Neurologic Disorders of Attention and Arousal: Assessment and Treatment

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Disorders of attention are common after a variety of insults to the central nervous system. Clinically observable disorders of attention have complex relationships to the hypothesized underlying core deficits that were reviewed in a previous article. Thus, the process of evaluating such deficits is equally complex. Treatments may be directed along a continuum from cellular chemistry and physiology to environmental modification. At present, there is little consensus about appropriate evaluation or treatment for attentional disorders.

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The current status of the scientific study of arousal and attention in normal individuals and in those with brain diseases was reviewed in a previous article.1 The status of that research does not yet allow for rational, theory-driven assessment or treatment design. However, there exists an independent treatment literature regarding attentional disorders.

For the purposes of this article, the research literature on assessment and treatment of neurologic disorders of arousal and attention over the last decade was reviewed. Additional clinical literature was also included where experimental studies were lacking. Because the volume of research on treatment in this area is still inadequate, the author will attempt to speculate from basic science understandings to the clinic where possible.

ASSESSMENT OF THE ATTENTIONAL NETWORK

Purposes of Attentional Assessment

There are at least three possible purposes of attentional assessment: detection of neuropsychologic abnormality, evaluation of specific cognitive mechanisms, and evaluation of clinically relevant naturalistic behavior. These purposes demand different assessment strategies, and even with respect to a particular assessment purpose, there is little consensus about optimal assessment tools.

In cases of mild neural injury it may be important to differentiate subtle cognitive deficits from normal function and to monitor recovery. In this context, the assessment priority is sensitivity in detecting any abnormality rather than evaluation of individual cognitive mechanisms. The Paced Auditory Serial Addition Test (PASAT) involves auditory presentation of a series of digits at a specific rate.2 The patient's task is to add each new digit to the preceding one and report the sum. For a patient who has sustained a concussion, the proportion correct is below normal, particularly at the higher rates of presentation. This task is highly sensitive in detecting brain damage, but likely relies on several distinct attention-related mechanisms, such as holding information in mind (eg, the previous digit), switching attention (among the two digits and their sum), and overall cognitive processing speed. A simple reaction time test (the subject must press a key whenever the stimulus arrives) presented without warning may also detect subtle brain damage.3 Other authors have suggested that a choice reaction time test (where the subject must press one of several response buttons as indicated by presentation of one of several stimuli) is a more sensitive indicator of brain damage.4,5 This task can be performed poorly because of diminished arousal (leading to slow responding), slowed cognitive processing (also leading to slowing), or lapses in attention or distraction (leading to errors or slowing on a proportion of trials). All of these assessments, therefore, may be more useful in detecting whether brain damage is present than in determining what its effect on attentional function is.

From the standpoint of research and in future designs for rational treatment, it is important to elucidate particular attentional mechanisms that are disordered. Posner6,7 has proposed that some patients with deficits in spatial attention have difficulty "moving" attention from one location in space to another whereas others have difficulty "disengaging" attention from one location in order to move it. These latter patients, once disengaged by a forceful cue, can...
move their attentional focus normally. Under this scheme, it might be important clinically to differentiate between these two types of patients. Assessment tools that relate to theoretically-based cognitive mechanisms are needed for this purpose.

In rehabilitation, the primary concern is functional behavior. Yet, little is known about the relationship between laboratory tests of attention and real-world performance problems. Hence, clinical assessment should always include a component regarding the presence of attentional symptoms in daily life tasks. Behavioral rating systems for assessment of Attention Deficit Disorder (ADD) exist, but these are not appropriate for the traumatic brain injured (TBI) and stroke populations. Thus, behavioral assessment tools suitable for such patients are needed.

Levels of Assessment

A review of the basic science literature on arousal and assessment suggests that these phenomena can be measured at a variety of levels of analysis. One can measure the firing of individual neurons, the generation of event-related electrical potentials, changes in accuracy and speed, overt movements of the sense organs, and clinical symptomatology. However, there is a tradeoff between the precision obtained from studying the lower, more molecular levels and the clinical relevance obtained from studying the higher more behavioral levels.

