1 Relationships and modules within language perception and production: An introduction

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The title of the present book reflects both a common interest of its contributors and a common approach which is emerging within the field at large. The approach treats perception and action as 'integrated-and-equal' rather than 'separate-and-unequal' and is part of a relatively small but rapidly growing tradition in psychology and related disciplines. Of the two, the separate-and-unequal tradition is by far the more prevalent approach to the relations between perception and action (see also Jarvella and Deutsch, Chap 3). Since the time of Descartes, most philosophers have viewed the afferent processes which mediate perception of the external world as separate from the efferent processes which mediate action in the external world. Philosophers have also viewed action as subordinate in importance to perception on functional, temporal, and evaluative grounds: functionally subordinate because they considered perception the sole means by which knowledge is acquired, temporally subordinate because they considered perception a necessary precursor to action, and evaluatively subordinate because they considered perception and contemplation as more important to life than action. Even when 'motor theories' had their heyday in psychology about a hundred years ago, and movement was thought to determine perceptual structure, theorizing remained solidly within the separate-and-unequal tradition (see Scheerer, 1984).

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Of late, psychologists within the separate-and-unequal tradition, or as Jarvella and Deutsch prefer to call it in psycholinguistics, the apples-and-oranges approach to speaking and listening, have concentrated almost exclusively on perception, rather than on production or on the relation between the two, and often attribute quite different functions to these supposedly separate systems: perceptual systems are supposed to register and to construct a meaning for sensory events, whereas motor systems are supposed to translate goals into motor commands. As Turvey (1977) points out, perception and action have virtually no contact with one another within this framework: how a perceptual system perceives neither influences nor is influenced by how the motor system uses perception.

Psychologists within the separate-and-unequal tradition have explicitly attempted to study perception so far as possible in the *absence* of perception-related action, e.g., with tachistoscopic stimuli presented so briefly as to minimize the possibility of eye movements. As a result, two separate research areas, with little or no interaction between them, have developed in parallel within the separate-and-unequal tradition, one set specializing in afferent processes, the other in efferent processes. Theories of action have been constructed without reference to perception, and theories of perception have been constructed without reference to action, but as Howell and Harvey (1983) point out, virtually no theories have attempted to solve the problems of both perception and action at the same time.

There are of course exceptions, and at least two major theories of perception–production relationships (discussed below) have emerged in the study of language. Why has language been the focus of so much more interest in perception–production? Two reasons stand out. One concerns the obvious structural similarities between the units and products of language perception and production: Both make use of common or at least homomorphic units at the sentential and phonological levels, and one of the main goals of production is to duplicate in the listener the representational structure of the speaker.

The second reason is that language perception and production are intimately related and difficult to separate operationally. Every speaker is simultaneously a listener, and every listener is at least potentially a speaker. From an evolutionary perspective as well, language perception and production are virtually inseparable: The capacities for perceiving and producing speech could only have evolved simultaneously because if a series of mutations enabled a set of humans to understand language, their chances of surviving to transmit the mutation would only improve if a second (perhaps overlapping) set of humans underwent mutations which enabled them to speak (see Geschwind, 1983). Likewise, mutations which enabled a set of humans to speak would only improve *their* chances of survival if they had a language to speak and someone to understand them when they spoke. Like other communicative systems, speech perception and production are so closely intertwined as to require mutual adaptation or conjoint evolution.

Early theories of the perception–production relationship

Two early psycholinguistic theories explicitly attempted to relate speech perception and production: the 'classical' theory and the 'motor' theory of speech perception. Both theories exhibit the (perhaps unintended) influence of the separate-and-unequal tradition in philosophy: For example, both theories assume that components for speech perception and production are completely separate rather than shared.

