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Why cross-linguistic frequency cannot be equated with ease of acquisition in phonology

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1 Introduction

In phonology, typological tendencies have often fed theories about the synchronic grammar of language users. For example, in the seminal work of Chomsky and Halle (1968), it is pointed out that a good description of the system in the language users' mind ought to reflect the fact that some sound changes or distributions are more likely than others. Thus, although both changes in examples (1) and (2) below involve the same number of features, the one in (1) is much more likely than the one in (2) (from Chomsky and Halle 1968:400, examples 1.a.i and ii in the original):

(1) i $\longrightarrow$ u
(2) i $\longrightarrow$ ɨ

Furthermore, some have argued that these tendencies are part of an innate linguistic module, such that more typologically attested phenomena may be easier for the language learner to acquire. For example, Stampe (1973) proposed that cross-linguistically common processes and those found in child language are the same, suggesting that cross-linguistic frequency and ease of acquisition may be equivalent. More recently, this position was expanded upon within the Optimality Theoretic framework (Smolensky 1996, Tesar and Smolensky 1998). In this work, the phonological grammar is represented by a set of ranked and violable constraints. Constraints are of two types, Markedness and Faithfulness. Faithfulness constraints are structured so as to maintain forms exactly as they exist in the input, while Markedness constraints are structured to minimize deviations from universal markedness, for example, by reducing syllabic complexity. Infants are assumed to have access to the full set of constraints that characterize all human languages. Within the Markedness set, constraints are ranked mirroring typological frequency. For instance, a constraint banning closed syllables (*CVC) would outrank one banning open syllables (*CV), given that CVC syllables are less common than CV ones in languages

	Adults	**Infants and children**
Production	Schane and Lane (1974) Wilson (2006)	Barlow and Gierut (1999)
Perception	Moreton (2006)	Saffran and Thiessen (2003) Seidl and Buckley (2005)

Table 1: Psycholinguistic evidence on the relationship between cross-linguistic frequency and ease of acquisition.

across the world. Given that language learners are professed to be born with this ranking, it must be easier to acquire phonological patterns that do not violate high-ranking constraints, from which follows that ease of acquisition is predicted directly from cross-linguistic frequency.

Some work in psycholinguistics seems to support the view that equates frequency with ease of acquisition, both for the developed grammar (adult grammar) and the developing one (infant and child grammar). Most of this work tests the prediction that cross-linguistically frequent distributions are easier to learn by exposing participants to a regularity and then testing their learning through tasks involving production and/or perception. Table 1, though not exhaustive, summarizes the studies that will be discussed in more detail below.

Previous results in production all support the hypothesis that highly frequent patterns are easier to learn and are reproduced in acquisition. Participants in an experiment in Schane and Lane (1974) were exposed to sequences of words presented as adjectives and nouns. For half the subjects, when the noun began with an onset, the final consonant of the adjective was deleted. The other half had to learn that the deletion of the final consonant of the adjective occurred before vowel-initial nouns. External sandhi rules in which a final consonant is deleted before consonant-initial words are very common in languages across the world, but final consonant deletion before vowels is unattested. Although all subjects learned both patterns by the end of the experiment, performance was much higher for those learning the frequent pattern.

Further support comes from Wilson (2006). Here, the task involved an interactive language game. In these experiments, subjects sat in front of a computer, which guided them through the study. In the training phase, the computer displayed the message "I say," and then played the "original," an unpalatalized pseudo-word. Immediately afterward, it would display the message "you say" and play the palatalized version of the pseudo-word. Crucially, the training stimuli were organized so as to train subjects on some environment and targets and then test their generalization to untrained environments or tar-

gets. For example, in two conditions, some subjects were trained only with stops followed by /e/ while others heard only /i/ as environment in which the palatalization occurred. The variable of interest, therefore, was to see whether the pattern of generalization to the untrained vowel repeated typological implications: palatalization before the front mid vowel is rarer than that before the front high vowel, and when it does occur, it implies palatalization before /i/ but not vice versa. In the testing phase, the displays remained unchanged, and the computer played the unpalatalized version, whereas subjects had to produce the 'game' word. Results confirmed the hypothesis that the extension of palatalization would follow cross-linguistic patterns, so that the tendency in subjects trained on /e/ to palatalize before /i/ was more robust than the tendency to palatalize before /e/ by subjects trained with /i/.[1]

Acquisition of the first language has also been claimed to mimic cross-linguistic tendencies. Barlow and Gierut (1999) point out that children's simplification of syllabic structures proceeds from more marked, less frequent templates to less marked, more common ones. Thus, children tend to produce CV syllables for CVC ones, which the authors argue follows from children's ranking markedness constraints, such as NoCoda, more highly than faithfulness constraints and not from physical constraints.

