Rehabilitation of attention disorders: a literature review

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1 Introduction

Impairments of attentional functions are very frequent and can be expected to occur in 80% of all brain-damaged patients (van Zomeren, Brouwer and Deelman, 1984). Impairments give rise to a specific problem per se by slowing down the patient’s reactions in everyday life, increasing irritability, and, especially after damage of the right cerebral hemisphere, by leading to a complete neglect of one intra- and/or extrapersonal lateral space. Attentional deficits may impair the efficacy of rehabilitation of other cognitive functions. Wood and Eames (1981) have pointed out that patients with severely impaired attentional functions profit least from rehabilitation programmes.

Following recent experimental and neuropsychological theorizing, attention has to be divided into separable domains. They are distributed according to two dimensions (van Zomeren and Brouwer, 1994): on the one hand, intensity which includes the tonic and phasic alertness, sustained attention and vigilance aspects; on the other hand, selectivity which comprises the selective or focused attention domains and divided attention (for more details on these specific attentional components see Chapter 1).

There is strong evidence now that differently localized brain lesions lead to different impairments concerning specific attentional mechanisms. Even if contemporary neuropsychological views of attention favour its implementation in widespread cortical and subcortical networks (Posner and Petersen, 1990; van Zomeren and Brouwer, 1994), numerous studies have shown that specific attention functions can be impaired selectively by focal brain damage. Impairments of both alertness and vigilance or sustained attention have been reported after lesions of the brainstem part of the reticular formation (Mesulam, 1985) and after lesions of the right hemisphere (Howes and Boller, 1975; Sturm and Büssing, 1986). Furthermore, studies with lateralized stimulus presentation in healthy subjects (Heilman and van den Abell, 1979; Sturm, Reul and Willmes, 1989) and in split-brain patients (Dimond, 1979) corroborate the assumption that the right hemisphere plays a crucial role in maintaining and controlling intensity aspects of attention. Additional evidence for right-hemisphere dominance in alertness and sustained attention comes from measurement of cerebral blood flow in PET or fMRI activation studies (Lewin et al., 1996; Pardo et al., 1991; Paus et al. 1997; Sturm et al. 1999).

Certain aspects of attention selectivity can be impaired in patients with left-hemisphere cortical lesions (Dee and van Allen, 1973; Sturm and Büssing, 1986), leading to a slowing down of response time and to increased error rates in choice reaction paradigms. Bisiach et al. (1982) and Jansen et al. (1992) also showed left-hemisphere dominance for choice reactions in studies with lateralized stimulus presentation in healthy subjects. In a PET scan study Corbetta et al. (1991) demonstrated the special role of the left lateral orbitofrontal cortex, of the basal ganglia (globus pallidus, caudate nucleus) and of the posterior thalamus during the performance of a selective attention task. In the same study, the authors also claimed a potentially important role for the dorsolateral prefrontal cortex of the right hemisphere in a divided attention task. Unfortunately, the task used by the authors did not strictly follow the commonly accepted divided attention paradigm, but closely resembled a sustained attention task. In the ‘selective attention’ condition of their experiment, subjects had to respond only to changes of one feature (colour, speed or shape) in a visual task, whereas in the ‘divided attention’ condition they were asked to respond to changes of any of these features. Since the latter task condition neither asks for any kind of selectivity nor shows any features of a dual- or multiple-task paradigm, the interpretation of the results in terms of a divided attention task becomes equivocal. There is, however, additional evidence from animal studies focusing on the important contribution of the dorsolateral frontal cortex in memory and attention control processes (Funahashi et al., 1989; Goldman-Rakic, 1987). These findings agree with a frontal supervisory attentional system proposed by Shallice (1988) which is very similar to Baddeley’s notion of a central executive in working memory (1986). The strong connection between these two processes is pointed out by Baddeley’s recent notion (1993) that ‘one is attending with one’s working memory’.

2 Retraining of attention disorders

The number of publications concerning the retraining of attention disorders is relatively limited, and we will give an account of the main existing studies. We will subdivide these works into two categories. On the one hand, we will call some interventions ‘unspecific’ because the adopted training doesn’t target one or several specifically impaired attentional mechanisms. Indeed, early attempts to retrain disorders of attentional processes after brain damage were quite global and did not take into account the
distinctiveness of attention functions. In these types of studies the diagnoses before the intervention are not very differentiated and most of the time interventions consider attention as a unitary function. On the other hand, in the studies we call 'specific', a differentiation of the attentional components with clear identification of the impaired aspects has been made, and the rehabilitation plan takes into account the specific aspects of attention impairments. These studies have in common an approach which includes a comprehensive diagnosis of the attentional functioning, with the intervention targeting the components that are specifically disturbed.

2.1 Unspecific attention training

Blackburn (1958) and Shankweiler (1959) as well as Sturm and Büssing (1982) studied the influence of motivating instructions on the reaction performance of brain-damaged patients. Calming-down, reinforcing or instigating instructions were used and the performance in simple or choice reaction tasks following these instructions was compared with the baseline performance. Unequivocally the authors found a significant increase in performance after any kind of motivating instruction, although the patients never reached the performance level of normal control subjects.

Kallinger (1975; see also Hofer and Scherzer, 1977) tried to improve the reaction performance after brain damage by means of a complex choice reaction time apparatus, the Wiener Determinationsgerät (WDG; Vienna Determination Apparatus). Subjects have to respond as quickly and correctly as possible to differently coloured visual signals and/or to differently pitched tones, by depressing response keys with the hand or foot. Four control tests (simple reaction time task, cancellation test d2, tachistoscopic presentation of dot patterns, and a perseveration task by Mittenecker) were used before and after the training of the patients and of a normal control group to look for generalizing training effects. The brain-damaged group improved significantly in all four tasks, the normal group in only two. The author interpreted this result as a generalized effect of the training procedure. A verbal reinforcement did not show any additional beneficial effect. Unfortunately there was no baseline condition before the training period and so it is hard to disentangle spontaneous recovery and test repetition effects from the effects of the training.

