6
Asymmetries Between Perception and Action

> Many psychologists, including the present authors, have been disturbed by a theoretical vacuum between perception and action. The present volume is largely the record of prolonged—and frequently violent—conversations about how that vacuum might be filled.
>
> (Miller et al., 1960, p. 11)

> Roughly speaking, the listener has to reverse the process of speaking.
>
> (Bierwisch, 1966/1985, p. 123)

The present book has so far concentrated mainly on symmetries or similarities in the structures and processes for perception and production. Mental nodes represent the main structural symmetry, and these shared theoretical components for perception and action contribute to empirical symmetries such as the Freudian error symmetry (see also Chapter 2). The Freudian error symmetry refers to the virtual indistinguishability of Freudian misperceptions versus misproductions. Compare these examples: *carcinoma* substituted for *Barcelona* by someone preoccupied with the disease, and *battle scared general* substituted for *battle scarred general* by a speaker believing the general to be scared of battle (see Chapter 4). One error is a misperception, and the other is a misproduction, but it would be difficult for an otherwise uninformed observer to tell which was which.

The fact that perception and production share identical microprocesses (e.g., priming and activation; Chapter 1) represents the main processing symmetry in the node structure theory. This **microprocessing symmetry** contributes to empirical symmetries such as the fact that speed or rate of processing trades off with errors in the same way for both perception and production. Misperceptions and misproductions increase with rate of processing, because priming must summate over time before an appropriate node can be activated. In comprehending the word *Barcelona*, for example, its lexical content node, *Barcelona*(noun), must acquire greater priming than any other (extraneous) node in its domain when its activating mechanism is applied. Because extraneous nodes receive priming which approximates a *random* distribution at any point in time, whereas the appropriate or summating-from-below node receives priming which increases

Asymmetries between perception and action. Ch 6 (pp. 111-125) in MacKay, D.G. (1987). *The organization of perception and action: A theory for language and other cognitive skills* (1-254). Berlin: Springer-Verlag.

systematically over time, the appropriate node eventually acquires more priming than these extraneous nodes if priming is allowed to accumulate for long enough. Thus, reducing the time available for summation increases the likelihood of error, because errors occur when the appropriate node lacks sufficient time for its summated priming to exceed that of all other nodes in its domain when the activating mechanism is applied. This same summation process also explains the greater frequency of misperceptions on word-middle than word-initial segments (Chapter 4) as well as speed–accuracy trade-off in production (Chapter 3).

However, many phenomena are asymmetric between perception versus production, and theories must explain asymmetries as well as symmetries. The present chapter concentrates on asymmetries and shows how they arise from structural and processing asymmetries in the node structure theory. Table 6.1 provides an overview of the theoretical symmetries and asymmetries together with the empirical symmetries and asymmetries to which they contribute. To

TABLE 6.1. A summary of symmetries and asymmetries in the node structure theory and the empirical symmetries and asymmetries to which they contribute.*

Symmetries in the Node Structure Theory	
I.	**Mental Node Symmetry**
	Freudian Symmetry
II.	**Shared Microprocess Symmetry**
	Speed–Accuracy Symmetry
Structural Asymmetries in the Node Structure Theory	
I.	**Muscle Movement Asymmetry**
	Stuttering Asymmetry
II.	**Sensory Analysis Asymmetry**
	Masking Asymmetry
III.	**The Uniqueness Asymmetry**
	Sequential Domain Asymmetry
	Garden Path Asymmetry
IV.	**The Linkage Strength Asymmetry**
Processing Asymmetries in the Node Structure Theory	
I.	**The Priming Summation Asymmetry**
	The Maximal Rate Asymmetry
	Phonological Similarity Asymmetry
	Sequential Error Asymmetry
	Position-Within-a-Word Asymmetry
	Word Boundary Asymmetry
	The Synonymic Error Asymmetry
II.	**The Connection Formation Asymmetry**
	The Word Production Asymmetry
III.	**The Level of Activation Asymmetry**
	The Maximal Rate Asymmetry
	The Lexical Error Asymmetry
IV.	**The Sequential Activation Asymmetry**

*Theoretical symmetries and asymmetries are boldfaced; empirical symmetries appear in italic.

distinguish the empirical from the theoretical, I have used bold type to identify *theoretical* symmetries and asymmetries in Table 6.1 and throughout the chapter. Although some of these theoretical asymmetries have already been mentioned earlier in the book, bringing them together here not only helps to explain the empirical asymmetries, but provides a useful contrast with "strictly symmetrical" theories of relations between production and perception, discussed in the following section.

