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Versatility of phonemic pitch in affective iconicity and perceptual reorganisation

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References

- Abboub, N., Nazzi, T., & Gervain, J. (2016). Prosodic grouping at birth. *Brain and Language*, 162, 46–59.
<https://doi.org/10.1016/j.bandl.2016.08.002>
- Adelman, J. S., Estes, Z., & Cossu, M. (2018). Emotional sound symbolism: Languages rapidly signal valence via phonemes. *Cognition*, 175, 122–130.
<https://doi.org/10.1016/j.cognition.2018.02.007>
- Akita, K. (2021). A typology of depiction marking: The prosody of Japanese ideophones and beyond. *Studies in Language*, 45(4), 865–886. <https://doi.org/10.1075/sl.17029.aki>
- Anikin, A., & Johansson, N. (2019). Implicit associations between individual properties of color and sound. *Attention, Perception, & Psychophysics*, 81(3), 764–777.
<https://doi.org/10.3758/s13414-018-01639-7>
- Arimitsu, T., Minagawa, Y., Yagihashi, T., O. Uchida, M., Matsuzaki, A., Ikeda, K., & Takahashi, T. (2018). The cerebral hemodynamic response to phonetic changes of speech in preterm and term infants: The impact of postmenstrual age. *NeuroImage: Clinical*, 19, 599–606.
<https://doi.org/10.1016/j.nicl.2018.05.005>
- Arimitsu, T., Uchida-Ota, M., Yagihashi, T., Kojima, S., Watanabe, S., Hokuto, I., Ikeda, K., Takahashi, T., & Minagawa-Kawai, Y. (2011). Functional hemispheric specialization in processing phonemic and prosodic auditory changes in neonates. *Frontiers in Psychology*, 2, Article 202.
<https://doi.org/10.3389/fpsyg.2011.00202>

- Aryani, A., Conrad, M., & Jacobs, A. M. (2013). Extracting salient sublexical units from written texts: “Emophon,” a corpus-based approach to phonological iconicity. *Frontiers in Psychology*, 4, Article 654.
<https://doi.org/10.3389/fpsyg.2013.00654>
- Aryani, A., Conrad, M., Schmidtke, D., & Jacobs, A. (2018). Why “piss” is ruder than “pee”? The role of sound in affective meaning making. *PLoS ONE*, 13(6), e0198430.
<https://doi.org/10.1371/journal.pone.0198430>
- Aryani, A., Hsu, C.-T., & Jacobs, A. M. (2019). Affective iconic words benefit from additional sound-meaning integration in the left amygdala. *Human Brain Mapping*, 40(18), 5289–5300.
<https://doi.org/10.1002/hbm.24772>
- Asano, M., Imai, M., Kita, S., Kitajo, K., Okada, H., & Thierry, G. (2015). Sound symbolism scaffolds language development in preverbal infants. *Cortex*, 63, 196–205.
<https://doi.org/10.1016/j.cortex.2014.08.025>
- Aslin, R. N. (2012). Questioning the questions that have been asked about the infant brain using NIRS. *Cognitive Neuropsychology*, 29(1–2), 7–33.
<https://doi.org/10.1080/02643294.2012.654773>
- Aslin, R. N., & Mehler, J. (2005). Near-infrared spectroscopy for functional studies of brain activity in human infants: Promise, prospects, and challenges. *Journal of Biomedical Optics*, 10(1), 011009. <https://doi.org/10.1117/1.1854672>
- Asutay, E., & Västfjäll, D. (2017). Exposure to arousal-inducing sounds facilitates visual search. *Scientific Reports*, 7(1), 10363.
<https://doi.org/10.1038/s41598-017-09975-8>

- Auracher, J., Albers, S., Zhai, Y., Gareeva, G., & Stavniychuk, T. (2011). P is for happiness, N is for sadness: Universals in sound iconicity to detect emotions in poetry. *Discourse Processes*, 48(1), 1–25.
<https://doi.org/10.1080/01638531003674894>
- Auracher, J., Menninghaus, W., & Scharinger, M. (2020). Sound predicts meaning: Cross-modal associations between formant frequency and emotional tone in stanzas. *Cognitive Science*, 44(10), e12906. <https://doi.org/10.1111/cogs.12906>
- Azhari, A., Truzzi, A., Neoh, M. J.-Y., Balagtas, J. P. M., Tan, H. H., Goh, P. P., Ang, X. A., Setoh, P., Rigo, P., Bornstein, M. H., & Esposito, G. (2020). A decade of infant neuroimaging research: What have we learned and where are we going? *Infant Behavior and Development*, 58, 101389.
<https://doi.org/10.1016/j.infbeh.2019.101389>
- Baayen, R. H., Davidson, D. J., & Bates, D. M. (2008). Mixed-effects modeling with crossed random effects for subjects and items. *Journal of Memory and Language*, 59(4), 390–412.
<https://doi.org/10.1016/j.jml.2007.12.005>
- Bailey, T. M., & Hahn, U. (2001). Determinants of wordlikeness: Phonotactics or lexical neighborhoods? *Journal of Memory and Language*, 44(4), 568–591.
<https://doi.org/10.1006/jmla.2000.2756>
- Banse, R., & Scherer, K. R. (1996). Acoustic profiles in vocal emotion expression. *Journal of Personality and Social Psychology*, 70(3), 614–636. <https://doi.org/10.1037/0022-3514.70.3.614>
- Bänziger, T., & Scherer, K. R. (2005). The role of intonation in emotional expressions. *Speech Communication*, 46(3–4), 252–267. <https://doi.org/10.1016/j.specom.2005.02.016>

- Baroni, A. (2014). On the importance of being noticed: The role of acoustic salience in phonotactics (and casual speech). *Language Sciences*, 46, 18–36.
<https://doi.org/10.1016/j.langsci.2014.06.004>
- Barrett, L. F., & Russell, J. A. (1999). The structure of current affect: Controversies and emerging consensus. *Current Directions in Psychological Science*, 8(1), 10–14.
<https://doi.org/10.1111/1467-8721.00003>
- Barton, D. N., & Halberstadt, J. (2018). A social Bouba/Kiki effect: A bias for people whose names match their faces. *Psychonomic Bulletin & Review*, 25(3), 1013–1020.
<https://doi.org/10.3758/s13423-017-1304-x>
- Bates, D., Mächler, M., Bolker, B., & Walker, S. (2014). Fitting linear mixed-effects models using lme4. *arXiv:1406.5823 [Stat]*.
<http://arxiv.org/abs/1406.5823>
- Belin, P., Zilbovicius, M., Crozier, S., Thivard, L., Fontaine, A. A., Masure, M.-C., & Samson, Y. (1998). Lateralization of speech and auditory temporal processing. *Journal of Cognitive Neuroscience*, 10(4), 536–540.
<https://doi.org/10.1162/089892998562834>
- Belyk, M., & Brown, S. (2014). The acoustic correlates of valence depend on emotion family. *Journal of Voice*, 28(4), 523.e9–523.e18. <https://doi.org/10.1016/j.jvoice.2013.12.007>
- Berger, J. (2011). Arousal increases social transmission of information. *Psychological Science*, 22(7), 891–893.
<https://doi.org/10.1177/0956797611413294>
- Berger, V. W., & Zhou, Y. (2014). Kolmogorov–Smirnov test: Overview. In *Wiley StatsRef: Statistics Reference Online*.

