3. Toward the Integration of Resource Allocation into a General Theory of Aphasia

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When a particular theoretical perspective within a scientific community gains acceptance by the majority of its members, according to Kuhn (1970), a *paradigm* is said to exist. Identifying if a paradigm exists is important because it uncovers the assumptions that guide the development of the discipline and actually determines, to a great extent, the legitimacy of questions to be asked and approaches to be taken to the development of the discipline.

We believe that there *is* a paradigm in aphasia. We will discuss what we see as three stages in the development of this paradigm and will summarize our concerns for its basic tenets. Finally, we will propose an alternative or supplement to the current approach to aphasiology.

At the core of the current paradigm of aphasia is the notion that there are brain *centers and pathways* used for, or perhaps dedicated to, the storage and transmission of linguistic information. This prescriptive view of aphasia has basically conformed to a minimally edited Wernicke-Lichtheim model (Lichtheim, 1885; Wernicke, 1874) with its resultant syndromes. One good source of evidence for a paradigm's existence is what authors choose to discuss in elementary textbooks. With few exceptions, there is a discussion of the neural centers where language is housed, a discussion of the primary pathways connecting these centers, and an account of how strategically placed lesions result in specific linguistic impairments that conform to the classical syndromes (e.g., Boone, 1987; Ewanowski, 1980; Fitch-West, 1984). That the "centers and pathways" paradigm is real is also evidenced by the fact that the only allowable syndromes are those conforming to the model that predicts damaged centers or damage to specific pathways connecting one center to another (cf. Goodglass, 1981). As an illustration of the level of acceptance of these basic premises, it is still a matter of surprise that anomic or conduction-aphasic subjects demonstrate syntactic deficits (Peach, Canter, & Gallaher, 1988) and it is not at all surprising that this discussion should occur in the context of the traditional syndromes.

The second stage in the development of the paradigm took root in the early 1970s and involved the search for linguistic validation of syndromes. This enterprise has dominated the study of aphasia, at least by nonclinical aphasiologists, over the past 2 decades. For example, an impressive number of studies have been published with the explicit goal of refuting or confirming specific semantic and syntactic deficits in Wernicke- and Broca-aphasic subjects (Darley, 1982). This stage can be credited predominantly to Harold Goodglass, although Jakobson and others also had influence. This new stage saw the mapping of linguistic constructs onto the Wernicke-Lichtheim model, a development that brought a measure of specificity not found in the more general modalities approach represented by such aphasiologists as Schuell, Jenkins, and Jimenez-Pabon (1964) and Wepman (1951). The idea was that if adequate linguistic specification could be given to aphasic errors, simultaneously with increasing neuroanatomical specification (Naeser & Hayward, 1978), the ultimate understanding of aphasia would be within reach. However, with this sophistication came some hidden and insidious assumptions about the fundamental nature of the deficit. That is, the only means of describing aphasic language was to use the tools and constructs of formal linguistics. In linguistic theory building the only need was for categorizing the structures of the language and the rules that governed the structures. The goal of linguistics was to describe the representations, not the implementation or the use, of those structures and rules. In other words, in the borrowed theories of language applied to aphasiology, no provision was made for the so-called "processing" or "doing" of the language. In fact, it has been made quite clear by some linguists such as Chomsky (1975) that performance factors are impediments to the development of a theory of language. Unstated, but implicit, in most of the linguistic descriptions and explanations of aphasia is the belief that linguistic competence is affected. Some aphasiologists have even made this explicit (Grodzinsky, 1990). This assumption is necessary when language is invoked as an explanation for aphasia, because there is no built-in account of the processing component when failure at a particular linguistic level occurs.

Recent models of aphasic language deficits incorporate elements of computations or processing (e.g., Bub, Black, Howell, & Kertesz, 1987; Caplan, 1987). These models would seem to allow for performance deficits rather than competence ones. Aphasiologists such as Caplan and Hildebrandt (1988), Shapiro and Levine (1989), and others do not deny that performance deficits can serve as alternative explanations in their linguistic investigations of aphasic subjects. However, they state clearly that a "loss" view of particular syntactic operations accounts best for some of their patients' deficits. It appears, then, that these models still view the mental operations as obligatory computations that can be "lost." This amounts to a competence-performance dilemma, set in the "processing" plane rather than the traditional representations plane. However, as we will discuss later, these studies have applied only one of the two tests that seem necessary for the attribution of a "loss" of a linguistic representation or computation.