The classical theory of perception–production

The 'classical theory' was motivated by Broca's and Wernicke's discovery of distinct types of aphasia arising from lesions at different cortical sites, and holds that the systems for perception and production at every level of processing employ separate components in anatomically separate areas of the brain (see Straight, 1980): Early studies of left hemisphere brain injuries seemed to suggest that production is localized in one area of the brain and perception in another, interconnected but separate area. However, recent studies using a variety of new and more sophisticated techniques suggest that the picture may be more complicated. Brain scan and cerebral blood flow studies indicate that Broca's area (which under the classical theory only becomes active during production) also becomes active during comprehension (Lassen and Larsen, 1980), and *vice versa*. Moreover, expressive and receptive deficits are usually commensurate in extent: with appropriate controls for lesion size, aphasics with severely impaired production also display severely impaired comprehension, and *vice versa* (Mateer, 1983). Finally, the distinctiveness of perception versus production deficits has recently become a topic of lively debate. Because aphasics can make up for comprehension deficits using non-linguistic cues, production deficits tend to be more obvious than perceptual deficits in everyday life, and Cooper and Zurif (1983) showed that appropriate tests of comprehension require controls for semantic and pragmatic cues. Using these more sophisticated tests, Cooper and Zurif (1983) argue that Broca's aphasics display comprehension deficits which parallel their more readily observed production deficits, and Wernicke's aphasics display production deficits which parallel their difficulty to demonstrate comprehension

deficits. Interestingly, Wernicke was also aware of this parallel, but viewed the production deficits as secondary to and derivative of the perceptual deficits; by hypothesis, the production errors were induced by defective monitoring of self-produced feedback (see Geschwind, 1974, pp. 47–48). For Wernicke, production was both separate and subordinate, in complete agreement with the separate-and-unequal tradition in philosophy.

The early motor theory of speech perception

The early motor theory of speech perception (Liberman, Cooper, Harris and MacNeilage, 1962; Studdert-Kennedy, Liberman, Harris and Cooper, 1970) recognized the importance of interactions between the ability to perceive and to produce speech: motor units which are (necessarily) distinct from their corresponding perceptual units come to the aid of the perceptual units under the early motor theory. That is, speech perception and production employ separate components, but at least some speech sounds are perceived with the help of the components that are used for producing them. As in the separate-and-unequal tradition, perception and production also remain unequal in early motor theory: by making production more important than perception, only the sign of the inequality has been changed (see also Scheerer, 1984).

As Howell and Harvey (1983, p. 215) point out, 'Motor theory attempted to explain something about which very little was known (i.e., speech perception) in terms of something else about which even less was known (i.e., speech production). The problems associated with it are legion.' One of the problems concerned the logical basis of the theory. In order for a pattern of acoustic energy to call up its appropriate production components, a full-fledged perceptual analysis is necessary (see Morton and Broadbent, 1967; and Pick and Saltzman, 1978). This brings the basis for the theory into question because a full-fledged perceptual analysis prior to motor consultation means that perceptual components can accomplish speech recognition without help from the motor components. Later versions of the motor theory (see Studdert-Kennedy, Chap 4 and Porter, Chap 5) have attempted to overcome this and other problems, in part by adopting a subtly but at the same time significantly different framework, described below.

The integrated-and-equal approach to perception and production

The separate-and-unequal approach is not just unsuited (by definition) for studying the relation between perception and production: recent developments in many disciplines have contradicted its basic premise that perception and production are completely separate, and call for a new approach to the whole topic. A classical example is Karl Lashley's (1951, p. 186) observation that common components and mechanisms must underlie speech perception and production because 'the processes of comprehension and production of speech have too much in common to depend on wholly different mechanisms'. A more recent example is the neurolinguistic work of Ojemann (1983) and Mateer (1985) demonstrating cortical sites where electrical stimulation interferes with both the perception and the production of speech, as if identical sites play a role in both perception and production. Such observations suggest that the traditional anatomical separation between afferent versus efferent processes can no longer be usefully maintained, and are less consistent with separate-and-unequal theories than with the hypothesis of Lashley (1951), Miller, Galanter and Pribram (1960), MacKay (in press), and Studdert-Kennedy (Chap 4) that speech perception and production share some of their components.

Others have noted that functionally and temporally too, the relation between perception and action is generally interactive-supportive rather than dominant-subordinate. The main function of perceptual and cognitive systems is to guide purposeful actions, and to adjust ongoing actions to the situation at hand. As Allport (in press) points out, perceptual systems have evolved in all species of animals solely as a means of guiding and controlling action, either present or future. Perceptual systems are not primarily designed to describe and to classify the environment in answer to a question such as 'What is out there?', but to address the more general question 'What does it signify for me?: What must I *do* about what's out there?' (after MacKay, 1984). In short, the nature of the information required for the guidance of production ultimately determines how perceptual systems structure the sensory input: functionally, perception is as subordinate to action as action is to perception.