On the other hand, results of studies focusing on perception do not provide such support to the hypothesis that acquisition replicates cross-linguistic tendencies. For example, Moreton (2006) reports on adult subjects' learning of three different phonotactic constraints, which varied in cross-linguistic frequency. In his first experiment, learning of constraints varying in frequency was assessed. One set of participants had to learn a "height-height" constraint, in which the height of one vowel depended on the height of the preceding vowel (a fairly common harmonic or disharmonic process, which is also phonetically grounded—that is, it might be related to a perceptual bias); the other set of participants was exposed to a "height-voice" distribution, in which the height of a vowel depended on the voicing of a previous consonant (an infrequent process cross-linguistically, although, as with the height-height pattern, phonetically grounded). After a period of brief exposure, participants listened to pairs of words, one following the familiarized pattern and the other violat-

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[1]It must be noted, however, that not all the results this study found follow cross-linguistic tendencies. For example, in the condition where /e/ was the training vowel, palatalization was also extended to /a/ (and in spite of the fact that the training set included examples of /a/ where the 'game' word was *not* palatalized). Therefore, perhaps a better explanation takes into account the distribution of vowels in the phonological system, such that if the training vowel is at an edge (like /i/) there will be less generalization than in the case where the training vowel is in the middle (like /e/).

ing it. Participants had to choose which one seemed more similar to the words presented during the familiarization. Performance was much higher for the frequent pattern, that of "height-height," and since the phonetic basis for both rules was the same, an explanation based on cross-linguistic frequency might seem attractive. However, this conclusion can be challenged from the point of view of the phonological complexity of the patterns involved. Specifically, the "height-height" pattern is simpler in that it establishes a relationship between like sounds, whereas "height-voice" requires noticing a regularity among different types of sounds, vowels and consonants. In order to test this alternative explanation, the constraint used in the second experiment required consonants from adjacent syllables to agree in voicing, a constraint that is unattested as well as phonetically unlikely. Learning was significantly better in the height-height and voice-voice conditions as compared with the height-voice condition. Moreton therefore concludes that frequency in the world's languages is dependent both on the phonetic precursors of a sound change (that is, how perception and production might impact the likelihood of a change) and on other cognitive biases, namely phonological complexity. On the other hand, these results suggest that cross-linguistic frequency cannot predict ease of learning in adults, given that the frequent 'height-height' and the unattested 'voice-voice' elicited similar performances. In addition, just because such duality of bias exists for adult learners does not mean that the same duality, and certainly the same weighting, of bias exists for first language learners.

It might be argued that adult subjects might have turned off their original frequency biases after prolonged exposure to their native language. If so, one might be able to find such biases in infants. Seidl and Buckley (2005) argue that this is not the case. In this study, 9-month-old infants were familiarized with either a common or an uncommon phonotactic pattern. Half the infants heard CVCV pseudo-words in which the intervocalic consonant was always voiced, while for the other half it was voiceless. Infants were then tested on legal (that followed the same constraint as in familiarization) and illegal (that violated the phonotactic constraint) items. In this adaptation of the Head-Turn Preference procedure to artificial grammar learning, used by e.g. Saffran and Thiessen (2003), successful learning is shown by significantly different looking times to illegal and legal items. Although the authors found no advantage for the common intervocalic voicing pattern, the design may be criticized on two counts. First, it could be the case that the length of familiarization (three minutes) led to a ceiling effect, whereby the cross-linguistic frequency effects would be hidden. Second, their test items included consonants used in familiarization as well as novel ones. Thus, it could be the case that infants were simply responding to the fact that illegal items were all novel, whereas legal

ones were, from a certain perspective, more similar to the familiar ones.

