UNIVERSITY OF CALIFORNIA, SAN DIEGO

The Acquisition of Ungrammaticality: Learning a Subset in L2 Phonotactics

A dissertation submitted in partial satisfaction of the requirements for the degree Doctor of Philosophy

in

Linguistics

by

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2009

The Dissertation of Cynthia D. Kilpatrick is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

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2009

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LIST OF ABBREVIATIONS

L1	First language
L2	Second language
E1S2	Native English speaker who has learned some Spanish
S1E2	Native Spanish speaker who has learned some English
MS	Monolingual Spanish speaker
ME	Monolingual English speaker
BI	Speaker bilingual in English and Spanish
SLA	Second Language Acquisition
CGV	Consonant~Glide~Vowel
LP	Linguistic Perception Model
L2LP	Second Language Linguistic Perception Model
PFA	Perceptual Full Access

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ACKNOWLEDGEMENTS

First and foremost, I am indebted to my advisor, Eric Bakovic, for his support not only in the writing of this dissertation, but also throughout my grad school career. I've taken up countless hours of his time talking through some nebulous ideas (most of which never went anywhere), asking him to read drafts that were unreadable, and forcing him to provide moral support even when I gave him nothing on which to base his encouragement. He repaid me by being an excellent advisor, an outstanding teacher, and an inspiring mentor whose example I hope to follow with my own students. More than anything else, I am grateful that Eric helped me keep perspective; he pushed me to examine my interests and then follow my own path even when it diverged from his, and he frequently reminded me that there is more to life than academia. I consider myself to have been extremely lucky to have worked with him.

My development as a phonologist has also been influenced by the opportunities I've had to work with Sharon Rose and Jessica Barlow. To Sharon I owe many thanks for always making me think more, and raising issues that made me question my own conclusions. I am particularly glad that she forced me (sometimes with great resistance on my part) to focus more on examining the data and less on simply finding a convenient theoretical mechanism to handle a particular phenomenon. Jessica's willingness to allow me to get involved with her lab and her work fed my interests in phonological acquisition, for which I'm extremely grateful.

I am also indebted to Rachel Mayberry and Vic Ferreira for their expertise and assistance with experimental aspects of my research. Rachel's helpfulness and

assistance in experimental design were invaluable, and her continuous support of my work provided me with the encouragement I needed to know that I could do this. Vic's willingness to help some random student with stats was also essential to my success. While I can only hope to eventually gain even half the knowledge of experimental methodology and statistics that he has, his manner and approachability put even a novice at ease.

I would be remiss not to acknowledge my appreciation of the numerous subjects who willingly participated in my experiments – I could not have completed this dissertation without them. Also vital to the process were my undergraduate research assistants: Nicole Hutchinson, Daniel Scarpace, Kim McSorley, Cristina Rangel-Uribe, and Jamie Resheske. Nicole and Daniel in particular were crucial to the completion of these experiments, as they kept me and the lab on track and running.

I must say, there's no way I would've made it through grad school without Laura Kertz and Hannah Rohde – I so appreciate the practice talks, pep talks, and cry-on-your-shoulder talks throughout! I look forward to being colleagues in a whole different way as we all move on, and I hope our friendship continues well beyond the boundaries of UCSD. Katie McGee and Rebecca Colavin have been two of my greatest friends and supporters since I met them, and they have made my life better just by being in it.

My family has, forever and always, been a source of support and love that has made my life more complete, no matter how far apart we were. My parents have given me endless support, even when my returning to school may not have seemed

like a smart decision to them, and my dad may be the only person who ever reads this document in its entirety. I feel incredibly blessed to have sisters who are also some of my closest friends, and they have endured endless hours of phone calls, which often had to to be at my convenience so that I could multi-task more effectively. I promise not to call anymore with endless questions about the way you speak (I'll do it in person instead!).

I should also mention a couple people whose encouragement during the last year of writing this dissertation almost made up for not having known them well during the rest of grad school. Michal Temkin-Martinez was the perfect companion to go through dissertation hell and the job search process with, providing both support and distraction as needed. It was so great to know that I was not alone (and it's good that we both got jobs so we don't hate each other now)!

To Patrick, you came in late in the game, but your support during the home stretch was invaluable – thanks for being my cheerleader on both good days and bad, for believing in me when I wasn't sure I believed in myself right then, and for always making me smile just by being there (and no, that does not rhyme!). I look forward to sharing life's ups and downs with you for a long time to come.

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ABSTRACT OF THE DISSERTATION

The Acquisition of Ungrammaticality: Learning a Subset in L2 Phonotactics

by

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University of California, San Diego, 2009

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This dissertation investigates the Complement Problem, which second language learners face when the set of forms grammatical in their second language (L2) is a subset of those grammatical in their first language (L1). This problem arises due to two common assumptions: (1) the Subset Principle, and (2) full transfer of L1 properties to the L2 grammar. According to the Subset Principle, learning follows a path from the most restrictive grammar to less restrictive grammars. If L1 properties are fully transferred to the L2, then this in combination with the Subset Principle creates the Complement Problem: a learner begins with the L1 grammar and then needs to move into a *more* restrictive grammar. If both (1) and (2) hold, the L2 learner

is expected to never be able to learn that some of the forms grammatical in their L1 are *ungrammatical* in their L2.

I present experimental evidence that shows that learners *are* able to acquire this knowledge. L2 learners of English and Spanish participated in wordlikeness rating tasks and direct comparisons of different forms, both of which illustrated the successful acquisition of ungrammatical forms in the L2. In a set of experiments focused on final consonants in English and Spanish, L1 English~L2 Spanish speakers exhibited knowledge in Spanish of the ungrammaticality of some final consonants, even when those final consonants were legal in English. A second set of experiments showed similar results for L1 Spanish~L2 English speakers' judgements of consonant~glide~vowel sequences in Spanish and English. These results indicate that the acquisition of ungrammaticality is possible in L2 learning.

In order to account for this knowledge, I propose a modification to Escudero's (2005) Second Language Linguistic Perception Model in which the L2 grammar is not fully transferred. Instead, the perception grammar reverts to the most restrictive state, while the production grammar is fully transferred to the L2. This modification, which I call Perceptual Full Access, accounts for the subset knowledge seen in the experiments presented here, as well as continuing to account for transfer effects in both production and perception, as it was designed to do.

1

The Complement Problem in L2 Acquisition

The Subset Principle (Dell 1981, Manzini and Wexler 1987) is a well-established assumption in first language acquisition. This principle describes the learning path that a language learner takes when faced with a choice between two possible generalizations in the grammar, one of which will generate a grammar that is a proper subset of the grammar generated by the other. When this occurs, the Subset Principle holds that the generalization that creates the most restrictive grammar – the *subset grammar* - is chosen. In essence, this means that a learner begins with the most restrictive grammar and moves by incremental steps into less restrictive grammars, so that they are are always building into less restrictive grammars which accept as grammatical a superset of the forms that are grammatical in the current grammar.

The reverse, moving from a less restrictive grammar to a more restrictive grammar, is assumed to be impossible. That a language learner cannot narrow their grammar to a more restricted set of forms is a logical argument that follows directly from the widely-held belief that language is learned on the basis of positive evidence.

That is, language learning relies on what the learner hears around them. Because restricting the grammar to a subset of the forms it accepts would require negative evidence, or evidence regarding the incorrectness or ungrammaticality of an utterance, acquiring a subset grammar has been assumed to be impossible, as the lack of positive evidence leads to what Baker (1979) refers to as the subset problem: the learner must determine that some forms that their grammar accepts are ungrammatical, without any positive evidence. By following the Subset Principle, the learner never has to face the subset problem.

While this principle may be unproblematic for first language (L1) acquisition, its validity in second language (L2) acquisition, and particularly in second language phonology, has yet to be determined. A large body of work argues either for or against the validity of the Subset Principle in second language acquisition (White 1989, Hamilton 1995, Van Buren 1996, among others), but a consensus has not been reached. Furthermore, most of these arguments are related to syntax, while little research has been done that speaks to the validity of the Subset Principle in L2 phonology.

Whether the Subset Principle holds in L2 acquisition is a relevant question because many researchers (e.g., Broselow et al. 1998, La Fond et al. 2001, Shea and Curtin 2006, among others) either implicitly or explicitly assume that the initial state of the L2 grammar is the L1 grammar. If the Subset Principle holds in L2 acquisition and the initial state of the grammar of the L2 is identical to the grammar of the L1, then this would mean that the most restrictive grammar a learner would ever have is

that of the L1. Suppose that there are two sets of grammatical forms, one generated by a learner's L1 grammar, and the other generated by the learner's L2 grammar. Now suppose that the forms generated by the learner's L2 are a subset of the forms generated by the learner's L1. All of the forms generated by the L2 grammar are also generated by the L1 grammar; this set of forms I will refer to as the subset. On the other hand, the L2 grammar does not generate some of the forms that the L1 does; this set of forms will be referred to as the complement to the subset.

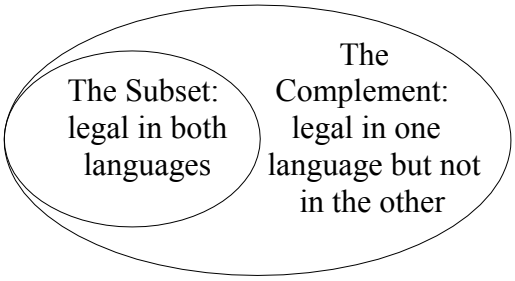

Figure 1.1 The Subset and the Complement

When the L1 grammar of the learner is a subset of the grammar of the L2, the Subset Principle does not present a problem, as the learner is building into a less restrictive grammar. It is when the L2 grammar is a subset of the L1 grammar that a problem arises. In these cases, in order to successfully learn the L2 grammar, the learner must acquire the knowledge that the complement is ungrammatical in the L2. This is what I will term the *Complement Problem.*

(1) The Complement Problem

The problem that L2 learners face when they must learn a subset and acquire the knowledge of ungrammaticality in their L2 grammar

The Complement Problem arises because L2 learners often face situations where the grammatical possibilities of the L2 are a subset of the grammatical possibilities of the L1. Application of the Subset Principle thus predicts that the L2 learner would not perform in a native-like manner in relation to complement structures. Instead, when an L2 grammar is more restrictive than an L1 grammar, then a learner who produces grammatical L2 forms, should not recognize that some forms that are grammatical in their L1 are ungrammatical in their L2. Rather, they should view the complement to also be acceptable in their L2, because acquiring the knowledge of ungrammaticality is impossible.

In this dissertation, I address the following questions: Do second language learners restrict phonotactic patterns of their L2, that is, do they make different judgments in their L2 than they do in their L1, or are their judgments similar in their two languages? Specifically, is it possible to learn a subset phonotactic grammar?

This dissertation thus investigates the learning of a subset grammar in L2 phonology, specifically in the area of phonotactics, which restricts where specific sounds are and are not allowed to occur. Using L2 learners of Spanish and English, I show that it is possible to learn a phonotactic grammar for an L2 in which sound occurrences are more restricted than in the L1. Experimental evidence is presented that indicates that L2 learners of Spanish and English are able to learn a more restrictive phonotactic grammar. Results like those presented here are problematic for many linguistic theories of language acquisition which implicitly assume the Subset Principle because they cannot account for the acquisition of ungrammaticality.

What L2 learners know, implicitly, about their L2 can reveal to us what the state of their L2 grammar is, and how that may differ from the grammar of their L1. If learners learn a subset grammar, then this has implications for learnability in general, especially for learning algorithms and theories that assume the Subset Principle.

In Section 1.1, I define and present the Subset Principle, and define the Complement Problem, which L2 learners face when they learn an L2 in which only a subset of the grammatical forms of the learner's L1 should be acceptable. This is followed in Section 1.2 by a discussion of transfer effects in second languages, with a discussion of the Subset Principle in Section 1.3. In Section 1.4, I give a brief overview of the types of evidence available to language learners, and then discuss how second language learners face the Complement Problem in Section 1.5. Section 5 outlines the dissertation and concludes.

1.1 The Subset Principle

The Subset Principle (Dell 1981, Berwick 1985, Manzini and Wexler 1987) is an established part of linguistic learnability theories. This principle, assumed to be a part of Universal Grammar, is as follows:

(2) The Subset Principle

> Whenever there are two competing grammars generating languages of which one is a proper subset of the other, the learning strategy of the child is to select the less inclusive one. (Dell 1981:34)

This principle accounts for the fact that learners, when making a choice between two possible generalizations that hold for the data at hand, choose the more restrictive of the two even in the absence of positive data that would establish the necessity of this choice. This principle is an underlying assumption of learnability within generative grammar, and is often built into different learning algorithms and learnability assumptions.

Dell's formulation of the Subset Principle is based on an optional phonological rule in French, in which a word-final liquid is deleted when it is preceded by an obstruent. As shown in (2), when the liquid [l] or [r] is preceded by the obstruent [b], two different surface forms may arise, one in which the liquid has been deleted, and one in which it has not:

(3) Optional final liquid deletion after obstruents in French

	French form	English gloss	possible realizations	
a.	*Quelle table*?	'which table'	[kɛltabl]	[kɛltab]
b.	*Quel arbre*?	'which tree'	[kɛlarbr]	[kɛlarb]

However, when the liquid is preceded by a segment other than an obstruent, such as another liquid, deletion cannot occur:

(4) Prohibited final liquid deletion after liquids in French

Parle	'speak'	[parl]	*[par]

A child learning French will have heard pairs, like those in (2), where the liquid is only sometimes deleted after obstruents, and they will also likely have heard, for some words, only one part of the pair, i.e., only the form that has undergone

deletion for some words, and only the form that has not undergone deletion for other words. Crucially, they will not have heard forms where the liquid deleted after another liquid, as in *[par] 'speak', but will have no way of knowing if this is simply accidental – perhaps it just so happened that every time they heard *parle* 'speak', the liquid did not delete, but it could have. The child is thus faced with a decision as to where it is allowable to delete a liquid:

(5) Possible rules for optional liquid deletion in French

Rule A: Optionally delete word-final liquids only after obstruents

Rule B: Optionally delete word-final liquids after all consonants

Both rules in (4) fit the data that the child has heard, but Rule A is more restrictive than Rule B: the segments after which deletion can occur by application of Rule A form a proper subset of the segments after which deletion can occur by application of Rule B. Dell argues that the learner must select Rule A, rather than Rule B, in order to arrive at the adult grammar of French, under which deletion after sonorants in forms like *[par] 'speak' is ungrammatical.

Dell's argument for the required choice of the more restrictive rule is based on overgeneration and the type of evidence available to a language learner: if a child were to choose the less restrictive Rule B, then at some point they would have to figure out, on the basis of forms that they never hear, that their rule is overgeneralizing. Based only on the data that they hear (direct positive evidence), the learner would never realize that they were overgenerating, and would continue to view final liquid deletion to be possible after any consonant. Because adult speakers of

French consistently view deletion after sonorants to be ungrammatical, and assuming that learning requires direct positive evidence, Dell argues that the learner, when faced with a choice between two possible grammars, must choose the more restrictive of the two when one describes a proper subset of the other.

Subsequent work on the Subset Principle (Berwick 1985, Manzini and Wexler 1987, among others) has argued for its validity in L1 acquisition, and linguistic theories of language acquisition generally assume the application of this principle. In essence, the Subset Principle requires that learners always be acquiring knowledge of grammatical forms, or that their grammar continually expand to allow a greater set of acceptable forms. The acquisition of *ungrammaticality*, or learning that some forms that the grammar allows are actually ungrammatical, is impossible, and the learner should never have to face this situation.

1.2 Transfer effects and the L2 grammar

A large part of the problem with assuming the Subset Principle in L2 acquisition is due at least in part to assumptions regarding what the initial state of the L2 grammar is. Much recent work has made the assumption that the initial state of the L2 grammar is the L1 grammar (Broselow et al. 1998, La Fond et al. 2001, Shea and Curtin 2006). For instance, Schwartz and Sprouse (1994, 1996) propose a model of second language acquisition that is reliant on the notion of *Full Transfer:* the L1 grammar is fully transferred as the initial-state L2 grammar.

This assumption is due to a vast amount of research that shows the effects of transfer and interference in L2 acquisition. Language transfer occurs when a language learner uses knowledge from their L1 in their L2 grammar. When the effect of transfer is negative – when it results in a form or structure that is not what native speakers of that language would produce in that instance – transfer is viewed as *interference*. The effects of transfer have been shown to hold in all areas of language development, including syntax, morphology, and pragmatics, and is often obvious in a foreign accent in the areas of phonetics and phonology. Through the 1960's, the focus of second language acquisition work revolved around the effects of transfer, and it is generally agreed upon that any theory of second language acquisition must be able to account for transfer of properties from the L1 grammar into the L2 (Towell and Hawkins 1994).

Transfer and interference of the L1 phonological system to the L2 is an area of second language research that has produced an immense amount of work. Much of this work examines the effects of transfer of articulatory and acoustic properties of segments from the L1 into the L2. For instance, Munro et al. (1996) investigated the production of different consonants in English by native Italian speakers, and a number of studies have investigated the property of VOT (voice onset time) in the production of second language speakers (Fowler et al. 2006, Yavas and Wildermuth 2006, Pater 1997, among others) or other acoustic effects in the production of L2 speech.

Some work has also been done on the effects of transfer in segmental contrast. For instance, Eckman, Elreyes, and Iverson (2001) (see also Muñoz-Sanchez 2003)

investigated the acquisition of an allophonic split, a situation in which a pair of native language allophones must be split into separate phonemes in the L2, which was argued by Lado (1957) to be a maximally difficult learning situation. The difficulty of an allophonic split lies in the fact that an L2 learners must take two different phonetic realizations (allophones) of the same abstract category (phoneme) in the L1, and in the L2, somehow learn that the two phonetic realizations map to separate abstract categories. What much of this work shows is that L2 learners produce segments in their L2 in the same ways that they do in their L1, even when native speakers of the learner's L2 produce them differently. For instance, native Spanish speakers who have learned English often pronounce the voiceless stops [p, t, k] in English with a much shorter voice onset time than what native English speakers produce. However, this causes problems because the VOT values for the voiceless stops [p, t, k] in Spanish are the same VOT values that correspond to the voiced stops [b, d, g] in English. The L2 learner of English thus may produce [pæt] instead of [p^hæt], which native speakers of English are likely to perceive as /bæt/ 'bat' rather than /pæt/ 'pat'.

Other work has shown that vowel production and perception in the L2 is largely reliant, at least in early stages, on L1 values. For instance, native speakers of Spanish have problems in both production and perception of English vowels, as there are only five contrastive vowels in Spanish and more than twice as many in English; thus the native Spanish speakers are faced with learning many different vowel contrasts in English. In early stages, L1 knowledge interferes, and L2 learners cannot reliably distinguish the difference between the different vowels (Morrison 2006).

In addition to segmental interference, phonotactic interference is also obvious in second language acquisition. For example, English allows initial consonant clusters that begin with [s], such as in *sleep* and *sneeze*. Spanish, however, disallows s-initial clusters. This phonotactic restriction often leads to interference for Spanish learners of English; they produce the forms as [ɛslip] and [ɛsniz], with an initial vowel that is not present in the productions of these words by native English speakers, but that is consistent with phonotactic patterns in the Spanish lexicon.

Due to the incontrovertible evidence that transfer occurs from the L1 to the L2, proposals like that of Schwartz and Sprouse (1996) accept the effects of transfer and capitalize on this property of L2 speech in the development of a model of L2 acquisition. However, this inevitably leads to the Complement Problem if the Subset Principle is assumed to hold in L2 acquisition. In some cases, a learner of a second language will be faced with learning a grammar that is a subset of the grammar of their L1. If there is full transfer from the L1 to the L2 grammar, and the Subset Principle holds, then the most restrictive grammar that an L2 learner can ever have is that of the L1. This means that the language learner will never be able to acquire the ungrammaticality of those forms that are legal in their L1 but illegal in their L2; they will not be able to overcome the Complement Problem.

Consider a hypothetical example of the Subset Principle in action and how the Complement Problem arises. Imagine that a language learner begins with a grammar that only allows simple onsets, such as the grammar of Japanese. For a Japanese learner of English as a second language, positive evidence will exist which can lead

them to expand their grammar to include a larger set of forms; the learner will hear complex onsets in words like *sleep, play, truck, stop, clean, strong,* and many more. Based on these forms that the learner has heard, he can conclude that these clusters exist in English. This situation is unproblematic for the Subset Principle; the learner is acquiring a superset grammar, not a subset grammar. However, when an English speaker learns Japanese as a second language, the opposite is true. The learner must acquire a subset grammar that only includes simple onsets as grammatical. Complex onsets – the complement to the subset – are illegal.

1.3 The Subset Principle and L2 Acquisition

Most work that investigates whether the Subset Principle holds in L2 acquisition has utilized the Principles and Parameters approach to syntax. L1 learners initially select the setting of the parameter that is most restrictive, and only switch that setting on the basis of positive evidence that they hear in the language. While some work suggests that the Subset Principle also holds in L2 acquisition (Van Buren 1988, Berent 1994, Kang 2002), a large body of work in the acquisition of syntax indicates that the Subset Principle does not operate in second language acquisition (Van Buren 1996, White 1989, Hamilton 1995, among many others). For instance, Hirakawa (1990) examines the acquisition of reflexives in English by native speakers of Japanese, and concludes that the Subset Principle does not hold in L2 acquisition. This conclusion is based on experimental evidence that shows that L2 learners accepted a broader set of reflexive antecedents than the L2 allows, which he accounts

for by direct transfer from the L1. Because the learner did not begin with the most restrictive grammar, Hirakawa concludes that the Subset Principle was not operative. However, given the assumption that the L2 grammar is a copy of the L1, his results are actually consistent with the Subset Principle holding – the learners were simply not able to restrict the set of grammatical possibilities in their L2 due to superset transfer from the L1.

Other work, such as that by Cho (1991, 1993), shows that L2 learners do appear to be able to restrict their L2 grammar to a subset of forms generated by their L1. Cho shows that native Korean speakers who are very advanced L2 learners of English are able to learn that only a subset of the acceptable structures of their L1 are acceptable in their L2. These L2 learners judge those structures not included in the subset to be ungrammatical in their L2. Cho claims that this late acquisition of a subset indicates that 'indirect negative evidence' may be used in the successful acquisition of an L2; language learners notice that certain things do not occur, and assume that their absence implies ungrammaticality, especially when the non-occurring structure is generally considered to be marked. In Cho's view, 'indirect positive evidence' may also be possible, in that direct positive evidence for some forms and structures may trigger reanalysis of an incorrect overgeneralization. Cho presents little argument for any type of indirect evidence, and it is unclear if his experimental results actually support this claim or if it is simply a convenient alternative to reliance on the Subset Principle. Nevertheless, the data do suggest that advanced second language learners are able to recognize forms in their L2 as

ungrammatical even when those same forms and structures are grammatical in their L1; they appear to have learned a subset grammar and acquired knowledge of ungrammaticality.

However, the data are not as clear as might be desired. Berent (1994) argues that previous research on the Subset Principle in L2 syntax has been flawed due to experimental design, and as such cannot be used to defend an argument against the application of this principle to L2 research. He instead argues the reverse, that the Subset Principle is indeed psychologically real in second language acquisition. Much of his argument, however, is based on theoretical grounds, rather than on data that reveal whether subset learning has truly taken place by L2 learners.

1.4 Types of evidence available to learners

1.4.1 Positive evidence

The reasoning behind the Subset Principle relies crucially on the assumption that positive evidence is the only evidence available to a language learner. Positive evidence generally refers to what the learner hears in the ambient language. Hearing certain forms and structures provides the learner with the knowledge that these forms do in fact occur in the language they are learning; thus the learner gains knowledge that the language allows these forms (White et al. 1991). Positive evidence, then, gives the learner information about what is allowed, or what is grammatical, in the language they are learning. Within generative frameworks, language acquisition is assumed to rely on what is heard, and not on what is not heard.

1.4.2 Direct negative evidence

Negative evidence, on the other hand, gives the learner information about what is *not* grammatical in their language, and may take one of two forms: direct negative evidence or indirect negative evidence. Direct negative evidence is generally thought of in terms of correction (Cook 1985, James 1994); a learner produces a grammatically incorrect form, and the response from a native speaker, especially a language instructor, to this incorrect form communicates its ungrammaticality. This may be through explicit correction, but may also take the form of a "recast", where the ungrammatical utterance is repeated, often as a question, but corrected. An example of a recast is given in (6).

(6) Recasting in teacher~learner interactions (Ellis and Sheen 2006)

Learner: I stand in the first row.

Teacher: You **stood** in the first row?

Learner: Yes, in the first row, and sit, ah, sat in the first row.

The efficacy of negative evidence in language acquisition has long been a matter of debate. Negative evidence in the form of correction or feedback has been argued by some to be effective in language acquisition. For instance, Gozzard, Baker, and McCabe (2008) show that four-year-old children improve their pronunciation when clarification is requested for words that are mispronounced. Laufer and Girsai (2008) also show that feedback and correction are effective in the teaching of words and collocations with L2 learners of English; students that were given feedback and

explanation of errors significantly outperformed students that did not receive the same feedback.

Others argue that negative evidence does not appear to be an effective tool in language learning. In first language acquisition, children often ignore corrections and continue to produce forms and structures that are ungrammatical (Braine 1971, McNeill 1966). Negative evidence has also been argued to be ineffective in L2 acqusition. For example, Gray (2004) argues that corrections in student writing rarely have an influence on production, and appear to be largely ineffective. Truscott (1996) also points out that "Veteran teachers know there is little connection between correction and learning: Often a student will repeat the same mistake over and over again, even after being corrected many times."

Direct negative evidence that does not rely on explicit correction, termed "implicit negative evidence", has also been argued to be available to language learners, even in L1 acquisition (Sokolov and Snow 1994), and may provide learners with implicit feedback on the grammaticality and ungrammaticality of utterances. This type of evidence often involves the way that a discourse participant responds to ill-formed vs. well-formed utterances. For instance, Hirsh-Pasek, Treiman, and Schneiderman (1984) found that parents repeated more of their children's ill-formed utterances than well-formed ones, while Demetras, Post, and Snow (1986) found that responses to well-formed statements furthered the conversational topic, while responses to ill-formed statements generally requested clarification. This difference in

responses may be enough to make a language learner pick up on the fact that an error has been made.

Kang (2007) also investigated the the use of negative evidence in the acquisition of the Korean past tense by heritage speakers of Korean. He compared the usefulness of negative evidence with lack of negative evidence, and found that explicit (= explicit rule instruction taught during the course of the conversation) and implicit (= recast or clarification, but no explicit rule instruction) negative evidence, both resulted in improved performance on the past tense. While he found no significant difference in performance improvement between the implicit and explicit negative evidence, he did find that those learners who received some form of negative evidence improved significantly more than those who received no negative evidence.

An additional problem with negative evidence, such as corrections, is that it is very inconsistent. In L1 acquisition, parents do not always correct an incorrect utterance. Even when they do, as Braine (1971) and McNeill (1966:69) point out, children appear to often completely ignore it. Brown and Hanlon (1970) found that parents are more likely to question the truth-value content of an utterance rather than its grammatical form. Thus the necessity of negative evidence has been strongly argued against (as in Marcus 1993). Without consistent feedback, negative evidence would not lead to the consistency of grammars that native speakers exhibit as adults.

1.4.3 Indirect negative evidence

While the effectiveness of direct negative evidence is generally questioned, whether implicit or explicit, the effectiveness of indirect negative evidence has gained more acceptance. Indirect negative evidence refers to taking advantage of an expectation not being met, the expectation being that certain forms, particularly grammatically simple or 'unmarked' ones, will be present in the language being learned. Their absence is enough to make the learner take notice, and to adjust their grammar accordingly.

Chomsky (1981:7) mentions the possibility of using indirect negative evidence, stating that "a not unreasonable acquisition system can be devised with the operative principle that if certain structures or rules fail to be exemplified in relatively simple expressions, where they would be expected to be found, then a (possibly marked) option is selected excluding them in the grammar". He continues by allowing that indirect negative evidence may be relevant for language acquisition, even though direct negative evidence is probably unnecessary.

A number of other researchers have more recently considered the use of indirect negative evidence in L2 acquisition. For instance, Dahl (2004) considers the possibility of negative evidence in the L2 acquisition of English passives by native Norwegians, and finds that the L2 English learners do not show definitive knowledge of the ungrammaticality of forms that native English speakers clearly view as ungrammatical. However, Dahl concludes that these learners have successfully utilized some degree of indirect negative evidence because they at least appear

skeptical of the ungrammaticality of these forms. She concludes that the use of inference as indirect negative evidence is the most likely strategy; learners do not encounter a particular structure in the L2, and they infer that it must be ungrammatical due to its absence.

The idea of indirect negative evidence as noticing something about the grammar has been capitalized on in several different theoretical and practical approaches to L2 instruction, including Corder 1967, which distinguishes between *input* and *intake*. Input is simply what a learner hears, while intake requires the learner to take the input and use it to help build their grammar. Intake thus relies on the input being comprehensible, at least to the extent that learning can take place. This does not rule out the possibility of using indirect negative evidence as intake, and, as a matter of fact, crucially requires some sort of inference, as the learner must be able to take what is heard in the input and make some generalization across it. Schmidt (2001) equates noticing with the psychological correlate of attention, and concludes that intentionally focused attention may be necessary if language learning is to be successful. This idea of focused attention is evident in L2 instructional techniques such as Focus on Form (Long 1991, Long and Robinson 1998), which requires focused attention on forms during different tasks, and Contrastive Analysis (Lado 1957), in which grammatical differences between the L1 and the L2 are discussed and explicitly compared.

Plough (1992) also views indirect negative evidence as a type of inductive learning that takes place in three stages during L2 acquisition. The first stage is

scanning what is known, in either the L1 or the L2, or even other knowledge that may play into the learning process. Stage 2 is linking new material with what is known, and Plough indicates that this is the point at which it is possible to notice the absence of a new structure. When there is a mismatch between new and old, the learner infers from the absence of a structure that it must be ungrammatical. This inductive reasoning is, in essence, indirect negative evidence, which in Stage 3 guides the learner in establishing generalizations based on the mismatch between what is already known and what the new material shows. By having the learner compare what is already known with new material, Plough allows for a clear distinction between L1 and L2 acquisition; L1 learning takes place with no previous knowledge, so no comparison between the new and the old is necessary.

1.5 Facing the Complement Problem

Whether L2 learners can actually learn a subset grammar is an empirical question that has not been addressed in phonological research until recently. In general, work in second language phonology has focused primarily on the acquisition of segments and segmental contrasts, and has largely ignored such things as phonotactic knowledge: the knowledge of how different sounds are and are not allowed to combine in a given language.

Phonotactic learning is a particularly good testing ground for determining whether L2 learners successfully overcome the Complement Problem, because the only kind of evidence available to the learner to determine that the complement is

ungrammatical is indirect negative evidence. Looking at learning a subset in phonotactics removes the possibility of both positive evidence and direct negative evidence. That is, because forms that violate the phonotactic restrictions of the language do not exist, the learner will not hear forms in the ambient language that have phonotactic violations. As such, no positive evidence is available to them; they will not hear these forms in their input. In addition, it is not expected that a learner will attempt to produce complement forms that are phonotactically illegal in their L2, because the forms they hear constitute a subset of the forms that are acceptable in their L1. Because these forms do not exist, the learner will not attempt to produce them, and thus will not be corrected or receive any kind of feedback regarding the ungrammaticality of these forms. Due to this, the learner should never receive direct negative evidence, and should not be corrected or have their productions recast in a more grammatical way. In essence, the **only** form of evidence available to the learner for the ungrammaticality of the complement is indirect negative evidence.

In order to determine whether L2 learners have successfully overcome the Complement Problem, two cases are examined, both of which focus on the phonotactic grammars of English and Spanish. First is the case of final consonants, where the set of legal final consonants in Spanish is a proper subset of the set of legal final consonants of English. If native English speakers who have learned Spanish as a second language illustrate knowledge that complement forms (codas that are legal in English but not in Spanish) are less acceptable than subset forms (codas that are legal

in both languages), then this provides some evidence that L2 learners can successfully overcome the Complement Problem and acquire knowledge of ungrammaticality.

In order to establish this even further, a second case will be examined, which is predicted to be more difficult to learn due to the nature of the phonotactic restrictions. Research has shown that some types of restrictions are learned more quickly and easily than others (Warker and Dell 2006), so this second subset learning experiment will include sequences that are predicted to be more difficult to learn. In this second set, the phonotactic restriction at hand is one that is reliant on a string of segments that includes the glide [j], preceded by a consonant and followed by a vowel. In this set of experiments, English allows only a subset of the possibilities of Spanish. As with the final consonants, if L2 learners of English recognize that complement sequences are not as acceptable as subset sequences, more evidence is provided as to the success of L2 learners in acquiring ungrammaticality.

1.6 Structure of the dissertation

It has not yet been established just what second language learners actually do learn regrading ungrammaticality, and this is especially true regarding the Subset Principle and phonotactics in phonology. Work on the Subset Principle in L2 acquisition has mainly focused on syntactic complexity, and work within phonology has focused, as previously noted, on the acquisition of segments and contrasts that do not appear in a language learner's L1. Only a very small body of work has concentrated on second language knowledge of phonotactics, and this has not looked

specifically at the question of whether learning a subset of phonotactic restrictions is possible in second language phonology.[1] However, recent work has shown that phonotactic knowledge affects a number of processing tasks, so lack of phonotactic knowledge could affect how accurately and quickly L2 learners process speech. In Chapter 2, I discuss work that speaks to the use of phonotactic knowledge in native speech processing as well as in second language speech.

In Chapters 3 and 4, I present 2 sets of experiments, one using final consonants and one using consonant~glide~vowel (CGV) sequences, that determine whether L2 learners of Spanish and English distinguish between subset and complement forms in different tasks. For both the final consonant and CGV sequences, the results of the experiments show clearly that L2 learners successfully overcome the Complement Problem and learn a subset. These learners have been able to acquire the knowledge of ungrammaticality.

A major problem in relation to the Subset Principle is that it is assumed to hold in first language acquisition, and many linguistic analyses of second language acquisition data have simply adopted L1 learning algorithms for use in second language acquisition, in addition to assuming that the initial state of the L2 is the L1. Because L2 learners are able to acquire a subset grammar, as the experiments in Chapters 3 and 4 show, both of these assumptions cannot hold; a learner cannot begin with the L1 grammar, follow the Subset Principle, and still learn a subset grammar. In Chapter 5, I examine the Second Language Linguistic Perception model (L2LP) of

[1]But see Trapman and Kager 2009, published just as this dissertation was being completed.

Escudero (2005), which is one of the most comprehensive models of L2 speech perception and its acquisition. I show that this model as it currently stands is not designed to account for subset learning in L2 phonotactics, and I propose a modification to the assumptions of this model in order to better account for the results of the experiments reported here.

2

The Role of Phonotactics in Speech Perception

As discussed in Chapter 1, the Subset Principle leads to the Complement Problem in L2 acquisition, a situation in which an L2 learner is faced with learning a more restrictive grammar than that of the L1. Previous research has not established that language learners successfully overcome the Complement Problem in L2 phonotactics. Rather, knowledge of the ungrammaticality of complement forms has been largely ignored in favor of the acquisition of segmental contrast and phonetic realizations. However, knowledge of what is phonotactically ungrammatical is of great value to the language learner in terms of speech perception.

