SYNOPSIS A typological study of place assimilation shows that nasals are more likely to assimilate in place than oral consonants (Jun 1995). Jun argues that this typological asymmetry derives from a difference in perceptibility of [place] in nasals and in oral stops. Since the place contrasts in nasals are perceptually weaker than the place contrasts in oral stops speakers are more willing to neutralize the former. However, evidence for the weaker perceptibility of the place contrasts in nasal consonants in the previous phonetic and psycholinguistic research is mixed (Hura et al. 1992; Mohr & Wang 1968; Pols 1983; Winter 2002). To settle this debate, this paper reports a similarity judgment experiment and an identification experiment in noise, which both support the lower perceptibility of the place constrasts in nasals. The results lend support to Jun's idea that the asymmetry in place assimilation may result from a difference in the perceptibility of the place contrasts.

EXPERIMENT I: METHOD The first experiment was a similarity judgment study. The three conditions were nasals, voiced stops, and voiceless stops. For each condition, all three combinatorial possibilities of different places were included (i.e. labial vs. coronal, labial vs. dorsal, coronal vs. dorsal). Our stimuli consisted of [am-an], [am-aŋ], [an-aŋ], [ab-ad], [ab-ag], [ad-ag], [ap-at], [ap-ak], and [at-ak]. Two native speakers of English produced these tokens 10 times in a sound-attenuated booth. Four best tokens were selected from each speaker. To avoid similarity rating being affected by irrelevant phonetic dimensions, their speech was re-synthesized with a flat pitch contour at 250Hz and the peak amplitude was adjusted to 0.7 by Praat. Pairs of sounds were created by concatenating two sounds with 500 ms ISI. One pair of sounds was presented to our listeners per trial, and they were asked to judge the similarity of the pair using a 5-point-scale: 1. "almost identical", 2. "very similar", 3. "similar", 4. "not so similar", 5. "completely different". Each token was repeated 7 times, so that each pair was presented 56 times (2 speakers * 4 tokens * 7 repetition). Nineteen native speakers of English participated in this experiment.

EXPERIMENT I: RESULT AND DISCUSSION

Table 1: The average similarity rating scores.

	Nasals	Voiced stops	Voiceless stops
Labial vs. coronal	2.69	3.64	3.98
Labial vs. dorsal	2.49	3.67	4.00
Coronal vs. dorsal	2.57	3.60	4.02

Table 1 shows the average similarity ratings (in which lower numbers mean higher similarity judgments). A general mixed-model shows that nasal pairs were judged to be more similar than voiced stop pairs ($t = 12.62, p < .001$), and voiced stops were judged to be more similar than voiceless stops ($t = 4.42, p < .001$).

EXPERIMENT II: METHOD The next experiment was an identification task under noise. The stimuli consist of [am, an, aŋ, ab, ad, ag, ap, at, ak]. To mimic the real communicative situations, we used cocktail party noise. The current experiment used three S/N ratios: -6dB, -12dB, and -15dB where the signal dB was kept at the average of 60dB RMS amplitude. In order to make the results comparable to the previous two experiments, for each stimulus, possible responses given were binary. For example, for [am], one possible response was [am] or [an] and the other was [am] or [aŋ]. This format allowed us to calculate the perceptual distance between any two minimal pairs differing in place. Thus, in the experiment phase, each sound was presented followed by two visual cues. The visual cue for [ŋ] was "ng". Both possible orders of the visual cues were included. Twenty-four native speakers of English participated in this study. Five tokens of each sound were presented with two orders of visual cues. We calculated d' as a measure of a perceptual distance between two sounds.

EXPERIMENT II: RESULTS AND DISCUSSION

Table 2: The average d' values.

-6dB	Nasals	Voiced stops	Voiceless stops
Labial vs. coronal	0.62	0.55	1.99
Labial vs. dorsal	0.39	1.29	1.01
Coronal vs. dorsal	0.47	1.33	2.41
-12dB	**Nasals**	**Voiced stops**	**Voiceless stops**
Labial vs. coronal	0.24	0.36	2.07
Labial vs. dorsal	0.34	0.86	1.03
Coronal vs. dorsal	0.39	0.87	2.37
-15dB	**Nasals**	**Voiced stops**	**Voiceless stops**
Labial vs. coronal	0.23	0.13	1.61
Labial vs. dorsal	0.04	0.62	0.60
Coronal vs. dorsal	-0.03	0.78	1.90

Table 2 shows the average d' values for each comparison in each S/N ratio condition (where higher d' values correspond to the higher perceptibility between two sounds). A general mixed model comparing nasals and voiced stops shows that their d' values are different ($t = 5.87, p < .001$). The difference between voiced stops and voiceless stops was also significant ($t = 10.29, p < .001$). A follow-up experiment in which we placed the stimuli in a pre-consonantal position shows the same hierarchy.

GENERAL DISCUSSION Both of our experiments support the following perceptibility hierarchy: nasal < voiced stop < voiceless stop. Our results thus support Jun's (1995) hypothesis that nasal place contrasts are perceptually weaker than oral stop place contrasts. However, we also find other perceptual asymmetries which are not necessarily reflected in phonological patterns. For example, we consistently find that voiceless stop place contrasts are more salient than voiced stop place contrasts, but as far as we know, this difference is not reflected in phonology. In Experiment II, we find that pairs of voiceless stops involving labials and dorsals show lower d' values; however, non-coronal consonants are less likely to undergo place assimilation than coronals (Jun 1995). Taken together, our experiments show that perceptibility differences in nasal vs. oral consonants do underlie the asymmetrical phonological patterns (Jun 1995, Steriade 2001), but that not all perceptibility differences can be reflected in phonology (Kochetov and So 2007).