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Phonological Disorders in Aphasia

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INTRODUCTION

Phonological disorders in aphasia can be defined as the difficulty or impossibility to transmit and/or receive information by means of spoken words, that is, the inability of aphasic subjects to produce and/or perceive words correctly, in the absence of damage to the articulatory production and peripheral reception mechanisms. As words are represented as a linear sequence of consonant and vowel units, phonological disorders may originate either from *paradigmatic* errors due to the systematic substitutions of segments or specific features or *syntagmatic* errors (i.e. inversions, exchanges, segmental unit perseveration or anticipation, etc.), due to the inability of an aphasic subject to maintain a correct serial order. Together with these errors, we need to include those related to phonetic implementation, which are errors of articulator-y production of phonological units in the absence of peripheral disorders, as well as errors associated to disorders of the central auditory mechanisms.

The task of identifying the various different kinds of disorders and understanding their cause may be achieved only by referring to a specific mental linguistic information representation model at a phonological level, which relates to the knowledge a speaker has of the phonological form of words, to the procedures used to process this information (i.e. selection, recalling, checking, correction, etc.) and the implementation of such knowledge by the speaker.

Throughout this chapter, we will refer to the most commonly accepted theories from both the linguistic field, namely the theory known as generative phonology (Chomsky & Halle, 1968), and the psycholinguistic field, involving the hierarchical serial model (Garrett, 1980; Levelt, 1989).

The adoption of one of the latest non-linear phonologies (e.g. Clements, 1985) or articulatory phonology (Browman & Goldstein, 1986, 1989), that propose important changes in the structure and ordering of phonological units, may provide a variety of innovative suggestions to help explain phonological and phonetic errors in aphasic subjects. Likewise, lexical word recalling mechanisms and the explanation ofsyntagmatic and paradigmatic error production would be different if a connectionist model were chosen (Dell, 1986; Dell and Juliano, I99 1; see also Levelt, 1989).

As far as the production of single words is concerned, the serial-hierarchical psycholinguistic model will be specified, whereas phonological suprasegmental disorders (intonation, phrase prosody, juncture) will not be dealt with here. We shall only mention the fact that an utterance is not merely a chain of words in their quotation form, but these are subject to prosodic and intonation variations that depend on linguistic choice factors such as sentence type and syntax structures, as well as on the communication of paralinguistic information, namely emotions and attitudes (Scherer, 1982, 1984). Our approach also provides a more precise description of problems concerning production relating to perception, since linguists and psycholinguists have dedicated a much greater attention to the coding process, and thus a greater amount of data is currently available.

According to traditional linear phonology theories, the phonological representation of a word consists of a sequence of distinctive sounds, graphically represented by means of IPA (International Phonetic Alphabet) symbols.

Phonemes, in turn, are represented as bundles of features, i.e. distinctive properties, identified by means of articulatory labels relating either to voicing (± voiced) or the position of the tongue (± high, ± low), or to the articulation manners (± continuant, ± delayed solution) and the articulation places (± coronal, ±back), according to the system of Chomsky and Halle (1968), or by acoustic-perceptive labels, according to Jakobson, Fant and Halle (1952), which in any case depend on articulation manners and places and on the presence or absence of vocal folds vibration.

No tnatter which feature inventory is actually adopted, a column of + or – signs is associated to each phoneme (see Fig. 10.1), indicating the presence or absence of a specific distinctive feature. This kind of binary classification system makes it easy to characterise the regularity of phonological systems such as, for instance, the identification of natural sound classes, or groups of sounds that have one or more common features (e.g. the ‘continuant’ feature identifies the stop consonantal phonemes /p, b, t, d, k, g/), and to quantify the differences between the phonemes (e.g. the ‘+ sonorant’ and ‘+ nasal’ features distinguish /m/ from /p/).

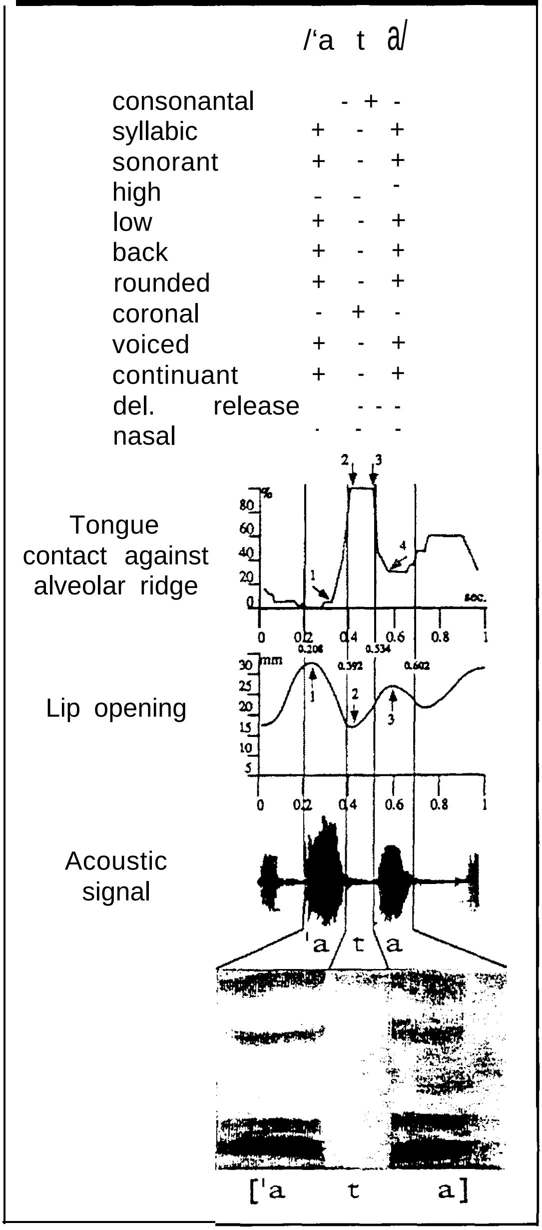
If the descriptive system of the features, intended as abstract, discrete elements, each independent from one another and timeless, is also adopted as a representation of the phonological competence of the speaker, it will be necessary to account for the processes that have been carried out starting from these features up to the production of movement of the various phonoarticulatory organs, in other words, to the phonetic implementation of phonological information (see Fig. 10.1).

The realisation of each phone requires the co-ordination of all the various organs (i.e. lips, jaw, tongue, velum, vocal folds and respiratory system) and their temporal organisation. For instance, consider the interval between the release of a bilabial, dental, or velar occlusion and the onset of vocal folds vibration, defined as the Voice Onset Time, or VOT. In addition, the movements of the articulator-y organs are extremely variable, even with respect to the same consonantal or vocalic target, due to the proximity of the elements that make up the phonetic chain. Co-articulatory phenomena, such as transitions between one target and another, and the anticipation or perseveration of features, for instance nasalisation or lip rounding, are determined by computational rules (Perkell, 1980) or by coproduction of dynamic gestures (Fowler, 1980, 1985).

These movements determine a change in the global shape of the vocal tract and therefore the production of an acoustic signal according to the acoustic speech production theory rules (Fant, 1960) both in terms of stationary spectrum characteristics (i.e. formant patterns in the vowels, friction noises, etc.) as well as transitions (i.e. spectrum changes between two sound segments). From the waveforms so produced, the listener will have to extract the abstract phonological representation, that is the speaker’s coded information, through various processing stages.

With serial hierarchical models (Garrett, 1980; Levelt. 1989) the passage from a linear sequence of phonemes that correspond to a word and from the relative feature columns to articulatory movements requires at least three processing stages, namely:

FIGURE 10.1



Relationship between the phonological representation and the phonetic realisation, i.e. the articulatory and acoustic signals, for /'ata/.

1. Recalling the phonological sequence that corresponds to a word.
2. Their insertion into a phrase positioning level representation (see Fig. 10.2) that makes provision for specification of serial word order and their morphological and prosodic structure, ordering segments in syllables and the application of allophonic rules. During this phonological encoding stage, the role of syllables is of considerable importance, due to the fact that they are considered as the ordering units of articulatory gestures, since the execution of these gestures depends upon their position within the syllable. A syllable consists of a nucleus, which for most languages is invariably a vowel, an *onset* (or starting point), that is, all consonantal material preceding a vowel, and a coda, generally a consonant that closes the syllable (see Fig. 10.3). This phonological unit is characterised by several internal regularities, the most important (and universal) being the "voicing scale", according to which the consonants with greater voice value are always located close to the nucleus, whereas the consonants situated at greater distance from the nucleus will be characterised by a lower degree of voicing.