A subject who has an impairment of the "disengage" mechanism of spatial attention, related to a parietal lesion, may show clinical neglect in randomly organized materials but not in materials with ordered rows of stimuli. This is just one example of how a deficit detected at one level may be modulated by additional factors at a higher level. Consequently, when assessing attentional function in patients one must choose the most appropriate level(s) of assessment depending on the clinical question.

If one chooses the precision of certain laboratory tasks, one will likely need also to assess clinically relevant symptoms. Furthermore, when it comes to treatment, one must keep in mind that interventions may be clinically successful without "repairing" the underlying deficit. In the example above, for instance, arranging written materials in rows might suggest that the patient's neglect has been cured but performance on a reaction time task might still reveal a lateral bias.

Arousal and attention may be seen as the substrate of performance of all conscious tasks. Thus, there are no "pure" tests of attentional function. All such tests rely on detecting patterns of performance in motor, perceptual, and cognitive tasks. Although this is true to some degree in all neuropsychological assessment (i.e., an aphasia battery requires that the patient can hear the directions and has intact vocal mechanisms), it is particularly dramatic in the assessment of attention. Attention is intimately intertwined with the performance of virtually all assessment tasks.

It remains unclear whether there are separate attentional mechanisms controlling information from different sensory modalities or whether there is a single supramodal attentional system. This controversial question has important implications for clinical assessment. Does detection of neglect on a visual paper and pencil test imply that a patient will neglect auditory stimuli? Does difficulty in sustained performance on an auditory detection task suggest that prolonged visual tasks will also suffer? Until these questions are settled, clinicians must remain alert to the possibility of differences in outcomes from different sensory modalities and must be prepared to assess each modality where appropriate.

Assessment of Arousal

Tonic arousal refers to the slow fluctuations in alertness that relate to circadian rhythm, food intake, drug effects, etc. Arousal can be measured in a variety of ways, including EEG spectral analysis, indices of autonomic activity (pupil size, heart rate, electrodermal response), critical flicker fusion frequency, and measures of reaction time and accuracy. Because wide interindividual differences exist in all of these measures, they are probably most useful as indices of changes in arousal in the individual subject. Thus, one could use these to determine whether a patient is differently aroused at different times of day or on different medications, but one could not compare reliably the arousal levels of different patients.

None of these measures exists as a standardized test that is widely available clinically. Hence, they are of most use in clinical research. However, as such research proceeds, one or more of these may be validated for clinical use in specific patient populations.

Behavioral observation can also reveal problems in tonic arousal, but probably only at its extremes. That is, a patient who drifts off to sleep during a task is probably inadequately aroused. General use of behavioral classification is confounded by the possibility that neuropsychological underarousal may sometimes lead to behavioral overarousal (agitation and restlessness), as evidenced by the fact that psychostimulants may sometimes calm agitated and restless behavior.

Phasic arousal refers to rapid fluctuations in alertness that occur in response to task demands, or warning stimuli. To assess phasic arousal, single individuals can be compared with and without warning, with simple vs complex tasks, etc, and can serve as their own controls. Changes in pupil size, heart rate, electrodermal response, reaction time, and accuracy, have all been used to assess phasic changes in arousal level in normal individuals. However, in patients with brain damage, the many different changes that normally occur in concert may become unlinked. Therefore, it is not clear which of these is the most reliable index of phasic arousal changes in a neurologic population.

In our laboratory, we have chosen to measure phasic arousal through changes in speed and accuracy in response to warnings. This is based on the notion that we are ultimately more interested in perception and response than in autonomic function. In addition to evaluating the presence of a warning-induced change in performance, we look for its time course. Do patients with brain injury increase their arousal level promptly in response to warning? Are they able to maintain that aroused state for a reasonable length...
of time until a stimulus comes? Although our data are preliminary, it appears that at least some patients have difficulty maintaining the phasic arousal response for an adequate period (fig 1).

Once again, there are no standard clinically available measures of phasic arousal. At a behavioral level, however, clinicians can observe whether alerting cues (calling the patient's name, tapping an arm, etc) tend to improve performance of brief tasks that are presented afterwards.

