Kobe J. Med. Sci., Vol. 51, No. 6, pp. 95-105, 2005

Assessment of Traumatic Brain Injury Patients by WAIS-R, P300, and Performance on Oddball Task

YASUO NAITO [1], HIROSHI ANDO [1], and MICHIO YAMAGUCHI [2]

[1] *Kobe University Graduate School of Medicine, Faculty of Health Sciences*

[2] *Yamaguchi Clinic, Nishinomiya, Hyogo, Japan*

Received 29 September 2005/ Accepted 6 January 2006

Key words: TBI, ERP, WAIS-R, behavioral indices, the number of omission errors

The present research investigates factors that prevent traumatic brain injury patients from returning to work. Participants included 40 patients and 40 healthy individuals. Participants' intelligence quotients and the P300 component of event-related potentials elicited during an auditory oddball task were compared. The patients' mean intelligence quotient was significantly lower than that of the control group. However, some patients had normative intelligence, suggesting that the WAIS-R test results could not fully explain their inability to return to work. The peak of the P300 component could not be determined from recordings of 9 patients. When compared to the control group, the mean latency and amplitude for the remaining 31 patients were significantly longer and smaller, respectively. The mean reaction time of the patients was significantly longer than that of the controls. Omission errors were significantly more frequent in the patient group than among controls, suggesting that the patients were suffering from deficits in the allocation and maintenance of attention. Based on the number of omission errors, patients were divided into a group comprising individuals who committed fewer than two omissions (n=26) and a group comprised of individuals who committed more than three omissions (n=14). The frequent omission errors observed among individuals in the latter group may indicate their inability to sustain an adequate level of vigilance. This deficit would be a factor preventing the patients' return to work.

A variety of short- and long-term cognitive impairments are frequent consequences of traumatic brain injury (TBI). Even after recovering from the acute stage of injury, victims of TBI often demonstrate a wide range of cognitive dysfunction. Returning to work after TBI is a weighty consideration for most TBI victims. Often they return to work too soon because they have not received any advice about the difficulties they may encounter, or because they ignore such advice. Therefore, one of the most discouraging consequences of TBI may be unemployment.

Deficits in attention and concentration, and the impairment of problem solving, judgment, and reasoning can all detrimentally affect the injured worker's ability to perform his or her job. To assess these deficits induced by brain injury, several neuropsychological approaches have been employed (23,25,30). Among them, the Wechsler Adult Intelligence Scale-Revised (WAIS-R) (33) is frequently used. The WAIS-R consists of 11 subtests. From these subtests, total intelligence quotient (TIQ), verbal IQ (VIQ) and performance IQ (PIQ) scores are obtained; furthermore, variables such as "abstract reasoning", "social comprehension", and "remote memory" may also be obtained by re-grouping the subtests. In general, the PIQ scores of TBI victims are often more depressed than the VIQ scores;

Phone: +81-722-50-2111 Fax: +81-722-50-2129 E-mail: naitoh@rehab.osakafu-u.ac.jp

however, the differences are small and some contradictory observations have been made (18).

IQ scores are also related to the ability to return to work or school (8,14). In particular, PIQ scores have emerged as a significant predictor of return to work or school. Watanabe et al. (32) reported that TBI patients with PIQ scores of 85 or higher were more likely to return to work than those with PIQ scores of less than 85. For example, a TBI patient with a PIQ score of more than 100 is predicted to have a 68 % chance of returning to work, with the remaining 32 % indicating the unlikelihood of returning to work (8). In reality, some TBI patients with PIQ scores over 100 and almost intact expressive language skills have been observed to have difficulty returning to work. In such patients, deficits in some higher brain functions may have been camouflaged by their almost intact expressive language skills (2).

For the assessment of employability, therefore, some methods other than the WAIS-R are desired. As a physiological measure of cognitive and attentional function, the P300 component of event-related potential (ERP) is appealing, since it may shed light on behaviorally non-observable underlying processes. The P300 component does not require the subject to produce overt responses, and it is less affected by motivational state than behavioral measures (25,28,29). Typically, to elicit the P300 response, 'oddball' tasks are used wherein two types of stimuli are presented with unequal frequency, and the participant is asked to attend or respond to the infrequent one. The component is considered to be a manifestation of central nervous system activity when attention is engaged to update memory representations (6,7,25). The P300 component was reported to indicate information processing speeds, attentional capacity, and attention (11). Several studies have shown that severe TBI patients have prolonged P300 latency (15,21). In contrast, a study by Paratap-Chand et al. (22), showed that P300 latency was not correlated with the severity of brain damage.