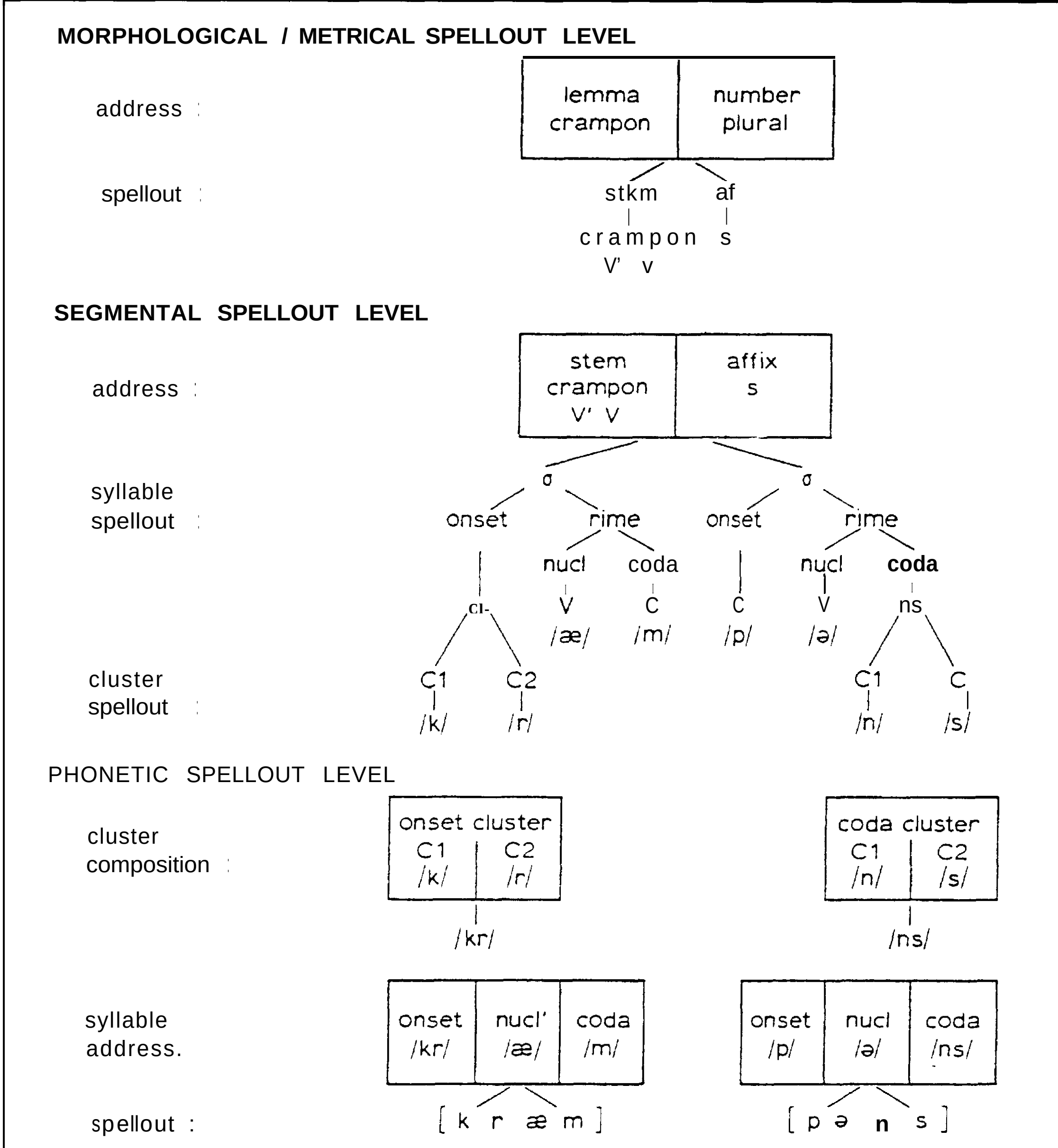
On the basis of the behaviour of syllable constituents in lapsus and their role in determining the "syllabic weight", even the syllable constituents have a hierarchical order (see Fig. 10.3) in the sense that the nucleus and the coda are the elements that combine to make up the *rhyme,* whereas only the onset maintains its role as an independent component.

Allophonic rules are also important: these are formal descriptions (which may vary from one language to another) of the structural changes that take place within the characteristics of a segment in a particular context. Allophonic rules include those referring to assimilation, dissimilation, cancellation and insertion.

The passage from the phonological form of a recalled word to the positional level of representation is performed by a "scan-copier" device (Buckingham, 1986: Christman, 1992) whose function is to select phonemes belonging to the word being produced, retrieving these phonemes from a memory buffer and placing them in the appropriate syllabic slots in the phonological phrasal frame. After having carried out this positioning process, a check-off system removes the copied phoneme from the processing memory to avoid copying the same segments a second time.

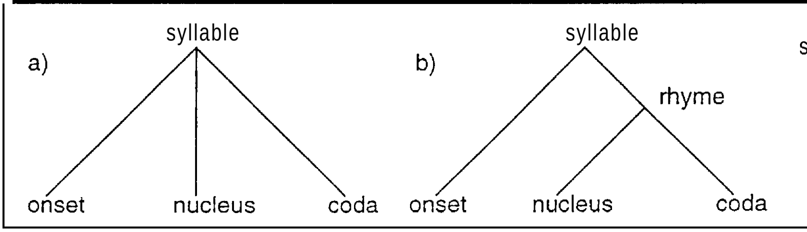
3. The result of the phonological encoding process is an abstract representation, often known as a phonetic plane, describing the manner in which the utterance will be performed. The information held by this phonetic plane, once placed inside the articulatory buffer, will need to be

FIGURE 10.2



Levels of processing in generation of phonetic plan for the word **"crampons"** (from Levelt, 1989).

FIGURE 10.3



Two different organisations of the syllable structure.

implemented in sequence, that is, the information has to undergo motory execution. According to phoneticians adopting the so-called "extrinsic timing" theories (Perkell, 1980: see also Levelt, 1989), even the final stage of phonetic implementation involves the application of a series of further processing operations, including a pre-planning of the temporal order, an articulatory reordering on the basis of feedback information, a predictive exploration to calculate the expansion of characteristics by assessing compatibility between features, and eventually determining the motory commands to be sent to the various articulators.

As far as perception is concerned, the serial-hierarchical computation approach assumes that acoustic signal processing is carried out in a number of stages, starting from the extraction of auditory and phonetic indices or cues and terminating with the identification of the phonological percept (see Pisoni and Sawush, 1975).

After the voice signal has been received by the peripheral auditory systems, the central auditory system performs the process of extraction and encoding of acoustic information, including the spectral structure, the fundamental frequency, the energy and the duration of the signal (Stevens, 1980). It is therefore possible to obtain an auditory representation of speech signals that may be used for phonetic classification operations. For instance, the voicing feature of a stop consonant located at the beginning of a phonetic chain is identified by the voice onset time (VOT), the transition frequency of the first formant and the energy of the explosion noise. This phonetic analysis stage is considered to involve the setting up of specific phonetic characteristic detection modules (see Darwin, 1976; Diehl, 1981; Jusczyk. 1986; Remez, 1994). In the stage that follows, phonetic representations are mapped onto distinctive features that may be considered as abstract perceptual and amnesic codes that represent both a set of acoustic attributes and their articulatory correlates. Therefore, the phonological processing stage produces information regarding the structure of specific sounds associated to the various spoken languages which, when applied to the phonetic matrix, makes it possible to obtain the phonological matrix (Chomsky & Halle, 1968). In other words, the phonological rules applied to the phonetic input determine the extent by which the phonetic segments serve as distinctive language elements and how well these attributes may be predicted by the specific rules pertaining to a single language or to universal linguistic principles.

These hierarchical models are also known as "constructive" models, owing to the fact that, for example, after having identified and distinguished the various acoustic cues, the stage that follows involves a synthesis of their meaning, which requires cognitive cues integration and/or separation operations to be carried out. Consider, for instance, the integration of explosion noise, transitions and vowel formant in the perception of stop consonants, or the perception of silence as an index of the recognition of the articulation manner and place, besides the VOT feature, or the definitions of category boundaries, the formation of units or prototypes, and so on. There is all the more reason for considering the phoneme identification as a cognitive operation: the listener learns to interpret two speech sounds or as perceptually equivalent (that is, belonging to one phonological category) or as distinct (that is, belonging to two different phonological categories). As a consequence of this categorical phonological perception it is generally difficult to discriminate two acoustically differing stimuli that belong to the same category (i.e. the allophones of a phoneme), while it turns out to be quite simple to distinguish phones (speech sounds) belonging to separate categories (/p/ and /t/). The listener thus breaks up the acoustic signal according to the phonological categories pertaining to his/her own language and ignores the unessential allophonic cues.