The ability to sustain arousal in tedious tasks can be assessed in a prolonged reaction time task without warnings. In such a task, a patient is asked to respond to a target (visual or auditory) which arrives at unpredictable times over a long testing interval, usually interspersed with non-target stimuli. Declining arousal is reflected in slowing of reaction time, declining accuracy, and a more conservative response criterion (fewer responses). The continuous performance task has been used clinically to assess sustained detection in children with ADD. In this task, one must indicate whenever a particular sequence of (usually auditorily presented) letters occurs.

Although such a task is sensitive to declining arousal, it also reveals other deficits. For example, a subject may show errors of commission rather than omission, suggesting a problem in inhibition or impulse control rather than arousal. Furthermore, it has been shown that the rate of stimulus presentation, and amount of perceptual analysis and memory required, can influence whether such a task measures arousal or some other aspects of central processing. It appears that a slowly paced task that places few demands on memory or perceptual analysis is likely to be most sensitive to arousal level. However, no standard clinical measures that meet these specifications are available. Clinical observations of declining participation over time may suggest a problem in sustained arousal. If changing the task restores performance, this further suggests an arousal deficit, because task changes may augment phasic arousal.

As more becomes known about the specific types of arousal, it may be possible and important to distinguish (for example) perceptual arousal from motor preparedness.

Assessment of Attentional Capacity

The notion of attentional capacity comes from the resource theory of attention. This theory proposes that attention is a limited commodity that can be allocated flexibly to one or more tasks. It has been suggested that this commodity is, in fact, arousal, because increased arousal levels may allow for the performance of more complex tasks.

Coslett and coworkers have shown that patients with a right hemisphere stroke have a reduced capacity to perform two simultaneous tasks. Thus, one might argue that an assessment involving such simultaneous performance could be a measure of attentional capacity and, hence, of arousal. However, it has been shown that the specific combination of tasks assigned can affect the amount of capacity used. Certainly, for patients who may find specific tasks particularly demanding, it is unclear how to use task combinations as measures of capacity in any straightforward way.

Nonspatial Selective Attention

Electrophysiologic methods have been used to assess subjects' abilities to attend to selected (particularly auditory) stimuli. In the "odd-ball task," the subject listens to a series of tones in order to count the occasional tone of a different frequency or loudness. Event-related potentials (ERPs) to the target tones (P300 wave) are more pronounced when that tone is being counted than when it is being ignored. Disorders or instructions that interfere with a subject's ability to attend often lead to reduced P300 waves.

At present, electrophonic respiration methods of assessment are still in an investigational stage. The neural structures that generate these waves are not precisely known, which makes their interpretation unclear. However, it is likely that future research will lead to the use of ERP methods in cognitive diagnosis of attentional disorders independent of motor response.

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![Fig 1](https://example.com/fig1.png)

**Fig 1**—Phasic arousal as assessed with a reaction time task. The task is to press an RT button when a visual target appears but not when an irrelevant stimulus (foil) appears. Auditory warning tones are presented to warn the subject to "get ready" for the visual stimulus. The interval from the warning to the stimulus (WSI) ranges randomly from 0 seconds (simultaneous presentation in which no arousal prior to the stimulus is possible) to 0.8 seconds (in which the subject must try to stay aroused for a considerable period before the stimulus arrives). Note that one TBI patient's reaction time (open circles) is fastest with a 0.2 second warning, but he is unable to stay optimally prepared with longer intervals. Another patient (solid circles) requires more time (0.4 seconds) to become optimally prepared, but he is able to stay aroused for up to 0.8 seconds.
Spatial Selective Attention

Numerous measures exist for the assessment of spatial selective attention. Posner's cued RT task appears to have the greatest specificity for particular cognitive operations, and correlates reasonably well with other paper and pencil tasks. This task is relatively simple to administer via computer, and involves presentation of central warning cues telling the subject where the next peripheral stimulus will appear. Some of these cues are misleading. That is, on 20% of trials a central arrow may point to the right, but the target actually appears on the left or vice versa. On such trials, where the cue directs attention to the favored side but the target appears unexpectedly on the neglected side, right parietal patients' reaction times are grossly prolonged and sometimes the stimulus is missed altogether. Although this task has been fairly widely disseminated, it is still considered a research tool.