Several studies have concomitantly used neuropsychological and electrophysiological methods. For example, the P300 latency obtained using an auditory oddball task was negatively correlated with the TIQ, VIQ and PIQ values of normal individuals (19), as well as scores on some subscales of the WAIS-R (16). Potter (26) reported attentional deficits in mild head injury patients using neuropsychological and electrophysiological methods. In TBI patients, however, the latency of P300 was not found to be correlated with WAIS-R scores (3).

In our previous studies on TBI patients, we observed some subjects who had difficulty performing the oddball task during ERP recordings (20). These patients missed responding to some target stimuli (omission error). Potgieter et al. (27) reported similar omission errors. Specifically, very low birth weight children with attentional dysfunction tended to have frequent omission errors during the oddball task. Thus, the number of omission errors can be used as an index of attentional dysfunction. To our knowledge, no previous reports have been conducted on the number of omission errors in TBI patients. That is probably because TBI patients commit too many omission errors, making ERP measurement impossible; thus, such subjects would have been excluded from the study.

Therefore, to investigate factors that prevent TBI subjects from returning to work, we examined TBI victims' WAIS-R IQ scores, WAIS-R subscales, performance on an oddball task (number of omission errors, reaction time), and electrophysiological responses (P300 component).

MATERIALS AND METHODS

Research Participants

Traumatic Brain Injury (TBI) Group

Participants were 40 moderate to severe TBI patients (38 males and 2 females) who were residing at their home after discharge from hospital. Patients' mean age and mean length of education were 48.3±13.6 years and 10.9±2.5 years, respectively. All subjects were injured in either traffic accidents or industrial accidents and had difficulty returning to their original work. Among the 40 TBI patients, 29 cases had diffuse axonal injury (DAI), 7 cases had focal injury, 2 cases had acute epidural hematoma with DAI, and 1 case had acute subdural hematoma with DAI. Diagnosis of DAI was made according to Gennarelli's criteria (12).

All participants were recruited following their workers' compensation adjudication, in which each was evaluated as possessing approximately 50 % of a normal individual's work ability. Patients were excluded if they had experienced any neurologic deficits before their accident. The hearing ability of all participants showed no impairment when their speech was checked during an interview.

Normal Control Group

The normal control group comprised 40 normal participants (38 males and 2 females) with a mean age and mean length of education of 50.9±4.2 years and 11.9±1.9 years, respectively. No significant differences in mean age and mean length of education were observed between the control and TBI groups. All normal subjects were employed in an ordinary corporation and had no history of neurologic disease.

All participants gave informed consent to participate in the present study.

PROCEDURE

P300s

EEGs were recorded using silver electrodes referenced to linked ears from Fz, Cz, and Pz, according to the international 10-20 system of electrode placement. EEGs were amplified and digitized at a sampling frequency of 250 Hz. An auditory oddball paradigm was used to elicit the P300 component of ERP. Each participant was presented with a pseudo-random sequence of two distinguishable stimuli; 1000 Hz tone bursts (80 %) and a 2000 Hz tone (target tone, 20 %). Stimuli were delivered binaurally through earphones at random intervals ranging from 1300 to 1700 ms. Subjects were instructed to press a button when the target tone was given. Target stimuli were presented 50 times. Before beginning the ERP recordings, several trial stimuli were presented to subjects in order to confirm their understanding of the instructions. Evoked potentials were averaged using a personal computer (SONY, Japan). The peak of the P300 component was identified as the maximum positive deflection in the time window between 280 and 550 ms.

Reaction time to the target 2000 Hz tone was also recorded. If the subject did not press the button before 900 ms after the onset of the target stimulus, the trial was regarded as an omission error.

WAIS-R

The Japanese version of the WAIS-R (33) was administered in a quiet room for the assessment of current intellectual abilities. In addition to TIQ values, the VIQ, PIQ, and all subtest values were collected and analyzed.

