutmann. There is a close similarity between the figures in the first two groups of cases, while those in Gutmann's series have a larger proportion of slight injuries.

It is now generally agreed (Symonds, 1932; Russell, 1932; Greenfield, 1938; Jefferson, 1942) that the disorders of consciousness following head injury are usually dependent on neuronal trauma and are rarely due to vascular complications such as hæmorrhage, œdema or increased intracranial pressure. Study of the duration of amnesias following injury carries us a step further, for this makes it necessary to postulate many degrees of neuronal commotion which, for example, may recover fully in ten minutes or may "feel their way" gradually to recovery in ten days.

Reduction of P.T.A.—Though the duration of P.T.A. is usually more or less permanent and unchanging, there are exceptions. Occasionally it becomes reduced spontaneously as in the following case:

Fus. R. sustained a head injury on July 19, 1942. On August 4 he had a momentary retrograde amnesia (R.A.) and a P.T.A. of six days with an "island" on the fourth day. Ten weeks after the accident he regained spontaneously another island in the P.T.A., for while sitting quietly in bed he suddenly remembered being on the floor of a moving truck, and this was, in fact, the way he was brought to hospital.

Cases of reduction in P.T.A. under barbiturate hypnosis are described later. These recoveries of things forgotten are reminiscent of hysterical amnesia and yet there is no reason to suppose they are hysterical.

Delayed P.T.A. and lucid interval.—In some few cases of accidental head injury all details of the injury and of events which closely followed it are clearly recalled, but there follows later a period of confusion and amnesia. This can be referred to as *delayed post-traumatic amnesia*. In most cases, especially in gunshot wounds of the brain, the delayed P.T.A. probably indicates that vascular complications of the wound are responsible for the delayed amnesia. 2.5 per cent. of 1,029 cases of accidental head injury had delayed amnesia, while the figure for gunshot wounds of the skull and brain was much higher, being 14 per cent. in 372 cases. In a very few cases of relatively slight injury the short lucid interval seems to correspond with a period of intense stimulation for the patient which may "keep him awake" for a time. For example, a cyclist whose motor-cycle caught fire after the accident remembers trying to put out the fire and

then no more for many hours. Or again an airman after a crash remembered turning off the petrol before his P.T.A. developed. In this type of case the disturbance of consciousness is relatively slight and a strong stimulus may lead to registration of an event so well that it can be subsequently recalled.

The phenomenon of a lucid interval has for long been recognized as a clinical feature in the diagnosis of extradural hæmorrhage. It should be noted, however, that it is only those cases which have little initial concussion which show this well-developed lucid interval before cerebral compression supervenes. It is equally important to note that there may be a lucid interval followed by delayed confusion in the absence of any gross intracranial complication such as hæmorrhage. This is usually easy to distinguish clinically from the progressive stupor and coma of cerebral compression. These slight degrees of delayed confusion appear sometimes to be due to subarachnoid hæmorrhage, or to minute intracerebral hæmorrhages in the brain-stem (Denny-Brown, 1941).

Islands of memory in P.T.A.—The loss of memory for all events during the time covered by the P.T.A. is not always uniformly complete. In some cases islands of memory emerge which are often concerned with special events such as an operation or the visit of a relative. They are liable to appear when confusion is slight and the patient able to converse and behave in a sensible way. In 13 cases showing an early island in the P.T.A. the final duration of amnesia was one to twenty-four hours in 4 cases, one to seven days in 4 cases, and over seven days in 5 cases. In most of these cases of early islands in the P.T.A. the underlying factors are probably the same as in the cases of delayed amnesia already referred to, but the injury being more severe there is immediate loss of consciousness, then partial recovery or lucid interval corresponding to the "island", and then the delayed amnesia due to vascular complications. As with cases of delayed amnesia, the "island" with subsequent deterioration does not usually indicate that a serious degree of cerebral compression is developing. These islands, when they occur, cannot be localized, for they concern an isolated happening unconnected with the normal chain of memories—restricted paramnesias as Bannister and Zangwill (1941) term them. A special occasion may sometimes appear to be responsible for the return of continuous remembering and the end of the P.T.A. The suddenness with which the patient may "come to himself" is often a striking feature, and is of interest in considering the physiology of P.T.A.

Behaviour during period of P.T.A.—During the stages of recovery of consciousness many remarkable abnormalities are observed. In the first

place the patient's behaviour may closely approximate the normal, and many football players have continued the game and have even played well after a head injury, though they subsequently remember nothing of that part of the game which followed the concussion. Their behaviour may be such that their friends notice nothing amiss, but in other instances there is obvious confusion, as for example the football player who after a head injury plays towards the wrong goal.

Similar abnormalities are sometimes observed after epileptic fits, where again the patient's inability to recall his actions is a striking feature. The term *automatic behaviour* is used to describe this condition, but it must be stressed that the term may refer to behaviour which is obviously confused, or on the other hand to behaviour which is outwardly normal and rational, but in which only the loss of recall indicates that a high level of cerebral function is in abeyance.

