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Information processing deficits and brain injury: preliminary results

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Abstract

Information processing deficits are often reported in individuals who have sustained a brain injury. These deficits interfere with the patient's rehabilitation progress because of the brain's inability to efficiently process information. This article describes specific aspects of information processing (i.e. etiology, assessment, rehabilitation). A systematic treatment approach is further discussed using both a controlled group study and a single case design. The results, while tentative, suggest that a systematic approach toward the rehabilitation of information processing deficits was as qualitatively effective, and likely more cost-effective than traditional approaches.

Keywords: Information processing; Brain injury; Rehabilitation; Metacognition

1. Introduction

Information processing is a generalized term that incorporates those functions that enable the brain to deal effectively and efficiently with sensory and other information that constantly enters the system. A distinction is commonly made between automatic and deliberate processing [1,2]. After brain injury it is usually the deliberate, effortful aspects of processing that present the major problems [3]. There are two basic dimensions which underlie deliberate processing: capacity/speed [4], and control. The former refers to the amount of information a person can attend to

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within a given time [3]. The latter refers to a person's ability to guide the selective process by directing and organizing whatever processing capacity he or she has. This has been described by Shallice [5] as the 'Supervisory Attentional System'.

2. Information processing deficits and cognitive functioning

Slowing of information processing speed has been characterized as one of the most pronounced cognitive dysfunctions associated with brain injury [6–14]. Indeed, it has been proposed that a basic underlying deficit in information processing may be the major cause of the cognitive and behavioral sequelae found after brain injury [14,15], as information processing is the foundation for perception, discrimination, matching, creation and following of sequences, categorization, and the ability to relate the information to previously learned information [16,17]. These skills are critical components for all cognitive processes.

Increased complexity of information, distractions, stress and demands for faster rates of processing can overtax the reduced information processing capacity often seen following brain injury, and result not only in less effective processing but also disproportionate decrements in performance [6,11,18]. Thus tasks that can be successfully completed under test or structured conditions are frequently failed when done in real-life situations [12].

3. Information processing deficits and psychosocial functioning

Deficits in information processing can adversely influence psychosocial functioning. Slower processing and impaired simultaneous information processing skills can lead to confusion or difficulty in interpreting what is said or happening, especially within a group setting. For instance, the individual may respond to the specific details of what is said rather than evaluating them within the context of the total situation, leading to the drawing of erroneous conclusions, difficulties in interpretation of subtle humor and poor inferencing skills. This inability to understand the gestalt of a situation can lead to the development of lack of trust or paranoid thinking [19]. In addition, a person's inability to filter out non-relevant stimuli can lead to overload, causing decreased functioning in group settings and subsequent psychosocial withdrawal.

Godfrey et al. [20] reported that patients with brain injuries have deficits in social interaction and are often described as less productive, spontaneous, interesting, socially skilled, or likable. These problems are often compounded by communication problems, including tendencies to speak more slowly, speak for a shorter duration of time, and use less inflection and responsiveness in speech. Godfrey et al. [20] point out that social interactions require sustained and complex information processing skills. The results of their study did not support a direct relationship between information processing speed and social skills, although they emphasize that this is probably an artifact of the reaction time tasks they used, as these only require simple information processing skills.

Somatic and psychological complaints such as headaches, irritability and stress management difficulty can also develop as a result of reduced information processing capacity [18]. These concomitant problems can also have a negative impact on psychosocial functioning.

4. Areas of the brain involved in information processing

As previously noted, information processing can refer to generalized cerebral functioning. Van Zomeren and Deelman [4] concluded generally that brain injury reduces the channel capacity and/or the rate of information transmission in the brain, without any attempt to specify where. Posner et al. [21] report on a theory of attention which involves anterior and posterior systems — with some evidence now being available that the posterior attention system (PAS) involves processing speed for visual information [22]. This PAS includes areas of the posterior parietal cortex, the lateral pulvinar nucleus of the postereolateral thalamus and the superior coliculus [23]. This exciting research needs to be replicated and extended but offers an interesting perspective on the anatomical localization of information processing deficits. From a neuropathological perspective, information processing deficits reflect primarily the interactions among focal and diffuse brain injuries, although diffuse brain injury appears to be the primary causative factor underlying these difficulties in most individuals. The primary effect of diffuse injury is a slowing or disruption of signal conduction, transmission, and/or processing. These factors, in turn, result in disruption of dependent cognitive processes such as attention, memory, perception, communication and executive functions, which ultimately effect general intelligence and learning. Whereas localization of function is recognized for sensory and motor skills, some aspects of language processing, and higher levels of perceptual skills, it is now understood that most cognitive processes require the integrity of the entire brain for successful performance [24]. Hence, decreases in processing speed may induce widespread impairments in the ability of a brain injured patient to meet the expectations of others and to function adequately during activities of daily living (ADLs).