The phonological component is involved even in a series of cognitive tasks that are not strictly connected to the articulatory acoustic channel. This situation is referred to as phonological mediation, or specifically, the use of phonological information for processing the central levels of the language, both written and spoken. Examples of involvement of a phonological component (see Wagner & Torgasen, 1987) may be seen in the following cognitive abilities:

- Phonological awareness and information processing in tests such as: (a) distinguishing the single sounds that make up a perceived word; (b) building up a word from the single sounds provided separately; (c) reversing the order of sounds in a perceived word;
- Conversion of written symbols into a representation system that is based on sounds and enables lexical access. This ability is associated to the grapheme/phoneme conversion mechanism, a non lexical reading technique (see Denes, Cipolotti, & Zorzi, Chapter 14 of this volume);
- Conversion of written symbols into a representation system that is based on sounds and is suitable for temporary process memorisation for the time needed to process the information (see Vallar, Chapter 15 of this volume).

PRODUCTION DISORDERS

Phonological disorders in aphasia affect both segmental (phonetic and phonemic) and suprasegmental or prosodic (stress, rhythm, intonation) aspects of production. The latter, however, are affected to a much lesser extent. The main body of research refers undoubtedly to the segmental aspects. It is in this field, perhaps, that one can find the beginnings of neurolinguistics, with the appearance in I939 of an article by Alajouanine, Ombrèdane, and Durand. This was based, for the first time, on the collaboration between a neuropsychologist and a linguist (see Lecours & Lhermitte, 1976).

Investigation techniques

The analysis of the acoustical characteristics of produced sounds is made possible by the use of instruments that perform spectral analyses (for a description of these instruments see Ball, 1989). This technique is particularly useful in studies on articulatory disorders, and therefore more relevant to phonetic aspects.

A second technique focuses on the analysis of the movements of individual articulatory organs (tongue, velum, and msndibula) during the actual production of linguistic sounds. However, this method is not used very often in aphasiological studies, as it requires complex instrumentation. Two of these measuring techniques are described by Itoh et al. (1979, 1980). The first technique uses a television recording of the movements of the palate velum by means of optical fibres. The second allows the simultaneous movements of some articulators to be followed by using a computer controlled cineradiographical technique.

Finally, it is possible to transcribe phonetically what the patient pronounces, both according to the phonological aspect ("broad/wide" transcription) and according to the phonetic aspect ("tight" transcription), preferably using the IPA notation system. A source of variation which has not always been taken into consideration is the method of eliciting the patient's speech. Different contexts, for example naming, repetition, or spontaneous speech, lead to differences in the patient's performance (Blumstein, 1988; Kohn, 1985; see later).

Anatomy

When dealing with phonetic aspects, the fact that phonoarticulary disorders are not always of an aphasic origin is important. Such disorders can in fact originate after a complete and correct codification of the linguistic message.

A weakness or a muscular malfunctioning of phonoarticulary organs can be caused by a series of lesions which occur at different levels in the nervous system: bilaterally to the corticobulbar pyramidal tracts (at any level, up to the nuclei of cranial nerves which affect articulation), to the extrapyramidal system, to the cerebellum, and to the lower motoneurones. Articulatory disorders that follow this type of lesion are referred to as "dysarthria" (see Luzzatti, 1992; Whitaker, 1976).

On the other hand, the control over the codification of the verbal message is based in the left hemisphere. Lesions in the right hemisphere usually lead to transient difficulties in articulation, while articulatory problems due to lesions in the left hemisphere are much more serious and often permanent. This in spite of the fact that the undamaged right hemisphere can, like the left one, control the phonoarticulatory muscles bilaterally. It is not clear which function is connected to the thalamus, whose role is dealt with elsewhere in this volume.

Aphasiologists are essentially interested in the range of phonological disorders caused by lesions in the left hemisphere, on the assumption that their nature differs from those due to subcortical lesions. However, even in connection with lesions in the left hemisphere, as with subcortical ones, it is possible to find disorders that are exclusively of an articulatory nature even though, apparently, they are not due to an articulatory weakness. Such disorders, very rare in isolation, are referred to in various ways. The most used and the least ambiguous terms used to define them are "aphemia" (Goodglass & Kaplan, 1972) and "anarthria" (Marie, 1906). More often, this type of disorder is an essential component of more complex, non-fluent aphasia, such as for instance those that can be included in the classic term "Broca's aphasia". The clinical differences between dysarthria and articulatory disorders of aphasic nature are described later.

The clinical picture

The first aspect to be examined from a clinical point of view is the articulation. One should observe the degree and type of distortion with which the patient produces the different linguistic sounds, as well as the effort required to produce them. An absolute mutism can be observed in the acute phase of a CVA but, if it persists, in the majority of cases it is much more likely to be an indication of damage to the subcortical structures, rather than to the cortical ones.

Consonants are the sounds that are more likely to be distorted, especially if they are situated in the context of long or uncommon words, whereas vowels are in general better maintained. One characteristic of articulatory disorders in the case of aphasia is their inconsistency. A linguistical segment that at first had been distorted can be clearly pronounced either later, or in a repetition context. This is unlike dysarthria, where errors show much more constant characteristics. Even the production of serial language (alphabet, months of the year, days of the week, prayers, and poems) can be used when in doubt between dysarthric and aphasic disorders. In the case of aphasia the improvement of articulation under these conditions is much more evident. Finally, when in doubt between dysarthria and aphasia it is useful to check the written language, which a dysarthric person should not have any problems in using.

Aphasic errors in articulation, such as phonetic errors or phonetic paraphasias, consist of distorted sounds, allophonic variants, or sounds that do not belong to the speaker's language (see later for relevant research on their nature). Whoever wishes to transcribe these sounds must use not only the IPA notation system, but also diacritics in order to show possible modifications of correct production (e.g. nasalisation, lengthening, glottal attack). Note, however, that this description does not cover all the possibilities of articulatory disorders. The sound that is being produced as a consequence of the articulatory disorder may be a sound that is not distorted and which still belongs to the speaker's language. In this case, it is impossible to distinguish between phonetic and phonemic paraphasia.

A phonemic paraphasia does not involve the emission of unacceptable sounds, but consists, rather, of omissions, transpositions, additions, or repetitions of phonemes within a word. At times, more than one phonemic paraphasia is found within a word. In extreme cases, the word that is being heard is no longer recognisable, bearing no resemblance to the target word. In this case one refers to "neologism". Some (for example Butterworth, 1979) extend this term to all pat-aphasias to indicate that. in any case, one is not dealing with real words. On the other hand, this makes it just as important to distinguish between neologisms whose target is still recognisable and neologisms whose target is no longer recognisable. Amongst those whose target is still recognisable one must still single out those whose target is inferred from the context rather than from phonetic similarity. A speech that contains so many neologisms as to compromise entirely or almost entirely its understanding is called neologistic or phonemic jargon. The distinction between these two types, as well as the explanation of jargonaphasia, is neither clear nor well established (Alajouanine, Sabouraud, & de Ribaucourt, 1952; Brown, I98 I ; Butterworth, 1979). If one wishes to retain the label "neologistic jargon" , it seems possible to use it even when many real words (usually belonging to the "closed" class: "function words without their own specific meaning") are recognisable, and when the neologisms appear to substitute the "open" class lexical items (i.e. mainly nouns, verbs, and adjectives). In this case it would not just be a question of a purely phonological disorder, but also of a lexical one. "Phonemic jargon", on the other hand, would refer to an uninterrupted flow of neologisms. But it must be clear that the boundaries between the two different situations are often hard to define. On the question of production of neologisms see Buckingham. Whitaker, and Whitaker (l978), Butter-worth (1979). Brown (1981), and. for a comprehensive review, Buckingham (1988).

An interesting phenomenon is also the phonemic *"conduites d'approche"* which one encounters mainly in conduction aphasia. It consists of a collection of successive approximations to the intended sound which the patient produces in his/her attempts at self-correcting. It may or may not be successful. Both Blumstein (1973) and Joanette, Keller. and Lecours (1980) have studied these approximations and found that they often reflect a gradual and systematic change which usually concerns one segment at the time.