- John Wiley & Sons.
<https://doi.org/10.1002/9781118445112.stat06558>
- Berlin, B. (2006). The first congress of ethnozoological nomenclature. *Journal of the Royal Anthropological Institute*, 12(s1), S23–S44. <https://doi.org/10.1111/j.1467-9655.2006.00271.x>
- Binder, J. R., Frost, J. A., Hammeke, T. A., Bellgowan, P. S. F., Springer, J. A., Kaufman, J. N., & Possing, E. T. (2000). Human temporal lobe activation by speech and nonspeech sounds. *Cerebral Cortex*, 10(5), 512–528.
<https://doi.org/10.1093/cercor/10.5.512>
- Blasi, D. E., Wichmann, S., Hammarström, H., Stadler, P. F., & Christiansen, M. H. (2016). Sound–meaning association biases evidenced across thousands of languages. *Proceedings of the National Academy of Sciences*, 113(39), 10818–10823.
<https://doi.org/10.1073/pnas.1605782113>
- Boersma, P., & Weenink, D. (2024). *Praat: Doing phonetics by computer* (Version 6.4.12) [Computer software].
<http://www.praat.org/>
- Bosseler, A. N., Taulu, S., Pihko, E., Mäkelä, J. P., Imada, T., Ahonen, A., & Kuhl, P. K. (2013). Theta brain rhythms index perceptual narrowing in infant speech perception. *Frontiers in Psychology*, 4. <https://doi.org/10.3389/fpsyg.2013.00690>
- Bourke, J. D., & Todd, J. (2021). Acoustics *versus* linguistics? Context is Part and Parcel to lateralized processing of the parts and parcels of speech. *Laterality*, 26(6), 725–765.
<https://doi.org/10.1080/1357650X.2021.1898415>
- Bremner, A. J., Caparos, S., Davidoff, J., de Fockert, J., Linnell, K. J., & Spence, C. (2013). “Bouba” and “Kiki” in Namibia? A remote culture make similar shape–sound matches, but different

- shape–taste matches to Westerners. *Cognition*, 126(2), 165–172. <https://doi.org/10.1016/j.cognition.2012.09.007>
- Broca, M. P. (1861). Remarques sur le siège de la faculté du langage articulé, suivies d’une observation d’aphémie (perte de la parole). *Bulletin de la Société Anatomique*, 6, 330–357.
- Brysbaert, M., Mandera, P., & Keuleers, E. (2018). The word frequency effect in word processing: An updated review. *Current Directions in Psychological Science*, 27(1), 45–50. <https://doi.org/10.1177/0963721417727521>
- Cai, Q., & Brysbaert, M. (2010). SUBTLEX-CH: Chinese word and character frequencies based on film subtitles. *PLoS ONE*, 5(6), e10729. <https://doi.org/10.1371/journal.pone.0010729>
- Champely, S., Ekstrom, C., Dalgaard, P., Gill, J., Weibelzahl, S., Anandkumar, A., Ford, C., Volcic, R., & Rosario, H. D. (2020). *pwr: Basic functions for power analysis* (Version 1.3.0) [Computer software]. <https://cran.r-project.org/web/packages/pwr/index.html>
- Chan, J. Y., Hssayeni, M. D., Wilcox, T., & Ghoraani, B. (2023). Exploring the feasibility of tensor decomposition for analysis of fNIRS signals: A comparative study with grand averaging method. *Frontiers in Neuroscience*, 17, 1180293. <https://doi.org/10.3389/fnins.2023.1180293>
- Chan, M. K. M. (1996). Some thoughts on the typology of sound symbolism and the Chinese language. In C. Cheng, J. Packard, J. Yoon, & Y. You (Eds.), *Proceedings of the Eighth North American Conference on Chinese Linguistics* (Vol. 2, pp. 1–15). Los Angeles: GSIL Publications.
- Chang, Y.-H., Zhao, M., Chen, Y.-C., & Huang, P.-C. (2021). The effects of Mandarin Chinese lexical tones in sound–shape and

- sound–size correspondences. *Multisensory Research*, 35(3), 1–15. <https://doi.org/10.1163/22134808-bja10068>
- Chen, A., & Kager, R. (2016). Discrimination of lexical tones in the first year of life. *Infant and Child Development*, 25(5), 426–439. <https://doi.org/10.1002/icd.1944>
- Chen, A., Stevens, C. J., & Kager, R. (2017). Pitch perception in the first year of life, a comparison of lexical tones and musical pitch. *Frontiers in Psychology*, 8, Article 297. <https://doi.org/10.3389/fpsyg.2017.00297>
- Chen, Y. (2022). Mind the subtle fo modifications: The interaction of tone and intonation in Sinitic varieties. *Stellenbosch Papers in Linguistics Plus*, 62(02), 113–136. <https://doi.org/10.5842/62-2-904>
- Chen, Y., & Gussenhoven, C. (2008). Emphasis and tonal implementation in Standard Chinese. *Journal of Phonetics*, 36(4), 724–746. <https://doi.org/10.1016/j.wocn.2008.06.003>
- Chen, Y.-C., Huang, P.-C., Woods, A., & Spence, C. (2016). When “bouba” equals “kiki”: Cultural commonalities and cultural differences in sound-shape correspondences. *Scientific Reports*, 6, 26681. <https://doi.org/10.1038/srep26681>
- Chiou, R., & Rich, A. N. (2012). Cross-modality correspondence between pitch and spatial location modulates attentional orienting. *Perception*, 41(3), 339–353. <https://doi.org/10.1068/p7161>
- Citron, F. M. M. (2012). Neural correlates of written emotion word processing: A review of recent electrophysiological and hemodynamic neuroimaging studies. *Brain and Language*, 122(3), 211–226. <https://doi.org/10.1016/j.bandl.2011.12.007>