Sturm et al. (1983) also made use of programmable versions of the Vienna Determination apparatus (WDG) plus the 'Vienna Cognitrone'-both manufactured by the Schuhfried company in Mödling, Austria-to retrain attention deficits in brain-damaged patients, mostly with traumatic etiology. With the cognitrone the subject has to indicate, by depressing a response key, whether a configuration formed by light-emitting diode bars is identical to one of a multiple choice set of four configurations presented for comparison. The set is changed after every ten items. Thus, both training devices follow choice reaction paradigms and represent trainings of selective attention. It is necessary to underline that all the subjects were submitted to the same selective attention training despite the fact that the deficits they presented probably related, at least for some of them, to other types of attentional processes. The efficacy of the training, including generalization to non-treated functions, was tested using a battery of sixteen standardized psychometric tests. This battery comprised tasks similar to the training procedure, and others which were related but which were not directly trained attention tasks, as well as tests of more general intellectual functions such as reasoning, word fluency, or spatial abilities. By means of a cross-over experimental design, two groups of patients and two normal control groups, matched for age, were studied to control for spontaneous recovery and test-retest effects. The results revealed training effects beyond spontaneous recovery and test repetition, which generalized to non-treated functions, although the largest improvements were related to tasks similar to the training procedure. The training effects remained stable at follow-up examination four weeks later.

Similar generalizing effects after the same unspecific training in traumatic brain injury (TBI) patients in the post-acute stage were reported by Poser et al. (1992).

Malec et al. (1984) studied the impact of two types of video games on sustained attention in a population of ten young subjects who were suffering from a severe TBI in the course of the six months (mean=80 days) preceding the experimentation. The two games used moving targets presented on a screen; the most complex task included distractor stimuli moving in between the targets. Baseline testing comprised the Stroop paradigm, a symbols and letters cancellation task and a reaction time task with warning signal ('Ready?!'). Subjects were randomly submitted to one of two sequences ABAB or BABA, where 'A' corresponds to playing games and 'B' to a period without training. The training on computer games was spread over periods of one week with two daily sessions of 30 minutes, each subject being submitted to re-evaluation on the different tests at the end of each four-week period. The authors point out that: 'Subjects in the study appeared to enjoy and to be engaged by the video games. The subjects actively participated in video game sessions even though many were highly uncooperative and distractible in other rehabilitation activities' (p. 22).
Data analysis showed no significant relation between the improvements on the dependent measurements during the study and age, sex, coma duration, GOAT score (Gavelston Orientation and Amnesia Test: Levin et al., 1979) or brain lesions evaluated by CT scan. There was no significant difference between performance conditions: periods A or B. Only the data from the reaction time test approached the significance level after the training sessions.

The four patients in Wood's study (1986) were young victims (average age: 30) of very severe brain injury with a long post-traumatic amnesia (two months to one year) and in chronic phase (post-onset: 4 to 6 years) at the time of intervention. These subjects presented important attention difficulties in different activities which severely challenged the rehabilitation interventions. Two of these patients were first submitted to a behavioural approach with reinforcement procedures (token economy), with the aim of improving overt attention behaviour, namely head and gaze orientation towards the therapist during the training session. At the end of this first stage, which was fruitful, a similar procedure was implemented, this time including more cognitive aspects of attention. This procedure was applied daily for 28 days: each correct response was reinforced by a token which the patient could exchange for a reward; each error led to withdrawal of a token. The author pointed out that during a discrimination task of digits presented auditorily: 'this type of contingency avoided a high proportion of false-positive responses' (Wood, 1986, p. 48). The same reinforcements were delivered during a tracking task in which the subject had to control the movement of a light spot using a joystick in order to match it with specific symbols presented on the screen. Measurements used during baseline testing and after training were taken from video-recording the subjects' behaviour in different environmental settings, and three auditory memory tasks: a digit span test, the subtest of logical memory from Wechsler's memory scale and Rey's auditory memory test (Lezak, 1995).

At the end of the training, there was a statistically significant progressive improvement (p < .01) for the two tasks used. This improvement concerned the stability of attention during progressively longer periods, and an increase in information processing with concomitant reduction of errors. Analysis also showed a significant increase in attention behaviour (video recording) but, apart from a small improvement in Rey's test, no significant change in the three tasks of auditory memory.

It would have been interesting to evaluate the transfer of the training effects to some tasks requiring classical attentional selectivity (decision time, number of false alarms in multiple reaction time tasks, etc.) instead of assessing the impact of the training on memory tests. Indeed, it seems unrealistic to hope that this type of training may have some positive effects on memory functions which imply a set of much more elaborated processes than those solicited by tasks of visual and auditory discrimination. Furthermore, considering the lack of follow-up evaluation it is not possible to know if the observed improvements were stable over a prolonged period of time.

Ponsford and Kinsella (1988) assigned ten young (average age=24) victims of a relatively recent (average interval between injury and study=13.8 weeks) and severe brain injury to three experimental conditions: no treatment (phase A), followed by training without feedback (phase B), and finally treatment with feedback and reinforcements (phase C). The assessment of the information processing speed was carried out by a task of transcoding (one oral, one written), a multiple reaction time task and a cancellation task, which were submitted before, during and after the training. Attentional behaviour was assessed by means of a rating scale by occupational therapists and a video recording in the occupational setting.

