

## **Experimental Validation of OT Solutions to the Comprehension–Production Dilemma**

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### **Abstract**

The relationship between perception and production remains an unresolved issue within the study of phonological acquisition. Recent developments in optimality theory offer potentially new solutions to this long-standing problem; but thus far, the proposals that have been advanced are in the absence of actual perception–production data from a given child. This paper provides an empirical instantiation of the perception–production effects by appealing to data from children’s knowledge and use of syllables and segments. The demonstration shows that optimality theoretic accounts of the perception–production interface hold in part, but a crucial modification is required in order to obtain the full range of effects that are observed in phonological acquisition.

**Keywords:** *Optimality theory, perception, production, phonological acquisition*

### **Introduction**

The relationship between perception and production remains an outstanding issue in the study of language acquisition. The conventional assumption is that perception precedes production, with children seeming to comprehend language well before they produce it. While this assumption has garnered anecdotal and experimental support, it has recently come under scrutiny on both in principle and empirical grounds. Naigles (2002), for example, has argued that the domains of perception and production reflect independent, but complementary components in the language learning process. By this view, a correspondence between perception and production is neither necessary nor sufficient because each domain serves a different function. As another example, deVilliers and colleagues (Coles-White, deVilliers, & Roeper, 2003) have shown experimentally that children produce complex sentence types, with little insight to the semantic meaning of their constructions. This finding that children evidence language use in the absence of underlying linguistic knowledge has been replicated in other studies of first language learning (e.g., Edwards, 1974; Eilers & Oller, 1977). Such results challenge the conventional view of perception before production and raise the prospect that a full range of logically possible relationships may obtain between the two domains. This likelihood

poses obvious challenges for theoretical accounts of the perception–production interface in language acquisition. In this paper, we explore these issues by examining the interplay between perception and production within the specific context of optimality theory (OT) as it is applied to phonological acquisition. Our goal is three-fold: (1) to summarize data that demonstrate four logically possible relationships between perception and production, (2) to consider the validity of available OT accounts of such patterns, and (3) to offer an alternative OT solution that better accords with the data.

### **The data: Perceptual similarity and productive outputs**

In a series of studies, we set out to establish what children know about the internal constituent structure of certain phonological units. To access this type of knowledge, a constrained classification task was used, whereby children were asked to judge the perceived similarity of stimuli (cf. Treiman & Breaux, 1982). On psycholinguistic grounds, this task is said to reveal a speaker’s analogical hypotheses about underlying structure (Shepard, 1972). In our applications, children were shown an equilateral triangular game board. In each corner of the board, identical pictures of a character (e.g., a turtle) were mounted. A child was instructed to listen to each character’s name, and then to pick which two of three were friends. Character names were systematically manipulated to sample the internal constituents of syllables in one set of studies (Gierut, Storkel, & Morrisette, 2002) and segments in another (Gierut, Morrisette, & Storkel, 2003). In conjunction with these classification tasks, we also elicited children’s productions, explicitly recruiting two groups of participants: those who produced the structures in question versus those who did not. This then provided two logically possible productive outputs, +production and –production respectively, for subsequent mapping onto the perceptual similarity results.

#### *The syllable*

Onsets of syllables were the focus of study in seven experiments, for reasons associated with their unmarked status in forming the basic CV syllable, salience in perceptual processing, and resilience in application of phonological rules. Three dimensions of onset-internal structure were instantiated in five types of segments/segmental sequences; these are summarized in Table I. Relevant structural dimensions were the number of segments in initial position, presence of onset-internal branching (as associated with the representation of affricates and clusters), and conformity to the Sonority Sequencing Principle (as associated with all but s+obstruent stop sequences). The singleton /k/, affricate /tʃ/, true cluster /tw/, adjunct cluster /sp/, and three-element cluster /skw/ were each combined with a range of vowels to form the CV syllables that served as the experimental input. Consistent with the classification task, children were to judge the perceived similarity of these stimuli,

Table I. Dimensions of structural similarity.