A growing body of work in the area of speech processing indicates that phonotactic knowledge affects many processing tasks, influencing the ways in which speakers perceive segmental sequences, how the speech stream is segmented, and how quickly and accurately words are recognized and repeated. This work has obvious

implications for second language learning, because it implies that definitive knowledge of a phonotactic system is necessary in order to successfully process speech. Therefore, lack of phonotactic knowledge that complement forms are ungrammatical could lead to problems in various areas of speech perception and processing. For instance, a Spanish speaker, upon hearing [lospanes] will parse this automatically as *los panes* 'the bread', because [sp] is not a legal onset. An English speaker, on the other hand, might parse it as either *los panes* or *lo spanes (*nonsense phrase) because the phonotactics of English allow [sp] as an onset.

In this chapter, I begin in Section 1 with an introduction to phonotactics, followed by a brief discussion in Section 2 of a few key studies that speak to the effect of phonotactic knowledge on speech processing in one's native language. In Section 3 I extend this discussion to include work that indicates the degree to which non-native speakers have knowledge of the phonotactic restrictions of their second language. Section 4 concludes with a look at work that has directly addressed the Subset Principle in phonology.

2.1 Phonotactics

Phonotactics, in general, refers to what sounds can occur in a language, possible sound combinations, and environments and structural positions in which different sounds or sound combinations can occur. For instance, in English, the sound [ŋ] appears frequently, in words such as *sing* [siŋ], *hanger* [heŋɚ], and many more. However, native English speakers recognize that [ŋ] never begins words in English.

In short, the phonotactics of the English language restrict the environments in which [ŋ] appears, and only non-initial occurrences are allowed.

While there is little debate whether phonotactics control sounds and sound combinations, just what it is that creates phonotactic knowledge has been of great debate. Within formal linguistics, phonotactics has been generally accepted to be grammatically-based, regulated by rules (or constraints, if you will) that are part of the intrinsic grammatical knowledge that speakers possess. However, recent work has made claims that phonotactic knowledge is based on distributional regularities rather than being formally grammatical, and measures such as phonotactic probability have come into common usage.

Phonotactic probability, as defined by Jusczyk, Luce, and Charles-Luce (1994), refers to "the frequency with which a phonological segment...and a sequence of phonological segments...occur in a given position in a word."[2] The general idea is that the more often we hear sounds and combinations of sounds, the better they sound to us. This has been shown, for instance, by Coleman and Pierrehumbert (1997), who model Coleman's (1996) results which found that listeners rated some nonce words with non-occurring sequences as better than some nonce words with occurring sequences. The difference appeared to be driven by the high familiarity of some sequences, such as final *-ation*, which made a word appear more familiar to a speaker of English, even when the initial cluster was unfamiliar and phonotactically illegal.

[2]In this definition, "a given position" refers to linear order, rather than syllabic structure. Phonotactic probability does not rely on how often different segments or combinations of segments occur as codas or onsets, but rather how often they appear as the first, second, third segment, etc in a string.

Therefore words like [mɹu'peɪʃn], with familiar [-eɪʃn] but non-occurring initial [mɹ-] were rated better than words like [splɛtɪsɑk] with no apparent phonotactic violations. Coleman and Pierrehumbert conclude that the high frequency of [-eɪʃn] overrides the apparent illegality of [mɹ-]. A number of other researchers have shown that probabilities appear to make a difference in how listeners perceive well-formedness of sequences. In essence, work on phonotactic probability simply shows that the more often one hears sounds and sound sequences, the better one thinks they are.

2.2 Phonotactic knowledge and native speakers

Whichever definition of phonotactics one prefers to use, it is clear that this knowledge that speakers have of where sounds and sound combinations can occur is of great importance in the area of speech perception. A growing body of work shows that phonotactic knowledge in native speakers affects speech processing. One way in which this appears to be true is in the area of speech segmentation; knowledge of phonotactics helps determine where word boundaries fall, thus aiding in speech segmentation. This has been shown in word-spotting experiments in Dutch (McQueen 1998), as well as in English (Weber 2000). Word-spotting, an experimental paradigm in which strings of segments are played auditorily to listeners, requires that the listener spot real words hidden in the strings of segments. For instance, in Weber's English experiment, listeners were presented with strings like [punlʌk], in which the real English word *luck* was embedded. An accurate response corresponded to spotting of a real word (in the example given, by repetition of the word *luck*). Responses and

response times to stimuli like [punlʌk] were compared with those to stimuli like [marplʌk], where the parsing possibilities differed. According to English phonotactics, the only possible parse of the former is [pun.lʌk], because [nl] is neither a legal onset nor a legal coda. In the latter, however, two parses are possible: [marp.lʌk] and [mar.plʌk]. Weber's results showed that responses were quicker and more accurate in response to stimuli in which only a single parse was possible. That is, *luck* was recognized faster and better in [punlʌk] than in [marplʌk]. Thus, wordspotting was facilitated by knowledge that the other parses were phonotactically illegal.

Similar results were evident in McQueen's (1998) study of wordspotting in Dutch, but his stimuli differed from Weber's in that he tested stimuli with one possible parse against stimuli with no possible parse (where any possible parse would result in either an illegal coda or an illegal onset). He too found that the presence of only a single parse facilitated word-spotting: words with no legal parse resulted in slower and less accurate responses. Again, phonotactic knowledge aided in the finding of a word in the midst of a string of sounds; knowledge that some parses were illegal led to facilitation when only a single parse was available. However, when all parses were phonotactically illegal (because parsing left an illegal coda in the preceding portion), responses were slower and less accurate, showing that knowledge of illegality affected the responses of the participants. Together, McQueen and Weber's studies show that knowledge of the phonotactic possibilities of onsets and codas affects how quickly and accurately a string of segments can be parsed into recognizable words.

In addition to aiding in the segmentation of speech, phonotactic knowledge has been shown to help in the identification of speech sounds. Massaro and Cohen (1983) showed that knowledge of phonotactic goodness affected how listeners perceived combinations of segments. They created a continuum between [ri] and [li] by manipulating the onset frequency of the third formant, and then paired steps along this continuum with different possible initial segments. The results showed that listeners were more likely to judge the [l] end of the continuum as [r] when the initial segment was [t]; when perceived as [l], the resulting onset would be [tl], an onset that does not occur in English. However, the opposite end of the continuum was more likely to be perceived as [l] when it was preceded by [s]. Again, the resulting onset would otherwise be a non-occurring one in English: [sr]. In this experiment, the unacceptable onsets [sr] and [tl] were misperceived as acceptable onsets, leading Massaro and Cohen to conclude that listeners possess a bias toward phonotactically legal sequences; when presented with an onset in a potentially ambiguous situation, the listener is pre-disposed to an acceptable cluster.

In addition to helping with the identification of speech sounds, phonotactic knowledge has been shown to aid in recognition of sound sequences as well. For instance, Vitevitch et al. (1997) showed that listeners consistently judged bisyllabic nonce words with highly frequent segments and segment sequences to be more English-like than nonce words with segments and segment sequences that are infrequent. Using phonotactic probability as a measure, Vitevitch and Luce (1998, 1999, 2005) found that higher probability nonce sequences were repeated more

quickly than nonce sequences with low probability. Results like these indicate that the more familiar one is with the sequences of a language, the better one is at recognizing and producing words, and possible words, in one's language.

Another lexical frequency effect that has been shown to affect speech perception is that of neighborhood density. Neighborhood density refers to the number of words in the lexicon that differ from a target word by only a single phoneme. A word like *cat* has many neighbors, including *mat*, *kit, cap, at,* and *scat,* while a word like *hue* has only a few neighbors, such as *cue* and *few.* As Luce and Pisoni (1998) discuss, high neighborhood density can lead to lexical competition, a situation in which infrequent words with many neighbors are identified less accurately and less rapidly than frequent words with few neighbors. Neighborhood density, then, like phonotactic probability, also affects how quickly and accurately words are perceived.

The effects of phonotactic probability and neighborhood density were also investigated by Bailey and Hahn (2001), who compared the two in an effort to determine their effects on wordlikeness judgements. Their results showed that both of these measures contributed independently to wordlikeness ratings. However, Bailey and Hahn also showed that these measures were unable to account for all of the effects that were evident in judgements of wordlikeness.

Bailey and Hahn are not alone in their assessment of lexical frequency effects like phonotactic probability and neighborhood density as being unable to account for some effects in the perception of wordlikeness. That frequency alone is not enough to

account for the differences in perception of acceptability of different forms has also been shown by Pitt (1998). Pitt makes the argument that knowledge of phonotactics affects phoneme processing, but argues in addition that a perceptual bias cannot be accounted for solely in terms of frequency or neighborhood density effects. This claim is based on a series of experiments, one of which examined the plausibility of a frequency effect for the Massaro and Cohen (1983) results, and found that the differences in effect size that a frequency account would predict did not hold for the clusters in question. An account based on phonotactic legality, however, makes successful predictions. Pitt also examined the question of phonotactic legality by progressively lengthening the steady state of a liquid in a cluster to create the impression of a schwa emerging, which would create two syllables and break up the consonant cluster. He found that listeners were more likely to label illegal sequences such as [tl] to be bisyllabic than legal sequences such as [tr]. He concludes that a phonotactic bias exists which influences the perception of a vowel between the consonants of an illegal cluster.

Moreton (2002) also shows that phonotactic knowledge affects the way that sound sequences are perceived, and argues that the perceptual bias effects he finds must be the result of structural restrictions and not simply frequency. He does this through the use of the stop-sonorant clusters [dl] and [bw], which are both unattested as syllable onsets in English. However, while [bw] seems to be a marginal cluster, [dl] is claimed to be an impossible one (Hammond 1999, Catford 1988). This is due to the sonority difference between the consonants of the clusters: [d] and [l] are closer in

sonority than are [b] and [w], and the closer segments are in sonority, the stronger the ban on same-place sequences (Selkirk 1988, Padgett 1991). A frequency account would predict no difference in any bias against the two clusters, because both have zero frequency in English, while a structural account would predict a stronger bias against [dl]. Moreton tested the strength of the bias against each of these clusters, but found a significant phonotactic bias only found against [dl]. Because English speakers have identical experience with [dl] and [bw] (since they are both non-existent in English), this result would be unaccounted for by a model based solely on frequency. A model that views phonotactics as structural rather than frequency-based would better account for this result. Moreton's experiment thus argues strongly for a structural account of the perceptual bias that exists in native speech perception.

That phonotactic knowledge is not reliant only on lexical effects such as frequency or similarity to existing words is also argued by Shatzman and Kager (2007). In an auditory lexical decision task, Shatzman and Kager found that listeners rejected nonce words faster when they violated a phonotactic constraint, even when any dependence on lexical factors was removed. They argue on the basis of this experiment that pure abstract phonotactic constraints are involved in speech perception.

In general, what all of this work has shown is that phonotactic knowledge affects the way that speech is perceived and processed. This finding carries with it important implications for second language learning. If the perception of L2 learners is affected by the phonotactics of their L1, then the way that language learners

perceive and segment speech in their L2 could be detrimentally affected. On the other hand, if L2 learners of a given language do process and segment speech in the same ways that L1 speakers of that language do, then this could provide evidence that these speakers have acquired phonotactic knowledge of their L2. In terms of the Complement Problem discussed in Chapter 1, if L2 learners cannot learn a more restrictive grammar, then they will not have knowledge of the ungrammaticality of some L2 forms, which will have negative consequences on their L2 speech perception.

2.3 Phonotactic knowledge and second language speakers

Work that investigates whether L2 learners have acquired phonotactic knowledge in their L2 has been largely overshadowed by work that deals more with the acquisition of segments and segmental contrasts, or with perceiving segments in the L2 when category boundaries between different segments differs in the L1 and the L2. However, a few studies (Bayley 1996, Young-Scholten 2004, Swanson 2001) have investigated whether L2 learners learn to apply phonological rules in their production. For instance, Swanson (2007) compared the acquisition of different phonological processes in a longitudinal study in which learners participated in pronunciation training. French speakers learning English are faced with learning to suppress the processes of palatalization and aspiration, while English speakers learning French are faced with acquiring these processes. In Swanson's experiment, after pronunciation training, the productions of L2 English speakers were more accurate than those of L2 French speakers, leading her to conclude that acquisition of

these processes (learning to apply them in the appropriate instances in the L2) was more difficult than suppression of them (learning not to apply them in the L2).

While studies like that of Swanson (2007) indicate that L2 learners appear to apply newly-learned phonological processes in their production, they fail to show that the L2 learner finds ungrammatical any form that they do not produce. It is possible that the learner has simply learned lexical items separately, even when they are morphologically related, or that the learner has simply picked up on the distribution of relevant segments. In other words, production of one segment instead of another is not necessarily an indication that the learner finds the one they did not produce to be ungrammatical.

Consider, for instance, a native English speaker learning German. German, with a final devoicing process, has a phonotactic restriction against final voiced obstruents, while English freely allows both voiced and voiceless obstruents in word-final position. A native English speaker learning German, especially in the early stages, may always produce voiceless obstruents in final position, but may still consider word-final voiced obstruents to be acceptable. They may simply be learning individual lexical items without any connection between morphologically related forms that would provide evidence that the voiceless obstruent in final position was underlyingly voiced. In other words, just because L2 learners produce only voiceless segments word-finally does not necessarily mean that they do so because their grammar restricts the production of voiced obstruents in final position. The lack of voiced obstruents in final position may simply be a function of their lexicon and not an

indication of the ungrammaticality of final voiced obstruents. Thus, in order to determine what is and is not considered to be grammatical in L2, more than just production is necessary.

2.3.1 Acquisition of restrictions on lax vowels

One study that set out to directly test knowledge of phonotactic restrictions in an L2 is Cebrian (2003), which tested the knowledge of lax vowel restrictions in L2 English learners who were native speakers of Catalan. English differs from Catalan in terms of restrictions on lax vowels: in Catalan, lax vowels are not restricted, while in English, lax vowels exist, but are restricted from appearing in stressed open syllables. Cebrian auditorily presented participants with two nonce forms, one with a tense vowel, such as [griz], and one with a lax vowel, as in [grɪz]. The participant then had to complete the two sentences in (7) with the forms they had been given.

(7) Cebrian's sentence completion

These are two _____.

The one on the left is called _____.

Because the nonce words ended in a vowel followed by [z], both sounded like possible plural forms in English. However, if the lax vowel word was a plural, then its singular form would end in a lax vowel, and due to restrictions on lax vowels, [gri] is a possible word of English, but [grɪ], with a lax vowel, is not. Therefore, Cebrian hypothesized that if the L2 learners had acquired knowledge of the lax vowel restrictions of English, they should choose [grɪz] as the singular form, and [griz] as the

plural. This is what happened, at a level significantly more often than chance, though results for L2 learners of English were not as strong as for native speakers. Thus, Cebrian argued that L2 learners exhibited some knowledge of the restrictions on lax vowels.

A second picture-naming task supported Cebrian's conclusion. In this task, participants were shown two identical pictures, and heard the statement "These are two [nonce word inserted]". Then they were shown only one of the same picture, and had to give the singular form, by completing the statement "And here is one _____." As in the first task, the crucial stimuli were those in which a lax vowel was followed by [z], as in [grɛz]. For these forms, native English speakers left the singular form unmodified 97% of the time, analyzing the [z] not just as a plural morpheme, but also as part of the singular form. That is, when given [grɛz] as the plural, they offered [grɛz] as the singular as well. L2 English speakers, on the other hand, only left the singular unmodified 60% of the time in these lax vowel forms, but this was significantly more often than they left the singular unmodified in tense vowel words. These results thus also supported Cebrian's conclusions that L2 learners had acquired some knowledge of the lax vowel constraints, but that the learners were still not exhibiting native-like knowledge.

Cebrian's results support the conclusion that L2 learners of English have acquired phonotactic knowledge that they do not have in their L1, specifically in terms of the Lax Vowel Constraint. However, a problem exists with this conclusion in that the effect of transfer is not ruled out as a possibility. The participants did not

participate in a similar task in Catalan that determined whether they showed the same dispreference regarding lax vowels in open syllables in their native language. Regardless of the acceptance of lax vowels in open syllables in Catalan, it is possible that a preference still exists for tense vowels in this position, which would mean that this phonotactic knowledge could be a result of transfer rather than L2 learning. Based on the body of work discussed in Chapter 1 that shows the effects of transfer and interference in L2 phonology, eliminating transfer as a possible explanation is a necessity.

2.3.2 Perception of consonant clusters in L2

Altenberg (2005a) also investigated the acquisition of phonotactics in L2 speech, but she examined knowledge of consonants rather than vowels. In tasks designed to investigate the perception of /sC/ clusters, she compared the results of native English speakers with L1 Spanish~L2 English speakers. Native and non-native speakers rated the acceptability of written nonce words in English on a scale of 1 (completely acceptable) to 5 (completely unacceptable), and then the non-natives also rated nonce words in Spanish, allowing for a comparison of their two grammatical systems. Results showed that both groups rated words as highly acceptable in English when they were legal in both languages as well as when they were legal in English but illegal in Spanish. However, ratings of English and Spanish words differed significantly for native Spanish speakers. Because identical words were given distinct

ratings in English and in Spanish, these results indicate that participants were using different criteria to judge the forms in their two languages.

Overall, Altenberg's results show that non-native speakers performed very much like native speakers on the English portion of the task, leading her to conclude that even beginning learners of English as a second language have accurate knowledge of these consonant clusters in English. Because native Spanish speakers performed differently on the same task in Spanish and English, she also claims that the knowledge that the L2 learners have of English is unaffected by the status of the clusters in Spanish; in other words, illegality of a cluster in Spanish did not cause participants to judge that cluster as illegal in English: there was no interference from the L1 (Spanish) in the L2 (English) task.

In a second task, Altenberg (2005a) had native and non-native speakers of English listen to nonce words and write down what they heard. Under the hypothesis that the perception of L2 listeners is affected by the phonotactics of their L1, L1 Spanish~L2 English listeners should have more trouble correctly perceiving onsets that do not occur in Spanish. The results showed significance only for the mean number correct between natives and non-natives, and between beginning and advanced L2 learners. No differences were found based on the type of word or error. In other words, L1 Spanish~L2 English listeners did *not* make more errors on onsets that are phonotactically restricted in Spanish but not in English. Altenberg concludes that there was no effect of transfer, because L1 Spanish speakers did not rely on their knowledge of Spanish when they were involved in perceptual tasks in English, but that

instead the L2 learners used knowledge of phonotactics that they had acquired in the L2.

Another experiment that shows that L2 learners have knowledge of phonotactic restrictions in the L2 is that of Kilpatrick (2007), which replicated Moreton's (2002) experiment on phonotactic bias against [dl] and [bw]. In this experiment, L2 learners of English, regardless of language background, showed a bias against [dl] but not against [bw]. Participants whose L1 contained no consonant clusters at all, or at least not these clusters, showed this bias, as did speakers from Slavic languages, where clusters such as [dl] exist. Kilpatrick concluded that L2 learners were using the same phonotactic knowledge in their perception as native English speakers did in Moreton's (2002) experiment, and that they must have learned this knowledge, as there is no reason to believe that it would be transferred from the native language. However, like Cebrian (2003), Kilpatrick's aim was to determine whether learners had access to some specific knowledge, and thus did not definitively rule out transfer as a possible explanation.

2.3.3 Transfer and interference in L2 listening

Weber and Cutler (2006) also investigated the effects of native language phonotactics in non-native listening, comparing the results of very proficient L2 learners of English, all of whom were native speakers of German, with those of native English speakers. The purpose of the comparison was to determine if the perception of L2 learners of English was affected by phonotactic restrictions in the same way that

native speaker perception was affected. Weber and Cutler administered a wordspotting task (see Section 2.2 for an explanation of this task) in English to both the L2 learners of English as well as to the L1 speakers of English, and found that identification for both groups was facilitated by preceding contexts that forced a word boundary due to phonotactic restrictions. This result held in cases where the preceding context forced a word boundary in both English and German, as in [nl] and [nw] sequences, as well as in cases where the preceding context forced a word boundary in English but not in German, as with [ʃl] and [ʃw] sequences, which are acceptable onsets in German but not in English. While this facilitation was evident for both native and non-native speakers of English, native German speakers were also facilitated by contexts that forced a word boundary in German but not in English, as in [sl] and [sw] sequences, which are acceptable onsets in English, but not in German. In these cases, German speakers were facilitated in recognition of *led* in a form like [birslɛd] due to the [sl] sequence, while English speakers were not facilitated in recognition in these cases. The authors conclude that the L2 learners had acquired phonotactic knowledge of their L2, but they still experienced interference from the L1.

In terms of acquisition, Weber and Cutler's results seem to show that L2 English learners had acquired some knowledge of the phonotactics of English; [ʃl] is not restricted in German but is restricted in English, and these L2 learners exhibited knowledge of this, as evidenced by facilitation of word identification in these contexts. However, the reverse does not seem to be true: results for L1 German~L2 English listeners indicated that they were not able to rid themselves of restrictions that exist in

their L1, but that do not exist in their L2, as evidenced by facilitation of word identification by L2 learners in acceptable English contexts. In essence, the L2 learners were able to learn a new restriction, assumed not to be present in their L1, but were unable to 'unlearn', or suppress, a restriction that existed in their L1 but not in their L2.

Weber and Cutler's results, then, conflict with those of Altenberg (2005a), which suggest no effect of transfer from the L1. Other studies have also shown that perception by non-native speakers does seem to be affected by the grammatical structure of their L1. Broselow (1988), in a word-boundary detection experiment, found that native speakers of English misperceived word boundaries in Arabic and attributed this to the differences in English and Arabic syllable structures. Altenberg (2005b), which had L1 Spanish~L2 English listeners distinguish between sequences in English such as *keeps parking* and *keep sparking*, found that listeners performed more poorly on stimuli where one answer choice violated Spanish phonotactics and the other did not, suggesting that listeners were relying on their L1 knowledge in completing the task. This work indicates that restrictions that exist in first language grammars may affect perception in second language tasks.

Additional evidence that interference occurs in perception has been presented in work on a phenomenon referred to as 'perceptual epenthesis', which indicates that L2 learners use the phonotactics of their L1 to make decisions regarding what they hear in their L2 (Dupoux et al 1999, Kabak 2003, Matthews and Brown 2004, Kabak and Idsardi 2007, Berent et al. 2007). Dupoux et al (1999) administered

discrimination tasks to native Japanese speakers, and found that the participants could not reliably distinguish between CC and CVC sequences. This led to the claim that these L2 learners actually perceive a vowel in the midst of consonant clusters that are illegal in their L1. While vowel epenthesis to break up illegal clusters had been noted in production previously (Singh 1985, Broselow 1987, 1992, Davidson and Stone 2004, Davidson 2006), its presence in perception is a relatively new finding. That this perceptual epenthesis occurs has also been investigated by Berent et al. (2007), who tested the sensitivity of English speakers to onset clusters that do not occur in English but that vary in terms of markedness. They found that forms with those clusters that are more marked, such as [lbif], were more likely to be judged to have two syllables than forms with less-marked clusters, such as [bdif]. Berent et al. argue that this perceptual illusion effect is at least partially dependent on linguistic experience, because speakers of Russian (a language in which these clusters occur) perceived these clusters much more accurately, though not entirely reliably.

The limited work on phonotactic knowledge in L2 learners, then, indicates several things about the implicit grammatical knowledge that second language speakers may have about their L2. First, learners know something about the phonotactic restrictions that exist in their L2. Cebrian's (2003) work on the LVC, Kilpatrick (2007) on [dl] bias, and Weber and Cutler's (2006) experiment with word-spotting all indicate that L2 learners exhibit knowledge of phonotactic restrictions of their second language. Second, L1 phonotactic knowledge appears to interfere in some tasks in the L2. This is evident from Weber and Cutler's (2006) word-spotting

experiment as well as from Altenberg (2005b) and Berent et al. (2007). Finally, work by Weber and Cutler (2006) and Cebrian (2003) indicates that while L2 learners show some knowledge of the phonotactic restrictions of their L2, this knowledge is not identical to that of native speakers, or at least is not exploited in the same ways in metalinguistic tasks.

2.3.4 Phonotactic knowledge and artificial learning

There also exists a growing body of work in relation to the acquisition of phonotactics in artificial learning paradigms. Several studies have found that phonotactic restrictions are learned with only brief auditory experience (Dell et al, 2000, Onishi et al, 2001; Goldrick 2004, Taylor and Houghton 2005). Because speech errors have been shown to follow phonotactic constraints rather than to violate them (Vousden, Brown, and Harley 2000, Mackay 1972, but see Rose and King 2007 for experimental evidence that speech errors occur most frequently on forms that violate phonotactics, but the errors do not not necessarily correct the violation), several studies have induced speech errors in order to test for the learning of phonotactic constraints. For instance, Dell et al. (2000) induced speech errors after participants were trained on language-specific constraints, and found that these language-specific constraints were not violated in speech errors. Even on the first day of training, only 4 of 184 errors violated the newly-learned constraints, showing effective learning even with limited exposure. No significant performance improvement occurred with

subsequent training sessions, leading to the conclusion that phonotactic constraints are learned very quickly and effectively.

Goldrick (2004) also examined the speech errors induced in an artificial learning experiment, but compared the learning of two different kinds of constraints. Some constraints restricted certain segments to a single syllabic position all the time (/f/ always as an onset), and others encoded featural information as well (labiodentals /f/ and /v/ as an onset 75% of the time). Goldrick found that participants were able to acquire both segmental and featural information, and while performance improved across the course of the study, differences were not found to be significant. Again, these results indicate that phonotactic constraints, at either a segmental or featural level, can be learned quickly.

That phonotactic restrictions are learned fairly quickly is also shown by Onishi et al (2002) but this experiment involved only listening. The authors found that listeners became sensitive to novel phonotactic regularities on the basis of the testing phase, where sequences that were legal (= appeared in training) were repeated more quickly than illegal sequences (= not heard in training).

While much of the work in artificial learning of phonotactic restrictions has investigated first order constraints reliant on a single segment in a single position (e.g., /k/ cannot be an onset), Warker and Dell (2006) investigated the learning of novel second-order constraints, in which restrictions were dependent on some other characteristic of the syllable (e.g., /k/ can only be an onset if the vowel is /ɪ/). They found that adult learners were able to acquire new phonotactic restrictions, but that

novel second-order constraints required more extensive training than previous work has shown for first-order constraints. Participants in this experiment did learn the second-order constraints, but only with more extensive exposure; their errors did not reflect the new constraints until the second day of training, while in previous experiments errors reflected new constraints almost immediately. Second-order constraints thus appear to take more extensive exposure to learn effectively, so phonotactic restrictions that rely on them may be more difficult to learn.

2.4 Phonotactic knowledge and the Complement Problem

Only a few studies exist that directly speak to the learning of a subset in L2 phonology, and each of them approaches the problem quite differently. Here, we look at each of them in an effort to determine what they reveal about the acquisition of ungrammaticality by L2 learners.

2.4.1 Acquiring phonological processes

Two relevant studies related to the acquisition of phonological processes will be discussed here. The first is that of Zampini (1997), whose production study investigated whether L2 Spanish learners acquired spirantization, an allophonic alternation which changes a stop ([b,d,g]) to a spirant ([β,ð,ɣ]) in post-vocalic position.[3] The results showed that more advanced L2 learners of Spanish spirantized in

[3]There is some debate as to whether the alternation is actually spirantization or fortition (see, for instance, Bakovic 1994 and Barlow 2003 for fortition accounts). However, Zampini assumes spirantization, which is crucial to her argument, and I follow her assumptions here for the ease of discussion.

a superset of the environments in which intermediate learners did. Based on this, Zampini concluded that the acquisition of spirantization follows the Subset Principle. However, while Zampini's study supports the fact that learners are building into superset grammars, it does not address whether learners who are faced with a grammar that is a subset of their L1 recognize the ungrammaticality of complement forms.

A second study related to the acquisition of phonological processes is that of Swanson (2007), previously discussed in Section 3 of this chapter. While Swanson does not interpret her results in terms of subset learning, her results are relevant to the acquisition of ungrammaticality. Swanson's results indicate that her participants were able to successfully acquire the phonological processes of aspiration and palatalization. In general, phonological processes are thought to occur due to some phonotactic restriction; a certain sound or sequence of sounds is restricted in a specific environment, and the grammar repairs it in some way. Therefore, acquisition of phonological processes serves to restrict the grammar. Assuming that Swanson's participants actually acquired the process and the impetus behind it, then they actually were able to further restrict their grammar. In essence, they learned that some sounds were acceptable only in some environments, so they acquired knowledge of ungrammaticality. Swanson's results, then, indicate that subset learning is possible.

2.4.2 Learning a subset vowel inventory

The third study that addresses subset learning is that of Boersma and Escudero (2002, 2003, 2004 2008), which focuses on the learning of a vowel subset by native

Dutch speakers who are L2 learners of Spanish. In Dutch, the three vowels [i], [ɪ], and [ɛ] occupy the same acoustic vowel space as the two Spanish vowels [i] and [e]. The L2 learners, then, are faced with narrowing down their three L1 vowel categories into only two in the L2. However, this again is not a problem of recognizing the ungrammaticality of a form in the L2 that is acceptable in the L1, but is instead a situation in which the L2 learner must find a way to convert their mapping of the vowel space from three segments to only two. That is, they do not acquire the knowledge that some forms that are grammatical in their L1 are not grammatical in their L2. Instead, acoustic realizations of [ɪ] may remain grammatical, but simply be mapped to a different phonological representation. In other words, what is involved in learning a phonetic subset with vowels is not the same as the acquisition of ungrammaticality that is addressed here.

Escudero and Boersma (2003, 2004) examine the subset problem in Dutch learners acquiring Spanish, because Spanish has a smaller vowel inventory than Dutch does. Their tasks and analysis focus solely on whether the L1 Dutch~L2 Spanish speakers have established new phonemic boundaries, and whether that boundary is similar to the category boundary evident in native Spanish speakers. They do not consider any contextual effects that might affect the vowels, nor do they question whether or not participants view the vowels as good or bad exemplars of their L2 vowels. Their concern is purely the acquisition of a new category boundary. As such, this is quite a different situation from one in which learners would view forms outside of the subset to be ungrammatical, as the segmental work assumes that the

vowel space is simply re-allocated, so that the original space of the three vowel categories of their native Dutch is divided into only two categories, with no loss of possible vowel space. However, it is possible that this re-allocation of vowel space would result in viewing some vowels as bad exemplars of the vowels of the L2.

For example, Escudero and Boersma mention that some native Dutch speakers viewed some of the vowels they heard in the Dutch portion as 'un-Dutch' or 'Spanish-like', but it is not clear if participants did the same thing in the Spanish portion. If they viewed some vowels as 'Dutch-like', then this might be an indication that they were acquiring a subset, and that they viewed vowels within certain parts of the vowel space as bad exemplars. As this is not the question that Escudero and Boersma are attempting to answer, they ignore this possibility in favor of examination of how the vowels would be identified. However, just because speakers were able to accurately identify the vowels does not tell us anything about how 'Spanish-like' they view them to be. Based on this work, it is still unclear if the L2 speakers acquired a subset in the same sense that it has been used here in the acquisition of phonotactic knowledge, which requires that some knowledge of ungrammaticality be acquired, rather than a shifting of boundaries which re-allocates the acoustic vowel space from three separate vowels into only two.

2.4.3 Learning a subset of consonant clusters

Only one study that I know of has dealt with the Subset Principle in phonology in the same way that it is approached in this dissertation, as acquisition of

ungrammaticality. In this study, Trapman and Kager (2009) compare the acquisition of subset and superset knowledge in L2 through an examination of the acquisition of Dutch consonant clusters by Russian and Spanish speakers. However, the situation they examine is somewhat different from that presented in Chapters 3 and 4.

In Trapman and Kager's work, Dutch is both the subset and the superset grammar. Spanish speakers who learn Dutch are faced with acquiring a superset of forms, while Russian speakers who learn Dutch are faced with acquiring a subset.

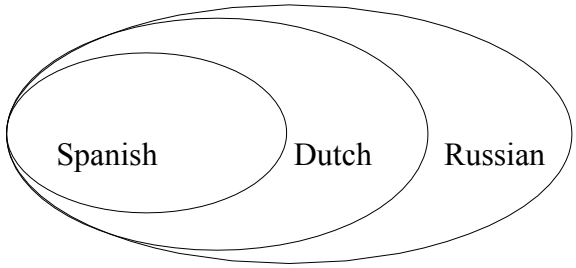

Figure 2.1 Trapman and Kager's Subset~Superset situation

Native Dutch speakers, Spanish learners of Dutch, and Russian learners of Dutch participated in a wordlikeness rating task in Dutch. Included in the stimuli were three different types of forms, which varied as to their legality in the different languages:

(8) legality of Trapman and Kager's stimuli

(a) legal in all three languages

(b) legal in Russian and Dutch, but illegal in Spanish

(c) legal in Russian, but illegal in Dutch and Spanish

The results for the native Spanish speakers showed that no significant difference was found between ratings for forms that contained legal vs. illegal clusters in Spanish, indicating that they had acquired superset knowledge, and recognized that

some illegal clusters of Spanish are legal in Dutch. In addition, the native Spanish speakers gave significantly higher ratings to onset clusters legal in Dutch than they did to onset clusters illegal in Dutch, showing that the L2 learners had been able not only to acquire a superset of the onset clusters available to them in their L1, but that they were also able to distinguish between two kinds of clusters that did not occur at all in the L1: clusters occurring in Dutch, and clusters non-occurring in Dutch (the Russian superset). However, for coda clusters, this result only held for advanced learners; the beginning learners had not acquired the knowledge that some coda clusters that do not occur in Spanish also do not occur in Dutch.

For the Russian speakers, who were learning a subset, even the beginning speakers differentiated between legal and illegal onset and coda clusters, assigning significantly higher ratings to words that were legal in Dutch than to words that were illegal in Dutch. This result indicates that the Russian speakers had successfully overcome the Complement Problem and acquired the knowledge that these forms are ungrammatical in Dutch, even though they are grammatical in Russian. In addition, while additional experience aided the Spanish learners of Dutch in recognizing superset codas, the results for subset learning were the same for both beginning and advanced learners.

The results of Trapman and Kagers's wordlikeness task also indicated that the native speakers of Dutch have gradient phonotactic knowledge within the larger distinction of legal~illegal, and advanced language learners also exhibited this knowledge to some degree. The Russian learners of Dutch discriminated degrees of

wordlikeness within the legal clusters of Dutch, while the Spanish learners of Dutch discriminated degrees of wordlikeness within the illegal clusters of Dutch.

In addition to their wordlikeness task, Trapman and Kager also presented participants with a lexical decision task. In this case, native Dutch speakers took longer to reject phonotactically well-formed non-words than non-words that violated phonotactic rules of Dutch. This distinction was also seen in the response times of the Russian learners of Dutch, but only for onset clusters, not for coda clusters. For the Spanish learners, no difference was found between response times to illegal and legal forms, regardless of whether the illegality was due to the onset or the coda.

Trapman and Kager's work shows that for consonant clusters, L2 speakers have observable knowledge that subset forms are preferred over complement forms. However, several problems exist with their study. One is related to the effects of transfer. Due to the vast amount of research that shows the effects of transfer from L1 to L2, including work discussed in Section 3 of this chapter that illustrates that L1 phonotactic knowledge interferes with L2 perception, this study lacks one major factor in order to make the claim that subset learning has occurred: verification that the knowledge illustrated by the Russian speakers was not, in fact, transferred from the L1. Because the clusters legal in Russian but illegal in Dutch are more marked in terms of sonority, it is possible that these forms are simply subject to a universal preference hierarchy. For instance, Russian has coda clusters of rising sonority (stop~nasal, as in [pn], stop~liquid, as in [pl] , fricative~nasal, as in [sm], and fricative~liquid, as in [sl]), which violate the commonly-held assumptions of the

sonority hierarchy (e.g. Jespersen 1926), which indicates that codas should fall in sonority, while onsets rise in sonority. Berent et al. (2007) argue on the basis of experimental evidence that speakers exhibit preferences for more sonorous clusters (bd > lb) even when neither of the clusters exists in the speaker's L1. As coda clusters are also subject to sonority restrictions, it seems likely that the same preferences exist in relation to them.