The training tasks were selected to provide repeated practice in responding rapidly, but selectively, to information presented visually on a computer screen. They allowed for measurement of change in accuracy as well as speed of response over time (Ponsford and Kinsella, 1988, p. 698). Tasks included simple reaction time to stimuli presented in different parts of the visual field, a task of matching with visual material, and three multiple reaction time tasks: the subject had to react as quickly as possible to some specific coloured shapes, letters (letters vs. digits) or specific numbers.

All the subjects improved their performances with time, an observation probably linked to spontaneous recovery as the majority of them were still in acute phase (see above). However, analysis did not demonstrate significant impact of the training on the dependent variables. A lack of improvement was also observed for the comparison between phases B and C (treatment without and treatment with reinforcement), 'although there was a tendency for some subjects to respond to the feedback and reinforcement given' (p. 706). Results of the video-recording analysis were also disappointing: absence of any significant effect or of interaction between groups and experimental conditions. Ponsford and Kinsella argue that the difference between their results and the more favourable ones observed in other studies was possibly due to a more diversified approach to the deficits: the intensive training of several different attentional aspects instead of limiting the intervention to one of these aspects (processing speed).
authors also suggest examining the influence of such factors as subject's mood and motivation which might explain the lack of improvement.

Middleton, Lambert and Seggar (1991) compared the effects of two different trainings on two subgroups of patients. One treatment specifically targeted logical reasoning, the other attention and memory. Thirty-six subjects were distributed across two comparable groups. Patients were in a chronic state: the average time post-onset was one to three years. The majority of patients had suffered from a closed (82%) or an open (6%) head injury; the others had suffered from a cerebrovascular accident (6%) or an illness of a different etiology (6%). The training (total of 32 hours, spread over 8 weeks) was based on different computer tasks from Bracy's battery (1982, 1985), exercises targeting attention and memory for one group, and logical reasoning for the other one. The pre- and post-treatment evaluations of the attention/memory aspects were done by three tests: the digit span, the Knox cube subtest from the WAIS-R, and the Paired-associates subtest from the Wechsler Memory Scale.

The analysis demonstrated significant improvements for both groups: 12% for the group assigned to exercises of attention/memory, and 16% for the group assigned to the logical reasoning training. Intergroup comparisons did not show any specific effect attributable to each type of training. Middleton et al. also underlined the considerable variability among individual data. A multiple regression did not show significant effects of age, sex or length and severity of the illness.

Beyond the lack of specific impact of interventions, the absence of a control group in this study casts doubt on the assumption that the observed improvements were related to the training. This doubt is enhanced by the fact that all patients, in addition to the specific training, 'received 96 hours of educational training as part of the programme in which they were already enrolled. This focused on improving attention, concentration, perceptual skills, and problem solving' (Middleton et al., 1991, p. 528). So, in addition to a lack of specificity in the approach, there were also severe methodological problems with this study.

In 1991, Sturm and Willmes repeated their study (Sturm et al. 1983, see above), but this time only in patients with vascular brain damage strictly confined to one cerebral hemisphere: 27 with a left-hemispheric lesion (LHL), and 8 with a right-hemispheric lesion (RHL). The time between the lesion onset and the beginning of the training was 4 to 36 weeks. In order to differentiate training effects for practice or spontaneous recovery, the authors constructed an experimental design including several sessions of control testing (Figure 12.1). Three subgroups were submitted to this design.

Two subgroups respectively comprised the RHL patients and half of the LHL patients; they were labelled 'late' because training started after two control test sessions separated by three weeks. The third subgroup was constituted from the other half of the LHL patients paired for age, sex and time post-onset with the first subgroup; treatment of this subgroup, labelled 'early', started immediately after the baseline testing. To look for stability of effects a follow-up session was conducted for each of the three subgroups. The evaluation sessions (± 90 minutes) consisted of applying a battery of 10 psychometric tasks with a total of 14 variables. This battery included specific versions of the tasks used during the training, different tests of alertness, vigilance and selective attention, and several cognitive tasks without direct relation to the training tasks, for example, reasoning tasks or the WAIS Similarities subtest.

The three subgroups were assigned to a training for three weeks (14 sessions of 30 minutes) with a set of computerized tasks extracted from the Vienna Determination apparatus described above. These could be varied with respect to several parameters: stimulus type (visual vs. auditory or combined), speed and mode of presentation, and specific stimulus-response combinations. By manipulating these parameters, the difficulty level of the training could be increased. Moving up to the next level was effective only when the subject showed 90% correct responses for the last trained level. Statistical analysis demonstrated variable improvement according to the subgroup. General tendencies can be summarized as follows:

1 improvement was more marked in the subgroup of patients with LHL than for the RHL subjects, a difference which, as will be pointed out later, was probably induced by the types of tasks selected for the training;
2 the observed improvement in the LHL subgroup concerned more specifically some aspects of selective attention while for the RHL subgroup there was a general lack of improvement;
3 observed improvement was not attributable to spontaneous recovery nor to test repetition;
4 improvement remained stable at the end of 6 weeks for the 'late' subgroup and 9 weeks for the 'early' subgroup;
5 authors underlined the existence of a relatively constant relation between the amount of improvement and the initial level of performance, the most pronounced improvements being recorded in patients with lower initial level.
The generalization effects to other specific attentional functions were limited, and absent within other cognitive functions. In this study the generalizing effect of training was much more limited than in the first study with TBI patients after diffuse brain damage. It was confined to improvement in tests similar to the training procedure or to tests assessing the same attention function as the training, i.e. selective attention in choice reaction paradigms or in cancellation tests. Intensity aspects of attention, e.g. vigilance, did not improve nor was there any improvement in other cognitive tasks, e.g. verbal or non-verbal reasoning.

