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Ordering Thoughts on Thought Disorder

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A common denominator can be found permeating thought disorder at various levels – the lack of executive planning and editing. With data available from aphasiology and neuropsychology, certain features of thought disorder can be reinterpreted as being consistent with dysfunction of the frontal lobe. It is hypothesised that thought disorder may reflect a dysfunction of the cortical–subcortical loops that project into the pre-frontal cortex. The hypothesis predicts that thought-disordered patients will have impaired performance on tests of frontal lobe function, regardless of diagnosis.

> "My thoughts get all jumbled up. I start thinking or talking about something but I never get there. Instead I wander off in the wrong direction and get caught up with all sorts of different things that may be connected with the things I want to say but in a way I can't explain. People listening to me get more lost than I do." (McGhie & Chapman, 1961, p. 108)

> "The problem as I have discovered, is an enormous one, and what one might term the neurology of psychotic speech forms a veritable terra incognita, a lush and unplotted jungle terrain." (Critchley, 1964, pp. 353–354)

The topic 'language and psychosis' covers a broad range of literature and interests. A review of this area reveals many debates that seem to have captured the imagination of researchers perhaps at the expense of the advancement of science. The romantic concept of a 'schizophrenic language' suggested that patients with a similar diagnosis shared a common dialect. The sterile 'concrete versus astract' debate and the exhausting debate on whether thought disorder is a type of aphasia are examples of how research into thought disorder has generated more heat than light.

When the term 'thought disorder' is used in this paper, it refers only to disturbance in the form of thought, or, more precisely, the manner in which thoughts, as reflected in speech, are linked in language. It is not used to describe disturbance in the content of the speech, such as delusions. We describe someone as thought disordered when we, the listener, become confused attempting to follow the speaker's discourse. The content can add to this confusion, but the crucial distinction between disorder in the form of thought and disorder of the content of thought needs to be kept clear in the researcher's mind when attempting to tease out the underlying neurology of these symptoms (Hamilton, 1985; Simpson & Davis, 1985).

The '*terra incognita*' of psychotic speech has been investigated at a range of levels, from phonology to discourse. Between are studies that examine pauses in speech, word association (a vast amount of work has been done at this level), type:token ratio (an index of the frequency of word repetition), syntax (grammar), cloze analysis (an index of the predictability of speech), and within-sentence and between-sentence cohesion (e.g. linkage of references). There is no denying that some of these studies have yielded valuable results, but none seems to capture the defining feature of thought disorder. The one category of analysis that has come closest to this is work done at the level of discourse.

Within each of the categories of analysis of thought disorder there is one feature that recurs. Whether it be at the level of words or at the highest level of discourse planning, it appears that thought-disordered speech lacks executive planning and editing. There is mounting evidence that this may result from a dysfunction of the frontal lobe.

Many articles have been written summarising the results of linguistic analysis of thought disorder (Schwartz, 1978; Rochester, 1980; Andreasen *et al*, 1985). These reviews have traditionally been structured around the various levels of linguistic analysis, for example, word level, syntax, discourse. This is the obvious way to group the data; however, because many of these levels of analysis fail to capture the essential quality of thought disorder, studying these reviews can leave the reader bewildered. In this review, the results of past surveys are organised in a novel fashion that is informed by work from neuropsychology and aphasiology. This is done in a spirit of inquiry; other researchers could organise the available data in other fashions.

A brief review of aspects of current thinking on the functions of the frontal lobe, with particular reference to language, is followed by a selective review of the literature on thought disorder. A speculative hypothesis is outlined and methods to test this hypothesis presented.

The frontal lobe and language

The literature about the so-called 'frontal lobe patient' highlights that lesions of various parts of the frontal lobe can result in a wide spectrum of behavioural changes. This is not surprising when one considers that the frontal lobe has a rich supply of efferent and afferent connections to almost every other part of the brain.