- Citron, F. M. M., Gray, M. A., Critchley, H. D., Weekes, B. S., & Ferstl, E. C. (2014). Emotional valence and arousal affect reading in an interactive way: Neuroimaging evidence for an approach-withdrawal framework. *Neuropsychologia*, 56(100), 79–89. <https://doi.org/10.1016/j.neuropsychologia.2014.01.002>
- Coon, J., Silva, P. N., Etz, A., & Sarnecka, B. W. (2024). Bayesian tools of the trade for developmental psychologists: A quick-start guide using JASP. *Journal of Cognition and Development*, 26(1), 1–49. <https://doi.org/10.1080/15248372.2024.2386032>
- Cowen, A. S., & Keltner, D. (2017). Self-report captures 27 distinct categories of emotion bridged by continuous gradients. *Proceedings of the National Academy of Sciences*, 114(38), E7900–E7909. <https://doi.org/10.1073/pnas.1702247114>
- Crisinel, A.-S., Cosser, S., King, S., Jones, R., Petrie, J., & Spence, C. (2012). A bittersweet symphony: Systematically modulating the taste of food by changing the sonic properties of the soundtrack playing in the background. *Food Quality and Preference*, 24(1), 201–204. <https://doi.org/10.1016/j.foodqual.2011.08.009>
- Crisinel, A.-S., & Spence, C. (2009). Implicit association between basic tastes and pitch. *Neuroscience Letters*, 464(1), 39–42. <https://doi.org/10.1016/j.neulet.2009.08.016>
- Crisinel, A.-S., & Spence, C. (2010a). A sweet sound? Food names reveal implicit associations between taste and pitch. *Perception*, 39(3), 417–425. <https://doi.org/10.1068/p6574>
- Crisinel, A.-S., & Spence, C. (2010b). As bitter as a trombone: Synesthetic correspondences in nonsynesthetes between tastes/flavors and musical notes. *Attention, Perception &*

- Psychophysics*, 72(7), 1994–2002.
<https://doi.org/10.3758/APP.72.7.1994>
- Cristia, A. (2018). Can infants learn phonology in the lab? A meta-analytic answer. *Cognition*, 170, 312–327.
<https://doi.org/10.1016/j.cognition.2017.09.016>
- Cruttenden, A. (1997). *Intonation* (2nd ed.). Cambridge University Press. <https://doi.org/10.1017/CBO9781139166973>
- Cuskley, C., Simner, J., & Kirby, S. (2017). Phonological and orthographic influences in the bouba–kiki effect. *Psychological Research*, 81(1), 119–130.
<https://doi.org/10.1007/s00426-015-0709-2>
- Cutler, A., Dahan, D., & van Donselaar, W. (1997). Prosody in the comprehension of spoken language: A literature review. *Language and Speech*, 40(2), 141–201.
<https://doi.org/10.1177/002383099704000203>
- Cutler, A., & van Donselaar, W. (2001). *Voornaam* is not (really) a homophone: Lexical prosody and lexical access in Dutch. *Language and Speech*, 44(2), 171–195.
<https://doi.org/10.1177/00238309010440020301>
- Ćwiek, A., Fuchs, S., Draxler, C., Asu, E. L., Dediu, D., Hiovain, K., Kawahara, S., Koutalidis, S., Krifka, M., Lippus, P., Lupyan, G., Oh, G. E., Paul, J., Petrone, C., Ridouane, R., Reiter, S., Schümchen, N., Szalontai, Á., Ünal-Logacev, Ö., ... Winter, B. (2021). The *bouba/kiki* effect is robust across cultures and writing systems. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 377(1841), 1–13.
<https://doi.org/10.1098/rstb.2020.0390>

- Darwin, C. (1998). *The expression of the emotions in man and animals* (3rd ed, With an introduction, afterword, and commentaries by Paul Ekman). Oxford University Press.
- Davidson, R. J., Sherer, K. R., & Goldsmith, H. H. (Eds.). (2009). *Handbook of affective sciences*. Oxford University Press.
- De Carolis, L., Marsico, E., Arnaud, V., & Coupé, C. (2018). Assessing sound symbolism: Investigating phonetic forms, visual shapes and letter fonts in an implicit bouba-kiki experimental paradigm. *PLoS ONE*, 13(12), e0208874.
<https://doi.org/10.1371/journal.pone.0208874>
- De Klerk, M., De Bree, E., Kerkhoff, A., & Wijnen, F. (2019). Lost and found: Decline and reemergence of non-native vowel discrimination in the first year of life. *Language Learning and Development*, 15(1), 14–31.
<https://doi.org/10.1080/15475441.2018.1497490>
- Dehaene-Lambertz, G., Dehaene, S., & Hertz-Pannier, L. (2002). Functional neuroimaging of speech perception in infants. *Science*, 298(5600), 2013–2015.
<https://doi.org/10.1126/science.1077066>
- Dehaene-Lambertz, G., Hertz-Pannier, L., & Dubois, J. (2006). Nature and nurture in language acquisition: Anatomical and functional brain-imaging studies in infants. *Trends in Neurosciences*, 29(7), 367–373.
<https://doi.org/10.1016/j.tins.2006.05.011>
- Deroy, O., & Spence, C. (2013). Why we are not all synesthetes (not even weakly so). *Psychonomic Bulletin & Review*, 20(4), 643–664. <https://doi.org/10.3758/s13423-013-0387-2>
- Di Lorenzo, R., Pirazzoli, L., Blasi, A., Bulgarelli, C., Hakuno, Y., Minagawa, Y., & Brigadoi, S. (2019). Recommendations for

- motion correction of infant fNIRS data applicable to multiple data sets and acquisition systems. *NeuroImage*, 200, 511–527. <https://doi.org/10.1016/j.neuroimage.2019.06.056>
- Dingemanse, M. (2015). Ideophones and reduplication: Depiction, description, and the interpretation of repeated talk in discourse. *Studies in Language*, 39(4), 946–970. <https://doi.org/10.1075/sl.39.4.05din>
- Dingemanse, M., Blasi, D. E., Lupyan, G., Christiansen, M. H., & Monaghan, P. (2015). Arbitrariness, iconicity, and systematicity in language. *Trends in Cognitive Sciences*, 19(10), 603–615. <https://doi.org/10.1016/j.tics.2015.07.013>
- Dingemanse, M., Schuerman, W., Reinisch, E., Tufvesson, S., & Mitterer, H. (2016). What sound symbolism can and cannot do: Testing the iconicity of ideophones from five languages. *Language*, 92(2), e117–e133. <https://doi.org/10.1353/lan.2016.0034>
- D’Onofrio, A. (2014). Phonetic detail and dimensionality in sound-shape correspondences: Refining the bouba-kiki paradigm. *Language and Speech*, 57(3), 367–393. <https://doi.org/10.1177/0023830913507694>
- Ekman, P. (1992). An argument for basic emotions. *Cognition and Emotion*, 6(3–4), 169–200. <https://doi.org/10.1080/02699939208411068>
- Ekström, A. G., Nirme, J., & Gärdenfors, P. (2022). Motion iconicity in prosody. *Frontiers in Communication*, 7, 994162. <https://doi.org/10.3389/fcomm.2022.994162>
- Evans, K. K., & Treisman, A. (2011). Natural cross-modal mappings between visual and auditory features. *Journal of Vision*, 10(1), Article 6. <https://doi.org/10.1167/10.1.6>

- Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, 41(4), 1149–1160. <https://doi.org/10.3758/BRM.41.4.1149>
- Fernández-Prieto, I., Navarra, J., & Pons, F. (2015). How big is this sound? Crossmodal association between pitch and size in infants. *Infant Behavior and Development*, 38, 77–81. <https://doi.org/10.1016/j.infbeh.2014.12.008>
- Filippi, P., Ocklenburg, S., Bowling, D. L., Heege, L., Güntürkün, O., Newen, A., & de Boer, B. (2017). More than words (and faces): Evidence for a Stroop effect of prosody in emotion word processing. *Cognition and Emotion*, 31(5), 879–891. <https://doi.org/10.1080/02699931.2016.1177489>
- Fischler, I., & Bradley, M. (2006). Event-related potential studies of language and emotion: Words, phrases, and task effects. *Progress in Brain Research*, 156, 185–203. [https://doi.org/10.1016/S0079-6123\(06\)56009-1](https://doi.org/10.1016/S0079-6123(06)56009-1)
- Fort, M., Martin, A., & Peperkamp, S. (2015). Consonants are more important than vowels in the bouba-kiki effect. *Language and Speech*, 58(2), 247–266. <https://doi.org/10.1177/0023830914534951>
- Fort, M., & Schwartz, J.-L. (2022). Resolving the bouba-kiki effect enigma by rooting iconic sound symbolism in physical properties of round and spiky objects. *Scientific Reports*, 12(1), Article 1. <https://doi.org/10.1038/s41598-022-23623-w>
- Frick, R. W. (1985). Communicating emotion: The role of prosodic features. *Psychological Bulletin*, 97(3), 412–429. <https://doi.org/10.1037/0033-2909.97.3.412>

- Friendly, M., & Meyer, D. (2015). *Discrete data analysis with R: Visualization and modeling techniques for categorical and count data*. CRC Press.
- Frota, S., Butler, J., Lu, S., & Vigário, M. (2016). Infants' perception of native and non-native pitch contrasts. *Speech Prosody 2016*, 692–696. <https://doi.org/10.21437/SpeechProsody.2016-142>
- Frota, S., Butler, J., & Vigário, M. (2014). Infants' perception of intonation: Is it a statement or a question? *Infancy*, 19(2), 194–213. <https://doi.org/10.1111/infa.12037>
- Gage, N. M., & Baars, B. J. (2018). Language and thought. In *Fundamentals of cognitive neuroscience: A beginner's guide (2nd ed.)* (pp. 185–214). Academic Press. <https://doi.org/10.1016/B978-0-12-803813-0.00006-4>
- Gallace, A., & Spence, C. (2006). Multisensory synesthetic interactions in the speeded classification of visual size. *Perception & Psychophysics*, 68(7), 1191–1203. <https://doi.org/10.3758/BF03193720>
- Gandour, J., Dziedzic, M., Wong, D., Lowe, M., Tong, Y., Hsieh, L., Satthamnuwong, N., & Lurito, J. (2003). Temporal integration of speech prosody is shaped by language experience: An fMRI study. *Brain and Language*, 84(3), 318–336. [https://doi.org/10.1016/S0093-934X\(02\)00505-9](https://doi.org/10.1016/S0093-934X(02)00505-9)
- Gandour, J., Tong, Y., Wong, D., Talavage, T., Dziedzic, M., Xu, Y., Li, X., & Lowe, M. (2004). Hemispheric roles in the perception of speech prosody. *NeuroImage*, 23(1), 344–357. <https://doi.org/10.1016/j.neuroimage.2004.06.004>
- Gemignani, J., & Gervain, J. (2021). Comparing different pre-processing routines for infant fNIRS data. *Developmental*

Cognitive Neuroscience, 48, 100943.

<https://doi.org/10.1016/j.dcn.2021.100943>

Gervain, J. (2015). Plasticity in early language acquisition: The effects of prenatal and early childhood experience. *Current Opinion in Neurobiology*, 35, 13–20.

<https://doi.org/10.1016/j.conb.2015.05.004>

Gervain, J. (2018). The role of prenatal experience in language development. *Current Opinion in Behavioral Sciences*, 21, 62–67. <https://doi.org/10.1016/j.cobeha.2018.02.004>

Gervain, J. (2020). Typical language development. In A. Gallagher, C. Bulteau, D. Cohen, & J. L. Michaud (Eds.), *Handbook of Clinical Neurology* (Vol. 173, pp. 171–183). Elsevier.

<https://doi.org/10.1016/B978-0-444-64150-2.00016-2>

Gervain, J., Minagawa, Y., Emberson, L., & Lloyd-Fox, S. (2023). Using functional near-infrared spectroscopy to study the early developing brain: Future directions and new challenges. *Neurophotonics*, 10(2), 023519.

<https://doi.org/10.1117/1.NPh.10.2.023519>

Getz, L. M., & Kubovy, M. (2018). Questioning the automaticity of audiovisual correspondences. *Cognition*, 175, 101–108.

<https://doi.org/10.1016/j.cognition.2018.02.015>

Gianotti, L. R. R., Faber, P. L., Schuler, M., Pascual-Marqui, R. D., Kochi, K., & Lehmann, D. (2008). First valence, then arousal: The temporal dynamics of brain electric activity evoked by emotional stimuli. *Brain Topography*, 20(3), 143–156.

<https://doi.org/10.1007/s10548-007-0041-2>

Godoy, M. C., & Ananias, T. (2022). The bouba-kiki effect in a production task. In J. Culbertson, A. Perfors, H. Rabagliati, & V. Ramenzoni (Eds.), *Proceedings of the 44th Annual*

Conference of the Cognitive Science Society (Vol. 44, pp. 763–770).

González-Alvarez, J., & Sos-Peña, R. (2022). Perceiving body height from connected speech: Higher fundamental frequency is associated with the speaker's height. *Perceptual and Motor Skills*, 129(5), 1349–1361.

<https://doi.org/10.1177/00315125221110392>

Green, P., & MacLeod, C. J. (2016). SIMR: An R package for power analysis of generalized linear mixed models by simulation. *Methods in Ecology and Evolution*, 7(4), 493–498.