The Importance of Asymmetries Between Perception and Action

Theories incorporating identical perception–production components often assume symmetrical processes for perception and production (Bierwisch, 1966/1985). Perceptual processes in these theories are simply the reverse of corresponding production processes, like the bidirectional reactions in chemical formulas. Gordon and Meyer (1984, p. 171) use a flow chart to summarize current theories incorporating this "symmetry assumption." In the chart, arrows in one direction represent perceptual processes, while arrows in the opposite direction represent production processes.

Symmetry between perception and production has been a popular assumption (Fodor et al., 1974), which in principle enables researchers to devote all of their efforts to studying perception. If perception and production engage symmetric processes, studies of production are redundant and unnecessary. Solving the problem of perception also solves the problem of production. Like the philosophical and theoretical traditions discussed in Chapter 1, the symmetry assumption subordinates action and encourages researchers to adopt a perception-without-action approach.

The main point of the present chapter is that the symmetry assumption is incorrect. Perception and production engage identical microprocesses but in asymmetric ways. These asymmetries indicate that studies of production and comparisons between perception and production are both necessary and theoretically important. The asymmetries also call into question the philosophical traditions that consider it necessary and sufficient to study perception-without-action.

Empirical Asymmetries Between Perception Versus Production

A review of the literature reveals four general classes of empirical asymmetries between perception versus production: the word production asymmetry, the maximal rate asymmetry, the listening practice asymmetry, and asymmetries between slips of the tongue versus slips of the ear. Not all of these asymmetries have been firmly established. Some have yet to undergo statistical comparison (for methodological reasons discussed later in the chapter), but all are large in magnitude and enjoy theoretical support. As will be shown, the node structure theory predicts them all.

The Word Production Asymmetry

The word production asymmetry is the oldest and most famous of the empirical asymmetries and refers to the fact that production vocabularies tend to be much smaller than recognition vocabularies. In general, children can recognize and understand a word long before they can use it in speech production (E. Clark & Hecht, 1983).

The Maximal Rate Asymmetry

The maximal rate asymmetry is one of the most striking differences between speech perception and speech production, and refers to the fact that we can perceive speech at a faster rate than we can produce it. Foulke and Sticht (1969), Duker (1974), and Seo (1974) have summarized the evidence on the perception of speeded or time-compressed speech.

Electromechanical devices that systematically sample and compress acoustic signals provide a wide range of acceleration without introducing pitch changes. Connected paragraphs accelerated in this way remain highly intelligible at rates up to 400 words per minute (about 20 to 30 ms per phoneme), and intelligibility remains as high as 50% when monosyllabic words are reduced in duration by 75% to 85%. By way of contrast, *producing* speech at comparable rates and levels of intelligibility is well beyond human capacity.

The usual explanation of why perception is so much faster than production is that extra time and effort are required to physically move articulators such as the jaw. However, this explanation of the maximal rate asymmetry conflicts with my 1981 data on the rate of internal speech (D. G. MacKay, 1981). I had subjects produce sentences internally (silently without moving the lips) as rapidly as possible, pressing one key when they began a sentence and another key when they ended it. The maximal rate, measured at asymptote after many practice trials with the same sentence, was about 91 ms per phoneme. This rate is much faster than the maximal rate of overt speech. Subjects producing identical sentences *aloud* as quickly as possible only achieve an asymptotic rate of about 133 ms per phoneme after many trials of practice. Nevertheless, although faster than overt speech, the maximal rate of internal speech is considerably slower than the 20- to 30-ms per phoneme rate during perception of time-compressed speech. Because the articulators do not move during internal speech, this remaining rate difference indicates that muscle movement factors cannot completely explain the maximal rate asymmetry. A satisfactory account requires reference to fundamental differences between processes underlying perception versus production.