The third developmental stage of the paradigm has involved two refinements. First, there has been an increasing awareness that the neuroanatomical underpinnings of the model are at best tenuous, and that the homogeneity within any clinical aphasic syndrome is illusory. Second, the strict "competence deficit" as a way to account for aphasia is gradually receiving modification from "accessing" or "processing deficit" views.

Both clinicoanatomical correlations and clinicobehavioral patterning have failed to provide the necessary evidence for the homogeneity of aphasic syndromes (Caramazza, 1984; Darley, 1982; Schwartz, 1984). Despite the widely held belief that different aphasic syndromes can be localized onto well-defined brain regions, carefully controlled studies have failed to support this belief (Mazzochi & Vignolo, 1979). DeBleser (1988), for example, concludes: "The only relatively hard fact about brain-and-language obtained in 100 years of aphasiology is that aphasia usually co-occurs with a lesion in the perisylvian region of the left hemisphere" (p. 182).

Although it is not a particularly recent idea (e.g., Freud, 1891; Kreindler & Fradis, 1968; Lenneberg, Pogash, Cohlan, & Doolittle, 1978), recognition of the importance of performance factors in aphasia has more recently gained favor. Evidence from studies of semantics, syntax, and phonology is accumulating for the claim that linguistic units and rules are not lost—that is, linguistic competence is preserved. For example, semantic priming has been demonstrated in Wernicke-aphasic subjects by Blumstein, Milberg, and Shrier (1982), Milberg and Blumstein (1981), and Milberg, Blumstein, and Dworetsky (1988). They argued that these effects could only surface with intact lexical-semantic representations of the words and their associations. Similarly, after demonstrating syntactic priming, Kilbourn and Fredericci (1989) argued that asyntactic comprehension in Broca-aphasic subjects might be an impairment of automatic processing, not a loss of syntactic rules.

Since aphasia seems best characterized as a performance, not a competence, disorder, the nature of the performance factors requires investigation. Contemporary investigators are offering increasingly specific descriptions of language processing. Language processing mechanisms are seen as separate from the rules and representations of language, that is, the grammar (Fodor & Garrett, 1966; Frazier, 1988). These rules and representations refer to grammatical units and their manipulation in the abstract. At this level the units and rules exist without reference to the specific words and phrases. Language processing includes (but is not restricted to) the actual mapping of the rules and representations onto the referents used; it provides the algorithms whereby grammatical rules are executed. For some researchers "processes" are synonymous with "computations."

Processes or computations are presumably dynamic operations constrained by real time (Bierwisch, 1983). Because of the intrinsic temporal properties of processes, they function in either serial or parallel fashion to execute the nontemporally bound abstract rules and procedures of the language. Inextricably bound to the notion of processing are concepts of storage and working memory. However, we will not address these constructs in this article.

Some researchers hypothesize a one-to-one correspondence between a "process" and a grammatical rule or representation. It seems that most theory-building aphasiologists conceptualize each of these processes as an autonomous, encapsulated mental computation. In fact, it is a necessary assumption of these models that the processing components are discrete and operate independently of each other at the more central levels (Bub et al., 1987; Caplan & Hildebrandt, 1988; Caramazza, 1986; Grodzinsky, 1990). As such, each linguistic processing unit is assumed to be separate from and unaffected by processing in another unit and is, therefore, capable of selective damage. In this conception, grammatical processing is viewed as modular in the same strict sense that Fodor (1983), Forster (1979), or Garrett (1980) use to refer to the modularity of cognitive activity.