Sturm and Willmes explained the difference in results, as compared to their first study, by the fact that the more focal vascular lesions in the second study caused more distinct cognitive impairments beyond pure attention deficits, possibly masking the benefit of the training in some tests; for example, language for the aphasic patients or non-verbal reasoning for the RHL subjects. Furthermore, the fact that there was no transfer of training even to some attention tests, especially those representing intensity aspects, led the authors to the conclusion that distinct attention deficits might need specific training.

Gray and Robertson (1988) and Gray et al. (1992) studied a heterogeneous population of 31 patients including a majority of severe TBI subjects in the subacute phase. Patients were randomly divided into two subgroups: one composed of 17 subjects assigned to an attentional training with a set of computerized tasks; the other including 14 patients assigned to recreational activities. A post hoc analysis demonstrated that the two subgroups were correctly matched for age, sex, severity of attentional deficits assessed with the PASAT (Gronwall, 1977), duration of the disease and the subjects' scores for different questionnaires of anxiety, depression and social behaviour. A set of psychometric tests related to a broad range of cognitive functions (22 variables) was applied three times: before, during treatment, and in a follow-up session conducted six months after the end of training. The experimental subgroup was confronted with five training programmes:
1. a set of simple and multiple reaction time tasks;
2. a detection task of digit sequences repeatedly presented with variable length and duration of presentation;
3. a digit/symbol matching task;
4. a version of the Stroop paradigm;
5. two tasks of divided attention, one of which required mental calculation.

The observed improvements were significantly more important in the experimental group. The benefits essentially concerned tasks requiring the processing of digits and manipulation in working memory: e.g. the global score in the PASAT (p=.01), the longest stretch without error in the PASAT (p <.05) and the score in the Arithmetic subtest (p <.05), of the WAIS. In fact, several tasks included in the training required maintenance and manipulation of information in working memory. Generally speaking there was no significant change for variables not targeted by the procedure. The performance of the experimental subgroup continued to improve after the end of the treatment, increasing the difference between the subgroups. Gray et al. interpreted this observation as the consequence of the learning of strategies acquired during the training phase, strategies which would become progressively automatic and finally should integrate into a broader behavioural range. In contrast, the improvement observed at the beginning in the control group was followed by a performance degradation in the follow-up session. This observation was interpreted in terms of non-specific treatment effect, i.e. the temporary increase of the level of attention and activation limited to the period of practice of recreational activities.

Finally, both subgroups showed some changes in their psychological wellbeing (Goldberg's, 1978, subscales of depression and anxiety) at the end of training and at follow-up as well. Considering the absence of any inter-group difference for the specific subscales at the end of the treatment and at followup, these changes were interpreted as unspecific effects, too.

In summary, this study demonstrated improvements for some attentional processes with favourable generalization to non-trained tasks assessing the same cognitive mechanisms. Effects of the observed improvements on the subjects' daily life activities were not investigated.

It is hard to understand why the favourable impact observed on working memory functioning had no beneficial effect on the evaluations of executive functions. Indeed, as underlined above, the notions of the central executive system described in Baddeley's model of working memory (1986) and the supervisory attentional system in Shallice's model (1982, 1988) very much resemble each other. Thus improvement in the different cognitive variables labelled as 'working memory functions' should also have shown up for the 'frontal functions' variables in which control of attention plays a crucial role. This lack of generalization to tasks addressing the 'central executive' might suggest that the central executive system itself has to be fractioned into several subcomponents.
As already pointed out earlier, all the studies we have described until now have in common that training procedures were not specific with respect to a certain aspect of attention. In particular, the choice of the training tasks was not directly influenced by the results of the pre-treatment assessment which should have permitted differentiation of the deficient aspects of attention from those that are preserved. Table 12.1 recapitulates the different procedures applied in these studies.

### 2.2 Specific attention training

More recently, different therapeutical approaches taking into account the specificity of attention dysfunctions have been tried. These approaches make use of specific therapy programmes attributed to separable attention domains.

#### Table 12.1 Exercises used for the treatment in the non-specific studies

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Exercises</th>
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<tr>
<td>Blackburn (1958)</td>
<td>Simple and multiple reaction time with reinforcements and motivating instructions</td>
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<td>Shankweiler (1959)</td>
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<td>Sturm and Büsing (1982)</td>
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<tr>
<td>Kallinger (1975)</td>
<td>Complex multiple reaction time according to colours, pitched tones and response type</td>
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<tr>
<td>Sturm et al. (1983)</td>
<td>Matching of visual configurations in multiple choice set</td>
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<td>Sturm and Willmes (1983)</td>
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<tr>
<td>Malec et al. (1984)</td>
<td>Video games</td>
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<tr>
<td>Wood (1986)</td>
<td>Behavioural approach with reinforcements (token)</td>
</tr>
<tr>
<td>Ponsford and Kinsella (1988)</td>
<td>Simple, multiple reaction times and matching</td>
</tr>
<tr>
<td>Middleton et al. (1991)</td>
<td>Attention/memory computerized programs (Bracy 1982, 1985)</td>
</tr>
<tr>
<td>Gray and Robertson (1988)</td>
<td>Simple and multiple reaction time, auditory detection, matching, Stroop, divided attention</td>
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<tr>
<td>Gray et al. (1992)</td>
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By means of an electronic device, called the 'Orientation Remediation Module' (ORM), Ben-Yishay, Piasetzky and Rattok (1987) treated 40 patients using five tasks of increasing complexity. Their population consisted of severely TBI subjects (young war victims) in the chronic phase of the disease: one to four years post-injury. They used this programme to address some of the most common attention impairments of these patients: (a) lack of alertness, (b) increased attentional variability paired with substantial lack of selectivity or focused attention, (c) problems with sustained focused attention over longer periods of time (vigilance), and (d) delayed, badly adapted responses and perseverations.