Research on phonetic impairment level

Such research aims at understanding if, how much, and, above all, how the sounds produced by aphasic patients differ from those produced by normal speakers. As has been said previously, this type of research uses mainly acoustic analyses, but interesting data have been obtained directly from the experimental study of phonoarticulatory movements.

The pioneering work of Alajouanine et al. in 1939 suggested that aphasic patients with anterior lesions showed a series of disorders labelled with the term "phonetic disintegration syndrome". In paradigmatic cases such a syndrome would gradually proceed from a first phase called *paretic* (whose characteristics such as malocclusion and affrication of stop-consonants are described in detail), to a post paretic phase, called *dystonic* (which would imply other phenomena such as the substitution of nasal vowels with oral ones, or the transformation of voiced consonants into voiceless ones).

This detailed analysis verified its main points by a spectrographic study carried out much later (Lehiste, 1968)-lacked, however, a clear acknowledgement of the aphasic, rather than motor nature of the disorder. The former, as further research has shown, arises specifically in the course of the production of linguistic sounds, without being supported by a weakness in the phonoarticulatory system. In fact no specific group of muscles seems to be weakened, contrary to Alajouanine et al. who mentioned paresis, postural rigidity, and dystonia. Moreover, it has become evident that these articulatory errors are varied and unreliable, another characteristic that hardly supports the hypothesis of motor damage. A similar line is followed in the conclusions drawn by Lecours and Lhermitte (1976) following a theoretic revision of the work of Alajouanine et al. Lecours and Lhermitte also noticed that the so-called *phonetic disintegration syndrome*, as it is described, would include disorders at the phonemic level.

Another assumption in Alajouanine et al. (1939) was later disproved. It suggested that the hierarchical sequence in the loss of phonetic functions would follow in reverse the sequence in which such functions are acquired during development. This theory was further developed by Jakobson (1956) but soon disproved, as far as the phonetic level was concerned, by Fry (1959) and Shankweiler and Harris (1966). The latter work, which used a repetition task, also proved that: (a) the phoneme that is most frequently affected is the initial one; (b) consonants, including fricatives and affricates are more affected than vowels; and (c) specific difficulties are encountered in the pronunciation of specific consonants.

These observations were followed by a series of studies aimed mainly at establishing a dichotomy between phonetic disorders and Broca's aphasia on the one side, and phonemic disorders and Wernicke's aphasia on the other. Currently, with descriptions based on classic syndromes no longer being carried out, these studies (De Renzi, Piezcuro, & Vignolo, 1966; Lecours & Lhermitte, 1969; Poncet, Degos, Deloche, & Lecours, 1972) still need to be remembered for their unanimous conclusion, already anticipated by Marie (1906): Broca's aphasia (and therefore an anterior/frontal lesion) produces phonetic disorders and phonemic errors, whereas the errors in Wernicke's aphasia that are exclusively of a phonemic type (although some exceptions that prove the rule will be mentioned later). The problem with discriminating between different aphasic syndromes also characterised, at first, studies that were based on the acoustic analysis of some specific phonetic parameters.

The VOT, as already mentioned corresponds to the time interval which, in the process of production of a stop consonant, elapses between the moment of opening of the vocal tract and the beginning of vibration of the vocal folds and, therefore, of sonorisation. The VOT's length systematically distinguishes voiceless from voiced occlusives in different languages.

Production of a correct VOT requires a specific time coordination between the actions of the articulatory and phonatory system, and it is this time sequence that becomes altered in some aphasic patients. In some aphasic productions of stop consonants the beginning of the first formant is no longer aligned with the beginning of the others in the pronunciation of a voiced consonant, and the interval that characterises voiceless consonants is no longer adhered to for the necessary time length. The consonant that is pronounced is something in between a voiced and a voiceless one, so that the listener is unable to identify it. In the spectrographic representation one can see a first formant of intermediate length. (Blumstein, Cooper, Goodglass, Statlende, & Gottlieb, 1980; Blumstein, Cooper, Zurif, & Caramazza, 1977; Hoit-Dalgard, Murry, & Kopp, 1983; Shewan, Leeper, & Booth, 1984; Tuller, 1984, all in anglophone aphasics; Itoh, Susanuma, Tatsumi, Murakami, Fukusako, & Suzuki, 1982, in Japanese aphasics; Gandour & Dardarananda, 1984, in Thai aphasics). It is interesting to note that there is no relation between these errors, which consist of an inappropriate variation of the VOT in initial position, and those produced by the same patient in post-vocalic sonorisation (Tuller, 1984).

The same studies have also shown that both Broca and Wernicke aphasics, when substituting a voiceless consonant with a voiced one (and vice versa), quite often do not produce intermediate sounds, but rather a consonant which is correctly produced but opposite to that of the original one with respect to the voicing. It is difficult to say whether these errors are of a phonemic nature and reflect, therefore, inappropriate choice of phoneme or distinctive feature, or whether they are of a phonetic nature and reflect therefore a mistake in articulation leading to the production of a sound that actually exists in the speaker's language. On the contrary, errors that produce "intermediate" sounds along the voiced/voiceless axis are undoubtedly of a phonetic type. On the other hand, when one analyses aphasic patients' errors which are based on a wrong place of articulation (still with regard to occlusive consonants: e.g. labial instead of alveolar) there is no record of "intermediate" sounds. According to Shinn and Blumstein, 1983, such errors appear to be, therefore, of a phonemic nature. In these patients, moreover, there are also difficulties in the production of alveolars, due to poor laryngeal control linked to only limited closure of the oral cavity.

In the analysis of phonetic errors, further information has been obtained by using the techniques mentioned earlier in order to register movements (articulatory dynamics, Itoh et al., 1979, 1980, 1983). It has thus been possible to establish that errors involving nasal consonants are derived from a premature lowering of the palatal velum and from a poor coordination between velar movements and those of tongue and lips.

In the same studies, it has also been noticed how Wernicke's aphasics tend to substitute nasals with occlusives (and vice versa) by means of perfectly correct movements corresponding to the substituting consonant.

Finally, Duffy and Gawle (1984) have shown that Broca's aphasics produce shorter than usual vowels.

The study of other parameters has shown that the problem underlying articulatory errors in aphasics does not concern the length of all articulatory components regardless. Some simple phonetic attributes appear to be very resistant to aphasic damage. For instance, the length of the vowels, even though decreasing, as mentioned earlier, normally varies according to the context. Similarly, the duration of vocalic phonemes which differ in the distinctive trait of their length is relatively normal (Gandour & Dardarananda, 1984). Even the fricative sound of voiced and voiceless fricatives and the duration of voiceless fricatives are normal in aphasic patients with phonetic disorders (Code & Bali, 1982; Harmes et al., 1984; Kent & Rosenbeck, 1983).

All of these results have led Blumstein (1988) to conclude that disorders of phonetic type seem to arise in aphasia when one requires an articulatory movement that necessitates the coordinated use of various independent articulatory structures, rather than in the articulation of individual phonetic traits.

At the end of the description of phonetic-level disorders it is necessary to note a contrast between Broca's and Wernicke's aphasia: the fact that detailed analyses have found phonetic errors even in the latter type of aphasia (Ryalls, 1986; Tuller, 1984) is probably a further corroboration of the limits that bind the use of the classic categories of aphasia.

A further example of problems arising from the use of classic categories comes from a study by Schiff, Blumstein, Ryalls, and Schinn (1985) on VOT, in which two groups of articulatory disorders within Broca's aphasia are singled out. A first group (defined as *uphemia)* consistently presented an early sonorisation, independently from the target in question. The production of the second group (defined as *apraxia ofspeech)* showed a much lesser consistency of error.

Coarticulation disorders

Only a few studies have queried whether aphasic patients show the same coarticulation effects as normal speakers. Two techniques have been used. The first consists in measuring the frequency of the formant in various pre-fixed positions of the sound wave, in such a way as to determine if and when the coarticulation effects appear. The second consists in gathering normal speakers' comments on sections of growing length from the beginning of a pronounced syllable (e.g. /si/ or /su/) whose final section has been removed. The aim is to establish at which point the listener is able to identify with certainty which vowel follows the initial consonant (in the previous example, for instance, when the listener is able to establish with certainty that the vowel that follows /s/ is /i/ or /u/). Normally, it is already possible to establish correctly which vowel will follow after 50msec from the beginning of the /s/.

Research on aphasics has shown that fluent aphasics pronounce in the same way as normal speakers. Non-fluent aphasics, on the other hand, show the effect of coarticulation with some delay (Katz, 1987; Tuller, 1987; Ziegler & von Cramon, 1985, 1986). It might therefore, take longer to identify the vowel that follows a consonantic phoneme when the syllable is pronounced by a Broca's aphasic than when the syllable is pronounced by a Wernicke's patient or by a normal speaker. In Broca's aphasics, moreover, the effect of coarticulation diminishes if the context to which the syllable belongs is longer than the individual syllable (Tuller, 1987).