<https://doi.org/10.1111/2041-210X.12504>

Gu, F., Zhang, C., Hu, A., & Zhao, G. (2013). Left hemisphere lateralization for lexical and acoustic pitch processing in Cantonese speakers as revealed by mismatch negativity. *NeuroImage*, 83, 637–645.

<https://doi.org/10.1016/j.neuroimage.2013.02.080>

Gussenhoven, C. (1992). Dutch. *Journal of the International Phonetic Association*, 22(1–2), 45–47.

<https://doi.org/10.1017/S002510030000459X>

Gussenhoven, C. (2004). *The phonology of tone and intonation*. Cambridge University Press.

<https://doi.org/10.1017/CBO9780511616983>

Gussenhoven, C. (2016). Foundations of intonational meaning: Anatomical and physiological factors. *Topics in Cognitive Science*, 8(2), 425–434. <https://doi.org/10.1111/tops.12197>

Hamann, S. (2012). Mapping discrete and dimensional emotions onto the brain: Controversies and consensus. *Trends in Cognitive Sciences*, 16(9), 458–466.

<https://doi.org/10.1016/j.tics.2012.07.006>

- Hamilton-Fletcher, G., Pisanski, K., Reby, D., Stefańczyk, M., Ward, J., & Sorokowska, A. (2018). The role of visual experience in the emergence of cross-modal correspondences. *Cognition*, 175, 114–121. <https://doi.org/10.1016/j.cognition.2018.02.023>
- Harmon-Jones, E., Harmon-Jones, C., & Summerell, E. (2017). On the importance of both dimensional and discrete models of emotion. *Behavioral Sciences*, 7(4), Article 4. <https://doi.org/10.3390/bs7040066>
- Haudricourt, A.-G. (1954). De l'origine des tons en vietnamien. *Journal Asiatique*, 242, 69–82.
- Herbert, C., Junghofer, M., & Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology*, 45(3), 487–498. <https://doi.org/10.1111/j.1469-8986.2007.00638.x>
- Hinojosa, J. A., Haro, J., Magallares, S., Duñabeitia, J. A., & Ferré, P. (2020). Iconicity ratings for 10,995 Spanish words and their relationship with psycholinguistic variables. *Behavior Research Methods*, 53(3), 1262–1275. <https://doi.org/10.3758/s13428-020-01496-z>
- Hinton, L., Nichols, J., & Ohala, J. J. (Eds.). (2006). *Sound symbolism*. Cambridge University Press.
- Hisagi, M., Shafer, V. L., Strange, W., & Sussman, E. S. (2010). Perception of a Japanese vowel length contrast by Japanese and American English listeners: Behavioral and electrophysiological measures. *Brain Research*, 1360, 89–105. <https://doi.org/10.1016/j.brainres.2010.08.092>
- Hockett, C. F. (1958). *A course in modern linguistics*. Macmillan.
- Homae, F., Watanabe, H., Nakano, T., Asakawa, K., & Taga, G. (2006). The right hemisphere of sleeping infant perceives

- sentential prosody. *Neuroscience Research*, 54(4), 276–280.
<https://doi.org/10.1016/j.neures.2005.12.006>
- Homae, F., Watanabe, H., Nakano, T., & Taga, G. (2011). Large-scale brain networks underlying language acquisition in early infancy. *Frontiers in Psychology*, 2, Article 93.
<https://doi.org/10.3389/fpsyg.2011.00093>
- Huang, Y.-H., Pratoomraj, S., & Johnson, R. C. (1969). Universal magnitude symbolism. *Journal of Verbal Learning and Verbal Behavior*, 8(1), 155–156.
[https://doi.org/10.1016/S0022-5371\(69\)80028-9](https://doi.org/10.1016/S0022-5371(69)80028-9)
- Hugdahl, K. (2000). Lateralization of cognitive processes in the brain. *Acta Psychologica*, 105(2), 211–235.
[https://doi.org/10.1016/S0001-6918\(00\)00062-7](https://doi.org/10.1016/S0001-6918(00)00062-7)
- Huppert, T. J., Diamond, S. G., Franceschini, M. A., & Boas, D. A. (2009). HomER: A review of time-series analysis methods for near-infrared spectroscopy of the brain. *Applied Optics*, 48(10), D280–D298. <https://doi.org/10.1364/AO.48.00D280>
- Hyman, L. M. (2014). What is phonological typology? *UC Berkeley PhonLab Annual Report*, 10(10), 101–118.
- Imai, M., Kita, S., Nagumo, M., & Okada, H. (2008). Sound symbolism facilitates early verb learning. *Cognition*, 109(1), 54–65. <https://doi.org/10.1016/j.cognition.2008.07.015>
- Imai, M., Miyazaki, M., Yeung, H. H., Hidaka, S., Kantartzis, K., Okada, H., & Kita, S. (2015). Sound symbolism facilitates word learning in 14-month-olds. *PLoS ONE*, 10(2), e0116494.
<https://doi.org/10.1371/journal.pone.0116494>
- Issard, C., & Gervain, J. (2018). Variability of the hemodynamic response in infants: Influence of experimental design and

- stimulus complexity. *Developmental Cognitive Neuroscience*, 33, 182–193. <https://doi.org/10.1016/j.dcn.2018.01.009>
- Kager, R. (2018). How do infants disaggregate referential and affective pitch? *Frontiers in Psychology*, 9, 1–3. <https://doi.org/10.3389/fpsyg.2018.02093>
- Kambara, T., & Umemura, T. (2021). The relationships between initial consonants in Japanese sound symbolic words and familiarity, multi-sensory imageability, emotional valence, and arousal. *Journal of Psycholinguistic Research*, 50(4), 831–842. <https://doi.org/10.1007/s10936-020-09749-w>
- Kamiloğlu, R. G., Fischer, A. H., & Sauter, D. A. (2020). Good vibrations: A review of vocal expressions of positive emotions. *Psychonomic Bulletin & Review*, 27(2), 237–265. <https://doi.org/10.3758/s13423-019-01701-x>
- Kashima, Y., Coman, A., Pauketat, J. V. T., & Yzerbyt, V. (2020). Emotion in cultural dynamics. *Emotion Review*, 12(2), 48–64. <https://doi.org/10.1177/1754073919875215>
- Kissler, J., Herbert, C., Peyk, P., & Junghofer, M. (2007). Buzzwords: Early cortical responses to emotional words during reading. *Psychological Science*, 18(6), 475–480. <https://doi.org/10.1111/j.1467-9280.2007.01924.x>
- Kissler, J., Herbert, C., Winkler, I., & Junghofer, M. (2009). Emotion and attention in visual word processing—An ERP study. *Biological Psychology*, 80(1), 75–83. <https://doi.org/10.1016/j.biopsycho.2008.03.004>
- Knoeferle, K., Li, J., Maggioni, E., & Spence, C. (2017). What drives sound symbolism? Different acoustic cues underlie sound-size and sound-shape mappings. *Scientific Reports*, 7(1), 1–11. <https://doi.org/10.1038/s41598-017-05965-y>

