Language universals at birth

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The evolution of human languages is driven both by primitive biases present in the human sensorimotor systems and by cultural transmission among speakers. However, whether the design of the language faculty is further shaped by linguistic biological biases remains controversial. To address this question, we used near-infrared spectroscopy to examine whether the brain activity of neonates is sensitive to a putatively universal phonological constraint. Across languages, syllables like *blif* are preferred to both *lbif* and *bdif*. Newborn infants (2–5 d old) listening to these three types of syllables displayed distinct hemodynamic responses in temporal-perisylvian areas of their left hemisphere. Moreover, the oxyhemoglobin concentration changes elicited by a syllable type mirrored both the degree of its preference across languages and behavioral linguistic preferences documented experimentally in adulthood. These findings suggest that humans possess early, experience-independent, linguistic biases concerning syllable structure that shape language perception and acquisition.

human newborns | speech perception | NIRS | sonority | phonology

It is well known that the design of human language is shaped by both cultural and biological constraints (1, 2). However, whether those biological constraints are limited to sensorimotor restrictions on the production and perception of language, or whether they also include linguistic principles, remains controversial. To address this question, we examine the sensitivity of newborn infants to a putatively universal linguistic principle that defines syllabic structure. Our results suggest that precursors of this universal principle are active in the newborn brain. These findings are consistent with the presence of biological linguistic constraints on language acquisition.

Phonology is pivotal to the design of the human language faculty (3–6). Not only is it present in every language—spoken or signed (7)—but distinct languages appear to share common phonological restrictions. One such restriction concerns the internal structure of syllables. Across languages, syllables like *blif* are more frequent than syllables like *lbif* (8, 9). These restrictions are attributed to a putatively universal constraint on syllable structure, known as the Sonority Sequencing Principle (SSP; ref. 10). Sonority (s) is a scalar phonological property that correlates with the salience of phonological elements (e.g., loudness of speech sounds; ref. 11). Least sonorous are obstruents (e.g., /t/, /b/, /f/), with a sonority level of 1 (s = 1), followed by nasals (e.g., /m/, /n/, s = 2), liquids (e.g., /l/, /r/, s = 3), glides (/w/, /j/, s = 4), and finally vowels, which are the most sonorant phonemes of all (s = 5). The SSP states that syllables maximize the sonority distance (Δs) from their margins to their nucleus—the larger the sonority distance, the better formed the syllable is (10). In syllables like *blif*, there is a rise in sonority from the obstruent (*b*) to the liquid (*l*) (Δs = 2), whereas in *lbif*, there is a sonority fall (Δs = −2). In between these two extremes are syllables such as *bdif*, where the two initial consonants (two obstruents) exhibit a sonority plateau (Δs = 0). Under the hypothesis that languages favor a large distance in sonority in onset position, syllables like *blif* (Δs = 2) are expected to be better formed than *bdif* (Δs = 0), which, in turn, are expected to be better formed than *lbif* (Δs = −2). The frequency of those syllables across languages is consistent with this prediction (12). Not only are syllables like *lbif* infrequent—they are less frequent than either *bdif* or *blif*—but languages that tolerate such syllables tend to also exhibit their better-formed counterparts (i.e., *bdif*, *blif*) (8, 12).

Experimental research has further shown that the SSP modulates the perception of syllables by individual speakers. As the syllable structure becomes worse formed (as defined by the SSP), people tend to systematically misidentify the syllable. For example, people tend to misidentify syllables such as *lbif* (e.g., as *lebif*), they are less likely to misidentify *bdif*, and least likely to misidentify *blif*. This phenomenon has been documented in numerous languages with both isolated syllables [e.g., English (12–14), French (15), Hebrew (16), Korean (17)] and continuous artificial speech (18). Crucially, these effects occur even if the specific syllables under investigation are unattested in the native language of participants (12–18). These findings open up the possibility that the SSP might not be induced from linguistic experience. Nonetheless, these results are silent as to how the SSP arises in the course of development—whether such restrictions are active at birth, or whether their emergence is triggered by experience with the articulatory production of spoken language.