Conversation during period of P.T.A.—Many interesting aphasic phenomena occur during recovery from concussion, but these will not be considered here. When the patient is still severely confused he may occasionally give information regarding his injury which is subsequently quite forgotten. Burton (1931) has found that this information may be correct, but care must be taken not to be misled by confabulation.

Case of Memory Regarding Accident During Period of Confusion which was Later Forgotten within R.A.: Confabulation and False Accusation.

W. D. (Case P 91), an electrician aged 38, had a motor-cycle accident on 8.8.33, while swerving to avoid a dog. There was a laceration in the left frontal region and a linear fracture of the middle fossa of the skull. Two days after the injury he repeatedly said "It was a dog!" He was however quite confused, and gave the date at February, 1933. He gradually became more alert and confabulated aggressively regarding this early memory, and some information probably derived later from his wife. On 16.8.33 he gave the date and place correctly and said he had been in hospital for a week. "I'm supposed to have had a smash up, but it wasn't my fault—dog flew at me and I flew at it—a big black dog with a white spot on its chest. Farmer's son turned on me and smashed me with an instrument in his hand for damaging him. He is getting arrested to-day—plain clothes officer told me he had been arrested—that is one of the charges I have against him. I've the money to fight the case. I can prove what I said. . . . The police have found the instrument, and everything is turning out as I said. Marks on the instrument and everything . . . the dog did not harm me . . . it was the man that hurt me . . . etc."

The condition improved steadily and he was discharged home about three weeks after the accident and resumed work two months after leaving hospital. When re-examined on 9.1.34 he had no recollection of his period in hospital except the last four days (P.T.A. sixteen days). The R.A. was two days, and those two days

were a "complete blank". He was quite fit with no headache or giddiness and he considered his work capacity and memory to be as good as ever.

A witness, who was near when the accident occurred, said it was due to his swerving to avoid a large, black dog with white spots belonging to the adjacent farm. The farmer's son accompanied the patient to hospital in the ambulance, but the patient now has no idea even what the farmer's son looks like.

Occasionally the P.T.A. lengthens in the early days after recovery of consciousness as though the memory of events soon after recovery of consciousness is not retained with sufficient firmness for recall at a much later date. Barbiturate hypnosis may facilitate recall as in the following case:

Case of Lengthening P.T.A. Subsequently Reduced by Barbiturate Hypnosis.

SPR. C. had a R.A. of a few seconds. When questioned *seven* hours after the accident his first memory was of being lifted on to a stretcher. From the account of a witness of the accident this was half an hour after it occurred. Then he remembered nothing more until he heard someone saying that he needed two stitches in his lip: this was half an hour later. When questioned again *one week* after the accident, his first memory of being lifted on to a stretcher had gone, and the earliest memory now was someone saying he needed two stitches. The memory of the entire day of the accident was then vague, whereas it had been quite clear at the first examination. A fortnight after the accident his remembrances were unchanged but his memory of the day of the accident had become even more vague, and he could not give a satisfactory account of his medical examination on the day of admission. Under pentothal, however, he remembered being lifted on to the stretcher, and he also remembered an old lady saying: "Lift him carefully; he's badly injured". (This remark was confirmed by the police.) He now remembered part of the journey in the ambulance, but thought he must have gone to sleep for the last part of it, as he remembered nothing more until he was being stitched. His memory of his medical examination on admission remained, however, as vague as before.

"Visions" relative to the injury.—A curious phenomenon which seems allied to those described above is occasionally described by the patient after full recovery of consciousness. This consists of a transient and sometimes repeated "vision" of something seen just before the accident, though events concerning the vision cannot be recalled in the usual way and fall within the R.A.

One of us (Russell, 1935) described a case of head injury in which for a period of one week only after recovering consciousness (P.T.A. twelve hours) the patient frequently had a sudden vision of the huge tyre of a motor lorry bearing down on him. Though the retrograde amnesia was only a few seconds and the injury was actually due to a motor lorry knocking him down he was never able to remember seeing the lorry which in fact could only have been visible to him for a moment before the injury occurred.

We have recently observed similar cases which were investigated under pentothal hypnosis without restoring any memory of the events relative to the hallucination:

DRIVER T.'s first memory on coming round in hospital was of seeing a horse as in a cloud. He had a very clear idea of the horse; it was a brown cob, and he had a side-view of it. It was galloping with its head up, coming from right to left. There was no cart attached to it; he was unaware of any background of road or surrounding scenery or people or noise. He was unaware of being frightened or of any feeling that an accident was about to occur. This vision at once passed and he was aware of two nurses making his bed. He asked them what had happened, and they told him he had had an accident. He then asked them whether it was anything to do with a horse, and they told him they did not know, but that he had already told them that it occurred through a horse. He himself had no recollection of having told them this. This story of the accident has been confirmed: he did collide with a runaway horse.