Various attempts have been made to dissect the main syndromal clusters of behaviour resulting from dysfunction of the frontal lobe. One of the main distinctions has been drawn between lesions of the orbitomedial frontal regions, which result in a clinical picture of increased impulsivity and distractibility, v. lesions involving the dorsolateral convexity, which produce an impoverished, adynamic picture (Walsh, 1987). In the production of speech, this simple distinction may be relevant. A mental state characterised by adynamia could lead to poverty of speech, while distractibility could lead to tangentiality, derailment and loss of goal.

Recent work on cortical–subcortical connections has suggested that, instead of asking which part of the frontal cortex causes a certain clinical finding, we should ask which functionally segregated cortical–subcortical loop is dysfunctional (Alexander *et al*, 1986).

Stuss & Benson (1984) provide a succinct account of behaviour resulting from damage to the frontal lobes, distilling the various clinical features into several core features (a–d).

(a) Pre-frontal damage can separate action (response) from knowledge. This can be seen in patients who cognitively understand the task requirements but who cannot use this knowledge to guide their performance. It has often been cited in the literature as a curious dissociation between knowing and doing (Konow & Pribram, 1970). In speech production, which at surface level is a complex motor act, one could postulate that such a dissociation could lead to a failure to execute the discourse originally planned.

(b) Another key feature of patients with pre-frontal dysfunction is an inability to monitor personal behaviour, to monitor for errors, and to utilise these errors to modify behaviour. Errors in speech production are common and there is a constant need to monitor our speech for failure to communicate (Deese, 1978). A failure to monitor or utilise error during the production of speech would lead to error-prone, inefficient communication.

(c) Pre-frontal damage can impair the ability to establish a set. One must be able to generate a set, or frame of reference, to initiate communication. Failure to initiate a set could underlie the poverty of speech and the poverty of content of speech sometimes seen in psychiatric patients and in patients who have suffered damage to the dorsolateral pre-frontal cortex.

Once a set is established, the subject should be able to maintain this set as needed. This ability is impaired in patients with lesions of the pre-frontal cortex. Luria & Homskaya (1964) commented that patients with a frontal lobe lesion were susceptible to the influence of outside associations. Clinically, failure to maintain a set is often linked with increased distractibility. In the production of efficient communication, maintenance of set is vital in order to keep the discourse focused on a topic, on the 'right track'. Spontaneous loss of set and loss of set due to distractibility would certainly contribute to the classic features of positive thought disorder such as tangentiality, derailment and loss of goal.

The ability to change a set is classically affected in patients with lesions of the pre-frontal cortex. A failure to 'disattend' could lead to perseveration at a variety of levels of speech organisation. Words, clauses or themes could intrude repeatedly at the expense of focus on the topic.

(d) Pre-frontal damage can impair the ability to handle sequential behaviour. The role of the frontal lobe in executive planning has been of considerable interest, with several new productive paradigms being introduced (Fuster, 1980). Warrington & Wieskrantz (1982) postulate a "mediational memory system" that involves the frontal lobes. Within this mediational memory system "memoranda can be manipulated, interrelated and stored in a continually changing record of events" (p. 242). Support for such a concept has come from animal work (Goldman-Rakic, 1987).

The process of first- and second-order representations of memory being subserved by the temporal and frontal lobes respectively has recently linked 'theory of mind', autism, and schizophrenia (Frith, 1989). The role of the frontal lobes in representing a second-order memory for complex planning and editing, and for the executive control of sequential behaviour, seems to be a core feature of this system. Such a facility would be crucial for the complex and dynamic planning and editing required to organise speech into communication.

Shallice (1982) postulates two levels of information processing. At one level is 'contention scheduling', which has a store of simple, overlearned sequences that may operate very quickly with or without conscious awareness. Perhaps stock phrases, salutations and rote-learned speech sequences can be handled at this level. At a functionally higher level, the 'supervisory attentional system' is required for complex, novel planning tasks. This system operates at a more conscious level and is not as immediate as contention scheduling. It can veto and organise the lower-order contention scheduling in order to maintain the desired goal and edit overlearned sequences that may 'capture' the system at the expense of the higher goal. Perhaps in speech such a system could edit irrelevant material that may distract the speaker and suppress overlearned speech sequences that may intrude into the speaker's thoughts. Failure of this function could lead to perseveration and distractibility.