Furthermore, some evidence in favor of artificial grammar learning co-inciding with cross-linguistic tendencies comes from Saffran and Thiessen (2003). Eight-month-old infants were familiarized with pseudo-words dis-playing a phonotactic regularity that concerned a phonetic and phonologically natural class (such as voiceless stops, in Experiment 2) or an arbitrary class (e.g. /p, d, k/, in Experiment 3). When infants in the phonetic class condition showed evidence of learning and those in the arbitrary condition did not, the authors pointed out that this might be related to the fact that phonotactic pat-terns and phonological processes affecting natural classes are more common than those that affect an arbitrary set of sounds. On the other hand, if infants are sensitive to phonological complexity, this pattern of results can be inter-preted as evidence that a rule on an arbitrary or disjoint set of sounds is more costly to learn than one on a natural class. We cannot conclude, at least from this study, which of the two factors (cross-linguistic frequency or phonological complexity) underlies infants' failure to learn in Experiment 3.

In conclusion, studies with adults and children using production tasks show learning that follows cross-linguistic tendencies. It can be argued, how-ever, that cross-linguistic frequencies are affected by the tendencies of the production system, as is learning in these tasks, so that results are uninter-pretable due to the presence of that lurking variable. Studies on perception in adults show an effect of phonological complexity that may override cross-linguistic frequency effects, while previous studies with infants do not yield clear evidence on the matter. For this reason, we decided to design an experi-ment that addressed the shortcomings of previous infant studies on this topic. We reduced the familiarization time in comparison with Seidl and Buckley (2005) to prevent ceiling effects, and we used novel segments only in testing, so that learning can only be interpreted as a response to the *abstract* constraint learned, and not to novelty effects. Our objective was to assess whether cross-linguistic frequency predicts ease of acquisition above and beyond phonologi-cal complexity by comparing learning of two phonotactic patterns whose pho-netic bases had been matched.

2 Experiment

In this experiment, 7-month-old infants listened to a large set of pseudo-words whose onset belonged to either the class of oral and nasal stops or to the group-ing of nasals and fricatives. These two sets of sounds are matched first because they occur as phonologically active groupings almost equally frequently in the

languages sample of Mielke (2004, 2005) and second because they both have a phonetic basis. As to the first, Mielke (2004) reviewed the phonologies of about 500 languages, and found that, among those in which nasals, fricatives and stops were involved in some process, nasals and fricatives pattern together to the exclusion of stops in about 45% of the cases (including languages such as Korean and Russian) while stops and nasals pattern together to the exclusion of fricatives in the remaining 55% (e.g. in Spanish and Comanche). Second, there are phonetic reasons why these three sets of sounds may be paired thus. Nasals and stops share an articulatory gesture of complete closure in the vocal cavity, and have a similar acoustic structure, as reflected by the fact that they use the same acoustic cues for place of articulation (Kurowski and Blumstein 1984). Nasals and fricatives are similar articulatorily because in neither is the airflow completely interrupted. Acoustically, nasals and fricatives tend to be, among the consonants, longer and louder (which is reflected in the fact that they serve as syllabic nuclei more often than stops do), as well as structurally similar in that voiceless nasals can be likened to fricatives while voiced fricatives may pattern like nasals (Ohala and Ohala 1993).

The two patterns used in familiarization were thus matched in cross-linguistic frequency and phonetic bases. However, only the nasals and stops grouping is phonologically simple, given that, according to phonological theory, nasals and fricatives do not form a natural class. Following Moreton (2006), we can predict that phonologically simple and phonetically grounded patterns will be frequent across languages. One may further predict that patterns that lack one of these characteristics will tend to be more infrequent.

2.1 Method

We used a modified version of the Head-Turn Preference Procedure similar to that used in Saffran and Thiessen (2003), so that infants in this study were familiarized with a set of pseudo-words displaying a phonotactic regularity. They were then tested on items that either followed (legal items) or broke (illegal items) that regularity. The dependent measure during the presentation of these items is orientation, such that statistically significant orientation preference provides evidence for learning of the regularity.

2.1.1 Participants

Twenty-four 7-month-old (M = 6.92, range 6.5-7.2; 9 female) infants were tested. A further 13 infants were tested whose results are not reported for the following reasons: 3 for being more than 4 weeks premature and/or having

a birth-weight below 6 pounds; 6 for fussing or crying; 2 for being exposed to languages other than English more than 20% of the time; and 2 for having looking times for difference scores (illegal–legal) more than 2.5 standard deviations above or below the mean.