The Listening Practice Asymmetry

D. G. MacKay and Bowman (1969) reported a "conceptual practice effect," which has an interesting but asymmetric counterpart on the perceptual side, reported here for the first time. The subjects were German–English bilinguals, who were presented with sentences one at a time and simply produced each sentence as rapidly as possible. An example is "In one corner of the room stood three young men." Following a 20-s pause, the same sentence was presented again, for a total of 12 repetitions or practice trials with each sentence. There were 12 different sentences in all, and for reasons that will become clear shortly, six were in English and six in German. The independent variable was trial of practice, and the dependent variable was the time to produce the sentence.

Results for this "physical practice condition" appear in Table 6.2 and are averaged over the first four and last four practice trials for 12 sentences. As can be seen in Table 6.2, speech rate was 15% faster for the last four than for the first four practice trials, even though the subjects were attempting always to speak at their maximum rate.

Twenty seconds after the twelfth repetition of a "practice" sentence, the subjects received a "transfer" sentence in their other language, which they also produced at maximal rate for four trials. This transfer sentence was either a translation or a nontranslation of the practice sentence. Nontranslations were unrelated to the original sentence in meaning, syntax, and phonology, while translations had the same meaning as the original but differed in phonology and word order. To control for sentence difficulty, the transfer sentences were counterbalanced across subjects, so that exactly the same sentence occurred as either a translation or a nontranslation, depending on the nature of the practiced sentence.

The subjects produced each transfer sentence four times, again with 20 s between repetitions, and these data are averaged across repetitions for the 12 transfer sentences in Table 6.2. The rate of speech for translations was 8% faster than for nontranslations (2.44 s per sentence versus 2.24 s per sentence), a statistically reliable difference indicating an effect of practice at the conceptual level in speech production (see D. G. MacKay, 1982, for a detailed explanation).

Consider now the perceptual analogue of this conceptual practice effect. The critical condition involved *listening practice*, which was designed to determine whether repeated *listening* to a sentence leads to facilitation in the same way as repeated *production*. Twelve German–English bilinguals listened to a tape recording of the subjects discussed previously who had produced the sentences

TABLE 6.2. Practice and transfer effects (in secs per sentence) for the physical practice and listening practice conditions.

	Production times (per sentence)					
	Practice condition		Transfer condition			
	First 4 trials	Last 4 trials	Non-translation	Translation	Difference	% Facilitation
Physical practice	2.33	2.03	2.44	2.24	.20	8%
Listening practice	2.33	2.03	2.57	2.31	.26	10%

12 times at maximal rate. To ensure that "listening practice" subjects were paying attention to the sentences in this condition, the listeners were instructed to indicate whether "physical practice" speakers made changes or errors from one repetition to the next. (No such errors actually occurred.)

A transfer phase, identical to that in the physical practice condition, followed each set of 12 listening practice trials. In this transfer phase of the listening practice condition, subjects produced out loud and at maximal rate a sentence that was either a translation or a nontranslation of the sentence that they had heard repeated 12 times. The results appear in Table 6.2. As before, production times were faster for translations (2.31 s), than for nontranslations (2.57 s) in the transfer phase of the listening practice condition, a 10% facilitation effect compared to the 8% facilitation effect for the physical practice condition. However, there was an asymmetry in the *absolute* production times for transfer sentences in the physical versus listening practice conditions. Absolute production times (see Table 6.2) were significantly longer in the listening practice condition than in the physical practice condition, both for nontranslations (6% longer) and for translations (3% longer).