The production of a topic-focused discourse that efficiently communicates a complex notion requires the ability to establish, maintain and change a set. It requires two levels of error monitoring: firstly, an internal process of monitoring output for errors; and secondly, monitoring the listener for apparent confusion and evidence of communication failures in order to reprogramme output. All these executive operations would be a function of the supervisory attentional system in this model. Shallice believes that the frontal lobes play a crucial role in this system.

Apart from the classic literature detailing Broca's aphasia, the literature on the effects of lesions of the pre-frontal cortex on traditional indices of language is sparse. What has been published has caused considerable interest in psychiatry (Morice, 1986).

Kaczmarek (1984) analysed the utterances of patients with various cortical lesions as compared with normal controls. He found that the left dorsolateral frontal region was crucial in the planning of sequential organisation of linguistic information, and that the subjects with frontal lobe damage displayed perseverations and distractibility caused by accidental associations. In a later study of patients with lesions of the frontal lobes in particular, Kaczmarek (1987) found that patients with lesions of the dorsolateral cortex perseverated, used simple sentences, and had poverty of speech. The group of patients with left orbitofrontal lesions digressed frequently and did not appear to monitor their errors.

Novoa & Ardila (1987) investigated language in patients with lesions of the pre-frontal cortex compared with matched controls. They found classic frontal lobe behaviour expressed in the speech samples, including perseveration and free association of ideas, as well as apathy and adynamia. They concluded that while language was formally conserved in patients with pre-frontal lesions, executive functions that require complex or conceptual verbal activities were dysfunctional.

Alexander *et al* (1989) reviewed the role of the frontal lobes and language and highlighted, among other things, the role of the left cingulate and supplementary motor area in activating speech. Lesions in this region can lead to reduced verbal output (poverty of speech). Left anterior frontal regions are required for the organisation and executive control of language. The non-dominant pre-frontal region also has a crucial role to play in the organisation of language, particularly in the social and situational context. The authors describe the clinical manifestations of right frontal communication disorders as including "tangentiality, unanticipated changes of topic, socially inappropriate discourse, and humour, and, in severe cases, frankly confabulatory or delusional context in a clear sensorium" (p. 684).

If the classic neuropsychological features associated with frontal lobe dysfunction are applied to language, then one would predict, *a priori*, communication characterised by the inability to establish, maintain and change sets, an inability to handle the planning of sequential behaviour, and the inability to use errors. One does not have to look far to find a large group of patients who display exactly this clinical syndrome of language and communication dysfunction.

Thought disorder

As has been described above, patients with dysfunction of the frontal lobes exhibit certain types of behaviour. Four broad headings are used below in a novel categorisation of the findings associated with thought disorder in psychiatric patients. It is proposed that such an ordering of the findings has considerable heuristic value.

(a) The establishment of a set: poverty of speech and content of speech

The initiation of speech not only requires the formation of a general intention to talk, but also the establishment of a topic focus that will guide the communication. The inability to generate such a topic-focused set could lead to the 'negative' aspects of thought disorder, when the patient has either nothing to say or, because of a lack of focus, conveys little information. Poverty of speech and poverty of content of speech are subscales on the Scale for the

Assessment of Thought, Language and Communication (TLC; Andreasen, 1979). Certainly, clinical practice confirms that many chronic psychiatric patients have very little to say, and what they do say may convey little information.