2.1.2 Stimuli

During the familiarization and testing period, infants listened to monosyllabic CVC words, in which the vowel was one of the set /i, a, ɔ, u/ and the consonant could be any phonotactically legal consonant of English (that is, /m, n, ŋ, l, r, s, z, θ, f, v, ʃ, tʃ, p, b, t, d, k, g/). As mentioned above, the initial consonant of the word displayed the regularity that infants were required to learn. In order to ensure that responses were not simply biased by the presence of some especially attractive phoneme, a counterbalanced design was adopted, by which half the infants in each condition were familiarized with a group of consonants that the other half were tested on and vice versa. Sixty items were generated randomly, though minimizing variation across conditions and orders. Of those sixty items, 57 were presented during familiarization for a total exposure time of 1 minute and 40 seconds.

The remaining three items in each order and condition were reserved for testing. During testing, infants heard three pseudo-words with fricative onsets, which were illegal for the infants familiarized with stops and nasals (S&N), but legal for those exposed to the fricatives and nasals (F&N) pattern, and three pseudo-words with stop onsets, legal for the S&N group but illegal for the F&N one. Furthermore, we wanted to make sure that the response pattern was not just a result of hearing novel onsets, but truly the result of learning of an abstract class. For that reason, infants heard only novel onset phones during testing, those used for familiarization of the other order. Table 2 summarizes the onsets that infants heard during familiarizations (columns) and testing (rows), and what legality value each of the testing onsets had according to every familiarization condition and order.

2.1.3 Apparatus and Procedure

Infants were familiarized and tested using a modified version of the Headturn Preference Procedure (Jusczyk and Aslin 1995, Kemler Nelson et al. 1989). In this procedure, the infant is seated on a caregiver's lap in the middle of a small three-sided enclosure. The sides of the enclosure are made of white pegboard panels of about 4.5 feet in height, and white curtains hang from the ceiling to meet the pegboard. The pegboard panels were backed with cardboard ex-

Order	Familiarization A		Familiarization B	
Condition	Natural	Arbitrary	Natural	Arbitrary
Testing	/m, n, t, g/	/m, n, f, z/	/m, n, b, k/	/m, n, v, ʃ/
/t, g/	–	–	Legal	Illegal
/f, z/	–	–	Illegal	Legal
/b, k/	Legal	Illegal	–	–
/v, ʃ/	Illegal	Legal	–	–

Table 2: Onsets in pseudo-words presented in each Condition and Order

cept for three openings on the front panel. Through these, a camera records the session and the experimenter (and sometimes a second observer) observes the infant's headturns. Below the opening for the camera, approximately at the infant's eye level, there is a green light. On each side of the booth there are red lights, behind which Cambridge Soundworks Ensemble II speakers are placed. These lights are made more salient by dimming the overhead light. The experimenter signals the infant's orientation towards the front or the sides through a button box to the Macintosh G4 computer controlling the experiment. This computer controls the presentation of the speech samples and the randomization of the side of presentation, and records the observer's coding of the infant's orientation. All the equipment as well as the experimenter are not visible to the infant. Finally, both the caregiver and the experimenter are blind to the auditory stimuli that the infant listens to through the presentation of masking music on Peltor Aviation Headset 7050 headphones.

Each trial begins when the green light at the front flashes to attract the infant's attention to the center of the booth and to situate her in an unbiased position with respect to the side lights. When the infant orients towards the front, the green light is extinguished and one of the side lights begins to flash. Orientation toward these side lights is recorded for as long as the infant faces the flashing light or within a thirty degree range of it. If the infant turns away for more than two seconds, the side light is turned off and the front light begins flashing again, starting the process over. If the infant turns away for less than two seconds, the light is not extinguished until the audio file ends, but the time that the infant is not oriented toward that side is not counted in the overall orientation time.

As in the traditional Headturn Preference Procedure, the speech sample is presented through only one side speaker and only for as long as that side light is on during the test phase. Our procedure differs from the traditional one during familiarization, when the lights are contingent on the infant's looking,

but presentation of speech is not. Instead, the familiarization audio file is continuously played through both side speakers at the same time until the file finishes. The testing phase, however, follows exactly the traditional procedure where both sound and light are contingent on the infant's looks.