An additional argument for the need to rule out the effects of transfer in order to definitively claim subset learning is that Trapman and Kager themselves show gradient judgements within the categorization of legal and illegal within their own experiment. For instance, in addition to showing gradient judgments by native Dutch speakers, they also show that Spanish learners of Dutch distinguished degrees of legality for forms that they never heard in Dutch, but not for forms that they did hear in Dutch. If Spanish speakers, with no knowledge of these clusters at all from either their L1 or their L2, show gradient judgments, it is quite possible that Russian speakers also show gradient judgments, of these same clusters, even though they occur in their L1. Perhaps they come into the L2 learning environment with a persistent bias against these clusters already, regardless of their existence in the L1. In order to determine if subset learning has truly taken place, similar judgement tasks with Russian speakers using possible Russian words are necessary to rule out the possibility of transfer.

In Chapters 3 and 4, I present complementary experiments to those undertaken by Trapman and Kager (2009). The results are similar, showing that L2 learners do

acquire phonotactic knowledge early, regardless of whether they are acquiring a subset or a superset. However, the experiments of Chapters 3 and 4 include examinations of participants' judgments in their L1 as well as in their L2, showing definitively that the L2 results cannot be the effect of transfer from the L1.

In addition, the phonotactic phenomena under examination are not that of clusters, but of single segment codas and consonant~glide~vowel sequences. Due to the results of Dell and Warker (2006) regarding the relative degree of difficulty in acquiring second-order constraints, it is necessary to determine not only whether first-order phonotactic constraints are acquired early in L2 subset learning, but also if this early learning is possible with second-order constraints. That is, does subset learning appear to be easy due to the nature of the (first-order) constraints that have been examined, or do L2 learners show similar effects with second-order constraints? The experiments of Chapters 3 and 4 indicate that L2 learners appear to learn the second-order constraints in subset learning just as they do the first-order constraints.

3

Final Consonants in English and Spanish

In Chapter 1, the question was raised whether learning a phonotactic subset in second language is possible; do language learners successfully overcome the Complement Problem and acquire knowledge that forms from the complement are ungrammatical while forms from the subset are not? In this chapter, we examine the case of final codas in English and Spanish, which forces L1 English speakers who are learning Spanish to face the Complement Problem, and present a series of experiments that tested L2 knowledge of final coda acceptability.

Experiment 1 was aimed at determining if L1 English~L2 Spanish (E1S2) speakers judged words in Spanish whose final codas appear in the subset differently from those whose final codas appear in the complement. This experiment showed that E1S2 participants distinguished between subset and complement forms, with a preference for subset forms, as evidenced by a wordlikeness rating task. This

indicates that some knowledge of the grammatical difference between the subset and the complement has been acquired by these speakers.

Experiment 2 replicated Experiment 1, but with English words rather than Spanish ones. This experiment showed that native English speakers did not judge subset forms to be more English-like than complement forms, indicating that the preference of L2 Spanish speakers evidenced in Experiment 1 was not likely to be simply a result of transfer from the L1. However, this experiment also showed that native Spanish speakers who had learned English exhibited a preference for some codas over others, but this distinction was not dependent on whether the coda fell into the subset or the complement.

Experiment 3 supports the results of Experiment 1 regarding L2 judgements of the unacceptability of complement codas in Spanish. In a forced-choice judgment task, L2 learners of Spanish found words with final codas in the subset to be more Spanish-like than words with final codas in the complement, at a level well above chance. Experiment 4, like Experiment 3, presented learners with a forced-choice judgment task, but with comparisons of English forms rather than Spanish ones. This experiment supports the results of Experiment 2, illustrating that the distinction between subset and complement words was not a result of transfer from the L1.

The collective results of these experiments are argued to support the claim that L2 learners have knowledge of the phonotactic system of their L2, regardless of whether that knowledge constitutes a subset or a superset of the possibilities allowed by the phonotactics of their L1.

In what follows, I first discuss the final coda possibilities of English and Spanish in Section 3.1, in order to establish just what the subset and complement forms are. This is followed in Section 3.2 by some relevant preliminaries related to all of the experiments that will be presented in Chapters 3 and 4, specifically, determinations of native-like behavior (Section 3.2.1), reliable measures for language usage and exposure (Section 3.2.2), and justification of experimental methodologies (Section 3.2.3). This is followed by presentation of a set of experiments that show that L2 speakers reliably distinguish between subset and complement forms in Spanish, providing evidence that subset learning does occur in L2 phonotactics. Sections 3 and 4 present wordlikeness experiments in Spanish and English respectively, while Direct comparisons of subset and complement forms in Spanish and English are presented in Sections 5 and 6. Section 7 discusses and concludes.

3.1 Establishing subset and complement

As discussed in Chapter 1, the set of final codas that are legal in Spanish is a subset of those that are possible in English. In general, all consonants that appear in English, with the exception of [h], can occur as word-final codas. In (9), the possible final codas of English are shown, with illustrative words noted for each one.

(9) final single-segment codas in English

[p] 'sip'	[t] 'sit'	[k] 'sick'
[b] 'sub'	[d] 'mud'	[g] 'hug'
[f] 'huff'	[s] 'kiss'	[ʃ] 'hush'
[v] 'move'	[z] 'buzz'	*[4]
[θ] 'bath'	[ʧ] 'much'	[l] 'full'
[ð] 'bathe'	[ʤ] 'judge'	[r] 'fur'
[m] 'hum'	[n] 'sun'	[ŋ] 'sing'

While the set of final codas in English is fairly large, that of Spanish is notably smaller, consisting of only five possible sounds, as shown in (10)

(10) final single-segment codas in Spanish

[ð] 'sed'

[s] 'las'

[n] 'son'

[l] 'facil'

[r] 'hablar'

The set of final consonants legal in Spanish is thus a subset of the possible legal codas of English, as shown in Figure 3.1.

[4]Words that end in [ʒ] such as 'rouge' [ruʒ], do occur in English, but are often viewed as notably foreign, or are regularly produced as the more acceptable [ʤ], as in 'garage' [gəraʤ]. We make no argument here as to whether [ʒ] is an acceptable final coda in English, as this sound is not part of the phonetic inventory of Spanish and will thus be irrelevant to the subset~complement distinction that we are outlining.

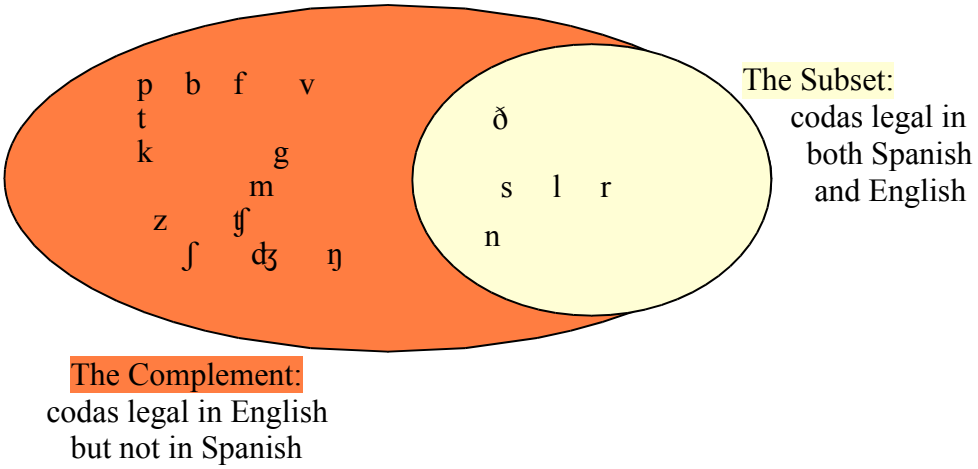

Figure 3.1 Complement and subset codas in Spanish and English

As can be seen with a quick comparison of the English and Spanish possible final codas, the set of final codas that is legal in Spanish is a subset of those acceptable in English. Specifically, Spanish allows a small set of coronal codas, but never labial or velar ones, while English allows a variety of codas, including not only the coronals acceptable in Spanish, but also other coronals, as well as labials and velars.

Assuming, as discussed in Chapter 1, that the initial L2 grammar is a copy of the L1 grammar, the Complement Problem is directly relevant for speakers of English who learn Spanish. While Spanish speakers who learn English must learn that additional consonants are legal word-finally, English speakers who learn Spanish must pare down their legal set of final codas into a subset of them, and learn that all of those codas in the complement are not acceptable in final position. The question is whether English speakers are successful in narrowing their grammar down to the legal subset evident in Spanish. That is, do native English speakers successfully overcome the

Complement Problem and acquire the knowledge that those codas in the complement are not acceptable in Spanish, while those in the subset are?

If L1 English~L2 Spanish speakers successfully overcome the Complement Problem, then they should show some knowledge that forms with final codas that are part of the subset (subset forms) are different than forms with final codas that are part of the complement (complement forms). Specifically, in Spanish, complement forms should be considered less acceptable, or less Spanish-like, than subset forms, because subset forms are legal and complement forms are not. In English, however, no distinction is expected between subset and complement words, because both subset and complement forms are legal in English. For second language speakers, having a distinction between subset and complement forms in Spanish when that difference does not exist in English provides evidence that these learners have successfully overcome the Complement Problem and learned a subset.

3.2 Preliminaries to the experiments

3.2.1 "Native-like" behavior in L2 learners

In second language research, a question that arises is that of ultimate attainment, or whether L2 learners are able to attain 'native-like' results. Whether truly native-like results are possible has been questioned by many, with proponents on both sides (for native-like competence: Birdsong 1999, 2004, Bongaerts et al. 2000, Montrul and Slabakova 2001; against: Seliger 1978, Scovel 1988, Long 1990). In a number of the experiments discussed in Chapter 2, the performance of L2 learners

indicated that they had some knowledge, but this knowledge was not necessarily commensurate with that of native speakers. For instance, both Cebrian (2003) and Altenberg (2005) show that L2 learners have acquired new knowledge of their second language; In Cebrian's experiments, L2 learners responded at a level greater than chance, but not at as high a level as native speakers.

In considering whether L2 learners have acquired a subset, then, there are two issues that should be considered. One is the simple question of whether L2 learners find a distinction between subset and complement forms; if subset forms are grammatical while complement forms are not, then this should be reflected in judgments regarding different forms. In addition, establishing if this distinction is roughly the same as what native speakers do will determine whether L2 learners are attaining a native-like grammar. In other words, not only is it necessary to establish what L2 learners know, but also how that knowledge differs from that of native speakers, or at least how it plays out differently from that of native speakers in metalinguistic tasks.

In order to establish the degree of native-like behavior in the L2 learners, native speakers will be used as controls. However, a question arises as to what type of native speakers to look at. In many tasks, “native” speaker controls are used, but what type of native speakers are included is not defined. While this may seem a trivial matter, much work in bilingualism has shown that bilingual attainment is not the same as that of monolinguals, even when the bilingual is technically a native speaker of the language under investigation. For instance, Nguyen-Hoan (2006) argues that early

bilinguals exhibit differences from monolinguals in phonemic awareness and processing in English, and Watson (2007) shows that voice onset time, a phonetic measure of stop consonant production, differs significantly in monolinguals and bilinguals, even though bilinguals distinguish voice onset time in their two languages. While these are only two examples, bilingual speech has been shown to differ from that of monolinguals in a number of ways

Based on the apparent fact that bilingual native speakers do not show the same performance that monolingual native speakers do in a number of tasks, it seems somewhat unfair to expect L2 learners to attain a level equal to that of monolinguals; it would be a more fair contrast to expect them to look "native-like" in comparison to bilinguals, rather than monolinguals. However, it is unclear if the perception of phonotactic goodness is an area in which early bilinguals and monolinguals differ. Thus, we will include as controls participants who are early childhood bilinguals as well as those who are monolingual to act as our control comparison groups.

In the ensuing discussion, the term "monolingual" will be used in reference to those participants who have learned only one language, with such minimal exposure to other languages that they have virtually no communicative ability in or understanding of any language other than their native one. The term "bilingual" will refer to an early childhood bilingual, who learned both English and Spanish before the age of 6. Both of these groups of participants, monolinguals and bilinguals, will be considered "native speakers" for the purposes of these experiments. The term "L2 learner" will

be used to refer to any second language learner who learned one language alone first, and then learned their second language later, after the age of ten.

3.2.2 Language Background Questionnaire

In order to determine the language backgrounds of different participants, and to be able to place them in the appropriate groups, participants filled out an on-line questionnaire regarding their language skills and experience. This questionnaire consisted first of a set of general questions where participants listed the languages that they spoke, and where they self-rated their proficiency in each language (on a scale of 0 – 4, where 0 = knows only a couple words and 4 = native-like fluency). Participants also shared information related to where they had lived and for how long, as well as information related to the languages spoken in their homes. This information was used to determine whether participants qualified for the experiment.

Because, as discussed in Chapter 1, transfer effects from the L1 to the L2 clearly occur, participants who had early exposure to any language other than English and Spanish were disqualified. For instance, when a participant was a heritage speaker of some language other than Spanish or English, they were not considered eligible for this experiment. In addition, participants who had extensive language learning courses in other languages, or who self-rated their proficiency of any language other than Spanish or English higher than "0" were not included. This was to rule out the possible effects of transfer or interference from any language other than

the ones under study here. This created a situation in which the only logical place that transfer could come from for qualified participants was English or Spanish.

An issue in much work on second language acquisition is related to finding reliable measures of proficiency. As more proficient second language learners are more likely to have more knowledge of the phonological system of their L2, it was important to be able to easily and accurately assess the language proficiency of participants, particularly in the areas of speaking and listening, which were thought to be the most reflective of phonological knowledge. Phonological knowledge relies also on hearing the language spoken, and not just on reading words on paper.

A number of studies suggest that self-reported measures correlate with linguistic ability, though these results are quite variable. Ross (1998) argues that self-assessment measures generally correlate with teacher assessment of skills, but Delgado et al. (1999) show that bilinguals judged their linguistic competence more accurately in their dominant language, and, in the non-dominant one, more accurately assessed their reading and writing skills than their speaking and listening skills. A self-assessed rating, then, may be necessary, but did not seem to be sufficient for our purposes.

Marian et al. (2007) found language exposure to be the factor that accounted for the most variance in their examination of validity and reliability of their language proficiency questionnaire. This measure included not only total time exposed to the L2, but also exposure in terms of reading, TV, radio, and friends. Language exposure

and usage were thus gathered from our participants in order to give the fullest picture of their language history.

In order to account for factors related to language exposure, in addition to the qualification questions on the language background questionnaire, participants also responded to a series of 33 questions related to their exposure to and use of language. Responses to these questions were then used to compute a Language Usage and Exposure (LEU) score. For each question, participants answered with one of five possible choices: "Only English", "Mostly English", "Both English and another language equally", "Mostly a language other than English", and "Only a language other than English". Responses that referred to a language other than English were verified to refer to Spanish and not any other spoken language. Responses were assigned a point value from 1 (Only a language other than English) to 5 (Only English), with a final percentage score calculated for each participant. This score was the Language Exposure and Usage (LEU) score.

Because "Only English" responses were assigned the highest number of points, high LEU scores indicate greater exposure to English and less exposure to Spanish, while lower scores indicate more Spanish exposure and less English exposure. Thus, for instance, monolingual English speakers with no exposure to or usage of Spanish should have a very high percentage LEU score, while monolingual Spanish speakers should have very low LEU scores, somewhere in the 20's (the lowest possible score was 20%, with the only response given for any questions being "Only a language other than English"). This score was used to help determine the language group to which

participants were assigned (monolinguals, second language learners, bilinguals). Table 3.1 describes the characteristics of each group. In addition to LEU ranges given, age and sex characteristics are also listed.

Table 3.1 Participant characteristics

language group	total # participants	LEU range	age range	# male female
ME	15	94 – 100	18 – 23	3M/12F
E1S2	18	80 – 99	18 – 25	10M/8F
BI	19	40 – 98	18 – 27	9M/10F
S1E2	16	21 – 40	18 – 48	
MS	15	20 – 25	18 – 60	

It should be obvious from the table above that the age range of the groups varies widely. This is due to the recruitment methods used. For English monolinguals and L2 speakers of Spanish, participants were recruited at the University of California, San Diego, where the bulk of them were undergraduate students. The same was true of the bilinguals. On the other hand, in order to find monolingual Spanish speakers, or L2 speakers of English who were late learners (rather than starting in kindergarten), it was necessary to look outside of English-dominant communities. This the monolingual Spanish speakers and the L2 speakers of English were recruited in Guatemala, where a number of the speakers were older professionals rather than college students. These differences in age could be responsible for some of the variability in results that are seen in the experiments.

Another point to note is the slight overlap in the LEU scores of the monolingual groups and second language groups. This is due to several factors. The

first is passive exposure to a language other than the L1. While every effort was made to limit participants to only those that had no knowledge of another language, the monolingual participants live in communities in which other languages are spoken often. Thus, they have heard other languages spoken within their community. In the case of the monolingual Spanish speakers, many watch American movies, which are often subtitled in Spanish but include the original voices in English.

A second factor that contributed to the overlap was that several participants who were included in the monolingual group had some exposure to sign language, and this affected whether or not they responded with "Only English". In addition, some participants had been enrolled in a foreign language course for 1 semester or less, and considered themselves not to be at all proficient in that language, but still had some exposure, thus affecting the LEU score.

3.2.3 Experimental methodologies

For the experiments presented in the this chapter and the following one, two kinds of experimental methodologies are employed: wordlikeness ratings and direct comparisons. In a wordlikeness rating task, participants use a pre-determined scale to evaluate nonce words as to how word-like they sound. Wordlikeness ratings are commonly used to show the extent to which sound sequences are typical of other words in a speaker's language. Judgements of wordlikeness have been shown to correlate with phonotactic probability (Frisch et al. 2000, Vitevitch et al. 1997), and

neighborhood density has also been shown to predict wordlikeness ratings (Bailey and Hahn 2001, Gathercole and Martin 1996, Greenberg and Jenkins 1964).

Wordlikeness rating tasks have also been used to support claims related to judgements of grammaticality and acceptability, especially in support of gradience in grammar. While generative grammar traditionally focused on categorical judgments of grammaticality (Halle 1962), more recent work on gradience in grammar has shown that speakers perceive degrees of grammaticality within the larger categorization of legal and illegal (Coleman and Pierrehumbert 1997, Sorace and Keller 2005). Wordlikeness ratings have been used to determine both categorical and gradient effects in grammar. For instance, Kirby and Yu (2007) utilize wordlikeness judgements in an investigation of systematic and accidental gaps in the Cantonese lexicon, and Berent and Shimron (1997) use wordlikeness rating tasks in order to determine if speakers of Hebrew view nonce words with occurring sequences to be better than nonce words with apparent violations of a phonotactic constraint against sequences of identical consonants.

The use of wordlikeness ratings has become a fairly standard measure in determining grammaticality, and we adopt this methodology here in an effort to determine whether L2 learners view subset and complement forms differently. In addition, we utilize a direct comparison task, in which participants hear two words and have to determine which sounds more like the target language. This type of task is less common than wordlikeness, but has been used effectively by Berent and Shimron (1997), as well as Coetzee (2004, to appear).

3.3 Experiment 1: Wordlikeness ratings in Spanish

3.3.1 Methods

3.3.2.1 Participants

Forty-five people participated in this experiment. All participants reported normal hearing and no history of speech problems. Either class credit or monetary compensation was offered in exchange for participation.

Each participant was assigned to one of the following experimental groups based on three criteria: (1) self-reported language ability, (2) age of acquisition, and (3) overall language exposure and usage (LEU) score:

(11) Language groups tested in Experiment 1

E1S2 = L1 English~L2 Spanish

BI = early bilinguals

MS = Monolingual Spanish

The monolingual speakers, MS, had no functional ability in any spoken language other than their native tongue, and their LEU score was below 5.0. The second language speakers, E1S2, had all learned their second language no earlier than age ten. They had no functional ability in any spoken language other than English and Spanish, and their LEU scores ranged from 80 to 94.9. Participants who had learned both languages before the age of six were considered to be bilinguals, BI, regardless of self-assessment and LEU score. As with the rest of the participants, the bilinguals had no functional ability in any spoken language other than English and Spanish.

Once divided into the appropriate groups, there were 15 participants in each group. All participants in the MS group were recruited by word of mouth in one of the two largest cities in Guatemala: Guatemala City and Quetzaltenango, and they ranged in age from 18 to 60. All had at least a high school education. Of this group, 7 were male and 8 were female. The E1S2 group was recruited through classes at the University of California, San Diego (UCSD), and ranged in age from 18-30. There were 8 males and 7 females in this group. In the BI group, 11 participants were recruited at UCSD, and 4 in Guatemala. However, 3 of the Guatemalan bilingual participants were found to have had extensive exposure to languages other than English and Spanish, so their results are not included here. With these 3 excluded from this group, ages ranged from 18-26, and there were 5 males and 7 females.

3.3.1.2 Stimuli

As noted above, the possible final Spanish codas [ð, s, n, r, l] constitute a subset of those of English. For this experiment, [ð, s, n] were selected to be tested. The [r] of English is noticeably different phonetically from that of Spanish, and the [l] more likely to be misperceived according to preliminary stimuli testing in which speakers of English were asked to transcribe what they heard. In addition, the three complement codas [p, m, k] were selected, so that both labial and velar stops were included, as well as the bilabial nasal, which could be compared with the coronal nasal [n]. The velar nasal [ŋ] was misperceived in preliminary stimuli testing more often than [m], thus making the labial a better choice for the experiment than the velar was.

Using these six codas, nonce word stimuli were created which were bisyllabic and carried stress on the final syllable. Because phonotactic probability has been shown to affect wordlikeness judgements, in an effort to control the phonotactic probability of all segments other than the coda, the stimuli were created in sets such that all words within each set were minimal pairs that varied only in final consonant. Each of the three subset codas ([ð, n, s]) and three complement codas ([p, m, k]) were used in each set. In (6) below, the sets appear as vertical columns:

(12) Stimuli for Experiment 1

Subset Codas:

[fikoð kefuð lopað poleð tunoð]

[fikon kefun lopan polen tunon]

[fikos kefus lopas poles tunos]

Complement Codas:

[fikop kefup lopap polep tunop]

[fikom kefum lopam polem tunom]

[fikok kefuk lopak polek tunok]

All stimuli were recorded in a sound-attenuated booth by a female native speaker of Spanish who was trained in phonetics. This speaker was also a fluent English speaker who was expected to have no trouble pronouncing those codas that do not occur in Spanish. She read each stimulus in the carrier sentence "Voy a decir [stimulus] tres veces" (*I will say [stimulus] three times*). The same speaker recorded all stimuli in a single session, which also included recording of all fillers. For the

fillers, additional sets of nonce words were created, but the fillers varied in initial onset (for example, [meðin, feðin, seðin, beðin]) or in the vocalic nucleus ([mjuso, mjoso, mjeso, mjaso]). Stimuli were spliced out of the carrier sentence using Praat version 4.3.01 (Boersma and Weenink 2005) and their amplitude normalized such that all the sound files sounded more or less as loud as each other without any distortion of individual files.

3.3.2 Procedure

Participants were tested individually in a quiet room. As far as was possible, all communication took place in Spanish. For those L2 participants with limited Spanish ability, instructions were given orally in English first, and then participants were asked to read the instructions in Spanish.

The task that participants undertook was a determination of wordlikeness in Spanish. Stimuli were presented through headphones, one at a time, using Psyscope X on a MacBook laptop. While hearing a stimulus, participants saw on the screen in front of them the question 'How Spanish-like did that sound to you?' and a scale with endpoints identified, but no orthographic representation of the stimulus. Each stimulus was then rated, through use of a number key on the laptop keyboard, on a scale of one to nine, with one being the lowest (least Spanish-like) rating, and nine being the highest (most Spanish-like). Participants could not request repetition of a stimulus, and they were required to rate each stimulus before continuing to the next

one. However, stimuli with response times over 3500ms were disregarded in the analysis of the results.

Stimuli were presented in three blocks of 97 stimuli, with each block containing all stimuli and all fillers, and with each block individually randomized. Thus, each stimulus was heard and rated three times by each participant. Between each block, participants could rest if needed. Each block began with five fillers, so that participants could accustom themselves to the task before hearing experimental stimuli.

3.3.3 Analyses

The measurement used for analysis was the rating given to the relevant forms, averaged over its three repetitions. The ratings were subjected to an analysis of variance (ANOVA) with a mixed design. The ANOVA was 2 X 3, with a within-subjects factor of legality (subset, complement), and a between-subjects factor of language group (E1S2, BI, MS). Effects were considered significant at $p<.05$.

In this experiment, it was found that not all participants used the full scale 1-9 in the same way. Most participants used the full scale to some extent, but clustered in different areas; some used mostly 1 – 3, others used mostly 6 – 9, and still others clustered around the center. In order to account for this variability without losing the value of a single individual's use, individual item scores were normalized to what I will call the *z-score* in comparison to the *rating,* which will refer to the actual ratings given by the participants in this task. The z-score was calculated by subtracting the

individual subject mean from the response for each individual item for that subject, then dividing by the standard deviation for that subject:

(13) z-score calculation

$$\frac{\left(\begin{array}{c}\text{response for item x}\\ \text{for participant y}\end{array}\right)\left(\begin{array}{c}\text{overall mean}\\ \text{for participant y}\end{array}\right)}{\text{standard deviation for participant y}}$$

Due to the calculation of the z-score, ratings for each subject that were exactly average now fall at "0". Thus, ratings for each subject that were higher than average are represented by positive values, and ratings that are lower than average are negative values.

Statistical analyses were run using both mean rating as well as z-scores. Other than for an effect of language group, which the z-score effectively eliminates, the statistical analyses showed the same results; therefore, only the statistical analyses for z-scores are presented and discussed below in all other cases.

3.3.4 Predictions

The phenomenon being tested in this experiment is whether forms with final codas in the subset are judged differently than forms with final codas in the complement. The main question at hand lies with native speakers of English who have learned Spanish. Whether a distinction is made between subset and complement

forms sheds light on whether these speakers have successfully overcome the Complement Problem and learned a subset. If they show a preference for subset codas over complement codas, then this would provide evidence that they have some knowledge that the subset is more grammatical than the complement. If, however, the L2 learners do not show a distinction between subset and complement, there is no reason to believe that they have been able to learn a subset.

For native speakers, it is expected that complement codas will be dispreferred to subset codas, because complement codas do not occur in Spanish. This prediction will be tested with monolingual Spanish speakers as well as with early childhood bilinguals who had learned both English and Spanish by the age of six.

It is unclear whether bilinguals and monolinguals may differ in their responses to these forms, as they are both expected to exhibit differences in ratings of subset and complement forms. However, because second language learners are faced with handling two distinct grammars, it is expected that their results will be more similar to those of bilinguals rather than monolinguals. That is, in terms of "native-like" performance, L2 learners may look "native-like" in comparison to bilinguals, even though not in comparison to monolinguals.

3.3.5 Results

Results for the ANOVA revealed a significant interaction between legality and language group ($F(2,41) = 11.5$, $p=.0001$). This interaction indicates that the groups

did not all respond identically to the subset~complement distinction, as shown in Figure 3.2.

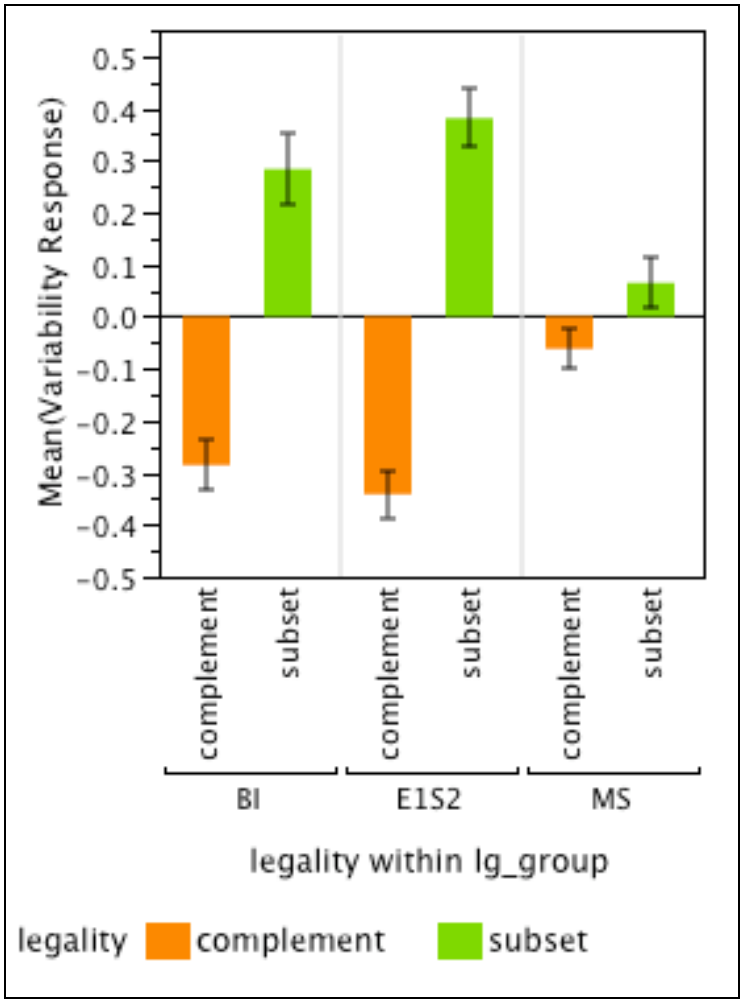

Figure 3.2 Significant interaction between language group and legality

As indicated in Figure 3.2, this interaction was driven by the results of the MS group. For the BI and E1S2 groups, pairwise comparisons of subset~complement within each language group revealed a significant difference between their subset and complement responses, but this difference was not significant for the MS group. For the E1S2 group, subset ratings (mean = 0.38, SD = 0.84) were significantly higher

than complement ratings (mean = -0.34, SD = 0.67; t(14) = 7.94, p<.0001), just as they were for the BI group (subset mean = 0.28, SD = 0.89; complement mean = -0.29, SD = 0.64; t(11) = 5.61, p<.0001). For the MS group (subset mean = 0.07, SD = 0.74; complement mean = -0.06, SD = 0.57), the difference was not significant (t(14) = 1.4, p=0.17). This resulted in a main effect of legality (F(1,41) = 75.2, p<.0001) such that subset responses (mean = 0.24, SD = 0.83) were overall higher than complement responses (mean = -0.26, SD = 0.64).

Table 3.2 Differences between subset and complement forms by group for final consonants in Spanish

group	subset mean	subset SD	complement mean	complement SD	significant difference between subset and complement?
E1S2	0.38	0.84	-0.34	0.67	***
BI	0.28	0.89	-0.29	0.64	***
MS	0.07	0.74	-0.06	0.57	
* = p<.05, ** = p<.001, ***=p<.0001					

For language, there was no main effect for the z-scores (F(2,41) = 1.07, p=.352), indicating that the overall means of the language groups did not differ significantly, but this was the one area where mean ratings and z-scores differed. For mean ratings, there was a main effect of language (F(2,41) = 3.5, p = 0.04) such that BI (mean = 4.47, SD = 2.08) and E1S2 (mean = 4.3, SD = 2.02) ratings were both higher overall than MS (mean = 3.06, SD = 2.2) ratings were. This was confirmed with independent t-tests, which showed that BI had a significantly higher mean than

MS did ($t(26) = 2.33$, $p=0.03$), as did E1S2 ($t(28) = 2.2$, $p=0.03$), but there was no significant difference between BI and E1S2 ($t(26) = 0.25$, $p=0.8$).

3.3.6 Discussion

The results of this experiment indicate that L2 learners make a clear distinction between subset and complement forms, with significantly higher ratings for subset forms than for complement forms. This indicates that the native English speakers who have learned Spanish have some knowledge that complement forms are less acceptable than subset forms are.

In terms of native-likeness, the L2 learners do appear to exhibit native-like judgements, as long as native-likeness is measured against bilinguals and not monolinguals. It was predicted that both groups of native speakers would distinguish between subset and complement forms, due to the illegality of complement forms in Spanish. However, this was not the case. While bilinguals rated subset forms significantly higher than complement forms, the difference between the two sets was not significant for monolinguals. This is surprising in light of much previous research that shows differing responses for either legality or frequency (Berent and Shimron 1997, Coetzee 2004 on legality; Coleman and Pierrehumbert 1997, Vitevitch and Luce 1999 on frequency), both of which are at stake here. The complement codas, with zero frequency, are typically considered to be illegal in Spanish, while the subset codas are legal and occur often. One possible reason for this difference is that any significance for the monolinguals was obscured by the overall low ratings that the

monolinguals gave. The overall ratings that this group gave were significantly lower than those given by the other two groups, with an average of only 3.4. These speakers may have simply thought that all words sounded un-Spanish-like due to the initial sequences of the sets created, so rated them all so low that any difference between subset and complement forms was too minimal to reach a significant level. If this is the case, then in direct comparisons of subset forms vs. complement forms, results may be clearer. If in fact monolingual speakers do distinguish between subset and complement forms, then this should be obvious in the results of Experiment 3.

A second possibility for the apparent discrepancy lies in the different codas that appear in each legality condition. As previously noted, the subset codas included [ð, n, s] while the complement codas included [p, m, k]. It is possible that one or more of the codas themselves obscured any overall result. Comparison of individual coda responses shows that this appears to be the case. Specifically, the codas [ð] and [m] were rated by both native Spanish groups like complement and subset codas respectively, rather than the opposite, expected result. Based on legality and frequency in Spanish, this is a surprising result.

For the coda [ð], it must be noted that [ð] alternates with [d] as a result of the phonological process of spirantization. As such, it is possible that the allophonic change from a stop to a spirant interferes with the task that the participants were asked to do. Very little research has investigated the effects of allophonic changes on wordlikeness and grammatical acceptance, and just how speakers respond to them is not clear. For instance, in a word-spotting experiment, Smith and Hawkins (2000)

found no significant difference in response times or accuracy to appropriate vs. inappropriate allophones in coda position, and Whalen et al. (1997) also found no significant differences in ratings for allophones in appropriate and inappropriate contexts. Peperkamp et al. (2003) show that French allophones are easily discriminated in isolation, but poorly discriminated in context, which could be an indication that listeners perceive what they expect to be there, rather than what is actually produced. That this occurs in phonotactics has been shown by Massaro and Cohen (1983) as well as Moreton (2002): listeners are biased toward the production of legal sequences.