Early work found a link between chronic schizophrenia and a paucity of speech (Siegel *et al*, 1976); however, more recent investigations have focused more specifically on thought disorder and its linguistic correlates. For example, Allen (1983) found fewer and 'shorter' ideas and low speech variability in thought-disordered patients. Poverty of speech has also been found to correlate with other measures of language (described in more detail below). These include the type:token ratio from a written sample (Manschreck *et al*, 1987), the cloze score (Ragin & Oltmanns, 1987), and poor reference behaviour in thought-disordered speakers (Harvey & Brault, 1986; Docherty *et al*, 1988).

Liddle (1987) looked for correlations between neuropsychological tests and clinical subgroups of patients with schizophrenia. One such subgroup (with the disorganisation syndrome) is characterised by poverty of content of speech, positive thought disorder, and inappropriate affect. Liddle's results led him to speculate that this group may have had frontal lobe dysfunction.

In a group of neurological patients with lesions of the dorsolateral pre-frontal cortex, Kaczmarek (1984) found that they had, among other things, poverty of speech.

(b) The ability to change sets: perseveration

The salient aspect of perseveration is the inability to 'disattend' from an action or a cognition, in other words the inability to change sets. A patient may perseverate on a certain response to a traditional neuropsychological test. Motor actions can 'capture' the system and be repeated inappropriately. One should remain mindful that speech is, in fact, one of the most complex of motor actions.

Andreasen (1979) defines perseveration as persistent repetition of words, ideas or subjects. Studies show that at least mild perseveration is found in 8% of normals, 24% of patients with schizophrenia, and in 34% of manic patients (Andreasen *et al*, 1985). When one examines the speech of thought-disordered patients, perseveration can be seen at various levels. At the phonological level, patients can produce sentences according to the phonological features of the previous words rather than to a topic focus: types of 'clang' associations, while infrequent, are an example of this (Chaika, 1974).

At the lexical level, perseveration results in the repetition of words and can be measured with the type:token ratio. This is merely the gross word count in a speech sample divided by the total number of different words in that sample. The more frequently the same word is repeated in the sample, the lower the score. It has been used in numerous studies of thought disorder (a good summary table is given by Cozolino (1983)). In an elegant study by Manschreck *et al* (1981), a strong correlation between thought disorder and a reduced type:token ratio was found.

Perseveration may also operate at the next level of language organisation: clauses and sentences. Manschreck *et al* (1985) looked at the higher level of phrase repetition and once again found that thought-disordered speakers repeat phrases more frequently than non-thought-disordered patients and normals.

A theme can repeatedly intrude into a discourse even though it bears no direct link with the topic. The result of such perseveration of themes is a decline in efficiency of communication, and an additional burden on the listener. The thought-disordered speaker who continues to erode the topic focus by mentioning a bizarre delusion or an intrusive thought fails to disattend. The governing mechanism that ensures topic focus is failing to edit and to suppress the recurring, inappropriate theme. The system is captured by the theme at the expense of the topic focus and to the frustration of the listener. Perseveration at the level of repeated interpenetration of themes has been commented on by early writers such as Cameron (1944).

This observation has much in common with early theories concerning thought disorder, such as the perseverative chaining model proposed by Cohen (1976) and the 'disattention deficit' model proposed by Cromwell & Dokecki (1968).

In a review of schizophrenic speech, Barr *et al* (1989) proposed an elegant experimental model of verbal perseveration. They found that perseverative error accounted for 20% of the total error on their confrontation Naming Task. They suggest that this is due to a dysfunction of the executive frontal lobe mechanisms that monitor language output.

Reports of language performance in neurological patients with lesions of the pre-frontal cortex (Kaczmarek, 1984; Novoa & Ardila, 1987) comment that perseveration is a feature in this group. These studies offer more support for an underlying frontal lobe dysfunction as an aetiological factor in thought disorder.

(c) The ability to sequence: planning and editing

Numerous levels of planning and editing are required in the production of speech. Several of these levels,

ranging from choosing words to ordering ideas, have been studied and have been shown to be impaired in thought-disordered speakers.