Phonemic-level disorders

A series of cross-linguistic studies has shown a similar error pattern (Bouman & Grunbaum, 1925 and Lecours & Lhermitte, 1969, with regard to French; Bouman, & Grunbaum, 1925 and

Goldstein, 1948, with regard to German; Green, 1969, and Blumstein, 1973, with regard to English; Peuser & Fittschen, 1977, with regard to Turkish; Luria, 1966 with regard to Russian; Niemi, Koivusolka, Sallinen, & Hanninen, 1985, with regard to Finnish).

On the contrary, the study of the distribution of types **of** errors in different forms of aphasia (Broca, Wernicke, conduction), has produced contradictory results. Whilst Blumstein (1973) did not find differences in distribution, other authors (Dubois et al., 1964; Hecaen &Albert, 1978; Strub &Gardner, 1974), noticed a tendency in conduction aphasics (who nevertheless make all types of errors) towards sequence errors linked to the immediate context (e.g. transposition of phonemes). These distribution differences, however, only occur in some tasks (Nespoulous et al., 1987; Trost & Canter, 1974). In practice, this field lacks individual case studies that clearly show the dissociation of some types of errors and which reflect the selective destruction of a specific mechanism such as the (at the moment hypothetical) one responsible for the correct order of phonemes.

Other researchers (Blumstein, 1973; Canter et al., 1985; Green, 1969; Kohn, 1985; Nespoulous et al., 1984, 1987; Trost & Canter, 1974) have investigated the nature of substitution errors and have also tried to establish how much the erroneous production deviates from the target. The results are not univocal (the patients' tasks were very different) but two types of behaviour have nevertheless been identified. While, on the one hand, many aphasics (like normal speakers, see Shattuck, Hufnagel, & Klatt, 1979) more frequently make mistakes that only deviate from the target by one distinctive feature, some aphasics, usually conduction or Wernicke's, make a high percentage of errors that deviate by more than one distinctive feature. This latter data suggests that behind errors only one distinctive feature lies a disorder of production, in which the phonological representation is maintained. When, on the other hand, the deviation from the target is more than one distinctive feature, this would imply that the phonological representation is affected.

Unfortunately, as Blumstein (1988) points out, the results of these studies sometimes cannot be compared, as different criteria of analysis have been used for the distinctive features. Consider, for example, the substitution between /g/ and /d/. According to the theoretic system proposed by Chomsky and Halle (1968), the two phonemes are differentiated by two features, whereas, according to the feature system proposed by Jakobson, Fant, and Halle (1952), the difference would concern only one feature!

An explanation of a physiological type for some phonemic errors has been proposed by MacNeilage in 1982, on the basis of data by Trost and Canter (1974) which showed how voiced consonants were more easily substituted by voiceless ones, rather than vice versa. This effect was more evident towards the final position in the word, to such an extent that in the last position one could not find any substitutions from voiceless to voiced consonants. MacNeilage observed that, in a final position, the production of voiced consonants is more difficult than that of voiceless ones, due to the fact that the pressure of the air coming from the lungs is, at this point, reduced. This consideration would favour the idea that even phonemic paraphasias (or at least some types of them), would originate more from articulatory factors, rather than from a wrong "central" planning.

A last piece of evidence concerns another peculiarity of substitution errors. Already in 1973 Blumstein showed that the majority of consonant substitutions take place when the target consonant is isolated, in contexts such as CV, VCV, or VC, whereas few substitutions take place if the context is a group of consonants. This finding fits nicely with the hypothesis that the phonological representation in aphasic patients is relatively maintained, and that the errors occur mainly at the more peripheral stage of recalling at the stage of articulatory codification.

Phonemic disorders and their localisation within production models

Recent attempts at placing phonemic disorders within a model of linguistic production have not led to particularly positive results. At the moment, it does not seem possible to derive influences on the construction of more complex models than the existing ones. What follows is an overview of the present level of knowledge, together with some suggestions for future research. This account is made more complicated by the fact that, as observed, different models have been proposed, whose components are not always and not strictly comparable due to the lack of an identical representative content.

Additionally, one often lacks the information necessary to attribute errors to the malfunctioning of a single component in the elaboration processes, adding a further increase in uncertainty. The levels considered here, and which are contained more or less in all models, are those of phonological representation and a successive level at which the events that prepare the actual representation are realised. Disorders affecting levels preceding the latter do not produce noticeable phonological disturbances.

In fact, if there is a lack of access to the abstract form of the word *(lemma* stage, Levelt, 1989) there might be an omission, a semantic par-aphasia, a synonym, or, finally, a circumlocution. These errors are attributable to a lack of functioning of the semantic system, but can also reflect disorders of the phonological representation, possibly coupled with compensation strategies.

On the other hand, disorders involving the access to phonological representation (phonological lexicon or lesseme stage), would result in omissions, substitutions, or casual re-arrangements within the phonological characteristics of a word. For instance, a group of Wernicke's aphasics (Kohn, 1985) made errors that included a wrong number of syllables, exchanges in the position of phonemes, and addition of many phonemes or whole syllables that did not belong to the target word. According to Kohn, these errors were a sign of lack of access to a complete representation in the phonological lexicon. According to Butterworth (1979) some neologisms appearing after rather long pauses that follow the preceding word (even if relatively well formed according to the phonological rules of the speaker's language) are due to a generating mechanism which keeps the production fluent in order to compensate for a blockage in the access to the phonological lexicon.

In practice, however, if a patient does not produce anything, or only produces phonemes in meaningless sequences, it is difficult to establish whether the problem is in the access to the lemma or in the morphophonological formation.

When a patient is not capable of producing a word, he/she can, however, possess a certain amount of information which can vary from the initial phoneme to the number of syllables and the collocation of the stress ("tip of the tongue" phenomenon (Goodglass, Kaplan, Weintraub, & Ackerman, 1976). Similarly, some patients, even if they cannot produce the complete phonology of the word, are able to select from various pictures the two with which the name rhymes. These observations point to a difficulty at the stage where, once the lemma stage is overcome, the morpho-phonological form is being elaborated: the access to some components is reached, but not all information is available.

In order to distinguish the total loss of phonological information from an access problem, it has been proposed to observe the effects of phonological suggestions, which should not be effective if the loss of information is total. The proposal, however, might not be able to activate a partial representation (see, for similar deductions, the chapter on semantic-lexical disorders). At the moment, the theory on the effects of phonemic suggestions is too vague, and it is not clear at which moment of the elaboration process of a word such help can be effective, in normal speakers as well as in aphasic patients. However, a positive effect derived from a phonemic suggestion (as well as from a semantic one) indicates that the phonological representation is not entirely lost.

Similar observations apply to the consistency criterion proposed by Butterworth (1992) to distinguish errors that are attributable to a phonological representation from errors due to poor transmission and preparatory planning of the articulation. A consistency in the type of errors (and for this reason tests repeated on the same items would be advisable) would point to representation problems. A lack of consistency does not seem to provide as much information, as it could result from different attempts at overcoming the lack of information produced by an incomplete representation. Once again, one can only notice the similarity between these problems and those present in the field of semantic-lexical disorders.

Once a complete morpho-phonological form has been reached, the various models agree, as noted earlier, on the existence of a process of translation and planning prior to the articulation. The process is complicated because it implies the insertion of morpho-phonological representations within sentences, and the integration with prosodic aspects. To make things simpler, all of these operations will be considered as if they all related to one level.

