LEXICAL EXCEPTIONS IN STRESS SYSTEMS: ARGUMENTS FROM EARLY LANGUAGE ACQUISITION AND ADULT SPEECH PERCEPTION

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Some, but not all, languages with fixed stress exhibit lexical exceptions to their stress rule. Under the assumption that lexical exceptions can occur in a language only if its native speakers can perceive stress contrasts, I argue that the presence of these exceptions depends on the age at which infants discover the stress rule of their language. If the stress regularity is easy to infer from the surface speech stream, then it will be acquired very early, and stress will not be encoded in the phonological representation of words in the mental lexicon; as a consequence, stress contrasts are not well perceived by adult speakers and lexical exceptions are excluded. If, by contrast, the regularity is difficult to infer, then it will be acquired relatively late, after the format of the phonological encoding of words has been fixed. That is, stress will be redundantly encoded in the mental lexicon, and lexical exceptions can thus be perceived and stored by adult speakers. A typological survey concerning the occurrence of exceptions in languages with fixed stress supports this proposal. A comparison with a metrical approach to exceptional stress is made, leading to a proposal about the division of labor between psycholinguistics and theoretical phonology.*

1. INTRODUCTION. Languages with fixed stress sometimes have lexical exceptions to their main stress rule. These exceptions are mainly words of foreign origin. In Macedonian, for instance, regular stress is antepenultimate, but there are some exceptions with penultimate or final stress, such as *literatúra* 'literature' and *metró* 'metro' (Comrie 1976). This article deals with the question of which types of languages with fixed stress allow for lexical exceptions. Starting from the observation that a language can have lexical exceptions only if its native speakers can perceive them as such, I consider these generalizations in light of early language acquisition and its consequences for adult speech perception. Specifically, I argue that a language allows for exceptions to the main stress rule if and only if its native speakers encode stress in their phonological representation of words in the mental lexicon, hence if stress is used for word recognition. Crucially, the question of whether stress is encoded is shown to depend on the age at which infants acquire the stress regularity of their language. Following Peperkamp and Dupoux (2002), I argue that certain types of languages with a purely phonological stress rule are structured in such a way that infants can infer the stress regularity before they can segment speech into separate words. I argue that adult speakers of these languages do not encode stress in the phonological representation of words in their mental lexicon. Hence, they are unable to store exceptional stress patterns of, for instance, foreign loans; such patterns will rather be regularized automatically. In other languages with a purely phonological stress rule, by contrast, the regularity can only be inferred once word segmentation is in place. I argue that adult speakers of these languages redundantly encode stress in the phonological representation of words, hence, they are able to store exceptional stress patterns. In this type of language, then, foreign words can be integrated without modification of their stress pattern.

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Peperkamp and Dupoux (2002) provided experimental evidence about the link between early acquisition and adult speech perception. Specifically, they showed that adult speakers of some but not all languages with purely phonological stress have difficulties in perceiving foreign stress contrasts, depending on whether stress can or cannot be acquired before word segmentation. In this article, I test the predictions concerning the occurrence of lexical exceptions in a typological survey of languages with purely phonological stress. In particular, these data reveal a statistically highly significant tendency for exceptions to occur only in those languages in which the stress regularity cannot be acquired before word segmentation is in place. The experimental data concerning the perception of stress by adult speakers and the typological data concerning the occurrence of exceptions converge; together, they provide strong evidence in favor of the acquisition algorithm of Peperkamp and Dupoux (2002).

Ultimately, this article contributes to bridging the gap between phonologists and psycholinguists by showing how experimental data and psycholinguistic modeling can offer insight into constraints on the phonology of human languages. Given that languages are acquired by infants without explicit instruction, they must be structured in such a way as to allow infants to deduce their grammar. Knowledge about the developmental pathways of language acquisition can therefore shed light on what might and what might not be attested in natural language.

2. EARLY PHONOLOGICAL ACQUISITION. Experimental research with infants shows that phonological acquisition begins right after birth and develops considerably during the first year of life, that is, before the first words are uttered. In particular, infants have been shown to build a phonological representation of their native language and, consequently, come to perceive speech sounds in a language-specific fashion (Jusczyk 1997), much the same way as adults do. In §2.1, I review some of these experimental data.

Theoretical models of how phonological systems might be acquired by young children have equally been proposed by, among others, Dresher and Kaye (1990), Pulleyblank and Turkel (2000), and Tesar and Smolensky (2000). These models are based on the assumption that children have access to individual word forms. This is a problematic assumption, since, as mentioned above, several aspects of the native phonology are acquired before word segmentation is in place. Realistic learning algorithms should therefore take as their input a representation that is close to the surface speech stream. In §2.2, I focus on the acquisition of stress and lay out a proposal developed in Peperkamp & Dupoux 2002 about how infants might infer the stress regularity of their language before constructing a lexicon.

2.1. EXPERIMENTAL DATA. There is a wealth of experimental evidence about infants' acquisition of phonological properties of their native language during the first year of life, before the onset of lexical acquisition. In this section, I mention some results that are of direct importance to the issue addressed in this article. For an overview of experimental techniques used in infant speech perception research, assessing infants' discrimination capacities as well as their listening preferences, see Polka et al. 1995.

During the first year of life, infants develop a sensitivity to increasingly smaller phrasal units. First, Hirsh-Pasek and colleagues (1987) showed that at seven months, infants listen longer to passages in which pauses are inserted at clause boundaries than to passages in which pauses are inserted within clauses. Second, using the same pause-insertion technique, Gerken and associates (1994) showed that at nine months, infants are sensitive to the boundaries of phonological phrases. Finally, Myers and associates (1996) found that eleven-month-old infants are sensitive to word boundaries. They showed that infants listen longer to passages containing pauses at word boundaries than

to passages containing pauses within words. These results hold when the crucial words are unfamiliar, infrequent, and not repeated within the passage, suggesting that infants have some general capacity to recognize word boundaries in fluent speech.

As to infants' sensitivity to suprasegmental properties, there is evidence that this also arises during the first year of life. In particular, it has been shown that nine-month-old infants prefer to listen to words with the metrical pattern that is predominant in their native language rather than to words with a marked metrical pattern (Jusczyk, Cutler & Redanz 1993).[1] Nine-month-old infants are also sensitive to phonotactic properties, as shown by Friederici and Wessels (1993). They reported that Dutch infants of this age prefer to listen to phonotactically legal words rather than to illegal ones. Similarly, Jusczyk and colleagues (1994) found that nine-month-old American infants, when listening to monosyllabic nonwords, prefer those with a high-probability phonotactic pattern rather than those with a low-probability phonotactic pattern. Jusczyk, Friederici, and associates (1993) reported, furthermore, that nine-month-old American infants listen longer to unfamiliar English words than to Dutch words. The latter contain segments and sequences that are illegal in English, suggesting again that infants of this age are sensitive to the phonotactics of their language. This is corroborated by the finding that no differences are found when the stimuli are low-pass filtered, hence do not contain any segmental information.

The onset of word segmentation has been reported to lie at seven and a half months. Jusczyk and Aslin (1995) found that at this age, infants listen longer to passages containing a word to which they are habituated than to passages that do not contain such a word. The same results are obtained if infants are habituated to passages containing several instances of certain words and tested on these words in isolation. Thus, infants listen longer to words that are contained in the passages they heard previously than to words that are not contained in the passages.

Finally, there is experimental evidence that the distinction between function words and content words is acquired early in life as well. Specifically, Shady (1996) found that $10\frac{1}{2}$-month-old American infants distinguish between normal English passages and the same passages in which function words are replaced by nonwords having the same phonological properties. By contrast, they do not distinguish between the normal passages and those in which content words are replaced by nonwords having the same phonological properties. This suggests that at this age, infants not only make a distinction between function words and content words, but also recognize the actual function words of English. That they do not yet know the semantics of these words was evidenced by a follow-up experiment. This experiment showed that infants do not distinguish between normal passages and passages in which all the function words are interchanged, leading to ungrammatical sentences.[2]

[1] Jusczyk, Cutler, and Redanz (1993) tested American infants and found a preference for disyllables with stress on the first syllable. This experiment, however, has not been carried out with a language that shows the reverse metrical pattern. It could, therefore, be the case that the obtained preference stems from a universal bias, rather than being related to the predominant metrical pattern of disyllables in English.

[2] Although this experiment has not been replicated with other languages, there is evidence that function words can universally be set apart from content words on the basis of acoustic, phonological, and distributional cues. Function words can indeed typically be distinguished from content words by a range of such properties; for instance, they often have a short duration, a low relative amplitude, a simple syllable structure, centralized vowels, and they tend to occur at utterance boundaries. Shi 1995 and Shi et al. 1998 showed that taken together, these cues are sufficient for a self-organizing neural network to classify words as function words or content words with an accuracy of 84–90 percent in infant-directed speech in English, Mandarin Chinese, and Turkish.

2.2. THE ACQUISITION OF STRESS. No experimental data are available regarding the acquisition of main stress rules in languages with fixed stress. However, given the findings about phonological development during the first year of life in general and the attested preference for the predominant metrical pattern in particular, it is reasonable to assume that stress rules are acquired early in life.