The integrated-and-equal approach therefore views perception and production as potentially equal and integrated, i.e., fundamentally interactive rather than separate, and takes as its main focus the *relations* between perception and production. Of course, the principles of the integrated-and-equal approach can be generalized to apply to *any* pair of heterogeneous systems, perception and production being only one highly salient pair. In particular, the integrated-and-equal approach extends also to the relations between different systems *within* language perception, or *within* language production. These within-domain relations crop up repeatedly in the book, especially relations between different types of perception, an example being Massaro's (Chap 6) demonstrations of low level interactions between

the *auditory* mechanisms for hearing a syllable, and the *visual* mechanisms for seeing the speaker's moving lips.

One final point. As the above examples illustrate, the integrated-and-equal approach tends to criss-cross traditional disciplinary boundaries and approaches, and the present book contains information with origins in many different areas, not just psycholinguistics and linguistics, but mainstream psychology, neurology, and even kinesiology. The fact that the conference on which this book was based took place at the Center for interdisciplinary Research (ZiF) is anything but accidental.

Major themes of the book

Having reviewed the general approach represented in the book and its historical relations to the field at large, some signposts are in order regarding its chapters, their main lines of argument, and how they interconnect. The emphasis here is on what unites the chapters rather than on what differentiates them, which when not superfluous in a general introduction, tends to be premature. What holds the book together are two major themes which run throughout the book, and a set of minor themes which a smaller number of chapters share and which we used for organizing the book into sections.

Relationships within and between language perception and production

Relationships between the various systems and subsystems involved in language perception and production represent one of the main themes of the book (as its subtitle suggests), and the relationships taking part in this theme can be divided into four types (see also Marr and Poggio, 1977): (i). Relationships in the sense of influences, constraints, or mutual adaptations of one system or subsystem on another. (ii). Relationships in the sense of common and/or homologous representations or units shared by different systems or subsystems. (iii). Relationships in the sense of common and/or homologous processes, or functions shared by different systems or subsystems. (iv). Relationships in the sense of shared or separable cognitive structures or functional components. As will be seen, these four different types of relationships also weave their way into the fabric of the other main theme of the book (modularity).

Constraints, interactions, and mutual adaptations

Cutler (Chap 2), Massaro (Chap 6) and Studdert-Kennedy (Chap 4) deal with relations in the sense of constraints, interactions, or mutual adaptations between the systems and subsystems for language perception–production. Cutler argues that sentence production is adapted on-line to perception because speakers are constrained in their choice of syntax, words, and even phonology so that listeners can readily understand them. Massaro examines how perceptual information coming from different sources interacts and combines, as when we simultaneously hear a speech sound and see a speaker's moving lips. Studdert-Kennedy examines the constraints of perception on production seen when children imitate or reproduce utterances which are functionally equivalent to those heard.

Units of representation and their interrelations

Theoreticians are in general agreement that language perception and production employ identical distinctions, descriptive characteristics, or units of representation, at least for higher level units such as words and phrases. Studdert-Kennedy (Chap 4) and Porter (Chap 5) advance a much more radical proposal, namely that speech production and perception employ some of the same representational distinctions at very low, phonetic/articulatory levels. This 'units of representation' issue arises again at a slightly higher level in Campbell's (Chap 7) discussion of whether a common phonological code is accessed during speaking–hearing versus during mouthing–lipreading, i.e., producing silent lip-movements versus seeing a speaker's moving lips.

Essentially similar questions arise in the chapters on reading: Venezky and Massaro (Chap 8) ask a basically descriptive question about how the units of pronunciation in English are related to the units of orthography. Kay (Chap 9) asks a more process oriented question about whether visual word recognition and spoken production make use of the same phonological code, and Besner (Chap 11), Feldman (Chap 10) and Scheerer (Chap 12) take this question one step further by asking whether the involvement of phonological units in studies of visual word recognition is a language-specific effect of the writing systems studied, so that readers can proceed directly from letters to word meanings in some languages but not in other languages. The issue of relations between visual and phonological units of representation arises again when Besner and Feldman disagree about the extent to which lexical knowledge determines pronunciation in phonologically transparent writing systems, and also when Scheerer and

Kay ask whether letters which are visually undifferentiated sometimes represent phonological-articulatory components which are fundamentally different, e.g., vowels versus consonants or syllable-final versus syllable-initial consonants (see MacKay, 1982). Jarvella, Job, Sandström and Schreuder (Chap 13) add a further dimension by focussing on language-specific effects of morphological structure during reading.