Errors in Perception Versus Production

Even though production has received much less attention than perception in the field at large (Chapter 1), slips of the tongue have been collected and studied much more often than slips of the ear, the perceptual errors that occur when listening to conversational speech (Fromkin, 1980). However, studies of misperceptions and misproductions have been undertaken for the same basic reason. Regularities in misperceptions and misproductions allow inferences about the otherwise hidden mechanisms underlying everyday perception and production, and they "test" existing theories, because theories that are incapable of explaining the errors that occur are incomplete or inadequate as accounts of mechanisms underlying "veridical" perception and production (see, e.g., Bond & Garnes, 1980; Freud, 1901/1914; Meringer & Mayer, 1895). Interestingly, however, systematic comparisons of misperceptions and slips of the tongue do not currently exist. What follows are some preliminary comparisons suggesting six general classes of asymmetries for further empirical test: sensory asymmetries, muscle movement asymmetries, phonological asymmetries, sequential asymmetries, lexical asymmetries, and semantic asymmetries.

Sensory Asymmetries

Sensory factors contribute to perceptual errors but have no analogous effect on production errors. An example is the masking asymmetry. Extraneous environmental noises often cause misperceptions by masking incoming speech sounds at the sensory analysis level, but speech errors directly attributable to extraneous (nonspeech) sounds have never been reported.

Muscle Movement Asymmetries

Whole classes of production errors lack a perceptual analogue. An example is stuttering, a class of speech errors that simply never occurs in perception. Listeners never misperceive someone to say *p-p-p-please* when the speaker in fact said *please*. This asymmetry is one of many sources of converging evidence suggesting that "intrinsic" stuttering (D. G. MacKay & MacDonald, 1984; and Chapter 8) originates within the muscle movement system.

Phonological Asymmetries

The Syllabic Position Asymmetry

Phonological production errors obey a syllabic position constraint (Chapter 3). Syllable-initial segments substitute with other syllable-initial segments and never with syllable-final or -medial segments. However, perceptual metatheses, for example, *know* misperceived as *own* (Bond & Garnes, 1980), are reversals in the order of segments within a syllable that violate this syllabic position constraint. Similar production errors involving transposition of a vowel and a consonant have never been collected from *adult* speech.

The Phonological Similarity Asymmetry

The phonological similarity asymmetry refers to the greater role of phonological similarity in misperceptions than in misproductions. Misproductions *sometimes* involve phonologically similar words such as *carcinoma* and *Barcelona* (Dell, 1980), but misperceptions virtually always involve phonologically similar words (Browman, 1980).

Sequential Asymmetries

The Sequential Domain Asymmetry

The sequential domain asymmetry refers to the greater role of syntactic class in misproductions than misperceptions. Misproduced words almost invariably substitute words from within the same syntactic class, for example, nouns interchange with other nouns and virtually never with verbs or adjectives (Chapter 3; Cohen, 1967; D. G. MacKay, 1979), but misperceptions frequently violate this syntactic class constraint. An example violation is the misperception of *descriptive* as *the script of*, where a determiner, a noun, and a preposition substitute an adjective (example from Bond & Garnes, 1980).

The Sequential Error Asymmetry

Sequential errors are the most common class of production error (Chapter 2) and include anticipations, preservations, and transpositions of about-to-be-uttered words and speech sounds. Two of Fromkin's (1973) examples are the phonological transposition *coat thrutting* for *throat cutting* and the word reversal "*We have a laboratory in our computer*" for "*We have a computer in our laboratory*." The sequential error asymmetry refers to the fact that perceptual errors resembling these high-frequency production errors have never been reported.

Lexical Asymmetries

The Word Substitution Asymmetry

The word substitution asymmetry refers to the greater frequency of word-for-word substitution errors in perception than in production. Units involved in misperceptions range in scope from entire phrases (e.g., *popping really slow* misperceived as *prodigal son*), to single features (e.g., *pit* misperceived as *bit*), to word substitutions, in which the listener mishears one word as another. These word-for-word substitutions predominate over other errors in collections of misperceptions (85% versus 15% in Browman, 1980), whereas the opposite is true in collections of speech errors. For example, word-for-word substitutions made up only 38% of the Garnham, Shillcock, Mill, and Cutler (1982) corpus, which includes every speech error from a large sample of recorded speech and is especially suited for this type of comparison.