Peperkamp and Dupoux (2002) argue that infants infer whether stress is contrastive or predictable before they begin building a lexicon, that is, PRELEXICALLY. Their proposal is couched within the framework of Mehler et al. 1990, two elements of which are relevant here. First, the phonological representation of words in the mental lexicon is language-specific in that it encodes only those segmental and suprasegmental distinctions that are used contrastively.[3] Second, from the onset of lexical acquisition, infants store words in this language-specific phonological format. Hence, prelexical infants reduce the set of universally available phonological distinctions to those that are used contrastively in their language; it is this latter set that they will use for phonological encoding as soon as they begin to construct their mental lexicon. The rationale behind this proposal is that having established the phonological representation helps lexical acquisition. In fact, a given word can surface in a near infinity of phonetic forms that—if the lexicon were constructed on the basis of a universal phonetic representation—would all be mapped onto separate lexical entries. Knowledge of what constitutes a lexical entry facilitates the subsequent task of finding word meanings.

In this framework, it thus follows that if word stress is predictable, then it need not be encoded; stress will in fact be derived by rule. A key notion here, to be developed presently, is SURFACE OBSERVABILITY of stress. It is important to note that predictable stress comes in several types, and both phonological and morphological factors can play a role in stress assignment rules. As for stress systems in which morphology plays a role, they surely cannot be acquired prelexically, since prelexical infants do not have access to morphological information by definition. Thus, if a stress rule makes reference to, for instance, certain affixes, or if it distinguishes between lexical classes, then it cannot be acquired prelexically. From the viewpoint of early acquisition, this type of system is similar to one with contrastive stress. That is, in both cases infants will not observe a general stress rule and they will therefore include stress among the properties that are encoded phonologically once they begin to build a lexicon. The questions that remain to be answered are whether and how prelexical infants acquiring a language with a purely phonological stress rule can observe that stress is predictable (see Table 1).

	STRESS KEPT IN PHONOLOGICAL REPRESENTATION?
CONTRASTIVE	yes
PREDICTABLE	
(partly) morphological	yes
purely phonological	?

TABLE 1. Phonological encoding of stress as a function of stress type.

Given the assumption that the set of properties that is encoded in the phonological representation of words is determined very early in life, infants must infer whether stress is purely phonological on the basis of a limited amount of information; in particular, they

[3] The same has been proposed by Church (1987), Frazier (1987), and Lahiri and Marslen-Wilson (1991). Alternatively, Klatt (1980), Marslen-Wilson and Warren (1994), and Goldinger (1998) argue for a universal acoustically or phonetically based representation of words.

must do so in the absence of full-fledged word-segmentation abilities. One might want to argue that infants attend to one-word utterances in order to deduce whether stress is purely phonological and hence need not be encoded.[4] Infant-directed speech, however, does not necessarily contain many one-word utterances (Aslin et al. 1996, van de Weijer 1999), and it is, moreover, unclear how infants could distinguish between one-word and multiword utterances (Christophe et al. 1994); everyone who has ever listened to continuous speech in an unknown language has indeed experienced that, contrary to written language, speech does not contain clear word-boundary markers.

Alternatively, Peperkamp and Dupoux (2002)[5] propose that prelexical infants look for surface stress regularities at the edges of utterances rather than of words.[6] Given that utterance edges necessarily coincide with word edges, they can extrapolate these regularities to the level of individual words. For instance, in French, stress falls on the word-final syllable (Schane 1968), as illustrated in 1, and all utterances end with a stressed syllable.[7]

(1) a. con'cept ‘concept’
b. concep'tuel ‘conceptual’
c. conceptuali'ser ‘conceptualize’
d. conceptualisa'tion ‘conceptualization’

Infants acquiring French can easily observe the surface-true regularity of utterance-final stress. Assuming that the location of main stress in the last word of the utterance does not differ from that of other words, they can subsequently deduce that stress is always word-final, and hence remove stress from the set of properties that will be used for phonological encoding in the mental lexicon. Thus, by paying attention to utterance endings only, and without having access to word boundaries, infants can correctly deduce that stress is purely phonological. In Spanish, by contrast, stress falls on one of the word’s last three syllables but is otherwise largely unpredictable (Navarro Tomás 1965).[8] Some examples are given in 2.

(2) a. final stress
dominó ‘domino’
corazón ‘heart’
b. penultimate stress
sabana ‘savanna’
dificil ‘difficult’

[4] For an algorithm that deduces phonological stress rules given a set of individual words with their surface stress pattern, see Dresher & Kaye 1990 and Dresher 1999.

[5] See also Dupoux & Peperkamp 2002 for an earlier version of this idea and its consequences for adult speech perception.

[6] Recall from §2.1 that utterances are perceived as prosodic units by infants as young as seven months old (Hirsh-Pasek et al. 1987). This justifies the assumption that prelexical infants can pay attention to utterance edges.

[7] Within phrases, words can end in an unstressed schwa such that heavy consonant clusters are avoided, as in *cadre carré* ‘rectangular frame’ [kadʁəkare]. At the end of utterances, word-final schwa is not pronounced, at least not in the Parisian variety under consideration.

Note also that especially in formal styles of speech, words can have an emphatic stress that falls on the first or second syllable of the word. This emphatic stress, however, has different acoustic cues from word-final stress, and the two stresses are actually co-present (Vaissière 2001).

Finally, French is sometimes characterized as having phrasal stress, with stress falling on phrase-final syllables (Grammont 1965). The question of whether French has word stress or phrasal stress is irrelevant here, given that under both assumptions, all utterances end in a stressed syllable.

[8] Penultimate stress is predominant, but about one quarter of polysyllabic words has final or antepenultimate stress (Sebastián & Costa 1997).

c. antepenultimate stress
sábana ‘sheet’
régimen ‘regime’

Hence, utterances neither begin nor end consistently with a main stressed syllable. Neither utterance edge thus presents a regular surface stress pattern, and Spanish-acquiring infants will therefore correctly infer that word stress is not purely phonological. As a consequence, they will keep stress for the phonological encoding of lexical items.

Importantly, the algorithm by which infants look for stress regularities at utterance edges may lead to the incorrect conclusion that stress is not purely phonological. In Polish, for instance, stress regularly falls on the penultimate syllable (Comrie 1976), as illustrated in 3.

(3) a. 'gazet/ga'zeta/gaze'tami ‘newspaper.GEN.PL/NOM.SG/INST.PL’
b. sprawie'dliwość/sprawiedli'wości ‘justice.NOM.SG/GEN.SG’

Utterances therefore generally end in an unstressed syllable immediately preceded by a stressed one (4a). But Polish has many monosyllabic content words that can obscure this final trochaic pattern. That is, utterances ending in a monosyllabic word have stress on the final rather than on the penultimate syllable (4b).

(4) a. . . . 'σ σ
b. . . . 'σ σ # 'σ

Prelexical infants who do not have access to word boundaries fail to detect the surface regularity according to which stress is penultimate. Hence, they will keep stress for phonological encoding, despite its being purely phonological. The problem for Polish-acquiring infants thus lies with the fact that the two-syllable window at utterance endings that contains the final stress can include a word boundary. For prelexical infants, who cannot locate word boundaries, this window therefore does not provide reliable information on the stress pattern of the utterance’s final word.

In Table 2, the features of the three languages introduced above are represented schematically. Notice that French and Polish, though they both have a purely phonological stress rule, show different patterns at utterance endings; only in French is this pattern completely regular.

	MAIN STRESS RULE	STRESS AT UTTERANCE ENDINGS[a]
FRENCH	final	final
SPANISH	3-syllable stress window	3-syllable stress window
POLISH	prefinal	prefinal or final

TABLE 2. Main stress rule and surface regularity at utterance endings.

[a]In the three languages discussed so far, main stress is assigned at the right edge of the word. This is not crucial to the proposal. In fact, infants are equally sensitive to surface regularities at utterance beginnings.

In other words, being purely phonological is a necessary but not a sufficient condition for infants to remove stress from the set of properties that are used for phonological encoding; stress should also be surface-observable, as defined in 5.

(5) A phonological regularity is SURFACE-OBSERVABLE if it can be inferred from bare utterances, that is, utterances in which word boundaries are not marked.

According to this definition, stress is surface-observable in French, but not in Polish.

French and Polish, both languages with a purely phonological stress rule, lie at the extreme ends of a scale that ranks languages according to their degree of surface observability. In fact, in French, the stress regularity is very easy to observe, while in

Polish, it is not surface observable at all. Peperkamp and Dupoux (2002) discuss two cases in which stress is surface observable but not as transparent as in French. First, in languages with a quantity-sensitive stress rule, infants must have acquired the difference between heavy and light syllables in their language before they can extract the stress rule. For instance, in Fijian (Dixon 1988), stress falls on the final syllable if it is heavy, that is, contains a long vowel or a diphthong, and otherwise on the penultimate syllable. Examples are given in 6; syllable boundaries are indicated by dots.