Human newborns provide a superb opportunity to investigate the ontogenetic origin of biases like the SSP*. Hearing newborns process speech preferentially with the left hemisphere (21),

Significance

It is well known that across languages, certain structures are preferred to others. For example, syllables like *blif* are preferred to syllables like *bdif* and *lbif*. But whether such regularities reflect strictly historical processes, production pressures, or universal linguistic principles is a matter of much debate. To address this question, we examined whether some precursors of these preferences are already present early in life. The brain responses of newborns show that, despite having little to no linguistic experience, they reacted to syllables like *blif, bdif,* and *lbif* in a manner consistent with adults' patterns of preferences. We conjecture that this early—possibly universal—bias helps shaping language acquisition.

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*Some researchers have argued that sonority is mostly a phonetic—as opposed to phonological—construct (19, 20). Our present results do not speak to this debate, because we have no basis to determine whether responses of infants reflect phonetic or phonological preferences. A purely phonetic account, however, fails to capture the adult data (e.g., the emergence of sonority effects with printed materials; ref. 14), suggesting that sonority effects might be partly phonological.

distinguish between languages based on their rhythmic properties (22), learn precociously the properties of intonation of their maternal language (23), and discriminate phonemic changes in syllables despite speaker variability (24). Moreover, by 4 mo of age, newborns exhibit phonological processing in left temporal brain areas, as evidenced by their enhanced sensitivity to phonetic changes that cross phonemic boundaries (25). These early dispositions suggest that some phonological knowledge is already in place in the first days after birth. Here, we asked whether newborn brains display precursors of the SSP. More specifically, we measured hemodynamic activity of healthy newborn infants during passive listening of speech items by using functional near-infrared spectroscopy (NIRS; refs. 26–28). Of interest is whether their hemodynamic responses reflect the syllable preferences predicted by the SSP.

Results and Discussion

Experiment 1 explored whether the brains of newborns react differentially to syllables that are well- or extremely ill-formed, as defined by the SSP. Twenty-four healthy newborns (mean age = 2.9 d, SD = 0.83) listened to blocks of $C_1C_2VC_3$ (C: consonant, V: vowel) syllables displaying either a sonority rise or a sonority fall between C_1 and C_2 (e.g., *blif* and *lbif*, respectively; see Table S1 for the full list of syllables). Syllables in both conditions were statistically undistinguishable in terms of average pitch, intensity, duration, and number of feature changes between C_1 and C_2. Because of their role in neonatal speech perception (21), we concentrated our analysis on bilateral temporal-perisylvian areas. Additionally, our NIRS probes allowed us to record bilateral frontoparietal cortex, which has been linked to the processing of suprasegmental properties of speech (29) (Fig. 1). Fig. 2*A* presents results for both oxyhemoglobin and deoxyhemoglobin, and all regions of interest. We found significant differences between conditions in oxyhemoglobin concentrations in both left temporal [$t(22) = 2.70$, $P = 0.04$] and right frontoparietal [$t(21) = 2.97$, $P = 0.029$] areas (all P values are corrected according to the Holm–Bonferroni procedure; see also Table S2 for all statistics including uncorrected P values). In both areas, well-formed syllables elicited lower oxyhemoglobin concentrations than ill-formed syllables. As in previous research with newborn infants (27), deoxyhemoglobin concentrations did not differ significantly between conditions (all uncorrected P values >0.33).

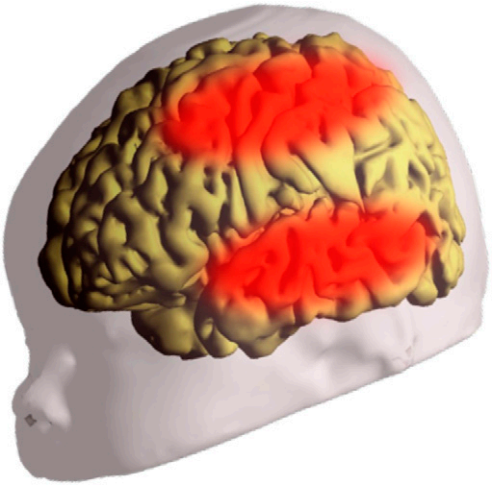

Fig. 1. NIRS probes were positioned on the heads of newborns so as to cover two regions of interest (ROIs) on each brain hemisphere. The inferior ROIs correspond roughly to temporal lobe and perisylvian areas, whereas the superior ROIs correspond to frontoparietal areas. Because the NIRS probes have a fixed size, the variability in head size and shape of newborns prevents precise scalp/brain mappings.