RESULTS

WAIS-R IQ scores

Mean WAIS-R scores were calculated for the control and TBI groups and are summarized in Table 1. Analysis of the TIQ, VIQ, and PIQ data disclosed highly significant difference on each test (Mann-Whitney U-test; $p<0.01$). For the TBI group, the mean score was approximately 85, while for the control group the mean was 100. According to the WAIS-R normative data, the mean and standard deviation (SD) of the TIQ, VIQ, and PIQ scores are 100 and 15, respectively. These findings indicate that our selection of individuals for the normal group was adequate and that the mean scores for the TBI patients were approximately one SD lower than those of the controls. However, it should be noted that the scores for some TBI patients were more than 100.

Performance on the oddball task (Number of omission errors)

Of the 40 control subjects, 38 committed no omission error and 2 subjects committed only one omission error. In contrast, although all of TBI patients understood the instructions and had completed the practice task when they received the oddball task instructions, 14 TBI patients omitted pressing the button more than three times. Omission errors were significantly more frequent in the TBI group than in the control group (Mann-Whitney U-test; $p<0.001$).

Table 1: Control group and TBI group scores on the TIQ, PIQ, and VIQ of the WAIS-R.

	Control (n = 40)		TBI (n = 40)		
	mean ± SD	range	mean ± SD	range	
WAIS-R TIQ	100.5 ± 14.2	70 - 134	83.4 ± 18.9	43 - 121	p< 0.01
WAIS-R VIQ	101.4 ± 15.0	70 - 140	87.3 ± 17.7	54 - 129	p< 0.01
WAIS-R PIQ	98.8 ± 13.2	71 - 133	81.7 ± 18.0	45 - 119	p< 0.01

Waveform of P300

Figure 1 shows the grand average (thick line) and individual ERP waveforms of control subjects and TBI patients. In all recordings, the peak of N100 could be identified as the maximum negative (upward) deflection in the time window between 70 and 140 ms after the stimulus onset. The presence of N100 indicates that all subjects “heard” the auditory stimulus.

The P300 component is usually identified as the largest positive (downward) deflection in the time window between 280 and 550 ms. For all control subjects, the peak of P300 was easily determined. However, the peak of P300 could not be determined from the recordings of 9 patients, because a prominent positive deflection was not present in the time window between 280 and 550 ms. Figure 2 shows the grand average and individual ERPs of these 9 patients. TIQ scores and the number of omission errors are also indicated in the figure.

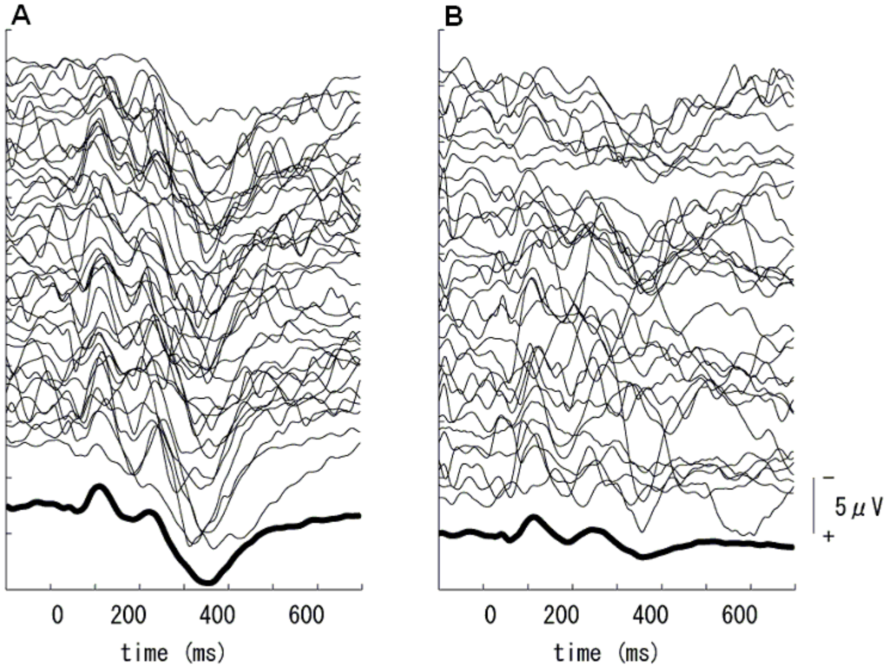

Figure 1: Grand average (thick line) and individual ERP waveforms recorded at Cz.
(A): Normal subjects. N100 and P300 peaks are always identifiable
(B): TBI subjects. Every N100 peak is clearly identified; but some P300 peaks are not clear (see Figure 2).