Onset	CV	Number of Sounds?	Presence of Branching?	Conformity to SSP?
Singleton	k+V	1	No	Yes
Affricate	tʃ+V	1	Yes	Yes
Cluster	tw+V	2	Yes	Yes
Adjunct	sp+V	2	No	No
Three-element cluster	skw+V	3	Yes	No

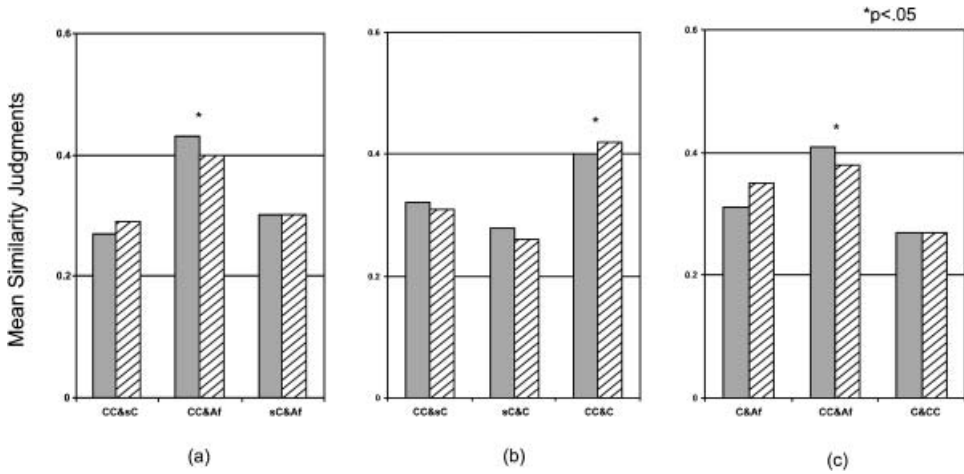


Figure 1. Mean similarity judgments based on (a) branching + SSP, (b) SSP alone, and (c) branching alone. Children who produced the onsets in question are shown by shaded bars; those who did not produce the onsets are shown by hatched bars.

when presented in triplets and varied along the dimensions of segmental number, branching and the Sonority Sequencing Principle, following from Table I.

Across studies, three main findings emerged, as illustrated by the representative plots shown in Figure 1 (a–c). First, children judged perceptual similarity based on a convergence of branching structure coupled with conformity to the Sonority Sequencing Principle (1a). Specifically, children grouped the affricate and cluster as alike, with these agreeing both in branching and sonority. Second, children also relied on the Sonority Sequencing Principle alone in their similarity judgments (1b). That is, they chose the singleton and true cluster as being similar. These differ in number of segments and branching, with the only dimension of structural overlap being the Sonority Sequencing Principle. Finally, children did use branching as an independent property in judgments of similarity, but only when the Sonority Sequencing Principle was held constant across items of the stimulus set (1c).

Notably, there were no differences in the response patterns of the +production versus –production subgroups across studies. This is particularly striking because, in the latter case, it suggests that children who did not produce the onsets in question still demonstrated keen insight to the subconstituent properties of onsets. These results thereby contribute two of four logically possible relationships between perception and production. Namely, one group of children had perceptual knowledge of the internal properties of syllables and also produced these same syllable types (hereafter, +perception/+production). Another group, as expected, had perceptual knowledge of the syllable onsets in the absence of productive use (+perception/–production).