Caplan and Hildebrandt (1988) contend that aphasic performance can indeed reflect selective impairment to a single syntactic processing unit. They interpret some performance data from their aphasic subjects as evidence for the existence of so-called "double dissociations." For example, one of their subjects was impaired in the ability to coindex pronouns but not noun phrases; in direct contrast, another subject was impaired in the ability to coindex noun phrases but not pronouns. This pattern represents a double dissociation, and it is taken as evidence by Caplan and Hildebrandt that different processing units were selectively damaged in each subject.

Such double dissociations serve as the primary source of evidence for the existence of isolated computational operations and the proposal of additional, possibly endless, computations in the process of model building. However, the evidence for dissociations is weak and has not been subjected to the necessary and logical tests to prove their existence.

This concludes a brief, simplified view of the current paradigm in aphasiology. This perspective of aphasia is sophisticated in many respects; however, it does not account for several fundamental aspects of aphasic performance, such as those discussed by McNeil (1988). While this article will not discuss all of these performance variables, the discussion will focus on multidomain language deficits, performance stimulability, and performance variability.

APHASIC PERFORMANCE UNACCOUNTED FOR BY THE CURRENT PARADIGM

Multidomain Language Deficits

As discussed earlier, several contemporary aphasiologists favor the view that aphasia can be expressed as a disturbance in a single language domain, or subcomponent, such as syntactic comprehension, or as being caused by damage to specific linguistic devices such as input or output buffers (Bub et al., 1987). Although they may recognize that aphasia typically presents as a multidomain disorder, they argue that selective impairment of a single language subcomponent, or of its associated computational unit/substrate, is both theoretically tenable and empirically evident. This perspective on aphasic impairment is not universally accepted, however; many investigators contend that aphasia must be manifested as a disturbance that crosses all language subcomponents, although impairment across the subcomponents may be expressed to different degrees (Darley, 1982; McNeil, 1982).

Controversy over the nature of aphasic deficits has been at the core of aphasia research since Broca and Wernicke, but recent discussions have benefited from parallel debates in cognitive science regarding the issue of modularity (Fodor, 1983; Forster, 1979; Garrett, 1980; Putnam, 1984; Shallice, 1987). Most theorists agree that among the numerous modular theories of cognition, language as a whole is *computationally* modular. That is, the format of the linguistic data, as well as the computational procedures, are specialized for use by the language system and cannot be used by other cognitive systems. As such a modular activity, language is similar to other mental domains defined by Gardner (1985). However, the computational modularity of language need not take the strong form of modularity whereby each mental domain is an encapsulated operation that is uninfluenced by activity in other domains. The subcomponents of the language such as syntax, lexicon, and phonology may be modular in an analogous (i.e., weak) sense. The representations and rules of syntax are surely different in kind and operation from those of phonology and lexicon. If, in addition, the notion of noninteraction with other modules is waived, then each language subcomponent can be considered modular (Blumstein, 1988; McClelland, 1987).

The theoretical position taken by proponents of selective impairment necessarily argues for a strict interpretation of the modularity thesis. That is, linguistic operations occur without influence from neighboring processing activities. While this position is theoretically possible, the data offered thus far do not support it. One piece of evidence that mitigates strict modularity of language is the knowledge that subcomponents of language appear to share processing resources. Arvedson and McNeil (1986), for example, demonstrated shared attentional capacity between lexical decisions and semantic judgments in normal and aphasic individuals using a dual-task auditory processing paradigm. Likewise, Tseng (1990) has demonstrated shared resources between phoneme monitoring and semantic judgments in both normal and aphasic individuals. Another piece of evidence that is inconsistent with a claim of strict linguistic modularity is that aphasia is commonly defined as a disorder that crosses all or several language modalities and all or several linguistic domains. The reason why these attributes have become part of the definition is that unselected groups of aphasic individuals have consistently been demonstrated to be multimodality and multidomain impaired (Darley, 1982; Schuell, Jenkins, & Jimenez-Pabon, 1964). The most parsimonious explanation for such pan-deficits is that the representational level of language is impaired; as a result, any modality accessing that store of information finds an impaired knowledge or representational base. However, there is scarce evidence for a fundamentally disturbed semantic, syntactic, or phonological data base. The current view of "access" or performance deficits fares little better in explaining the "multi" nature of aphasia. If linguistic computational operations (e.g., coindexing pronouns) can be selectively impaired, one cannot define the language deficit (i.e., the aphasia) as being multidomain. To reconcile the seemingly disparate notions that aphasia crosses all modalities and linguistic domains and yet each domain can be selectively impaired, one must propose that either many modules are circumstantially coaffected or there is impairment to a mechanism connected to all modules that can evidence selective impairment. On the surface, it is difficult to entertain a proposal of multiple, separate, yet co-occurring impairments in individual language processes: one impairment for coindexing pronouns, another for past tense computations, another for word order computations, and yet another for a specific lexical category.