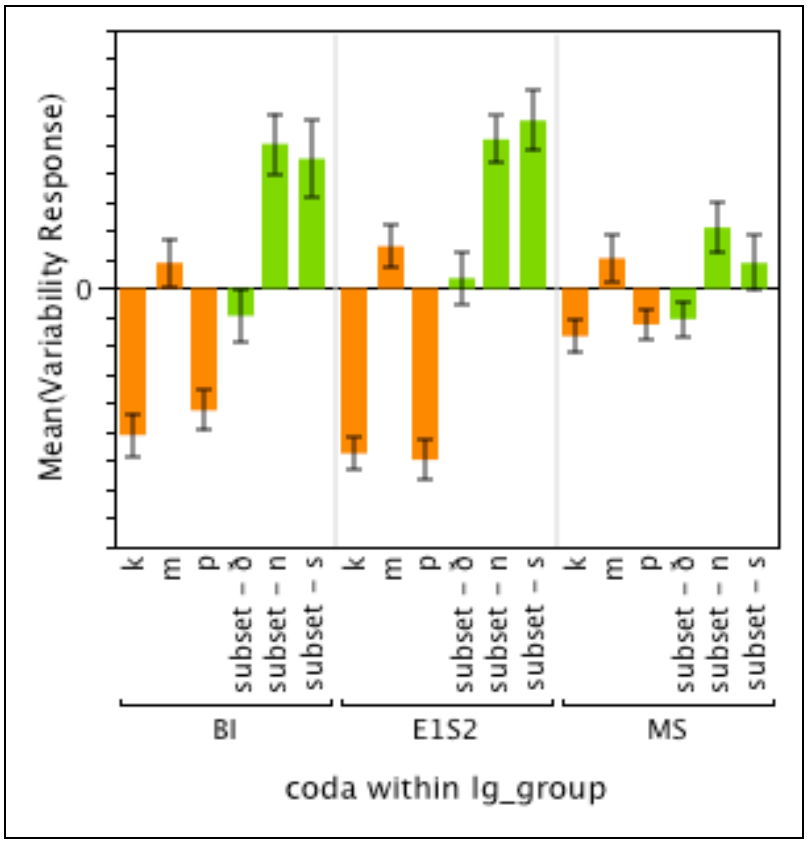

Figure 3.3 Coda comparisons by language

The coda [m] could be problematic for other reasons. Research has shown that nasals are more likely to be confused with each other than oral consonants are (Miller and Nicely 1955, Wang and Bilger 1973). It seems possible, then, that participants are hearing a nasal and perceiving it as an [n], or at least are unwilling to accept that it is *not* an [n], which is quite acceptable. If listeners are pre-disposed to hear legal sequences, perhaps they simply have a more difficult time distinguishing the [m] from [n] due not only to its confusability, but also to this predisposition.

If the ratings for [ð] and [m] are problematic for independent reasons, and they are excluded, it is clear that even the monolingual speakers make a distinction between the subset codas [n, s] and the complement codas [p, k] ($t(14) = 2.58$, $p=0.014$). Thus it appears that, at least with the exclusion of [ð] and [m], all the language groups make a distinction between subset and complement forms, with a clear preference for subset forms over complement forms. While this is expected for the native Spanish speakers, this result is problematic for the Subset Principle. Assuming that the L2 learners began with the grammar of the L1, English, which allows all the codas tested, then this would indicate that the L2 learners have successfully overcome the Complement Problem and learned a subset grammar. However, before this conclusion can be drawn, it is necessary to rule out the possible effect of transfer from the L1, a matter we turn to in Experiment 2.

3.4 Experiment 2: Wordlikeness ratings in English

Experiment 1 showed that L1 English~L2 Spanish speakers showed a clear distinction between subset and complement forms. In order to ensure that this distinction is in fact knowledge about the L2 and not just the result of transfer from the L1, a second experiment was undertaken. This experiment was similar to Experiment 1, but differed in that the experiment was designed to elicit wordlikeness judgments in English rather than in Spanish.

That native speakers of English might make a distinction between subset and complement codas is possible in light of research that indicates that more frequent sequences are judged to be more wordlike than less frequent sequences (Coleman and Pierrehumbert 1997, Vitevitch and Luce 1999, among others). In addition, a growing body of recent work (Belletti and Rizzi 1988, Sorace and Keller 2005, Coetzee and Pater 2008) argues for effects of gradiency in grammars, predicting that there are variations of acceptability among both legal and illegal structures. Work related to phonotactic probability and frequency inherently assumes the same thing: sounds or sound sequences that are more frequent should be perceived to be better than less frequent ones. Thus, in order to rule out any possible transfer effects due to gradiency in English grammar, native English speakers participated in a wordlikeness rating task in English. In addition, L2 speakers of English who are native speakers of Spanish participated in this experiment in order to determine if they distinguished between subset and complement in English, or if they viewed all forms to be equally wordlike.

3.4.1 Methods

3.4.1.1 Participants and procedure

There were 45 participants in this experiment. Participants were either students at the University of California San Diego, or were recruited by word of mouth in Guatemala, where participants were from one of the two largest cities: Guatemala City and Quetzaltenango. All participants reported normal hearing and no history of speech problems. Either class credit or monetary compensation was offered in exchange for participation.

As in Experiment 1, participants completed a language background questionnaire and were assigned to a language group based on their LEU score, self-reported proficiency, and age of acquisition of their L2. Group assignment followed the same criteria as in Experiment 1, but in this experiment, the monolingual group is monolingual English (ME) rather than Spanish, and the L2 group is L1 Spanish~L2 English (S1E2) rather than the reverse.

Each group included 15 participants. In the ME group, ages ranged from 18 to 23, with 3 male and 12 female participants. In the BI group, there were 8 males and 7 females, ranging in age from 18 to 27. The S1E2 group ranged in age from 18 to 40, with 7 males and 8 females.

3.4.1.2 Stimuli

The creation of stimuli in this experiment followed the same process as that of Experiment 1, utilizing the same selected subset and complement codas, [ð, n, s] and

[p, m, k] respectively. Five sets of six English nonce words were created, with all words within a set constituting minimal pairs that varied only in final coda The sets created were as follows:

(14) Experimental stimuli for Experiment 2

subset codas:

[við zað zeð ʒoð ʒuð]

[vin zan zen ʒon ʒun]

[vis zas zes ʒos ʒus]

complement codas:

[vip zap zep ʒop ʒup]

[vim zam zem ʒom ʒum]

[vik zak zek ʒok ʒuk]

Stimuli were recorded in a sound-attenuated booth by a native speaker of English who had completed a graduate level course in phonetics. All recordings were completed in a single session that included all stimuli and all fillers. As in Experiment 1, fillers consisted of sets of nonce words that varied in either onset or nucleus. All stimuli were spliced out using Praat version 4.3.01 (Boersma and Weenink 2005) and normalized for amplitude before presentation in the experiment.

3.4.2 Predictions

For this experiment, there are two questions at issue. One of them is whether or not native English speakers show a distinction between subset and complement

forms in English, even though all of them are legal and attested. If they do show a distinction and rate subset forms higher than complement forms, then the results for the L2 learners in Experiment 1 could be due to transfer from the L1 grammar rather than actually acquiring a subset grammar. Thus, the ratings of English forms by native English speakers, both monolingual and bilingual, are examined here in an effort to determine if they differentiate between subset and complement codas, and, specifically, to determine if they rate subset forms higher than complement forms as they did in Spanish. We predict that they will not make a distinction between subset and complement forms, which would indicate that the L2 learners of Spanish in Experiment 1 were not simply transferring knowledge from their L1, but that they had actually established a separate grammar.

The second question we attempt to answer here is simply the opposite of the Complement Problem: do second language learners acquire the knowledge that forms that are ungrammatical in their L1 are grammatical in their L2? As acquisition of this knowledge would be based on positive evidence, it should be unproblematic. Therefore, we predict that L2 learners will not rate subset forms significantly higher than complement forms, thus illustrating that they have gained superset knowledge. Whether these L2 learners are approximating native-likeness is also examined, but the expectation that the L2 learners will appear native-like in comparison to bilinguals rather than monolinguals still holds here as well.

3.4.3 Analysis

Statistical analysis was done using the same type of z-scores as in Experiment 1, submitting this score to a 2X3 ANOVA with a 2-level (subset, complement) within-subjects factor of legality, and a 3-level (BI, ME,S1E2) between-subjects factor of language group.

3.4.4 Results

The ANOVA for this experiment also found a significant interaction between language group and legality ($F(2,44) = 6.06$, $p=0.005$). This interaction reflects a difference between how the L2 learners performed in comparison with the native speakers.

Table 3.3 Differences in subset~complement by group for final consonants in English

group	subset mean	subset SD	complement mean	complement SD	significant difference between subset and complement?
S1E2	0.07	0.81	-0.07	0.76	*
BI	-0.06	0.83	0.05	0.77	
ME	-0.09	0.74	0.09	0.81	*
* = p<.05, ** = p<.001, ***=p<.0001					

Pairwise comparisons showed that both the ME ($t(14) = 2.55$, $p=0.02$) and the S1E2 ($t(14) = 2.1$, $p=0.04$) groups rated subset and complement forms significantly differently. However, the direction of preference varied. The S1E2 group rated subset

forms (mean = 0.07, SD = 0.81) significantly higher than complement forms (mean = -0.07, SD = 0.76), while the ME group rated complement forms (mean = 0.09, SD = 0.75) higher than subset forms (mean = -0.9, SD = 0.81). For the BI group, complement forms (mean = 0.05, SD = 0.77) were rated higher than subset forms (mean = -0.06, SD = 0.83), but this difference was not significant (t(14) = 1.53, p=0.14).

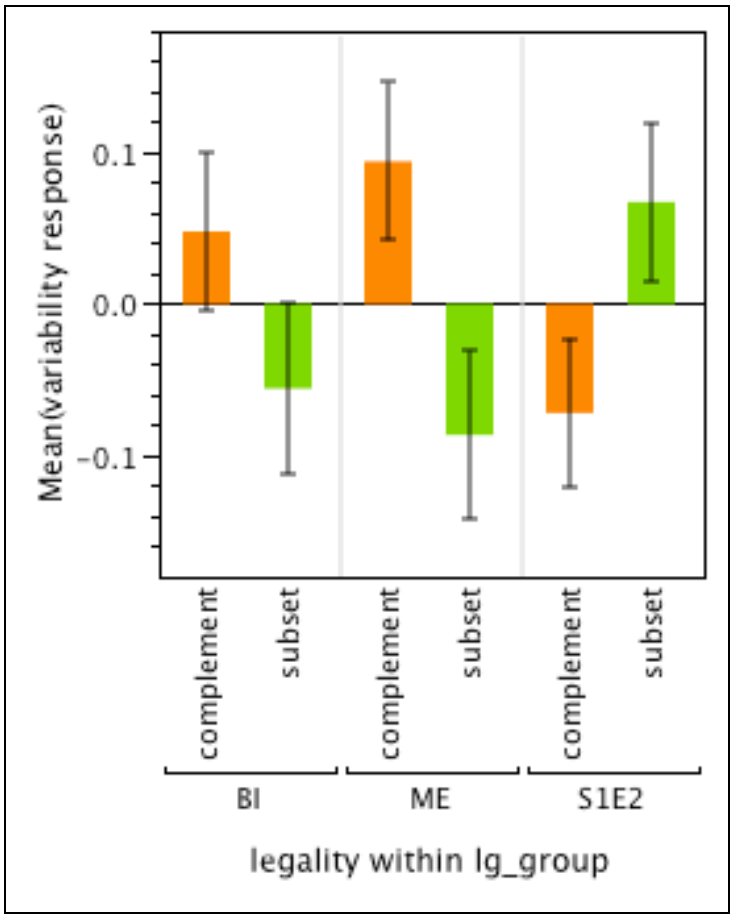

Figure 3.4 Interaction between language group and legality

This interaction obscured any possible main effect for either language (F(2,44) = 0.3, p=0.74) or legality (F(1,44) = 1.53, p=0.22).

3.4.5 Discussion

In relation to the predictions made initially for Experiment 2, the results show that native speakers of English do not show a clear preference for subset forms over complement forms; rather, the reverse appears to be true, for both bilingual and monolingual speakers of English. Native English speakers rated complement forms significantly higher than subset forms. This result is an indication that the results for the L2 speakers in Experiment 1 were not the result of transfer, but instead are the result of learning a new phonotactic grammar. If the responses in Experiment 1 for subset forms over complement forms were the result of transfer, then it would be expected that native speakers of English would rate subset over complement. As Experiment 2 shows, this is not the case.

While learning a superset was not expected to be problematic, results for the S1E2 group indicate that it may be. The S1E2 group rated subset forms higher than complement forms, as expected for Spanish, but not for English. As L2 learners of English, they may be less familiar with the complement forms, but they should, on the basis of positive evidence, be aware that they exist. That they do not rate them as high as subset forms may be an indication that they are using their knowledge of subset~complement in Spanish to rate the English forms. This result also speaks to the difficulty of learning a superset for these learners, a surprising result in light of the fact that positive evidence is available. However, these learners seem to be showing evidence of interference from the L1: because subset forms are more acceptable in Spanish than complement forms are, the L2 learners of English are judging the subset

forms to be better in English as well, though neither the bilingual nor monolingual English speakers make similar judgments.

One possible reason for the L2 learner results is related to the results in Experiment 1, where participants responded unexpectedly to certain codas, namely [ð] and [m]. In order to determine if responses to these codas were affecting the overall results, the two problematic codas were excluded and individual t-tests run comparing responses for subset and complement forms for each language group. .

With the exclusion of [ð] and [m], the distinction between subset and complement forms was not significant for either the bilinguals ($t(14) = 1.38$, $p = .18$) or the monolinguals ($t(14) = .88$, $p = .38$), but was still significant for the L2 learners ($t(14) = 2.88$, $p = .006$), with the subset mean of 0.11 (SD = 0.81) still significantly higher than the complement mean of -0.15 (SD = 0.8). That is, the L2 learners still appeared to be responding to the subset~complement distinction using their L1 knowledge of the illegality of complement forms.

Examination of the individual codas supports this conclusion, but also indicates that the L2 learners of English responded differently to subset forms than the native speakers of Spanish did in Experiment 1. As shown in (12), these results indicate that while they judged complement forms [p] and [k] with responses below the average, they also judged the subset form [s] as not very English-like.

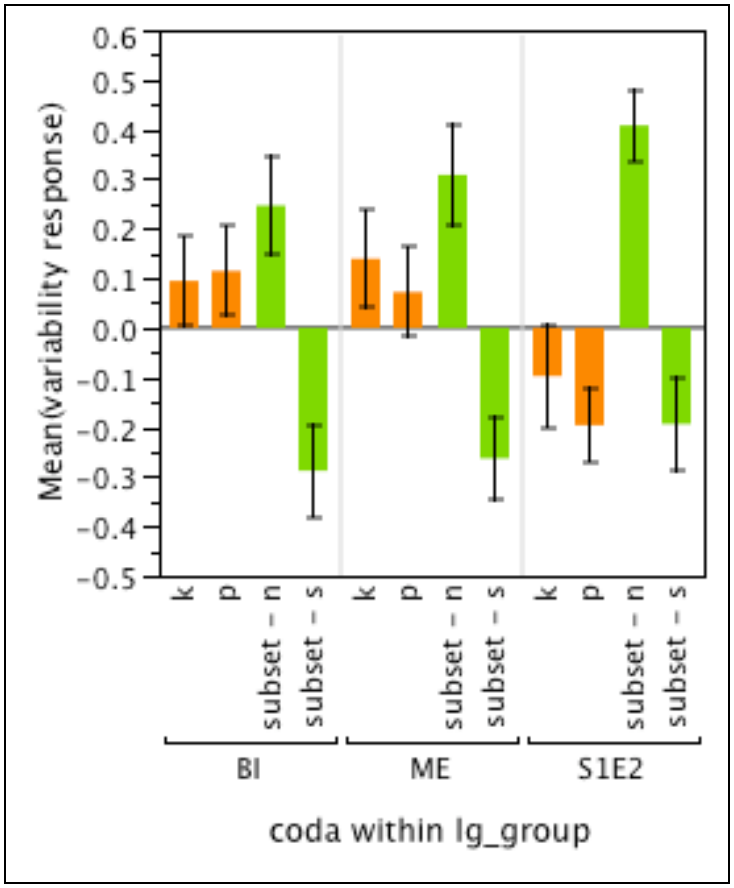

Figure 3.5 Coda responses by language

This response to [n] and [s] is different from what native Spanish speakers did in Experiment 1, as all participants there rated [n] and [s] higher than other forms.[5] However, that the L2 learners rated [s] with below-average scores indicates that they are becoming more native-like in their phonotactic knowledge, as this pattern was also evident in the native English speakers. In other words, even though the ratings of complement forms appears to be due to interference from the L1, the ratings of subset forms approximate L1 knowledge, making their judgements more native-like overall.

[5]Sharon Rose (p.c.) points out that the apparent illegality of final [s] could be due to an OCP effect, as the onsets are all fricatives. This was not directly investigated here, so I leave it as an avenue for further research.

3.5 Discussion of Experiments 1 and 2 together

Taken together, Experiments 1 and 2 paint a picture of second language acquisition that indicates that L2 learners do successfully learn a subset. Native English speakers who were L2 learners of Spanish gave subset forms in Spanish significantly higher ratings than they gave complement forms. That this is not the simple result of transfer from the L1 is evident from the lack of preference for subset over complement by native English speakers, whether monolingual or bilingual; if the distinction was a result of interference, we would expect to find the same result by native English speakers. Instead, we find that native speakers of English exhibit the opposite preference, for complement forms rather than subset forms, so the distinction in Spanish does not appear to be a result of transfer from English. In other words, L2 learners do not appear to be using their L1 phonotactic knowledge in their ratings of L2 forms. Instead, they appear to have successfully overcome the Complement Problem and learned a subset.

For L2 learners of English, who were acquiring a superset grammar, the effects of interference from the L1 were evident: they continue to give complement forms below average ratings, in a way that is consistent with native Spanish ratings in Spanish, but not with native English ratings in English. That is, these L2 learners do not appear similar to either monolingual English speakers or bilinguals in the way they rate English complement forms. Nevertheless, they appear to be acquiring some knowledge regarding the subset forms, rating forms with final [s] much lower than forms with final [n], in a way that is consistent with native English speakers' ratings of

English forms. Thus, the L2 learners of English do appear to have acquired some phonotactic knowledge of English, but not to the extent that L2 learners of Spanish have acquired the knowledge that complement forms are less acceptable.

This result is surprising in that acquiring a superset should be easier than acquiring a subset, on the basis of positive evidence, yet the opposite appears to be true. Native English speakers learning Spanish, with no positive evidence to tell them that complement forms are ungrammatical, show knowledge of this distinction, whereas native Spanish speakers learning English, with positive evidence to show them that complement forms are indeed legal, do not show knowledge that the subset~complement distinction does not hold in English.

In order to further investigate if these L2 learners were transferring L1 phonotactic knowledge in their L2 ratings, or if they have acquired new knowledge of their L2, part of the L2 learners who took part in Experiments 1 and 2 also participated in the task in their native language.

3.5.1 Comparison of judgments in L1 and L2

Fourteen of the S1E2 group that participated in Experiment 2 also participated in Experiment 1. Eleven of the E1S2 group that participated in Experiment 1 also participated in Experiment 2, along with an additional three native English speakers who had learned Spanish as a second language. This provided 28 participants, 14 E1S2 and 14 S1E2. All methodology and procedures were identical to that described previously for Experiments 1 and 2.

The z-scores of these 28 subjects for the complement codas [p] and [k] and the subset codas [n] and [s] were submitted to a 2 X 2 X 2 ANOVA, with between subjects factors of legality (subset, complement) and experimental language (English, Spanish) and a within-subjects factor of language group (E1S2, S1E2).

3.5.2 Results for comparisons of E1S2 and S1E2

The ANOVA showed a significant interaction for language group by experimental language by legality ($F(1,26) = 12.22$, $p = .002$).

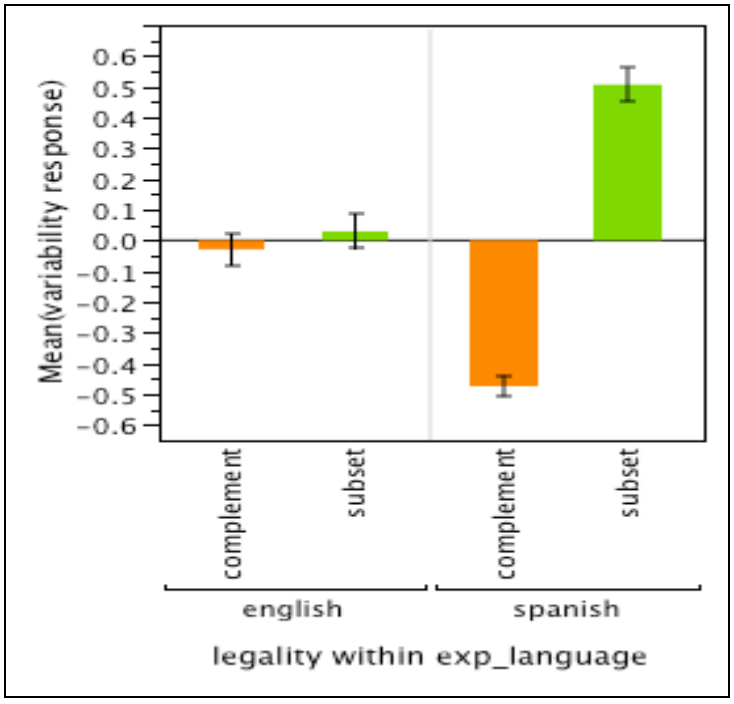

Figure 3.6 Comparison of English and Spanish responses for E1S2

For the E1S2 group, the difference between subset and complement in English was not significant (($t(13) = .32$, $p = .75$), while subset was rated significantly higher than complement in Spanish (($t(13) = 9.12$, $p<.0001$).

The S1E2 group, on the other hand, rated subset forms significantly higher than complement forms in both English ($t(13) = 2.19$, $p = .037$) and Spanish ($t(13) = 4.17$, $p = .0003$).

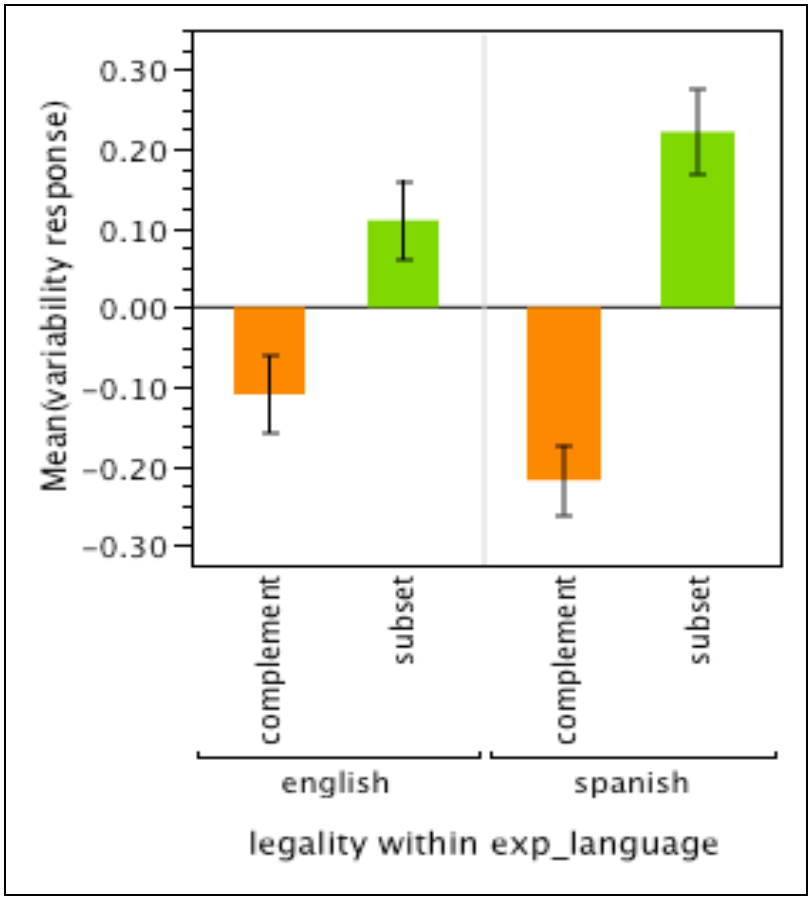

Figure 3.7 Comparison of English and Spanish responses for S1E2

3.5.3 Discussion of E1S2 and S1E2 comparison

That the same set of L1 English~L2 Spanish speakers rated words differently in English and Spanish provides clear evidence that the L2 learners of Spanish have been able to narrow their grammar to a more restrictive set of allowable codas; they

have successfully overcome the Complement Problem and learned a subset grammar. While no interference is evident in the ratings of the L2 learners of Spanish, it may still be a problem for the L2 learners of English. Rather than rating English complement forms to be equally as good as subset forms, these participants gave subset forms significantly higher ratings than they gave complement forms, as expected based on the results of Experiment 2.

In Experiments 3 and 4, additional evidence is provided that indicates that L2 learners are able to successfully acquire subset knowledge in their L2, whereas superset knowledge may be more difficult to acquire.

3.6 Experiment 3: Direct comparisons in Spanish

In this experiment, rather than having participants judge each word separately, words were presented as direct comparisons. Participants were subjected to a binary decision task and asked to choose the word that sounded more like Spanish to them.

3.6.1 Methods

3.6.1.1 Participants

The majority of participants from Experiment 1 participated in Experiment 3. However, 3 bilinguals and 4 E1S2 participants withdrew after the first experiment, leaving a total of 36 participants: 9 bilinguals (BI), 15 monolingual Spanish speakers (MS), and 11 English speakers who had learned some Spanish (E1S2).

3.6.1.2 Stimuli

The recordings of nonce word stimuli used in Experiment 1 were the same ones used for this experiment. However, using all of the stimuli would have created 45 pairs to judge, not including fillers, and pilot studies showed that that participants found the task too long for comfort. Thus, in order to make the experiment more manageable, only three of the five sets created were utilized. In addition, due to the possible complications with allophonic forms, the final [ð] stimuli were not included. Thus, the stimuli used in this experiment are as shown in (15).

(15) Experimental stimuli for Experiment 3

complement stimuli

[fikop	tunop	polep]
[fikom	tunom	polem]
[fikok	tunok	polek]

subset stimuli

[fikos	tunos	poles]
[fikon	tunon	polen]

Each complement stimulus was paired with each of the two subset stimuli of the same set, resulting in six pairs per set, or a total of 18 pairs.

3.6.1.3 Procedure

Participants were tested individually in a quiet room. As far as was possible, all communication took place in Spanish. For L2 participants with limited Spanish

ability, instructions were given orally in English first, and then participants were asked to read the instructions in Spanish.

The task that participants undertook was a forced-choice comparison of wordlikeness in Spanish. Stimuli were presented in pairs, with one subset and one complement form in each pair, counterbalanced for order. Participants responded with "1" when the first stimulus sounded more like Spanish, and with "9" when the second one did. Stimuli were presented through headphones, one at a time, using Psyscope X on a MacBook laptop. Participants saw on the screen in front of them the question "Which word sounded more like Spanish?" and the points "1" and "9" identified, but no orthographic representation of either stimulus. A response was required before continuing to the next stimulus, but comparisons with response times over 3500ms were disregarded in the analysis of the results.

Stimuli were presented in two blocks, with each block containing all stimuli and all fillers, and with each block individually randomized. Thus, each stimulus pair was heard and comparatively judged two times by each participant, with the pairs counterbalanced for order. Within each block, half of the stimulus pairs presented the complement form first, and half presented the subset form first. Between each block, participants could rest if needed. Each block began with five fillers, so that participants accustomed themselves to the task before hearing experimental stimuli.

3.6.2 Predictions

Based on the results of Experiment 1, it is predicted that all three groups will show a clear preference for the subset forms in comparison with the complement forms. However, due to the confusability of [m] evident in Experiment 1, it is predicted that comparisons with [m] may show a weaker preference for subset forms than comparisons with [p] and [k] do.

3.6.3 Results

The results indicate that all groups judged the subset form to be more Spanish-like than the complement form, though the percent of choices in favor of the subset vary by language group.

The preference was significantly higher than chance for all groups. The BI group judged the subset form to be more Spanish-like in 78% of comparisons ($t(8) = 5.85$, $p = .0004$), while the E1S2 preferred the subset form in 81% of comparisons ($t(11) = 10.62$, $p<.0001$). The percentage of subset preferences was lower for MS, at only 64.6%, but still significant ($t(14) = 3.74$, $p = .0022$).

Table 3.4 Subset preference choices for final consonants in Spanish

language group	% subset preference	significant preference?
MS	64.6%	*
E1S2	81%	***
BI	78%	**
* = p<.05, ** = p<.001, ***=p<.0001		

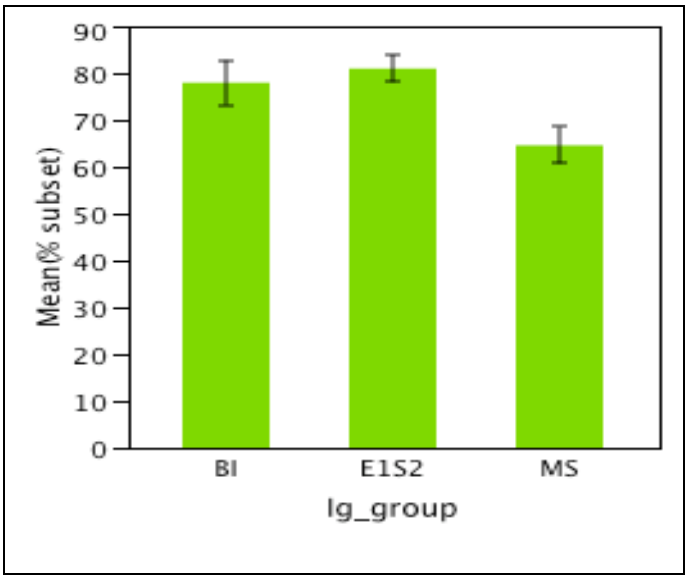

Figure 3.8 Proportion of responses in favor of the subset form

Analysis by coda indicated that comparisons with [p] and [k] elicited much higher proportions of responses in favor of the subset than comparisons with [m] did. This resulted in a significant difference between [p, k] and [m] for all groups.

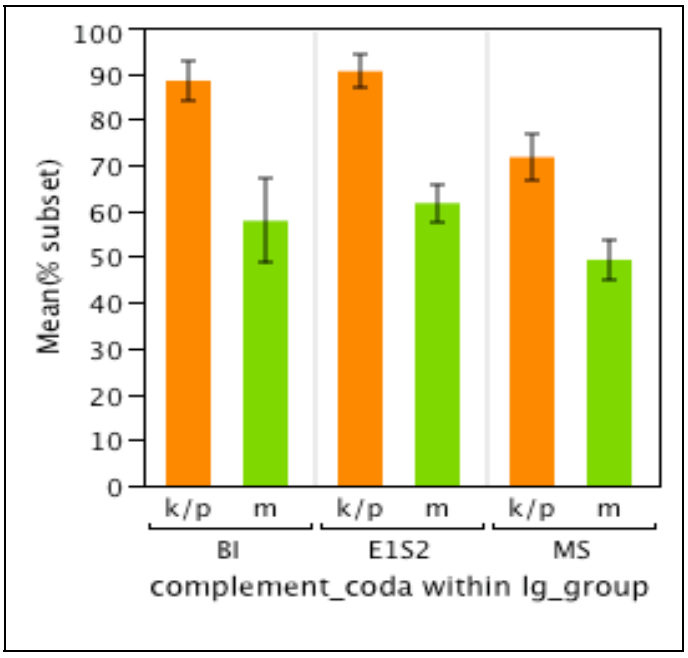

Figure 3.9 comparison of complement codas

For the BI group, [p, k] elicited responses in favor of the subset in 88.43% of comparisons, whereas [m] only elicited responses in favor of the subset in 57.83% of comparisons ($t(8) = 3.93$, $p = .0004$). The same pattern was evident for the E1S2 group, where the subset was favored in 90.5% of comparisons with [p, k], but only 61.7% of comparisons with [m] ($t(11) = 4.27$, $p = .0002$). For the MS group, comparisons with [m] fell at 49.3%, while comparisons with [p, k] were judged in favor of the subset in 71.7% of comparisons ($t(14) = 3.72$, $p = .0007$).

3.6.4 Discussion

In this experiment, it is clear that participants, regardless of their language background, were more likely to select a subset coda as sounding more Spanish-like than a complement coda. In direct comparison with a subset coda in comparison with a complement coda, subset codas were judged to be more Spanish-like than complement codas were. For the second language speakers of Spanish, this shows that these speakers are indeed sensitive to the subset~complement distinction.

However, the results show that how strong the preference is for complement codas is largely dependent on what the complement coda is. Within the complement codas, subset codas were preferred over [p, k] at significantly higher proportions than subset codas were preferred over [m]. All groups, regardless of language background, found this coda to be nearly as acceptable as the subset codas to which it was compared. This distinction between the different complement codas is particularly surprising in that none of these codas appear word-finally in Spanish. However, even

L2 speakers appear to have some knowledge that non-occurring final [m] is more acceptable than non-occurring [p] and [k].

A possible explanation for the unexpected acceptability of [m] is that it was a function of the stimuli, rather than the coda itself. In early stimuli testing, [ŋ] proved to be very confusable, and was thus not used as a possible stimulus. However, it is possible that problems with the confusability of [m] were hidden by the problems with [ŋ], and that there were confusability problems with [m] as well. This confusability is likely the result of a process commonly referred to as category assimilation (Flege (1995), or perceptual assimilation (Best 1994, 1995), which claims that non-native listeners assimilate non-native categories to the categories of their native language. That speakers perceive non-native sounds as similar sounds of their L1 has been shown in a number of experiments discussed in chapter 2, including Flege et al. (1995, 1999), Massaro and Cohen (1983), and Moreton (2002). In the experiment at hand then, speakers of Spanish, in listening to what they assume to be Spanish, hear a nasal, and knowing that only coronal nasals are acceptable word-finally in Spanish, assume that the nasal is coronal. Thus [m] may be assimilated to [n] in the perception of Spanish speakers.

There are two potential problems with this assumption. One is that category assimilation typically takes place when a sound of the L2 is not a part of the inventory of the L1. In Spanish, [m] does exist, and is contrastive with [n], as seen with pairs such as [maʧo] and [naʧo]. Thus, if perceptual assimilation were occurring here, causing confusion between [n] and [m] stimuli, then it would be occurring on a sound

that exists in the language, just not in that position. However, this is just what Massaro and Cohen (1983) show for phonotactic restrictions in English; when phonotactic restrictions are violated, listeners are more likely to perceive the sequences incorrectly, as legal sequences, than to perceive them correctly as illegal sequences.[6]

A second potential problem with assuming that [m] is undergoing perceptual assimilation is that whatever is going on with [m], it is not just with monolingual speakers of Spanish. The judgments of [m] by bilinguals and L2 Spanish speakers are similar to those of the monolingual Spanish speakers. These speakers, due to their native experience with English, which has word-final [m], might be unexpected to undergo perceptual assimilation with this sound in this environment. However, if we assume that these listeners have developed a phonotactic grammar of Spanish, then there is no reason to believe that they would not then undergo perceptual assimilation in the same way that native speakers do. Kilpatrick (2007) shows that non-native speakers of English exhibit a perceptual bias against illegal [dl], even when no evidence exists that this restriction is stronger in the L1 than restrictions against other clusters. Thus it appears that, if phonotactic knowledge of the L2 has been acquired, then perceptual assimilation may take place on the basis of L2 phonotactic knowledge, not just L1.