Both the theoretical approach and the practical handling of training closely followed Posner and Rafal's theory of attention (1987). Training addressed the attentional impairments in a hypothetically hierarchical order from (a) to (d). The training comprised five different exercises. The patient first learned to attend to signals from his surroundings and to respond quickly to them. This was accomplished by a simple visual reaction time task with feedback. The second exercise was aimed at reducing distractibility. A clock-like apparatus was used. By pressing a key, the pointer of the clock would start moving and the patient had to stop it at a distinct location by releasing the key. This location was changed several times within the same session.

The third exercise was aimed at an active scanning of the patient's surroundings including search for and identification of relevant signals. The training task comprised a board 80 cm in length on which two cubes could be arranged at different distances. The cube on the left-hand side contained a digital display, and the cube on the right five differently coloured lights. The signals in the two cubes could be presented either separately or simultaneously (divided attention) and showed a figure, a colour signal or both at the same time. The patient had to watch both sources and detect relevant signals in each one individually or in both simultaneously.

In the fourth exercise, patients were trained to rely on internal stimuli. They were instructed to estimate the length of time periods. At first, they were allowed to use a stop-watch and were asked to internalize the rhythm of the moving pointer. During later steps of training, the patients were asked to rely only on
their internalized time estimation. They were encouraged to use strategies such as rhythmical movements of the body, silent counting or visual imagery.

The fifth task was aimed at modulating and sequencing responses. The patients had to imitate different rhythms on a Morse key. First, they were presented with a sequence of tones which they were asked to internalize. They then had to anticipate each tone of the sequence to achieve a synchronization between the given tonal rhythm and the rhythm of pressing the Morse key.

All of these tasks were designed in order to adapt the level of difficulty to the subject's performance and his/her development during training. The training was administered for six years (!). Finally, a computerized version was developed (Piasetzky et al., 1983).

Before training, each patient was submitted to an assessment with a broad range of tasks including different cognitive, self- and hetero-evaluation measures, and several indices of functional adaptation: a total of 77 psychometric variables (Rattok et al., 1982). Each selected patient presented a stable baseline for three months. Treatment efficacy was estimated from the tasks used during training (pre- and post-treatment comparison) and by a partial baseline retest which was administered to each subject at the end of training. A subgroup of 11 patients was also evaluated in each of the five tasks of the procedure at the end of each specific training; these patients were re-evaluated three months after the end of training, five being retested again three months later.

Data analysis showed a significant (p <.001) improvement in each trained task. The group data show an improvement from an initially deficient to a normal level or even higher for some tasks. There was also a statistically significant improvement for four of the measurements selected in the psychometric battery: a visual reaction time task, the digit span and picture completion subtests from the WAIS, and a task of picture description. The scores for the 11 patients assessed after each specific training showed a significant (p <.005) improvement which remained stable. The follow-up testing at six months further demonstrated the stability of the intervention effects. Lastly, observed improvement was associated with a significant increase (correlation analysis) in different measures of functional daily life adaptation: activity and initiative level, orientation in the family environment and social cooperation.

Since all five exercises for each patient were performed in the same order, in 11 patients the effect of each exercise on the baseline scores of the next exercise was investigated. Interestingly, there was no transfer from one exercise to the next one but only an improvement for the task just trained. This observation suggests that the training effects were extremely specific without any generalization to other attentional aspects. In this study, however, interpretation of the results remains problematic since training and control tasks were identical. Thus, the results might only reflect 'trivial' practice effects and not real therapy effects in the stricter sense.

In summary, this study demonstrated the existence of specific improvements in tasks selected for training, with limited generalization to some of the control tasks, and to the subjects' daily life. Considering the length of the treatment period one may have some doubt about the relation between the training and the functional adaptation improvement. One should emphasize that in this study for the first time the training tasks were constructed in terms of specific attentional mechanisms derived from Posner and Rafal's model (1987). The organization of training tasks in a hierarchical way is also an interesting aspect of this study.

Strache's study (1987) concerned a heterogeneous group of 45 patients distributed over three parallel subgroups: two experimental and one non-treated control group.

Each of the two experimental groups was assigned to a different training procedure. For one of these groups (G1) the intervention was of increasing difficulty, regardless of the basic level of performance or the subjects' progress recorded during the training. For the other group (G2) the difficulty level was adapted according to the subjects' initial abilities and their progress during the training. The two groups were trained for four weeks by means of different tasks selected from the Vienna Test System according to the study by Sturm et al. (1983). Again, all training tasks mainly focused on sustained or selective aspects of attention. The author points out that 'generally, there was good acceptance of the training. Only about 15% experimental drop-outs occurred, the distribution of which indicates that the baseline and progress-dependent procedure was better accepted' (p. 4). Baseline and post-training assessments were conducted for the three groups from a set of tests comprised of 107 'intellectual, attentional and mnemonic variables'. The post-treatment evaluation was conducted four weeks after the end of the training.
Results may be summarized as follows: (a) the importance of improvement varied according to groups: 58, 56 and 47% of the dependent variables for groups G1, G2 and control respectively; (b) the difference between both experimental groups and the control group was statistically significant, suggesting that the progress in the experimental groups was related to training and cannot only be attributed to spontaneous recovery, practice effects or repeated evaluations; (d) improvements observed in group G1-standard training-concerned functions very close to those targeted by the training, while in group G2-training adapted to the subject's abilities-additional favourable consequences for other cognitive functions were observed: verbal fluency, short-term memory, free recall and recognition of verbal information. Qualitative analysis of improvements led Strache to point out the superiority of a procedure adapted to each subject's abilities. Transfer to daily life was not studied in this work but the period (one month) which elapsed between the end of training and the follow-up assessment testified to some stability of the intervention benefits.