The Lexical Error Asymmetry

The lexical error asymmetry refers to the fact that nonwords appear more often as misproductions than as misperceptions. Listeners almost invariably misperceive words as other words (Browman, 1980), whereas speakers often misproduce words as nonwords. For example, 63% of the phonological production errors in Dell's (1980) corpus resulted in nonwords, such as *thrutting* instead of *cutting*.

Position-Within-A-Word Asymmetry

The position-within-a-word asymmetry refers to the tendency for misproductions and misperceptions to involve different parts of a word. That is, in both perception and production, some parts of a word are more susceptible to errors than others, but the parts susceptible to perceptual errors differ from the parts susceptible to production errors. Word-initial segments are more likely to be misproduced than word-middle segments (D. G. MacKay, 1970e), whereas word-middle segments are more likely to be misheard than word-initial segments (Browman, 1980).

Word Boundary Asymmetry

In word boundary errors the juncture between words is mislocated, as in the misperceptions *tenure* for *ten year*, and *take a pillow* for *take a pill out*. The word boundary asymmetry refers to the fact that these errors are relatively common in perception, making up about 18% of the 1980 Garnes and Bond corpus, but they simply do not appear in collections of tongue slips. Production errors resembling "*They had a ten-year party. . . . Excuse me, I mean, a tenure party for Marlene*" have never been reported.

Semantic Asymmetries

The Garden Path Asymmetry

The garden path asymmetry refers to the absence of garden path errors in production. Garden path miscomprehensions (Chapters 1 and 4) are relatively common. Listeners often perceive the wrong meaning of an ambiguous word, such as, say, *crane*. However, speech errors resembling garden path miscomprehensions have never been reported. Normal speakers never begin to discuss one type of *crane*, say, *machine cranes*, and then *inadvertently* end up discussing *bird cranes*.

The Synonymic Asymmetry

The synonymic asymmetry refers to the absence of synonymic errors or blends in perception. A typical synonymic error is "*He was sotally responsible for that*, a blend of "*He was solely responsible for that*" and "*He was totally responsible for that*." Blends are relatively common among speech errors, making up 15% of all word errors in Garnham et al. (1982), but blends lack a perceptual analogue. For example, listeners never mishear *solely* as a combination of *solely* and *totally*.

Methodological Issues

Error collections pose well-known analytic difficulties for both misproductions (D. G. MacKay, 1980) and misperceptions (Bond & Small, 1984; Cutler, 1982), and comparisons between misperceptions and misproductions can only compound these difficulties. Listener–collectors can't observe and record misperceptions *directly*. Misperceptions must be inferred in one way or another, often from pragmatic context, and it seems likely that many more misperceptions than misproductions go undetected by researchers and lay people alike (all other factors being equal; Warren, 1982). Moreover, some production errors may be more difficult to perceive (and collect) than others (Bond & Small, 1984; Cutler, 1982). This means that collections of misproductions and misperceptions may be nonindependent and statistically incomparable on a priori grounds and that the asymmetries discussed previously require further empirical support. What is needed are laboratory techniques for inducing misperceptions and misproductions experimentally. A prototype technique of this sort has already been developed (Chapter 2; and D. G. MacKay, 1978), but so far has only been applied to a single species of phonological errors. Extending such techniques to a wider range of experimentally induced misperceptions and misproductions could both test and extend the list of asymmetries discussed previously.

Structural Asymmetries in the Node Structure Theory

I turn now to asymmetries in the node structure theory which explain the empirical asymmetries discussed previously. I begin with structural asymmetries: Top-down connections differ from bottom-up connections in four fundamental ways in the node structure theory. One of these theoretical asymmetries reflects a difference in the distribution of top-down versus bottom-up connections in the network at large, the **uniqueness asymmetry**; another reflects a difference in the relative strength of top-down versus bottom-up connections, the **linkage strength asymmetry**; and two reflect the independent status of sensory analysis versus muscle movement nodes in the theory, the **sensory analysis and muscle movement asymmetries**.