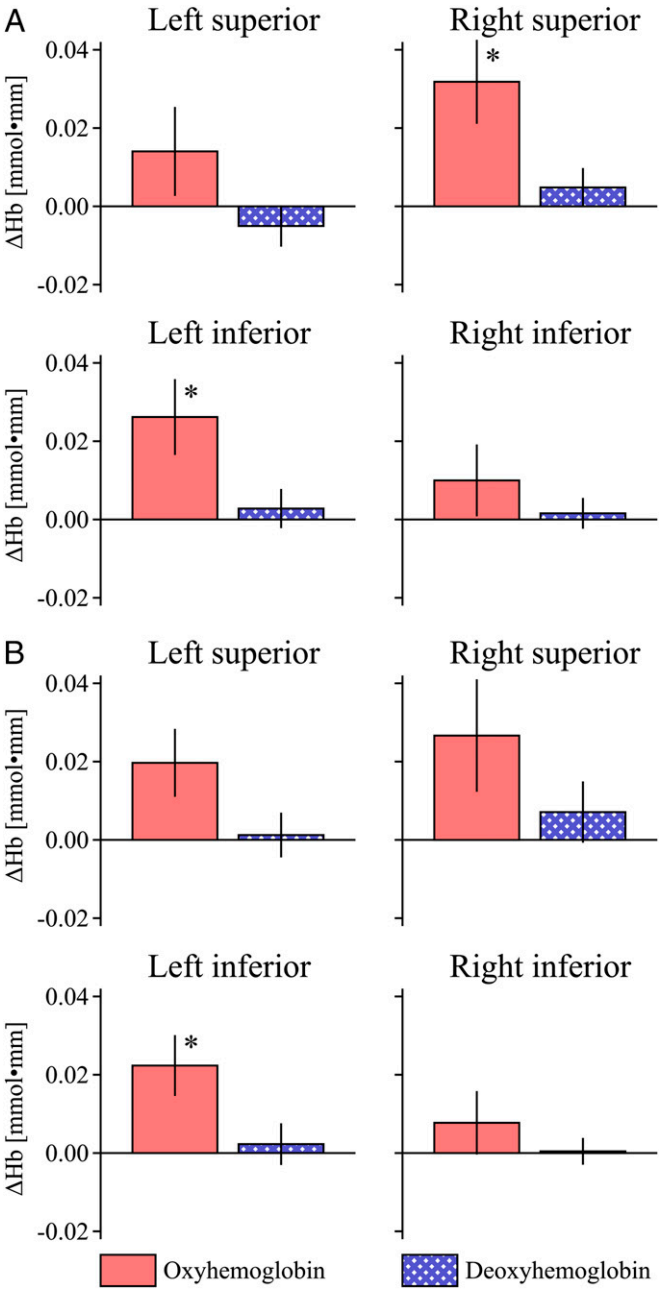

Fig. 2. Differences in concentration changes (ill-formed minus well-formed) for both hemoglobin species and all four ROIs. (*A*) Experiment 1 ($n = 24$), contrasting sonority rises and falls (e.g., *blif* vs. *lbif*). (*B*) Experiment 2 ($n = 24$), contrasting sonority rises and plateaus (e.g., *blif* vs. *bdif*). *$P < 0.05$ (Holm-Bonferroni corrected).

These results show that newborn brains distinguish syllables that obey the SSP from syllables that violate it. To do so, newborns must have abstracted a common structure from each syllable type, notwithstanding huge phonetic and phonemic variations. The difference in activity in left temporal cortex was expected given the strong evidence linking early phonological capacities to this brain area (21, 25). Frontoparietal differences in the right hemisphere could be due to differences in suprasegmental properties of speech such as the speech envelope (29, 30), or to frontal mechanisms monitoring salient stimuli (31).