The heterogeneity of the study population limits the possibility of replication. It would also have been of interest to know the number of single patients showing improvement or not after this intervention; moreover, the author gives no information about the specific outcome of some subjects according to the etiology of their disease.

Lamberti et al. (1988) constructed a computerized training to improve intra-individual response time variability and sustained attention in psychotic and brain-damaged patients of vascular origin. The training tried to optimize the patients' response time using a warning stimulus preceding the imperative stimulus in a phasic alertness procedure. For this, the trainees were offered a number of strategies, e.g. internal counting to predict the occurrence of the stimulus after the warning, or self-induced 'thought stop' to control for internal distractors. There were improvements in the variability of response times for different attention functions (e.g. alertness and selective attention) plus a generalization of the training effects to verbal memory tasks.

Sohlberg and Mateer (1987, 1989), using a multiple baseline across subjects single case design, also reported highly specific results after training either of attention or of visuo-cognitive functions in four patients: two closed head injury, one open brain injury and one patient suffering from a rupture of an aneurysm. Patients were rather young (25 to 30) with a similar educational (11-13 years) and intellectual (IQ=80 to 87) level. The duration of their illness varied between 12 and 72 months; the time post-onset being sufficiently long to rule out the incidence of spontaneous recovery. The experimental design was based on a multiple baseline analysis across cases. In such a design, the treatment is applied sequentially to each of several target variables, and is considered to be effective when changes occur for the trained behaviour while untreated behaviours remain unchanged (Barlow and Hersen, 1984). Each subject in this study presented deficient performance in two tasks: the PASAT used to assess attention, and a test of spatial relations used to evaluate visuo-spatial control. To constitute the baseline before the treatment each subject was tested twice with these two tasks. The training comprised 7 to 9 individual sessions per week, and the duration of the intervention (4 to 8 weeks for each specific training of attention, visuo-spatial or memory) was determined by the severity of deficits. Training of attention targeted five components: focal and sustained attention, distractibility, attentional flexibility and divided attention. It included about fifteen exercises of increasing difficulty extracted from a module 'Attention Process Training' designed by the authors (Sohlberg and Mateer, 1986, 1989) or adapted from a set of published computer programs (among others: Gianutsos, 1983).

Once one subject had reached a certain level (predetermined according to his/her difficulties in the baseline) for each task of the specific attentional treatment, he/she was assigned to training of visuo-spatial control. At the end of this, three of the four subjects were additionally trained for memory functions. In order to control the possible impact of the order of the specific interventions, this order was reversed for one of the subjects. In order to estimate the impact of each type of intervention on the dependent variables, the baseline measures were applied several times before, during and after each specific training. Each specific intervention led to a significant improvement on the related measures. With regard to attention, each subject improved their performance in the PASAT during the attention training. The patient who first received the visuo-spatial training unexpectedly also showed an improvement in the PASAT, with continuation of improvement in this task during training of attention. These observations clearly demonstrate the existence of a specific effect of each type of intervention, an effect also present in the three other subjects. The increasing scores observed in the PASAT after training of attention remained stable: after 23, 23 and 12 weeks respectively for the three subjects who were first assigned to this type of training. The score for the visuo-spatial task remained stable during the attention training period while performances in the PASAT continued to increase; performances in the visuo-spatial task only improved with the specific training. As underlined by the authors: This double dissociation provides powerful support for independent improvements in specific cognitive areas' (Sohlberg and Mateer, 1987, p. 128).
Prior to the start of the training, none of the four subjects was living independently or successfully employed. At the end of the treatment, each of these subjects was living independently, two of them obtained sheltered employment and the two others could work in a normal environment. This increasing autonomy was still effective 5 to 8 months after the end of training. With justified caution, Sohlberg and Mateer (1987) point out: ‘Although we cannot attribute these outcomes solely to cognitive training, observed functional gains correlated in time with improvements in cognitive performance’ (p. 128).

Gray and Robertson (1989) presented three single cases also studied using a multiple baseline methodology. The three patients presented marked sustained attention deficits. For patient 1, a young man who was the victim of a severe TBI (post-traumatic amnesia > 2 months), the target measure was a score combining a forward and backward digit span and a calculation task; a complex reaction time task was used as a control measure. Training (duration: two months) included two computerized tasks: the detection of the repeated occurrence of a digit, and a task of symbol/digit matching (from the Braun et al. battery, 1985). Statistical analysis showed the stability during the baseline of the target function and the control functions, followed by a progressive and significant improvement of the targeted function during the training only.

Patient 2 was a 30-year-old man with bilateral frontal damage after an extremely severe brain injury he had suffered three years before. He was submitted to a computerized version of the Stroop test (Dyer, 1973), a version including three levels of cueing which are gradually faded out until the subject is able to decide which rule to use, to maintain the rule in working memory and to switch rules after error feedback. The target measure was the same as for patient 1. The control measure used during baseline and training periods was a score of recall from memory (Buschke paradigm); this score remained stable for the two periods. The target function, stable during the baseline, improved significantly during the training. The pre- and post-treatment comparisons of the performance in the PASAT and Wisconsin Card Sorting Test (Nelson, 1976) confirmed the existence of significant improvements.

The last patient was a 19-year-old man who six months earlier had suffered a severe brain injury. He underwent treatment for eight weeks, which included a combination of exercises of digit/symbol matching, tasks of the Stroop type, and exercises of psychomotor speed and visuo-motor coordination. Here again performance in the control task (Buschke) remained stable while, after treatment, there was a statistically significant improvement in the target measure, the Wisconsin Card Sorting Test and the PASAT.