(6) a. ˈkam.ba kam.ˈba.ta ‘climb/climb it’
b. te.ʔe.ˈvuː te.ʔe.ˈvuː.na ‘start/start$_{TR}$’
c. pu.ˈlou pu.ˈlou.na ‘be covered/cover$_{TR}$’

Monosyllabic content words are allowed, provided that they be heavy. All utterances therefore have stress on the last syllable if it is heavy, and otherwise on the penultimate syllable. Or, stated differently, all utterances have stress on the syllable containing the penultimate mora, as illustrated in 7.

(7) a. . . . L ˈH
b. . . . H ˈH
c. . . . ˈL L
d. . . . ˈH L

Hence, infants acquiring Fijian must be able to count moras in order to extract the stress regularity. In particular, they must be able to distinguish between short vowels on the one hand and long vowels and diphthongs on the other hand.[9] Given experimental evidence about the acquisition of phonotactic regularities, Peperkamp and Dupoux (2002) argue that this type of knowledge is acquired before the fixation of the phonological representation. They thus predict that Fijian-acquiring infants remove stress from the set of properties that will be used for phonological encoding.

The other language discussed by Peperkamp and Dupoux (2002) that ranks between French and Polish on the scale of surface observability of stress is Hungarian. In Hungarian, word stress is on the first syllable (Vago 1980), as shown in 8a, but not all utterances begin with a stressed syllable, due to the presence of utterance-initial unstressed function words (8b).

(8) a. ˈemberek ‘men’
b. az ˈemberek ‘the men’

Thus, utterances that begin with a content word have stress on the first syllable, but utterances that begin with an unstressed function word have stress on the second syllable. In order for infants to detect the stress regularity, they must have acquired the distinction between function words and content words in their language.[10] Recall that infants acquire this distinction during the first year of life. Based on this evidence, Peperkamp and Dupoux (2002) argue that Hungarian-acquiring infants extract the stress regularity before fixing the phonological representation and, therefore, exclude stress from the set of properties that need to be encoded in the mental lexicon.

[9] Note that if monomoraic content words were allowed, stress could fall on utterance-final light syllables. Fijian would then be like Polish, in that stress at utterance endings would not be completely regular and additional access to word boundaries would be necessary in order to extract the stress rule. I return to this point in §4.1.

[10] In French and Fijian, unstressed function words do not interfere with the stress regularity at utterance endings. In French, function words in phrase-final position are either stressed (e.g. *donne-les* [dɔnˈle] ‘give them’) or they are consonantal (e.g. *dis-je* [ˈdiʒ] ‘say I’). In Fijian, there are no phrase-final function words.

To sum up the argument, prelexical infants keep stress for the phonological encoding of lexical items if and only if they infer—rightly or wrongly—that stress is not purely phonological. Infants acquiring Spanish correctly deduce that stress is not purely phonological; hence, they will encode stress in the phonological representation of words once they start building a lexicon. Infants acquiring French, Fijian, or Hungarian correctly deduce that stress is purely phonological, and, therefore, will not encode stress. Finally, infants acquiring Polish incorrectly conclude that stress is not purely phonological, due to the fact that stress is not surface observable; they will thus keep stress in the set of phonologically relevant properties, resulting in the redundant encoding of stress in the phonological representation of words. Table 3 summarizes the features of the languages discussed so far, as well as the implications for the surface-observability of their stress rules (if any) and, hence, the encoding of stress in the mental lexicon.

	MAIN STRESSED SYLLABLE	STRESS REGULARITY AT UTTERANCE EDGE	SURFACE OBSERVABILITY OF STRESS	PHONOLOGICAL ENCODING OF STRESS
PURELY PHONOLOGICAL				
French	final	final	yes	no
Fijian	final if heavy, otherwise prefinal	final if heavy, otherwise prefinal	yes	no
Hungarian	initial	initial, modulo function words	yes	no
Polish	prefinal	prefinal, modulo monosyllables	no	yes
CONTRASTIVE				
Spanish	within final 3-syllable stress window	within final 3-syllable stress window	–	yes

TABLE 3. Relevant features of four languages with purely phonological stress, one with contrastive stress. (The former are ordered according to transparency of stress regularities at the surface.)

The present approach calls for a small but important modification of the framework of Mehler et al. 1990. Recall from above that in this framework, the phonological representation of words in the mental lexicon is established early in life and encodes those segmental and suprasegmental distinctions that are used contrastively in the native language. We have seen that as far as stress is concerned, prelexical infants can include this property among those that need to be encoded even if it is noncontrastive in their language, due to the fact that they fail to observe its predictability. I thus propose that a given distinction is encoded in the phonological representation of words if and only if it is either contrastive or predictable but not surface observable.

3. ADULT SPEECH PERCEPTION. The way in which speech sounds are perceived depends heavily on the listener's native language. Indeed, listeners typically have difficulties with perceiving contrasts that are either completely absent from their native language or present in an allophonic relationship only. Japanese, for instance, has only a single liquid consonant, [ɾ]. Japanese listeners have difficulties perceiving the distinction between American [l] and [ɹ]; they assimilate both to [ɾ] (Goto 1971). Likewise, English speakers have difficulties distinguishing [t], the voiceless aspirated stop that occurs after [s] only, from [d] (Pegg & Werker 1997). Much evidence has also been gathered about the perception of suprasegmental contrasts, such as tone (Gandour 1983), length (Dupoux et al. 1999), and stress (Dupoux et al. 1997). In particular, Dupoux and colleagues (1997) found that French speakers, as opposed to Spanish speakers, have difficulties perceiving stress contrasts. The influence of the native phonology on

the perception of non-native contrasts is attested even in early and highly proficient bilinguals. Spanish speakers who have learned Catalan before age six and who use Catalan on a daily basis have difficulties perceiving Catalan contrasts that are absent from Spanish, specifically [e-ɛ], [o-ɔ], and [s-z] (Pallier et al. 1997, 2001). Finally, training studies have shown that even though in a laboratory situation subjects can learn to improve their performance on the perception of non-native contrasts, they do not become native-like (Logan et al. 1991, Lively et al. 1993, 1994).

Findings like the above are generally interpreted as the absence of phonological encoding of contrasts that are not phonemic in the native language, be they segmental or suprasegmental. Moreover, the results with bilinguals suggest that once the phonological format is fixed, it remains stable, even after extensive exposure to a second language. This lack of plasticity of the phonological representation implies that adult speech perception can inform us about the way in which infants acquire their native phonology. Specifically, given the hypothesis that predictable properties will be encoded if prelexical infants fail to observe their predictability, it allows us to test if a given predictable property is acquired before or after the fixation of the format of the phonological representation: in the latter case, we predict that adult speakers should have no difficulties perceiving contrasts based on this property.

In order to test the learning algorithm for the acquisition of stress, Peperkamp and Dupoux (2002) assessed the perception of stress by speakers of different languages with a purely phonological stress rule. They used a short-term memory sequence recall task, as developed by Dupoux and colleagues (2001). In this paradigm, the recall performance of a stress contrast is compared with that of a control phonemic contrast, across different levels of memory load. The experiment is divided into two parts. In each part, subjects are required to learn two [CVCV] nonwords that are a minimal pair differing only in one phonological dimension, specifically, place of articulation of the second consonant or location of stress. In each part, subjects are taught to associate the two nonwords with the keys [1] and [2], respectively, of a computer keyboard. Subjects listen to random sequences of the two nonwords, which they are required to recall and transcribe as sequences of [1] and [2]. The length of the sequences varies from two to six. The segmental contrast in the first part is phonemic in all languages under consideration and hence equally easy for all subjects; this contrast is thus used to establish baseline performance.

Using this novel paradigm, the researchers (Dupoux et al. 2001) tested twelve native speakers of French and Spanish and confirmed the previous finding of Dupoux et al. 1997 that the former, as opposed to the latter, have difficulties in perceiving stress contrasts. That is, French but not Spanish listeners made significantly more recall errors with the stress contrast than with the phoneme contrast.[11] Peperkamp and Dupoux (2002) used the same paradigm to assess the perception of stress by native speakers of Finnish, Hungarian, and Polish.[12] Finnish has word-initial stress and there are no phrase-initial unstressed function words (Harms 1964). It thus presents the mirror image of French, in that stress can be straightforwardly inferred from utterance beginnings

[11] It should be noted, though, that French listeners can perceive stress contrasts on an acoustic basis: in the absence of acoustic variation—that is, when each item was instantiated by a single token—French listeners performed equally well on the phonemic and the stress contrast. This might explain how certain highly proficient bilinguals succeed in learning to correctly produce stress patterns in foreign words.

[12] Fijian, the remaining language introduced in §2.2, was not subject to testing, due to difficulties in recruiting native speakers in France.

rather than endings. The study found that native speakers of Finnish and Hungarian manifest the same difficulties with respect to the perception of stress as do French speakers; that is, they made significantly more recall errors with the stress contrast than with the phoneme contrast. Native speakers of Polish also made more recall errors with the stress contrast than with the phoneme contrast, but the effect was not significant. Moreover, there was no significant difference in performance between the Polish and the Spanish subjects. The authors therefore concluded that speakers of Polish do not have the same difficulties in perceiving stress contrasts as speakers of French, Finnish, and Hungarian.