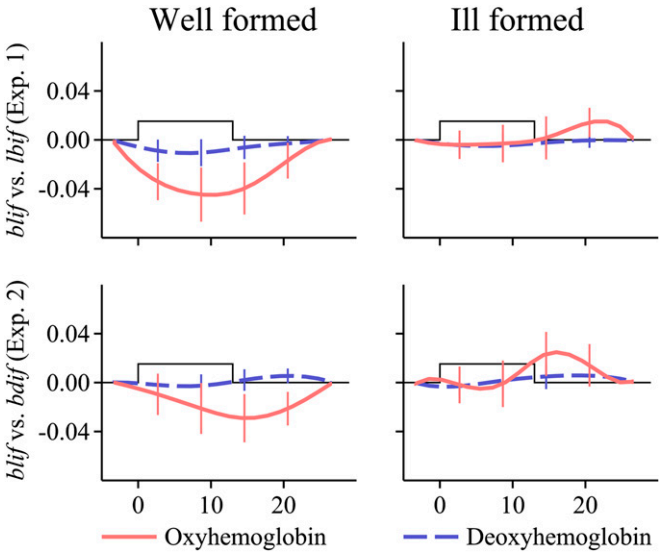

Fig. 3. Hemodynamic responses in the left inferior region of interest for Experiments 1 (*Upper*) and 2 (*Lower*). *Left* correspond to well-formed syllables (e.g., *blif*), whereas *Right* depict ill-formed syllables (e.g., *lbif*, *bdif*). Black lines depict baseline level and the time of stimulation. For all graphs, *x* axes display time elapsed from stimulation onset in seconds, and *y* axes display variations in hemoglobin concentrations measured in mmol•mm. Error lines indicate SEM.

Experiment 2 investigated sensitivity of newborns to an additional syllable type. A new group of 24 newborns (mean age = 3.0 d, SD = 0.66) listened to blocks of $C_1C_2VC_3$ syllables that presented either a sonority rise (e.g., *blif*) or a sonority plateau (e.g., *bdif*, where C_1 and C_2 have the same sonority) in their onset. Across languages, onsets of level sonority are dispreferred to sonority rises (12), and similar preferences have been documented behaviorally among adult individuals despite no experience with either structure (17). We thus ask whether the distinction between sonority rise and plateau is also present at birth and, if so, whether its hemodynamic manifestation aligns with the results of Experiment 1. Beyond its theoretical significance, the comparison of sonority plateaus and rises is convenient because it allows us to control for some acoustic and phonetic correlates of syllable structure present in Experiment 1. Indeed, the material therein used can be discriminated on the basis of their sonority contour, its speech envelope, or the fact that all syllables started with obstruents in one condition and with liquids in the other. Experiment 2 attenuates these factors and, thus, provides a stringent test for the sonority account.

Results revealed that oxyhemoglobin concentrations elicited by well-formed syllables are significantly lower than concentrations elicited by plateaus in the left temporal cortex ($t(22) = 2.88$, $P = 0.035$), in agreement with the sonority account and the results of Experiment 1. However, in the present experiment, discrimination was not evident at the right frontoparietal cortex [$t(17) = 1.86$, $P = 0.16$; see Fig. 2*B*]. Effect size measured by Cohen's d dropped 30% compared with Experiment 1 in the right frontoparietal region. This drop could be either due to the attenuation of phonetic cues in this experiment, or to the fact that the ill-formed syllables included in Experiment 2 (e.g., *bdif*) had a larger sonority distance than those in Experiment 1 (e.g., *lbif*).

Across Experiments 1 and 2, ill-formed syllables (as defined by the SSP) elicited higher oxyhemoglobin concentrations in left temporal-perisylvian areas. Specifically, compared with the well-formed sonority rises (e.g., *blif*), oxyhemoglobin concentrations were higher for sonority falls (e.g., *lbif*, in Experiment 1) and for sonority plateaus (e.g., *bdif*, in Experiment 2). Moreover, inspection of hemodynamic responses to each syllable type separately (Fig. 3) indicates that responses to well- and ill-formed syllables differ qualitatively. Well-formed syllables produce negative variations in oxyhemoglobin levels, a pattern absent for ill-formed syllables[†]. Together, these results suggest that neonates' brain activity systematically distinguishes well-formed syllables from ill-formed ones. These findings suggest that a precursor of the adult linguistic preference might be active at birth[‡].

To further determine whether newborns' response to *bl* and *lb* clusters depends on their syllable position, we next measured responses to the same clusters located across syllables. In Experiment S1 (*SI Results and Discussion*), we added a single vowel at the beginning of an ill-formed syllable like *lbif* to obtain disyllabic words like *olbif*. Because the sonority fall now spans across two syllables (*ol.bif*), rather than a syllable onset (e.g., *lbif*), such words should be perfectly well-formed. In line with this prediction, our results show that newborns' brain responses to disyllables like *oblif* and *olbif* do not differ. Finding that the same clusters (*lb* vs. *bl*) elicit markedly different responses, depending on their syllable position (e.g., *lbif* vs. *olbif*), suggests that infants constrain syllable structure rather than consonant sequencing per se.