Another possible explanation for the behavior of [m] is that there is something in the grammar of Spanish that provides a preference for [m] over other codas that do

[6]Narayan (2008) shows similar effects for nasals in English, with [ŋ] being misperceived more in initial position than in environments where it is legal.

not occur word-finally. For instance, nasals are subject to place assimilation with a following consonant, so that a sequence like /un biʧo/ 'a bug' is realized as [umbiʧo]. Therefore, this may provide Spanish speakers and learners with evidence that [m] is an acceptable coda, in a way that [p] and [k] are not, which ultimately affects their view of [m] as a coda. If this is the case, then the L2 learners of Spanish here have been able to pick up on this, so their acceptance of complement forms with [m] may be a reflection of their knowledge of Spanish beyond just simply final codas. In addition, it is possible that [m] is just a better coda, universally, than the others are, making it preferable to the others in general.

The question of just what the status of word-final [m] is in Spanish is a question I leave for further research, but I point out that the clear results for [p] and [k] provide ample evidence that second language learners of Spanish have some knowledge of the word-final phonotactic restrictions against these stops. Just as Experiment 2 confirmed that the results of Experiment 1 could not simply be the result of transfer from the L1, we turn now to Experiment 4, which replicates Experiment 3 but with English stimuli, and shows no preference for subset codas over complement codas by native speakers of English.

3.7 Experiment 4: Direct comparisons in English

3.7.1 Methods

3.7.1.1 Participants

The participants of Experiment 2 also participated in Experiment 4. However, 1 bilingual and 3 monolingual English speakers withdrew after Experiment 4. This left 41 participants in this experiment, including 14 bilinguals (BI), 12 monolingual English speakers (ME), and 15 Spanish speakers who had learned some English (S1E2). Criteria for group assignment were identical to those in Experiments 1 and 2.

3.7.1.2 Stimuli

The recordings of nonce word stimuli used in Experiment 2 were the same ones used here. As in Experiment 3, only three sets were utilized, and the final [ð] stimuli were not included. Thus, the stimuli used in this experiment were as shown in (16).

(16) Experimental stimuli for Experiment 4

complement stimuli

[vip	zap	zep]
[vim	zam	zem]
[vik	zak	zek]

subset stimuli

[vin	zan	zen]
[vis	zas	zes]

Each complement stimulus was paired with each of the two subset stimuli of the same set, resulting in six pairs per set, or a total of 18 pairs, just as in Experiment 3.

3.7.1.3 Procedure

The procedure for this experiment was identical to that of Experiment 3, except that all communication took place in English to the extent that it was possible.

3.7.2 Predictions

Because the results of Experiment 2 showed no preference for subset forms over complement forms for ME and BI groups, we predict no preference here either. However, we did see in Experiment 2 that [n] received ratings higher than complement forms, while [s] received ratings lower than complement forms. Therefore, we predict that, at least for the native speakers of English, the split might be between [n] and [s] codas, rather than between subset and complement codas. In other words, speakers will show gradient judgements of coda preference, but this preference will not be based on whether the codas are part of the subset vs. the complement.

In Experiment 2, the S1E2 group appeared to be subject to interference from Spanish in their judgements of comparisons with [p] and [k], rating them below average. Thus it is predicted that the same result may be evident here, and this group may prefer subsets over complements in general, indicating an effect of L1 transfer.

3.7.3 Results

Results indicate that no groups judged the subset form to be more English-like than the complement form. Overall, subset forms were preferred over complement forms only 41% of the time, but this result included a statistically significant difference between language groups ($F(2,39) = 5.02$, $p = .012$). Independent tests confirmed that the proportion of responses in favor of the subset was significantly lower than chance for both the BI group ($t(13) = 2.59$, $p = .027$) and the ME group ($t(11) = 4.17$, $p = .002$), but not the S1E2 group ($t(14) = .08$, $p = .939$).

Table 3.5 Subset preference choices for final consonants in English

language group	% subset preference	significant preference?
ME	32.4%	*
S1E2	49.7%	***
BI	40.8%	**
* = p<.05, ** = p<.001, ***=p<.0001		

Overall proportions were not significant between groups, except in the case of the ME group, at 32.4%, and the S1E2 group, at 49.7%, with ME choosing subset forms significantly less often than the S1E2 group did ($t(23) = 3.12$, $p = .0034$).

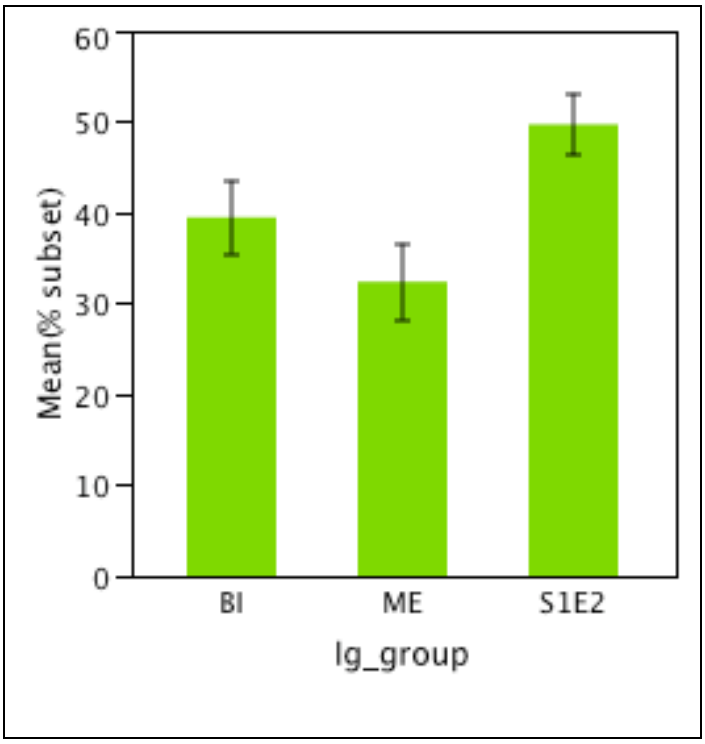

Figure 3.10 Proportions of judgements in favor of subset forms in English

However, this result was dependent on what the codas involved were. A 2 X 2 X 3 ANOVA with within subjects factors of subset coda ([n], [s]) and complement coda ([p/k], [m]) and a between subjects factor of language group (ME, BI, S1E2) found no significant interaction between all three factors ($F(2,39) = 1.97$, $p = .153$), nor between language group and subset coda ($F(2,38) = .75$, $p = .48$), but a significant interaction did exist for language group by complement coda ($F(2,38) = 3.76$, $p = .033$) and for subset coda by complement coda $F(1,38) = 8.19$, $p = .007$). These interactions were driven by main effects for both language group $F(2,40) = 4.44$, $p = .019$) and subset coda ($F(2,40) = 52.99$, $p < .0001$), such that the S1E2 group preferred subset over complements at an overall proportion significantly higher than that of the

ME group ($t(25) = 2.98$, $p = .005$), and [n] was preferred in comparisons significantly more often than [s] ($t(40) = 52.99$, $p < .0001$).

For complement codas, the interaction between language group and complement coda was driven by a significant difference between [m] and [p, k] for the ME group ($t(11) = 2.62$, $p = .013$) that was not present for the BI ($t(13) = 1.56$, $p = .126$) or S1E2 groups ($t(14) = 1.05$, $p = .302$).

In terms of the subset codas, all groups behaved similarly, with a higher percentage of responses favoring [n] over complement codas than [s] over complement codas. For the BI group, [n] codas were preferred over complement codas in 53.8% of cases, while [s] codas were preferred over complement codas only 26.6% of the time ($t(13) = 4.26$, $p = .0001$), and the ME group preferred [n] codas 47.7% of the time, but [s] codas only in 14.6% of comparisons ($t(11) = 4.78$, $p < .0001$). The S1E2 group, despite its preference for subset over complement in Experiment 1, also showed similar results, preferring [n] over complement codas in 61.9% of comparisons, but [s] in only 37.5% ($t(14) = 3.51$, $p = .0012$).

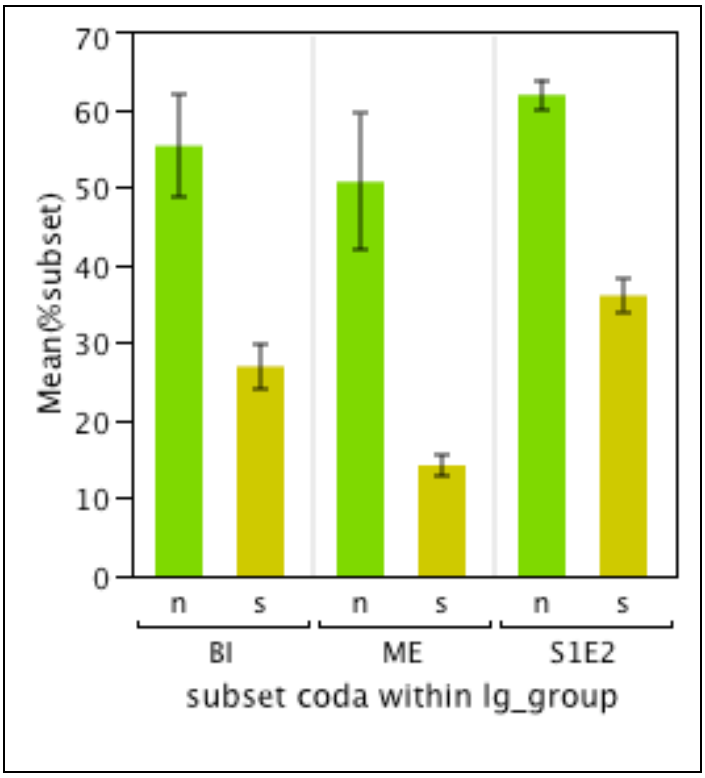

Figure 3.11 Proportions of subset preference by subset coda

This difference in coda responses also drove the interaction between subset coda and complement coda, such that [n] was preferred over [m] at a significantly higher proportion than it was preferred over [p, k] ($t(40) = 3.62$), while proportions in comparison to [s] were roughly equal.

3.7.4 Discussion

In this experiment, it is clear that participants did not readily judge subset codas to be preferred over complement codas in English. Instead, the reverse seems to be true: complement codas were judged to be more English-like than subset codas were, at least for native English speakers, whether monolingual or bilingual. For

native Spanish speakers, decisions between subset and complement codas fell at chance levels. From this, two main conclusions can be drawn: (1) native English speakers do not find subset codas to be more grammatical in English than they find complement codas in general. If anything, the reverse is true. However, as predicted, the split appears to be mainly between [n] and [s] codas, rather than complement and subset codas. This is in line with much work on gradience in grammar (e.g., Coetzee 2002, 2008, Berent and Shimron 1997). Regardless of what motivates the gradience here, it is clear that the subset~complement distinction is not it.

The second main conclusion evident here is that native Spanish speakers do not find subset codas to be more grammatical in English than they find complement codas to be. While the results of Experiment 2 indicated that the L2 learners of English gave [p] and [k] ratings lower than average, the direct comparisons here show that the L2 English speakers fall at chance in their preference of subset over complement. While they do have a preference for [n] over the complement codas, they also have a preference for complement codas over [s], in a pattern very similar to that of native English speakers. Thus it appears that the L2 learners are acquiring knowledge of whatever is driving the gradience in the English forms, and that their judgements are not based on a distinction between the subset and complement. In other words, these L2 learners are not experiencing interference from their L1, but instead are picking up on some other factors that are influencing how much different forms sound like English.

3.7.5 Discussion of Experiments 3 and 4 together

As previously discussed, Experiment 3 showed that all groups judged subset forms to be more Spanish-like than the complement forms they were compared with. This led to the conclusion that L2 learners of Spanish who were native speakers of English had indeed established some knowledge of the unacceptability of complement forms in Spanish. However, this was complicated by a higher acceptance rate for [m] than for the stops [p] and [k], even though none of the three occur as a final coda in Spanish. In Experiment 4, the results confirm those of Experiment 2 that the degraded acceptability of complement codas could not be explained as a result of transfer from English, even though the subset codas occur more frequently in English than complement codas do. Instead, it appeared that complement codas were just as acceptable, if not more so, than subset codas were.

The almost completely opposite results seen in Experiments 3 and 4 for the native English speakers provide fairly clear evidence that second language learners are establishing a new phonotactic grammar as they acquire their second language. Responses given to Spanish stimuli by L2 learners of Spanish do not appear to be the same responses that native speakers of English give to English forms. Rather, their patterns in English are the opposite of those exhibited in Spanish. For the native Spanish speakers who have learned English, the results of Experiment 4 indicate that they have learned something of the phonotactics of English, as they appear to recognize that the subset codas [n] and [s] are not both preferable to [m, p, k] in English, even though they are both clearly preferred in Spanish. Together, all of these

results support the idea that L2 learners have great success in facing the Complement Problem and learning a phonotactic subset.

3.8 Implications and further discussion

As the four experiments discussed here show, second language learners do indeed appear to be acquiring knowledge of their L2 phonotactic system.

Table 3.6 Overall results for final consonants: a ✔ indicates that the group correctly reflected the legality of subset~complement forms

Language group	English (subset legal, complement illegal)		Spanish (subset and complement both legal)	
	wordlikeness ratings	direct comparisons	wordlikeness ratings	direct comparisons
L1 English	✔	✔	N/A	N/A
L1 Spanish	N/A	N/A	✔ (for [p,k])	✔ (for [p, k])
L2 English	✔	✔	✔	N/A
L2 Spanish	✔	N/A	✔	✔

In the case of Spanish speakers learning English, this is a case of superset learning. On the basis of forms that they hear occurring in English, L2 learners of English can determine that complement codas are acceptable word-finally in English. In this case, language learners are expanding their current grammar into a superset of what they started with, which presents no problems for the Complement Problem. Instead, they

can learn this grammar in exactly the way that the Subset Principle predicts that they will, by building continually into a grammar that accepts a superset of the forms that the current grammar does. While Experiment 2 indicates that this might be problematic for Spanish speakers learning English, the direct comparisons in Experiment 4 show that the Spanish speakers show no preference for subset as a group over complement as a group, though they do show some gradience in their responses. However, this gradience is similar to that of the native Spanish speakers, which indicates that the L2 learners are approximating a native-like grammar, though they may not have yet determined the exact degree of gradient acceptability that native speakers exhibit. These participants showed clear preferences for subset forms in Spanish, but not in English, providing evidence that they have picked up on the fact that complement codas are not phonotactically restricted in English in the same way that they are in Spanish.

The results for English speakers learning Spanish show similar patterns: they show a preference for subset codas over complement codas in Spanish, but not in English. However, the explanation for how this occurs is not as simple. Because English has a larger possible set of final codas than Spanish does, English speakers who learn Spanish are faced with the Complement Problem: they must narrow down their phonotactic grammar to a subset of the forms they find acceptable in English. Just how this occurs is an issue that will be addressed in Chapter 4 with a theoretical model.

That L2 learners of Spanish who are native speakers of English have picked up on phonotactic patterns in their L2 is problematic for the Subset Principle, as these learners have no positive evidence on which to rely to adjust their grammar. However, restrictions on single segments in specific syllable positions have been shown to be learned fairly early, with only brief auditory experience (Dell et al, 2000, Onishi et al, 2001; Goldrick 2004, Taylor and Houghton 2005). As discussed in Chapter 1, L2 learners may be expected to pick up on these first-order constraints easily. Based on this, it seems possible that these speakers may have picked up on the first-order phonotactic constraints regulating final codas easily and accurately, but they may have more trouble with second-order constraints, which have been shown to require more experience to learn (Warker and Dell 2006). We address this issue in Chapter 4, testing these same groups of speakers on their knowledge of second-order constraints related to consonant~glide~vowel sequences in English and Spanish.

4

Consonant~Glide~Vowel Sequences

In chapter 3, I presented experimental evidence showing that second language learners have knowledge of the phonotactic system of their L2, regardless of whether they were learning an L2 grammar that is a superset or a subset of the L1. However, Dell et al. (2000), Onishi et al. (2001), Goldrick (2004), and Taylor and Houghton (2005) have shown that phonotactic learning may occur with little exposure. Each of these studies concentrated on the learning of first-order constraints, or restrictions on segments in a specific syllabic position, regardless of other properties of the syllable. Warker and Dell (2006) compared first-order constraints with second order constraints, which rely on some other property of the syllable, such as whether or not a particular coda can occur with a specific kind of vowel. Their results showed that first-order constraints were learned much more quickly than second-order constraints, which required more extensive exposure for successful acquisition.

The experiments in Chapter 3 also investigated first-order constraints, in this case ones which restrict specific segments in the coda position, regardless of other properties of the syllable. Because this type of constraint is easier to learn, the first-order property may contribute to ease of learning. However, because second-order constraints are more difficult to learn, it is possible that L2 learners do not pick up on them so quickly or so reliably. Thus, it is possible that L2 learners are able to pick up on phonotactic restrictions that rely on first-order constraints, but may not as easily pick up on second-order constraints.

In this chapter, a series of experiments similar in design to those in Chapter 2 is presented, but in this case, subset learning with second-order constraints is investigated. In these experiments, language learners judged how English-like or Spanish-like they thought different nonce words of the target languages were, when different forms were either legal in both languages (subset forms) or legal in one but not the other (complement forms). Thus the experiments investigate the learning of a phonotactic subset, but this time, rather than examining the learning of first-order constraints like those on final codas, the experiments concentrate on the acquisition of a sequence that is restricted by second-order constraints. This phonotactic pattern involves the acceptability of consonant~glide~vowel sequences in English and Spanish, where the presence of a high front glide ([j]) after a preceding consonant determines the acceptability of specific vowels immediately following the glide. That is, acceptability of the vowel is dependent upon other aspects of the syllable, namely the presence of the preceding consonant and glide. With the high front glide [j], the

set of acceptable vowels in consonant~glide~vowel (CGV) sequences in English is a subset of the set of possible vowels in CGV sequences in Spanish. Whether second language learners are able to acquire this knowledge is the question at hand.

As with the final coda experiments of Chapter 3, each of the first two experiments consists of a wordlikeness rating task, where participants judged how wordlike the stimuli sounded in the target language. Experiment 5, the English rating task, was aimed at determining if L1 Spanish~L2 English (S1E2) speakers view words containing subset CGV sequences differently from forms containing complement CGV sequences. The results show that these L2 learners rated subset forms significantly higher than complement forms, indicating that they have successfully overcome the Complement Problem and have some knowledge that the subset is more acceptable than the complement.

Experiment 6 replicates Experiment 5, but with Spanish words rather than English ones, in order to (1) rule out transfer as a possible explanation for the results of Experiment 5, and (2) to determine if superset learning has taken place for L1 English~L2 Spanish (E1S2) speakers. This experiment shows that while significant differences were found between subset and complement forms, the higher ratings were given to complement, rather than subset, forms. This indicates that transfer from the L1 is not a viable explanation for the ratings given by the L2 English learners in Experiment 5, and illustrates that the L2 Spanish learners of this experiment have gained some superset knowledge of their L2.

The results of Experiments 5 and 6 are supported by the comparative judgment tasks in Experiments 7 and 8. Experiment 7 supports the results that were seen in Experiment 5 regarding L2 perception of the lack of acceptability of complement vowels in CGV sequences in English. In a forced-choice comparative task, L2 learners of English found forms with CGV sequences where the vowel is in the complement to be less English-like than words with CGV sequences where the vowel is in the subset. Experiment 8, like Experiment 7, presents learners with a forced-choice task, illustrating that the distinction between subset and complement words is not a result of transfer from the L1. In this experiment, participants judged subset CGV sequences in Spanish to be no more acceptable than complement forms, regardless of the specific complement form with which it was compared.

As with final codas in Chapter 2, these results are argued to provide evidence for the learning of a phonotactic subset in second language acquisition. That this appears to be unproblematic, even for second-order constraints, indicates that the level of difficulty of subset learning in phonotactics is minimal.

I begin in Section 4.1 with establishment of the subset~complement sequences of English and Spanish for consonant~glide~vowel sequences. This is followed by presentation of wordlikeness experiments in English (Section 4.2) and Spanish (Section 4.3), as well as comparative judgment tasks, also in English (Section 4.4) and Spanish (Section 4.5). Section 4.6 concludes.

4.1 Consonant~Glide~Vowel (CGV) sequences in Spanish and English

As discussed in Chapter 1, the set of CGV diphthong sequences that are possible in English is a subset of those possible in Spanish. Here, we concentrate only on sequences containing the glide [j], which, in Spanish, can be followed by any vowel.[7] Example words with CGV sequences are given in (17).

(17) CGV sequences in Spanish

abierto	australiano	estudioso	ciudad
tienda	fiambre	piojo	viuda
tierra	hacia	labio	triunfo
siete	viaje	canción	veintiuno

In English, however, CGV sequences are restricted to only those with the high back vowel [u], as in (18).

(18) CGV sequences in English

cube	[kjub]
huge	[hjudʒ]
fume	[fjum]
beauty	[bjuɾi]

[7]This is not technically true, as words with Cji are nonexistent in Spanish. However, it is often the case that adjacent identical segments are avoided or repaired through some phonological process (McCarthy 1986, Borowsky 1987, Yip 1988). It is thus likely that this gap is due to a restriction against sequences of identical or "sufficiently similar" (Bakovic 2006) segments, which are reduced to a single segment across word boundaries, as in 'mi hijo' [mi ixo] becoming [mixo]. Even if the non-occurrence of Cji sequences in Spanish is due to some other factor, it does not change the subset~superset argument above, as this sequence does not occur in English either.

That this restriction relies on more than simply the vowel itself is evident in the extent of combinational possibilities without the glide - what vowel can appear is determined by the glide and its preceding consonant. For instance, while only [u] can appear after a sequence of consonant~glide, when there is no consonant any vowel can appear after the glide [j], as shown in (3):

(19) Any vowel after just the glide [j]

[ju]	you
[jist]	yeast
[jæŋk]	yank
[jɛlo]	yellow
[jʌk]	yuck
[jok]	yoke
[jat]	yacht

In addition, without the glide, any vowel can follow any consonant in English. Illustrative examples with tense vowels and a voiceless coronal fricative [s], voiced bilabial stop [b], and voiceless velar stop [k] are shown in (4):

(20) any vowel without the glide

[sit]	seat	[bit]	beat	[kin]	keen
[set]	sate	[bet]	bait	[ken]	kane
[sut]	suit	[but]	boot	[kun]	coon
[sok]	soak	[bot]	boat	[kon]	cone
[sak]	sock	[bat]	bought	[kan]	con

Finally, even when a glide appears, all vowels are acceptable, provided that the glide is not [j]. For instance, the labiovelar glide [w] often appears between vowels and consonants, as in [swip] 'sweep', [swej] 'sway', [swun] 'swoon', and [swan] 'swan', without introducing restrictions on the vowel. Therefore, it must the combination of a consonant, followed by the glide [j], that restricts the vowels in this position.

As English only allows Cju while Spanish allows Cju, Cja, Cjo, Cje, a subset~superset situation arises for second language learners. Native speakers of English learning Spanish, who are faced with learning a subset in the final coda situation presented in Chapter 3, are here faced with learning a superset in the CGV problem here. On the other hand, native speakers of Spanish who are learning English are faced with the Complement Problem in CGV sequences, as they must learn that the only CGV sequence acceptable in English is Cju, and thus that the complement Cja, Cjo, Cje forms are illegal.

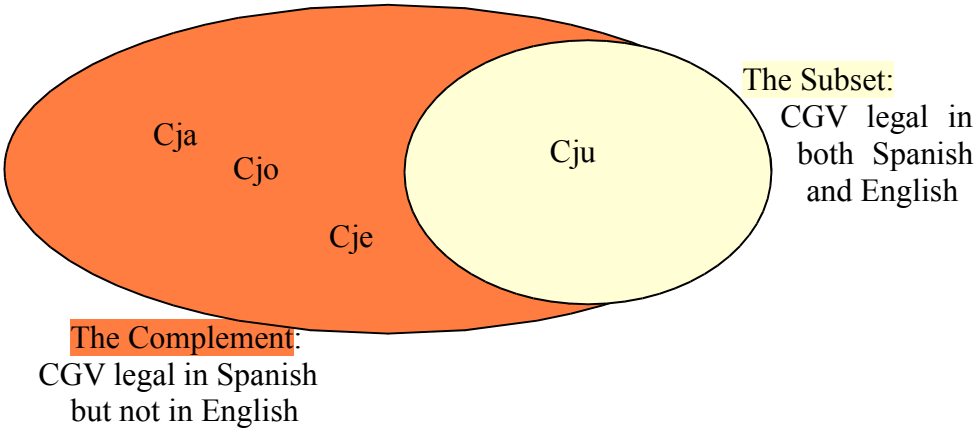

Figure 4.1 Complement and subset in CGV sequences

I test the knowledge of the subset~complement distinction experimentally with the same methodologies employed in Chapter 3 with final coda stimuli. Participants

determined the extent to which nonce words that contain these sequences sound like the target language, either by rating individual words, or by directly comparing two words. If second language learners of English have successfully overcome the Complement Problem and have learned a subset, it would be expected that they would judge forms with Cju sequences (the subset) differently than forms with Cja, Cjo, and Cje sequences (the complement). Specifically, if they have learned a subset, the participants should show a preference for the subset form in English, but not in Spanish, since all the sequences are legal in Spanish. For second language learners, having a distinction between subset and complement forms in English when that difference does not exist in Spanish would provide evidence that these learners have successfully overcome the Complement Problem and learned a subset grammar.

4.2 Experiment 5: CGV wordlikeness ratings in English

4.2.1 Methods

4.2.1.1 Participants

Forty-five people participated in this experiment, all but one of whom also participated in Experiment 2 in Chapter 3. Participants were students at the University of California San Diego, or were recruited by word of mouth in Guatemala, where participants were from either Guatemala City or Quetzaltenango. All participants reported normal hearing and no history of speech problems. Either class credit or monetary compensation was offered in exchange for participation.

Of the 45 participants, 15 were in each group. The ME group, with ages ranging from 18 to 23 had 3 male participants and 12 female. The BI group included 8 males and 7 females, with ages ranging from 18 to 27, and the S1E2 group included participants from 18 to 40, with 7 males and 8 females.

As in the experiments in Chapter 3, each participant was assigned to an experimental group based on self-reported language ability, age of acquisition, and LEU score. The ME had 14 participants, the BI 15, and S1E2 had 16 participants.

4.2.1.2 Stimuli

As noted above, the possible CGV sequences in English are a subset of those of Spanish. Each of the four possible CGV sequences possible in Spanish was tested in this experiment, though the target language of the experiment was English.

For this experiment, focusing on recognition of the English CGV subset, five sets of nonce word stimuli were created. All words were monosyllabic and included an initial consonant~glide~vowel sequence, followed by a single-segment coda. As in Chapter 3, phonotactic probability was controlled for by the creation of sets such that all words were minimal pairs within each set, varying only in the vowel that immediately followed the glide. This provided three complement stimuli for each one subset stimulus. The sets used were as follows:

(21) English CGV experimental stimuli

Subset CGV:

[gjud kjuf pjug sjul mjuʃ]

Complement CGV:

[gjad kjaf pjag sjal mjaʃ]

[gjod kjof pjog sjol mjoʃ]

[gjed kjef pjeg sjel mjeʃ]

All stimuli were recorded in a sound-attenuated booth by a female native speaker of English who had taken a graduate level course in phonetics. She was fluent in Spanish and pronounced all sequences of glide~vowel as a diphthong rather than with the vowels in hiatus. Each stimulus was read in the carrier sentence "I will say [stimulus] three times", then spliced out and normalized for amplitude. The same speaker recorded all stimuli in a single session, which also included recording of all fillers, as well as the stimuli for the final consonant experiments in Chapter 3.

4.2.2 Procedure

Participants were tested individually in a quiet room. As far as was possible, all communication took place in English. When the proficiency of an L2 speaker was so minimal that they were unable to understand English instructions, instructions were given orally in Spanish first, and then the participant read them in English.

The task that participants undertook was a determination of wordlikeness in English. Participants rated each stimulus on a scale of one to nine, with one being the

lowest (least English-like) rating, and nine being the highest (most English-like). Stimuli were presented through headphones, one at a time, using Psyscope X on a MacBook laptop. Participants saw on the screen in front of them the question, "How much did that sound like English to you?" and the scale with endpoints identified, but no orthographic representation of the stimulus. Participants responded by pressing a number key on the laptop that corresponded to their judgment, and a response was required before the next stimulus was presented. No stimulus could be repeated on demand, and stimuli with response times over 3500ms were disregarded in the analysis of the results.

Stimuli were presented in three blocks of 97 stimuli, with each block containing all stimuli and all fillers and individually randomized. Thus, each stimulus was heard and rated three times by each participant. Between each block, participants could rest if needed. Each block began with five fillers, so that participants could accustom themselves to the task before hearing experimental stimuli.

4.2.3 Analyses

Two separate measures were used for analysis. One was the mean rating given to the relevant forms by each subject. The second was the same normalization of the data which was used for the wordlikeness experiments in Chapter 3: a z-score, calculated for each stimulus by subtracting the overall mean for a given subject from the rating given that stimulus, then dividing by the overall standard deviation for that subject. The ratings and z-scores were subjected to an analysis of variance with a

mixed design. The ANOVA was 2 X 3, with a within-subjects factor of legality (subset, complement) and a between-subjects factor of language group (ME, BI, S1E2). Effects were considered significant at $p<.05$. Results by mean rating and transformation did not differ significantly other than in the effect of language; therefore, statistics based on the z-scores are presented rather than mean ratings for all but the effect related to language.

4.2.4 Predictions

Based on the evidence presented in Chapter 3 that L2 learners do exhibit some knowledge that complement forms are less acceptable than subset forms, it is predicted that L2 learners of English who are native speakers of Spanish will also judge subset and complement forms differently, effectively showing that they have acquired knowledge of the subset. In addition, because Cju is the only legal CGV sequence in English, it is predicted that native speakers of English, whether monolingual or bilingual, will show a significant difference between subset and complement forms.

4.2.5 Results

The ANOVA revealed no significant interaction for legality and language groups ($F(2,42) = 0.53$, $p=0.59$), indicating that the different language groups did not respond significantly differently to the subset~complement distinction. Thus, the main effect of legality ($F(1,42) = 21.0$, $p<.0001$) holds across all groups.

As shown in Table 4.1, pairwise comparisons indicate that this difference is only significant for the BI and S1E2 groups. For the BI group, the mean of 0.20 (SD = 1.13) for subset responses was significantly higher than the mean of complement ratings at -0.09 (SD =0.89) (t(14) = 3.01, p=0.005), a pattern also evident in the S1E2 group (subset mean = 0.23, SD = 1.08; complement mean = -0.08, SD = 0.95; t(15) = 3.21, p=0.003). However, while the mean of subset forms (0.15, SD = 1.01) for the ME group was somewhat higher than the mean of complement forms (-0.05, SD = 0.98), this difference did not reach significance (t(13) = 1.76, p=0.09).

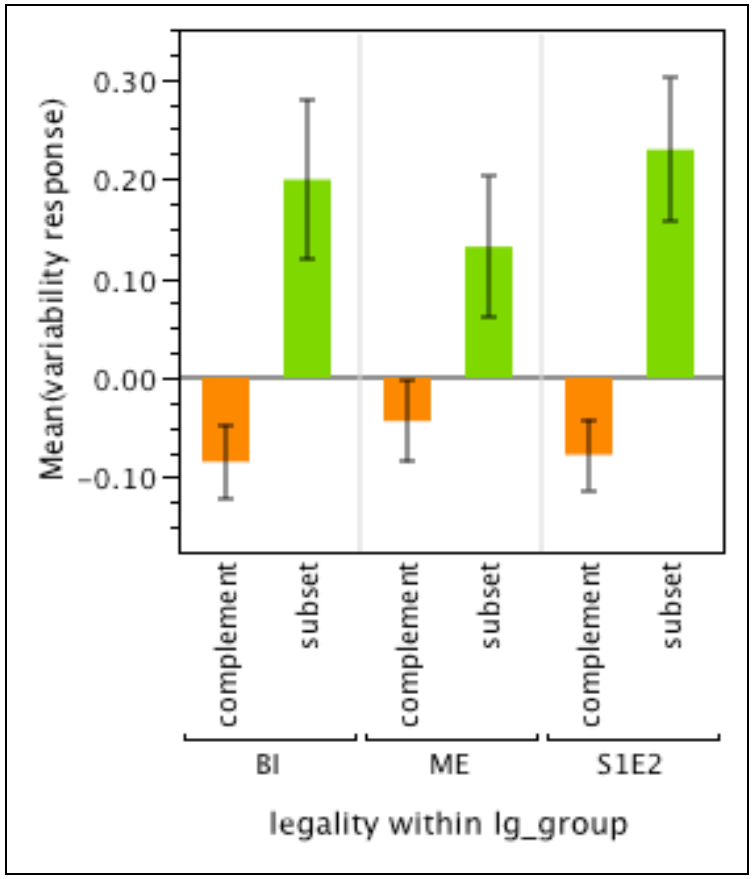

Figure 4.2 subset~complement responses by language group

In the mean ratings, there was also a main effect of language ($F(2,42) = 8.44$, $p<.001$), indicating that the overall mean ratings of individual language groups were significantly different for this set of stimuli. Specifically, the S1E2 group gave overall ratings that were significantly higher than both the ME ($t(28) = 3.81$, $p=0.0005$) and BI ($t(29) = 3.11$, $p=0.004$) groups.

Table 4.1 Differences between subset and complement forms by group for CGV sequences in Spanish

group	subset mean	subset SD	complement mean	complement SD	significant difference between subset and complement?
S1E2	0.23	1.08	-0.08	0.95	**
BI	0.20	1.13	-0.09	0.89	**
ME	0.15	1.01	-0.05	0.98	
* = p<.05, ** = p<.001, ***=p<.0001					

4.2.6 Discussion

This experiment clearly shows that L2 learners of English distinguish between subset and complement forms, and that they view subset forms to sound more English-like than complement forms. These results indicate that the second language learners of English (S1E2) do have some knowledge that subset forms with Cju are more acceptable in English than complement forms with Cja, Cjo, Cje. This further supports the claim made in Chapter 3 that second language learners can successfully overcome the Complement Problem and acquire knowledge that the complement is ungrammatical in their L2 even when it is grammatical in their L1.

The original prediction that native speakers of English would distinguish between subset and complement forms was only partially met. While bilinguals gave subset forms significantly higher ratings than complement forms, this trend was not significant for the monolingual English speakers. This group of speakers, who might be expected to have the strongest distinction between subset and complement forms, are instead the only group that has no statistically significant difference between subset and complement ratings. This is similar to what was seen with monolingual Spanish speakers in the final coda experiments in Chapter 3. As with that experiment, it is possible that the monolingual speakers were having trouble distinguishing real words vs. possible words in their minds, and thus gave low ratings overall, which obscured their overall preference for subset forms over complement forms. Experiment 7, with direct comparisons between subset and complement forms in English, will shed more light on whether or not native speakers truly have a preference for subset over complement.

The results here support the idea that second language learners are able to effectively learn phonotactic restrictions, even with the added complexity of second-order constraints that are dependent on properties of the syllable outside of the vowel itself. While Dell and Warker (2006) showed that learning second-order constraints took longer than learning first-order constraints did, effects of the second-order constraints were seen by the second day of training. This experiment indicates that L2 learners were able to pick up on the restrictions on CGV sequences in English.

However, Experiment 6 will rule out transfer effects as a possible explanation for these results.

4.3 Experiment 6: CGV wordlikeness ratings in Spanish

Experiment 5 showed that second language learners of English have some knowledge that forms within the subset (with Cju) are more acceptable in English than are forms within the complement (with Cja, Cjo, Cje sequences). This experiment is similar to the preceding one, but here wordlikeness ratings of Spanish nonce forms are elicited in order to examine whether native speakers of Spanish are making the same type of judgments in their L1, in order to rule out any transfer effects from the L1. In addition, this experiment investigates whether or not native English speakers who are learning Spanish make a distinction between subset and complement forms, or whether they are acquiring the knowledge that complement forms in Spanish are well-formed, even though they are unacceptable in English.