The present data lend plausibility to the acquisition algorithm in Peperkamp & Dupoux 2002. Specifically, the performance of the Polish subjects corroborates the hypothesis that the presence versus absence of stress in phonological encoding is determined before infants have complete mastery of word segmentation; native speakers of Polish appear to redundantly encode stress in the phonological representation of words. Note that I do not wish to deny that native speakers of Polish have implicit or explicit knowledge of the fact that stress is penultimate in their language.[13] But this stress regularity is acquired after word segmentation is in place; it is, therefore, not taken into account for the fixation of the format used for the phonological representation of words in the mental lexicon.

4. THE OCCURRENCE OF LEXICAL EXCEPTIONS TO MAIN STRESS RULES. Many—but not all—languages with a purely phonological stress rule have a number of lexical exceptions to this rule, mainly consisting of words of foreign origin. The framework of early language acquisition and its consequences for adult perception makes predictions about the type of languages in which exceptions can occur. I formulate these predictions and test their validity with a typological survey of languages with purely phonological stress, making a comparison ultimately with a metrical account.

4.1. TYPOLOGICAL PREDICTIONS. The argument developed in this section is based on the trivial observation that a language can allow for exceptions only if its speakers have no difficulties in perceiving stress contrasts, that is, if they encode stress in the phonological representation of words in their mental lexicon. Indeed, if they do not perceive—hence encode—exceptional stress as such, then they will not produce it either. From this it follows that in languages with a purely phonological stress rule, exceptions can occur only if infants incorrectly infer that stress is not purely phonological, that is, if stress is not surface observable.

In what follows, I consider four classes of languages, with fixed initial, final, penultimate, and antepenultimate stress, respectively. For each of these classes, I formulate predictions about the occurrence of lexical exceptions, based on whether stress is surface observable.[14] I abstract away from the presence of unstressed function words at the utterance edge where the default stress pattern is to be expected. In particular, following

[13] As to implicit knowledge of the stress regularity, native speakers of Polish are likely to use stress at a different level of speech processing, namely for word segmentation. They can do so by postulating the presence of a word boundary at the end of the syllable following a main stress. Of course, due to the presence of monosyllabic content words, this heuristic does not yield a one hundred percent correct segmentation. Cutler and Norris (1988) have shown, however, that probabilistic cues are exploited for the purposes of word segmentation.

[14] Languages with stress on the second syllable, so-called peninitial placement, are fairly rare (Hyman 1977, Hayes 1995) and are not discussed here. Similarly, languages with stress on the third mora or syllable from the left are too rare to be included.

the experimental data for Hungarian in §3, I assume that these function words do not interfere with the surface observability of stress, in that infants learn the distinction between content words and unstressed function words before the age at which they fix the phonological representation; they can thus strip off function words from the utterance edges when trying to detect a surface stress regularity. Similarly, I assume that quantity-sensitivity does not interfere with the surface observability of stress, in that syllable structure is acquired prior to the fixation of the phonological representation.[15]

First, I consider languages with initial or final stress. From a metrical point of view, word-initial and word-final stress might be very different, involving different foot types. In the present account, though, the two types of system are in one crucial sense alike: in both types, stress is surface observable since all utterances begin or end with a stressed syllable, respectively (modulo the presence of initial or final unstressed function words). Consequently, infants can conclude that stress need not be encoded in the phonological representation of words, and as adults, they will have difficulties with the perception of stress. This was shown for Finnish and Hungarian (initial stress) and French (final stress) in §3. Speakers of these languages are thus unable to store lexical exceptions to the stress regularity. I predict, therefore, that in languages with initial or final stress, lexical exceptions are excluded.

In languages with penultimate stress the presence of exceptions is tied to the presence of subminimal words. The logic is as follows. Given that infants do not have full word-segmentation abilities by the time the format of the phonological representation of words is fixed, the absence or presence of stress in this representation hinges on the occurrence of subminimal words. More precisely, stress is surface observable if and only if there are no subminimal words, that is, words consisting of a single mora or syllable, depending on whether the stress rule is quantity-sensitive or quantity-insensitive, respectively. This is illustrated in 9, which shows the possible utterance endings (modulo the presence of final unstressed function words) in languages with (9a) and without (9b) subminimal words, respectively; stress-bearing units, that is, moras or syllables, are represented by 'x', and the ending that disturbs the default pattern at utterance endings in languages with subminimal words is shown in boldface.

(9) Utterance endings in languages with penultimate stress

a. subminimal words allowed	b. subminimal words disallowed
. . . ˈx x	. . . ˈx x
. . . ˈx	

Polish, an example of a language with subminimal words, has quantity-insensitive penultimate stress and contains monosyllabic content words. In Polish, stress is not surface observable, and, as shown, its speakers do not have difficulties in perceiving stress contrasts. Indeed, according to Peperkamp and Dupoux's learning algorithm (2002), Polish-acquiring infants keep stress among the properties that need to be encoded in the phonological representation of lexical items. As to quantity-sensitive counterparts of Polish—languages with stress on the penultimate mora and in which monomoraic words are allowed—the stress regularity is likewise not surface observable. Speakers of these languages should thus have no difficulties with the perception of stress contrasts either. In both cases, lexical exceptions can therefore be stored. By contrast, in languages with penultimate stress and no subminimal words, stress is surface observable, since all utterances end with a trochee (modulo the presence of final un-

[15] This needs to be confirmed experimentally by showing that speakers of, for instance, Fijian cannot perceive stress contrasts (cf. §2.2).

stressed function words), be it syllabic or moraic. According to the learning algorithm, infants acquiring this type of language exclude stress from the list of phonologically relevant properties, and, consequently, as adults they are predicted to have difficulties with the perception of stress contrasts. Lexical exceptions to the language's stress rule, therefore, cannot be stored. I predict, then, that exceptions are excluded in languages with penultimate stress that have subminimal words, whereas they are allowed in the absence of subminimal words.

Finally, I turn to languages with antepenultimate stress. For stress to be surface observable, all utterance endings should conform to the default stress pattern, that is, have rightmost stress in antepenultimate position. Hence, in languages with quantity-sensitive stress, all utterances should end with a word that has at least three moras, while in languages with quantity-insensitive stress, all utterances should end with a word that has at least three syllables. Given that no language with polysyllabic words excludes the presence of bimoraic/disyllabic words, there are no such cases. Indeed, languages with a minimal word requirement exclude content words that do not contain a proper foot (McCarthy & Prince 1986); bimoraic/disyllabic words constitute a canonical foot and are thus always allowed. All possible utterance endings (modulo the presence of final unstressed function words) in languages with and without subminimal words are shown in 10a and 10b; as before, stress-bearing units are represented by 'x', and the endings that disturb the default pattern at utterance endings are shown in boldface.

(10) Utterance endings in languages with antepenultimate stress

a. subminimal words allowed	b. subminimal words disallowed
. . . ˈx x x	. . . ˈx x x
. . . ˈx x	**. . . ˈx x**
. . . ˈx	

In other words, stress is not surface observable in languages with antepenultimate stress. Infants who acquire a language with antepenultimate stress should therefore keep stress for the phonological encoding of words. As a consequence, adult speakers should have no difficulties perceiving stress contrasts, and should be able to store lexical exceptions. The prediction, then, is that languages with antepenultimate stress can have exceptions, regardless of whether they have subminimal words or not.

To sum up, I have argued that for lexical exceptions to occur in a language with purely phonological stress, speakers should be able to process them as such, hence they should perceive stress without difficulties; that is, they should encode stress in the phonological representation of words. Exceptions can thus occur if and only if stress is not surface observable, so that infants will (redundantly) encode stress once they start building a lexicon. In languages with initial or final stress this is never the case, while in languages with antepenultimate stress it always is. Finally, in languages with penultimate stress, the regularity is not surface observable if and only if there are subminimal content words. This is summarized in Table 4.

The predictions about the occurrence of lexical exceptions are summarized in 11.

(11) a. Languages with initial or final stress cannot have lexical exceptions.
b. Languages with penultimate stress can have lexical exceptions if and only if they have subminimal words.
c. Languages with antepenultimate stress can have lexical exceptions.

It should be noted that the present account does not preclude the existence of languages with penultimate stress and subminimal words or with antepenultimate stress that do

	STRESS IS SURFACE OBSERVABLE	STRESS ENCODED IN PHONOLOGICAL REPRESENTATION	LEXICAL EXCEPTIONS STORED
INITIAL	yes	no	no
FINAL	yes	no	no
PENULTIMATE			
without subminimal words	yes	no	no
with subminimal words	no	yes	yes
ANTEPENULTIMATE	no	yes	yes

TABLE 4. Relationship between surface observability of stress, phonological encoding of stress, and the possibility to store lexical exceptions (in five classes of languages).

not have exceptions. Indeed, the capacity of its speakers to store exceptional stress does not imply that lexical exceptions should be present in a given language. Lexical exceptions are most often words of foreign origin; contact with a language that has different stress patterns thus enhances the chances that exceptions enter the language.