Developments in the analysis of discourse have provided psychiatrists with some new insights into thought disorder. However, because of the complex and often tedious nature of the analysis required, these methods of analysis have been restricted to research and as yet have had no practical clinical application. Basically, discourse operates at the level that connects ideas to form a pattern of language. Just as words are organised into patterns by complex rules called grammar, sentences can be ordered to maximise ease of communication. The rules governing discourse production are many times more complex than grammatical rules.

When a speaker is required to communicate a simple notion to a listener, the speaker can draw upon a store of over-learned discourse patterns. Simple salutations and stock pragmatic exchanges do not require so-called 'higher-order' cognitive functions. A discourse that relates an incident or narrative will have an inbuilt chronological template to draw upon, a pattern or sequence in which to order both the concepts and, eventually, the words. The communication of a complex or novel notion will tap into a higher-level linguistic apparatus.

As humans have only one larynx and can only articulate one word at a time, one of the major linguistic tasks that a speaker must execute is the linear planning of the sequence of communication. The speaker may choose from an infinite variety of combinations and permutations of ideas in an attempt to communicate clearly. This serialisation or linearisation of discourse has been examined in normal subjects and has been shown to comply with some interesting rules of economy (Deese, 1978; Levelt, 1981). For example, ideas should be ordered in a sequence that places the least burden on both the speaker's and the listener's short-term memory.

When a speaker produces discourse he or she must take into account the needs of the listener. Some of the social rules that guide conversation have been codified as maxims by writers such as Grice, Leech and Searle (see review by Taylor & Cameron, 1987). Among other things, a speaker is expected to be clear, brief, and orderly in the communication of information. A process of constant checking and monitoring is required to ensure that the listener is able to comprehend the communication. The most carefully thought-out linear sequence of propositions may be indecipherable if the speaker does not provide the listener with enough information to interpret the communication. Information should be provided at a reasonable rate, in a logical, cohesive manner, with a mutually shared topic that sets the agenda for speaker and listener. If the speaker disobeys convention and rules of economy (e.g. by jumping from topic to topic, or not providing the listener with enough information), then communication efficiency suffers. The listener is forced to process the information using more labour-intensive methods (stacking information in memory buffers in the hope that the speaker will provide the missing data later, or disambiguate the unclear referrent, etc.). The listener will draw upon a wider repertoire of discourse structures and world knowledge in an effort to facilitate understanding.

With these models one can examine thought disorder in a new light. The thought-disordered speaker is unable to maintain the high processing load required to communicate a complex notion. The rules of discourse fall away, leaving the serialisation of propositions in a semiprocessed state. The language system may be captured by associations or strong themes. The patient may have interpenetration of these themes and perseverate. The topic focus will be distorted, such that the needs of the listener are not taken into consideration. The speaker does not actively monitor the two-way process of communication, failing to notice the fact that the listener is confused. Neither the errors in linearisation themselves nor the listener's confusion are monitored, and the planning and editing of discourse needed mid-sentence are lacking.

Discourse planning and editing taps into some of the core functions of the frontal lobes: the establishment, maintenance and changing of sets and the handling of sequences (in this case, ideas to be converted into speech). The execution of these complex planning and editing tasks in the production of speech can be monitored at a variety of levels, discussed under separate headings below.

Planning and editing of grammar

Despite some early work in the area (Pylyshyn, 1970), the syntax or grammatical construction of thought-disordered speech has been thoroughly investigated only in recent years. Morice & Ingram (1982) investigated transcribed samples of speech from patients with schizophrenia or mania, and normal controls. They found that patients with schizophrenia had reduced complexity of speech; that is, they used more simple sentences (e.g. fewer clauses and less complex clausal embedding). This work has been replicated on a different cultural group (Fraser *et al*, 1986; King *et al*, 1990) with comparable findings. It appears that some patients were less able to handle complex grammatical constructions.

These results are congruent with Kaczmarek's (1980) findings that patients with lesions of the dorsolateral pre-frontal cortex used more simple sentences.