The most affected type of aphasia is, in this case, conduction aphasia. Once more, the classification is guided by error analysis. At this point, one considers as typical errors those that are to be phonologically very close to the target. The presence of phonemic conduites d'approches also seems to indicate that the phonological representation has been constructed, but there is a difficulty in realising it at a prearticulatory level. Equally, there is agreement in placing the effects at this level when the same mistakes are noticed in different tasks, such as repetition and reading aloud. In these cases, the phonological representation is provided and therefore one cannot assume a problem of access or loss. There remains the possibility of a problem in the translation and planning towards the articulatory level. In these cases a clear length effect (Bub, Black, Howell, & Kerstesz, 1987; Caplan, Vanier, & Baker, 1986; Howard, Patterson, Franklin, Morton, & Orchard-Lisle, 1984; Miller & Ellis, 1987) has been noticed. The number of syllables, in particular, turns out to be critical. Complex consonant groups often present greater difficulty than simple consonants. Words that require complex syllabification rules present greater difficulty (Beland, Caplan, & Nespoulous, 1990). Errors are influenced by lexical frequency (McCarthy & Warrington, 1984: Pate, Saffran, & Martin, 1987), whereas they do not seem to be influenced by factors such as abstractness or imageability. At this level phonemic pat-aphasia almost never affects function words, whereas no differences have been observed among the various types of open class words (Caplan 1992). Caplan (1992) points out that errors that emerge due to malfunctioning of the preparatory level of articulation are not frequent in normal speakers within the context of single word production. Beland, Caplan, and Nespoulous (1990) propose a detailed description of some events which would follow each other in determining errors at a level that precedes the articulatory one and follows the formation of representation. Their theory is based on the fact that phonemic errors respect the relationships between three different levels of the phonological structure: phonemic segments, syllables and stress. In almost all types of phonemic aphasia, in fact, stress and syllabification are appropriate for the phonemes being used. Therefore, a phoneme being used incorrectly (for instance instead of another one), or unnecessarily added, activates a different syllabification and different stress (appropriate to itself and to the new context, but not necessarily to the phoneme that has been substituted, or to the old context). This re-elaboration could be very complex, and could result, through a *chain* mechanism, in further errors at phonemic level. The importance of Belan, Caplan, and Nespoulous (1990) lies mainly in the specification of the phonological representation not only in terms of phonemic-segmental contents, but also in terms of syllables and stress. They also attempt to check all the restrictions imposed by a system that is itself based on errors. The same patient can present different errors if these are made in isolated single words or in a phrase context. The most comprehensive study on this subject is perhaps by Kohn and Smith (1990), who describe a patient who made more errors with vowels than with consonants while repeating phrases, but made the same number of the two types of mistakes while repeating single words. When repeating phrases, the typical error made by the patient was the substitution of the vowel in one word with the vowel from a word close by. Kohn and Smith interpreted this deficit as being due to a persistency of the phonological information at the level of the exit phonemic buffer. A patient observed by Pate, Saffran, and Martin (1987), on the other hand, made identical mistakes in any condition. It appears therefore that phonemic paraphasia can arise both with regard to problems concerning the planning of a single word and those concerning the planning of a sentence.

An unusual case of conduction aphasia committing more errors on vowels than on consonants has been reported by Romani, Granã and Semenza (1996). This finding was found to demonstrate, in line with recent phonological theories, that vowels and consonants occupy different levels of representation.

Phonological problems in the repetition of words and nonwords

In neurolinguistics, repetition tasks are useful for two reasons:

1. They are used to classify classic syndromes. Note, for instance, that good repetition distinguishes sensorial transcortical aphasia from Wernicke's aphasia, while poor repetition is the most distinctive sign of conduction aphasia (see Chapter 8 by Cappa & Vignolo).
2. They help to establish the site of the functional defect within the cognitive level, as explained later.

It is usually easier for an aphasic patient to repeat a word spoken by the examiner, than while reading or naming, helped by the fact that, within the repetition context, it is not necessary to activate a phonological representation starting from a conceptual or semantic representation. Moreover, when articulating, it can be easier to plan a word whose phonological form is provided in aural form rather than to start from the abstract phonological form, which is in turn activated by the conceptual-semantic form. It is evident from the ease with which nonwords are repeated that it is possible to repeat by purely sublexical phonological means, avoiding the activation of semantic representations. In the case of word repetition, the semantic representation is instead automatically activated. McCarthy and Warrington (1984) clearly show from the examination of two patients the independent use of the nonsemantic and the semantic lexical routes. Some conduction aphasics showed that they could repeat phrases with a high semantic content better than phrases with a nontransparent semantic content, such as cliches ("to take with a pinch of salt"). However, cliches have the advantage, compared to other possible phrases, of presenting themselves in a consistent form, which helps the activation of the phonological lexical form. A transcortical motor aphasic was found to be advantaged in reproducing cliches in comparison to other types of phrases, a double dissociation that proves the independence, as far as repetition is concerned, of the semantic route from the nonsemantic one.

Repetition tasks can be affected by problems either at the *input/output* level of the stimulus, or at the *exit* level. If the problems are at the entry level (difficulty in lexical decision or phoneme discrimination tasks) they will not necessarily be associated with disorders relating to naming pictures or reading aloud. Problems at the exit level, on the contrary, should be similar, as these tasks have a *common output.*

Repetition problems will also arise in the case of damage to the phonemic buffer, i.e. the system of short-term memory that holds the exit information from the phonological lexicon for as long as it is necessary for a complete re-elaboration. Disorders in this system affect in the same way words and nonwords in all tasks which require the production of spoken words (therefore not only repetition tasks, but also reading aloud, naming etc.). A disturbance in the phonological system itself on the contrary, does not involve a repetition deficit, which can take place through nonlexical means.

What has been said so far is valid if it is assumed that there is no interaction between lexical and nonlexical elaboration, and therefore between lexicon and output phonological buffer. If this interaction exists, it is possible (Caplan, 1992), in the case of damage to the phonemic buffer, that the repetition of nonwords is more difficult than that of words, in spite of the fact that the buffer is equally involved in both types of words. The superiority effect of the word would thus be explained by a *spreading activation* type mechanism in reverse: nonwords would activate words, but with the risk of adding phonemes that do not exist in the target word. Vice versa, other words, although being activated, would be subjected to a lateral inhibition and would not therefore disturb the target word. The effects observed in some patients who presented a selective difficulty in the repetition of nonwords would therefore be explained (Caramazza, Miceli, & Villa, 1986).

Prosodic disorders

Prosody provides the listener both with information of emotive type and with information concerning the linguistic aspects of a message. Three types of acoustic characteristics distinguish the prosodic, emotive and linguistic aspects of discourse: fundamental frequency (FO), intensity, and temporal rhythm (given by pauses and syllable duration). An example of how prosodic information may vary is given by the difference between questions and statements: the fundamental frequency decreases towards the end of the sentence in a statement while it rises in a question. This implies that, as prosody indeed contains information of a grammatical nature, it can provide clues as to the ability of the speaker to plan a sentence.

The relatively few studies on this aspect are clearly summarised by Blumstein (1988):

- Some aphasics (such as Broca's) who are capable of planning sentences consisting of 3-4 words show a fall of the FO towards the last word in the sentence, but this last word is not lengthened as usual (Danly et al., 1979).
- Again in Broca's aphasics, normal effects such as the rise and fall of the FO, as well as the lengthening of the last word, disappear when the sentence reaches 7-l 4 words (Danly & Shapiro, 1982). These prosodic disorders seem to reflect the fact that such aphasics are not able to plan the syntactic structure of a sentence.
- Results on the possible variations of the fundamental frequency are contradictory. Whereas some authors (Cooper et al., 1984; Ryalls, 1982), whose findings agree with the clinical impression of considerable prosodic flatness, find a reduced FO variability in Broca's aphasics, others (Danly & Shapiro, 1982) observe an excessive variability.
- Apart from rare exceptions, Wernicke's aphasics seem to respect prosodic parameters (Shapiro & Danly, 1985). However, in some of Wernicke's aphasics small difficulties have been noticed, such as an increase in the FO's adjustments to the syntactical context (Danly et al., I983), while the same adjustments are not present in other situations (Danly et al., 1983). However, these data are related to reading tasks and it is not clear whether spontaneous speech is equally impaired (if not, perhaps the explanation of these phenomena should be related to problems within the reading mechanism).
- With regards to the connection between prosody and hemispheric lateralisation, one can reach the following conclusions that concern both the productive and the receptive side (Emmorey, 1987). Prosody in itself is not controlled by one hemisphere. However, when prosodic parameters convey linguistic information, they are elaborated by the left hemisphere. It is possible to show a dissociation between different components within the prosodic system following cerebral damage. In particular, the ability to use duration seems to be recovered more quickly after damage to the left hemisphere, when compared to the ability to produce a correct intonation pattern. With regards to prosody disorders linked to a lesion in the right hemisphere, see Ross (198 1).