- Köhler, W. (1929). *Gestalt psychology*. New York: Liveright.
- Köhler, W. (1947). *Gestalt psychology (2nd ed.)*. New York: Liveright.
- Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine*, 15(2), 155–163.
<https://doi.org/10.1016/j.jcm.2016.02.012>
- Koriat, A., & Levy, I. (1979). Figural symbolism in Chinese ideographs. *Journal of Psycholinguistic Research*, 8(4), 353–365. <https://doi.org/10.1007/BF01067139>
- Körner, A., & Rummer, R. (2022). Articulation contributes to valence sound symbolism. *Journal of Experimental Psychology: General*, 151(5), 1107–1114.
<https://doi.org/10.1037/xge0001124>
- Körner, A., & Rummer, R. (2023). Valence sound symbolism across language families: A comparison between Japanese and German. *Language and Cognition*, 15(2), 337–354.
<https://doi.org/10.1017/langcog.2022.39>
- Kotz, S. A., Meyer, M., & Paulmann, S. (2006). Lateralization of emotional prosody in the brain: An overview and synopsis on the impact of study design. *Progress in Brain Research*, 156, 285–294. [https://doi.org/10.1016/S0079-6123\(06\)56015-7](https://doi.org/10.1016/S0079-6123(06)56015-7)
- Kousta, S.-T., Vinson, D. P., & Vigliocco, G. (2009). Emotion words, regardless of polarity, have a processing advantage over neutral words. *Cognition*, 112(3), 473–481.
<https://doi.org/10.1016/j.cognition.2009.06.007>
- Kubozono, H. (2012). Varieties of pitch accent systems in Japanese. *Lingua*, 122(13), 1395–1414.
<https://doi.org/10.1016/j.lingua.2012.08.001>

- Kucharský, Š., Zaharieva, M., Raijmakers, M., & Visser, I. (2022). Habituation, part II. Rethinking the habituation paradigm. *Infant and Child Development*, 33(1), e2383. <https://doi.org/10.1002/icd.2383>
- Kuhl, P. K. (2004). Early language acquisition: Cracking the speech code. *Nature Reviews Neuroscience*, 5(11), 831–843. <https://doi.org/10.1038/nrn1533>
- Kuhl, P. K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental Science*, 9(2), F13–F21. <https://doi.org/10.1111/j.1467-7687.2006.00468.x>
- Kuppens, P., Tuerlinckx, F., Russell, J. A., & Barrett, L. F. (2013). The relation between valence and arousal in subjective experience. *Psychological Bulletin*, 139(4), 917–940. <https://doi.org/10.1037/a0030811>
- Lapolla, R. J. (1995). An experimental investigation into phonetic symbolism as it relates to Mandarin Chinese. In J. Nichols, J. J. Ohala, & L. Hinton (Eds.), *Sound symbolism* (pp. 130–147). Cambridge University Press. <https://doi.org/10.1017/CBO9780511751806.010>
- Laukka, P., Juslin, P., & Bresin, R. (2005). A dimensional approach to vocal expression of emotion. *Cognition and Emotion*, 19(5), 633–653. <https://doi.org/10.1080/02699930441000445>
- Lenth, R. V. (2023). emmeans: Estimated marginal means, aka least-squares means. *R Package Version 1.8.7*. <https://CRAN.R-project.org/package=emmeans>
- Leroy, F., Glasel, H., Dubois, J., Hertz-Pannier, L., Thirion, B., Mangin, J.-F., & Dehaene-Lambertz, G. (2011). Early

- maturation of the linguistic dorsal pathway in human infants. *The Journal of Neuroscience*, 31(4), 1500–1506.
<https://doi.org/10.1523/JNEUROSCI.4141-10.2011>
- Lester, D. (1974). Symbolism in the Chinese language. *International Journal of Symbolology*, 5(1), 18–21.
- Ley-Flores, J., Alshami, E., Singh, A., Bevilacqua, F., Bianchi-Berthouze, N., Deroy, O., & Tajadura-Jiménez, A. (2022). Effects of pitch and musical sounds on body-representations when moving with sound. *Scientific Reports*, 12, Article 2676.
<https://doi.org/10.1038/s41598-022-06210-x>
- Li, C. N., & Thompson, S. A. (1981). *Mandarin Chinese: A functional reference grammar*. University of California Press.
- Li, F. (2017). Analyses on arbitrariness of Chinese characters from the perspective of morphology. *ProtoSociology*, 34, 181–196.
<https://doi.org/10.5840/protosociology20173411>
- Li, V. P. H. (1986). Philology and power: Ezra pound and the regulation of language. *Boundary 2*, 15(1/2), 187–210.
<https://doi.org/10.2307/303430>
- Lialiou, M., Grice, M., Röhr, C. T., & Schumacher, P. B. (2024). Auditory processing of intonational rises and falls in German: Rises are special in attention orienting. *Journal of Cognitive Neuroscience*, 36(6), 1099–1122.
https://doi.org/10.1162/jocn_a_02129
- Lin, Y., Ding, H., & Zhang, Y. (2020). Prosody dominates over semantics in emotion word processing: Evidence from cross-channel and cross-modal Stroop effects. *Journal of Speech, Language, and Hearing Research*, 63(3), 896–912.
https://doi.org/10.1044/2020_JSLHR-19-00258