4.3.1 Methods

4.3.1.1 Participants and procedure

There were 41 participants in this experiment, all of whom also participated in Experiment 1 of Chapter 3. Participants were either students at the University of California San Diego, or were recruited by word of mouth in Guatemala, where participants were from either Guatemala City or Quetzaltenango. All participants

reported normal hearing and no history of speech problems. Either class credit or monetary compensation was offered in exchange for participation.

In the BI group, there were 12 participants, ranging in age from 18 to 26, with 5 males and 7 females. The E1S2 group consisted of 14 people, 8 male and 6 female, ranging in age from 18 to 40. The 15 participants in the MS group ranged in age from 18 to 60, 7 of which were male and 8 of which were female.

4.3.1.2 Stimuli

The creation of stimuli in this experiment followed the same process as that of Experiment 5, utilizing the same CGV sequences, where Cju was the subset sequence, legal in both English and Spanish, while Cja, Cjo, and Cje were complement sequences, legal in Spanish but not in English. Five sets of four Spanish nonce words were created, with all words within a set constituting minimal pairs that varied only in the vowel following the glide. The sets created were as follows:

(22) CGV stimuli for Spanish

subset CGV:	[biuno	kiufo	miuso	piugo	siuto]
complement CGV:	[biano	kiafo	miaso	piago	siato]
	[bieno	kiefo	mieso	piego	sieto]
	[biono	kiofo	mioso	piogo	sioto]

Stimuli were recorded in a sound-attenuated booth by a native speaker of Spanish who had been trained in phonetics. All recordings of both stimuli and fillers were completed in a single session. As in Experiment 5, fillers consisted of sets of

nonce words that varied in either onset or coda. All stimuli were spliced out using Praat version 4.3.01 (Boersma and Weenink 2005) and normalized for amplitude before presentation in the experiment.

4.3.2 Analysis

As in the wordlikeness experiment with English glides, two separate measures were used for analysis, but results for the two did not differ, except in the case of an effect for language. Thus we present only the results of the z-scores for all effects other than language. The scores were submitted to a 2 X 3 ANOVA, with a within-subjects factor of legality (subset, complement) and a between-subjects factor of language group (E1S2, BI, MS).

4.3.3 Results

The results of the ANOVA showed main effects for both legality $F(1, 38) = 16.43$, $p=0.0002$) and language ($F(2,38) = 21.48$, $p<.0001$), but no significant interaction between these two factors, indicating that the different groups did not respond differently to the subset~complement distinction.

While the trend was for complement forms to be rated higher than subset forms, pairwise comparisons revealed that this distinction reached significance only for the MS group (subset mean = -0.232, SD = 0.78; complement mean = 0.076, SD = 1.04; $t(14) = 3.64$, $p=0.0007$). The BI group barely missed significance ($t(11) = 1.87$, $p=0.067$) with a subset mean of -0.14 (SD = 1.01) and a complement mean of 0.04),

and the E1S2 mean complement rating of 0.04 (SD = 1.02) was not significantly different from the subset mean of -0.11 (SD = 0.91) (t(13) = 1.7, p=0.096).

Table 4.2 Differences between subset and complement forms by group for CGV sequences in Spanish

group	subset mean	subset SD	complement mean	complement SD	significant difference between subset and complement?
E1S2	-0.11	0.91	0.04	1.02	
BI	-0.14	1.01	0.04	0.98	
MS	-0.232	0.78	0.076	1.04	**
* = p<.05, ** = p<.001, ***=p<.0001					

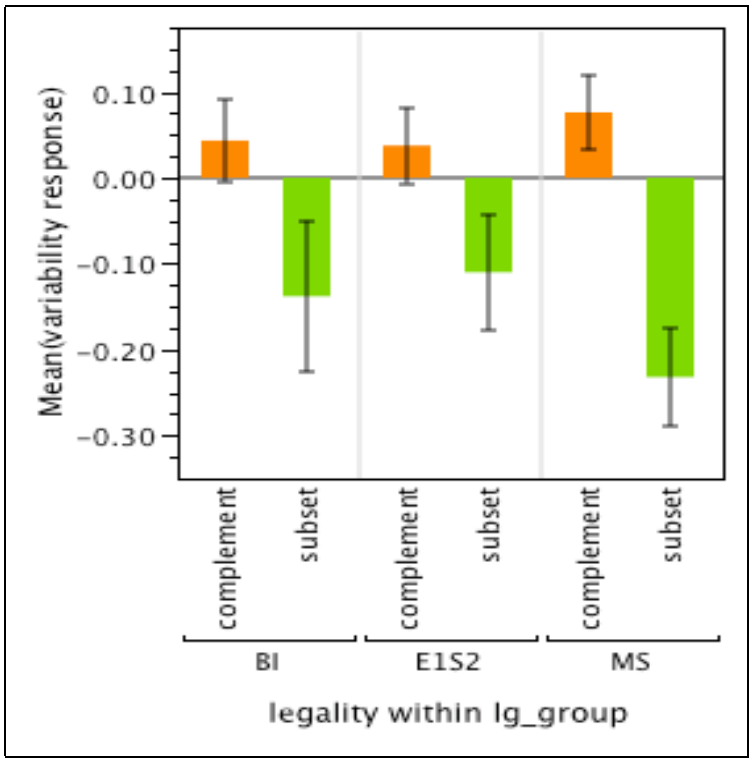

Figure 4.3 Subset~Complement responses in Spanish by language group

4.3.3.3 Analysis by glide type

While both mean rating and z-scores indicate that subset forms (Cju) were rated lower than complement forms (Cja, Cje, Cjo), these measures do not indicate if one of the three complement forms is significantly higher than Cju, driving the overall results. To discover if in fact the subset forms with Cju were truly rated lower than the complement forms, the z-score was analyzed with a second ANOVA, tone that was 4 X 3 for glide type (ja, je, jo, ju) and language group (E1S2, BI, MS).

This ANOVA showed a main effect of glide type ($F(3,38) = 9.01$, $p<0.0001$), but no effect for language ($F(2,38) = 0.17$, $p=0.846$), and no significant interaction for glide type and language ($F(6,38) = 1.79$, $p=0.105$). The glide [je] was overall the highest rated, with a mean of 0.02 (SD = 1.03), and pairwise comparisons showed that it was rated significantly higher than both [jo] (mean = -0.02, SD = 1.01; $t(38) = 3.15$, $p=0.002$) and [ju] (mean = -0.16, SD = 0.89; $t(38) = 5.15$, $p<.0001$). [ja] was also rated significantly higher than [ju] ([ja] mean = 0.02, SD = 1.03; $t(38) = 3.01$, $p=0.003$), while the difference between [ju] and [jo] barely missed significance ([jo] mean = -0.02, SD = 1.01; $t(38) = 1.89$, $p=0.061$).

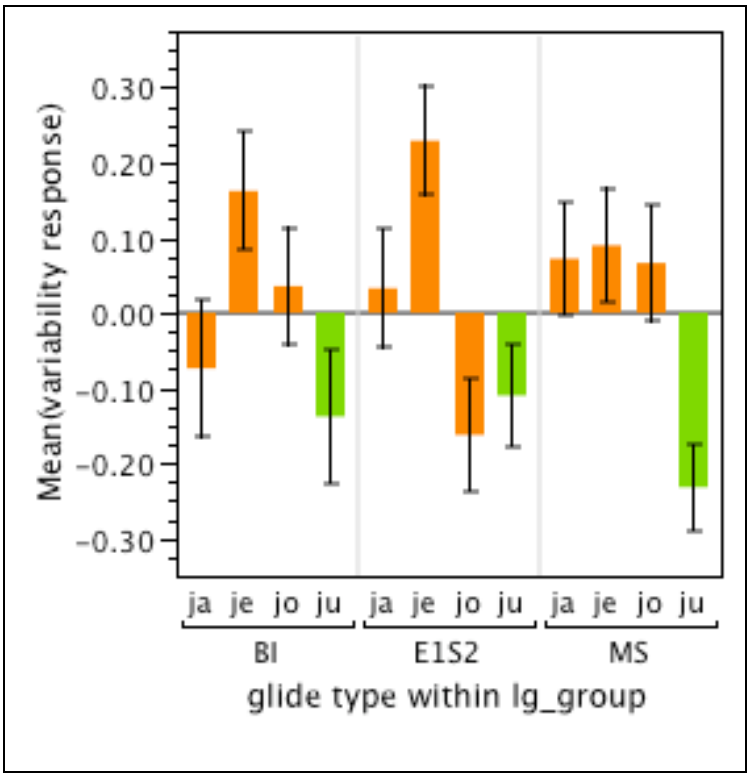

Figure 4.4 Responses by glide type in Spanish

Pairwise comparisons indicate that the distinction seen in the subset~complement ratings is driven by the difference between [je] and [ju]. Only the difference between [je] and [ju] is significant for both the BI ($t(11) = 2.72$, $p=0.007$) and E1S2 ($t(13) = 3.11$, $p=0.002$) groups, while the MS group rated [ju] significantly lower than all other glide types ([je]: $t(14) = 3.0$, $p=0.003$; [jo]: $t(14) = 2.99$, $p=0.003$; [ja]: $t(14) = 3.21$, $p=.002$).

4.3.4 Discussion

The results for Experiment 6 indicate that subset forms were not rated higher than complement forms in Spanish. Rather, the trend was in the opposite direction: complement forms were preferred over subset forms.

In regard to the predictions made at the outset of this experiment, it is clear that no group rates subset forms significantly higher than complement forms. For all groups, at least [je] was rated significantly higher than [ju], and for the monolingual Spanish speakers, ratings for all complement glide sequences (ja, je, jo) were rated significantly higher than the subset [ju]. For the bilingual speakers, there appears to be a great deal of gradience evident within the different glide types, but even this gradience does not point to a preference for subset forms over complement forms. Whatever is driving the gradience here, it is clearly not a distinction between subset and complement. This gradience is more fully explored with the direct comparisons of Experiment 8. In essence, what we see here is that the results that we saw for the L2 learners in Experiment 5, who rated subset forms higher than complement forms, cannot be a result of transfer from the L1, as the rating patterns are opposite for the English and Spanish experiments.

4.4 Experiment 7: Direct CGV comparisons in English

In this experiment, rather than having participants judge each word separately, words were presented as direct comparisons in which participants heard two words and had to determine which of the two sounded more like English.

4.4.1 Methods

4.4.1.1 Participants

There were 42 participants in this experiment. All completed the language background questionnaire that determined their overall LEU score. Based on this score, as well as self-reported proficiency level and age of acquisition, participants were assigned to one of three language groups: BI, S1E2, ME. Criteria for assignment were identical to those in the preceding experiments. In the BI group, there were 14 participants (8 male and 6 female, ages 18 to 27), with 12 participants in the ME group (2 males, 10 females, ages 18 to 23), and 16 in the S1E2 group (7 male, 9 female, ages 18 to 40).

4.4.1.2 Stimuli

The nonce word stimuli used in Experiment 5, originally given in (21), were the same ones used for this experiment and repeated here:

(23) English CGV stimuli

Subset CGV:	[gjud	kjuf	pjug	sjul	mjuʃ]
Complement CGV:	[gjad	kjaf	pjag	sjal	mjaʃ]
	[gjod	kjof	pjog	sjol	mjoʃ]
	[gjed	kjef	pjeg	sjel	mjeʃ]

Each subset stimulus was paired with each of the complement stimuli of the same set, resulting in three pairs per set, or a total of 15 pairs.

4.4.1.3 Procedure

Participants were tested individually in a quiet room. As far as was possible, all communication took place in English, though participants at times required that the instructions be given orally in Spanish in order to understand the task.

All participants took part in a forced-choice comparison of wordlikeness in English. Stimuli were presented in pairs, with one subset and one complement form in each pair, counterbalanced for order. Participants responded with "1" when the first stimulus sounded more like Spanish, and with "9" when the second one did. Stimuli were presented through headphones, one at a time, using Psyscope X on a MacBook laptop. Participants saw on the screen in front of them the question, "Which word sounded more like English?" and the points "1" and "9" identified, but no orthographic representation of either stimulus. Upon hearing the stimulus and seeing the question, participants entered a response by hitting a number key on the laptop keyboard. Participants could not request repetition of a stimulus, and a response was required before continuing to the next stimulus. However, comparisons with response times over 3500ms were disregarded in the analysis of the results.

Stimuli were presented in two blocks, with each block containing all stimuli and all fillers. Thus, each stimuli pair was heard and comparatively judged two times by each participant, with the pairs counterbalanced for order. Within each block, half of the stimuli pairs presented the complement form first, and half presented the subset form first. Between each block, participants could rest if needed. Each block began

with five fillers, so that participants could accustom themselves to the task before hearing experimental stimuli.

4.4.2 Results

Overall, the results show a preference for subset forms in comparison to complement forms for all groups, at a level significantly higher than chance for both the BI group (65.3%, $t(13) = 4.32$, $p < .0001$) and the S1E2 group (68.5%, $t(15) = 7.68$, $p < .0001$), but not the ME group (56.2%, $t(11) = 1.77$, $p = .085$).

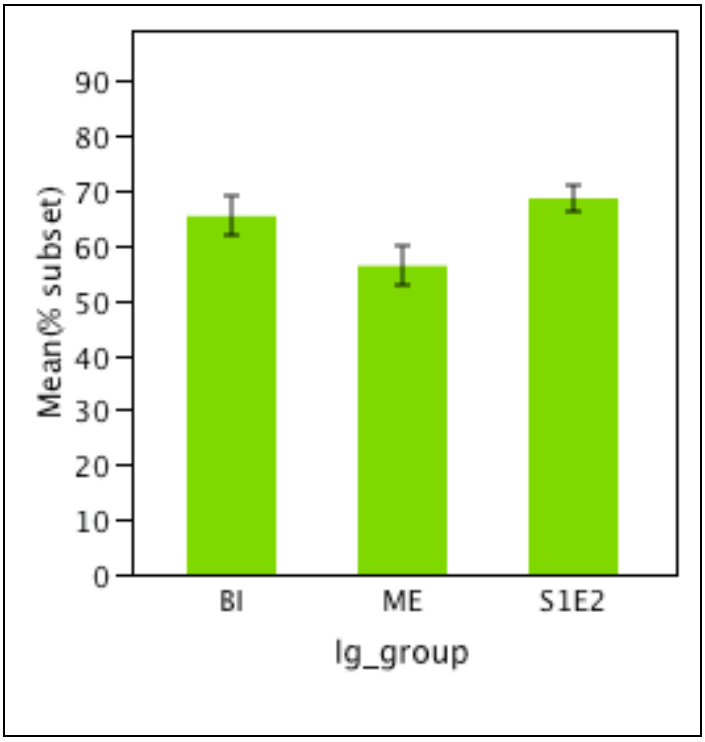

Figure 4.5 Proportion of responses favoring subset forms in English

Table 4.3 Percentage of subset preference in English CGV sequences

language group	% subset preference	significant preference?
ME	56.2%	*
S1E2	68.5%	***
BI	65.3%	***
* = p<.05, ** = p<.001, ***=p<.0001		

A 3 X 3 ANOVA with a within subjects factor of glide type (ja, je, jo) and a between subjects factor of language group indicated that proportions of responses in favor of the subset CGV sequence did not vary significantly by either language group ($F(2,39) = 1.82$, $p = .176$) or glide type ($F(2,39) = 1.82$, $p = .169$). Rather, subjects preferred the subset glide [ju] over all other types of glides in roughly equal proportions.

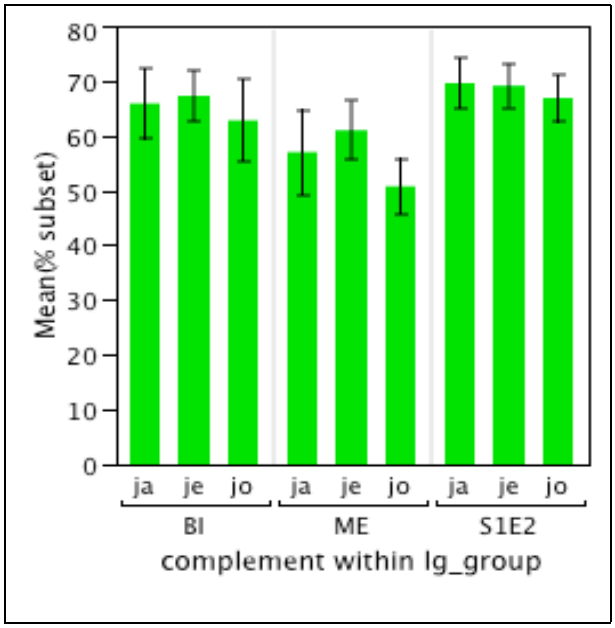

Figure 4.6 Proportion of subset preference by complement

4.4.3 Discussion

This experiment, like Experiment 5, shows that English speakers, whether bilinguals or L2 learners, have a preference for the subset CGV sequence [ju] over the complement CGV sequences [ja, je, jo]. Within the complement sequences, no clear preference for one over the other was found; that is, all of the complement sequences are equally dispreferred to the subset sequence.

In addition, the S1E2 group is approximating native-like behavior in comparison to the bilingual group, viewing subset forms as more English-like than complement forms. The results of this experiment, like those of Experiment 5, indicate that L2 learners are successfully facing the Complement Problem and are acquiring the knowledge that subset forms are more acceptable in English than complement forms.

4.5 Experiment 8: Direct CGV comparisons in Spanish

4.5.1 Methods

4.5.1.1 Participants

There were 36 participants in this experiment. All completed the language background questionnaire that determined their overall Language Exposure and Usage (LEU) score. Based on this score, as well as self-reported proficiency level and age of acquisition, participants were assigned to one of three language groups. In the BI group, there were 9 participants (6 female, 3 male, ages 18 to 26), with 12 E1S2

participants (5 female, 7 male, ages 18 to 21), and 15 MS participants (7 male, 8 female, ages 18 to 60).

4.5.1.2 Stimuli

The recordings of nonce word stimuli used in Experiment 6 were the same ones used for this experiment, as shown in (24).

(24) Spanish CGV stimuli

subset CGV:

[biuno kiufo miuso piugo siuto]

complement CGV:

[biano kiafo miaso piago siato]

[bieno kiefo mieso piego sieto]

[biono kiofo mioso piogo sioto]

Each subset stimulus was paired with each of the the complement stimuli of the same set, resulting in three pairs per set, for a total of 15 pairs, just as in Experiment 7.

4.5.1.3 Procedure

The procedure for this experiment was identical to that of Experiment 7, except that all communication took place in Spanish to the extent that it was possible.

4.5.2 Predictions

Based on the results of Experiment 6, it is expected that no subset preference will hold for any of the language groups under examination. Instead, it is predicted that complement forms will be preferred over subset [ju] forms, at least in the case of [je], which was rated much higher than the other CGV sequences in Experiment 6.

4.5.3 Results

The results indicate that none of the three participant groups judge the subset form to be more Spanish-like than the complement form. For the BI group, % of responses in favor of the subset fell roughly at chance (43.9%, $t(8) = .71$, $p = .497$), while those for both the E1S2 and MS groups were significantly below chance. The MS group judged the subset better than the complement in 38.2% of comparisons ($t(14) = 3.54$, $p = .0032$), while the E1S2 group judged the subset to be better than the complement in only 27.4% of comparisons ($t(11) = 5.1$, $p = .0003$).

Table 4.4 Percentage of subset preference for Spanish CGV sequences

language group	% subset preference	significant preference?
MS	38.2%	*
E1S2	27.4%	**
BI	43.9%	
* = p<.05, ** = p<.001, ***=p<.0001		

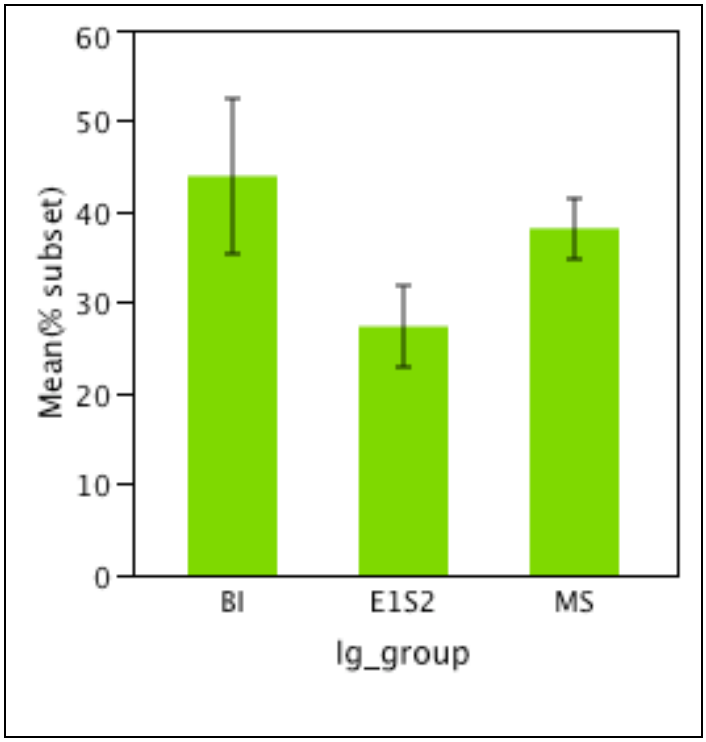

Figure 4.7 Proportion of responses in favor of subset form

A 2 X 3 ANOVA with a within-subjects factor of glide type (ja/jo, je) and a between subjects factor of language group showed a significant interaction for the two factors ($F(2,33) = 7.71$, $p = .002$) such that E1S2 group judged comparisons with [je] to be better than the complement [ju] significantly more than the comparisons with [jo/ja] ($t(11) = 3.83$, $p = .0005$), whereas there was no significant difference in these proportions for either the BI ($t(8) = 1.18$, $p = .247$) or the MS groups ($t(14) = 1.59$, $p = .121$).

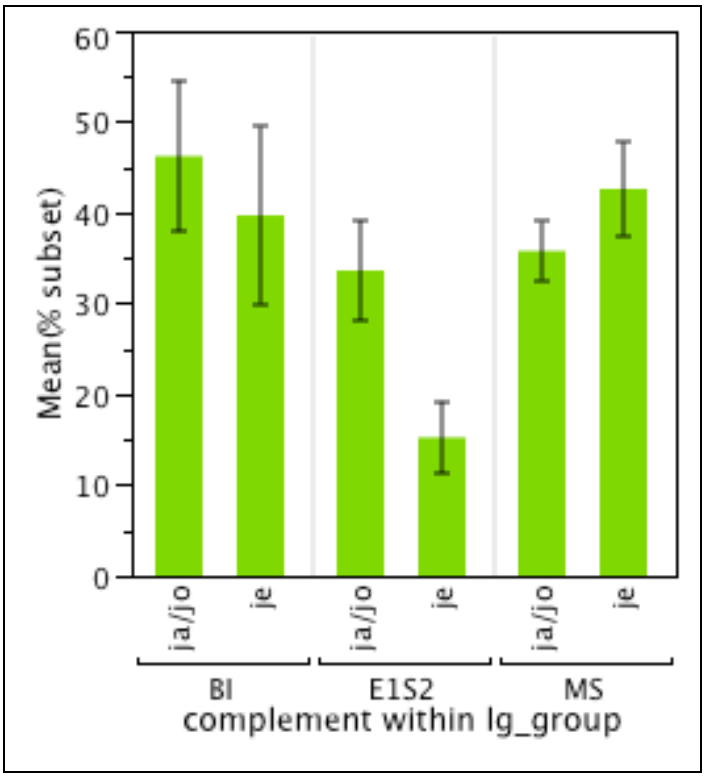

Figure 4.8 Proportions of subset-preference judgements by glide and group

The factors of language group ($F(2,33) = 3.4$, $p = .045$) and glide type ($F(1,33) = 4.53$, $p = .041$) barely reached significance, with the E1S2 overall proportions being significantly lower than both the BI ($t(19) = 2.35$, $p = .025$) and MS groups ($t(25) = 2.13$, $p = .04$)

4.5.4 Discussion

The results of Experiment 8 clearly illustrate that the subset preference seen in English is unlikely to be the result of transfer from the L1 grammar. Native speakers of Spanish in this experiment did not judge subset forms to be preferable to complement forms. Instead, proportions in favor of subset forms were significantly

lower than chance for both the L2 speakers and the monolinguals, indicating that they actually showed a preference for complement forms, rather than subset forms. This trend held regardless of language background, though the preference for complement forms was strongest for the L2 learners and weakest for the bilinguals. These results carry out the prediction made for this experiment, that participants will not view the subset as significantly better in Spanish than the complement.

In addition, there appears to be some degree of gradience between the complement forms, but the trend is in opposite directions for the two native speaker groups. Oddly, the E1S2 shows the greatest distinction, choosing forms with [je] to be better than the subset [ju] significantly more often than forms with [ja/jo]. This was not a significant difference for the bilinguals, but the data trends in the same direction. While this trend was reversed for the monolingual Spanish speakers, the overall preference for complement forms over subset forms still held for this group as well.

4.5.3 Discussion of all CGV Experiments together

Experiments 5 and 6 show that L2 learners of English have knowledge that subset forms with Cju are more acceptable in English than complement forms with Cja, Cje, Cjo. In Experiment 5, subset forms were rated significantly higher in English than complement forms, and Experiment 7 shows a preference for subset forms at a proportion well above chance. Together, these two experiments demonstrate that L2 learners have successfully overcome the Complement Problem and have acquired some knowledge of the phonotactic system of their L2.

That the phonotactic knowledge exhibited by the participants in Experiments 5 and 7 is not simply the result of transfer from the L1 is shown by Experiments 6 and 8, both of which show that judgments made in Spanish by native speakers of Spanish, whether bilingual or monolingual, are not the same as those by the native Spanish speakers who are L2 learners of English. Instead, it appears that the L2 learners of English have acquired knowledge of a phonotactic grammar that is distinct from that of their L1.

Table 4.5 Overall results of CGV experiments: a ✔ indicates that the group correctly reflected the legality of subset~complement forms

Language group	English (subset legal, complement illegal)		Spanish (subset and complement both legal)	
	wordlikeness ratings	direct comparisons	wordlikeness ratings	direct comparisons
L1 English	✔	✔	N/A	N/A
L1 Spanish	N/A	N/A	✔	✔
L2 English	✔	✔	N/A	N/A
L2 Spanish	N/A	N/A	✔	✔

Also shown in Experiments 6 and 8 is that L2 learners of Spanish who are native speakers of English are able to learn new phonotactic patterns as well. That is, even though native English speakers show a preference for subset over complement forms in English, the same preference is not shown in Spanish by native English speakers for whom Spanish is the L2. This is unsurprising in that positive evidence in

Spanish attests to the grammaticality of complement forms in this language, allowing the phonotactic restrictions against complement forms to be suppressed.

4.6 Implications and further discussion

Taken together with the results of the experiments in Chapter 3, these experiments present strong evidence that subset learning is indeed possible, and that this type of acquisition of phonotactic knowledge appears to be relatively unproblematic, even for second-order constraints, which have been shown (Warker and Dell 2006) to require more extensive exposure than first-order constraints. However, in Chapter 3, L2 learners of English appeared to be approaching native-like judgments regarding the gradient acceptability of different forms in relation to each other, as the L2 learners showed a distinct difference between [n] and [s] in the comparative judgement task. This same native-like behavior within the complement forms is not reflected in the CGV experiments of Chapter 4, which may be due to this pattern being more difficult to learn.

This knowledge of gradience aside, Experiments 6 and 8 do clearly show that native speakers of Spanish do not exhibit a bias against complement forms in their L1, so the obvious preference for subset over complement in English must not be the result of transfer from the L1. As Experiments 5 and 7 show, L2 learners of English who are native speakers of Spanish have acquired knowledge that subset forms are not as acceptable in English as complement forms are. However, there is no positive evidence in English that attests to the ungrammaticality of complement forms. Thus,

the question arises as to how to account for this knowledge. In Chapter 5, I investigate how this learning may be possible, and propose a modification to Escudero's (2005) model of second language speech perception which will account for the knowledge of complement ungrammaticality that L2 learners have been shown to possess.

5

Modeling subset knowledge in SLA

As discussed in Chapter 1, assuming the Subset Principle in Second Language Acquisition can be problematic. Because effects of transfer from the L1 abound in L2 production and category perception, current assumptions regarding the initial state of the L2 grammar hold that the L2 grammar is a copy of the L1. This leads to what I term the Complement Problem in L2 acquisition: L2 learners may be faced with learning a grammar that describes a subset of forms compared to that of their L1. Assuming that the initial state of the L2 grammar is the L1 grammar, these learners must somehow acquire ungrammaticality – they must learn that some forms that are grammatical in their L1 are ungrammatical in their L2. However, moving from the less restrictive L1 to the more restrictive L2 would require negative evidence, and how to incorporate negative evidence into a linguistic theory of language acquisition is unclear at best.

Previous work in L2 acquisition has shown that not only does the L1 grammar affect production and perception in the L2, but also that L2 learners progress in their knowledge, moving toward a more target-like grammar. The experiments in Chapters 3 and 4 also show that language learners somehow acquire knowledge of ungrammaticality in their L2, even when the forms that are ungrammatical in the L2 are grammatical in the L1. Therefore, a model that accounts for the acquisition of phonotactic knowledge in the L2 should account for each of the following:

(25) Problems to account for in L2 speech acquisition models

1. transfer from the L1 to the L2 in production and category perception
2. a mechanism for learning that leads to more target-like grammars
3. the possibility of learning a phonotactic subset

While several different models speak to (1) and (2), how to incorporate (3) into approaches to second language acquisition is problematic due to the necessity for something other than positive evidence in order to learn this knowledge, and the reliance on the Subset Principle as an operative principle.

Within the area of phonology, the most influential theoretical framework in the past 15 years is Optimality Theory (OT, Prince and Smolensky 1993/2004). In addition to effectively accounting for a number of different phonological phenomena in countless languages, research in OT has also been concerned with verifying that different grammars are in fact learnable. To this end, from OT's inception, learning algorithms have been proposed that model how learning takes place. For L1

acquisition, these learning algorithms have been particularly successful in a number of ways, and have recently been applied to L2 acquisition.

Unfortunately, within generative grammar, including Optimality Theory (OT), learning algorithms implicitly assume that learning takes place on the basis of positive evidence – that is, they assume the Subset Principle – and make no provision for alternative methods. Therefore, in order to integrate the acquisition of subset knowledge evident in Chapters 3 and 4 into any attempt at learnability in OT, some sort of modification is necessary. Here, I propose one such modification, and show that in fact this pattern can be effectively modeled within OT, but that certain assumptions must be made regarding the initial state of the L2 grammar.

In this chapter, I first introduce OT and discuss OT learning algorithms and their assumption of superset learning. This is followed in Section 5.2 by a description of the Second Language Linguistic Perception (L2LP) Model of Escudero (2005), an OT-based model which is one of the most comprehensive linguistic approaches to second language speech perception and acquisition, though not without its problems, as shown in Section 5.3. In Section 5.4, I propose the Perceptual Full Access model, a modification to the L2LP, which allows for the acquisition of subset knowledge that we see in L2 phonotactics, and which integrates into the model the use of indirect negative evidence in the learning process. Section 5.5 concludes.

5.1 Learning algorithms and the assumption of superset learning

Learnability has been an issue that has been of concern from the inception of OT. Under the original constraint demotion learning algorithm (Tesar and Smolensky 1993), as well as its subsequent revisions and explications (Tesar 1995, Tesar and Smolensky 1996, 1998, 2000), the Subset Principle is assumed for both the initial state grammar as well as in how learning proceeds. Additional algorithms (Prince and Tesar's Biased Constraint Demotion (1999), Boersma's Gradual Learning Algorithm (1997)) that differ significantly in other ways continue to make the same assumption, effectively eliminating the possibility of subset learning. In Section 5.1.1, a brief introduction to OT is given, followed by a discussion in 5.1.2 of how the learning algorithms work. Section 5.1.3 addresses the assumption of the Subset Principle in these algorithms.

5.1.1 A brief introduction to Optimality Theory

Optimality Theory (OT) (Prince and Smolensky 1993/2004) is a constraint-based model of grammar, under which specific surface forms arise in production due to resolution of conflicts between different constraints, and different grammars arise under different rankings of the constraints. Three main components of the model are *Gen*, *Con*, and *Eval*. *Gen* is a function which, from some given input (or underlying representation), generates an inclusive set of output (surface) forms, termed candidates. *Con* is a set of constraints, proposed to be universal, whose ranking determines the output of the grammar. The constraints are violable, but strictly

ranked, so that higher-ranked constraints take precedence over lower-ranked constraints. *Eval* determines the winner by evaluating the set of generated candidates against the given constraint ranking. The constraints are in a strict domination relationship, meaning that candidates that violate higher-ranked constraints are eliminated first. The winner is, in essence, the last man standing, the one candidate left when all other candidates have been eliminated by higher-ranked constraints, or by more violations of the same constraint. To illustrate, consider the tableau below, in which CONSTRAINT 1 dominates both CONSTRAINT 2 and CONSTRAINT 3:

Tableau 5.1 C1 >> C2, C3 (CONSTRAINT 1 *dominates* CONSTRAINTS 2 and 3)

/ input /	CONSTRAINT 1	CONSTRAINT 2	CONSTRAINT 3
a. ☞ cand a		*	
b. cand b	*!		
c. cand c		*	*!
d. cand d		**!	

In an OT tableau, violations of particular constraints are denoted with an asterisk (*); when a violation is fatal, removing that candidate from further consideration, the asterisk is followed by an exclamation point (!). In (2), Candidate (b) violates the highest-ranked CONSTRAINT 1 and is thus eliminated. Candidates (a), (c) and (d) all violate CONSTRAINT 2, but (d) violates this constraint twice, while (a) and (c) violate it only once. Candidate (d) is thus eliminated by virtue of having more violations of this constraint than the other candidates do. Note that with two violations of CONSTRAINT 2, Candidate (d) has more constraint violations than Candidate (b) does, but Candidate (b) is eliminated first; such is the nature of strict domination – the

higher-ranked the constraint, the more vital its satisfaction. Neither Candidate (a) nor Candidate (c) is eliminated on the basis of CONSTRAINT 2. They both violate it, but with an equal number of violations; because constraints are violable, a winning candidate can violate constraints, as long as its constraint profile is better than that of any of the other candidates. Thus both candidates are still viable until CONSTRAINT 3, where Candidate (c) is eliminated due to violation, leaving Candidate (a) as the winner, denoted by the pointing hand to the left of the candidate (☞).

The constraint set in OT includes two types of constraints: markedness constraints, which penalize the presence of certain structures, and faithfulness constraints, which penalize the lack of identity between the input and the output. The best output candidate, according to the faithfulness constraints, is the one that is exactly like the input. Different faithfulness constraints are violated on the basis of different types of unfaithfulness. For instance, two well-established faithfulness constraints are shown in (26):

(26) Common faithfulness constraints

a. DEP (no epenthesis)
Every segment of the output has an input correspondent

b. MAX (no deletion)
Every segment of the input has an output correspondent

These different faithfulness constraints may be ranked in different places of a constraint hierarchy, thus making some violations of faithfulness preferable to others.