4.2. TESTING THE PREDICTIONS. The languages with purely phonological stress that Peperkamp and Dupoux (2002) used for their experiments on the perception of stress by adult native speakers (French, Finnish, Hungarian, and Polish) conform to the predictions in 11. Indeed, exceptions are attested in neither French, which has final stress (Schane 1968), nor Finnish and Hungarian, which have initial stress (Harms 1964, Vago 1980); by contrast, Polish, with penultimate stress and subminimal words, is well known for having lexical exceptions (Comrie 1976). Native speakers I consulted not only confirmed the absence of exceptions in French, Finnish, and Hungarian, but they also asserted that the stress patterns of new loanwords are always regularized to the native pattern.[16]

In order to further test the predictions of the present acquisition and processing framework, I did an extensive crosslinguistic survey, with the aim of gathering more data concerning the occurrence of lexical exceptions in languages with purely phonological stress. Before describing this survey and its results, a caveat is in order. As Hayes observed (1995:32), languages with purely phonological stress are relatively rare, as are those with purely morphological stress; most languages with noncontrastive stress indeed have a system that mixes phonological and morphological factors.[17] The languages to be considered here are thus limited in number. Moreover, I consider only languages with exceptions that are individual lexical items with a deviant stress pattern; these exceptions have to be marked as such in the lexicon. The only work I am aware of that deals with the question of which languages allow for exceptions, namely Kager 1995, is not similarly confined. Kager puts phonologically and morphologically defined nondefault stress under the rubric of exceptions as well. The same holds for Hayes (1995), who often notes the existence of exceptions for individual languages, which

[16] Note that even if some highly proficient bilinguals might succeed in perceiving non-native stress patterns well and introduce novel loanwords with their deviant stress pattern, the large majority of individuals will subsequently regularize stress in these words. As a result, loanwords end up being lexicalized with the native stress pattern, even though some individuals might maintain a deviant stress pattern.

[17] As mentioned in §2.2, stress systems that are not purely phonological cannot be acquired prelexically, hence the prediction is that speakers of these languages encode stress in the phonological representation and can process lexical exceptions. Exceptions should thus freely occur. This type of stress system, though, is outside the scope of the present article.

might or might not be lexical. Sanuma Yanomama provides an example of phonologically defined exceptions. It was classified by Kager (1995) among the languages with penultimate stress that allow for exceptions; in this language, trisyllabic words have initial rather than penultimate stress. Likewise, Hayes (1995:204) observes that Chamorro allows for exceptions to its penultimate stress rule, but some of these exceptions are morphologically defined; in particular, certain prefixes attract stress (Chung 1983). In this article, I do not consider languages with classes of phonologically or morphologically defined exceptions. These exceptions are often quite numerous and they can therefore be assumed to be largely present at utterance beginnings and endings in the input on which infants carry out their analyses; as such, they interfere with the surface observability of stress. By contrast, lexical exceptions are generally limited in number and are typically low-frequency words of foreign origin; their occurrence at utterance edges is thus much rarer.[18] I therefore assume that infants treat the irregularities that they might introduce at utterance edges as noise in the signal. I return to the question of a possible interference of lexical exceptions with the surface-observability of stress below.

Data for the crosslinguistic survey were gathered as follows. I first considered all the chapters dealing with individual languages in the descriptive handbooks edited by Dixon and Blake (1979, 1981, 1983), Comrie (1990), and Kaye (1997). I then consulted as many original sources as possible of the languages dealt with by Halle and Vergnaud (1987), Hayes (1995), and Kager (1995). Occasionally, I would encounter an original source by other means. Besides a great number of monographs, the sources to which I had access include descriptive articles in the journals *Oceanic Linguistics* and the *International Journal of American Linguistics*, as well as several collections of papers in the Pacific Linguistics series of the Australian National University in Canberra.

For present purposes it is extremely important to rely on original sources rather than on work in which such sources are cited. As mentioned above, I do not consider languages in which stress is not purely phonological or in which exceptions are defined other than on a lexical basis; these limitations make it virtually impossible to rely on citations. There are two more reasons why it is preferable to consult the original sources directly. First, authors who cite these sources do not systematically mention the occurrence of exceptions, and explicit statements about the absence of exceptions are even rarer. Original sources themselves are more likely to note the presence or absence of lexical exceptions. Second, late phonological processes like unstressed vowel deletion can obscure the stress regularity in languages with otherwise surface-observable stress. For instance, in Colta Quechua, stress is penultimate, but final vowels are regularly devoiced or even deleted (Reyburn 1954). Again, these influences are more likely to be mentioned in the original sources, especially those that deal with more than just the stress system, as is often the case.

In constructing my survey, I used all library resources in Paris to their fullest extent. Inevitably, several original sources cited by Halle and Vergnaud (1987), Hayes (1995), and Kager (1995) remained unavailable to me. In what follows, I report primarily on those languages for which I did have access to such a source and that constitute a representative sample. Languages for which I could not consult such an original source are excluded from the results. In order to facilitate future research, they are listed

[18] Lexical exceptions might even be completely absent from the input on which infants carry out their analyses. For instance, exceptions in Polish are typically learned words of Latin or Greek origin; these words are likely to be very rare or nonexistent in infant-directed speech.

separately in footnotes; whenever—based on some citation of an original source—they seem to contradict one of the predictions in 11, this is mentioned.

Turning to the results, then, I first consider languages with initial or final stress, which are predicted in 11a to exhibit no exceptions. Languages with initial stress are the commonest. My survey contains 22 examples without exceptions: Anguthimri (Crowley 1981), Badimaya (Dunn 1988), Bengali (Hayes & Lahiri 1991), Chechen (Nichols 1997), Czech (Jakobson 1962),[19] Diyari (Austin 1981), Dyirbal (Dixon 1972), Finnish (Harms 1964), Garawa (Furby 1974), Gugu-Yalanji (Hersberger & Pike 1970), Hungarian (Vago 1980), Koya (Tyler 1969), Mantjiltjara (Marsh 1969), Northern Ostyak (Rédei 1965),[20] Ono (Phinnemore 1985), Pintupi (Hansen & Hansen 1969), Pitta-Pitta (Blake 1979), Sango (Samarin 1967), Selepet (McElhanon 1970), Tamil (Steever 1990), Wangkumara (McDonald & Wurm 1979), and Western and Central Slovak (Rubach 1993).[21] Five other languages with initial stress, though, appear to have exceptions, contrary to the prediction in 11a: Djapu (Morphy 1983), Estonian (Oinas 1966), Latvian (Fennell & Gelsen 1980), Watjarri (Douglas 1981), and Yuulngu (Wood 1978).[22]

Languages with final stress are less common. My inventory contains five: Cambodian (Nacaskul 1978), French (Schane 1968), Haroi (Tegenfeldt-Mundhenk & Goschnick 1977), Western Cham (Friberg & Hor 1977), and Tzutujil (Dayley 1985).[23] The first four are in accordance with the prediction in 11c that they cannot have exceptions, but the fifth, Tzutujil, is not: Dayley (1985) gives examples of Spanish loanwords that have nonfinal stress.[24]

Next, I turn to languages with penultimate stress. According to 11b, these languages can have exceptions if and only if they have subminimal words. I have found nine cases with exceptions: Awngi (Hetzron 1997), Djingili (Chadwick 1975), Polish (Comrie 1976), Tidore (Pikkert & Pikkert 1995), Tol (Fleming & Dennis 1977), Totoli (Himmelmann 1991), Tsou (Tung 1964), Yokuts (Kroeber 1963), and Zoque (Wonderly 1951). In accordance with the prediction in 11b, all of these languages have subminimal content words.[25] Recall that languages with subminimal words are not predicted to

[19] Robert Batusek (p.c.) notes that stress in loanwords is always regularized to the native pattern.

[20] Rédei (1965) states that 'stress is generally initial', without mentioning cases of noninitial stress. Given that in his detailed description, Rédei furthermore reports that stress in Russian loans is regularized to the native pattern, I assume that initial stress is exceptionless.

[21] In Selepet and Wangkumara, like in French, stress can shift under emphasis (see n. 7). Note also that Kager (1995) mentions Timucua as having initial stress, but cliticization interferes with the stress regularity, in that enclitics attract main stress (Granberry 1956).

[22] Icelandic and Faroese also have initial stress and exceptions, but morphology interferes with stress assignment, in that some prefixes (optionally) fail to attract stress and certain compounds have noninitial stress (Árnason 1999).

[23] Additional languages with final stress for which I did not have access to an original source are Aklan, Tübatalabal, and Weri. Note that Hayes (1995) does not report exceptions for any of these. Turkish (Sezer 1983) and Modern Hebrew (Bat-El 1993) are well known for having final stress, but in both cases final stress is just the predominant pattern, not the only one. In particular, morphological factors play an important role in assigning nonfinal stress.