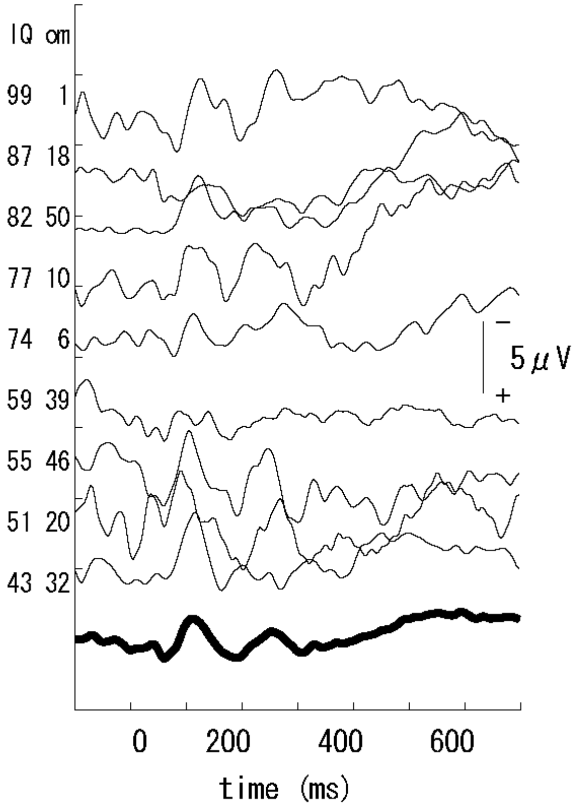

Figure 2: ERP waveforms of TBI patients lacking clear P300 peaks.
Grand average (thick line) and individual ERP waveforms recorded at Cz are shown with scores of TIQ and the number of omission errors (om).

Amplitude and latency of P300

After excluding the 9 recordings with unclear P300 components, peak amplitude and peak latency of the P300 component were measured from each recording (Table 2). The mean amplitude and mean latency of P300 for the 31 TBI patients were both significantly larger and longer than those of normal subjects (t-test; $p<0.05$, t-test; $p<0.001$, respectively).

Reaction time

The reaction times of successful responses to the target stimuli were recorded. When the subject did not press the button within 900 ms of the onset of the target stimulus, the trial was regarded as an omission error and was excluded. The mean and range of the reaction times are shown in Table 2. The TBI patients' mean reaction time was significantly longer than that of the control subjects (t-test; $p<0.001$) (Table 2).

Relationship between TIQ scores and P300 indices in TBI patients

The correlations between TIQ score and P300 amplitude, latency, reaction time, and number of omission errors are shown in Figure 3. There was moderate, negative, and significant correlation between TIQ and number of omission errors (Pearson regression analysis; -0.40, $p<0.01$). No significant correlations were observed between TIQ scores and mean amplitude, latency, and reaction time.