General Discussion

These results show that neonates are sensitive to putatively universal restrictions on syllable structure. The observation of such regularities close to birth, before the onset of experience with language production, shows that sonority-related biases in humans do not require extensive linguistic experience (34) or ample practice with language production. Although we cannot presently rule out the possibility of learning from prenatal perceptual experience (i.e., from Italian—the language spoken by the infants' mothers), this possibility is exceedingly unlikely given the strong intrauterine attenuation of sound frequencies above 300 Hz (35, 36)—conditions that render consonant discrimination improbable. Moreover, the proposal that infants can learn the syllable structure of their language in utero fails to explain the evidence for the acquisition of the phonotactic patterns of their language only by the end of the first year of life, and not earlier (37, 38).

Taken as a whole, our results show that human newborns listening to spoken syllables exhibit precursors of universal linguistic preferences. Our present findings are moot with respect to the precise source of such preferences—whether they reflect grammatical phonological constraints or phonetic pressures. Nonetheless, newborns display distinct oxyhemoglobin responses for well- and ill-formed syllables in channels located over their left temporal cortex. We consistently observed that oxyhemoglobin curves were higher for classes of syllables that are dispreferred across languages,

[†]Negative oxyhemoglobin deflections, or more generally noncanonical hemodynamic responses, are relatively frequent in infant research. Cases have been documented for "visual, olfactory, sensory-motor, and auditory cortices" (32). Although there is not yet consensus on the causes of such responses, some investigations suggest a role of systemic vascular activity (32, 33). Systemic activity cannot fully account for our results, because the data suggest that the crucial differences are occurring in left temporal-perisylvian brain areas. Even if systemic activity could display such localization, this activity must reflect the linguistic structure of the stimuli, because well-formed stimuli elicit different responses than ill-formed ones. Regardless of origin—systemic or cortical—such changes thus demonstrate the presence of a linguistic bias on syllable structure in newborn infants.

[‡]Our hemodynamic data do not directly indicate preference on the part of newborns. Nonetheless, there is a striking resemblance between the pattern of results across our experiments and the well-documented cross-linguistic preferences for syllabic well-formedness. Typological data and behavior of adults (e.g., ref. 12) show that syllables with sonority rises (*blif*) are preferred to both falls (*lbif*) and plateaus (*bdif*). Our findings closely match this pattern, inasmuch as well-formed sequences produce systematically higher hemodynamic responses than ill-formed sequences. Whether the absolute strength of hemodynamic response indicates preference is unknown. However, for our argument, the critical factor is not the absolute direction or magnitude (e.g., "stronger response = preference") but rather its pattern. Across our experiments, different types of ill-formed stimuli consistently produce the same pattern of hemodynamic response relative to well-formed stimuli. The consistency of this pattern is significant, because it suggests that neonates lump our different ill-formed stimuli as a category that is distinct from well-formed stimuli, just as adults do.

in agreement with previous research showing that the left temporal cortex is sensitive to phonological constraints very early in development. These results suggest that a precursor of the universal sonority-related preferences seen in adults (12–18) is present close to birth.

Biological biases have been shown to guide cultural transmission of birdsong: isolated colonies of zebra finches converge to a song repertoire similar to their wild type (39). We propose that subtle phonological biases such as the one here documented guide the cultural evolution of languages via similar mechanisms.

Materials and Methods

Participants. Our samples for Experiments 1, 2, and S1 are composed by 24 healthy newborns each. Newborns were recruited and tested at the Hospital, Azienda Ospedaliera Santa Maria della Misericordia, in Udine, Italy. Newborns were considered eligible to participate if they had a head circumference of at least 33 cm, an Apgar score of at least 7 at the first minute, and no cefalhematoma. Parents signed consent forms at the beginning of the experimental session. Our procedures and protocols were approved by the Scuola Internazionale Superiore di Studi Avanzati Ethics Committee.

Eight boys and 16 girls (mean age = 2.9 d, SD = 0.83) participated in Experiment 1. They had Apgar scores of 8.5 ± 0.83 and 9.0 ± 0.20 at the first and fifth minute, respectively, a gestational age of 39.3 ± 1.17 wk, weighted 3.310 ± 0.307 kg at birth, and had a head circumference of 34.5 ± 1.0 cm. An additional eight newborns were tested but rejected because of crying or fussiness (n = 4), difficulties in obtaining good NIRS signal (n = 3), or experimental error (n = 1).