DRIVER L. (Case 15207) was involved in a motor car accident in April, 1944. He was sitting next the driver and has been told that the accident was due to the steering rod breaking. When examined in September, 1944, he had made a good recovery apart from some headache. He had complete R.A. for about twenty minutes, and this amnesia included a special visit by car to a river. The P.T.A. was for three to four days. Under sodium amytal hypnosis five months after the accident he talked freely but no shortening of the R.A. or P.T.A. could be obtained. He did, however, recover an island in the R.A. during which he was sitting in the car reading a letter while they were travelling at about 35 m.p.h. He also thought that he could remember looking up suddenly, but had no recollection of the driver struggling with the steering wheel, nor had he any memory of the visit to the river.

"Visions".—About two weeks after the accident he had his first "vision" and he had six of these in all, of which four were during the two months following the injury. The "visions" consisted of the sudden appearance in his right visual field of a man, and especially the man's arms, struggling with the steering wheel of a car. This "vision" lasted for a few seconds. It only occurred while he was completely at rest both mentally and physically, generally while sitting in an easy chair. On the first two occasions of the "vision" he felt frightened, and his "stomach turned over", but in the more recent attacks he recognized the "vision" and there was no associated emotional reaction to it. He is naturally a visualist and has visual dreams during sleep, but has never seen this "vision" during sleep and has no dreams relative to the accident.

FITTER P. (Case MRC 232) (Hooper, McGregor and Nathan 1945) "came round" in hospital two and a half days after his accident. He became vaguely aware of the ward surroundings, but at the same time he seemed to hear a confused jumble of voices, shouts and the noise of brakes being applied; he saw two car lights, and had a vivid impression of being dragged along on his back. These sensations lasted for about two minutes and recurred later with a highly unpleasant and terrifying sensation as an aura to an attack which might have been an epileptic equivalent.

In this case, unlike the first three, a part of the hallucination was clearly remembered as occurring before the injury, for he remembered the screech of brakes and his being struck by a car but could never recall being dragged along the road.

These rare cases suggest that during the period of confusion isolated and dramatic events preceding the injury may be registered and retained which cannot be recalled in the normal way, but only in the form of "vision".

Confabulation.—During the period of confusion following concussion which falls within the P.T.A., speech and behaviour may be so nearly normal that confabulation misleads the unskilled observer. The subject matter for confabulation is usually unconnected with the injury, but in some instances the patient apparently realizes he has had an accident and confabulates with regard to it. This may lead to the patient making false accusations regarding the cause of the injury, as has been reported by Russell (1935) and Symonds (1937). The hallucinations referred to in the last paragraph may play a part in the confabulation in some cases.

The confabulation may be rational and yet the period of abnormality usually falls within the P.T.A. In such cases the mental activity approximates to normality but there is a loss of continuous remembering, and the context of the confabulation is forgotten.

Secondly there are cases in which the confabulation is subsequently remembered, as may occur after alcoholic intoxication or psychosis of Korsakoff's type. In these instances the faculty of continuous remembering has recovered while the confabulation persists, as in the following case:

Case of Prolonged Confusion with Memory of Abnormal Behaviour after Recovery of Full Consciousness.

R. D. (Case P 150) had a severe motor-cycle accident on 3.5.31. When seen a few hours later he was stuporose and very restless. On 4.5.31 he was violent and required forcible restraint for several days. His speech was at first meaningless, but gradually he became very talkative, emphasizing all he said with powerful gestures. He talked incessantly of his ability as a sheep-shearer and fisher, and promised money to Sister and Doctor if they would let him go home. This continued until about 23.5.31 when his behaviour and conversation became normal, and he was most apologetic for his abnormal behaviour. He remembered many events during his confusion, especially during the last week. He had a clear recollection of being strapped in bed, refusing medicine and struggling with the nurses. The R.A. was momentary.

When re-examined nine months after, he was back at work and had made an excellent recovery. He was more talkative than before the injury, but said his memory was excellent, except that he had no idea of the number of sheep he counted six hours before the accident. He was driving his motor-cycle as fast as ever.

The abnormality of localization of islands of memory may contribute considerably to confabulation, as in the case of a fitter, who had an accident on October 10, 1941, while walking in Norwich, and who gave his

story on October 28 in such a way that it was clear that though he gave some particulars correctly, he was confusing his injury with an accident near Epsom which he had two years previously. The confusion was clearly due to failure to localize his memories of the more recent injury.

A similar disturbance of localization has been produced by Flescher (1941), by giving schizophrenics various material to remember before electric shock therapy. He was able to show that though much was correctly remembered it was often localized quite incorrectly in time.

RETROGRADE AMNESIA (R.A.)

The curious phenomenon of retrograde amnesia which is so well known in head injury is also found after electric convulsion therapy, status epilepticus, meningitis and acute cerebral anoxia as in hanging, CO poisoning and severe loss of blood. R.A. is for events which occurred before the injury while the patient was still fully conscious. The events occurring during this period were often dramatic and must have been registered by the normally acting sensorium, yet the injury intervenes and these events are thereby prevented from being retained, or if they are retained they cannot be recalled. The clinical features of R.A. present many interesting variations.