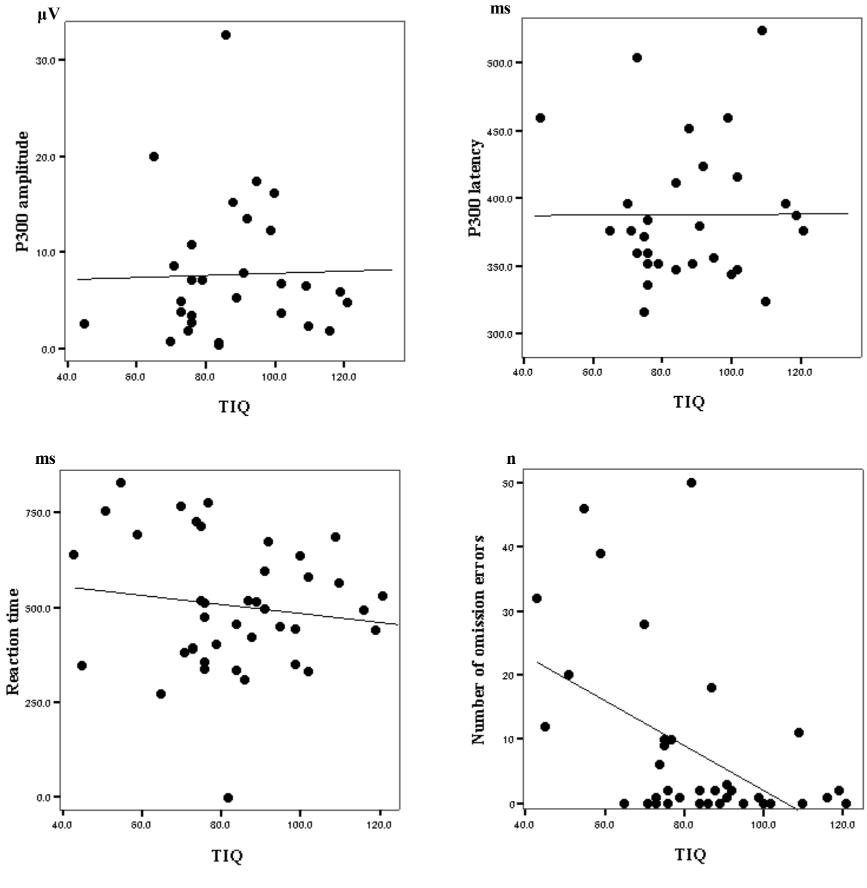

Figure 3: Correlations between TIQ scores and P300 amplitude, latency, reaction time, and number of omission errors among TBI patients. A significant ($p<0.01$) correlation was observed between TIQ score and number of omission errors.

Table 2: Amplitude and latency of the P300 component, and reaction time (RT) to target stimuli. For the analysis of amplitude and latency, 9 TBI cases were excluded from analysis because a clear P300 peak was not observed.

		Control	TBI	
amplitude	**n**	**40**	**31**	
	mean ± SD	**12.0 ± 6.7**	**7.7 ± 7.0**	**p< 0.05**
	range	**0.4 - 32.6**	**1.7 - 29.7**	
latency	**n**	**40**	**31**	
	mean ± SD	**351.5 ± 27.2**	**399.0 ± 77.2**	**p< 0.001**
	range	**292 - 424**	**316 - 708**	
reaction time	**n**	**40**	**40**	
	mean ± SD	**306.4 ± 51.4**	**472.5 ± 156.5**	**p< 0.001**
	range	**134.0 - 845.0**	**143.8 - 897.5**	

Subgroups of TBI patients

Based on the number of omission errors, TBI patients were divided into two groups. The TBI-I group (n=26) comprised individuals who committed fewer than two omission errors, while the TBI-II (n=14) group comprised all other participants. As described above, the peak of the P300 response could not be determined for 9 TBI patients. Of these 9 TBI patients, only one patient belonged to the TBI-I group (Table 3). The remaining 8 TBI patients comprised more than half (8/14) of the TBI-II patients. Thus, significantly more TBI patients whose peak P300 could not be determined were included in the TBI-II group (Fisher's exact test; $p<0.01$).

Table 3: Presence of clear P300 peaks in the TBI-I and II groups.

Clear P300-Peaks	TBI-I	TBI-II	Total
present	**25**	**6**	**31**
absent	**1**	**8**	**9**
Total	**26**	**14**	**40**

WAIS-R scores and subscales among participants in the TBI-I and TBI-II groups

Mean scores on the TIQ, VIQ, and PIQ subscales of the WAIS-R are summarized in Table 4. Mean TIQ, VIQ, and PIQ scores for the TBI-I group were significantly higher than those for the TBI-II group (Mann-Whitney U-test; $p<0.01$).

Among the WAIS-R subtests, significant differences were observed for digit span, similarities, picture completion, block design, digit symbol (Mann-Whitney U-test; $p<0.01$), comprehension, and object assembly scores (Mann-Whitney U-test; $p<0.05$). Mean scores for information, vocabulary, arithmetic, and picture arrangement were not significantly different.