Shared and asymmetric processes

Several papers deal with relationships in the sense of processes which are either shared or asymmetric between language perception and production. Gordon and Meyer (Chap 20), and Keele (Chap 21) argue that hierarchic processing plays a fundamentally similar role not just in the production and perception of speech and other skills, but in the acquisition, transfer, and flexibility of perception–production skills (see also MacKay, 1982). Keele (Chap 21), and MacKay (Chap 18) review evidence indicating that speech perception and production share some of the same timing mechanisms. Gordon and Meyer argue for 'the common use of processing resources by speech perception and production'. However, Jarvella and Deutsch (Chap 3) show that speakers and listeners process descriptive statements differently at the sentential level: processing procedures are not completely identical for perception versus production. Huttenlocher and Goodman (Chap 19) come (implicitly) to a similar conclusion, showing that unlike speech production which proceeds of necessity from left-to-right at the phoneme level, identification of spoken words (and non-words) is not a strictly left-to-right process.

Shared, versus separate, cognitive structures

Relationships in the sense of shared versus separate cognitive structures for perception–production arise in many chapters, as the main focus in some, implicitly or indirectly in others. The 'structures' referred to are identified in psychological or functional rather than neuroanatomical terms. For example, the memory system embodying the listener's lexicon of phonological word forms — the phonological input lexicon (see e.g., Monsell (Chap 14), Howard and Franklin (Chap 16), Funnell and Allport (Chap 17), and Huttenlocher and Goodman (Chap 19)) — is one such postulated cognitive structure. In this example, one of the central questions at issue is whether the same structural component embodies both the listener's and the speaker's knowledge of lexical forms — that is, whether the phonological input lexicon and the phonological output lexicon are one and the same, or whether they are separate structural components (Monsell). A

similar question can be raised with respect to the orthographic lexicon (Coltheart and Funnell, Chap 15). While evidence from brain-injured patients may be used to address this kind of question, the identity of the postulated structural components is necessarily defined, at least initially, in terms of the psychological functions that they serve. The characteristic theoretical notation used by several of the contributors to represent their hypotheses is the structural 'box-and-arrow' diagram. Other contributors address questions of shared structural components, but without directly raising questions about the structural channels of communication between components, and so do not need such diagrams. For example, the evidence of Keele (Chap 21) and MacKay (Chap 18) implicates a shared structural component involved in the timing of speech perception–production and other skills without indicating how the timing, sequencing and content components are interconnected (but see MacKay, 1982; and in press).

Interestingly, closely related perception–production issues can arise as either a units-of-representation question or as a structural components question. For example, Monsell (Chap 14) and Coltheart and Funnell (Chap 15) examine the same basic relations between language perception versus production as Porter (Chap 5) and Studdert-Kennedy (Chap 4), but with a structural components focus. Porter and Studdert-Kennedy are concerned with what distinctions or descriptive units play a role in speech as it is perceived and speech as it is produced. What properties are abstracted out, and at what levels in speech perception–production? Monsell and Coltheart and Funnell ask whether or not the same specific cognitive structures are involved (in particular at the lexical level) in the perception and the production of spoken and written language.

Clearly, these two sorts of questions are closely related, and carry important implications for one another: If it turned out that language perception and production employed radically different distinctions or units of representation at all levels, then shared cognitive structures for perception–production would be out of the question. Similarly, unambiguous evidence for the existence of shared cognitive structures in language perception–production would seem to imply common units of representation for perception and production.

On the other hand, these closely related questions are not the same question in different guise. Common distinctions or representational units do not *necessarily* entail common cognitive structures (but see the earlier discussion for relevant data). Although the brains of different speakers of English represent say, phonemes, equivalently, this does not mean that they are one and the same brain in this respect; only that the individual, physically separate structures are in some way homomorphic. Likewise, as in Wernicke's theory, intimately interconnected but nevertheless distinct

cognitive structures might represent the receptive and the expressive sides of language, even though these distinct cognitive structures encode equivalent properties or contrasts.