In addition to the empirical evidence cited above, another reason for questioning the strict modularity view stems from the weak evidence for selective impairment and dissociations. The evidence for selective impairment is derived from single and double dissociations, but it is not compelling. Researchers argue that performance below chance level in one domain and above chance level in another is a dissociation and is indicative of a loss or permanent processing impairment (Caplan & Hildebrandt, 1988; Caramazza, 1986; Shallice, 1987). However, researchers can use these sorts of data as evidence for dissociation only for comprehension tasks, because in these measures, the probability structure of the task can be determined. Even if a task is performed below a chance level, one can propose that the knowledge is actually there, and a more severe form of accessing deficit is really the agent. In production tasks, on the other hand, where there is little or no constraint on the range of responses, any correct response is sufficient evidence to claim an intact representation, rule, or associated processing unit.

Researchers also argue that a linguistic rule, representation, or process is "intact" when it is handled at a significantly higher level than other representations, rules, or processes (Caplan, 1986; Caplan & Hildebrandt, 1988). However, it is not uncommon to find that these supposedly "intact" functions are handled at levels below those of normal performance, although normal performance typically has not been established for these tasks. For example, Caplan (1986) claimed that one subject had "no difficulty" in a coindexing operation with an 83% correct performance. Without evidence that 83% was in fact "normal" for that particular task, these data do not necessarily indicate intact functioning.

It seems that one prerequisite for treating significantly different levels of performance as evidence for dissociations is that the two tasks be equated in difficulty. No studies claiming dissociations in aphasia have presented tasks of demonstrated equal difficulty. In this absence, the only legitimate data for demonstrating dissociations are those in which one task is performed at a level below chance *and* the other at a level equivalent to that of normal subjects.

To summarize, a dissociation can serve as evidence for selective impairment if either of two criteria are met: (a) there is significantly different performance on two tasks whose difficulty has been demonstrated and (b) high performance levels are equivalent to normal performance *and* low performance levels are at chance levels.[1]

Evidence against selective impairment implies that the identified aspects of the systems that are used to do language are not modular in a strong sense. That is, there is interaction somewhere in the system. Either the actual computations are shared between linguistic domains or another mechanism common to the various linguistic computations is shared. Since there is little evidence that subcomponent processing units are modular, and in fact some rather compelling evidence that they are not

[1] Performance that is significantly below chance level suggests that an active process is interfering with performance. "Chance" and "below chance" performance, therefore, require different interpretations. We wish to thank Joseph Duffy for alerting us to this circumstance.

(i.e., aphasia crosses all modalities and the execution of one computation has a direct effect on others), researchers are left with an option in which a superordinate mechanism is shared by linguistic processing units. This superordinate mechanism will be elaborated on following the discussion of the other two challenges to the current paradigm.

Stimulability

The second feature of aphasic performance that is not addressed by the current processing approaches to aphasia is stimulability. The language performance of the aphasic person is manipulable, and the majority of the effective techniques used for this manipulation do not involve direct or even indirect control of linguistic information. Such variables as the loudness of the stimuli, the size and color of the printed matter, the modality of presentation in the case of the deblocking paradigm, the effects of visual and auditory background noise, delayed auditory feedback, variations in the speed or rate of stimulus presentation, the scheduling of stimulus presentations and reinforcement, and a host of other variables can elicit a correct linguistic response from an aphasic person following an inability to do so without the intervention (Loverso & Prescott, 1981; McNeil & Kimelman, 1986; see Darley, 1982, for a review). These successful linguistic productions or comprehensions cannot be attributed to relearning any language element or to the repair of a "broken" linguistic computation. The sizable body of data that have accumulated on the generalization of functions consequent to aphasia treatment must also be considered evidence that the linguistic operations that have been made available in the absence of direct treatment were always there, but somehow inaccessible or unavailable. In much the same vein, Shallice (1987) has argued that priming effects and improved performance with slow presentation rates should be obtained with an access disorder but not with a degraded store deficit.