Paper and pencil tests of hemi-spatial inattention also exist. These include line bisection, letter cancellation, requests to draw symmetrical figures such as clocks, etc. The research literature shows that the placement of the paper, the degree of organization or disorganization of the stimulus array, the hand performing the task, and many other factors may affect performance. Although the stimulus materials are widely available in the clinical environment, the precise protocol for administering them has not yet been agreed upon. Hemi-spatial inattention can be assessed in subjects unable to write or draw by scoring their ability to guess or "label" their side in the Motor-Free Visual Perception Test. All of these tasks are in the visual modality. Comparable assessments of tactile and auditory neglect are less widely available.

At a minimum, it seems that an assessment of hemi-spatial inattention should consider (1) the side of the body that receives the sensory information (ie, the visual hemifield or hand that is stimulated); (2) the side of the environment that the stimulus originates from (if the head or eyes are turned, this may not be the same as item 1); (3) the side of the body that is executing the response (ie, left vs right hand); (4) the side of the environment to which the response is directed (eg, the right hand might be asked to point to the left side of space); (5) the degree of organization or disorganization of the stimuli to be detected (eg, rows vs random arrays); (6) whether the task requires noticing gross stimuli on the left side of space or left sided details of stimuli in right or left hemi-space; and (7) the sensory modality of the stimuli (auditory, visual, or tactile).

It is likely that recovery of neglect in paper and pencil tasks can occur while subjects continue to demonstrate attentional biases on more sensitive measures. This is because these clinical tasks allow for learning of alternative strategies to compensate for the neglect. Thus, the choice of assessment may depend on whether the priority is maximal sensitivity to core impairments or detection of current clinical deficits.

Wilson has developed a more naturalistic assessment of hemi-spatial inattention. This battery uses stimuli as photographs of plates of food to evaluate what information patients detect or ignore. Although this test has been shown to correlate with paper and pencil tests of neglect, it has not been validated against clinically relevant symptoms such as bumping into walls or leaving half of one's food uneaten. Nor has it been shown to correlate with clinical neglect symptoms more highly than do paper and pencil tests.

Assessment of hemi-spatial inattention in naturalistic tasks is critical. For example, a tendency to bump into or trip over objects, to ignore dressing some limbs, to ignore food on one side of the plate, etc, are of the greatest clinical relevance. Behavioral inventories or similar strategies for accurately documenting such problems and their resolution are needed.

Speed of Information Processing

Speed of information processing can be measured fairly simply in a choice-RT task. In one version of this task, a subject presses a central button until a number flashes on a computer screen. It is the subject's task to move to and press a correspondingly numbered button as quickly as possible. In different portions of the task, the subject must select among two, four, or eight possible numbers. The number of possible choices influences the subject's speed in making the decision (ie, time until the finger is lifted from the resting button). Provision of warning tones prior to each trial minimizes the influence of arousal and makes this test more specific for rate of information processing. The slope of the function that relates decision RT to the number of choices is an index of processing speed (fig 2). This slope is steeper in TBI patients and flattens during recovery. Further work is needed to determine whether speed of information processing, measured in this way, is related to slowness in activities of daily living, work, etc.

In the clinic, it is sometimes difficult to differentiate slowed information processing from decreased arousal. However, if slowing improves with increased task complexity or "interest," this suggests an arousal problem, because more demanding tasks tend to elicit greater arousal. In contrast, if task complexity exacerbates the problem, this suggests that the intrinsic rate at which the nervous system can transmit information is reduced. Speed may also appear as a relevant measure in more complex attention-related tasks, such as the digit-symbol substitution subtest of the Wechsler Adult Intelligence Scale, Trail Making Test, Parts A & B, etc. However, here slowness is open to multiple interpretations beyond mere slowing of information transmission. A patient may, for example, have impairments in perceptual processing, movement speed, or in switching of attention that interfere with performance.