Table 4: WAIS-R subscale scores and IQ scores among the TBI-I and II groups. Results were compared using the Mann-Whitney U-test.

	TBI-I		TBI-II		
	Range	average	Range	average	
Information	3 - 13	7.54 ± 3.20	4 - 11	6.21 ± 2.19.	n.s.
Digit Span	5 - 15	9.62 ± 2.64	1 - 11	5.43 ± 3.23	**
Vocabulary	4 - 16	9.00 ± 3.16	3 - 12	7.50 ± 2.85	n.s.
Arithmetic	3 - 17	8.35 ± 3.41	3 - 10	6.29 ± 2.02	n.s.
Comprehension	2 - 16	9.04 ± 3.63	2 - 11	6.36 ± 2.87	*
Similarities	5 - 15	9.38 ± 3.24	2 - 14	6.07 ± 3.71	**
Picture Completion	2 - 15	9.12 ± 2.85	1 - 12	4.57 ± 3.37	**
Picture Arrangement	4 - 13	8.08 ± 3.06	1 - 12	6.00 ± 3.40	n.s.
Block Design	3 - 16	9.31 ± 3.10	1 - 16	5.93 ± 4.34	**
Object Assembly	4 - 13	7.73 ± 2.47	1 - 13	5.36 ± 3.93	*
Digit Symbol	1 - 15	7.35 ± 3.72	1 - 12	4.36 ± 2.92	**
TIQ	65 - 121	90.08 ± 15.52	43 - 109	70.93 ± 18.73	**
VIQ	63 - 129	93.12 ± 16.24	54 - 99	76.36 ± 15.33	**
PIQ	58 - 110	87.59 ± 13.72	45 - 119	70.08 ± 20.48	**

**: $p < 0.01$
* : $p < 0.05$
n.s.: not significant

DISCUSSION

To investigate factors that prevent TBI patients from returning to work, we examined neuropsychological (WAIS-R), electrophysiological (P300), and behavioral (reaction time and number of omission errors) indices. Mean TIQ (83.4), VIQ (87.3), and PIQ (81.7) scores for the TBI group were significantly lower than those for the control group. These findings are consistent with previous studies (24). Indeed, the mean IQ of the TBI patients was low. However, some patients had IQ scores higher than 100, and were unable to return to work. This finding indicates that the WAIS-R test alone might not be able to distinguish patients who have trouble returning to work. Thus, we recorded the P300 component of ERP, which evaluates the brain function of TBI patients from another perspective. As shown in Figure 3, no significant correlations were observed between TIQ and P300 amplitude, latency or reaction time. These observations suggest that these indices reflect the brain function of TBI patients from a different perspective.

The P300 component is considered to be a manifestation of central nervous system activity when attention is engaged to update memory representations (9,10,25). From all recordings of control subjects, including some individuals with TIQ scores of approximately 70, the peak of P300 could be identified. However, in recordings of nine TBI subjects, a clear P300 peak was not present. Excluding their responses, the mean peak latency (399 ms) of TBI subjects was significantly longer than that of the control group and the mean amplitude was significantly smaller than that of the control group. Gaetz et al. (11) reported that ERPs tend to be associated with the cognitive processing that occurs in distributed cortical and subcortical networks. The latency of P300 has been suggested to indicate an upper limit on categorization and stimulus evaluation time (4), or the time taken to allocate resources and engage memory updating. Furthermore, reduced amplitude and the absence of a clear P300 peak are suggested to be a manifestation of damaged central nervous system activity (5,17).

In the present study, the mean reaction time of the TBI patients was significantly slower than that of the controls. Segalowitz et al. (31) demonstrated that reaction time reflects the ability of TBI patients to allocate attention. The slow reaction time of the TBI patients in the present study indicates that they could not sustain sufficient arousal and attention during the performance of the oddball task. The slow reaction time of the TBI patients also implies reduced information processing speed and capacity (13).