### *The segment*

Using the same experimental procedures, we sampled the perception–production interface in a related set of studies examining the featural composition of segments. Here, the dimensions of structural similarity involved manner, with continuancy as the primary, and stridency as the secondary property. The segments /t s θ/ (coronal place of articulation) and

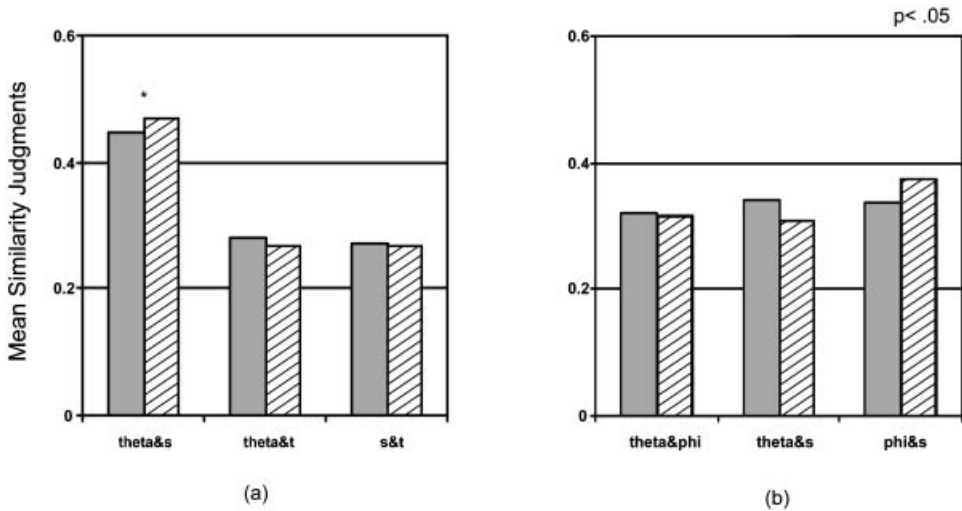


Figure 2. Mean similarity judgments based on (a) continuancy and (b) stridency. Children who produced the stridency distinction are shown by shaded bars; those who did not produce the contrast are shown by hatched bars.

/p f  $\phi$ / (labial replications) were combined with a range of vowels to form the stimulus sets. As before, two sub-groups of children were enrolled, those who produced a stridency distinction between /s  $\theta$ / (+production) versus those who did not (-production).

Across three studies, the main finding was that children consistently judged the perceptual similarity of segments based on continuancy, but not stridency. Representative results are shown in Figure 2 (a, b). This was true for both subgroups of children, independent of their corresponding production of the stridency contrast. These segmental results provide the remaining logical possibilities in the relationship between perception and production. That is, we have children who produced a phonemic stridency contrast, but did not have perceptual insight to the parameters of that same contrast in their similarity judgments (-perception/+production). There were also those who neither produced nor perceived the stridency distinction (-perception/-production).

In sum, the collective data from our studies of syllables and segments provide evidence of a complex relationship between perception and production, with all logical possibilities having obtained. This is consistent with prior reports, but these data extend the observation by sampling the internal structure of multiple phonological units, utilizing consistent perceptual methods, and recruiting two distinct sub-groups of children as based on their productions. For the present purposes, these observations set the stage for an evaluation of the adequacy of theoretical accounts of the relationship between perception and production as advanced within the framework of OT.

### OT in perception and production

OT is unique in that it regards the process of language acquisition as central to its tenets. This is in contrast to other formal models, which have viewed acquisition as a form of external (secondary) evidence. OT also stands apart with its attention to perception, in the interest of dually accounting for acquisition of both modes within a unified model. For the most part, other linguistic theories have focused singularly on accounts of production phenomena. For these reasons, OT emerges as an attractive model that is well suited to these data.

Briefly, the essence of this theoretical approach lies in constraints that are posited to derive optimal correspondence relationships between input and output (and vice versa). Constraints are universal and available to all learners; they are also hierarchically ranked and violable. It is the ranking that differentiates among languages and stages of development. There are two basic types of constraints. *Markedness constraints* operate on outputs by forbidding structural complexity, whereas *faithfulness constraints* dictate that the output must be identical to the input. These two types of constraints operate in an antagonistic relationship, banning and preserving structure, respectively. With regard to acquisition, the initial state grammar is characterized by markedness ranked above faithfulness. That is, early on, a child will opt for simpler structure at the risk of being unfaithful to that of the surrounding speech community. The final state grammar is characterized as just the reverse, with faithfulness outranking markedness. The progression from initial to final state grammars involves then the demotion of markedness constraints (Tesar & Smolensky, 1998).