Strategic Control of Attention

Strategic control of attention refers to the goal-directed allocation of attention in accordance with plans and task priorities. The concept may include the ability to set, maintain, and modify performance goals, the ability to resist distraction by irrelevant information, the ability to switch attention back and forth between tasks flexibly, the ability...
to perform multiple tasks concurrently, the ability to manipulate information mentally while keeping the overall goal in mind, and other features.

The ability to ignore irrelevant information within a task can be measured with the Stroop task or Stuss’s redundant information RT task. The Stroop task requires the patient to name the color of ink in which (conflicting) color words are printed. That is, the word “green” might be printed in blue ink, and the patient is to say “blue”. The speed at which a subject can name a list of colors is an index of the degree to which color words are being effectively “screened out”. The task designed by Stuss is similar except that there is no direct conflict between stimulus features; one feature is simply irrelevant to the correct response. In both tasks, optimal responding requires that irrelevant features be ignored.

There is no standard test of distraction by extraneous stimuli, although this is a common clinical complaint. In our laboratory, we have assessed this by performing naturalistic distracting actions (making a phone call, filing papers, etc) during subjects’ independent work tasks. Subjects are videotaped doing 45 minutes of independent work while these distractors occur. Videotapes are then coded for the proportion of time the subject is attending to the task (as judged by eyes on the stimulus materials) with and without distractors present. The table shows the results of this assessment for four TBI patients. Note that the patient who is least attentive overall (patient 32) nevertheless shows no negative impact from distracting stimuli. Two other patients who are about equally attentive overall (patients 18 & 41) show very different responses to distractors. Thus, sensitivity to external distraction does not appear related to overall level of attentiveness.

We also measure the ability to detect a visual target on a computer screen when a salient moving stimulus appears at a similar time. Figure 3 shows the results from one clinically distractible TBI patient. His reaction time to the targets became significantly prolonged when a visual distractor appeared shortly before the target (data not shown). Both of these tasks appear, in preliminary data, to be sensitive to brain injury generally, and clinical distractibility specifically. However, more research is needed to verify that this laboratory distractibility task correlates with clinical sensitivity to extraneous events. Shallice has developed a task for assessing incidental “utilization behavior,” where a patient handles and manipulates nearby objects that are irrelevant to the task at hand. This may be conceived of as a kind of distractibility induced by extraneous objects.

The ability to switch sets and attend to a formerly irrelevant feature is generally assessed with the Wisconsin Card Sorting task in which subjects must categorize the cards according to some feature (eg, color) but must revise this categorization in response to changing feedback. Flexibly switching between subtasks may also be assessed through the Trail Making Test, especially Part B, in which a subject must search out an alternating sequence of letters and numbers (ie, 1-A-2-B-3-C . . .).

### Multifaceted Measures of Attention

The way in which components of the attentional network are assessed is highly dependent on the theory of attention that guides the assessment. Thus, in the discussion above, I have divided the phenomenon along the lines of arousal, selection, speed, and strategic control. However, there are numerous measures of attentional function that appear to be sensitive to brain damage, and to correlate generally with clinical problems in attention, but which probably combine many components of the attentional network in a complex fashion.

Tasks such as backwards digits, subtraction of serial sevens, spelling long words backwards, etc, have all been

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In each case, on-task behavior is defined as eyes facing the task materials and no concurrent conversation. On-task behavior is disallowed for the entire session as well as separately for periods in which distractors were or were not present in the room.
ATTENTION AND AROUSAL—CLINICAL, Whyte

Fig 3—Distractions as assessed with a reaction time task. The task is to press a RT button when a visual target appears but not when an irrelevant stimulus (foil) appears. A colorful moving image appears above the stimulus location at various intervals before or after the presentation of target or foil. Thus, the subject’s task is to attend to the target or foil and ignore the distracting stimulus. The distractor appears randomly at intervals ranging from 0.9 seconds prior (−900 msec) to 0.9 seconds after (900 msec) the target or foil. (A) A distractible TBI patient shows a profound drop in accuracy (D'), which is greatest when the distractor and target or foil appear simultaneously (DSI or distractor-stimulus-interval = 0). Yes rate reflects the proportion of trials where the subject responds at all (where 0.5 is the most appropriate value, because 50% of the stimuli are targets). (B) The same subject shows a large drop in responding when the distractor occurs at about the same time as the target or foil. That is, he “misses” the stimulus all together.