Duration of R.A.—The R.A. is in most cases for a few moments only. The motorist remembers approaching the cross-roads, the cyclist remembers losing control on a steep hill, or the window-cleaner remembers losing his balance. This momentary R.A. is observed after injuries of all degrees of severity and presumably has a clear and uniform physiological basis. In cases of prolonged R.A. other factors require consideration.

TABLE IV.

Duration of P.T.A. and R.A. compared in 1,029 cases of "accidental" head injury (gunshot wounds excluded).

<i>Duration of R.A.</i>		<i>Duration of P.T.A.</i>					No record	Total
		< 1 hr	1-24 hr.	1-7 days	>7 days			
Nil	99	23	9	2	0	0	133	
Under 30 minutes	—	178	274	174	80	1	707	
Over 30 minutes	—	3	16	41	73	0	133	
No record	—	4	14	14	15	9	56	
Total	99	208	313	231	168	10	1,029	

In Table IV the R.A. in 1,029 cases is roughly estimated, and compared with the P.T.A. In Table V, fifty consecutive cases from each P.T.A. group have the R.A. recorded in greater detail. These tables indicate how very constant some period of R.A. is in all injuries which disturb consciousness

TABLE V.

Detailed comparison of duration of P.T.A. and R.A. using 50 consecutive cases from each P.T.A. group.

<i>Duration of Post-Traumatic Amnesia</i>					
<i>Duration of Retro- grade Amnesia</i>	< 1 hr.	1-24 hr.	1-7 days	> 7 days	Total
Nil	9	1	1	—	11
1 minute	34	35	15	12	96
1-30 minutes ..	6	13	21	18	58
$\frac{1}{2}$ -12 hours	1	1	9	6	17
$\frac{1}{2}$ -2 days	—	—	3	7	10
2-10 days	—	—	1	6	7
Over 10 days ..	—	—	—	1	1
Total	50	50	50	50	200

sufficiently to produce even a short P.T.A. These records were made by many observers, and some errors there must be. It is common, for example, in street accidents for the victim to remember being struck by a vehicle but nothing more. His head injury may, however, have been due to his striking the ground a second or two later, and this would be recorded according to our standards as a momentary R.A. Such cases may easily be entered in error as R.A.: nil. However, there is no doubt that certain cases of accidental concussion with a short P.T.A. clearly remember the head injury, and in Table V there are 11 cases of this type in 200 cases. On the other hand in 186 cases of G.S.W., brain or skull, with a definite period of P.T.A., there were no fewer than 65 with no R.A., that is to say the patient remembered his head being struck by the missile.

Case of Accidental Head Injury from a Falling Stone with R.A.: Nil, and P.T.A.: Twenty-four Hours.

A. M. (P 203), a quarryman, was injured by a falling stone, which was about the size of a man's fist. The stone fell from a height of about 60 feet, and striking his head caused a fissure fracture of the skull in the parieto-occipital region. When questioned ten days after the injury he said that he remembered hearing the stone falling, and he ran to get out of the way. Then he remembers clearly a dull, crushing sensation in his ears, but nothing more until he came to himself in hospital twenty-four hours later. He did not remember falling to the ground after being struck, but the ground was soft, so that it is unlikely that he had a second injury while falling.

Accidental Head Injury: P.T.A.: One Hour, R.A.: Nil.

A. M. (MRC 876) was playing goal in a football match. He remembers diving at the feet of the opposing centre forward, and deflecting the ball. He then remembers seeing a boot coming towards his face, then a blinding flash, but has no memory of the impact. He came to himself in hospital over an hour later.

While cases of this type with no R.A. are common in gunshot wounds, they are, as has been shown, uncommon in accidental injuries. In the two

examples given above, however, it is noteworthy that the accidental injury was of the type which is likely to cause focal brain injury as they were due to a fast moving object striking the skull. They were in some ways, therefore, similar to the wounds caused by the high velocity missile.

Absence of R.A.—The absence of R.A. with definite P.T.A. in gunshot wound cases must be connected with the more focal type of injury. Certainly the immediate loss of memory after the wound occurs too quickly for it to be explained on a vascular basis, and these cases must be clearly distinguished from the delayed amnesias already referred to. Perhaps some diaschisis effect causes the disturbance of consciousness and, if so, the memory of the injury is registered and retained before the trans-neuronal shock effect spreads to prevent further remembering.

Shrinkage of R.A.—During the gradual recovery of consciousness, while there is still some confusion, the R.A. is often very long. This may be so marked that the patient gives the date as several years previously with a corresponding reduction in his age. For example a Polish airman, who crashed in 1941, when questioned three weeks later, was still confused and said it was 1936, and when asked about war with Germany replied "We are not ready yet."