Fourteen boys and 10 girls (mean age = 3.0 d, SD = 0.66) participated in Experiment 2. They had Apgar scores of 8.5 ± 0.51 and 9.3 ± 0.44 at the first and fifth minute, respectively, a gestational age of 38.9 ± 1.50 wk, weighted 3.429 ± 0.378 kg at birth, and had a head circumference of 35.0 ± 0.8 cm. An additional 16 newborns were tested but rejected due to crying or fuzziness (n = 10) or difficulties in obtaining good NIRS signal (n = 6).

Ten boys and 14 girls (mean age = 3.2 d, SD = 0.80) participated in Experiment S1. They had Apgar scores of 8.6 ± 0.7 and 9.1 ± 0.5 at the first and fifth minute, respectively, a gestational age of 39.3 ± 1.3 wk, weighted 3.359 ± 0.398 kg at birth, and had a head circumference of 34.7 ± 1.1 cm. An additional 18 newborns were tested but rejected because of crying or fuzziness (n = 11) or difficulties in obtaining good NIRS signal (n = 7).

Stimuli. A female native speaker of Russian recorded all words used in our experiments. Russian allows all syllable types studied in our experiment. Thus, Russian speakers can produce those items natively. A large list of words was recorded in a single session in a sound-attenuated booth, from which a phonologist selected sets of eight words per condition among the best recorded exemplars. We used CCVC (C, consonant; V, vowel) syllables for Experiments 1 and 2 and VCCVC bisyllables for Experiment S1 (Table S1). Within each experiment, syllable sets did not statistically differ in terms of their duration, average pitch, or number of feature changes between the two adjacent consonants (t tests, all P values >0.29). Sound intensity was set to 70 dB for all words.

Procedure. Newborns were tested in their crib in a silent room assisted by a medical doctor, either during sleep or in a quiet state of alert. Sound stimuli were presented via two loudspeakers located approximately 70 cm in front of the neonate. A Mac PowerPC G5 operated the fNIRS machine and presented the auditory stimuli using the software PsyScope X (http://psy.ck.sissa.it). Our procedure followed a block design (40): newborns listened to blocks consisting of words from a given type. Each stimulation block lasted approximately 13 s, presenting all eight words of a given condition in random order. Random pauses separated consecutive words (0.5 or 1.5 s) and blocks (25 or 35 s). We presented 10 blocks per condition, for a total duration of the experimental session of approximately 15 min. An infrared videocamera was used to monitor the state and behavior of neonates.

Data Acquisition. The cortical hemodynamic activity of newborns was recorded by using fNIRS (ETG-4000; Hitachi). This machine emits continuous near-infrared light of two wavelengths (695 and 830 nm) through 10 emitters and records light absorption through eight detectors. Emitters and detectors are arrayed in two Chevron-shaped silicon probes, providing 24 recording channels. Emitter-detector distance is 3 cm, sampling rate is 10 Hz, and total laser power output per optical fiber was set to 0.75 mW. Using the vertex and tragus as skull landmarks, we positioned probes over the scalps of newborns: one over each hemisphere, with the concave side of the Chevron shape surrounding the ears.

Data Processing and Analysis. Variations in oxyhemoglobin and deoxyhemoglobin were obtained from light absorption recordings by using the modified Beer–Lambert Law (27). Hemodynamic signals were band-pass filtered between 0.02 and 0.5 Hz. Epochs were extracted starting 5 s before each block and finishing 15 s after its end, for a total epoch length of 33 s. Single channels for specific blocks were rejected if light absorption was less than 1% of the total light emitted or if the hemodynamic signal contained movement artifacts (changes in the signal greater than 0.1 mmol•mm in an interval of 0.2 s). Epochs with more than 12 rejected channels were excluded. Only participants with at least three good epochs per condition were considered for analysis.

A baseline was linearly fitted between the mean of the initial and final 5 s of each epoch and subtracted from the signal. Statistical analyses involved the area under each hemodynamic curve over the whole epoch: Area values were averaged for each newborn across all channels composing each region of interest (ROI). Comparisons were conducted by means of paired t tests, using the Holm–Bonferroni procedure (41) to correct for multiple comparisons. Because rejection criteria were applied on a channel-per-channel basis separately for each infant, t tests corresponding to different ROIs might have different numbers of degrees of freedom.