To test the hypothesis whether specific attention deficits do need specific training, Sturm et al. (1997) developed computerized training programmes for the retraining of four attentional components: alertness, vigilance, selective attention and divided attention. All programmes have a game-like design but strictly reflect the four attention paradigms, converting them, however, into everyday-like situations. Alertness is trained by means of an animated car or motorcycle driving task, in which the patient has to control the speed of the vehicle in such a way that a high average speed is maintained, at the same time avoiding collisions with obstacles which suddenly appear on the road. One of the vigilance training tasks is a radar screen task, in which the subject has to watch flying objects which move extremely slowly across the screen. The patient has to respond either to sudden changes in the speed of the objects or to additional objects appearing on the screen for a short time. For the training of selective attention a choice reaction paradigm was adopted. In one training task a ‘trap shooting’ game is animated and the patient has to respond to a particular object or particular pairs of objects flying across the screen. A second training is called ‘photo safari’, in which the subject has to watch for relevant single or double objects popping up in front of a scenic background (e.g. a landscape). To retrain divided attention, a ‘flight simulator’ task was developed, in which the patient has to monitor up to three different stimulus sources (horizon, speedometer, motor sound) in combination.

To control for therapy effects, the respective subtests of the test battery for attention performance (TAP, Zimmermann and Fimm, 1994) were administered. These represent the same attention paradigms addressed in training, but they do it by completely different tasks. Thus, training and test procedures can clearly be separated from each other. Patients with vascular unilateral lesions, who showed attention deficits in at least two of the four attention domains, i.e. percentile ranks of <25 in the respective TAP subtests, at first were trained for fourteen training sessions in one of the impaired attention domains. After a second test session each patient was trained in one of the other impaired attention functions. At the end of this second phase a third test session was carried out (Figure 12.2). Since each patient showed deficits in at least two attention domains, with this type of study design in each of the two therapy periods there was one attention deficit which was trained specifically, and at least another one for which the training was not specific.
The results revealed that intensity aspects of attention (alertness and vigilance), especially, have to be trained specifically, i.e. significant improvement can only be achieved by the specific training procedure. For selectivity aspects of attention (selective and divided attention) too, the error rate could only be influenced positively by the specific training programmes; response time, however, for these attention domains could also be improved by training of attention intensity (Sturm et al., 1997). These results were corroborated by a multicentric study including TBI patients (see Sturm et al., Chapter 13 in this book) and by a study in patients suffering from multiple sclerosis (Plohmann et al., 1998).

All in all these results showed (a) that it is very important to start an attention therapy with comprehensive diagnosis to work out the specific attention deficits the patient suffers from, and (b) that specific deficits have to be treated specifically. This is stressed by the fact that in patients with impairments of intensity aspects of attention, a 'wrong' training, e.g. focusing on selectivity aspects, may lead to a further deterioration of the already impaired function, probably due to overload of the system (Sturm et al., 1997). In a PET activation study before and after training of alertness in patients with right-hemisphere vascular lesions, the authors (Longoni et al., 1999, 2000) demonstrated a right-hemisphere prefrontal perilesional functional reorganization in patients who regained normal alerting function after the training.

To close this review we would like to mention the Robertson et al. study (1995) which found an interesting effect of a 'sustained attention training' in patients with right vascular lesions and left neglect. After the training there was not only an improvement of sustained attention but also a significant reduction of the neglect symptoms although no specific neglect training had been carried out. The authors interpret the effect as a spreading of attention activation from the frontal to the parietal areas of the right hemisphere.

Table 12.2 summarizes the targeted attentional deficits and the tasks used for the training in the studies using a specific approach.

### 3 Comments

As a whole and despite the fact of their relatively limited number, investigations of the efficacy of different types of training aiming at an improvement of attention lead to very divergent results. Indeed, the conclusions of these studies vary between the absence of any effect on attentional performance and significant improvements. Nevertheless, the existence of studies that have clearly demonstrated some progress is encouraging.

Table 12.2 Tasks and principal attentional functions targeted by the specific approaches

<table>
<thead>
<tr>
<th>Study</th>
<th>Task Details</th>
<th>Attentional Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ben-Yishay et al. (1987)</td>
<td>Visual reaction time with feedback</td>
<td>Alertness</td>
</tr>
<tr>
<td></td>
<td>Control of displacements of a clock hand</td>
<td>Sustained attention</td>
</tr>
<tr>
<td></td>
<td>Detection of targets appearing on one screen or two screens</td>
<td>Selective attention</td>
</tr>
<tr>
<td></td>
<td>Reproduction of sequences of tones</td>
<td>Divided attention</td>
</tr>
<tr>
<td></td>
<td>Multiple reaction times: targets of different colours and tonalities</td>
<td>Attention and memory</td>
</tr>
<tr>
<td>Lamberti et al. (1988)</td>
<td>'Attention Processing Training' and published computerized software</td>
<td>Selective, divided, sustained attention</td>
</tr>
<tr>
<td>Sohlberg and Mateer (1989)</td>
<td>Tasks of detection, matching and visuomotor coordination</td>
<td>Sustained attention</td>
</tr>
<tr>
<td>Gray and Robertson (1989)</td>
<td>Set of computerized tasks (AIXTENT) selected according to deficit types</td>
<td>Alertness, vigilance, selective and divided attention</td>
</tr>
</tbody>
</table>

The diversity of the results obtained may be caused by the fact that, considered as a whole, these studies are disparate and sundry. The diversity relates to the populations, types and duration of intervention, and number and type of selected variables used to evaluate the impact of treatment. This renders comparisons difficult or even risky. Nevertheless and despite this diversity, it is possible to divide these works into three categories (see Table 12.3). The first is one for which no improvement could be demonstrated. In this category we also put the studies demonstrating some progress but for which doubts exist about the methodology used: absence of control group, absence of repeated baseline assessment or of clear differentiation between the tasks used for the training and those used to assess
the impact of the intervention; for the latter indeed the improvements might only represent a practice effect.