Modularity and the generality of language mechanisms

This second theme only comes to the surface in a relatively small number of papers (e.g., Monsell (Chap 14), Funnell and Allport (Chap 17), Keele (Chap 21), Gordon and Meyer (Chap 20), and MacKay (Chap 18)), but in fact flows quietly beneath every paper in the book. Modularity is central to the theme, but directed to the issue of what the true modules are, rather than to the idea of modularity *per se*, which is taken for granted. The common goal of this theme is to identify the *functionally separable subsystems* involved in language perception and production, and to show in detail how these different subsystems operate and communicate with one another.

One relatively homogenous set of papers (Monsell (Chap 14), Coltheart and Funnell (Chap 15), Howard and Franklin (Chap 16), and Funnell and Allport (Chap 17)) begins with a hypothesized module known as the lexicon, a system of word-specific mechanisms which is embodied somehow in the brain and which makes explicit the unique identity of each individual word-form by representing the otherwise arbitrary correspondences between the phonological, conceptual, syntactic and orthographic aspects of words (in so far as orthographic rules cannot uniquely specify the word's pronunciation). The goal of these chapters is to identify how many and what kinds of word-specific subsystems there are, and the nature of their connections to each other and to other, *non*-lexical systems, in short to provide a map of the lexical module and its relations to other modules for language perception–production. However, the modularity theme is more general than this 'cognitive architecture' approach: Other chapters, such as those by Scheerer (Chap 12), Kay (Chap 9) and Besner (Chap 11), take a different approach, but address the same questions about the separability of lexical and sublexical systems representing phonological and orthographic units.

Presupposed within the modularity theme as a rather strong working assumption is at least some degree of *specialization* of psychological mechanisms and their internal channels of communication. Not one chapter in the book deals with a 'general purpose' or non-modular mental mechanism capable of serving indifferently now this basic function and now that, without structural differentiation or specialization. Whether this modular bias reflects chance, artifact, or necessity is of course difficult to

tell. After all, Fodor (1983) has argued that this approach may be the only viable one, and that we may as well give up hope of understanding cognitive processes in a 'general' or 'central' system where everything will interact with everything else in a way that no kind of experimental ingenuity or conceptual analysis can expect to disentangle. According to this somewhat pessimistic appraisal, the cumulative discovery of modules and the way they work is an essential precondition for any further progress in understanding cognitive processes.

However, if the idea of modularity is generally accepted in the book, Fodor's choice of specific modules and modular processes is not: For example, Fodor (1983) viewed perception and action, and language perception and production in particular, to be separate modules, whereas paper after paper in the present volume show that language perception and production have too much in common and are too interactive to be considered independent modules. Nor does the book adhere to the rigid 'encapsulation of processing' that Fodor (1983) considered essential to modularity. Indeed, modules may form a null set under this criterion, and MacKay (1982; and Chap 18) suggests a way of salvaging Fodor's concept of modularity by arguing for the 'partial encapsulation' of processing within modules, i.e., for the encapsulation of some but not all types of processing. Specifically, MacKay presents evidence indicating that 'processing' is an ambiguous term which must be further specified as either *priming* (which is unencapsulated, automatically crossing the boundaries between modules and systems within modules) or *activation* (which requires a module-specific activation mechanism and is therefore encapsulated or confined within particular modules or systems).

Closely related to the modularity theme is the issue of generality: whether language use shares some of the same underlying mechanisms as other behaviors. For example, Keele and MacKay review evidence indicating that speech and other action systems share the same timing mechanisms. Massaro likewise asks whether the mechanism responsible for integrating heterogeneous sources of information within language also plays a role in other (non-linguistic) perceptual systems. Finally, Keele, and Gordon and Meyer argue that the nested hierarchic organization so prevalent in language production also characterizes other complex behaviors such as piano playing, typing, gymnastics, and drawing. Indeed, Keele develops an intriguing functional argument for why evolution should favor hierarchic sequencing processes, and claims that the innate ability to learn and to modify hierarchic structures is most highly developed in humans, with language production and perception representing only a récent refinement of this more general genetic endowment. This view provides a clear challenge to current conceptions of how perception–action

modules evolve, with particular perceptual devices emerging during evolution to provide information for particular actions, and Keele's challenge suggests that the modularity–generality issue will be with us for some time to come.