A case previously described (Russell, 1935) was that of P. A. S. (P 234), a green-keeper, aged 22, who was thrown from his motor cycle in August, 1933. There was a bruise in the left frontal region and slight bleeding from the left ear, but no fracture was seen on X-ray examination. A week after the accident he was able to converse sensibly, and the nursing staff considered that he had fully recovered consciousness. When questioned, however, he said that the date was in February, 1942, and that he was a schoolboy. He had no recollection of five years spent in Australia, and two years in this country working on a golf course. Two weeks after the injury he remembered the five years spent in Australia, and remembered returning to this country; the past two years were, however, a complete blank as far as his memory was concerned. Three weeks after the injury he returned to the village where he had been working for two years. Everything looked strange, and he had no recollection of ever having been there before. He lost his way on more than one occasion. Still feeling a stranger to the district he returned to work; he was able to do his work satisfactorily, but had difficulty in remembering what he had actually done during the day. About ten weeks after the accident the events of the past two years were gradually recollectd and finally he was able to remember everything up to within a few minutes of the accident.

R.A. at First for Six Months—Shrinking to a Few Minutes.

P.T.A. Two Months.

GNR. J. W. T. (MRC 516) was injured in an air-raid on 28.11.40. When first seen he was deeply comatose with flaccid limbs. Recovery of consciousness was very slow, and he did not begin to talk until a month later. On 11.3.41 his mental state was still greatly retarded. The R.A. was for about six months, and he had

no recollection of three months in the Army. He now remembered coming to himself in hospital in January, 1941, when he found two women and a man sitting at his bed. These people told him they were his wife, mother and a close friend. He remembers arguing with them and saying he was not even married, and that he was certain he had never seen the man before. He was now correctly orientated, but was still very uncertain of the main facts concerning himself. He did all intelligence tests badly, and had difficulty in reading. He was very cheerful and friendly.

By 16.4.41, the R.A. had shrunk to a few minutes, and he remembers standing by the guns on the night he was injured, and that a few shells had been fired, but he does not remember any bombs; the P.T.A. was for about two months. He remained popular with the patients, but childish and slow in his movements with periods of irritability. He was invalided in May, 1941, and returned to light manual work in February, 1942. He found his right leg and arm "untrustworthy", and his relatives said he was forgetful and hesitated in his speech.

In one of this group of cases in which the patient, while still slightly confused but orientated, had a dense R.A. of about a year's duration, amytal was given in an attempt to recover the amnesia but without any improvement.

In these cases of slow shrinking R.A., the P.T.A. terminates long before the R.A. shrinks to its final duration. While the R.A. extends over many months or years the patient may, to careful testing, be slightly confused, but he has often recovered sufficiently to have continuous memory and to behave in a rational way.

During this period of shrinking amnesia the patient is unable to recall an important group of memories which, as later recovery shows, were well registered. The recovery occurs not in order of importance but in order of time. Long-past memories are the first to return, and the temporary blocking of relatively recent memory may be so marked that *several years of recent life may be entirely eliminated*. For a limited time the patient may re-live his childhood, a state of affairs reminiscent of the case of senile dementia.

During recovery the R.A. shrinks at a varying rate to a point where memory of subsequent events ceases abruptly. This usually leaves the duration of R.A. clearly indicated, but this can only be estimated accurately after full recovery of consciousness.

By the time the R.A. has shrunk to a few minutes or less the patient has usually fully recovered consciousness, and indeed a brief R.A. is often an accurate indication of mental normality.

Table V shows the increasing proportion of cases with a permanent long R.A. as the P.T.A. lengthens, though as has been mentioned the R.A. may be very short in severe injuries. In some cases this matter can be explained very simply, for in attempting to estimate the R.A. the

patient who has emerged from a long P.T.A. endeavours to remember events which occurred perhaps over a week previously. Many uninjured individuals are unable to describe what happened a week ago, unless there is some special experience to remind them.

Prolonged R.A.—This simple explanation does not, however, explain the long R.A. in many cases, especially those in which events of importance to the individual were forgotten. It has already been suggested that the common momentary R.A. is due to a physiological effect of the injury which blocks the retention of events seen or heard in the moments before the concussion. Some very different explanation is required for the relatively long R.A. which may be recorded in severe cases with a long P.T.A. In Table V, 14 per cent. of the cases with P.T.A. over seven days reported R.A. of over two days. These periods of R.A. are completely blank to the patient and often cover important events.

An example of important memories lost during an R.A. lasting several days is the following case kindly provided by Sir Charles Symonds:

FLIGHT-LIEUTENANT T., aged 31, was seen on February 7, 1936. Following a head injury when flying in 1934 he had been posted to ground duties which he had performed inefficiently, and was charged with being unable to account for stores to the value of £100. On examination he was orientated, voluble, facile and dysarthric. He could not retain more than six digits, showed three errors in repeating name, address and flower after five minutes, and failed in simple mental arithmetic. His face was expressionless with weakness of the left facial muscles. There were no other abnormal physical signs.