- Lin, Y., Ding, H., & Zhang, Y. (2021). Unisensory and multisensory Stroop effects modulate gender differences in verbal and nonverbal emotion perception. *Journal of Speech, Language, and Hearing Research*, 64(11), 4439–4457.
https://doi.org/10.1044/2021_JSLHR-20-00338
- Lindquist, K. A., Wager, T. D., Kober, H., Bliss-Moreau, E., & Barrett, L. F. (2012). The brain basis of emotion: A meta-analytic review. *The Behavioral and Brain Sciences*, 35(3), 121–143.
<https://doi.org/10.1017/S0140525X11000446>
- Liu, L., Götz, A., Lorette, P., & Tyler, M. D. (2022). How tone, intonation and emotion shape the development of infants' fundamental frequency perception. *Frontiers in Psychology*, 13, Article 906848.
<https://doi.org/10.3389/fpsyg.2022.906848>
- Liu, L., & Kager, R. (2014). Perception of tones by infants learning a non-tone language. *Cognition*, 133(2), 385–394.
<https://doi.org/10.1016/j.cognition.2014.06.004>
- Liu, L., & Kager, R. (2016). Perception of a native vowel contrast by Dutch monolingual and bilingual infants: A bilingual perceptual lead. *International Journal of Bilingualism*, 20(3), 335–345. <https://doi.org/10.1177/1367006914566082>
- Liu, P., & Pell, M. D. (2012). Recognizing vocal emotions in Mandarin Chinese: A validated database of Chinese vocal emotional stimuli. *Behavior Research Methods*, 44, 1042–1051.
<https://doi.org/10.3758/s13428-012-0203-3>
- Lloyd-Fox, S., Blasi, A., & Elwell, C. E. (2010). Illuminating the developing brain: The past, present and future of functional near infrared spectroscopy. *Neuroscience & Biobehavioral*

- Reviews*, 34(3), 269–284.
<https://doi.org/10.1016/j.neubiorev.2009.07.008>
- Lockwood, G., & Dingemanse, M. (2015). Iconicity in the lab: A review of behavioral, developmental, and neuroimaging research into sound-symbolism. *Frontiers in Psychology*, 6, Article 1246. <https://doi.org/10.3389/fpsyg.2015.01246>
- Lockwood, G., Hagoort, P., & Dingemanse, M. (2016). How iconicity helps people learn new words: Neural correlates and individual differences in sound-symbolic bootstrapping. *Collabra*, 2(1), 7. <https://doi.org/10.1525/collabra.42>
- Louwerse, M., & Qu, Z. (2017). Estimating valence from the sound of a word: Computational, experimental, and cross-linguistic evidence. *Psychonomic Bulletin & Review*, 24(3), 849–855. <https://doi.org/10.3758/s13423-016-1142-2>
- Lovčević, I., & Tsuji, S. (2024). The developmental pattern of native and non-native speech perception during the 1st year of life in Japanese infants. *Infant Behavior and Development*, 76, 101977. <https://doi.org/10.1016/j.infbeh.2024.101977>
- Lowe, M. L., & Haws, K. L. (2017). Sounds big: The effects of acoustic pitch on product perceptions. *Journal of Marketing Research*, 54(2), 331–346. <https://doi.org/10.1509/jmr.14.0300>
- Ludwig, V. U., Adachi, I., & Matsuzawa, T. (2011). Visuoauditory mappings between high luminance and high pitch are shared by chimpanzees (*Pan troglodytes*) and humans. *Proceedings of the National Academy of Sciences*, 108(51), 20661–20665. <https://doi.org/10.1073/pnas.1112605108>
- Luk, G., & Bialystok, E. (2005). How iconic are Chinese characters? *Bilingualism: Language and Cognition*, 8(1), 79–83. <https://doi.org/10.1017/S1366728904002081>

- Maddieson, I. (2023). Tone is not predominant; Tone is not primordial. In R. Skarnitzl & J. Volín (Eds.), *Proceedings of the 20th International Congress of Phonetic Sciences* (pp. 1901–1905). International Phonetic Association.
- Marks, L. E. (1974). On associations of light and sound: The mediation of brightness, pitch, and loudness. *The American Journal of Psychology*, 87(1/2), 173–188.
<https://doi.org/10.2307/1422011>
- Marks, L. E. (1987). On cross-modal similarity: Auditory–visual interactions in speeded discrimination. *Journal of Experimental Psychology: Human Perception and Performance*, 13(3), 384–394. <https://doi.org/10.1037/0096-1523.13.3.384>
- Marks, L. E., Hammeal, R. J., Bornstein, M. H., & Smith, L. B. (1987). Perceiving similarity and comprehending metaphor. *Monographs of the Society for Research in Child Development*, 52(1). <https://doi.org/10.2307/1166084>
- Massaro, D. W. (2015). Speech perception. In *International Encyclopedia of the Social & Behavioral Sciences* (pp. 235–242). Elsevier. <https://doi.org/10.1016/B978-0-08-097086-8.52021-2>
- Matsui, M. (2020). Effects of pitch of short pure tones on onomatopoeic expressions: A cross-linguistic study of Japanese and Chinese. *Acoustical Science and Technology*, 41(2), 472–480. <https://doi.org/10.1250/ast.41.472>
- Mattock, K., & Burnham, D. (2006). Chinese and English Infants' tone perception: Evidence for perceptual reorganization. *Infancy*, 10(3), 241–265.
https://doi.org/10.1207/s15327078in1003_3

- Mattock, K., Molnar, M., Polka, L., & Burnham, D. (2008). The developmental course of lexical tone perception in the first year of life. *Cognition*, 106(3), 1367–1381.
<https://doi.org/10.1016/j.cognition.2007.07.002>
- Maurer, D., Pathman, T., & Mondloch, C. J. (2006). The shape of boubas: Sound-shape correspondences in toddlers and adults. *Developmental Science*, 9(3), 316–322.
<https://doi.org/10.1111/j.1467-7687.2006.00495.x>
- May, L., Byers-Heinlein, K., Gervain, J., & Werker, J. F. (2011). Language and the newborn brain: Does prenatal language experience shape the neonate neural response to speech? *Frontiers in Psychology*, 2, Article 222.
<https://doi.org/10.3389/fpsyg.2011.00222>
- Mazuka, R., Hasegawa, M., & Tsuji, S. (2014). Development of non-native vowel discrimination: Improvement without exposure. *Developmental Psychobiology*, 56(2), 192–209.
<https://doi.org/10.1002/dev.21193>
- McCormick, K., Lacey, S., Stilla, R., Nygaard, L. C., & Sathian, K. (2021). Neural basis of the sound-symbolic crossmodal correspondence between auditory pseudowords and visual shapes. *Multisensory Research*, 35(1), 29–78.
<https://doi.org/10.1163/22134808-bja10060>
- McLean, B., Dunn, M., & Dingemanse, M. (2023). Two measures are better than one: Combining iconicity ratings and guessing experiments for a more nuanced picture of iconicity in the lexicon. *Language and Cognition*, 15(4), 716–739.
<https://doi.org/10.1017/langcog.2023.9>
- Melara, R. D. (1989). Dimensional interaction between color and pitch. *Journal of Experimental Psychology: Human*

Perception and Performance, 15(1), 69–79.

<https://doi.org/10.1037/0096-1523.15.1.69>

Melara, R. D., & O'Brien, T. P. (1987). Interaction between synesthetically corresponding dimensions. *Journal of Experimental Psychology: General*, 116(4), 323–336.