2.2 Results

An ANOVA with Condition (Stops and Nasals, Fricatives and Nasals) and Order (A, B) as factors and difference looking times (illegal–legal) as the dependent measure showed a main effect of Condition ($F(1,23) = 7.26$, $p < 0.02$), no effect of Order ($F(1,23) < .04$), and no interaction between Order and Condition ($F(1,23) < .14$). For this reason, we collapsed across orders and calculated *t*-tests comparing orientation to legal versus illegal items within each condition. For the Stops and Nasals condition, there was a significant effect of Test item type (legal, illegal), $t(11) = 3.06$, $p < .01$, with longer orientation times to illegal items. Ten out of twelve infants in this condition followed this pattern. In the Fricatives and Nasals condition, there was no effect of Test item type, $t(11) = 1.39$, $p > .19$. Only five out of twelve infants oriented longer to illegal test items. Means and standard deviations can be found in Table 3 and average looking times are shown in Figure 1.

Condition	Illegal	Legal
Stops and Nasals	12.19 (6.16)	9.08(5.17)
Fricatives and Nasals	9.71 (4.18)	11.94(6.4)

Table 3: Mean orientation time by Condition and Test item type, standard deviations in parentheses.

2.3 Discussion

The present results provide evidence to reject the null hypothesis that phonological complexity has no effect on two phonetically and statistically matched rules. On the contrary, it appears that even though the two patterns used were matched on the basis of acoustic cues and cross-linguistic frequency, phonological complexity still impacted infants' learning. In other words, only the infants exposed to the natural class were able to abstract the phonotactic pattern and correctly distinguish test items whose onset belonged to the familiar class from those whose onset did not belong to the class. Infants in the other condition were not able to learn the phonotactic pattern, in spite of the fact that
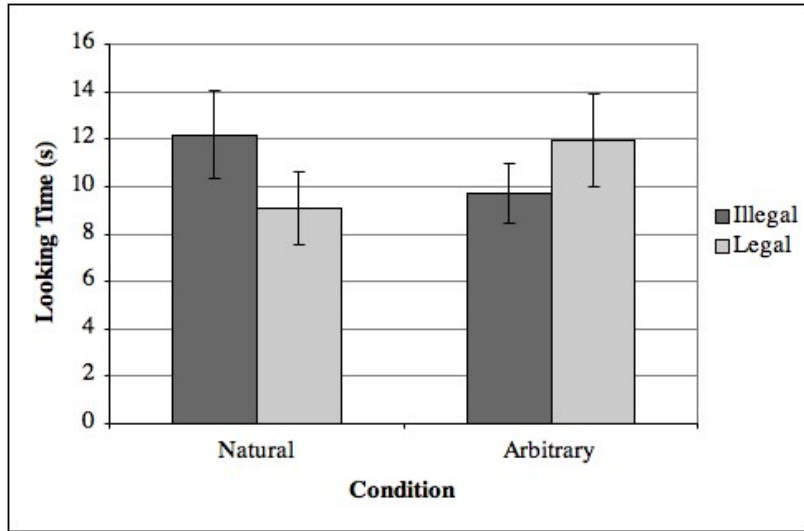
Figure 1: Average looking time in seconds to legal versus illegal test items. Error bars represent standard error.

phonological patterns and processes affecting nasals and fricatives, to the exclusion of stops, are frequent in Mielke (2004, 2005)'s sample. These results are not compatible with the hypothesis that cross-linguistic frequency predicts ease of acquisition, but they do provide evidence for a correlation between ease of acquisition and phonological complexity.