Variability

A third source of contention with the present paradigm comes from variability in aphasic performance. Although this has not been studied adequately to convince every aphasiologist, evidence is available that all linguistic or cognitive operations that are thought to support language are variable within the aphasic person (Kolk & van Grunsven, 1985; McNeil, 1983). The variability to which we refer here is that of inconsistent performance on the identical linguistic activity presented in precisely the same contextual environment. For these purposes, we are not referring to variability of the sort in which an aphasic person cannot retrieve a particular word in one conversation but can in another conversation or in which a particular syntactic structure appears to be particularly difficult in one sentence but not in another. The kind of variability represented in the latter examples does not serve as evidence of latently intact knowledge and/or computations; there are a multitude of both top-down and bottom-up sources of variability in these instances. If aphasic persons can be shown to do some aspect of language at one moment and not at another under the identical circumstances, then a variable (perhaps internal-state) function must govern the circumstances under which the operation will or will not be performed. Because few aphasia test batteries have incorporated into their designs the necessary psychometric requirements for capturing the kind of variability that can serve as evidence, little research has documented this kind of language performance inconsistency. Shallice (1987) has also observed that within-item consistent performance should be evidenced in a degraded store, but not in an access deficit.

To summarize, there are several challenges to the current paradigm of aphasia. First, the features of variability and stimulability are not accounted for by the current theories of language processing. Second, processing accounts have not addressed the fact that multimodality and multidomain deficits characterize aphasic performance. The current paradigm needs revision, and this has not gone unnoticed by some aphasiologists.

One refinement proposes that dual or multiroute models can account for the variability and stimulability of language (e.g., McCarthy & Warrington, 1984). In these models, when a task is inconsistently performed, an alternative set of computational operations or an alternative "route" is proposed to account for the variability. Inconsistent selection of these routes could create variable performance, even with the same stimulus. This means that the aphasic person sometimes selects the impaired route and sometimes the intact route. Although this scenario could account for item-specific variability, such an inconsistent selection process seems imparsimonious and hence improbable. If the aphasic person has available, as a strategic option, the use of an intact route, it seems unlikely that it would not be used. If the intact route is not always available as an option or if the wrong option is often chosen, then it seems necessary to propose an executive system that is impaired in its control of these route selections. Humphreys and Evett (1985) have argued persuasively, on other grounds, against the two-route model for the reading modality. Likewise, Grodzinsky (1990) has criticized the current process models as being infinitely modifiable so that a new box or alternative route can always be added, with the result that they provide no opportunity to be disproven.

Another way to refine the current paradigm so that it accounts for all aspects of aphasic performance is to appeal to a more global cognitive functioning perspective on aphasia. Integral to this approach is the notion of cognitive attention or cognitive effort.

ATTENTION AND EFFORT

The general theory of attention is founded in large measure on constructs and ideas generated by cognitive psychology. The term *attention* is also referred to as *resources, capacity,* or *effort*. Gopher and Sanders (1984) conceptualize the cognitive mind as one that consists of an information-processing machinery and a control structure that directs and monitors the operations of the structures. Cognitive deficits of any kind can thus be envisioned as either those of the machinery or those of control breakdown. The terms *machinery* and *control* can be conceptualized, consistent with the current undertaking, as the representations, rules, and computations that are equivalent to the machinery, and an executive function that is equivalent to the controller. As argued above, aphasia has long been viewed as a deficit of machinery breakdown (i.e., the representational and/or computational machinery), which is not easily reconciled with the problems of variability, stimulability, and multidomain deficits. It should be made explicit that in our view, the current "processing" models of language do not include the necessary components to be processing models in the sense that we would think of them. Although the majority of contemporary models invoke notions of interaction among levels, stages, or other mental operations performed in the process of a linguistic operation, it is a failure of one or more mental stages or operations that is eventually invoked to explain the deficit. "Processing models" are necessarily envisioned as deficits of the machinery; our conception of them refers to the control mechanism and its eventual effects on or interactions with the machinery.