Foreign accent syndrome

In the course of the last 50 years about 10 cases have been described that are characterised by a difficulty, following a left hemispheric lesion in producing phonetic and phonemic contrasts typical of one's own mother tongue (Blumstein at al., 1987; Monrad-Krohn, 1947). As a result, the patient acquires a different accent (pseudo accent, Lecours, Lhermitte, & Breious, 1983; *non-learned foreing accent,* Graff-Radford at al. 1986) sometimes with embarrassing consequences. One Norwegian patient, described by Monrad-Kron (1947) started to speak with a German accent during the German occupation! The *Foreign Accent Syndrome* (FAS) must not be confused either with dysarthric disorders or with prosodic disorders following a lesion in the right hemisphere (Ross, 198 1). In this connection, it is useful to remember that even the most serious aphasics, within the context of an extremely reduced verbal production, maintain their regional accent. Although pure FAS cases have been described, in the majority of cases the FAS is linked to an aphasic context often characterised by transitory or short-term agrammatism. Sometimes the symptom manifests itself when the patient has re-acquired an adequate functional communication with normal verbal fluency.

Studies on the prosodic and segmental dimensions of the utterance in FAS patients have shown a mixture of both segmental and suprasegmental deficits. However, as opposed to articulatory disorders in dysarthric or aphasic patients in which there is a violation of phonetic parameters common to all natural languages, the FAS patients' production is characterised by the presence of VOTs that are absent in the mother tongue but present in other natural languages, and whose nature can be referred back to a prosodic deficit, with disorders relating both to prosody itself and to rhythm (Blumstein at el., 1987).

COMPREHENSION DISORDERS

In the introduction to this chapter it was noted that the perception of spoken language is the result of the elaboration of the acoustic signal at different levels, both aural and linguistic (phonetic and phonological), linked to auditory specific neuronal systems which are mainly situated in the left hemisphere. These systems can be affected both selectively and, more frequently, at the same time as neuronal structures responsible for the elaboration of other linguistic parameters. It follows, therefore, that a disorder in the elaboration of linguistic sounds is often associated with a more general aphasic framework. According to Varney (1984) more than 20% of aphasic patients show disorders in the elaboration of words, at an acoustic and/or phonological level.

Lhermitte et al. (197 I) suggested the term *central acoustic disorder;* later also used by Kanshepolsky. Kelley, and Waggener (1973) and Miceli (1982), as the most suitable to describe a deficit in the elaboration of acoustic stimuli which follows supratentorial cerebral damage. This term can cover a disorder in the elaboration of linguistic and nonlinguistic sounds *(cortical deafness,* Henschen, 19 16), a selective impairment in the recognition of verbal sounds (*pure verbal deafness* or *verbal acoustic agnosia,* Lichteim 1885) and, finally, a deficit in the recognition of meaningful verbal sounds *(acoustic agnosia,* Vignolo, 1982). The term *central acoustic disorder* is intentionally ambiguous as it does not imply a definite position either concerning the relation between the aforementioned disorders, or the nature of the deficit. According to some authors, there is a continuum between these disorders, within which cortical deafness represents the most severe degree. Cortical deafness often evolves towards acoustic agnosia and/or verbal deafness. Moreover, acoustic agnosia and verbal deafness often coexist and the character of this symptomatological complex fades therefore into cortical deafness.

Other authors, however, maintain that these deficits should be more clearly distinguished. According to Michel, Perronet, and Schott (1980), cortical deafness is due to an anatomic and functional disconnection of the auditory cortex from acoustic impulses, whereas verbal deafness and acoustic agnosia follow a selective disorder, of perceptive or associative nature, in the auditory cortex.

Anatomy

The fibres originating from the medial geniculate bodies (MGB), project to the primary acoustic area through acoustic radiations which pass through the sublenticular portion of the internal capsule.

Using the primary evoked responses technique, Liegeois et al. (199 1) have been able to map the human primary auditory area with precision, situating it in the postmedial region of Heschl's gyrus. As well as those to the primary acoustic area, there are other projections from the MGBs to different cortical areas, including the posterior two thirds of the superior temporal gyrus and frontal and parietal opercula. A persistent auditory deficit will be produced only following a bilateral lesion that interrupts all projections from MGBs to the cortex (lesion of the ventro-lateral white matter to the posterior side of the putamen, Tanaka et al., 1987).

Auditory deficits

As explained earlier, a bilateral lesion of central, cortical, or subcortical acoustic tracts rarely leads to a serious and persistent auditory loss (cortical deafness). In the majority of cases only slight audiometric deficits remain. These are accompanied by more or less serious disorders in the ability to understand the meaning of both linguistic and nonverbal sounds. According to Tanaka et al. (1991) the relevant literature reports only six cases of cortical deafness still persisting, with no variation, six months after its onset.

Subclinical deficits of auditory ability following a bitemporal lesion have been described by Albert and Bear (1974); Chocholle et al. (1975); and Auerbach et al. (1982). These include disorders in temporal discrimination (Albert & Bear, 1974), in the ability to place the source of sounds (Chocholle et al., 1975). A significant link between unilateral (both left and right) temporal lesion and a deficit in the appreciation of variations in the intensity of nonverbal stimuli has recently been demonstrated by Blattner, Scherg, and von Cramon (1989).

An impairment in the perception of physical characteristics of the acoustic stimulus, consisting in a selective difficulty in perceiving very rapid variations of acoustic stimuli (both verbal and nonverbal ones), has been suggested by Tallal (Tallal & Piercy, 1974, 1975; Tallal & Newcombe, 1978) as the basis of comprehension deficits in both developmental and acquired aphasia. Tallal and Newcombe (1978) gave a number of patients with left hemisphere lesions the task of identifying a pair of synthesised syllables (/ba/ ;/da/) which varied in relation to the direction of the second formant's transition. One pair of syllables was characterised by short (40msec) transitions on all formants, while the other had longer transitions (80msec). In comparison to normal speakers, the patients significantly failed in the identification tasks involving syllables characterised by short transitions, while the lengthening of transitions led to a significant improvement in identification ability. The subjects who showed a deficit when dealing with syllables containing short transitions also had a similar difficulty in distinguishing the presentation sequence of two tones when there was a very short interval between the two stimuli (8-305msec). The latter deficit was significantly correlated to a failing of the Token Test. On the basis of such data, Tallal and Newcombe (1978) suggested a causal chain starting from a disorder in appreciating very rapid variations of nonverbal acoustic stimuli, followed by a deficit in the perception of phonetic contrasts signalled by rapid transitions in the formants, and culminating in a disorder in language comprehension.

Similar deficits have been found in some cases of cortical deafness. Jerger, Weikarks, Shartrough, and Jerger (1969) suggested that at the basis of the syndrome was a deficit both in intensity discrimination and in the ability to perceive the presentation order of acoustic stimuli. According to Albert and Bear (1974) the syndrome is due to a specific problem with auditory resolution ability, and with the ability to perceive the stimuli in the correct time sequence. According to this hypothesis, cortical deafness does not therefore necessarily imply an anatomic disconnection of the acoustic cortex. This is confirmed by the fact that in some cases of both cortical (Motomura et al., 1987) and verbal (Denes et al., 1986) deafness only the late components of the evoked responses are absent or distorted.

In 1960, Landau, Goldstein, and Kleffner described a case of verbal deafness without macroscopically evident lesions and associated with epileptic crises and behavioural problems. Since then, about 80 cases have been described (see Denes et al., 1986, for a review). The syndrome appears between the ages of 18 months and 13 years, but mostly between 4 and 7 years. Contrary to developmental aphasia of vascular or traumatic origin, the most evident symptom is the comprehension deficit. In spite of the hearing deficit, however, the patient can sometimes learn and communicate effectively by means of the written language. The etiology of the syndrome is unknown and laboratory tests (CSF and CT scan) have proved to be negative.

Disorders at the acoustic-phonemic level

In a study that turned out to be fundamental for the understanding of the nature of phonologic deficits in aphasia, Blumstein et al. (1977b) described two types of deficits in acoustic-phonetic elaboration. When undergoing a test for the discrimination and identification of synthetic phonemes differing only by a single acoustic parameter (Voice Onset Time, VOT), some aphasic patients showed a discrimination deficit (that is, they were not capable of deciding whether two phonemes, /pa/ and /da/ for example. were the same or different). However, for the others the deficit was only limited to the identification of the phonemes. Blumstein et al. suggested that the ability to use phonological information in a linguistically relevant way (i.e. in order to identify a phoneme) is preceded by a stage in which perceptual characteristics, such as VOT or other acoustic parameters necessary for the categorisation process, are extracted. Deficits at prephonemic and phonemic level were thus distinguished. A reduced discrimination ability is present in a large number of aphasic patients, especially in the acute phase (Varney, 1984). Moreover, phonemic pairs that differ by just one distinctive feature are more difficult to discriminate than pairs that differ by more than one feature (Baker, Blumstein, & Goodglass, 198 1; Blumstein, Baker, & Goodglass, 1977a; Basso, Casati, & Vignolo, 1977; Blumstein et al., 1977b; Miceli et al., 1980).Vocalic sounds are usually easier to discriminate than consonant sounds (Shankweiler & Studdert-Kennedy, 1967), perhaps because of the physical characteristics of the stimulus (steady state of vocals as opposed to rapid transitions in consonants). The articulation place feature is perceptively more difficult than the voicing feature. According to Miceli et al. (1980) this finding is related to the physical characteristic of the different features. While voicing is linked more closely to acoustic invariants and less dependent on the context, the articulation place requires a greater restructuring of the signal, as it varies according to the context. Finally, occlusives are more easily discriminated from each other than fricatives (Caplan, 1992).