The head injury occurred in a crash on April 15, 1934, and there was a P.T.A. of twenty-one days. He came to himself in an eight-bedded ward which he describes in considerable detail, and has a consecutive memory of subsequent events. The story of his R.A. is as follows: The injury occurred on a Monday, and he had joined his unit eight days previously on a Sunday. He remembers arriving on the Sunday night and noticing that his room was of a different type from any he had slept in before. He has an isolated memory of firing at a ground target the following day, and of visiting a café sometime on that day, but has no recollection of the subsequent week. During this period he was on flying exercises of a kind he had not done before in an aircraft to which he was accustomed, doing several trips a day. He had studied his log book giving the details of these exercises over and over again in a fruitless attempt to recall the memory of these days. On May 21, 1927, he had had a head injury with a permanent R.A. of fifteen minutes and P.T.A. for three days followed by a headache for several days.

Islands in R.A.—It is clear that severe head injury may have a specific effect on very recently acquired memories, and this will be discussed later. A long R.A. with a P.T.A. of only twenty-four hours is very unusual, but the following case illustrates this:—

Case of R.A. with Islands for Over 24 Hours. P.T.A. 24 Hours. Investigation of R.A. Under Amytal Hypnosis Made Little Alteration.

CPL. G. W. (MRC 2039) was thrown from his horse on 20.7.41. He came to

himself twenty-four hours later, and his memory thereafter is quite clear. When examined on 22.8.41 his memory of events before the injury was normal up to the morning of the day before the injury (19.7.41). On this day, over twenty-four hours before the injury, he remembers reporting sick at about 9 a.m. with synovitis of the knee. He was excused duties, but remembers little more of that day—he does not even remember leaving the M.I. room. His wife came to meet him that evening, but he has no memory at all of her visit except that he remembers getting into a bus with her, to see her home, and later being at a station near where she was staying. For the day on which the accident occurred he has no memory except one island—he remembers tying up his horse at the gate where his wife was staying, going to the house and being told his wife was out. From 9 a.m. of the previous day, therefore, there was complete amnesia, except for three short islands. When he came to himself on 21.7.41 his first memory was of tying the horse to the gate.

Under the influence of sodium amytal he became sleepy, euphoric and talkative. Repeated attempts were made to reduce the R.A. and P.T.A. or to increase the islands in the R.A., but without success, except that one further island appeared—he now remembered leaving camp on the evening of 19.7.41, and walking with his friend, Bill, past some sentries.

He made a good recovery, and went to a Convalescent Depot on 2.10.31. Eighteen months later he was Category A, and was then serving efficiently in the Middle East.

In most cases of persistently long R.A. the P.T.A. has also been long. The following are typical examples:—

F/O P. S. G. (MRC 2) crashed on 13.11.39. He was demonstrating a low attack on troops which he had done twice, but on the third attack he hit a tree and his crew of one was killed.

When examined in March, 1940, the P.T.A. was for twenty-eight days. His last memory before the injury was meeting an officer on the way to Ipswich, where the flying was to be. This was two days before the injury, and he has no memory at all of what happened during these two days before the crash.

He made a remarkably good recovery, returned to duty in an administrative capacity, and resumed flying duties successfully in January, 1942. He reported that he was very fit in January, 1944.

2/Lt. E. N. W. D. (MRC 357) had a severe motor-cycle accident on 25.9.40. When examined on 23.11.40 the P.T.A. was complete for five days. About a week before the injury he remembers his unit taking up positions on the coast, and this was of course an exciting time with the prospect of invasion. However, his memory of the week before the injury is very vague. He has an indistinct memory of a demonstration and of one day's training a few days before the injury but otherwise his R.A. is dense for one week.

The injury caused some permanent intellectual impairment and personality disorder. He returned to duty, but found himself to be slow and easily muddled. There was permanent anosmia. He was, however, still in the Army in April, 1944, and his general health was satisfactory.

In these cases there is clear inability to recall important events which must previously have been well registered, retained and recalled before the injury. This type of amnesia is obviously different from the R.A. for events occurring a few moments only before an injury. When important events are obliterated from memory after head injury they are usually

for relatively recent happenings. Recent memories are therefore more vulnerable than those that are remote, but it is remarkable that recent memories for important events should be so completely obliterated from memory as they often are. This long R.A. differs from the memory disorders of organic dementias. In both conditions recent memories are lost, but in the traumatic cases the ability to recall events since the injury has recovered well.

In the case of permanent long R.A. the memory loss resembles that which, as has been mentioned, is often observed during recovery from traumatic confusion, before the R.A. has shrunk down to its final length. In both types of case the relative vulnerability of recent memory is very evident. The retention of recent memories is evidently less firmly established and may, as in these last cases, be abolished permanently by the physical effects on the cerebral neurones of a severe head injury.

Association of ideas may assist the reduction of R.A., as in the case of a soldier who, after recovering consciousness, had an R.A. of over an hour—his last memory was setting out on his journey driving a truck in the dark. Some months later at the cinema he was watching the picture of an aeroplane crashing with the appropriate sounds. The patient found this a very upsetting experience, and suddenly the noise brought back to his mind the noise he heard as his truck crashed.