3 Conclusions

It has been commonly assumed that cross-linguistic frequency and ease of acquisition mirror each other, so that common patterns are easy to learn and those that are hard to learn tend to be uncommon across languages. However, 7-month-old infants failed to learn a common pattern, suggesting that ease of acquisition may not be a direct reflection of cross-linguistic frequency. Furthermore, the fact that this pattern is common in the world's languages, despite its difficulty for young infants, suggests that other factors may be conspiring to account for its frequency. First, it is possible that harder, more complex patterns are indeed learnable after extended exposures; therefore, had we familiarized infants over a more extensive period of time, we might have found

different results. Another possible solution to the paradoxical frequency of the pattern in the face of infants' difficulty to learn it may be that while 7-month-olds possess a complexity bias, other learners, who have more of an effect on language change, do not. Indeed, sociolinguistic investigations reveal that the impetus of language change comes from young adults (Labov 1972, 1994), and it still remains to be seen whether these patterns are equally difficult for this population or even for young children. If this were the case, then ease of acquisition at the early age tested in this study may have little impact on cross-linguistic frequency. A third hypothetical solution to this paradox is that covert phonetic factors in the languages in which the nasal and fricative pattern is attested add to the perception and subsequent learning of these patterns. For example, in might be that Korean nasals have more in common with fricatives acoustically than the English nasals and fricatives that we tested on do. Thus, language-specific phonetics may interact with phonological learning in interesting ways.

Regardless of how the results of this study bear on the question of cross-linguistic frequency of phonological patterns, they demonstrate that featural classes are learnable by infants, although not all classes in these stimuli are acquired with equal ease. Finally, it is phonological complexity, rather than cross-linguistic frequency, that correlates with ease of learning in infancy. Thus, even frequent sound groupings may be hard to learn at a young age when they are phonologically complex.

References

Barlow, Jessica A., and Judith A. Gierut. 1999. Optimality theory in phonological acquisition. *Journal of Speech, Language, and Hearing Research* 42:1482–1498.

Chomsky, Noam, and Morris Halle. 1968. *The Sound Pattern of English*. New York: Harper and Row.

Jusczyk, Peter W., and Richard Aslin. 1995. Infants' detection of sound patterns of words in fluent speech. *Cognitive Psychology* 29:1–23.

Kemler Nelson, Debbie, Kathy Hirsh-Pasek, Peter W. Jusczyk, and Kimberly Wright Cassidy. 1989. How prosodic cues in motherese might assist language learning. *Journal of Child Language* 16:55–68.

Kurowski, Kathleen, and Sheila E. Blumstein. 1984. Perceptual integration of the murmur and formant transitions for place of articulation in nasal consonants. *Journal of the Acoustical Society of America* 76:383–390.

Labov, William. 1972. *Language in the Inner City: Studies in the Black English Vernacular*. Washington: Washington Center for Applied Linguistics.

Labov, William. 1994. *Principles of Linguistic Change*. Cambridge, MA: Blackwell.

Mielke, Jeff. 2004. The Emergence of Distinctive Features. Doctoral Dissertation, Ohio State University.

Mielke, Jeff. 2005. Ambivalence and ambiguity in laterals and nasals. *Phonology* 22:169–203.

Moreton, Elliott. 2006. Phonotactic learning and phonological typology. Talk presented at NELS 37, University of Illinois Urbana-Champaign, October 14.

Ohala, John, and Manjari Ohala. 1993. The phonetics of nasal phonology: Theorems and data. In *Nasals, Nasalization, and the Velum. Vol. 5: Phonetics and Phonology Series*, ed. M. K. Huffman and R. A. Krakow, 225–249. San Diego, CA: Academic Press.

Saffran, Jennifer, and Eric D. Thiessen. 2003. Pattern induction by infant language learners. *Developmental Psychology* 39:484–494.

Schane, Sanford B., and Harlan Lane. 1974. On the psychological reality of a natural rule of syllable structure. *Cognition* 3:351–358.

Seidl, Amanda, and Eugene Buckley. 2005. On the learning of arbitrary phonological rules. *Language Learning and Development* 1:289–316.

Smolensky, Paul. 1996. The initial state and 'richness of the base' in optimality theory. Ms., Baltimore, MD: Department of Cognitive Science, Johns Hopkins University. [Available on Rutgers Optimality Archive, ROA-154].

Stampe, David. 1973. *A Dissertation on Natural Phonology*. New York: Garland.

Tesar, Bruce, and Paul Smolensky. 1998. Learnability in optimality theory. *Linguistic Inquiry* 29:229–268.

Wilson, Colin. 2006. Learning phonology with a substantial bias: An experimental and computational study of velar palatalization. *Cognitive Science* 30:945–982.

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