Markedness constraints, rather than being concerned with identity between the input and the output, are instead only concerned with the output. These constraints work to eliminate output candidates with certain segments and structures. For

instance, the most common type of syllable is thought to be one made up of a single consonant and a single vowel (CV). Thus a common markedness constraint, given in (27), prefers that syllables not have final consonants, but that they end in vowels:

(27) A common markedness constraint
NoCoda
Syllables should not have final consonants

The permutation of the ranking between the constraint in (27) with those in (26) illustrates another crucial assumption of OT: different grammars arise due to different rankings of the constraints. For instance, given a form with a final consonant as an input, a ranking of both Dep and Max over NoCoda will require the final consonant to surface in an output, as in the tableau in (5):

Tableau 5.2 Dep, Max >> NoCoda: codas preferred over deletion/epenthesis

/ CVC /	Dep	Max	NoCoda
a. ☞ CVC			*
b. CV.CV[8]	*!		
c. CV		*!	

However, when NoCoda dominates either of the two faithfulness constraints, the CVC input is repaired. This repair could be epenthesis of a vowel to create another syllable, thus eliminating the coda, as in (6), or deletion of the final consonant, as in (7).

Tableau 5.3 NoCoda, Max >> Dep codas repaired by epenthesis

/ CVC /	Max	NoCoda	Dep
a. CVC		*!	
b. ☞ CV.CV			*
c. CV	*!		

[8]The period here indicates a syllable boundary, such that candidate (b) will not have a coda, but instead the second C will become the onset to the epenthesized vowel.

Tableau 5.4 NoCoda, Dep >> Max codas repaired by deletion

/ CVC /	Dep	NoCoda	Max
a. CVC		*!	
b. CV.CV	*!		
c. ☞ CV			*

As the tableaux illustrate, for a marked output to be optimal, as in (5), faithfulness must dominate markedness. When markedness dominates faithfulness, as in (6) and (7), potential marked structures are avoided through some violation of faithfulness.

Two more important points about OT will be relevant to the ensuing discussion. The first is the idea of Richness of the Base (RotB). In simple terms, RotB prohibits constraints on inputs; that is, languages may not differ in terms of the forms of their inputs, but only in terms of the forms of their outputs. Because different grammars arise through different constraint rankings, there is no need to rely on different inputs as well: the constraint ranking for a given language should rule out impossible forms for that language regardless of what the input may be. For example, American English does not include in its phonetic inventory the trilled r ([r]), but RotB requires that the ranking of the constraint set of English account for this, rather than the assumption that inputs in English do not include trills. The constraint set, then, must be ranked in such a way that if an English form did have an input with a trill, [r] would still not appear in optimal outputs of this language. In other words, the constraint ranking must rule out those forms that are unacceptable in the grammar, no matter what the input is.

A second important concept in OT is *lexicon optimization* (Prince and Smolensky 1993/2004). According to this principle, a learner would never posit as an underlying representation a form that contains some property that never arises on the surface, unless there was evidence based on morphophonological alternations that forced this conclusion. In other words, even though RoTB requires that the grammar disallow forms that do not arise on the surface, a learner is not expected to posit as an underlying representation just any random form, but instead to posit as the underlying representation the form that is the most similar to the surface form as possible.

Work in OT has accounted for synchronic phonological patterns through the use of faithfulness and markedness constraints ranked with respect to each other according to patterns evident in the relevant language. The constraint ranking selects as optimal those forms that are grammatical in a given language when a speaker has acquired that particular language. However, work in OT has modeled not just consistent patterns and processes evident in adult grammar, but also those patterns that arise in the course of language acquisition.

5.1.2 Modeling of acquisition in OT

A large body of recent literature in OT has focused on language acquisition, with the bulk of this work addressing childhood acquisition of a first language (e.g., Goad 1997, Barlow and Gierut 1999, Dinnsen et al 2001, among many others). According to Tesar and Smolensky's (1993) learning algorithm, the learning of the grammar takes place through the re-ranking of constraints. Different rankings at

different stages in acquisition are evident in the types of errors that children make. The task of the language learner is to discover the constraint ranking that will yield the outputs that they hear all around them, gradually re-ranking constraints until they converge on an output that matches what is heard. While several proposals have been put forth regarding limitations on the mechanics of constraint re-ranking, it is widely accepted that the initial state of the L1 grammar is one in which all markedness constraints dominate all faithfulness constraints (Smolensky 1996, Gnanadesikan 1995/2004).

Smolensky (1996) argues convincingly for the necessity of all markedness dominating all faithfulness in the initial state, citing as a case in point a hypothetical language that only allows CV syllables, the 'least-marked' case. If the grammar begins with markedness dominating faithfulness, then a language learner, hearing only CV syllables and having no reason to assume an input other than CV for any form, would have no need to re-rank any constraints in order to converge on the adult grammar (at least in relation to syllable structure). CV syllables, as the least marked structures, would violate no markedness constraints. The same would be true if the initial state began with faithfulness over markedness: no constraints would need to be re-ranked in order to get the right result. However, the result would be a grammar that also generates complement forms, making this grammar crucially different from that of an adult speaker of this language. If the learner were to hear a form that is not CV, they would assume that it is an acceptable output of their grammar. An adult speaker, on the other hand, would assume that the form was deviant for some reason. Herein

lies part of the reasoning behind the arguments for all markedness dominating all faithfulness in the initial state. The grammar that a learner acquires is used to guide their productions, but it also determines what forms are acceptable to them in perception, and thus must rule out those forms that are not part of the ambient language.

Whether markedness initially dominates faithfulness or faithfulness initially dominates markedness makes different predictions regarding whether or not a non-CV form will be considered grammatical. Consider that in a grammar that allows only CV outputs, if markedness dominates faithfulness, so that, for instance, NoCoda (= no final consonants) dominates Dep (= no epenthesis), then a CVC form is unacceptable in the grammar. Candidates with final consonants will be eliminated by a higher-ranked constraint than those with epenthesized vowels that allow the final consonant to become the onset of a second syllable. In this case, if a speaker who has acquired such a language hears a CVC form, they would recognize that form to be an unacceptable output of their language, and thus might consider it to be a foreign word, or an impossible word. Because the constraints of the grammar deem satisfaction of markedness (NoCoda) to be more important than satisfaction of faithfulness (Dep), the speaker knows implicitly that any possible CVC input would be repaired in the output (i.e., rendered CV.CV by vowel epenthesis), and thus will not accept as part of their language any CVC forms that they hear. These speakers, then, only produce CV syllables, and they are aware that syllable structures other than CV are intolerable. The lack of CVC is a principled gap, determined by grammatical restrictions.

If, however, faithfulness initially outranks markedness, the lack of CVC forms would not be a principled gap, but an accidental one. Consider the same constraints as above, but in the opposite order, so that DEP (together with any other relevant faithfulness constraints) dominates NOCODA. A speaker of a language with such a ranking, hearing a CVC form, would not rule this form out as unacceptable in their grammar. Though the form violates NOCODA, modifying the form from its input (i.e., epenthesizing a vowel to break up the cluster) would incur a worse violation, so according to the grammar, the faithful CVC output would be well-formed. This being the case, speakers who have acquired this language would only produce CV forms if that is all they hear, but upon hearing a CVC form, would judge it to be acceptable in their grammar. That these forms have not yet been heard would simply be an accidental gap in the lexicon; no grammatical restrictions would forbid them. As data from loanwords and L2 acquisition show, this second position is untenable: speakers recognize forms with more complex structures than those in their L1 as noticeably foreign, and judge them to be ill-formed in their language. For instance, Coleman and Pierrehumbert (1997) and Frisch, Large, and Pisoni (2000) show that speakers judge nonce forms consisting of segmental sequences that do not occur in English to be less English-like than nonce words that include sequences that do occur in English.

As Smolensky points out, that speakers view forms that do not occur in their language to be ungrammatical is a compelling argument for the domination of markedness over faithfulness in the initial state. This is also consistent with the idea of Richness of the Base: no matter what input is posited for a given form, the output

should conform to those acceptable outputs determined by the constraint ranking of that language. In other words, if a particular structure never appears, the constraint ranking should be such that it rules out that particular structure as ungrammatical. If nothing in the ranking of a particular language rules out the form, speakers of that language should consider the form to be grammatical, even if it never actually occurs. These arguments for initial markedness over faithfulness follow the same lines as those of Dell (1981) regarding the Subset Principle: learners must begin with the most restrictive grammar, because if they overgeneralize, there is no positive evidence that will ever lead them to re-analysis. That markedness dominates faithfulness in the initial state is, in essence, simply a requirement that the Subset Principle be observed in Optimality Theory.

Consider how the argument above applies to acquisition, where the grammar is not yet stable; language learners are instead attempting to determine the ranking of the constraints in their grammar. In the initial state, all markedness dominates all faithfulness, but no ranking is established among the faithfulness constraints, nor among the markedness constraints. There are two levels, or strata, of constraints: one composed of all markedness constraints, which dominates the other, composed of all faithfulness constraints:

(28) The 2 strata of the initial state:

S1: Markedness >> S2: Faithfulness (M >> F)

A language learner, hearing some form in which markedness is violated, and assuming that the forms they are hearing are part of their language, knows that this

form should be optimal in their own grammar, and re-ranks their constraints in such a way that this form can arise as a winner. Thus, on the basis of the input they hear, learners must eventually alter the order of M >> F by demoting constraints to accommodate the patterns in their language. In order for this to happen, every losing candidate must violate a higher-ranked constraint than the winner does, thus eliminating all the losers before the winner receives a fatal violation. Therefore, *some* constraint that each loser violates (but it could be *any* constraint that the loser violates, it does not matter which one) must dominate *all* constraints that the winner violates; otherwise, the winner will never be the optimal candidate because it will be eliminated on the basis of its constraint violations.

Consider the case of coda restrictions previously discussed. The constraint NoCoda prefers that syllables not have codas, while Dep and Max militate against epenthesis and deletion respectively. Respecting the initial state M>>F restriction, NoCoda must initially dominate both Dep and Max. A learner with this ranking, upon hearing a form with a final consonant, is faced with a problem: their grammar, with NoCoda dominating both Dep and Max, will not produce this form.

Tableau 5.5 codas disallowed

	NoCoda	Max	Dep
a. ☹[9] CVC	*!		
b. CV		*	
c. CV.CV			*

[9] I use this symbol to indicate a form that should be the winner, but the grammar does not recognize it as an optimal output.

While candidate (a) should be the winner in the tableau above, both (b) and (c) are better candidates, because they violate lower-ranked constraints than does candidate (a), by deleting the final consonant, as in (b), or by epenthesizing a final vowel, as in (c). The language learner, knowing on the basis of forms that they have heard that CVC forms are acceptable outputs, must then re-rank their constraints so that candidate (a) is optimal: so that all losers are eliminated by some constraint violation before the winner is eliminated. Rather than the ranking in the tableau in (9), NoCoda must be demoted below both Max and Dep, producing a successful result: candidate (a) is now recognized by the grammar as an acceptable output:

Tableau 5.6 codas allowed

	Max	Dep	NoCoda
a. ☞ CVC			*
b. CV	*!		
c. CV.CV		*!	

Given this oversimplified case, it may seem that promotion of Max and Dep would be just as easy as demotion of NoCoda. However, according to Tesar and Smolensky, re-ranking only takes place as a result of constraint demotion: a constraint that is violated by the winner is demoted to the stratum immediately below the one where the loser's highest-ranked constraint violation resides. Constraint demotion, as proposed by Tesar (1995), is *error-driven*: language learners hear marked forms, and demote markedness constraints so that such forms are allowed in their grammar.

That it is markedness that must be demoted in early learning is due to the assumption, by lexicon optimization, that the learner takes as their input the exact

form that they have heard; in other words, deriving the output form from the input should not rely on violation of faithfulness, but should ensure that the output that has been heard can arise as a winner in some situation. For instance, if NoCoda dominates Max and Dep, then no codas will ever arise in optimal outputs, regardless of the input: they will always be repaired (by epenthesis or deletion). In order to allow codas in any optimal output, NoCoda cannot dominate these faithfulness constraints. What is at stake is whether the marked forms can arise as optimal or not, regardless of whether they are faithful. In this case, markedness constraints must be demoted below those faithfulness constraints that would lead to modification of the marked structure or the marked structure will never appear in any optimal output. This demotion of markedness relies not on whether faithfulness constraints are violated, but on whether a form could ever arise as optimal, whether it is faithful to the input or not.

5.1.3 Implications for subset learning in OT learning algorithms

Due to their inherent assumption of the Subset Principle, the learning algorithms for OT fail to account for the acquisition of ungrammaticality, even though they are effectively able to model learning that proceeds from a more restrictive grammar to a less restrictive grammar. This is due to the combination of two factors: reliance on positive evidence as the only motivating factor in modification of the grammar, and the requirement that constraints are only demoted as low as they need to be in order to account for that evidence. Because the grammar begins with all markedness constraints dominating all faithfulness constraints, the initial grammar is

the most restrictive one possible. Then, as learning takes place through the demotion of markedness constraints, learners are continually building into a superset grammar, because the demotion of markedness allows violation of the demoted constraints. This means that the grammar becomes less restrictive, as more marked forms are allowed. Crucially, this demotion is *error-driven*; that is, it takes place only on the basis of positive evidence. Learners hear specific forms around them, and on the basis of this evidence, demote markedness constraints that these forms violate. On the other hand, promotion of markedness constraints would require negative evidence that is simply not available to the learner, as they would have to promote constraints based on forms that they have never heard. Consider that a learner, hearing codas in the ambient language around them, is able to determine that final consonants must be acceptable in the grammar, and thus adjust their constraint ranking so that the markedness constraint NoCoda can be violated. But on what basis would a learner ever be able to determine that codas were *not* acceptable if their grammar already permitted them, and promote markedness to reflect this? For how long would they need to not hear a coda before they determined that this was unacceptable and promoted NoCoda ? Due to the lack of positive evidence, under the standard OT algorithms, markedness is never promoted.

One more recent algorithm that does allow the promotion as well as demotion of constraints is the Gradual Learning Algorithm (GLA) of Boersma (1997). Boersma and Hayes (2001) argue that the GLA fares as well as the standard algorithm of T&S in most cases of learnability, and that it is superior in cases related to gradience in the

grammar. This is largely due to the view of the grammar learned by the GLA as stochastic; constraints are ranked with respect to one another, but the distance between the constraints differs, and constraints that are close to each other may at times switch places, leading to variable productions. As a learning model, the GLA gradually re-ranks constraints when the grammar will not produce a form that a learner hears. Rather than simply demoting markedness, the GLA promotes all constraints that the incorrect winner violates, and demotes all constraints that the desired winner violates. Whereas T&S's standard algorithm would simply demote the markedness constraint NoCoda in the tableau below, the GLA would promote Max and Dep, as well as demoting NoCoda.

Tableau 5.7 a learning tableau

	NoCoda	Max	Dep
a. ☹ CVC	*!		
b. CV		*	
c. CV.CV			*

Because demotion and promotion occur by small increments, the move is not immediate, but adjusts the probabilities involved in whether certain forms will arise. The GLA effectively accounts for variability and gradience in the grammar, which previous algorithms have not been able to do.

However, while the GLA may improve on other algorithms in some ways, it is still error-driven, and relies on positive evidence in order to effect a change in constraint rankings. Thus, even this algorithm is unable to learn a subset grammar due to the lack of positive evidence. While this may be unproblematic for L1 acquisition,

problems arise in L2 acquisition for just the reasons discussed in Chapter 1: L2 learners are often forced to acquire a grammar which allows only a subset of the possibilities of their L1. If a model of full transfer is assumed, then, we should expect that L2 learners never acquire subset knowledge, but that instead they believe, regardless of their level of L2 knowledge, that all forms that are phonotactically acceptable in their L1 are also acceptable in their L2.

As discussed in Chapter 1, too much evidence for transfer from the L1 to the L2 exists to deny that the L1 must play an integral role in the L2 grammar. In addition, as shown in Chapters 3 and 4, L2 learners do appear to have knowledge that complement forms are less acceptable in their L2. However, this acquisition of a subset grammar is problematic due to the error-driven nature of the learning algorithms of OT. The question then is how this acquisition of ungrammaticality can be accounted for. In the rest of this chapter, I propose one possible way to effectively account for just this situation of subset learning.

5.3 The Second Language Linguistic Perception Model (L2LP)

One of the most comprehensive models of L2 speech perception is the Second Language Linguistic Perception Model (L2LP) of Escudero (2005). The L2LP is an extension of the Linguistic Perception Model (LP) of Escudero and Boersma (2003), which models infant acquisition of a first language. As an extension of the LP, the L2LP models second language acquisition, effectively accounting for transfer effects in production as well as in phonetic categorization. In addition, the L2LP explicitly

outlines how learning takes place and a new grammar is reached. The basic structure of the LP is presented in 5.3.1, followed by a discussion of the L2LP and how it accounts for transfer effects in 5.3.2. In 5.3.3, problems with this model are outlined and discussed.

5.3.1 The structure of the LP

The LP is a linguistic model for sound perception that involves components that are not only phonological (modeling of a formal linguistic grammar to account for language-specific perception), but also psycholinguistic (the online speech signal processing is performed by the perception grammar), as well as phonetic (auditory-phonetic properties are referred to by constraints of the perception grammar) (Escudero 2005). This model is extended in the Second Language Linguistic Perception model (L2LP) in order to account for speech perception in a second language. The L2LP (and the LP on which it is built) is based on Boersma's (1998) Functional Phonology model, which argues that production and perception are handled by two separate components. The perceptual component maps acoustic input to perceptual input, which is then mapped to an underlying form. The production component does just the reverse, going from the perceptual specification of the underlying form back through articulatory and acoustic outputs to a perceptual output.

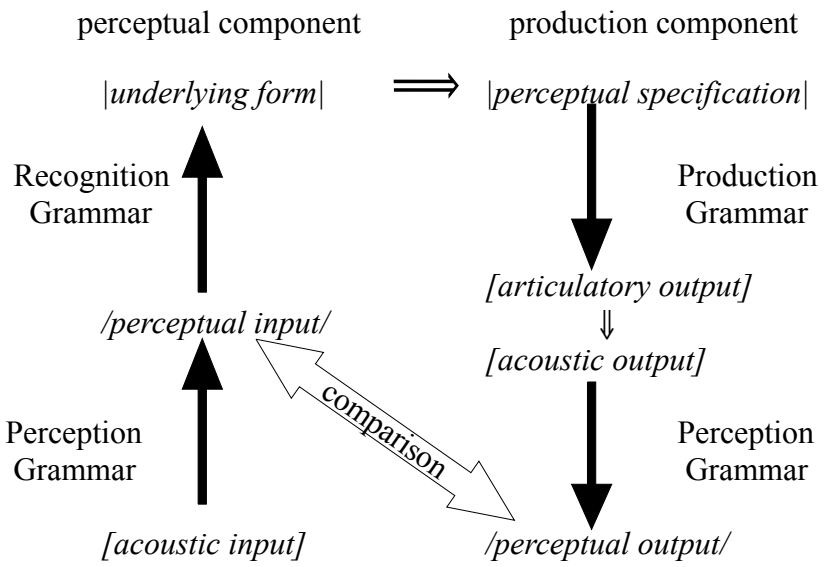

Figure 5.1 The perceptual and productive components of the LP

(adapted from Boersma 1998:269)

The *Perception Grammar* is a categorization system that takes the raw acoustic data (the *acoustic input*) and converts it to a perceptual representation (the *perceptual input*). This same Perception Grammar is used by the production component to convert a speaker's own acoustic output to a perceptual output that they can then compare to their own perceptual input. This *comparison* is a crucial component of the grammar, because it is through this comparison that learning takes place. Specifically, the GLA promotes and demotes constraints as necessary when there is a mismatch between the perceptual input and the perceptual output.

Another concern here is with the perceptual grammar, which is shown with more detail in (13).

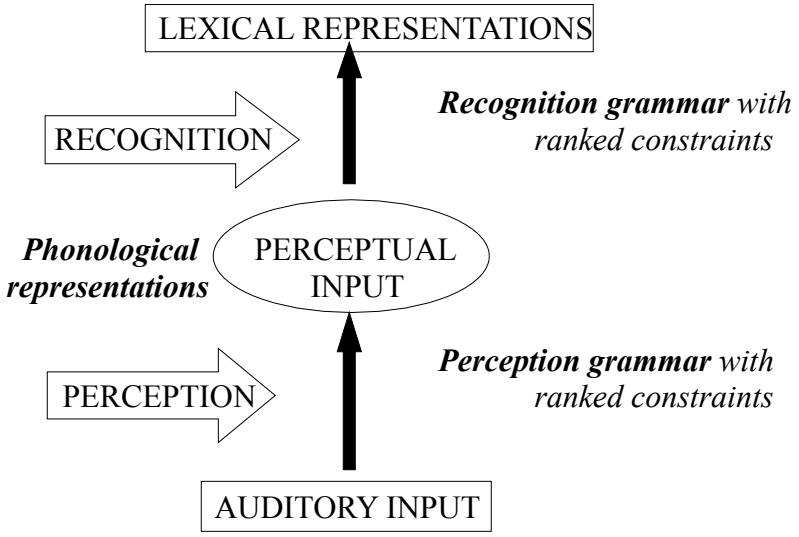

Figure 5.2 The perceptual component of the LP (Escudero 2005:43)

In this two-level model of perception, the *Perception Grammar* maps *auditory input* (acoustic values) to the *perceptual input,* where phonological representations are formed. This perceptual input then becomes the input to the *Recognition Grammar*, which maps these inputs to *lexical representations*.

As discussed in Chapter 2, the aim of Boersma and Escudero in their work with the LP and LPL2 is to account for language specific differences in the perception of speech sounds. In order to do this, they propose that in addition to the markedness and faithfulness constraints that form the basis of any OT grammar, there is an additional type of constraint in the perception grammar, which they refer to as *cue constraints*. These cue constraints are in effect restrictions on phonetic acoustic continua and where boundaries between different features and segments lie along these continua. The constraints may be one-dimensional, with a specific mapping

between an auditory form and a single phonetic or featural value, or they may be multi-dimensional, where a generalized constraint is conditioned by more than one parameter. In these cases, the combination of parameters maps to a segment. These multi-dimensional constraints are arbitrary mappings from auditory form to featural and segmental values. Examples of cue constraints are given in (29):

(29) Example cue constraints (Escudero 2005:59)

a) An F1 of 300 Hz is not /i/

b) A duration of 120 ms is not /i/

Thus the cue constraints are in general concerned with the establishment of phonetic categories and phonological representations of segments and features. They connect auditory events with vowels and consonants, whose values are determined by the ranking of the cue constraints. Thus, the cue constraints of the Perception Grammar filter the acoustic input in order to determine what segments are perceived, that is, what segmental value the listener will attribute to any given token that is heard. The LP provides for the learning of phonological categories through these cue constraints in a way that no previous linguistic model has been able to do quite so explicitly. Because the LP accounts for auditory and acoustic continua that determine mappings to individual segments, this model thus provides an advantage over other models that makes it appropriate as a model for L2 speech perception as well.

5.3.2 The L2LP: Full Transfer/Full Access

As a phonological model, the L2LP is meant to account for how specific perceptual inputs are mapped onto discrete features and segments, providing an account of transfer in both production and perception in the L2. Like the model of Schwartz and Sprouse (1996) discussed in Chapter 1, the L2LP is a full transfer/full access model which makes the explicit claim that the initial L2 grammar is a full copy of that of the L1; that is, the L1 grammar is fully transferred to the L2, so that the initial state of the L2 grammar includes exactly the constraints and rankings of the L1. Because the grammar is identical to that of the learner's L1, the learner perceives and produces forms of the L2 in the same way that they would perceive and produce similar forms in the L1.

In terms of production, because the L2 grammar is a copy of the L1, outputs are restricted in the L2 in exactly the same way they are restricted in the L1. The optimal output candidate is determined by the ranking of the constraints in the grammar. Therefore, when there are forms in the L2 that would violate output restrictions of the transferred L1 grammar, the speaker does not produce them in the same way that a native speaker of the L2 would, but instead produces them as they would be produced if they were inputs in the L1. The full transfer aspect of the L2LP thus accounts for many effects of transfer from the L1 in L2 production.

Another kind of transfer that the L2LP accounts for is that of phonetic boundaries and phonological categorization. This type of transfer assumes that beginning L2 learners re-use their L1 categories when they create lexical

representations in the L2. Because the cue constraints determine where boundaries lie between different features and segments, they establish, in infancy, the segments and features to which a learner is sensitive. Copying these into the L2 provides the learner with a set of phonetic categories that can then be modified as needed with the addition of more input from the ambient (now second) language. As Escudero and Boersma (2004) point out, it is advantageous to begin with the L1 category knowledge, rather than where L1 learners begin, as the category knowledge of the L1 effectively gives the learner a head start, and thus allows learning to proceed more quickly. As much work has shown the transfer of category boundaries in L2 speech perception (Flege and Mackay 2004, Navarra et al. 2005, Chen and Fon 2007, Park and de Jong 2008, among many others), the copying of cue constraints provides an account of this type of transfer in the L2 grammar. Due to the copying of constraints and rankings from the L1 grammar to the L2 grammar, the L2LP accounts for transfer effects in both production and perception. This is advantageous in that the model thus accounts for effects of transfer that will be common in early stages of L2 acquisition, just as research has shown to be the case.

In addition to being a full transfer model, the L2LP is also dependent on full access. The full access property allows access to Universal Grammar and the Language Acquisition Device of generative grammar, which, in the L2LP, simply means that there is full access to the Gradual Learning Algorithm (GLA). Because the GLA is the aspect of the grammar that promotes and demotes relevant constraints in

L1 acquisition, access to it in L2 acquisition means that a learner has access to the same learning tools in L2 acquisition that they had in L1 acquisition.

5.3.3 Problems with the L2LP

As discussed above, Escudero's formulation of the L2LP includes a full transfer component, in which the L1 is directly copied to provide an initial L2 grammar. For the phenomena in which Escudero and colleagues are interested – the perception of different categories which are crucially dependent on acoustic factors – the LP is able to model how different acoustic values are mapped onto different features and segments, thus providing an explanation for how categories are learned in L1 acquisition. For L2 acquisition, the L2LP is also an appropriate model for this type of learning, showing how L2 learners initially utilize L1 values. Eventually, though, with extensive input from the L2, learners are able to acquire new perceptual categories or establish new boundaries for categories that exist with different cut-off values in the L1.

Unfortunately, the L2LP faces the same problem that was discussed in Chapter 1 in relation to L2 acquisition of a subset. If the initial grammar of the L2 is a copy of that of the L1, then any knowledge of ungrammaticality that a language speaker has of their L1 is automatically transferred to the L2. In addition, due to the error-driven nature of the GLA and its reliance on positive evidence, a learner is never expected to be able to acquire the knowledge that forms that are grammatical in their L1 are ungrammatical in their L2. Thus the model predicts that whatever is grammatical in

the L1 should be perceived to be just as grammatical in the L2. That this is incorrect has been established empirically with the experiments in Chapters 3 and 4. The question, then, is how to allow for the acquisition of ungrammaticality without losing the advantages of the L2LP in accounting for transfer effects.

In Boersma and Escudero's work, the focus is on the establishment of phonetic categories and phonological representations, and in the L2LP , Escudero is focused on learning new category boundaries or shifting an L1 category boundary to a point more appropriate to the L2. That is, they are concerned with the acoustic values associated with different segments, and how these segments may be misperceived or miscategorized in a second language due to differences in the values associated with them.

The phonetic categorization problems that Boersma and Escudero discuss are crucially different from the phonotactic cases that I am concerned with here. The different values associated with similar segments in a speaker's L1 and L2 relies on perception such that different values along acoustic continua may lead to perception of a different phoneme in one language but not the other. Phonotactic knowledge, however, is not reliant on acoustic continua. Instead, phonotactic knowledge restricts the possible combinations or presence of segments in different environments. For instance, Escudero's empirical tests of her model consist of learning a new sound category, learning a subset vowel inventory (see Chapter 2, Section 6 for a brief review of this), and learning a similar sound. All of these involve learning sounds that are not restricted to particular positions or combinations; instead she is simply

concerned with the acquisition of the sounds themselves. As such, the cue constraints are her focal point.

Phonotactic restrictions, however, do not rely on cue constraints. In both cases I discussed in Chapters 3 and 4, final consonants and consonant~glide~vowel (CGV) sequences, none of the segment categories are different in significant ways, and should not affect the perception of their phonotactic distributions. Instead, the L2 learners were faced with learning in what environments and in which combinations different sounds can occur, rather than learning a new sound. Phonotactic knowledge relies not on cue constraints, but on the ranking of markedness and faithfulness constraints. Boersma (2009:4) explicitly states that the faithfulness and markedness constraints of his multi-level model of phonology and phonetics are "the same ones that phonologists have been familiar with since Prince and Smolensky (1993)". From this, it is clear that the markedness and faithfulness constraints are accepted as part of the grammar in the LP and L2LP, though their role and ranking is largely irrelevant to the learning situations that Escudero discusses. However, because the ranking of markedness and faithfulness constraints determines the phonotactic grammar, it is the ranking of these constraints that I will be concerned with here.

In order to better understand where markedness constraints fit into the perceptual grammar of the L2LP, consider first the two levels of the perceptual component in Figure 5.2 above. These two levels correspond to learning stages. In infant language acquisition, learning with the GLA takes place in a two-stage process (Boersma, Escudero, and Hayes 2003). The first stage involves *auditory-driven*

learning, in which statistical regularities of auditory phonetic information are calculated, leading to the establishment of phonetic categories during the first year of an infant's life (Maye, Werker, and Gerken 2002, Jusczyk 1993, Jusczyk and Aslin 1995, Werker and Tees 2002). As Escudero (2005) points out, "language experience leads to early perceptual learning that does not occur with the aid of the lexicon." This early perceptual learning, then, is not dependent on the lexicon, but simply on the distribution of sounds that the learner encounters. In this stage, the perceptual space of the infant is shaped (or 'warped') according to the ambient language around them, as cue constraints map the auditory input to different phonetic categories. Thus the first stage of learning with the GLA establishes phonetic categories and the specific acoustic values that go along with them, and converts them into abstract perceptual categories that will be utilized in lexically-driven learning in stage 2.

Once auditory-driven learning has taken place and the lexicon begins to develop, the learner moves into the second stage, which involves *lexicon-driven learning*. This learning takes place when a mismatch occurs between the perception and recognition grammars, or when the recognition grammar would not, in production, allow a form that the learner hears. When this occurs, the GLA modifies the perception grammar by raising the ranking of all constraints violated by the erroneous winning candidate, and by lowering the ranking of all constraints violated by the candidate that should be the winner but is not. After an adequate number of perception errors, the constraint rankings mirror those of the adult grammar.

This developmental path for learning L1 speech perception moves from auditory-driven learning to lexicon-driven learning in eight steps, as shown in (15):

Table 5.1 Developmental path for the learning of L1 linguistic perception and sound representation (Escudero 2005:82)

Auditory-driven learning	Step 1	Create auditory-to-auditory constraints and auditory categories
	Step 2	Distributional learning: constraint rankings match the production distributions
	Step 3	Abstraction 1: turn auditory constraints and categories into one-dimensional cue constraints and phonological features
	Step 4	Phonological features are copied to the lexicon
Lexicon-driven learning	Step 5	One-dimensional constraint re-rankings and category boundary shifts
	Step 6	Abstraction 2: turn one-dimensional constraints into multi-dimensional ones (every auditory dimension maps onto every feature)
	Step 7	Initial cue integration Abstraction 3: turn features into segments and store them in the lexicon; turn featural cue constraints into segmental ones
	Step 8	Optimal cue integration (adult-like)

While Escudero does not explicitly address where phonotactic learning comes in, there is reason to believe that the auditory-driven stage of learning is the stage in which phonotactic learning takes place, specifically in Step 2 where distributional learning occurs. As discussed in Chapter 2, phonotactic knowledge has been argued by some to be frequency-driven, while others consider it to be largely grammatical. Strong evidence for both sides leads to the compromise that statistical patterns must play some role in the phonotactic grammar, though evidence suggests that frequency

does not tell the whole story. What is clear is that phonotactic knowledge in L1 acquisition is established early. Friederici and Wessels (1993) show that infants of only nine months are sensitive to phonotactic structure, and Friedrick and Friederici (2005) show that acoustic processing in 12-month-old children is affected by phonotactic familarity. In addition, Storkel (2001) argues that phonotactic probability aids in lexical development, which would mean that phonotactic probabilities are established before lexical representations, and Hayes (2004) proposes that the phonological grammar is more easily learned in stages: the phonotactic grammar is learned in the first stage, while alternations (which would require the learning of lexical forms which are morphologically related) are learned in the second.

As the L1 phonotactic grammar is established early, in the same learning period as segmental knowledge, then it is likely that it takes place in the same stage or stages. Escudero makes explicit that it is in distributional learning that cue constraints are learned, which are what ultimately guide segmental knowledge. That phonotactic knowledge happens in this same stage in L2 as well also seems like the most logical conclusion. Support for early learning of phonotactics also comes from work in artificial learning (see 2.3.4) which indicates that new phonotactic constraints are acquired quickly and easily in training. The results from the experiments in Chapters 3 and 4 also lend support to the idea of phonotactics being acquired early in the learning stages, as even the beginning learners appeared to have some knowledge of the phonotactics of their L2.

While the L2LP relies on both grammars in the perceptual component, all learning examples that Escudero (2005) deals with are lexically-driven. In each case, a learner makes an adjustment to the grammar because the lexical form produced is not the same as the lexical form perceived, or vice versa. As such, they take place in the second stage of learning, rather than in the first. Other than for the establishment of cue constraints, the stages of auditory-driven learning are virtually ignored in the L2LP. However, the establishment of cue constraints takes place primarily in L1 acquisition, and Escudero (2005:112) states that in L2 acquisition, auditory-driven learning only applies to non-previously-categorized dimensions, such as when a learner's L2 contains a vowel length distinction that the L1 does not have. Thus, other than for learning new dimensions, auditory-driven learning is largely ignored in the discussion of L2 learning. However, if phonotactic knowledge is driven by distributions in the lexicon, and L2 learners have phonotactic knowledge of their L2, then the auditory-driven stage of learning is crucial for the establishment of phonotactic knowledge, and thus for the acquisition of ungrammaticality in an L2.

In 5.4, I outline a proposal to modify the L2LP in order to account for phonotactic learning of the sort seen in Chapters 3 and 4. In order to distinguish this proposal from Escudero's original formulation of the L2LP, I will refer to this modified L2LP as the Perceptual Full Access model (PFA). However, I note that this naming distinction is for the ease of discussion rather than because the proposed PFA constitutes a substantial change to the way the L2LP works for what it was originally proposed.

5.4 Perceptual Full Access and the acquisition of ungrammaticality

As discussed above, the L2LP has many advantages as a model of second language speech perception, but is not designed to be able to account for subset learning. This failure is due to the combination of two assumptions: full transfer and the error-driven nature of the GLA. In order to account for the acquisition of ungrammaticality in L2 phonotactics I propose a modification to the L2LP which I will refer to as the Perceptual Full Access model (PFA). Under the PFA, three explicit assumptions must be made regarding the L2LP:

(30) Assumptions of Perceptual Full Access

A. The Production and Recognition Grammars are fully transferred as a direct copy of the L1

B. The established L1 cue constraints and their rankings are fully transferred to the L2 Perception Grammar

C. The initial ranking of markedness and faithfulness constraints reverts to M >> F in the Perception Grammar

Making these assumptions regarding the L2 grammar has certain consequences, which I outline in (31):

(31) Consequences of Perceptual Full Access

A. L1 interference in production and recognition are expected

B. L1 interference in category boundaries is expected

C. Phonotactic learning is expected to proceed just as in L1 acquisition, from the most restrictive grammar to progressively less restrictive grammars

The assumptions of (16A) and (16B) are identical to the assumptions that Escudero makes in the L2LP, as her model was designed to account for just those consequences in (17A) and (17B). The assumption of (16C) and its relevant consequence is, however, the key to this proposal. The learner, even while transferring a large portion of the L1 grammar, is still able to use positive evidence in the learning of the phonotactic grammar of the L2. In other words, the L2 learner is able to learn a subset, but in the same way that L1 learning proceeds – by using positive evidence and following the Subset Principle.