Temporal-perisylvian ROIs comprised channels above the ear: 11 and 12 (left hemisphere) and 23 and 24 (right hemisphere). Frontoparietal ROIs comprised channels closest to the vertex: 1 and 2 (left hemisphere) and 13 and 14 (right hemisphere). Given the great variability in the head shapes of neonates and the fixed shape of the NIRS probes, these localizations are approximate.

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Supporting Information

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SI Results and Discussion

The Sonority Sequencing Principle (SSP) states that *blif* is preferred to *lbif*, but the same conclusion is not valid for *oblif* and *olbif* despite the similarity of the two contrasts at a phonetic level. Crucially, the presence of the vowel at the beginning allows for *olbif* to be syllabified as *ol.bif*, taking the consonant cluster out of the domain of the SSP.

Experiment 1 found that oxyhemoglobin changes differ significantly between syllables with sonority rises and syllables with sonority falls in the left temporal-perisylvian and the right frontoparietal cortex. Experiment S1 investigated whether a similar pattern of neural activity holds for bisyllabic VCCVC words that presented a sonority rise or a sonority fall in their consonant cluster. We observed no significant differences between the syllable types in oxyhemoglobin concentration changes (all uncorrected P values >0.29, see Table S2). Deoxyhemoglobin differed significantly in the left frontoparietal region of interest [$t(21) = -2.12$, $P = 0.046$], although this result was no significant after applying the Holm-Bonferroni correction.

Table S1. Lists of words presented to newborns in Experiments 1 (monosyllabic rises vs. falls), 2 (monosyllabic rises vs. plateaus), and S1 (bisyllabic rises vs. falls)

Monosyllables			Bisyllables	
Sonority rises	Sonority plateaus	Sonority falls	Sonority rises	Sonority falls
pras	bkin	rvug	oblif	arbom
fros	dkan	rvem	ivros	ilvan
vlug	gdif	lbug	adrif	urpas
vlin	kdom	rveg	udros	arvud
brud	kvas	rdos	iflud	olbif
vros	kvif	rfug	uprif	olvud
from	fkom	lvug	oflug	urdos
bran	pkan	lbif	afrom	irvug

Table S2. Statistics for all three experiments and regions of interest, including uncorrected and corrected *P* values and both oxyhemoglobin and deoxyhemoglobin

Region of interest	Effect size (Cohen's d)	*t* statistic	Uncorrected *P* value	Corrected *P* value
Experiment 1 (oxyhemoglobin)				
Left superior	0.283	$t(18) = 1.23$	0.233	—
Left inferior	0.563	$t(22) = 2.70$	0.013	0.039*
Right superior	0.632	$t(21) = 2.97$	0.007	0.028*
Right inferior	0.232	$t(21) = 1.09$	0.289	—
Experiment 1 (deoxyhemoglobin)				
Left superior	−0.218	$t(18) = -0.95$	0.354	—
Left inferior	0.117	$t(22) = 0.56$	0.582	—
Right superior	0.207	$t(21) = 0.97$	0.342	—
Right inferior	0.086	$t(21) = 0.40$	0.692	—
Experiment 2 (oxyhemoglobin)				
Left superior	0.507	$t(19) = 2.27$	0.035	0.105
Left inferior	0.599	$t(22) = 2.87$	0.009	0.036*
Right superior	0.437	$t(17) = 1.85$	0.081	0.162
Right inferior	0.213	$t(19) = 0.95$	0.352	—
Experiment 2 (deoxyhemoglobin)				
Left superior	0.048	$t(19) = 0.21$	0.833	—
Left inferior	0.089	$t(22) = 0.42$	0.675	—
Right superior	0.214	$t(17) = 0.91$	0.376	—
Right inferior	0.029	$t(19) = 0.13$	0.900	—
Experiment S1 (oxyhemoglobin)				
Left superior	−0.104	$t(21) = -0.49$	0.632	—
Left inferior	0.165	$t(21) = 0.77$	0.449	—
Right superior	−0.247	$t(19) = -1.10$	0.283	—
Right inferior	−0.230	$t(21) = -1.08$	0.293	—
Experiment S1 (deoxyhemoglobin)				
Left superior	−0.453	$t(21) = -2.13$	0.046	0.184
Left inferior	0.268	$t(21) = 1.26$	0.223	—
Right superior	−0.196	$t(19) = -0.88$	0.392	—
Right inferior	0.166	$t(21) = 0.78$	0.444	—

*Denotes significant differences between conditions at the 5% level after applying the Holm-Bonferroni correction.