5. Assessment of information processing

As information processing is pervasively involved in all cognitive processes, most cognitive tests contain a general information processing component. Therefore speed and capacity of information processing can be assessed via several neuropsychological tests.

Decreased processing speed will be reflected in timed tests, such as several performance subtests of the Wechsler Adult Intelligence Scale-Revised (WAIS-R) [25], particularly in those cases where the person can do the task but not under the allotted time conditions (i.e. Picture Arrangement, Block Design). Other indicators include relatively impaired performance on the Seashore Rhythm Test, as compared to performance on the Speech Sounds Perception Test, both from the Halstead–Reitan Neuropsychological Test Battery [26]; slow performance on visual scanning tasks, such as Digit Vigilance [27], or the Stroop Neuropsychological Test [28]. Evidence of increased difficulty in task performance may also be demonstrated as the interstimulus interval decreases on the Paced Auditory Serial Addition Test (PASAT) [29,30]. Gronwall [30] demonstrated that recovery from post-concussive symptoms is reflected by a return to normal performance on the PASAT, but she also stressed the conclusion that 'the return of test scores to the normal range does not necessarily imply full recovery from the trauma' (p. 153).

6. Treatment and rehabilitation of information processing deficits

Rehabilitation of information processing deficits will typically address perception/discrimination, sequencing, categorizing, speed and capacity of processing. Reaction-time tasks are considered by some to measure information processing skills because they require continuous information processing and sustained attention [31]. However, Godfrey et al. [20] stated that reaction-time tasks do not require such processing but rely instead on quick, discrete decisions. Ponsford and Kinsella [8] used computer-based reaction-time tasks that led to measurable improvements in information processing speed, although it is unclear whether these were due to spontaneous recovery or to the treatment. It seems that reaction-time tasks may have a part to play in the treatment of information processing deficits, but they should not be used in isolation from other approaches. A multivaried approach seems important as the types of information to be processed by the human brain (concrete, abstract, semantic and behavioral), can not be expected to respond to a single treatment approach.

Gronwall and Wrightson [12] discriminated between the severity of injury in relation to treatment of processing problems. They stated that individuals with severe brain injuries should be treated primarily for attention and fatigue problems, whereas those with mild and moderate in-

9. A controlled group pilot study

The pilot study using these materials involved the comparison of 22 subjects with brain injury using the Information Processing Module, Part 1, and 18 control subjects with brain injury (see Table 1) who received computer-based and pen and paper exercises. The control tasks were not hierarchically graded or integrated in the same cohesive format as the Module materials.

Table 1
Patient information from a controlled group study, examining the effects of training of information processing skills

	Subjects $n = 22$	Controls $n = 18$
Marital status		
Married	15 (68%)	9 (50%)
Divorced	2 (9%)	0 (0%)
Single	5 (23%)	9 (50%)
Sex		
Male	19 (86%)	17 (94%)
Female	3 (14%)	1 (6%)
Occupation		
Managerial	5 (23%)	1 (6%)
Sales/Professional	5 (23%)	3 (16%)
Clerical	4 (18%)	4 (22%)
Blue-collar	7 (32%)	10 (56%)
Unemployed	1 (4%)	0 (0%)
Mean age	32 range (Range 19–53)	27.6 years (Range 19–40)
Mean years of education	12.36 years (Range 10–19)	11.44 years (Range 11–15)
Mean duration of coma	8.16 days (Range 0–35)	9.6 days (Range 0–49)
Severity of injury as measured by duration of PTA		
Very mild (< 10 min)	9 (41%)	4 (22%)
Mild (10–60 min)	1 (4%)	1 (6%)
Moderate (1–24 h)	0 (0%)	1 (6%)
Severe (1–7 days)	3 (14%)	2 (11%)
Very severe (> 7 days)	9 (41%)	10 (55%)
Mean time post-injury	4.39 months (Range 1.5–12)	6.06 months (Range 2–11)
Diagnosis		
Closed head injury	17 (77%)	14 (78%)
CVA	5 (23%)	4 (22%)

For this study, the metacognitive components of the Information Processing Module was not emphasized. Both groups of patients received in-patient therapy while at a Medical Rehabilitation Unit. These treatments in cognitive rehabilitation were part of the overall brain injury program. Both groups were initially assessed as having processing speed deficits on the PASAT. The PASAT is a commonly used measure of information processing [13,45]. Initial and final scores were taken on the PASAT; 17 of the 22 subjects improved more than 10% on PASAT scores (these were averaged over four separate speed trials), and 10 subjects improved more than 20% (mean gain for subjects = 21%, range = 0–50%). These results suggest functionally significant improvements in processing speed. However, the control subjects ($n = 18$) made similar gains (mean gain for controls = 18%, range = 0–41%). There was no significant difference between the groups when a T-test was calculated ($P = 0.74$). It can be concluded from this that the Information Processing Module materials worked as well as more traditional forms of cognitive treatment in improving speed of processing.