used to assess “concentration” or “mental control.” All of these tasks appear to require that a subject be able to simultaneously keep information in mind and perform some form of manipulation on it. Hence, it seems likely that performance could be disrupted from a variety of directions. If a subject is not able to maintain the goal of the task, switch attention from maintenance to manipulation and back to maintenance quickly, or has reduced capacity or arousal to accommodate the demands of the task, performance may suffer. Thus, it appears that tasks such as these are useful clinically in suggesting that patients may have difficulty with complex tasks that require mental manipulation, but they may not be informative about the specific source of such difficulties.

TREATMENT OF DISORDERS OF ATTENTION

Research on treatment of attention deficits is in the beginning stages, largely because so much about the psychology of attention is still unknown. Most studies of proposed treatments are not based on theories of specific cognitive mechanisms that may be disturbed, and most of the outcomes studied are not clinically relevant. Few studies have appropriate controls.

Further clinical attention research should address a number of key issues. It should be designed in relation to particular theories of the mechanics of attention so that the mechanism of action of the treatment can be clarified. For example, does a treatment for neglect “repair” the “disengage” mechanism or provide a compensatory verbal rule to guide behavior? Future research should measure changes in underlying mechanisms and laboratory tasks as well as in clinically relevant behaviors.

Controls are needed in research even in chronic stages, at least to assess nonspecific effects of treatment. Using subjects as their own controls is optimal in many situations because of the degree of inter-subject variability.

The limits of generalization of treatment effects is a much neglected area. We must know, for example, whether a behavioral-shaping treatment for neglect not only improves reading, but whether it improves the ability to detect an unexpected automobile entering the street from the neglected side. The answer to questions such as these is not only of practical importance, but of theoretical significance as well in defining the mechanisms of treatment effects.

Treatment of Arousal Deficits

Most attempts to improve arousal have been pharmacologic in nature. Psychostimulants such as methylphenidate (Ritalin) and D-amphetamine (Dexedrine) have proven useful in the treatment of ADD in children, but may act primarily through improved self-monitoring and strategic control of attention rather than simple arousal.

In case studies and small series in TBI, psychostimulants have improved therapists’ ratings of attention and have de-
increased “fidgeting,” and have improved global ratings of patient function. However, none of these reports includes a specific index of disordered arousal, nor a direct measure of its improvement. Hence, it is possible that other mechanisms are responsible for the improvement seen.

Given the multifaceted nature of arousal, it is likely that medications active on dopaminergic, noradrenergic, cholinergic, and serotonergic receptors may all have utility. At present, however, drug selection is a trial and error process. Furthermore, little research has been done on pharmacologic treatment of arousal in stroke or other populations.

In our laboratory, we are studying patients on and off psychostimulants using an array of information processing tasks that evaluate accuracy and speed, and through videotaped records of performance of independent work tasks in a distracting environment. In the patients treated with dopaminergic medications that we have studied to date, performance changes related to arousal have not been prominent. Other changes, such as increased inhibitory function, have been more significant. However, our subject selection requires that patients be alert enough prior to treatment to perform the computer and independent work tasks. We have encountered a much larger series of severely impaired TBI patients who have responded positively to clinical treatment with psychostimulants by showing increased participation in therapy and improved wakefulness.

Normal individuals can exert compensatory effort to maintain arousal in certain situations. It is conceivable that behavioral incentives could allow brain-damaged individuals to do the same to compensate for their arousal deficits. However, compensatory effort appears to work only for relatively short periods and no studies on its clinical use were identified. Whether brain injured subjects can harness effort in the same way as uninjured controls is also unclear.

Compensatory strategies for arousal impairments may also be of help. As mentioned, provision of alerting stimuli prior to performance improves responding in many patients with arousal deficits, and this fact may be incorporated into treatment and functional tasks. Some patients may benefit from naps or rest periods, and if they have consistent times of optimal performance, schedules can be tailored to their circadian rhythms. Certainly medications that lower arousal should be avoided in such patients.52

These may include the many medications with anticholinergic (gastrointestinal and genitourinary medications, antidepressants, antihistamines, motion sickness preparations), or dopaminergic blocking (metaclopramide, neuroleptics) effects.