[24] In addition, there is one unstressed adjectival suffix.

[25] There are a few languages that at first sight appear to contradict 11a in that they have exceptions but no subminimal words. In each one of these languages, though, stress is not surface observable despite the absence of subminimal words: in Colta Quechua (Reyburn 1954), unstressed vowel deletion obscures the stress regularity; in Digueño (Langdon 1970), stress is antepenultimate if the penultimate mora is schwa; in Iraya Mangyan (Tweddell et al. 1974), word stress tends to move to the last syllable utterance finally, and there are stressed monosyllabic function words; and in Kawaiisu (Zigmond et al. 1990), cliticization interferes with stress assignment.

necessarily have exceptions; I indeed found four languages with subminimal words for which no exceptions are mentioned: Balantak (Busenitz & Busenitz 1991), Nengone (Tryon 1967), Piro (Matteson 1965), and Suriname Arawak (Pet 1979).[26] Finally, there are five cases without subminimal words and for which the source does not mention exceptions either: Cavineña (Key 1968), Fijian (Dixon 1988), Huallaga Quechua (Weber 1989), Sama Baangingi (Gault 1979), and Sawu (Walker 1982). Of these, Huallaga Quechua is particularly interesting, since there is explicit evidence that exceptions are excluded: Weber (1989) mentions that deviant stress in loanwords is regularized to the native pattern. Again, these languages conform to the prediction in 11b.[27]

It proved extremely hard to find useful data for languages with antepenultimate stress. The prediction in 11c is that these languages can have lexical exceptions, regardless of the presence or absence of subminimal words. Macedonian (Comrie 1976) is a well-known case of an antepenultimate stress system with lexical exceptions, and it has subminimal (monosyllabic) words.[28] I have found no cases with exceptions in the absence of subminimal words, though. That antepenultimate stress is overall very rare is shown by the fact that my inventory contains no languages of this type without exceptions either; Macedonian is indeed the only language with antepenultimate stress that passed the criteria for being included in the results.[29]

To sum up, according to the predictions in 11, lexical exceptions to purely phonological stress are excluded in three types of languages: languages with initial stress, languages with final stress, and languages with penultimate stress and no subminimal content words. Table 5 summarizes the results from the fifty-one languages included in the survey.

Among the languages with surface-observable stress, 16% have lexical exceptions, whereas among those with non-surface-observable stress, 71% have lexical exceptions. The difference between the two classes of languages is highly significant

[26] Sentani, mentioned by Hayes (1995), might fall into this category as well, but I was unable to consult an original source.

[27] There are many other languages with penultimate stress discussed in the literature that are not taken into account here for a variety of reasons. In one group, morphology interferes with the phonological stress rule: Chamorro (Chung 1983), Dakota (Shaw 1985), Indonesian (Cohn 1989), Inga (Levinsohn 1976), Lenakel (Halle & Vergnaud 1987), Manam (Lichtenberk 1983), Oneida (Chafe 1977), Onondaga (Chafe 1977), Proto-Northern Iroquioan (Chafe 1977), Squamish (Kuipers 1967), Swahili (Wald 1990), Tacana (Key 1968), Warao (Osborn 1966), Yawelmani (Archangeli 1984), Yuanga (Schooling 1992), Yanam Yanomama (Migliazza 1972), and Wikchamni (Gamble 1978). In a second group, words of a certain length have deviant stress: Tigwa Manobo (Strong 1979), Tonkawa (Hoijer 1946), and Sanuma Yanomama (Borgman 1990). Still other languages are excluded for diverse reasons: Kilivila (Senft 1986) has a class of phonologically defined exceptions; in Modern Spoken Syriac (Solomon & Headley 1973) stress shifts under emphasis; in South-West Tanna (Lynch 1982) stress is quantity-sensitive, but there is no phonetic distinction between short and long vowels; Tiwi (Lee 1987) has a class of phonologically defined exceptions and unstressed vowel devoicing obscures the stress regularity; and in Tongan (Feldman 1978) morphosyntax interferes with stress assignment, and unstressed vowel devoicing obscures the stress regularity.

[28] At first sight, Cayuvava (Key 1967) and Paamese (Crowley 1982) appear to be of this type as well, but morphology interferes with the stress rule in these languages.

[29] Hayes (1995) lists Mae among the languages with antepenultimate stress, but it appears that his source (Capell 1962) contains a crucial typo: the data show that stress is indeed penultimate and that there are some exceptions with antepenultimate stress. (The language is not included in my sample of penultimate stress systems, since morphology interferes with stress assignment.) Kela is another language with antepenultimate stress for which I could not consult an original source. Hayes (1995) reports that it has subminimal words and he mentions no exceptions to its stress rule.

	EXCEPTIONS	NO EXCEPTIONS
STRESS IS SURFACE OBSERVABLE		
initial (N = 27)	5	22
final (N = 5)	1	4
penultimate (no subminimal words allowed) (N = 5)	0	5
TOTAL (N = 37)	*6*	*31*
STRESS IS **NOT** SURFACE OBSERVABLE		
penultimate (subminimal words allowed) (N = 13)	9	4
antepenultimate (N = 1)	1	0
TOTAL (N = 14)	*10*	*4*

TABLE 5. Lexical exceptions, as a function of whether language's stress regularity is surface observable.

($\chi^2(1) = 11.9, p < 0.0006$), providing evidence in favor of the present acquisition and processing account.

Still, what remains to be explained is how there can be any languages with surface-observable stress and lexical exceptions at all. Let us look first at Watjarri (Douglas 1981). This language has initial stress, but a few English loanwords are reported to have stress on the second syllable. Interestingly, the original English words begin with a consonant cluster, which is broken up by epenthesis in the Watjarri adaptations; for instance, we find [pu'ra:ku], from English *frock*. In the native vocabulary, only monosyllables have phonetically long vowels; stressed vowels are not otherwise lengthened. This leaves open the possibility that, contrary to Douglas's report, loanwords have phonemicized vowel length in the second syllable while being stressed on the first one. That is, stress in the source words is interpreted as vowel length, which in Watjarri is dissociated from stress.

There are two possible explanations for the five remaining counterexamples. The first relates to the fact that lexical exceptions might interfere with the surface observability of stress. I argued above that the presence of lexical exceptions at utterance edges is generally rare, due to the fact that exceptions are limited in number and are typically low-frequency words. I thus assumed that infants treat the irregularities that lexical exceptions might introduce as noise in the signal. However, if exceptions are more numerous and/or more frequent, the likelihood that infants infer that stress is not predictable increases. This might be the case for Estonian and Latvian. The former language has a large amount of exceptions, including common first names such as *Kris'tiina* and *Ma'ria*, the names of five months (*a'prill*, *sep'tember*, *oc'toober*, *no'vember*, *de-'tsember*), words with the foreign suffix *-nna* such as *laul'janna* 'singer.FEM', *sõ'branna* 'friend.FEM', and *tsaa'rinna* 'tsarina', and other frequent words such as *mo'dernne* 'modern', *pro'bleem* 'problem', *re'klaam* 'publicity', and *televi'sioon* 'television'. Virtually all of these exceptions entered the language due to prolonged contact with (Low-)German and Russian.[30] In Latvian, by contrast, the exceptions to word-initial stress are less numerous but they include several high-frequency words, such as *pal'dies* 'thank you', *ne'kas* 'nothing', *ar'dievu* 'good-bye', and *lab'dien* 'good-day' (Fennell & Gelsen 1980). Most of the exceptions are derived or compound words that are no longer analyzed as such by native speakers; productively formed mophologically complex words, by contrast, have regular initial stress (Sarmite Trupa, p.c.).

[30] Thanks to Rogier Blokland and Inga Vendelin for sharing their knowledge about Estonian with me.

The alternative explanation is that stress-clash resolution can obscure the surface observability of the stress regularity. Indeed, in many languages, configurations with two adjacent syllables carrying primary stress are disallowed (Selkirk 1984, Nespor & Vogel 1989, Hayes 1995). If a language with initial or final stress has stressed monosyllables, stress-clash configurations—that is, two adjacent stressed syllables—can arise at utterance beginnings and endings, respectively; if in such cases stress is reduced on the syllable at the utterance boundary, the stress regularity is no longer surface observable. All six languages with initial or final stress that have exceptions contain monosyllabic content words; hence, they have stress-clash configurations at utterance beginnings and endings, respectively. Unfortunately, the sources do not mention whether stress clash is allowed. This possible explanation, then, remains open. Of course, in order not to lose the predictive power of the present account, it would be important to find out the proportion of languages with initial or final stress that do not have monosyllabic content words; in these languages, stress-clash resolution cannot interfere and hence the prediction that initial and final stress are incompatible with the occurrence of exceptions remains valid.[31] I leave the issue of a possible interference of stress-clash resolution with the surface observability of stress for future research.