The Muscle Movement Asymmetry

The fact that muscle movement nodes play a role in production but not perception contributes directly to the stuttering asymmetry (Table 6.1). As discussed in Chapter 8, intrinsic stuttering is a disturbance that causes errors in the muscle movement system but nowhere else.

The Sensory Analysis Asymmetry

The fact that sensory analysis nodes play a role in perception but not production is directly responsible for the masking asymmetry (Table 6.1). Extraneous environmental noises introduce a disturbance within the sensory analysis system that causes misperceptions but not misproductions.

The Uniqueness Asymmetry

The **uniqueness asymmetry** refers to a difference in the distribution of top-down versus bottom-up connections to domains in the node structure network. Top-down connections to content nodes in a domain are generally unique or singular, so that only a single node in a domain normally receives top-down priming at any given time during production. On the other hand, bottom-up connections to content nodes are massively nonunique. Any given input simultaneously transmits bottom-up priming to many different nodes in many different domains. This **uniqueness asymmetry** contributes to at least three empirical asymmetries: The sequential domain asymmetry, the word boundary asymmetry, and the garden path asymmetry.

Sequential Domain and Word Boundary Asymmetries

Production errors rarely violate the sequential class constraint, because each lexical node receives priming from a unique source and passes on this unique priming to a single sequence node that determines the syntactic class of what gets produced. Errors can only occur when an extraneous node within the same sequential domain as the intended word achieves most priming when the sequence node becomes activated. As a result, words substitute in error with words from the same sequential domain or syntactic class, which is the syntactic class constraint.

However, bottom-up connections do not confine *perceptual* alternatives to a single sequential domain in the theory. Because a given input can transmit bottom-up priming nonuniquely to nodes in many different domains, an extraneous sequence node can receive greatest priming and become activated in violation of the syntactic class constraint. For example, when perceiving the word *descriptive*, *descriptive*(adjective) may receive and pass on less priming to its sequence node than does *the*(determiner), *script*(noun), and *of*(preposition), in part because of the lexical frequency of *the* and *of*, but perhaps also because of top-down (expectation) priming of *script*(noun). As a consequence, DETERMINER, NOUN, and PREPOSITION will become activated as the most primed sequence nodes, rather than ADJECTIVE, a multiple violation of the syntactic class constraint. As this same example illustrates, **the uniqueness asymmetry** also contributes to the word boundary asymmetry, the fact that word boundaries are subject to error in perception but not production.

The Garden Path Asymmetry

The nonuniqueness of bottom-up connections also contributes to the garden path asymmetry (see also Chapter 7). A lexically ambiguous word such as *crane* causes garden path miscomprehensions (D. G. MacKay, 1970d) because its syllable node, *crane*(stressed syllable), connects with and primes two lexical content nodes representing machine cranes and bird cranes, so that the wrong node can become activated under the most-primed-wins principle. However, the uniqueness of top-down connections prevents similar errors in production. Top-down connections from a node such as *the tall crane*(noun phrase) go to either *crane 1*(noun) or *crane 2*(noun) but not both. As a result, speakers can't intend to discuss bird cranes and *inadvertently* end up discussing machine cranes, because only the lexical node for machine cranes or for bird cranes receives top-down priming.

The Linkage Strength Asymmetry

The **linkage strength asymmetry** refers to the fact that bottom-up connections tend to be stronger than top-down connections, especially for higher level nodes, because we generally perceive words more often than we produce them: Listening–reading is a more common activity than speaking–writing–typing. Together with several other theoretical asymmetries, this **linkage strength asymmetry** contributes to the maximal rate asymmetry, which is the fact that perception can proceed faster than production, and to the word production asymmetry, which is the fact that we comprehend words long before we use them in speech production.

Processing Asymmetries in the Node Structure Theory

Although identical mental nodes and microprocesses play a role in perception and production, macroprocesses for perception and production exhibit four fundamental asymmetries, summarized here as the **priming summation asymmetry**, the **level of activation asymmetry**, the **sequential activation asymmetry**, and the **connection formation asymmetry**.