**Treatment of Deficits in Spatial Selective Attention**

Behavioral retraining of hemi-spatial neglect has been the subject of several studies. In general, these have involved increasing the salience of the left border of stimulus materials such as printed matter, and providing intensive cuing to attend to the neglected side with gradual fading of these cues. Some of these training approaches appear to improve the trained task and to generalize to other similar tasks. However, a controlled study of a computer-administered version of this type of treatment failed to show any benefit. Even in the successful studies, treatment effects are often small and treatment failures are common. The failure to find benefits from computerized training may reflect difficulties in generalization of strategies from the screen to the page. Unfortunately, the crucial issue of generalization has not been studied systematically across the broad range of spatial tasks that patients encounter in daily life. In addition, it appears that the ability to benefit from such training strategies may depend on the preservation of insight and self-awareness. Thus, a patient who “knows” that he/she has neglect, and is motivated to conquer it may benefit, whereas a patient with more widespread cognitive deficits and lack of awareness may not.

Visual processing is mediated by two distinct but interactive systems. The collicular system is more related to the detection of movement and generation of visual orienting (determining “where”), whereas the cortical system is more related to identification and recognition (determining “what”). Because the collicular visual system is generally preserved in cortical stroke, treatments that stimulate this system and orient attention to the neglected field are under investigation. For example, presentation of “jumping” visual stimuli at the left side of a task has diminished neglect, presumably because such stimuli activate collicular orienting mechanisms.

Treatments of hemi-spatial neglect have not addressed the probable heterogeneity of cognitive mechanisms responsible for this syndrome. It is likely that patients with different forms of neglect will require different treatments. Hence assessment and treatment approaches must be designed in parallel. Furthermore, treatments of neglect have only addressed visuo-motor tasks, so their impact on auditory or tactile neglect is unknown. Also, it seems likely that such shaping strategies will be most effective with highly structured stimulus materials, where a clear “edge” can be defined. Finally, many patients with neglect have other coexisting attentional (and nonattentional) deficits, such as diminished arousal and sustained attention. It is not realistic for scanning-based treatments to ameliorate all of these deficits.

Little is known about the mechanisms of treatment effects in hemi-spatial neglect. One study, for example, showed improvement in motor speed for responses on the neglected side during the course of rehabilitation. When subjects performed the task with eyes closed, however, this improvement disappeared. This suggests that the treatment had not “repaired” the damaged mechanism, but had provided an alternate route for performance that relied on visual exploration. Future treatment research should attempt to clarify the mechanisms involved because this will predict which tasks will be remediated and which will not. For example, a voluntary visual exploration strategy is unlikely to solve the problem of neglect for unexpected cars entering the street from the neglected side because the patient will not be expecting to use the strategy.

Pharmacologic treatment of neglect also holds promise. In one small series, patients treated with the dopamine agonist, bromocriptine, had amelioration of neglect during treatment, warranting further studies of this and other drugs. We have treated two patients with severe neglect...
that interfered with ambulation in one case, and with any exploration of the left hemi-field in the other. Both patients responded to bromocriptine to a clinically significant degree. In the first case, the medication had to be tapered because of hypotension, and the neglect intensified. The fact that a dopaminergic drug may improve neglect suggests either an interrelationship between the arousal system and spatial attention, or an independent dopaminergic affect on spatial attention.

For those with chronic neglect, compensatory environmental manipulation may be of benefit. For example, placing instructions on the nonneglected side and providing patient borders on the neglected side of task materials (chronically, for compensatory purposes) may improve performance. However, this assumes that the placement of stimulus material affects the severity of neglect, which may not be true for all patients. Patients will need to be assessed individually to determine the relevance of side of instructions versus side of required motor action in order to optimize treatment.