This type of case bears a remarkable resemblance to the behaviour of a repressed complex, in that an experience which had been registered and retained was not recalled except through an association of ideas, and this experience caused an emotional response which was appropriate to the forgotten material.

EFFECT OF BARBITURATE HYPNOSIS ON R.A. AND P.T.A.

It is obviously important that the possibility of altering the duration of traumatic amnesia under barbiturate hypnosis should be fully investigated, not only to preclude an hysterical factor in certain cases, but to investigate the possibility of using this method to reduce a purely organic amnesia. One of us (P. N.) has investigated 40 cases recovering from head injury under barbiturate hypnosis.

Method.

On admission to hospital the patient's history was taken in the usual way, but special attention was paid to memory of events preceding, during and following the amnesic period. Within the next few days the patient was again interviewed, encouraged to relax and to attempt to describe all events preceding and following the injury. He was then given slowly an

intravenous injection of sodium pentothal during a period of two to three minutes, until having passed through the stage of yawning he was no longer able to react to commands nor could respond to being shaken (the maximum quantity given was 0.5 grammes). He was gradually encouraged to waken by calling his name or being ordered to rouse himself. Having recovered consciousness sufficiently he was repeatedly pressed to recount all he knew of his accident and of the incidents which preceded and followed it. This was continued until he was able to walk back to bed unaided. During the following days or weeks he would be questioned again from time to time. Where possible the evidence was obtained from witnesses in order to check events elicited from the patient.

Results.

From this investigation of 40 cases with barbiturate hypnosis it was quite evident that in the majority no reduction of amnesia could be obtained. Thus in 28 of the 40 cases investigated the R.A. and P.T.A. remained unchanged.

In the remaining 12 cases, however, some additional memory was recovered, though this was sometimes insignificant.

In 3 cases both the R.A. and P.T.A. were reduced.

- L/Cpl. S. R.A. reduced from a few seconds to a moment.
P.T.A. reduced from five hours to one hour.
(Hypnosis two months after injury.)
- Cpl. B. R.A. reduced from two hours to a moment.
P.T.A. reduced from eighty-six hours to seventy hours.
(Hypnosis seven weeks after injury.)

In 3 cases the R.A. only was reduced while the P.T.A. was unaffected.

- L/Cpl. L. R.A. reduced from half an hour to nil.
P.T.A. reduced from forty-eight hours to nil.
(Hypnosis four weeks after injury.)
- Cpl. S. R.A. reduced from sixty-five minutes to three minutes.
P.T.A. fifty-two hours—unchanged.
(Hypnosis five weeks after injury.)
- Sgt. B. R.A. reduced from twenty minutes to a moment.
P.T.A. ninety-six hours—unchanged except for an island recovered in the partial amnesic period.
(Hypnosis five weeks after injury.)
- Sgt. J. R.A. reduced from seven hours to half an hour.
P.T.A. sixteen hours—no change.
(Hypnosis four weeks after injury.)

In 2 cases the P.T.A. was reduced while the R.A. showed no change.

- Dvr. E. R.A. half an hour—unchanged.
P.T.A. two days reduced by a few minutes only.
(Hypnosis three weeks after injury.)

In 4 cases the R.A. and P.T.A. were unchanged, but islands of memory during the amnesic period were recovered.

- Spr. C. R.A. momentary—unchanged.
P.T.A. one hour reduced to half an hour.
(Hypnosis six weeks after injury.)
- Cadet P. R.A. a few seconds—unchanged.
P.T.A. forty-eight hours—unchanged, but two brief islands of memory recovered.
(Hypnosis three weeks after injury.)
- Gdm. McN. R.A. about five seconds—unchanged.
P.T.A. fourteen days—unchanged, but several vague and brief islands of memory recovered.
(Hypnosis three months after injury.)
- Fus. K. R.A. seven minutes—unchanged.
P.T.A. three weeks—unchanged, but a few islands of memory recovered.
(Hypnosis five months after injury.)
- Dvr. S. R.A. twelve hours—unchanged.
P.T.A. eleven days—unchanged, but a few islands of memory recovered for the latter part of the amnesic period.
(Hypnosis six weeks after injury.)

Analysis of the material recovered under pentothal showed nothing in this material to warrant hysterical repression, and indeed the constancy with which the recovered material borders the fringes of the amnesic period makes it seem probable that the memories recovered were only incompletely abolished. They were recorded, but could not be recalled without a special stimulus applied by questioning during hypnosis. The examiner naturally stimulates the association of ideas, and the spontaneous recovery of forgotten items by a later experience has already been described.

These investigations under barbiturate hypnosis therefore provide confirmation of the view that both the R.A. and P.T.A. in most cases is the result of physical effect of injury on brain neurones.

Hysterical R.A.—Cases are described from time to time in fiction in which there is a permanent R.A. for a large part of the whole of previous life. This may be observed during the stages of recovery before confusion is fully resolved, but we have never observed an R.A. to extend over many months permanently except in hysteria or gross traumatic dementia.