The Priming Summation Asymmetry

The **priming summation asymmetry** arises from the fact that top-down priming *in action hierarchies* diverges via one-to-many connections, whereas bottom-up priming *in perceptual hierarchies* converges via many-to-one connections. This **priming summation asymmetry** contributes to at least six empirical asymmetries: the phonological similarity asymmetry, the maximal rate asymmetry, the word boundary asymmetry, the synonymic asymmetry, the position-within-a-word asymmetry, and the sequential error asymmetry.

The Phonological Similarity Asymmetry

The **priming summation asymmetry** ensures that misperceptions involve phonologically similar words more often than misproductions do. Bottom-up priming converges and summates to such an extent on the input side that misperceptions must incorporate most of the phonological components of the actual input. However, on the output side, bottom-up priming only converges on just-activated nodes, which are undergoing self-inhibition. As a result, only *divergent* bottom-up priming can introduce phonological similarity into misproductions, and only rarely because divergent priming is second order and relatively weak.

The Maximal Rate Asymmetry

The **priming summation asymmetry** is another contributor to the maximal rate asymmetry. Because priming converges and summates to a greater extent in perception than in production, mental nodes can be activated more quickly in perception than in production (for a given error criterion; D. G. MacKay, 1982).

Sequential Error Asymmetry

The **priming summation asymmetry** also explains why sequential errors are much more common in production than in perception. The anticipatory priming that results from divergent top-down connections readies upcoming units for activation and increases the probability of anticipatory errors in production. Now, anticipatory priming also occurs occasionally in perception, and misperceptions sometimes reflect what word the listener expects a speaker to say (Garnes & Bond, 1980). The difference is that anticipatory priming invariably occurs at all levels of production, but only sometimes, and only at the word level during perception. That is, perceptual expectations center on word concepts and not on units at higher or lower levels. We normally cannot anticipate the phonemes in upcoming words during perception, a necessary condition for sequential misperceptions resembling production errors such as *coat thrutting* for *throat cutting*. Nor can we generally anticipate phrases in perception, a necessary condition for sequential misperceptions resembling speech errors such as "laboratory in our computer" for "computer in our laboratory."

The **priming summation asymmetry** also promotes the sequential error asymmetry in another way. The fact that convergent summation is everywhere present in perception, but not in production, strongly constrains perceptual errors to resemble the actual phonological input, thereby initially ruling out perceptual substitutions of phonologically dissimilar words as in the preceding *laboratory-computer* example.

Position-Within-A-Word Asymmetry

The **priming summation asymmetry** also contributes to the position-within-a-word asymmetry, the fact that word-initial segments are more likely to be misproduced than word-middle segments, whereas word-middle segments are more likely to be misheard than word-initial segments. As already noted, the perceptual effect reflects the "left-to-right" summation of convergent priming which occurs in perception but not production, and the production effect reflects summation of divergent (anticipatory) priming which occurs in production but not perception.

The Synonymic Asymmetry

The **priming summation asymmetry** also contributes to the synonymic asymmetry, the fact that blends occur in production but not perception. Blends result under the theory whenever context enables two or more nodes in the same domain to receive exactly equivalent priming at the time when the activating mechanism is applied, so that both nodes become activated simultaneously (D. G. MacKay, 1973b; and Chapter 2). For example, if both *solely*(adverb) and *totally*(adverb) receive equivalent priming when ADVERB is activated in producing the sentence "He was solely/totally responsible for that," an error such as *sotally* will occur. Whatever phonological nodes receive more priming from either *solely*(adverb) or *totally*(adverb) or both will become activated. However, blends such as *sotally* cannot occur in perception, because bottom-up priming will converge on either *solely*(adverb) or *totally*(adverb) but not both.