Planning and editing for cohesion

This work stems directly from the recent advances in the analysis of discourse (Rochester *et al*, 1977). As mentioned previously, when discourse is structured, the speaker has to organise his or her thoughts into a linear sequence, which imposes structure down the various levels of ordering propositions, sentences, clauses, words and phonemes. The clauses must be linked closely, and conform to a topic focus. Some of the links between clauses have been defined and used to gauge the 'cohesion' of a text. One of the links involves reference performance. Take the following example: ***The patient relapsed because he had ceased his medication.*** In this example *patient* and *he* refer to the same person and the reader is left in little doubt as to the referrent in the subordinate clause. These links within and between sentences can be examined for errors and ambiguities in the speech of thought-disordered people.

Harvey (1983) found that thought-disordered schizophrenic speakers used unclear referrents and less effective cohesion and reference strategies. Another study looking at both manic and schizophrenic patients (Docherty *et al*, 1988) showed a correlation between incompetent reference and both poverty of content of speech and poverty of speech as measured on the TLC scale.

Planning and editing for discourse

Another method of examining discourse has been devised by Hoffman *et al* (1986). Basically these researchers have 'deconstructed' a sample discourse into branching constituent tree diagrams in an attempt to analyse thought-disordered speech. The findings suggested that patients with schizophrenia were unable to construct so-called 'strong hierarchies', while manic speakers jumped from one 'strong hierarchy' to another. They suggest that these data are consistent with a defect in planning and editing, and suggest that frontal lobe dysfunction may be implicated.

The rules that govern discourse are extremely complex and it would not be unexpected phylogenetically and ontologically that such a function would tap into the most recently developed portions of the human brain – the frontal lobes. The discourse of patients with closed head injuries displays altered cohesion (Mentis & Prutting, 1987); however, the performance of patients with specific lesions of the pre-frontal cortex does not appear to have been assessed. Alexander *et al* (1989) in a comprehensive review of language and the frontal lobes comment that the left frontal region is required for formulation, control and structuring of language, and that the right frontal region is required for organisation, particularly in social and situational contexts. One would predict that speech samples from patients with lesions in these regions would display altered patterns of cohesion.

Planning and editing for predictability

The planning and editing of discourse aims to present speech that is readily comprehended by the speaker. Cloze analysis, a semi-objective tool borrowed from journalism, has been used to assess predictability of speech. In this technique, a transcribed speech sample is 'mutilated' such that every fourth (or fifth) word is deleted and replaced with a space marker. The transcription is then given to a reader who is asked to guess the missing word. The percentage of correct guesses is the cloze score given to the sample of transcribed speech. It gauges the predictability of the speaker's discourse as judged by a reader. The more predictable the speech, the easier it is on both the speaker and the listener, placing less of a burden on the short-term memory of both participants.

Once again, there are many studies of thought disorder using the cloze score (for a summary table see Cozolino (1983)). Manschreck *et al* (1979) found that the cloze score was significantly lower (less predictable speech) in thought-disordered than in non-thought-disordered patients or than in normal controls. Interestingly, when the thought-disordered subjects were required to produce written rather than oral samples, this difference was lost (Manschreck *et al*, 1980). This suggests that the act of writing rather than speaking provides the subject with more executive control. In another well designed study, Ragin & Oltmanns (1987) examined patients with various diagnoses who had clinical thought disorder. They found that a low cloze score correlated with several of Andreasen's TLC subscales such as derailment, loss of goal, pressure of speech and poverty of speech.

It appears that thought-disordered subjects do not effectively plan and edit their speech in order to produce a predictable and therefore a readily comprehensible output for their listener.

(d) Failure to monitor errors

One of the most obvious distinctions between psychiatric patients with thought disorder and patients with classic aphasia is the simple fact that

most thought-disordered patients are not aware that they are making errors in communication, and that they rarely make an effort to correct these errors (Chaika, 1974). In many types of classic aphasia, the patients become frustrated with their poor performance, use non-verbal communication to improve communication, and enlist the aid of the listener.