4.3. Comparison with a metrical account. Working within a foot-based version of metrical phonology, Kager (1995) observes that languages with penultimate stress tend to have exceptions with final stress if and only if they have subminimal words. As mentioned above, Kager treats exceptions that are defined phonologically or morphologically on a par with lexical exceptions. His typological survey is thus not directly comparable to mine. But it is interesting to consider his analysis, since the present survey reveals the same tendency if only lexical exceptions are taken into account.

Kager's analysis relies on the notion of catalexis (Kiparsky 1991). Catalexis is the mirror image of extrametricality; that is, it consists of the adjunction of a segmentally empty mora or syllable at the beginning or end of a metrical domain. Languages differ in whether they allow for catalexis or not. A primary diagnostic for the availability of catalexis in a language is the presence of subminimal words, that is, words that do not contain a proper foot at the surface. This diagnostic crucially relies on the assumption that degenerate feet are universally disallowed: monomoraic feet are ruled out in languages with a quantity-sensitive stress rule, while monosyllabic feet are ruled out in languages with a quantity-insensitive stress rule. Subminimal words, then, satisfy minimality by containing a final catalectic mora or syllable that functions as the (invisible) weak branch of a foot. Hence, in languages with subminimal words, catalexis is available, while in languages without subminimal words, it is not.

It is now easy to see why languages with penultimate stress exceptionally have words with final stress if and only if they have subminimal content words. In these languages, penultimate stress is derived with a word-final trochee. If catalexis is available, both subminimal words and words with exceptional final stress are analyzed as containing a final catalectic element. If, by contrast, catalexis is unavailable, neither subminimal

[31] The three languages with surface-observable stress tested by Dupoux and colleagues (2001) and Peperkamp and Dupoux (2002) have monosyllabic content words, but stress-clash resolution does not interfere with the surface observability of stress. For French and Hungarian, this follows from analyses by Dell (1984) and Vogel (1988), respectively, whereas for Finnish, I listened to recordings of four female native speakers and found that initial monosyllabic content words are not destressed.

words nor words with exceptional final stress can occur. The analysis is illustrated in Table 6; catalectic elements are closed within square brackets.

	CATALEXIS AVAILABLE	CATALEXIS UNAVAILABLE
REGULAR PENULTIMATE STRESS	. . . ('x x)	. . . ('x x)
SUBMINIMAL CONTENT WORD	('x [x])	*impossible*
EXCEPTIONAL FINAL STRESS	. . . ('x [x])	*impossible*

TABLE 6. Role of catalexis for the representation of subminimal content words and exceptional final stress (language with penultimate stress rule).

The proposed analysis thus explains why the presence of exceptional final stress in languages with a penultimate stress rule depends on the presence of subminimal words. What remains to be explained is that exceptional antepenultimate stress in these languages is equally allowed only if there are subminimal words. Indeed, this type of exception is generally accounted for by lexically assigning extrametricality to the word's final mora or syllable (Liberman & Prince 1977). This is shown in 12; the extrametrical element is enclosed in angled brackets.

(12) exceptional antepenultimate stress: . . . ('x x) ⟨x⟩

Given that there are no restrictions on the occurrence of extrametricality, the prediction about exceptions with antepenultimate stress would simply be that all languages with regular penultimate stress can have them. This prediction is not corroborated by the present survey. In fact, the reader may recall that none of the languages with penultimate stress and no subminimal words has exceptions—whether with antepenultimate or with final stress. This should be compared to languages with subminimal words. In these languages, exceptions with antepenultimate stress appear to be as common as those with final stress: among the nine languages with exceptions, six have exceptions of both types (Djingili, Polish, Tol, Tsou, Yokuts, and Zoque), one has exceptions with final stress only (Tidore), and two have exceptions with antepenultimate stress only (Awngi and Totoli). These data confirm that the relevance of subminimality for the occurrence of exceptions holds whichever type of exceptions is examined.

Kager (1995) deals with exceptions only in languages with penultimate stress. In what follows, I consider the remaining classes of languages dealt with in the present survey to examine how a metrical analysis would fare. Following Kager's analysis of penultimate stress systems, I assume that catalexis, like extrametricality, is available as an analytical tool. First, recall that only a small percentage of languages with initial stress have exceptions. In metrical phonology, initial stress is derived by assigning trochees from left to right (13a). Exceptional stress on the second syllable could be obtained straightforwardly by marking the first mora or syllable extrametrical (13b).

(13) a. regular initial stress ('x x) . . .
b. exceptional peninitial stress ⟨x⟩ ('x x) . . .

Initial extrametricality is fairly rare, as evidenced by the scarcity of languages with regular peninitial stress (Hayes 1995); hence, it might not be surprising that there are so few languages with initial stress that have lexical exceptions. The metrical analysis, then, is comparable to the present proposal as far as initial-stress languages are concerned.

Second, languages with final stress also tend not to have exceptions in the present survey. These languages are analyzed differently, depending on whether they distinguish between light and heavy syllables (Kiparsky 1991, Kager 1995). In the former case, final stress is derived with a word-final iamb. In the latter case, the iamb is not available as a foot form; rather, these languages are analyzed as having word-final

trochees, the second syllable of which is catalectic. In both cases lexically marked penultimate stress can be derived: in quantity-sensitive languages, the final mora is made extrametrical, while in quantity-insensitive languages, final catalexis is turned off (Table 7).

	STRESS	
	QUANTITY-SENSITIVE	QUANTITY-INSENSITIVE
REGULAR FINAL STRESS	. . . (μ ˈμ)	. . . (ˈσ [σ])
EXCEPTIONAL PENULTIMATE STRESS	. . . (μ ˈμ) ⟨μ⟩	. . . (ˈσ σ)

TABLE 7. Analysis of lexical exceptions in languages with final stress.

The overall small number of languages with final stress in my survey does not allow for firm conclusions. But the prediction that follows from the metrical analysis is clearly different from the one formulated in the present account: given that there is no principled reason why lexically marked extrametricality and the incidental absence of catalexis, respectively, would not be allowed, exceptions are predicted to occur freely in both quantity-sensitive and quantity-insensitive systems.

Finally, in my account, languages with antepenultimate stress can have exceptions, regardless of whether they have subminimal words. In the presence of only one such language in my survey, the comparison with a metrical account remains purely theoretical. The predictions are as follows. Languages with antepenultimate stress can be analyzed as having trochees constructed from right to left, in conjunction with a rule assigning final extrametricality (Hayes 1995), as shown in 14a. In lexical exceptions with penultimate stress, extrametricality is exceptionally turned off (14b). As to lexical exceptions with final stress, an obvious analysis would be one in which extrametricality is turned off and a final catalectic mora or syllable is added (14c).

(14) a. regular antepenultimate stress . . . (ˈx x) ⟨x⟩
b. exceptional penultimate stress . . . (ˈx x)
c. exceptional final stress . . . (ˈx [x])

The prediction for exceptional penultimate stress is thus the same as in the present approach: it should be allowed in all languages with antepenultimate stress. Things are different for exceptions with final stress. It has been argued that catalexis is available only in languages with subminimal words. The metrical account thus predicts exceptional final stress to be ruled out in those languages that do not have subminimal words. The only language in my survey with antepenultimate stress, Macedonian, has subminimal words and is therefore uninformative with respect to this prediction.[32]

To sum up, I have shown that a foot-based metrical analysis is overly powerful in the class of languages with regular penultimate stress, in that antepenultimate exceptions can be derived in languages that do not have them and that—in the present account—are ruled out in these languages on principled grounds. Likewise, the metrical analysis of languages with final stress is less constrained than the present one, but in this case there are not enough data to reject one or the other analysis. For languages with antepenultimate stress, by contrast, the metrical analysis is more restrictive than the present proposal; again, the empirical data that would permit us to test the contrasting predic-

[32] Alternatively, one might want to argue that exceptional final stress is derived by turning off extrametricality and changing the foot form from trochaic to iambic. The availability of this latter analysis, though, is not unconditional either, since iambs occur only in languages with a quantity-sensitive stress rule (see Hayes 1987 and references cited therein). Under this analysis, then, Macedonian constitutes a problem, since it has quantity-insensitive stress and there are exceptions with final stress (for instance *me*ˈ*tro* 'metro').

tions are lacking. Finally, it is only for languages with initial stress that both accounts make the same predictions.

5. ON THE DIVISION OF LABOR BETWEEN PSYCHOLINGUISTICS AND THEORETICAL PHONOLOGY. The existence of lexical exceptions in languages with fixed stress raises two questions. The first question is in which type of stress systems exceptions may occur, and the second one is where in the word exceptional stress may fall. The acquisition-and-processing account allows for an answer to the first question, but it has nothing to say about the second one. That is, speakers of a certain language either encode stress and can hence store all kinds of lexical exceptions to their stress regularity, or they do not encode stress and therefore cannot store any exceptions at all. Metrical phonology, by contrast, is primarily concerned with the second question and has little to say about the first one. In the foot-based version of this theory, the fact that exceptional stress falls within a certain distance of the default position is accounted for by means of constraints on the number and size of constituents that can be marked as extrametrical or catalectic. As was shown in the previous section, the proposal that catalexis is available only in languages with subminimal words restricts the occurrence of exceptions that are derived by means of catalexis to exactly these languages. Exceptions whose analysis involves extrametricality, however, can freely be derived. All languages are therefore allowed to exhibit at least one type of exception. Alternative metrical theories are even less constrained. For instance, Idsardi 1992 and Halle & Idsardi 1995 derive stress by means of the placement of marks and boundaries and their projection on higher levels in a grid. Extrametricality and catalexis do not exist, but their effects are mimicked by means of edge marking. This marking is constrained in order to prevent exceptional stress from falling too far from the default position; the link between exceptions with final stress and the presence of subminimal words, though, is not made.