A deficit in pre-phonemic elaboration has been shown in some cases of verbal deafness by Auerbach et al. (1982). They suggested that verbal deafness might be due to two distinct deficits, prephonemic and phonemic. The first, more frequent, type follows a bilateral temporal lesion. On the other hand, a selective deficit of the processing at phonological level (characterised by a selective inability to identify linguistic sounds: see Caramazza et al., 1983; Saffran et al., 1982) is at the basis of the second type of verbal deafness, following a unilateral left temporal lesion (Chocholle et al., 1975). Finally, a compromise position, that at the basis of the syndrome there is a concomitance of auditory and phonetic deficits, is proposed by Praamstra et al. (199 1).

As for the *phonological level,* aphasia, even in the presence of normal discrimination abilities, gives rise to a reduced performance in tasks requiring the identification of consonantic phonemes, especially if the latter belong to the occlusive class (Basso et al., 1977; Blumstein, Cooper et al., 1977b). Wernicke's aphasics seem to show the greatest difficulties. However, a significant correlation between phoneme identification disorders and language comprehension deficits has not been found.

Similar results were obtained by Riedel and Studdert Kennedy (1985) who in a group study investigated the relation between discrimination and identification, on the part of aphasics, of occlusive phonemes differing in the articulation point: discrimination proved to be significantly easier than identification, independent of the type of aphasia or of the severity of the language comprehension deficit.

Acoustic agnosia

This term refers to a deficit in the recognition of significant nonverbal sounds in spite of normal peripheral hearing (Vignolo, 1982).

From a clinical point of view, it is important to distinguish the inability to associate a significant sound with the correspondent sound source from a naming disorder specific to the hearing modality (Denes & Semenza, 1975). The term acoustic agnosia is obviously applied only in the first case.

The relevant literature reports both generalised disorders in sound recognition, and selective deficits such as the inability to recognise human voice *(phonoagnosia*, Van Lancker, Cummings, Kreiman, & Dobkin, 198 1), onomatopoeic sounds and/or animal sounds (Assal & Aubert, 1979).

These deficits are usually observed in association with aphasia (Vignolo, 1982) and only exceptionally have they been found in isolation, either as a result of cortical deafness (Lambert et al., 1989; Motomura et al., 198 1) or appearing as such from the beginning (Spreen, Benton, & Fincham, 1965).

As in the case of cortical deafness, in the majority of cases the lesion is bilateral temporal, although some cases of acoustic agnosia following a right temporal lesion have also been described.

As to the nature of the deficit, opinions differ. According to Vignolo (1982) the acoustic agnosia that is present in aphasia is nothing but the epiphenomenon of a more general nonverbal conceptual deficit. Others favour instead the hypothesis of the presence of a psychoacoustic deficit in which the mechanisms of linguistic elaboration of the acoustic signal are maintained.

In pure acoustic agnosia, the dissociation between the perception of verbal and nonverbal sounds seems to confirm the hypothesis proposed by Blumstein, Baker, and Goodglass (1977a), and Riedel and Studdert-Kennedy (1985) who suggest that auditory information can be elaborated according to acoustic or linguistic parameters differing functionally and, perhaps, anatomically.

Phonological deficits and language comprehension

On the basis of a series of clinical observations, Pick (193 I), Kleist (1962), and, more recently, Luria (1970), have suggested that the comprehension deficit found in aphasia is linked to a specific disorder in the perception and discrimination of phonemes. The most explicit position, by Luria, is that the nucleus of sensory aphasia consists in the loss of phonemic *hearing*, leading to the inability to perceive the distinction between phonologically similar linguistic sounds.

However, experimental studies in the last 20 years have provided only a partial confirmation of Luria's hypothesis. If, as mentioned earlier, aphasics (in comparison with control groups and with left hemisphere damaged patients) have shown a reduced ability to discriminate both nonlinguistic acoustic stimuli and specific acoustic parts of the vocal signal, on the other hand not everybody agrees on the importance of such deficits in the linguistic categorisation of phonemes and on language comprehension in general. While Saffran et al. (1976) Auerbach et al. (1982), and Albert and Bear (1973) suggest, on the basis of some individual cases, that deficits in acoustic-phonetic elaboration might be responsible for a reduced ability in oral language comprehension, no correlation (or only a weak one) between phoneme discrimination ability and auditory comprehension was found in group studies by Basso et al. (1977), Miceli et al. (1980), and Gandour and Dardanaruda (1982).

Even regarding the relation between phonemic deficit and type of aphasia, recent studies do not support Luria's hypothesis. Suffice to say that Pizzamiglio et al. (Pizzamiglio & Parisi, 1970; Pizzamiglio, Appicciafuoco, & Razzano, 1976) do not find any significant differences in phoneme recognition tasks between different types of aphasia.

The lack of correlation between phonological deficits and auditory comprehension deficits can be due, as Blumstein (1992) points out, to different factors: in auditory comprehension under natural conditions the possible impact of a perception deficit is revealed only within the context of considerably long and complex speech. An investigation that is based only on the perception of isolated phonemes cannot therefore represent a sufficient indication of phonological competence. Moreover, the extraction of meaning from an auditory signal requires not only the perception of segmental indices, but above all the perception of auditory patterns of whole words (Klatt, 1980). Finally, the notion that the auditory comprehension deficit can be due to the inability to associate the acoustic representation to the meaning is also crucially important.

Starting from these premises, Blumstein at al. (Baker et al. 1981; Milberg, Blumstein, & Dworetzky, 1988) have postulated the existence of a close interaction between phonological and semantic factors in the word comprehension process. In particular, Baker et al. have demonstrated that the perceptive deficit, which can be absent in purely perceptive tasks, manifests itself when the semantic charge increases. In a modular view, therefore, Blumstein (1987) suggests that the phonological view is not functionally autonomous, but rather closely connected to higher elaboration levels, of the lexical-semantic type.

THE RELATIONSHIP BETWEEN PRODUCTION DISORDERS AND COMPREHENSION

Alajouanine et al. (1964) were among the first to experimentally investigate the relationship between production disorders and phonological comprehension in aphasia, finding a close correlation between the presence of phonemic jargon and disorders in phonemic discrimination and identification.

On the other hand, Gainotti, Caltagirone, and Ibba (1975) found a rather uncertain connection between phonetic disorders in production and comprehension. Their study, carried out on unselected aphasics, showed only a nonsignificant tendency to make more phonemic discrimination errors on the part of Wernicke's aphasics, whose production was characterised by phonemic rather than semantic errors (in their terminology phonemic Wernickes as opposed to *semantic Wernickes)*. The studies quoted so far used linguistic material which was more complex than individual phonemes (i.e. using words that were different or the same depending only on the initial phoneme). Studies using synthesised syllables were carried out, instead, by Basso et al. (1977) and Blumstein et al. 1977b). In the first, a correspondence between identification deficit and phoneme production was found. The second, more complex, study was based on the identification and discrimination of VOT at perceptual level, and on the spectrographic study of VOT in production. Due in part to methodological difficulties (limited number of patients) it was not possible to establish any link between production deficit and VOT comprehension.

Finally, a study by Miceli et al. (1980) demonstrated that if, on the one hand, aphasics with a phonemic production disorder on the whole show a greater impairment in phonemic discrimination compared to other aphasics, on the other hand there is no correspondence between the severity of the production disorder and that of phoneme discrimination. Moreover, the examination of individual cases has shown that some patients with a marked impairment in the phonemic level of production do not have any problems in discriminating between phonemes. The authors interpreted their results in the following way: while some patients who are simultaneously affected both in production and discrimination of phonemes have suffered damage to phonological integration, in other patients with a selective deficit in discrimination or production, it is the entry or exit channel that is affected accordingly. The problem with this interpretation is that the properties of the central elaborator, whose existence is only inferred by the coincidence in the disorders rather than being independently proven, are not sufficiently specified.