Several versions of attention theory have been developed to describe and explain the control system and its interactions with the computational system in humans. One that has been particularly influential is based on Kahneman's (1973) initial formulations and has been elaborated on by numerous other investigators (e.g., Navon & Gopher, 1979; Norman & Bobrow, 1975; Wickens, 1984). In these versions, two assumptions are fundamental. First, "there is a general limit on capacity to perform mental work," and second, "this limited capacity can be allocated with considerable freedom among concurrent activities" (Kahneman, 1973, p. 8). Data have accumulated demonstrating both aspects of the theory within the language domain (Arvedson & McNeil, 1986), between linguistic and nonlinguistic domains (Gaddie & McNeil, 1985; Klingman & Sussman, 1983), and with aphasic subjects (Arvedson & McNeil, 1986; Campbell & McNeil, 1985; Klingman & Sussman, 1983; Tseng, 1990).

This construct of attention plays a role equivalent to the power supply in man-made mechanical devices. Attention can be conceived of as effort per unit of time, or as a velocity, or perhaps as a volume-velocity measure. It is both indispensable and nonspecific for the completion of mental activity. This type of "fuel" input is as important as the information input specific to a given structure. The function of resources is to energize the machinery responsible for a particular task at hand. In this framework, attention is distinguished from basic orientation and arousal.

The control structure in an attention framework is composed of both the attention commodity itself (i.e., the mental effort) and the executor or controller that allocates the attention commodity to brain activities as required. Possible consequences of the limited resource assumption are that tasks may demand more mental effort than is readily available or that two or more concurrent tasks may compete for the available supply of attention. Humans are always responsive to several goals simultaneously. For example, in conversation, at least two global-level goals are interleaved at any point in time: understanding the received message and planning the response. How resources are distributed to different computational structures for the accomplishment of simultaneous or cascaded goals requires an evaluation (or monitoring) mechanism and an allocator, or an "allocation policy" in Kahneman's (1973) terms. In addition to its responsibility for task evaluation, the allocator is described by Kahneman (1973) by three other features: (a) its tendency to allot attention to novel stimuli, (b) its ability to provide attention for a particular domain or message, and (c) its ability to operate as a function of externally generated arousal levels. Presumably, impairments to the control structure could surface in any one of these areas.

The currently accepted view of attention is that it is not a single, undifferentiated property; rather, it is specialized to supply particular mental activities. The degree of specificity—that is, the degree of modularity—has become a topic of considerable controversy and research.

AN ATTENTION FRAMEWORK FOR APHASIA

The adoption of an attention framework for understanding aphasia is appealing because many principles of attention theory seem to explain the aspects of aphasic behavior that are not accounted for by other conceptualizations. Following are five theoretical principles that constitute an initial attempt to formulate an integrated attention theory of aphasia.

Relationship Between Attention, Arousal, and Language Processing Units

In the attention framework of aphasia, the concept of attention is closely affiliated both with notions of arousal and with the computations or processing units associated with each language subcomponent. These three mental constructs are interdependent and may be hierarchically related. Arousal subserves the ability of the organism to generate and allocate mental attention. Thus, deficits in arousal diminish either the available pool of attention or the ability to allocate attention effectively. Attention, in turn, activates computations such as those involved in producing language. Aphasic individuals do not appear to suffer from a notably reduced level of arousal (as might be true for closed-head-injured patients); however, subtle deficits may exist. To the degree that deficits in arousal level can fluctuate, one expects similar variations in the ability to allocate attention effectively. In addition, there is evidence that nonlinguistic alerting signals (e.g., Darley, 1982; Loverso & Prescott, 1981) result in improved language performance in aphasia. To the degree that these nonlinguistic signals affect arousal rather than attention allocation per se, some aphasic stimulability may be accounted for by altering levels of arousal.