Omission errors were significantly more frequent in the TBI group than in the control group. The increased number of omission errors and slower reaction times have been suggested to be the result of an inability to sustain an adequate level of vigilance over time (1,34). Based on the number of omission errors, the TBI patients were divided into two groups. The frequent omission errors and prolonged reaction time of the TBI-II group suggest that their ability to sustain an adequate level of vigilance was more severely damaged than in the TBI-I group. A clear P300 peak was absent in more than half (8/14) of the TBI-II patients, which may also suggest a more rapid fall in the vigilance level among TBI-II patients in comparison with TBI-I subjects during the oddball task. Therefore, even when a clear P300 peak was absent and no information was obtained from recorded waveforms, the reduction of the level of vigilance could be confirmed by the longer reaction time and higher rate of omission errors.

To our knowledge, no reports have been published regarding TBI patients' inability to sustain an adequate level of vigilance. All patients in the TBI-II group could complete all sections of the WAIS-R and some subjects scored more than 100. This suggests that the WAIS-R is not sensitive enough to detect the inability to sustain attention. Since the WAIS-R test was conducted under continuous supervision and dialogue with the examiner, the subjects had no opportunity to lose vigilance. In contrast, once the P300 recordings had begun, the auditory discrimination task was conducted without intervention by the examiner. For this reason, some TBI subjects may have lost their vigilance and committed errors of omission. This deficiency, which was revealed through P300 measurement during the oddball task, might have prevented them from returning to work. Therefore, we recommend using both neuropsychological (WAIS-R) and electrophysiological methods (P300) to assess the possibility of TBI patients returning to work.

ACKNOWLEDGEMENTS

We would like to thank all the individuals who participated in the present study. This work was supported in part by funds provided as a grant for medical research on traffic accidents by the General Insurance Association of Japan.

REFERENCES

1. **Arcia, E., C. T. Gualtieri.** 1994. Neurobehavioural performance of adults with closed head injury, adults with attention deficit, and controls. Brain Injury **8**: 395-404.
2. **Ashley, M. J., J. Ninomiya, and A. Berryman, et al.** 2004. Vocational Rehabilitation, p.509-538. In Ashley M.J. (ed.). Traumatic Brain Injury: rehabilitative treatment and case management. CRC press, Boca Raton.
3. **Baguley, I. J., K. L. Felmingham, S. Lahz, E. Gordan, I. Lazzaro, and D.E. Schotte.** 1997. Alcohol abuse traumatic brain injury: Effect on Event-Related Potentials. Arch. Physical Medicine Rehabilitation **78**: 1248-1253.
4. **Coles, M. G. H., H. G. O. M. Smid, and M. K. Scheffers, et al.** 1995. Mental chronometry and the study of human information processing. In Rugg MD,