TRAUMATIC AMNESIA AND TRAUMATIC INTELLECTUAL IMPAIRMENT.

In cases in which the P.T.A. exceeds seven days some loss of intellectual capacity is a common permanent disability. In these cases the general blunting of memory may contribute slightly to the loss of memory of

events before the injury. In considering a general traumatic impairment of memory one is presumably studying the same cerebral mechanism which is disturbed so grossly during the period of R.A. and P.T.A., and it is noteworthy that trauma sufficient to cause a long R.A. and long P.T.A. will also, in many instances, lead to a permanent impairment of the faculty of remembering.

SUMMARY AND DISCUSSION.

It is naturally important to discuss the significance of the phenomena described above in so far as they may throw light on cerebral mechanisms. In the first place it is clear that traumatic loss of consciousness prevents remembering, and that this inability to remember events persists in most cases until full consciousness has returned. In other words, the recovery of continuous remembering coincides with a late, if not a last, stage in recovering consciousness.

It may also be affirmed that a single blow of varying severity can disturb remembering, as it does consciousness, for very varying periods of time, and that the duration of this period depends usually on the severity of the initial neuronal commotion.

The almost constant occurrence of R.A. indicates that the injury, though it cannot have time to prevent what is last seen or heard from reaching the sensorium, does completely prevent its retention for future recall. The latter process presumably requires a few seconds of time for completion.

The occasional occurrence of a vision of events within the R.A. indicates that in these cases some form of registration has occurred with great vividness which, though it can never be properly retained for later recall, can reproduce itself from a relatively low level in the form of a momentary "vision." This appears to be a striking illustration of different levels of activity in the Hughings Jackson sense. The injury in such a case appears to have blocked the process of retention half-way.

The variations in the R.A. during recovery of full consciousness seem to be specially significant. Distant memories return first and loss of memories for the previous few years may, for a time, be so complete that the patient believes himself to be several years younger. After severe injuries there may be a permanent R.A. of several days' duration which may include events of great importance to the patient.

General brain trauma therefore has an effect on *recent* memory which is much greater than its effect on remote memory, and this fact must be

closely linked with the physiology of remembering. It is clear that the events forgotten are often of importance to the individual, yet for a time, and sometimes permanently, they are completely erased, while distant memories of little importance are returning freely.

The recovery of this type of memory loss is by shrinkage towards the present time. The long amnesic period recovers not so much according to the relative importance of events forgotten as according to the time before the injury that the events occurred. There is thus a vulnerability of memories which depends directly on their nearness to the injury.

We are thus forced to the conclusion that as memories become older they become more strongly established irrespective of their importance to the individual, while recent memories are relatively liable to traumatic extinction, however important they may be.

Further it is clear that a long R.A. is almost always associated with a long P.T.A. We have good evidence that a long P.T.A. usually means a very severe injury, hence a long R.A. is observed when severe general neuronal commotion has occurred. It can thus be concluded that a long R.A., whether temporary or permanent, occurs after severe neuronal commotion, and that severe neuronal commotion has a much more damaging effect on erasing recent than remote memories.

In the cases with long R.A. which recover spontaneously it is evident that the effect of this neuronal commotion is reversible, but in some cases the effect is permanent.

In either case the observation demands a physiological explanation. It seems likely that memory of events is not a static process. If it were, then distant memories would surely fade gradually and would be the more vulnerable to the effects of injury. On the contrary, when the brain is injured, these distant memories are the least vulnerable. It seems that the mere existence of the brain as a functioning organ must strengthen the roots of distant memories. The normal activity of the brain must steadily strengthen distant memories so that with the passage of time these become less vulnerable to the effects of head injury.

The patient with senile dementia may show a very similar loss of recent memory. She may forget the visit of her favourite grandchild within twenty minutes, yet she remembers an unimportant escapade of fifty years before in every detail. The distant memory shows no sign of fading and this suggests that it has received continual reinforcement and has survived not because it was important but because the brain throughout the decades has strengthened it automatically till it has become highly resistant to cerebral degeneration.

It is tempting to speculate on the possible physiological processes concerned in remembering which could behave in this way. The brain works through chains and circuits of neurones which can set a pattern for automatic responses of infinite variety. Presumably the synapses of such a chain pattern are "opened" to allow the least possible delay and to avoid diversions in other directions. The neuronal system concerned with a certain memory, if it is to behave with the passing of years in the way it does, must then be automatically strengthened or more strongly canalized by the normal activity of the brain, and perhaps indeed this facilitation of the circuit is carried out by the spontaneous rhythm of the neurones concerned.

The recall under barbiturate hypnosis, or occasionally in the state of traumatic confusion, of events which cannot be remembered in the normal state of consciousness is of considerable interest. It seems as if under certain conditions clinically manifest as clouded consciousness, and physiologically determined by impairment of function at Jackson's highest level, pathological recall may occur as a release phenomenon. The twilight states of dreaming and toxic or infective delirium are analogous, and in these also there may be recall of experience not available in the state of clear consciousness.

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