To the second category belong the studies for which a non-trivial significant improvement was observed at the end of treatment. However, in these studies the improvement was limited to some tasks similar to those used during the intervention representing the same attentional functions as those addressed during the treatment, i.e. for these studies no generalization could be observed.

Finally, the last category includes the studies for which an improvement was observed for the targeted functions and where there was a generalization to other cognitive aspects, attentional or not. There are, however, very few studies which have demonstrated a significant generalization of the attention improvements to other cognitive domains.

Table 12.3 Recapitulation of the reviewed studies (TBI=traumatic brain injury; CVA=cerebral vascular accident)

<table>
<thead>
<tr>
<th>Studies</th>
<th>Populations</th>
<th>Procedure</th>
<th>Treatment effects</th>
<th>Impact on daily life</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Absence of improvements and/or methodological problems:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kallinger, 1975</td>
<td>TBI</td>
<td>unspecific +?</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Malec et al., 1984</td>
<td>TBI</td>
<td>unspecific -</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Ponsford and Kinsella, 1988</td>
<td>TBI</td>
<td>unspecific -</td>
<td>No</td>
<td></td>
</tr>
<tr>
<td>Middleton et al., 1991</td>
<td>Mainly TBI</td>
<td>unspecific +?</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>II. Improvements limited to the trained functions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sturm et al., 1983</td>
<td>TBI &amp; CVA</td>
<td>unspecific +</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Wood, 1986</td>
<td>TBI</td>
<td>unspecific +</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Gray and Robertson, 1989</td>
<td>TBI</td>
<td>specific +</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Sturm and Willmes, 1991</td>
<td>CVA</td>
<td>unspecific +</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Gray and Robertson, 1988, Gray et al., 1992</td>
<td>Mainly TBI</td>
<td>unspecific +</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>III. Improvements with transfer to other cognitive functions:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ben-Yishay et al., 1987</td>
<td>TBI</td>
<td>specific ++</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Strache, 1987</td>
<td>TBI &amp; CVA</td>
<td>specific ++</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Lamberti et al., 1988</td>
<td>CVA &amp; psychotics</td>
<td>specific ++</td>
<td>Not assessed</td>
<td></td>
</tr>
<tr>
<td>Sohlberg and Mateer, 1989</td>
<td>TBI &amp; CVA</td>
<td>specific ++</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Sturm et al., 1997</td>
<td>CVA</td>
<td>specific ++</td>
<td>Not assessed</td>
<td></td>
</tr>
</tbody>
</table>

It is interesting to note that the majority of studies demonstrating favourable results explicitly refer to a theoretical model of attention. A theoretical frame of reference certainly helped to make a more precise diagnosis in terms of specific attentional impairments, to allow for a more precise choice of intervention and to help with the selection of measures to control the impact of treatment. In summary, the analysis based on a theoretical plan would seem to increase the precision of the approach both during the diagnosis and during the treatment phase.

Table 12.3 shows that the most favourable results were obtained in studies using a 'specific' training procedure (see also Park and Ingles, 2001), constructed in order to target as precisely as possible the deficient attentional components. Besides the fact that this type of approach turns out to be more efficient, it also allows us to refine the existing models of attentional functioning. Indeed, even if everyone agrees with the fact that the different attentional functions are interdependent, there is still very little agreement about relationships existing between these components. In particular, by the differential effects of specific approaches to the deficits a 'corner of the veil may be lifted'. Indeed, the functions of attention seem to be organized in a hierarchical manner. At the lowest level, one may expect to find aspects of an intensity dimension of attention. These aspects should constitute a necessary condition for an adequate functioning of the components of a higher attentional level, the selectivity
Another point also emerges from this presentation: the existence of favourable effects of the treatment benefits on the subject's daily life still has to be demonstrated. Apart from a few exceptions, this aspect has not been investigated in the papers we have reviewed. The absence of assessment of these crucial aspects is partly due to the lack of reliable and validated tools in the domain of attention. As underlined by Robertson (1990), we need a more extensive range of sensible tools for evaluating attentional functions in real life, in order to exclude the possibility that the observed improvements are exclusively confined to the tests used for the neuropsychological assessment. Daily life situations are most frequently characterized by a broad range of attentional requirements which are, in the present state of knowledge, extremely difficult to evaluate and differentiate on a functional basis. The progressive refining of the available models might contribute to the elaboration of sensible and reliable tools allowing a more ecological evaluation of the impact of the deficits and the efficacy of treatments on the subject's adaptation to daily life situations.

Finally, the majority of the studies we have reviewed were based on direct stimulation of the deficient attentional functions. In other words, they are targeted at a restitution or restoration (Rothi and Horner, 1983) of the impaired processes. But recourse to other types of strategies might also be efficient and could constitute a complementary contribution to the restorative approach. Thus, for example, Wilson and Robertson (1992) used a technique of conditioning and self-suggestion in order to remEDIATE the attentional fluctuations presented by a severely brain-injured patient during his reading activities. This subject was trained to use strategies of relaxation and breathing control which he had to practise before starting to read. He was also trained to define on his own a period of time during which he should try to read without lapses of attention; this duration was progressively lengthened. In a second phase of the treatment, the patient was trained to use the same strategies but this time in an environment with distractors, a situation closer to his usual employment setting. Thanks to these strategies, the patient became progressively able to read during longer and longer periods without lapses of attention. A generalization towards texts concerning his professional activities was also observed—texts which were not used during the treatment. Thus procedures or strategies supporting the subject’s implication in the self-control or self-regulation of his/her attention may contribute to optimize the benefits resulting from a restorative approach.

References