Electrophysiology of Mind. Coles M.G.H. (ed.). Oxford University Press, New York.
5. **Curry, S. H.** 1980. Event-related potentials as indicants of structural and functional damage in closed head injury. Progress In Brain Research **54**: 507-515.
6. **Donchin, E.** 1981. Surprise!. surprise. Psychophysiology **18**: 493-513.
7. **Donchin, E., M. Coles.** 1988. Is the P300 component a manifestation of context updating. Brain Behavioral Science **11**: 357-374.
8. **Dornan, J., C. Schentag.** 1995. Traumatic brain injury: factors predicting return to work or school. Brain Injury **9(5)**: 517-532.
9. **Fabiani, M., D. Friedman, and J. C. Cheng.** 1998. Individual differences in P3 scalp distribution in older adults, and their relationship to frontal lobe function. Psychophysiology **35**: 698-708.
10. **Fjell, A. M., K. B. Walhovd.** 2001. P300 and neuropsychological tests as measures of aging: scalp topography and cognitive changes. Brain Topography **14**: 25-40.
11. **Gaetz, M., D. M. Bernstein.** 2001. The current status of erectrophysiologic procedures for the assessment of mild traumatic brain injury. J Head Trauma Rehabilitation **16(4)**: 386-405.
12. **Gennarelli. T. A.** 1984. Emergency department management of head injuries. Emergency Medicine Clinical North America **2**: 749-760.
13. **Gentilini, M., P. Nicheli, and R. Schoenhuber.** 1989. Assessment attention in mild head injury, p. 163-175. Mild Head Injury. In Levin H. S., Eisenberg H. M., Benton A. L. (ed.), Oxford University Press, New York.
14. **Goran, D. A., R. J. Fabiano, and N. Crewe.** 1997. Employment Following Severe Traumatic Brain Injury: The Utility of the Individual Ability Profile System (IAP). Archives of Clinical Neuropsychology **12(7)**: 691-698.
15. **Haglund, Y., H. E. Persson.** 1990. Does Swedish armature boxing lead to chronic brain damage?. Acta neurol Scand **82**: 353-360.
16. **Jausovec, N., K. Jausovec.** 2000. Correlation between ERP parameters and intelligence: reconsideration. Biological Psychology **50**:137-154.
17. **Keren, O., S. Ben-Dror, M. J. Stern, G. Goldberg, Z. Groswasser.** 1998. Event-related potentials as an index of cognitive function during recovery from severe closed head injury. J Head Trauma Rehabilitation **13(3)**: 15-30.
18. **Kraiuhin, C., E. A. Shores, C. Roberts.** 1996. Sensitivity of the WAIS-R Verbal-Performance IQ difference and intersubtest scatter to traumatic brain injury. Brain Injury **10(9)**: 677-685.
19. **Kristine, B., W. Anders, and Fjell. M.** 2002. The relationship between P3 and neuropsychological function in an adult life span sample. Biological Psychology **62**: 65-87.
20. **Naito. Y., H. Ando, and M. Yamaguchi.** 2003. Assessment of severe traumatic brain injury patients by WAIS-R and P300 of event related potentials. Japanese J Of Occupational Medicine and Traumatology (in Japanese) **51(6)**: 398- 404.
21. **Papanicolaou, A.C., H.S. Levin, H.M. Eisenberg, B.D. Moore, K.E. Goethe, and W.M.Jr. High.** 1984. Evoked potential correlates of posttraumatic amnesia after close head injury. Neurosurgery **14**: 676-678.
22. **Paratap-Chand, R., M. Sinniah, and E. Salem.** 1988. Cognitive evoked potential (P300): A metric for cereberal concussion. Acta Neurol Scand **78**: 185-189.
23. **Park, D. C.** 2000. The basic mechanisms accounting for age-related decline in cognitive function. In Park, D. (ed.), Schwarz, N., Cognitive Aging: a Primer. Philadelphia, Psychology Press,

24. **Parker, R. S., A. Rosenblum.** 1996. IQ loss and emotional dysfunctions after mild head injury incurred in a motor vehicle accident. J Clinical Psychology **52(1)**: 32-43
25. **Polich, J.** 1996. Meta-analysis of P300 normative aging studies. Psychophysiology **33**: 334-353.
26. **Potter, D. D., K. Barrett.** 1999. Assessment of mild head injury with ERPs and neuropsychological tasks. J of Psychophysiology **13**: 173-189.
27. **Potgieter, S., J. Vervisch, and L. Lagae.** 2003. Event related during attention tasks in VLBW children with and with out attention deficit disorder. Clinical Neurophysiology **114**: 1841-1849.
28. **Reinvang, I.** 1998. Validation of reaction time in continuous performance tasks as an index of attention by electrophysiological measures. J Of Clinical and Experimental Neuropsychology **20**: 885-897.
29. **Reinvang, I.** 1999. Cognitive event-related potentials in neuropsychological assessment. Neuropsychological Review **9**: 231-248.
30. **Salthouse, T. A.** 2000. Aging and measures of processing speed. Biological Psychology **54**: 35-54.
31. **Segalowitz, S. J., J. Dywan, and A. Unsal.** 1997. Attentional factor in response time variability after traumatic brain injury: An ERP study. J of The International Neuropsychological Society **3**: 95-107.
32. **Watanabe, S. et al.** 1996. Neuropsychological Evaluation in Severe Traumatic Brain Injury. Japanese J Rehabilitation Medicine (in Japanese) **33**: 316-321.
33. **Wechsler D**, 1990. Wechsler Adult Intelligence Scale-Revised Japanese version.
34. **Whyte. J., M. Polansky, M. Fleming, B. Coslett, and C. Cavallucci.** 1995. Sustainedarousal and attention after traumatic brain injury. Neuropsychologia **33**: 797-813.