Minor themes and the structure of the book

Ordering of the chapters poses a major problem for a general book which resections and crossclassifies the field in a new way, and this was certainly true of the present volume. Traditionally, books on cognitive psychology move roughly from the peripheral to the central, starting with topics in perception, moving on to attention, and ending with memory, language, and thinking. If action or production is mentioned at all, it generally comes at the end, as an 'after-thought'. As editors, we were united in our opposition to this traditional organization, because neither perception–production relations nor language *per se* sit very well within a peripheral-to-central framework. After all, perception and production are closely related and central topics in the psychology of language, and language processing is virtually inextricable from a 'central' topic such as memory.

We therefore set about to determine what other themes or crossclassifying dimensions we could use to order our chapters. Six general dimensions stood out: experimental versus theoretical versus review chapters, lexical versus sublexical versus supralexical chapters, reading–writing versus listening–speaking chapters, perceptually oriented chapters versus production-oriented chapters versus perception–production chapters oriented towards the relation between the two, chapters oriented towards higher versus lower level processes, and finally, the four types of relationship (constraint-oriented chapters versus process-oriented chapters versus representation-oriented chapters versus chapters oriented toward cognitive structures).

In the end, after a great deal of soul searching, we decided on a compromise which took into consideration not just these six dimensions, but also our own special areas of expertise as editors. We divided the chapters into six sections and counting the book title as a seventh (phantom) section, we ordered adjacent sections and chapters on the basis of a 'greatest thematic overlap' principle. The result was complex but interesting, a sort of unity with a twist, not unlike a Möbius circle. The circle is readily traced along the higher- versus lower-level dimension, where the chapters flow down and then back up and join again in the end without actually intersecting. Section 1 (Constraints and asymmetries between language perception and production: Don MacKay, section editor) has

very close ties with the book title and deals with input–output relationships in sentence production and comprehension. Stepping down from these relatively high level considerations, the reader soon encounters the lowest levels of perception–production in the sections entitled Perception and production of speech sounds, and Perceptual integration and common codes (Wolfgang Prinz, section editor), which examine the perception–production of articulatory-acoustic phonetics and phonology, including lip-reading of mouthed or silently articulated speech sounds. The next section switches to reading, beginning at roughly the same level (spelling-sound regularities and irregularities). This section, entitled Reading and orthographies (Eckart Scheerer, section editor) begins the ascent of the Möbius circle, starting with phonologically 'shallow' writing systems (witness Serbo-Croatian) and ending with phonologically 'deep' writing systems (witness English) and the higher level morphological constraints on visual word recognition. This leads naturally to the section entitled Architecture of the mental lexicon (Alan Allport, section editor) which deals with the hypothesized lexical module, and raises issues about word-specific mechanisms and their relationships to other, non-lexical mechanisms, both 'higher' and 'lower' in the system. Word meanings provide the predominant focus, how they are expressed in speaking and writing, and how they are understood in listening and reading, and the functional relations between all four. The last section, entitled Sequencing and timing in language perception and production (Don MacKay, section editor), begins with the problem of sequencing and timing in perceiving and producing spoken words and syllables, and completes the return ascent to the highest level questions, ending with the relation between the evolution of mechanisms for timing and sequencing in speech perception–production and other perception–action systems.

A similar unity-with-a-twist emerges for the four types of relationships (constraints-representations-cognitive structures-processes). The book begins with constraints that speakers take into consideration in order for listeners to understand them, and moves quickly into representations at the phonetic and phonological levels of speech production–perception, and at the grapheme and morpheme levels of reading. The next section (architecture of the mental lexicon) deals with the shared (versus separate) cognitive structures for the perception–production of words, and the processing pathways linking print to meaning. The final section completes the Möbius circle: it begins with the processes and mechanisms underlying the timing and sequencing of speech sounds, syllables, words, and phrases in language perception–production, and returns again to the theme of constraints, this time constraints on theories of sequencing and timing in speech perception–production.

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