The L2 grammar would then look something like this:

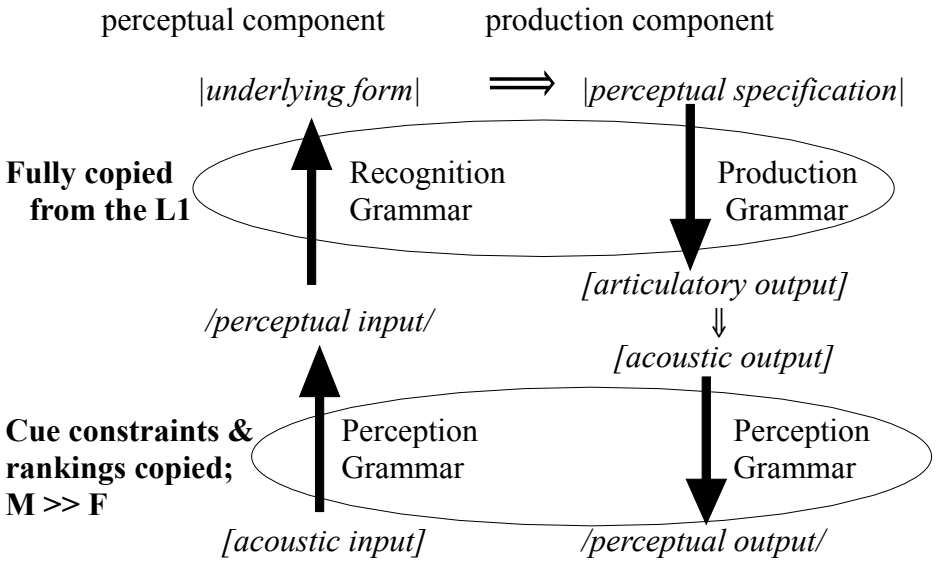

Figure 5.3 The initial state of the L2 grammar

As indicated in (A) of (16) above, only part of the grammar is copied from the L1: the Production Grammar and the Recognition Grammar. That these grammars be copied is a necessity, as the L2 learner has not yet established lexical knowledge. Unlike infants, who are not faced with producing lexical forms in the language while

the auditory-driven stage is being completed, L2 learners are often faced with learning and producing lexical forms before they have even gained solid knowledge of the distribution of sounds in the lexicon. Thus they are forced to establish lexical mappings that rely on L1 grammatical knowledge. In production, they rely on L1 grammatical knowledge in terms of constraints and their rankings, making the L1 grammar an integral part of the initial L2 grammatical system.

This reliance on the L1 grammar is not limited to just the Recognition and Production Grammars. The cue constraints and their rankings are also directly copied to the L2 grammar. This gives the learner a head-start on L2 acquisition; with phonetic categories already established in the L1, their use in the L2 provides the learner with pre-determined categories. With these categories already established, the learner can proceed quickly through distributional learning and the other steps of auditory-driven learning. However, because acoustic the properties of these sounds vary between the L1 and the L2, accepting these categories may lead to difficulties in both production and perception.

While the copying of the Production and Recognition Grammars, as well as the cue constraints, is identical to Escudero's proposal in the L2LP, my proposal regarding the state of markedness and faithfulness constraints is that the initial ranking is M>>F in the L2 perception grammar. In other words, Escudero assumes that the full transfer property of the grammar includes the entire grammar, and that the full access property is that the learner has access to the GLA. Under the proposal I am making regarding the initial ranking of markedness over faithfulness, the full transfer property is

satisfied by the copying of only part of the grammar, namely the cue constraints, the Recognition Grammar, and the Production Grammar. The full access property is then extended to include not only the GLA, but also full access to the perceptual grammar that an L1 learner has access to: a ranking of M>>F. Although this represents a departure from Escudero's L2LP, recall that the initial ranking of markedness and faithfulness constraints is not crucial to Boersma and Escudero's concerns. Thus making a different assumption about their ranking does not change the way that the L2LP model accounts for the data for which it was designed, but it does mean that the learner is now able to acquire the knowledge of ungrammaticality based on positive evidence, as the GLA requires. In addition, Escudero (2005:110) states that full access means that the learner "must go through the developmental stages that are found in the development of L1 perception." Thus, auditory-driven learning is accomplished in the L2 in the same way that it is in the L1, and in this stage, the learner must establish information regarding the phonotactic possibilities of their grammar.

Given the initial state of the grammar, consider how a learner would proceed to acquire more native-like L2 perception of final consonants. In the very early stages, the learner undergoes auditory-driven learning in the same way it occurs in the L1, with distributional learning controlling the re-ranking of markedness and faithfulness constraints. The GLA promotes and demotes relevant constraints so that the grammar allows different patterns as optimal. In this stage, a learner receives a flood of input, and due to the transferred ranking of cue constraints, maps different inputs to specific perceptual categories. For instance, the learner hears an [n], and due to the acoustic

factors of its production, maps it to /n/. This would be true regardless of the environment in which this [n] occurs.[10] In the case of the consonants that an L2 learner hears, an auditory input that corresponds to [n] in the L1 is mapped to /n/ in the L2, just as it would be in the L1. The learner thus recognizes that certain segments occur in the L2, and re-ranks constraints so that the grammar will be able to generate them.

In addition to mapping auditory input to established categories, in early learning the grammar also determines distributional regularities in the lexicon. The learner, hearing consonants in final position, learns that codas are acceptable, and demotes the constraint NoCoda to a point below Max and Dep in order to allow codas. Because the L2 learner is already mapping auditory input to segmental and featural representations due to the cue constraints of the L1, distributional learning can readily determine not only what features and segments are acceptable in the L2, but also the environments in which these features and segments occur. Thus the auditory driven stage of L2 learning establishes what the distributional regularities are in the L2 in just the same way that it does in L1 acquisition.

Because auditory-driven learning takes place in L2 acquisition, establishing what combinations of sounds can occur in different environments, second language

[10]When the acoustic factors that determine the mapping are different between the first and second language, the mapping may not correspond to that of a native speaker of the learner's L2, as in the case of Voice Onset Time (VOT). In Spanish, the VOT values that differentiate voiced from voiceless stops differ from those of English (Lisker and Abramson 1964, Cho and Ladefoged 1999, Docherty 1992). Thus in initial position, native English speakers who learn Spanish may initially misperceive [p] as /b/. This is the type of situation with which Boersma and Escudero are concerned because it involves shifting a category boundary, but should not affect the final consonant production of English and Spanish.

learners learn the distribution of sounds in their second language through positive, rather than negative, evidence. A Spanish speaker who learns English will determine that not only are [n] and [s] acceptable codas in English, but so are [p] and [k]. This would occur even if the perception grammar were directly copied from the L1, as in Escudero's L2LP. In that case, the learner would begin with the set of codas acceptable in their L1, and would simply extend it to the additional codas of the L2, effectively learning a superset grammar.

The opposite case, that of subset learning, is where the L2LP and the PFA crucially differ. Under the full transfer assumption of the L2LP, learning a subset is impossible, as discussed in 5.3.3. The English speaker who begins with all the codas of English as grammatical will never, with the GLA, be able to acquire the knowledge that some of those are ungrammatical. However, with the full access modification to the perception grammar, the PFA is not only able to learn a subset, but this learning still takes place on the basis of positive, rather than negative, evidence. The native English speaker, upon establishing their L2 grammar of Spanish, will undergo distributional learning just as described above. However, because the learner will only hear the subset codas, and not the complement codas, the grammar will only demote those constraints that the subset codas violate. Markedness constraints violated by complement but not subset forms need never be demoted because forms with complement codas are never heard.

Although the grammar is now able to learn a subset based only on positive evidence, this does not mean that indirect negative evidence is either unnecessary or

undesirable. A number of researchers have argued for the necessity of indirect negative evidence in second language acquisition. A larger problem has been how to incorporate it into a linguistic model of L2 acquisition. Under the assumptions of the PFA, however, indirect negative evidence is naturally incorporated. As previously noted, a crucial component of the grammar in the Linguistic Perception Model is that there is a comparison between the perception and production grammars, through which learning takes place. In the L1 grammar, this is a comparison of a language learner's perception and production. In the L2, under Escuderos' L2LP, the comparison is still more or less a comparison of the learner's L1 production and perception, because the L1 is fully transferred to the L2.

On the other hand, under the proposed PFA, the comparative component becomes a comparison between the L1 (the production grammar, fully transferred) and the L2 (the perception grammar, with cue constraints transferred but distributional regularities learned through auditory-driven learning in the L2). At the very beginning stages of lexically-driven learning, the learner should have a perception grammar that reflects the phonotactic regularities of the L2, but a production grammar that is purely L1. As such, the learner's productions are still filtered through the grammar of the L1, resulting in obvious effects of transfer from the L1 in many cases. Because the L1 is used for production, a mismatch occurs between the perceptual input and the perceptual output, and learning occurs. The incorporation of indirect negative evidence thus takes place at the point at which learners compare the perceptual input of the perceptual component with the perceptual output of the production component.

Consider the case of English speakers learning Spanish and Spanish speakers learning English as in the experiments in Chapters 3 and 4, using a very simplified grammar. Assume that the markedness constraint that restricts the type of coda is one that disallows non-coronal codas. Further assume that DEP, which militates against epenthesis, is undominated and thus that segments are never epenthesized. This leaves MAX as the faithfulness constraint that will conflict with the markedness constraint against non-coronal codas:[11]

(31) Relevant constraints of the simplified gramnar

A. NOCODA(-COR)
No non-coronal codas

B. MAX
No deletion

The ranking of these two constraints is crucial to whether non-coronal codas, like [p], [m], and [k], are allowed by the grammar. In English, non-coronal codas appear regularly, which indicates that MAX must dominate NOCODA(-COR). On the other hand, the Spanish ranking must be the opposite of this, because non-coronal codas do not exist. Thus the rankings for the two relevant languages are as follows:

(32) Rankings of relevant constraints in English and Spanish

A. English ranking
MAX >> NOCODA(-COR)

B. Spanish ranking
NOCODA(-COR) >> MAX

[11]I am not making a formal argument here that these are the actual constraints involved, but instead use them for ease of exposition. The constraints themselves may differ in the actual grammar, though the general argument will hold.

A native English speaker who learns Spanish thus begins their learning with a production grammar in which MAX >> NOCODA(-COR). The perception grammar begins with NOCODA(-COR) >> MAX (M >>F), and after distributional learning takes place, the ranking in the perception grammar remains NOCODA(-COR) >> MAX, because the learner has not heard any non-coronal codas which would lead to NOCODA(-COR) being demoted. With this ranking in the perception grammar, the learner will view forms with non-coronal codas as ungrammatical, but would accurately produce any item with a non-coronal coda due to the difference in ranking in the production and perception grammars. However, because forms with final non-coronal codas do not exist in Spanish, the difference in ranking is unproblematic.

For Spanish speakers learning English, on the other hand, the difference in ranking will lead to learning. With a Perception Grammar with a ranking of MAX >> NOCODA(-COR), the learner will accept non-coronal codas as grammatical. However, production of these forms may be difficult due to the ranking of NOCODA(-COR) >> MAX in the Production Grammar. Given a lexical item with a non-coronal coda such as 'hike' [hajk] the learner will delete the final /k/ rather than faithfully produce it. The acoustic output will thus be [haj], which will map to /haj/ 'hi' in the perceptual output. The learner then compares the perceptual input /hajk/ and the perceptual output /haj/, detects a mismatch, and allows the GLA to do its work of changing the ranking of the production grammar.

As previously noted, this comparison between a learner's input and output can be seen as the mechanization of indirect negative evidence in the learner's grammar

because it is essentially a comparison of the L1 grammar (the production grammar) and the L2 grammar (the perception grammar). When there is a mismatch between the two, the grammar 'notices' the difference. In other words, because the perception and production grammars differ, the learner is able to capitalize on this difference. Through the constant comparison of the production and perception grammars, the learner's grammar in itself provides a way to notice differences between the L1 and the L2. This learning process mirrors Plough's (1992) stages of inductive learning in L2 acquisition that were discussed in Chapter 1 and repeated below as (33):

(33) Plough's learning stages

1. Scanning what is known
2. Linking new material with what is known
3. Establishing generalizations based on the mismatch between old & new

The crucial stage for Plough is the second one, in which a learner links new material with what is known, and this is just what the comparison between the learner's production and perception grammars does when the two grammars differ. In other words, this comparison of the L1 and the L2 is just what was needed in order to incorporate indirect negative evidence into a linguistic model of L2 acquisition. The scanning of the grammar happens automatically as a part of the comparison module that is crucial for learning with the GLA, and when a mismatch is detected, the grammar modifies the constraint ranking in the production grammar in order to better account for the data.

5.5 Predictions of Perceptual Full Access in the L2LP

The assumption that markedness must dominate faithfulness in the L2 perception grammar as Perceptual Full Access (PFA) is only a minor departure from Escudero's (2005) formulation of the L2LP. The PFA still relies on both full transfer and full access: the production grammar and the cue constraints are fully transferred to the L2, and the learner has full access to the same learning mechanisms and principles that the L1 learner does. The difference lies only in whether the ranking of markedness and faithfulness in the perception grammar are determined by full access or full transfer. In the L2LP, the ranking of these constraints is fully transferred to the L2 learner's perception grammar. Under the PFA, on the other hand, the ranking of markedness and faithfulness constraints falls under the full access component, allowing the learner not only full access to the learning mechanism of the GLA, but also to the Subset Principle, which allows learning only with positive evidence as the GLA requires. In addition, learners have access to both stages of learning – auditory-driven and lexicon driven – which allows distributional learning of phonotactic generalizations over the surface forms. In the PFA, then, the perception grammar is one of full access, while the production grammar is one of full transfer.

If the state of the initial L2 grammar is one in which production is fully transferred (through use of the L1 grammar in production), and perception relies on full access, a crucial prediction is made regarding very early learners of an L2. Any L1 speaker of a superset grammar, even with only very limited knowledge of a second language, will judge L2 subset forms to be better than complement forms, illustrating

that phonotactic grammars are learned early, even without lexical knowledge. In Chapter 5, this prediction was tested and shown to hold true using the same tools employed in the experiments in Chapters 3 and 4, but with participants whose knowledge of their non-native language is minimal.

5.5.1 Subset learning with passive exposure

In order to test whether those with only minimal knowledge of a language have some knowledge of its phonotactics, the experiments in Chapters 3 and 4 were repeated with monolingual speakers of English and Spanish, respectively. Even though the participants were monolingual in the sense that they had no communicative ability and no lexical knowledge other than a few words, they had all been passively exposed to the other language due to the fact that both Spanish and English are common in the communities in which the experiments were run. In San Diego, where the monolingual English speakers were tested, Spanish is commonly heard in and around town, on TV and on the radio, and there are a number of streets, neighborhoods, and communities with Spanish names, as well as an abundance of restaurants that specialize in the foods of Latin America, and where the names of dishes are often in Spanish. Thus, even so-called monolingual English speakers in this area have had some limited exposure to Spanish.

The same is true for English in Guatemala, where the monolingual speakers were tested. The tourism industry in Guatemala brings thousands of English speakers

a year to the country[12], and it is impossible to escape the influence of English in print media, as well as on TV and on the radio. English is also generally taught, albeit minimally, starting in 'primero basico' (the equivalent of the first year of middle school). Finally, the communities in which subjects were recruited are the two largest cities in the country, and the people asked to help recruit participants are members of communities where English-speaking visitors, missionaries, and mission teams visit frequently. Therefore, passive exposure to English is virtually inescapable in these areas as well.

Due to the influence of passive exposure in these areas, "monolingual" speakers of English in San Diego and of Spanish in Guatemala have some knowledge of what the other language sounds like, even though they may have little to no lexical knowledge. Therefore, they provide a good testing ground to determine if they have acquired some phonotactic knowledge of the language to which they have been exposed, but not which they have actively acquired.

5.5.2 Monolingual English speakers' knowledge of Spanish as a subset

Six monolingual English speakers participated in the Spanish final consonant wordlikeness rating task discussed in Chapter 3. Stimuli and procedure were identical to those provided previously. The one difference was that the instructions were

[12]According to the Bulletin of Tourism Statistics, close to 516,000 visitors from North America entered Guatemala during 2008, along with an approximate 22,000 from the UK (http://www.almadetierra.com/boletinesestadisticos/2008.html). It is a safe assumption that a majority of these were native English speakers.

presented in English, rather than in Spanish because these speakers were obviously unable to read and understand the directions to the experiment in Spanish.

Results indicated that this group found a significant difference between subset and complement forms ($t(5) = 5.05$, $p = .004$), with an average rating for subset forms of 4.42 (SD = 1.74), and for complement forms of only 3.41 (SD = 1.46).

The same group of monolingual speakers participated in the Spanish comparative judgment task of Chapter 3. In this experiment, the monolingual speakers judged subset forms to be more Spanish-like than complement forms in 91.7% of comparisons, a proportion higher than any other of the groups reported in Chapter 3.

Both experiments clearly illustrate that monolingual English speakers who have only extremely limited exposure to Spanish still show great sensitivity to the subset~complement distinction. That is, they show a very strong preference for the subset forms over the complement forms. However, the gradient effects that were observed with the other groups were not seen with these speakers. These monolingual speakers rated [m] equally with [p] and [k]. This result may indicate that although L2 learners show a clear preference for legal vs. illegal forms, but that more extensive exposure is necessary in order to determine levels of gradience within each category.

These results indicate that monolingual speakers of English who have been passively exposed to Spanish have some knowledge of the subset~complement distinction, even though they have apparently not learned more complicated distributional patterns within the subset and complement forms. As such, these results

support the prediction that phonotactic knowledge is gained early, even before lexical forms have been established.

5.5.3 Monolingual Spanish speakers' knowledge of English as a subset

Similar results were evident for monolingual speakers of Spanish who participated in the experiments in Chapter 4. Ten monolingual speakers of Spanish participated in the wordlikeness rating task and the comparative judgement tasks in English that were presented in Chapter 4. All stimuli and procedures were identical to those in Chapter 4, though instructions were presented in Spanish rather than in English.

As speakers of Spanish, the participants' L1 accepts as legal all of the consonant~glide~vowel sequences presented, but English, as previously discussed, only accepts C[ju]. The results of the wordlikeness rating task indicated that these monolinguals rated subset (Cju) forms significantly higher than complement forms (Cja, Cje, Cjo) ($t(9) = 3.1$, $p = .013$). In addition, the comparative judgment task indicated that the participants judged Cju forms to sound more English-like than any of the other CGV sequences in 60% of comparisons.

These result indicate that even passive exposure to English provided the participants with enough information regarding distributional regularities to be able to make a reliable distinction between legal and illegal forms. However, while they distinguished between subset and complement forms, these speakers did not illustrate knowledge of distinctions within these forms in the way that L2 learners did. This

lends itself to an analysis in which learners pick up first on gross generalizations of distributional knowledge, which may translate into overall phonotactic legality. More finely-grained details of acceptability are only gained with more exposure to the target language.

5.6 Summary of the Perceptual Full Access modification to the L2LP

The proposed modification to the L2LP, here referred to as Perceptual Full Access (PFA), provides two advantages over the L2LP. The first of these is that the model can now account for the acquisition of subset knowledge in L2 learners whose L1 is *less* restrictive than the L2 is. The second is that the PFA provides for indirect negative evidence through a comparison between the the L1 grammar and the L2 grammar, but this result follows naturally from the assumptions of the PFA and the structure of the grammar as proposed by Boersma (1998).

In the PFA, the L2 grammar is still a grammar of full transfer and full access. The full transfer property is seen in the copying of the L1 Production Grammar, Recognition Grammar, and cue constraints. This accounts for transfer effects in production of the L2 in terms of acoustic output as well as phonotactic repairs. In addition, it accounts for transfer of native language speech categories and category boundaries due to the use of L1-established cue constraints in perception. The full access property, under the PFA, differs from the L2LP in that the ranking of markedness and faithfulness constraints in the L2 perception grammar is not transferred from the L1. Instead, these constraints revert to a grammar in which

markedness dominates faithfulness. Because of this initial ranking in the L2 perception grammar, L2 learners acquire a phonotactic grammar based on distributional learning, just as in the L1, which allows them to learn acceptable surface patterns using positive evidence.

6

Discussion and Implications

6.1 Summary of the dissertation

This dissertation has addressed the Complement Problem, which second language (L2) learners face when they must learn an L2 that is more restrictive grammar than their first language (L1). This is problematic due to the assumption within linguistic theories of language acquisition of the Subset Principle, which holds that the learner begins with the most restrictive grammar that the data allows, and only moves to a less restrictive grammar based on positive evidence for it. For a learner to acquire a subset grammar would crucially rely on negative evidence of some type rather than positive evidence. Thus the Subset Principle disallows the learning of a subset grammar, based on the logical argument of the necessity for positive evidence in language acquisition.

In second language acquisition, learners are often faced with the Complement Problem: their L1 grammar is less restrictive than what their L2 grammar should be. Because many current theories of L2 acquisition assume full transfer in the L2, the learner begins not with the most restrictive grammar possible but with the grammar of the L1. This full transfer assumption is supported by numerous studies that have shown that L2 learners show interference from their L1 in many ways, and this is especially true in the area of phonology. L2 learners tend to produce segments in the L2 in the same way they do in the L1, to perceive segments based on the acoustic features that define segments of their L1, and to repair L2 sequences that are phonotactically illegal in the L1 even when not illegal in the L2. Thus, a number of recent proposals (e.g. Schwartz and Sprouse 1996, Escudero 2005) have been put forth that explicitly claim the initial state of the L2 grammar to be the grammar of the L1; in effect, the L1 grammar as a whole is copied as the initial L2 grammar.

While a fully transferred L2 grammar accounts for many obvious transfer effects in L2, this property, in combination with the Subset Principle, makes the prediction that L2 learners will never learn a more restrictive L2 grammar than that of their L1. If the learner begins with the L1 grammar as their initial state, and the Subset Principle holds in L2 acquisition, then the most restrictive grammar that the learner will ever have in the L2 is that of the L1 because that is what they start with.

This conflict leads to the question of whether the Subset Principle holds in L2 acquisition, and particularly in L2 phonology. Arguments regarding the validity of the Subset Principle in syntax have attempted to defend or debunk this view, without a

true consensus being reached. Within phonology, however, the validity of the Subset Principle has only rarely been investigated. The question is relevant in that phonotactic knowledge has been shown to affect speech perception and comprehension, so knowledge of phonotactically unacceptable forms is crucial to native-like speech perception, even though it may not be crucial to native-like speech production (because these phonotactically unacceptable forms, by definition, never need to be produced).

The learning of a subset in L2 phonotactics, though, is problematic in that not only is positive evidence not available, but neither is direct negative evidence. In language learning classrooms, phonotactic goodness is typically only taught when the learner is forced to learn a phonotactic superset, where a greater number of possibilities exist in the L2 than in the L1. In these cases, interference from the L1 grammar leads to the repair of sequences in the L2, which are subject to correction and thus direct negative evidence. In learning a phonotactic subset, though, this type of evidence is unavailable simply because the forms do not exist in the L2, and are thus never produced – either correctly or incorrectly - by the L2 learner. If neither positive evidence nor direct negative evidence is available, then the only type of evidence the learner can rely on is indirect negative evidence, but how this can be incorporated into a linguistic theory of second language acquisition is problematic in and of itself.

That learning a phonotactic subset is possible was was shown in Chapters 3 and 4. The experiments presented in these two chapters show that L2 learners do have knowledge of the legality distinction between subset and complement forms in their

L2. In other words, these L2 learners have successfully overcome the Complement Problem and acquired a subset grammar.

Acquisition of a subset grammar was illustrated with two different types of phonotactic constraints. One of these was an example of a first-order constraint, which have been shown to be learned quickly and easily (Dell et al, 2000, Onishi et al, 2001; Goldrick 2004, Taylor and Houghton 2005). This was the case of final consonants in Spanish and English, where the set of possible final consonants in Spanish is a proper subset of those of English. Using wordlikeness judgments and a direct comparison task, I showed that the L2 learners of Spanish had knowledge that subset forms were more acceptable than complement forms in Spanish. That this was not the result of transfer from the L1 was shown with these same task in English experiments, where native English speakers, whether monolingual or bilingual, did not make similar judgments. Even the exact same participants exhibited different patterns in their judgments in the L2 than they did in the L1.

These same experiments also revealed that the learners who were acquiring a superset, who were learning English, did not at first glance appear to have acquired the knowledge that complement codas were acceptable in English. However, comparisons of individual codas showed that in fact these learners were exhibiting similar judgments to those of the native speakers of English in terms of overall goodness

Chapter 4 presented a second set of experiments with an example of a second-order constraint, which have been shown to be more difficult to learn than first-order constraints like the one in Chapter 3. In these experiments, Spanish speakers who had

learned English were presented with consonant~glide~vowel (CGV) sequences in which only a subset of those that are legal in Spanish are legal in English. Just as with the final consonants, L2 learners made a distinction between subset and complement CGV sequences, indicating that they viewed the complement sequences as less acceptable than the subset sequences. Subset CGV sequences thus also appeared to have been acquired by the L2 learners.

Chapter 4 thus provides support for the acquisition of phonotactic knowledge, even when the learner must learn a subset grammar, and even when the restrictions are second-order, relying on other properties of the syllable than just a single segment in a single position. These results indicate that the learning of phonotactic knowledge does not present a problem for L2 learners, regardless of whether the learner is acquiring a subset or a superset of the forms available to them in their L1.

That learners can acquire a subset grammar is problematic in light of the Subset Principle. Within Optimality Theory in particular, learning algorithms have been specifically designed to follow the Subset Principle because they are error-driven, based on positive evidence. In addition, the most common currently-held belief regarding the initial state of the L2 is that it is identical to the learner's L1 grammar. With a fully transferred grammar and the adoption of OT learning algorithms to second language acquisition, the implicit assumption is that an L2 learner will never acquire the knowledge of ungrammaticality. In other words, subset learning is not expected to occur.

As the experiments in Chapters 3 and 4 clearly show, L2 learners who are faced with learning an L2 grammar that is a phonotactic subset of their L1 do reliably discriminate between at least some subset and superset forms. In addition, it is clear from the experiments of each chapter that the knowledge that the L2 learners show of phonotactic goodness in the L2 is not explicable as a transfer effect from the L1. Native speakers of English do not distinguish between subset and complement forms in English in the same way that the L2 learners do in Spanish. Even the exact same speakers, when completing the task in both English and Spanish, make different judgements based on the language of the task. Thus, the L2 learners must be using a separate grammar for English and Spanish, and they must have acquired some different phonotactic knowledge in the L2 that they did not have in the L1.

So L2 learners have phonotactic knowledge of the L2, and this cannot simply be the result of a bias pre-existing in the learners' L1. Why does that matter?

For reasons of learnability, this makes clear that subset learning is possible in phonotactics, which might inevitably lead to the conclusion that the Subset Principle does not hold in second language acquisition. However, modeling this learning within a theory of language acquisition becomes the next problem. This is especially problematic in light of the fact that L2 learners receive no positive evidence that will indicate to them the ungrammaticality of the complement forms. Direct negative evidence is also unavailable to the learner, leaving only indirect negative evidence to play a role in the acquisition of ungrammatical forms.

While many researchers have discussed the possibility of using indirect negative evidence in language learning. how to incorporate it into a linguistic theory of language acquisition has been problematic, though the idea of 'noticing' differences between L1 and L2 grammars, or inductive reasoning regarding the grammars themselves, has been discussed at length (Plough 1992, Dahl 2004). Incorporation of such a concept into a formal linguistic theory, though, has been unclear.

One of the most comprehensive current theories of second language speech perception is an Optimality Theoretic approach called the Second Language Linguistic Perception model (L2LP), developed in Boersma and Escudero (citations needed) and detailed in Escudero (2005). Two properties of this model are full transfer and full access. The initial grammar of the L2 is a direct copy of the L1 grammar, and the L2 learner has access to the same learning tools that the L1 learner has, namely the Gradual Learning Algorithm (GLA).

While the L2LP accounts for the transfer effects of L1 phonological categories and category boundaries into the L2, and also accounts for how learners learn new boundaries and shift old boundaries, its original formulation had little to say about the acquisition of phonotactic goodness. As an OT model, though, the grammar contains markedness and faithfulness constraints, and it is the ranking of these that determines the phonotactic grammar. However, the full transfer property and the GLA work together in such a way that the model as proposed cannot account for learning a phonotactic subset in the way shown to be possible by the experiments presented in Chapters 3 and 4 (see also Trapman and Kager 2009).

I propose a modification to the L2LP in order to account for the learning of a phonotactic subset in L2, which I term Perceptual Full Access (PFA), in which only part of the L2 initial state grammar is copied from the L1. Specifically, the Recognition and Production Grammars are fully copied, which allows for the effects of transfer in production. In addition, the cue constraints established in the L1 are transferred, which provides the L2 learner with pre-established phonetic categorization; again, this provides for many effects of transfer from the L1. The difference between the L2LP and the PFA lies only in the initial ranking of markedness and faithfulness constraints in the L2 Perception Grammar. Rather than their ranking being transferred from the L1, I propose that their ranking reverts to markedness over faithfulness, as in an initial L1 grammar.

Allowing an M >> F initial state L2 grammar with cue constraints transferred and Recognition and Production Grammars copied allows for the subset learning seen in the experiments in Chapters 3 and 4 because learners begin with the most restrictive grammar possible in terms of markedness. Subset learning takes place by *following* the Subset Principle, not discarding it. The learner begins with M >> F, and on the basis of positive evidence in the L2, learns the phonotactic grammar through distributional learning. The L2 learner can thus learn a subset grammar at the same time that the Subset Principle holds in L2 phonotactic learning.

In addition to providing for subset learning, this modification to the L2LP allows crucial access to a mechanism for the use of indirect negative evidence in the L2: the *comparison* component of the grammar. That I know of, this is the first

explicit mechanization of indirect negative evidence into a linguistic theory of L2 learning.

6.2 Further implications of subset learning and Perceptual Full Access

As shown in Chapters 3 and 4, learning a phonotactic subset is possible, with either first or second-order constraints. However, there is much work yet to do to determine if Perceptual Full Access in the L2LP is viable. One issue that arises with the PFA is that of perceptual illusions. Dupoux et al. (1999) show that Japanese listeners perceive a vowel between the consonants in a cluster, and argue that this is due to phonotactic knowledge. However, Davidson and Shaw (2009) argue that the effects of Dupoux et al. may be due to a task effect, as performance improved when different repairs were tested. If perceptual illusions do occur in speech perception, then this directly conflicts with the claims of the PFA. Further work on perceptual illusions and the extent to which they truly occur in speech perception is needed in order to address this question, but whether or not these perceptual illusions are the result of phonotactic knowledge is a question that could shed light on whether or not the PFA is on the right track.

One area where the PFA might provide some insight is the case of what has been termed 'hidden transfer'. A number of researchers have observed that certain patterns seem to emerge in both second language acquisition and loanword phonology which are inexplicable based on the surface patterns evident in the native and non-native (or borrowed) language. While these patterns may not be evident in either of the

relevant languages, what particular speakers do appears to be consistent across speakers based on what their native language is, even when no surface evidence for the alternation/repair exists in the L1. For instance, in terms of consonant cluster repair in second language, speakers of the same L1, both independently and as a group, regularly either epenthesize or delete, even when there is no obvious evidence for either (see Petric (2001) for Slovene children learning German, Ross (1994) on Japanese learners of English, and Carlisle (1986) on Spanish speakers learning English). Because these patterns that arise seem to be dependent on properties of the L1, but the L1 has no direct evidence for them, these are often referred to as instances of hidden transfer, or, in OT, emergent rankings. With no obvious evidence for these rankings in either the L1 or the L2, an explanation for why this rankings arise is somewhat problematic. The PFA, however, provides for an additional explanation, one in which the default ranking of M>>F in the perception grammar gives rise to patterns that are present in neither the L1 nor the L2. Additional work on this phenomenon is needed to shed light on whether a default ranking in the perception grammar could give rise to these patterns.

A larger implication of this work is related to the idea of markedness. The most restrictive grammar, where all markedness dominates all faithfulness, is also thus the least marked grammar. In the final consonant experiment, learning a subset in essence meant learning a less-marked grammar, with learners eliminating the more marked non-coronal codas from their set of possibilities. It may be the case that this type of distributional regularity, which coincides with markedness, is easy to learn,

while others are not. Consider the same final coda situation presented in Chapter 3, but imagine that the subset grammar is not one that disallows non-coronal codas, but instead is one that disallows coronal codas, preferring non-coronal ones. Could a language learner effectively acquire this type of subset grammar? An artificial learning experiment could shed light on this type of question, testing how effectively a language learner could acquire a phonotactic grammar in which the acceptable forms are the most-marked ones, while the least-marked ones are restricted.

In addition to questions related to the theoretical grounding of the PFA, these experiments raises several issues related to specific sounds and sound sequences in the languages at hand. One of these was the apparent acceptability of [m] as a final coda in Spanish, even though it is non-occurring. Follow-up experiments are needed that investigate if the acceptability of this coda was due to task effects in these experiments, or if the labial nasal is acceptable even though non-occurring in Spanish.

In addition, the apparent unacceptability of [s] as a coda in English was surprising. As Sharon Rose (p.c.) points out, the use of fricatives as onsets in the nonce-word stimuli may have contributed to this result, as the OCP (Obligatory Contour Principle) may disallow fricatives in both onset and coda. One way to test this is to use nonce-word stimuli that include stops as onsets rather than codas. If the OCP is responsible for the effects seen here, then [s] should rise in acceptability when the onset is not a fricative.

If the OCP is responsible for the unacceptability of [s], then this raises another question in regard to the L2 speakers. Have they acquired the knowledge of this

restriction due to their knowledge of English? That the coda [s] was acceptable in the Spanish experiment would indicate that the OCP may not be an active restriction in Spanish as it is in English. Whether or not this restriction arises as a result of learning English or as a result of some universal properties of grammar is yet to be determined.

A final question that arises is related to phonological processes and the learning of phonotactics. This work has shown that L2 learners effectively learn a simple phonotactic distribution . However, in the situation described here, this was simply picking up on the presence or absence of different phonotactic surface patterns. But research has shown that learners often have difficulty learning new alternations in production, and that they have some difficulty learning to acquire or suppress phonological processes. The L2LP/PFA predicts that a learner will have trouble with this, due to full transfer in the production grammar. However, the PFA makes a different prediction regarding the acceptability of forms in the perception grammar; the learner will pick up on distributional regularities in the L2, rather than using those of the L1. Therefore, the learner's perception of application or suppression of a phonological rule is expected to abide by L2 rankings, rather than L1 rankings. In other words, the learner may not always produce alternations correctly, but their perception of them should be much more accurate (assuming that the phonetic details are such that the cue constraints do not map the alternating segment to a different L1 phoneme). Investigations into the acceptability of allophones used inappropriately could not only shed light on this issue, but could lead us to a better understanding of second language phonology in general.

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