The tenets of OT have been fruitfully applied to a wide range of production patterns documented in the course of phonological acquisition (e.g., Kager, Pater, & Zonneveld, 2004). OT applications in perception have not been as extensive, with two main proposals advanced. A first (Smolensky, 1996) renders markedness inoperative, with perception being solely determined by faithfulness. The reason is that markedness constraints, as defined generally, only affect outputs. In perception, the concern for the listener is not with the output, but rather the input. Thus, faithfulness constraints are the only elements of the constraint hierarchy that are relevant. Further, because faithfulness requires an identity match between input and output, the prediction is that children have fully faithful perception, even in the initial state. This solution thus allows for just two of four cases, these being +perception/+production and also +perception/–production.

An alternative proposal utilizes the full constraint hierarchy composed of markedness and faithfulness constraints (Pater, 2004). However, the processes of perception and production each make an independent pass through the grammar. To achieve this, two types of faithfulness constraints are posited, specific to each of perception and production. Like any other constraint, these too may be violated, thereby allowing for possible asymmetries between perception and production. None the less, the strong form of this proposal assumes that perceptual faithfulness is in a fixed ranking above production faithfulness during acquisition, with three explicit stages of learning. In the initial state, perceptual and production faithfulness are dominated by markedness, but in error relative to the target, thereby yielding cases of –perception/–production. Intermediate to this, perceptual faithfulness outranks some markedness constraint, which in turn outranks production faithfulness for instances of +perception/–production. In the final state, perceptual and production faithfulness outrank markedness, yielding target-appropriate +perception/+production.

Notice that neither of the available perceptual accounts provides for the case of –perception/+production as was observed in our data and reported the acquisition literature generally. This outcome can be achieved by maintaining independent perceptual and productive faithfulness constraints as above, with one crucial modification. The necessary provision is that the two types of constraints must be freely permutable in their ranking. That is, faithfulness to perception may be ranked above production and vice versa. This then allows for our particular finding that children produced a stridency distinction in the absence of corresponding perceptual knowledge of stridency. This provision likewise allows for the full complement of interfaces between perception and production as

instantiated in our data. In this way then, all logically possible relationships among the domains are joined within a unified theoretical framework.

While the advantages of an OT account may be clear from a modeling perspective, there are a number of questions that remain for future study. One issue pertains to continuity in the grammar, and how this may be implemented given that perception may outrank production and vice versa at various points in development. It is possible that the general learnability algorithm involving constraint demotion will provide a necessary solution. Another question relates to the empirical differences between an OT solution to the perception–production dilemma and other theoretical accounts of the same phenomenon. It will be important to document the empirical consequences of these various models and to differentiate among them on logical and experimental grounds. Perhaps the most puzzling question is why a child would ever come up with a solution such that perception lags production. It may be that these phases are indicative of shifts or transitions in the acquisition course. As a child begins to extend his or her knowledge of structure in new ways, this gain may be differentially implemented in perception and production. For example, productions might continue as they were prior to a knowledge spurt, but perception of new and emerging levels of insight might lag. This hypothesis has been borne out for adult learners (e.g., Janson, 1983; Gass, 1984), and if also true for children, we will need to document the various kinds of phonological insights speakers have, and to develop a range of tasks to differentially elicit such knowledge. In addition, it will be crucial to pinpoint the circumstances that promote transitional shifts in knowledge (albeit in perception or production), and to experimentally manipulate these in inducing and measuring change. Through these efforts, we may come closer to understanding the prime source behind the observed relationships between perception and production in phonological acquisition.

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