The next analysis examined the length of time it took each group to achieve these gains. The subjects took an average of 7 weeks, whereas the control subjects took an average of 11 weeks. A T-test showed this to be a highly significant difference ($P = 0.007$). This equates to a 37% reduction in treatment time. It can be concluded from this result that the use of the Information Processing Module led to a more efficient and cost-effective cognitive rehabilitation process than more traditional methods.

10. A single case study

The second part of the study took one patient in a single case design. The patient was a 28-year-old married Caucasian male naval officer with 16 years of formal education. Reported coma duration was 4 days and post-traumatic amnesia was estimated to be 6 weeks. The patient was admitted to the rehabilitation facility with a diagnosis of traumatic brain injury at 2 months post-injury.

He demonstrated significant processing speed deficits on the PASAT (scores averaged over four trials = 43%; normal = 72%). After an initial 5-week block of treatment using the approaches given to the control subjects in the group study described above, PASAT scores had increased to 48%. He was then discharged for a 5-month period of sheltered work assessment. Reassessment at the end of this period showed a PASAT score of 52%. It is likely then that this period of gains was the result of spontaneous improvement probably enhanced by treatment. This conclusion is substantiated by the fact that he was then sent back to the same work setting for a further period of sheltered work assessment for 6 months. No further gains in PASAT scores were recorded during this period. At this stage the patient was 14 months post-injury so spontaneous recovery would no longer be an issue.

This patient was then readmitted to the rehabilitation facility for cognitive rehabilitation and counseling for a period of 3 weeks. The majority of his 5-h therapy day was taken up with cognitive rehabilitation (90%), during which he was given the Information Processing Modules (Parts 1 and 2) to complete. Apart from the counseling session for 30 min/day no other therapy was provided. Reassessment at the end of this time yielded a PASAT score of 75%. It can be concluded from this result that the Information Processing Modules resulted in a highly significant improvement (within functional limits) in a patient whose spontaneous recovery had ended. In addition, it is suggested that this treatment may have been more effective than return to a sheltered work environment in achieving these gains.

11. Conclusion

The conclusions drawn from these two pilot studies are tentative at best. The control group were generally more severely impaired than the subject group (according to duration of PTA), so it is perhaps not surprising that they took longer to achieve the same level of information processing ability. Although it remains difficult to explain why both groups achieved the same level of information processing ability if severity level was an important issue, as it would be predicted that the more severely impaired control subjects would not progress as far as the subjects. The use of PASAT as the sole measure can be criticized, as it is not clear if the gains made were functionally relevant, other than from anecdotal evidence. Further studies need to examine the functional impact of these measured gains. In addition, Weber [3] stresses the importance of feedback to help patients understand the nature of their problems, learn strategies to overcome the problems, and to generalize their learning to meaningful everyday life situations. Although the study by Ponsford and Kinsella [8] hinted at the usefulness of feedback to improve performance, it was not overtly incorporated into any of the training materials. Similarly metacognitive aspects were not emphasized in the studies reported here. Metacognitive functions [43] are increasingly recognized as essential components in the study of cognitive [39,46]. Metacognitive functions may be viewed as awareness directors, as they oversee the thinking processes, allowing knowledge of 'thinking about thinking'. Ben-Yishay and Diller [39] contrast direct training approaches, which focus on the capacity aspects of processing, with the metacognitive component of training, which focuses on the control aspects of processing. Weber [3] considers it important to include both components in training materials, with different emphases dependent upon the underlying nature of the individual's processing difficulty. It cannot be guaranteed that the treatment gains as measured by PASAT were solely due to the module materials as all patients were also engaged in the brain injury program which involved other therapies. However, given that during the study period all patients received a similar overall program except for the type of cognitive rehabilitation approach, it is likely that differences between subjects and control subjects can be attributed to the module materials rather than to other factors.

In conclusion, given the preliminary results, a further study has been planned which will examine the relative importance of the exercises themselves and the metacognitive components of the materials, with the use of psychometric as well as real-life measures.

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