The Level of Activation Asymmetry

In everyday production, both higher and lower level nodes must become activated because the output must be produced in sequence. In everyday perception, however, only higher level nodes must become activated. Because of the strength of lower level connections and the convergent summation and overlapping timing characteristics of lower level bottom-up priming, lower level nodes need not become activated in order to pass on sufficient priming to reach commitment threshold of their connected nodes. As noted in Chapter 4, this principle of higher level activation is flexible in its application, and achieving this flexibility is one of the reasons why nodes are organized into modalities, systems, and domains (see Chapters 2 and 5).

The Maximal Rate Asymmetry

The **level of activation asymmetry** is a major contributor to the maximal rate asymmetry. Because all nodes become activated in production, whereas only higher level nodes normally become activated in perception, perception can proceed faster than production in the theory.

Lexical Error Asymmetry

The **level of activation asymmetry** also helps explain the lexical error asymmetry, the fact that nonwords result when speakers but not listeners make phonological errors. Because phonological units don't normally become activated in everyday speech perception, phonological errors resulting in nonwords are rare in perception.

The Sequential Activation Asymmetry

Order of activation is asymmetric under the node structure theory. Even when the same higher level nodes become activated during both perception and production, order of activation differs in perception versus production. As noted in Chapter 2, mental nodes that become activated in the order 1, 2, 3, 4, 5 during production will become activated in the order 3, 4, 2, 5, 1 during perception in the node structure theory (see Figure 2.2). Under Bierwisch's (1966/1985) symmetry assumption, however, production and perception might be expected to exhibit reverse orders of activation, that is, 1, 2, 3, 4, 5 during production, with the extremely unlikely reverse order, 5, 4, 3, 2, 1, during perception (see Figure 2.2).

The Connection Formation Asymmetry

A final asymmetry between bottom-up and top-down processes is that new connections between nodes are initially formed bottom-up rather than top-down in the node structure theory. As already noted, I discuss the process of connection formation elsewhere (D. G. MacKay, 1987), rather than in the present book. However, I mention the **connection formation asymmetry** here not just for the sake of completeness but for its potential role in the listening practice and word production asymmetries. The main reason that listening practice facilitates performance (see Table 6.2) may be because the relevant content nodes and their bottom-up connections become formed and strengthened during listening practice. However, listening practice facilitates performance *less* than physical practice (the listening practice asymmetry), because top-down connections do not become formed, activated, and strengthened during listening practice. Similarly, children can recognize and understand a word long before they can produce it, because activating a lexical content node with bottom-up connections from phonological and sensory analysis nodes suffices for recognizing a word under the theory. However, *producing* the word requires formation of several additional types of connections, each of which may delay development of the production vocabulary. One additional type of connection is top-down from the lexical content node to the appropriate phonological and muscle movement nodes. Another is the inhibitory connection between sequence nodes required for sequencing the phonological and muscle movement components for producing the word.

The Aphasic Asymmetry Prediction

Asymmetries in the node structure theory generate a large number of predictions. I discuss the aphasic asymmetry prediction as one example. Under the theory, production and perception will break down symmetrically in most aphasias. Most lesions will damage content nodes, causing symmetric impairment to production and comprehension under the theory, because content nodes are essential to both. Even when sequence and timing nodes are selectively damaged, leaving content nodes intact, effects will sometimes be symmetric. For example, selective damage to *sentential* sequence and/or timing nodes will impair production and comprehension of sentential components symmetrically, and will leave *phonological* perception and production intact: The patient will be able to produce and recognize phonological components without comprehending their meaning and will be able to identify and repeat acoustically presented nonwords.

However, selective damage to *phonological* sequence and/or timing nodes (again leaving content nodes intact) will only impair *production*, and in a strikingly distinctive way. The reason for this aphasic asymmetry prediction is that phonological sequence and timing nodes are unnecessary for perceiving common words because phonological nodes become activated during production but not during perception (the **level of activation asymmetry**). Moreover, when this aphasic asymmetry occurs, the theory predicts a severe and unique type of production deficit. Activation, sequencing, and/or timing of phonological components will be impaired, with unusual intonation and rhythm at the phonological level, and large numbers of spoonerisms and segment distortions, but no corresponding perceptual errors.