McNeil (1982, 1983) has also proposed that internal-state factors could account for the variable performance that has been documented by aphasic individuals (Hageman & Folkstad, 1986; McNeil, Odell, & Campbell, 1982). One possible source for this internal mechanism was postulated to be a (perhaps pathological) biological rhythm that could influence either arousal or attention allocation (McNeil, 1983). This notion was given some support by the demonstration that aphasic individuals evidenced patterns of variable performance on nonlinguistic tasks that mirrored their performance on language tasks (Norris, 1980).

Shared Attention Among Cognitive Domains

The capacity of attention or cognitive effort is not organized in a strict modular fashion. That is, a quantity of attention is usually dedicated to a given cognitive domain but, in certain cases, as yet ill defined, it may be shared with other domains. In the current state of wonderment about this system, one can envision a single pool of resources that is potentially available to all mental activity, with reservoirs devoted to particular cognitive domains, perhaps similar to the modular intelligences described by Gardner (1985). The attention that subserves math and language, for instance, does not differ in quality and thus can be shared if necessary;

nevertheless, a quantity of attention is held in reserve for use by a particular mental domain. If selective impairment were to be convincingly demonstrated and these deficits were shown to be variable and stimulable, one could propose another level of pooling beyond the reservoir (perhaps a fountain) that was dedicated to particular linguistic levels or computations.

Unequally Distributed Attention

In our current view, the supply of attention devoted to the language module subserves all processing subcomponents of language. For example, the cognitive effort available to process syntax is supplied by the same pool that is available to process lexical semantics. If a task requiring processing of both elements demands levels of attention that exceed the supply, insufficient mental effort will be available for the computations, and performance will be impaired. However, there is, as discussed above, evidence that resources are shared among modules when required. Several factors, such as the nature of the task or the motivation of the performer, may also influence how attention is actually distributed. If a particular load is placed on comprehending syntactic structures, attention may be allocated to processing syntax, leaving lexical semantics competing for those dedicated resources, perhaps falling short of its minimal activation level (before the executor summons additional resources from other reservoirs), and vulnerable to disruption. If the performer views the task as one with a particular goal, he or she may subconsciously allocate mental effort to that end. Finally, the concept of mandatory processing may play a role in the allocation of attention (Arvedson & McNeil, 1987; Bock, 1982). Language processing may be innately structured so that one aspect of language always demands and receives more attention.

Inefficient Allocation of Attention

In aphasia, the allocation of attention to particular linguistic tasks is inefficient, rather than reduced in its total capacity. The fact that, when required, resources can be shared among domains makes the notion of reduced total available resources a less compelling explanation for the impairments. In addition, a reduced supply of resources does not address the overriding issue of performance variability. Evidence for inefficient attention allocation is derived from the observation that aphasic performance is variable, at times reaching normal levels. Disruption of the allocation control system could occur for several reasons. For instance, the system may inappropriately evaluate task demands so that insufficient attention is allocated even though it is available in sufficient quantity.

Alternatively, the system may allocate intermittently because of fluctuating biological rhythms (McNeil, 1983).

Tseng (1990) recently examined the notion of inefficient attention allocation. His basic premise was that the higher the probability of an event, the more likely one is to devote attention to it. He presented a dual task using a single stimulus. Subjects were asked to perform a phoneme monitoring task and a semantic judgment task simultaneously. Subjects were presented with a word such as *salmon* and were asked to determine whether it was a member of the food category and if it contained the sound /b/. The probabilities with which either target was presented varied among 20%, 50%, and 80%. In one condition, called the *explicit condition,* subjects were explicitly told the target occurrence probability. In another condition, the *implicit condition,* they were not forewarned of the probability structure and therefore had to self-direct their internal resources. A group of normal subjects showed significantly faster response times with an increased target occurrence probability for both the implicit and explicit instruction conditions. Aphasic subjects did not differentially allocate resources to the various probability conditions, as measured by response times, even when they were informed of the probability structure and even though they performed above chance levels for all probability conditions in terms of accuracy. Tseng concluded that aphasic subjects inefficiently allocated attention to the changing features of the task. While this finding by no means provides conclusive evidence for inefficient attention allocation as a basis for all aphasic performance variability, it is consistent with that view and cannot be readily explained in other ways.