Patients with thought disorder are mostly unaware that they are breaking conventional rules, and ignore the fact that the listener is confused by their discourse. This difference was highlighted by Gerson *et al* (1977) who compared schizophrenia with posterior aphasia. They found that the group with posterior aphasia was more aware of the communication problem and made efforts to enlist the listener's aid.

Aspects of error monitoring have been examined by Harrow *et al* (1989). This group has been examining the concept of 'impaired perspective' in thought-disordered patients. Perspective is the ability to recognise the appropriateness of communication as matched against a broad consensual standard. It taps areas of self-monitoring and world knowledge and has been shown to be deficient in the thought-disordered speaker. These authors also highlighted the importance of 'perspective' in the dynamic planning and editing of speech.

As mentioned above, failure to monitor and use errors has been noted in patients with lesions of the frontal lobes by many authors (Luria & Homskaya, 1964; Konow & Pribram, 1970). Patients may tell the examiners that they know their responses to neuropsychological tests are wrong, but seem unable to use this knowledge to change their behaviour.

Kaczmarek (1984) found that in his sample of patients with lesions of the left orbitofrontal region there was a failure to monitor for errors in speech production.

Hypotheses and speculation

Recently detailed cortical–subcortical loops describe a closed loop between the pre-frontal cortex, part of the caudate nucleus, part of the internal segment of the globus pallidus, down to specific areas of the thalamus, and then back up to the pre-frontal cortex (Alexander *et al*, 1986). The subcortical parts of this loop are now accorded increased status in language production, whereas previously they were thought of as mere relay stations for the cortex (Crosson, 1985; Weinrich *et al*, 1987). Any speculation about the neurology of thought disorder must take these advances into account. Crosson & Hughes (1987), for example, remained mindful of these facts when they presented their case implicating the thalamus in schizophrenic thought disorder.

A synthesis of Shallice's (1982) model and the cortical–subcortical distribution of language production provides a heuristically strong framework to explain thought disorder. It can be postulated that the subcortical structures such as the basal ganglia and thalamus are involved in contention scheduling; the pre-frontal cortex would participate in the 'supervisory attentional system'. An intact and functional cortical–subcortical loop would be required to couple the two aspects of speech production. If the loop is dysfunctional, then a disconnection syndrome would follow, with the resulting speech production lacking executive planning and editing.

It is postulated that formal thought disorder results from a disconnection of parts of the pre-frontal region from subcortical regions. The pre-frontal region is required to establish, maintain and change sets, monitor errors, and handle complex sequencing. Disconnection would result in speech production lacking in these functions – in other words, thought disorder.

Early *et al* (1989*a*,*b*) have presented a hypothesis implicating a 'hemi-neglect' of higher cortical functions in schizophrenia and in schizophrenic thought disorder in particular. It is postulated that this hemi-neglect is due to a left-sided dysfunction of the dopamine-dependent fronto–striato–pallido–thalamic systems. However, as Alexander *et al* (1989) suggested that right pre-frontal dysfunction can also mimic key aspects of thought disorder, it would not be prudent to restrict any hypotheses involving cortical–subcortical disconnection and thought disorder to one side at this stage.

It is postulated that activation of these pre-frontal cortical–subcortical loops is triggered at a certain level of complexity to supervise the production of discourse. Patients with thought disorder seem unable to activate these loops when required, leaving their speech production lacking in executive planning. When the patient is involved in simple speech production (responses to direct or closed questions, simple pragmatic interchanges, etc.) then the discourse may be adequate. When a complex or novel discourse is required, the defect is exposed.