I would like to propose a division of labor between psycholinguistics and theoretical phonology, according to which the former is exclusively concerned with typological facts about the occurrence of lexical exceptions, and the latter with restrictions on the location of stress in exceptions. An integrative theory of lexical exceptions in languages with fixed stress should take both theories into account. Indeed, the attested patterns lie in the intersection of those that are admitted independently by the two theories. This is shown schematically in Figure 1.

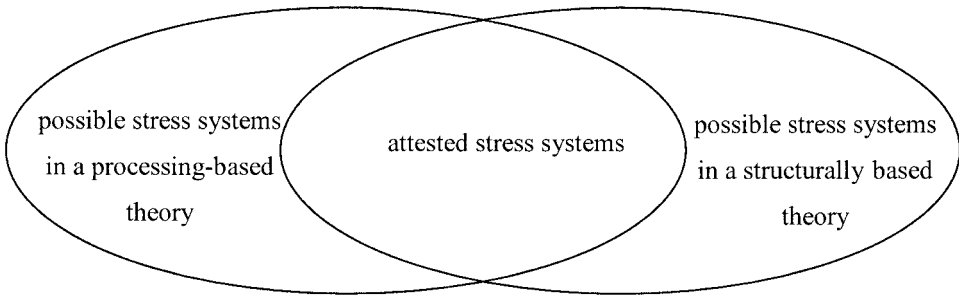

FIGURE 1. The relationship between a processing-based theory and a structurally based theory.

Under this view, both approaches are overly permissive. On the one hand, constraints on processing, which are themselves dependent on early language acquisition, act as a filter on the output of the phonological grammar. Among the possibilities generated by universal grammar they single out those systems that can be acquired by infants

and processed by adults. As a consequence, it is merely accidental that the absence of exceptions with final stress in one type of languages is accommodated independently by Kager (1995). More generally, to the extent that metrical phonology is not concerned with the types of languages in which exceptions can occur, the typological data presented in this article do not bear upon the question of which version of metrical theory is the most appropriate.

On the other hand, certain types of systems can be acquired by infants and processed by adults, but are excluded by the grammar. For instance, consider Polish, which has regular penultimate stress and exceptions with final and antepenultimate stress. Exceptions with preantepenultimate stress do not seem to occur, but there is no reason to think that Polish speakers have difficulties perceiving stress on the preantepenultimate syllable. But if the metrical analysis that excludes preantepenultimate stress due to restrictions on extrametricality is correct, exceptions with preantepenultimate stress can never enter the language. In particular, loanwords with this stress pattern would be predicted to be adapted in Polish to conform to the native pattern. One possibility is that stress is always regularized to the default penultimate pattern. Alternatively, its location might depend on which one of the last three syllables bears a secondary stress in the source word; secondary stress in the source language could be adapted into Polish as main stress. Whatever the precise nature of the loanword adaptation, this type of regularization is independent of limitations in the perception of non-native stress patterns. This is thus to be contrasted with the adaptation of stress in loanwords in, for instance, French: speakers of this language assimilate foreign words to their native stress pattern during perception, as evidenced by the fact that they have difficulties perceiving stress contrasts.[33]

6. CONCLUSION. In this article, I have shown that arguments from early language acquisition and adult speech perception can offer insight into typological facts. More specifically, I have argued that the model of Peperkamp & Dupoux 2002 for the prelexical acquisition of stress, via its consequences for adult speech perception, makes empirical predictions about the occurrence of lexical exceptions in languages with purely phonological stress. These predictions hinge on the assumption that speakers can store lexical exceptions only if they are able to perceive stress contrasts well, that is, if stress is encoded in the phonological representation of lexical items. This is summarized schematically in Figure 2.

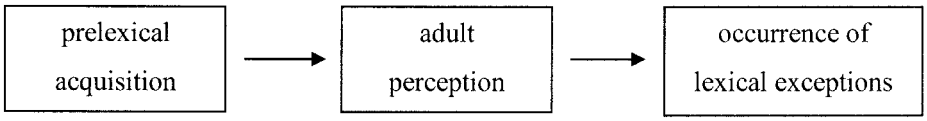

FIGURE 2. Implicational relations between early acquisition, adult speech perception, and the occurrence of lexical exceptions in languages with purely phonological stress.

A typological survey of fifty-one languages with purely phonological stress provided evidence for the present proposal. This survey indeed revealed a strong tendency for exceptions to be absent from languages in which stress is surface observable; according to the learning algorithm in Peperkamp & Dupoux 2002, it is exactly in these cases that the stress regularity can be inferred relatively early, leading to the absence of

[33] See Best 1994 for a model of perceptual assimilation and Peperkamp & Dupoux 2003 for the consequences of this model for loanword adaptations.

phonological encoding of stress in the mental lexicon. By contrast, exceptions were shown to be widespread in languages in which stress is not surface observable.

One caveat remains in order. Several languages with surface-observable stress, for example Finnish and Diyari, have complicated patterns of secondary stress that do not depend solely on rhythmic factors and that cannot be acquired prelexically. Finnish is especially interesting, since it has been established that native speakers of this language have difficulties perceiving stress contrasts. Indeed, the presence of nonrhythmic secondary stress not only poses a problem for Peperkamp and Dupoux's prelexical learning algorithm (2002)—how can infants remain sensitive to secondary stress once they have observed that main stress is predictable?—but it also seems to contradict the data about the perception of stress contrasts by adults. One could investigate the possibility that primary and secondary stress differ in their acoustic cues, and that the two types of stress are acquired and processed differently.

The present survey contains four languages for which a perception experiment has provided evidence that the encoding of stress in the phonological representation of words depends on the surface observability of stress. Indeed, speakers of French, Finnish, and Hungarian (all with surface-observable stress), but not those of Polish (with non-surface-observable stress), have difficulties in perceiving stress contrasts. Of course, more experimental evidence is needed to establish more firmly the links between the prelexical acquisition of stress, native speakers' perceptual capacities, and the occurrence of lexical exceptions in languages with a purely phonological stress rule. For instance, a referee observed that an alternative to account for the experimental perception data would be that speakers encode—hence, perceive—stress if and only if their language has purely phonological stress and no exceptions. French and Hungarian indeed have no exceptions and their speakers have difficulties perceiving stress contrasts, while the reverse holds for Polish. It appears necessary, therefore, to test the perception of stress by speakers of a language like Polish (that is, a language with penultimate stress and subminimal words that obscure the surface observability of stress), but without exceptions.[34] If speakers of such a language, like those of Polish, have no difficulties in perceiving stress contrasts, this would lend plausibility to Peperkamp and Dupoux's learning algorithm (2002), to the exclusion of the alternative hypothesis.

It would also be important to directly test the learning algorithm and assess the perception of stress by infants who acquire a language with surface-observable stress. My prediction is that these infants lose their sensitivity to stress contrasts before they have a lexicon. Notice that this line of research would equally permit the comparison of the present proposal with the alternative introduced above. Indeed, given that exceptions are often infrequent words of foreign origin, under the alternative account a very large lexicon would be needed in order to observe that stress is completely regular and hence need not be encoded. Consequently, the capacity to perceive stress contrasts well should not be lost before children are four years old and probably even later. A comparative experiment in which the perception of stress by French- and Spanish-acquiring infants is assessed is now under way.

Finally, the present proposal makes predictions about diachronic changes in situations of language contact. Consider an isolated language with a purely phonological stress rule and no exceptions. We can distinguish two cases. First, if the stress rule cannot be inferred by prelexical infants, then adult speakers will redundantly encode stress in

[34] Recall that the present survey contains four potential examples: Balantak (Busenitz & Busenitz 1991), Nengone (Tryon 1967), Piro (Matteson 1965), and Suriname Arawak (Pet 1979).

the phonological representation of lexical items and have no difficulties with the perception of stress contrasts. As soon as they come into contact with some foreign language with a different stress rule or with contrastive stress, they can thus integrate loanwords with an exceptional stress pattern. Provided a sufficiently large number of loanwords thus enters the language, stress can become contrastive. Second, if prelexical infants can infer the stress regularity, then adult speakers will have difficulties with the perception of stress contrasts. As long as stress remains surface observable, the stress pattern of foreign loans will be regularized to the native pattern, and the stress system will remain stable.

From the foregoing, it should be clear that an integrated approach of theoretical linguistics and experimental psycholinguistics can enlarge our understanding of what might and what might not be attested in natural languages. Further insights no doubt await such an integration.

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