Threshold of Activation

The notion of neural activation and decay is integral to the constructs of both attention and processing. Intuitively, it seems that a minimal threshold of activation must be reached to initiate or complete the processing of a language element. Deficits in the speed with which the threshold is reached, or a change in the threshold level, could result in slower performance, which has been repeatedly documented in aphasia (e.g., Brookshire & Nicholas, 1984; Efron, 1963; Tallal & Newcombe, 1978). Harrman and Kolk (1989) successfully computer modeled one aspect of "asyntactic comprehension" by varying the *rate* of information activation and decay. An inability to maintain the necessary level of neural activation might be observed as variable performance over time. An elevation or reduction in threshold could result in inactivation, perseveration, activation of a wrong node, or interference effects. Activation theories in this sense provide the terminology and set of policies for the assignment of resources to particular linguistic computations.

Recent theoretical treatments of aphasic performance data have alluded to facets of performance that are also consistent with elements of attention theory. *Automatic processing* and *processing load* are terms that now frequently appear in the aphasia literature. *Processing load* refers to the idea that the more complex or difficult the task, the greater is the processing load and the outlay of effort. Tasks that require effort and attention are said to be under *controlled processing*. Conversely, when the task is more automatic, the processing load is smaller and fewer resources, less attention, and less effort are required for its successful completion.

CONCLUSIONS

The focus in this article has been on theoretical developments in the area of attentional control of language computations that are traditionally not included in theories of language. Because researchers have failed to provide necessary and convincing evidence that the linguistic data and the computational linguistic operations are lost, the current linguistic models alone do not appear to constitute an adequate theory of aphasia. However, theoretical developments in the linguistic domain at both the representational and computational levels cannot be ignored. Although there seems to be no clear alternative to the borrowing of linguistic constructs for the description of aphasic behaviors, the use of these linguistic constructs provides tools without the power of explanation unless there is shown to be a once-and-for-all "loss" of the representational or computational linguistic machinery. At this time, it appears necessary to map notions of attention and memory onto computational operations for the description of what the aphasic person does or does not do consistently. To this end, an obligatory ingredient (but by no means the only ingredient) of a general recipe or theory of aphasia will necessarily be the specification of the processing mechanisms that can adequately account for the core features of the aphasic person's disorder.

If our notion of aphasia were shown to be useful or more capable of explaining aphasic behavior than other approaches, it would be legitimate, especially in this written form, to ask the relevance that this holds for clinical aphasiology. There is little doubt that the dominant forms of aphasia treatment fit somewhere into a "stimulation" approach. By our interpretation, this theoretical position is catching up to what clinicians already do. It does suggest, however, that the most effective means of maintaining the effects of stimulation is to make the language operation automatic. This implies that we can make the stimulus maximally salient and probably that we can do it with drill and repetition, because that is the primary way that behavior is made automatic. So-called ecological approaches to treatment that sacrifice drill and repetition for context (not that they have to be independent) are inconsistent with the mechanisms of the disorder and are likely to be inefficient and ineffective. It is, however, apparent that the discovery of the facilitating effects of context and their incorporation into treatment has not altered the basic principles of the stimulation/facilitation approaches. The "ecological" treatments that have been shown to be efficacious, which put a premium on conducting treatment in the environmental contexts in which a particular linguistic communicative act is likely to occur, have without exception used repetition and drill, sometimes with repetitions that reach the thousands (see the article by Oleyar, Doyle, Keefe, & Goldstein in this book). In this case, the context may be a potent variable in making the stimulus salient and thus available to the aphasic person; however, it is the repetition and drill that facilitate the learning and generalization. We are aware of no data on treatment efficacy that have documented the successful treatment of any aspect of aphasia by context alone, without using repeated stimulation in that context. In terms of assessment, tests and procedures designed to capture the variability and the stimulability of the aphasic person on various linguistic and communicative tasks will offer greater possibilities for prediction and more precise descriptions of patient change.

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