Clinically, it is not unusual for the degree of thought disorder in an individual to fluctuate over even short passages of time, and therefore it is postulated that an individual's ability to activate the loops can vary over time. It is further postulated that certain illnesses such as schizophrenia and mania predispose the individual to impaired loop activation. The core hypothesis is not restricted to any particular nosological category. Features of thought disorder can, rarely, be found in normals, and more commonly in a wide variety of psychiatric and

neurological patients (especially those with lesions of the pre-frontal region). It would be prudent to avoid linking this model to any one diagnosis at this stage; rather, predictions generated from the model should be applied to all groups that display the phenomena of thought disorder (Persons, 1986).

However, it is important to ask why certain illnesses are more likely to impair activation of these loops than others. One possible explanation is that, in certain major psychiatric illnesses, the cortical–subcortical connections may vary subtly, perhaps due to underlying genetic variations that encode neural connectivity during crucial developmental phases (Lewis, 1989).

What avenues exist for psychiatry to test these hypotheses, which are clearly speculative? Exploratory research should focus on exactly which neuropsychological tests correlate with formal thought disorder. This theory would predict that tests measuring the ability to establish, maintain and change sets, and tests designed to measure complex planning (some of the so-called frontal lobe tests) will be impaired in those patients who display thought disorder. This should generalise across the many diagnoses that can display this sign. The hypothesis would further predict that the performance on these tests should normalise as the thought disorder resolves.

Functional neuroimaging will aid the researcher in identification of parts of the brain that are being under- or over-utilised. Neuroimaging has been crucial in describing the role of subcortical regions in aphasia, and such research strategies are instructive for psychiatry (Metter *et al*, 1985, 1988; Weinrich *et al*, 1987). Correlation of functional neuroimaging (positron emission tomography, single-photon emission tomography, computerised electroencephalography) with anatomical neuroimaging (computerised tomography, magnetic resonance imaging) and with careful clinical and neuropsychological examinations are needed in the investigation of thought disorder. Such intelligent research design is already providing new insights into conditions such as Huntington's disease (Leenders *et al*, 1986) and Parkinson's disease (Perlmutter, 1988). Liddle *et al* (1990) found a characteristic pattern of regional cerebral metabolism in a group of schizophrenic patients with prominent positive thought disorder and inappropriate affect: it appeared that the medial pre-frontal cortex had increased metabolic activity and the posterior part of insula had decreased activity. Such work will help tease out the underlying neurological mechanism of thought disorder.

The importance of providing subjects in studies with a task that will stress the areas of interest must be taken into account (Berman, 1987). If the deficit is exposed only under conditions of maximal planning and editing, then these conditions should be reproduced as closely as possible during the examination. Samples of free speech or semi-structured interviews may not reliably elicit thought disorder. Means by which to precipitate thought disorder in a predictable, laboratory-controlled fashion need to be developed. Activation tasks should be specifically designed to load functions such as sequential planning, and the ability to establish, maintain, and change set. Increasingly complex verbal narration and description tasks may be useful in exposing a threshold effect in thought-disordered patients or subjects who are prone to thought disorder.

If such a theory gains support from research, what will this mean for the practising psychiatrist? Firstly, thought disorder could be interpreted as an objective sign of cortical–subcortical dysfunction. Other planning and editing tasks may also be expected to suffer, such as budgeting, and coping in a non-structured, stressful environment. More refined rehabilitation could be offered to those who display this sign.

For the researchers in basic sciences, it could redirect their attention to specific cortical–subcortical connections. Neuronal array and neuronal density in specific sites (Benes *et al*, 1986) could be reassessed by post-mortem neurohistopathology.

By focusing on signs and symptoms in a generic way, we may be able to free the 'log jam' that has bedevilled psychiatric research. It may allow us to understand better the quantum gap between synapses and neurotransmitters on the one hand and the disabilities and symptoms that our patients suffer on the other. By careful research with a clear focus on the defining characteristics of thought disorder it is hoped that the '*terra incognita*' of psychotic speech will yield its secrets, and provide the diligent researcher with insights into the workings of the minds and brains of our patients.

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