### Speed of Information Processing

Little systematic research has been done on the treatment of slowed information processing. In normal subjects, there is no evidence that voluntary effort or increased arousal can speed the buildup of perceptual information within the nervous system. If the same is true in brain injured subjects, then it would follow that the most that could be expected from treatment would be more rapid access, decision making, and action on the basis of the existing level of perceptual information. Unfortunately, in many tasks this would mean trading improved speed for reduced accuracy because decisions would be based on less complete information.

For the proportion of slowed information processing that is due to decreased arousal, it is possible that either pharmacologic treatment or behavioral treatments to improve consistency of effort may be of benefit. Preliminary research suggests that training for speed can have beneficial effects for some subjects.

### Treatments of Clinically Defined Attentional Problems

The treatments discussed above have been based on the concept of identifying and treating disorders of specific attentional mechanisms. Other investigators, however, have approached the problem from a more clinical perspective by training patients in a hierarchy of “attentional skills” without regard to specific cognitive diagnoses. Three studies of computerized attention-training protocols failed to show any effect on psychometric indices of attention or on observable behavior. In contrast, two other single case design experiments revealed benefits and generalization to related, but untrained, tasks. Neither of these studies assessed benefit in naturalistic tasks, however, which leaves open the question of clinical utility of such training protocols.

Behavioral reinforcement of “on-task behavior” (again, without a hypothesized mechanism of the deficit) has been shown to increase such behavior in the treatment environment, but as before, generalization to other environments was not studied.55

Pharmacologic treatments of global attentional problems have also been reported. Individual cases and small studies show some TBI patients to be more attentive, less restless, and with fewer behavior problems when treated with methylphenidate, D-amphetamine, or tricyclic antidepressants. The components of the attentional network responsible for such improvement are unknown. However, these same medications, after years of study, also have unknown mechanisms of action in ADD, where they are clearly effective. It has been postulated, in ADD, that these drugs increase activation of prefrontal structures and thereby improve self-regulation.

Little systematic research has addressed the treatment of strategic control of attention. How can some patients be made less responsive to extraneous stimuli? How can others be made more responsive? How can patients learn to shift their attention in a more efficient and functional way from one component of a task to another? How can patients learn to attend to the relevant aspects of a task and not the irrelevant aspects? All of these questions are critical, but very challenging at our present level of understanding of voluntary control of attention.

It is in the strategic control of attention that we encounter an interface between attention and intelligence. There is experience, judgment, and intelligence involved in deciding what steps in a task are a priority, what aspects of a task are relevant or irrelevant. Indeed, when the same task is presented to individuals of varying intelligence, autonomic indices of arousal and effort are lower in the more intelligent subjects. This suggests that they are allocating their attention and cognitive processes more efficiently and, hence, performing an “easier” task. Thus, attempts to treat deficits in strategic control of attention will rely on research not only in this area, but in other areas of cognitive psychology as well.

### SUMMARY

Arousal and attention are part of a complex cognitive system that is widely distributed in the brain. As a result, many kinds of brain disease can interfere with smooth operation of the attentional network. The activity of this cognitive network is manifested in the quality of performance of other cognitive functions. Hence, this complex and interactive system defies a straightforward assessment strategy.

Much work remains to be done to develop theoretically based assessment tools for studying arousal and attention. This will require further basic science research in this area, as well as exploration of different assessment strategies to determine their relative clinical validity.

In the mean time, one must select from a confusing array of tasks that rely on various forms of attentional function, but, inevitably, also rely on numerous other cognitive capacities simultaneously. By keeping the goal of the assessment clearly in mind (ie, detection of pathology, classification of...
deficit, evaluation of treatment response) one can select measures at the appropriate level of analysis from “micro” to “macro.”

Unfortunately, there is not yet even one treatment for neurologic disorders of arousal and attention that has both proven efficacy and clear patient selection criteria. However, there are many treatments that have been shown to have some benefit for some patients in some tasks. Consequently, clinicians in the field must, for the moment, wear the hats of researchers. Treatments must be selected with clear goals in mind, and pre- and postassessments that are relevant to those goals must be carried out. Most importantly, the limits of generalization of any benefits that are found must be documented. Through these attempts, research and clinical practice mutually will be advanced.

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