Michaud, A., & Sands, B. (2020). *Tonogenesis*. HAL open archive. <https://halshs.archives-ouvertes.fr/halshs-02519305>

Milne, A. E., Bianco, R., Poole, K. C., Zhao, S., Oxenham, A. J., Billig, A. J., & Chait, M. (2021). An online headphone screening test based on dichotic pitch. *Behavior Research Methods*, 53(4), 1551–1562. <https://doi.org/10.3758/s13428-020-01514-0>

Minagawa-Kawai, Y., Cristià, A., & Dupoux, E. (2011). Cerebral lateralization and early speech acquisition: A developmental scenario. *Developmental Cognitive Neuroscience*, 1(3), 217–232. <https://doi.org/10.1016/j.dcn.2011.03.005>

Minagawa-Kawai, Y., Mori, K., Naoi, N., & Kojima, S. (2007). Neural attunement processes in infants during the acquisition of a language-specific phonemic contrast. *The Journal of Neuroscience*, 27(2), 315–321. <https://doi.org/10.1523/JNEUROSCI.1984-06.2007>

Mitterer, H., & Cutler, A. (2006). Speech perception. In K. Brown (Ed.), *Encyclopedia of Language & Linguistics* (2nd ed.) (pp. 770–782). Elsevier. <https://doi.org/10.1016/B0-08-044854-2/00029-8>

Mok, P. P. K., Li, G., Li, J. J., Ng, H. T. Y., & Cheung, H. (2019). Cross-modal association between vowels and colours: A cross-linguistic perspective. *The Journal of the Acoustical Society of America*, 145(4), 2265–2276. <https://doi.org/10.1121/1.5096632>

- Molfese, D. L., Freeman, R. B., & Palermo, D. S. (1975). The ontogeny of brain lateralization for speech and nonspeech stimuli. *Brain and Language*, 2, 356–368. [https://doi.org/10.1016/S0093-934X\(75\)80076-9](https://doi.org/10.1016/S0093-934X(75)80076-9)
- Monaghan, P., Mattock, K., & Walker, P. (2012). The role of sound symbolism in language learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 38(5), 1152–1164. <https://doi.org/10.1037/a0027747>
- Monaghan, P., Shillcock, R. C., Christiansen, M. H., & Kirby, S. (2014). How arbitrary is language? *Philosophical Transactions of the Royal Society B: Biological Sciences*, 369(1651), 1–12. <https://doi.org/10.1098/rstb.2013.0299>
- Mondloch, C. J., & Maurer, D. (2004). Do small white balls squeak? Pitch-object correspondences in young children. *Cognitive, Affective, & Behavioral Neuroscience*, 4(2), 133–136. <https://doi.org/10.3758/CABN.4.2.133>
- Morton, E. S. (1977). On the occurrence and significance of motivation-structural rules in some bird and mammal sounds. *The American Naturalist*, 111(981), 855–869. <https://doi.org/10.1086/283219>
- Motamedi, Y., Little, H., Nielsen, A., & Sulik, J. (2019). The iconicity toolbox: Empirical approaches to measuring iconicity. *Language and Cognition*, 11(2), 188–207. <https://doi.org/10.1017/langcog.2019.14>
- Nazzi, T., Floccia, C., & Bertoncini, J. (1998). Discrimination of pitch contours by neonates. *Infant Behavior and Development*, 21(4), 779–784. [https://doi.org/10.1016/S0163-6383\(98\)90044-3](https://doi.org/10.1016/S0163-6383(98)90044-3)

- Needle, J. M., Pierrehumbert, J. B., & Hay, J. B. (2022). Phonotactic and morphological effects in the acceptability of pseudowords. In A. D. Sims, A. Ussishkin, J. Parker, & S. Wray (Eds.), *Morphological Diversity and Linguistic Cognition* (1st ed., pp. 79–112). Cambridge University Press.
<https://doi.org/10.1017/9781108807951.005>
- Nielsen, A., & Dingemanse, M. (2021). Iconicity in word learning and beyond: A critical review. *Language and Speech*, 64(1), 52–72.
<https://doi.org/10.1177/0023830920914339>
- Nielsen, A., & Rendall, D. (2011). The sound of round: Evaluating the sound-symbolic role of consonants in the classic Takete-Maluma phenomenon. *Canadian Journal of Experimental Psychology / Revue Canadienne de Psychologie Expérimentale*, 65(2), 115–124.
<https://doi.org/10.1037/a0022268>
- Nielsen, A., & Rendall, D. (2018). Comparative perspectives on communication in human and non-Human primates: Grounding meaning in broadly conserved processes of voice production, perception, affect, and cognition. In S. Frühholz & P. Belin (Eds.), *The Oxford handbook of voice perception* (pp. 278–308). Oxford University Press.
<https://doi.org/10.1093/oxfordhb/9780198743187.013.13>
- Nikroshkina, S. V. (2019). Linguistic and psychological aspects of universal sound symbolism studies. *Proceedings of the International Conference on “Humanities and Social Sciences: Novations, Problems, Prospects” (HSSNPP 2019)*, 333, 262–266. <https://doi.org/10.2991/hssnpp-19.2019.49>
- Nishiyori, R. (2016). fNIRS: An emergent method to document functional cortical activity during infant movements.

- Frontiers in Psychology*, 7, Article 533.
<https://doi.org/10.3389/fpsyg.2016.00533>
- Nuckolls, J. B. (1999). The case for sound symbolism. *Annual Review of Anthropology*, 28, 225–252.
<http://www.jstor.org/stable/223394>
- Oakes, L. M. (2010). Using habituation of looking time to assess mental processes in infancy. *Journal of Cognition and Development*, 11(3), 255–268.
<https://doi.org/10.1080/15248371003699977>
- Oakes, L. M., Sperka, D., DeBolt, M. C., & Cantrell, L. M. (2019). Habit2: A stand-alone software solution for presenting stimuli and recording infant looking times in order to study infant development. *Behavior Research Methods*, 51(5).
<https://doi.org/10.3758/s13428-019-01244-y>
- Ohala, J. J. (1983). Cross-language use of pitch: An ethological view. *Phonetica*, 40(1), 1–18. <https://doi.org/10.1159/000261678>
- Ohala, J. J. (1984). An ethological perspective on common cross-language utilization of f_0 of voice. *Phonetica*, 41, 1–16.
<https://doi.org/10.1159/000261706>. PMID: 6204347.
- Ohala, J. J. (1994). The frequency code underlies the sound-symbolic use of voice pitch. In L. Hinton, J. Nichols, & J. J. Ohala (Eds.), *Sound symbolism* (1st ed.) (pp. 325–347). Cambridge University Press.
<https://doi.org/10.1017/CBO9780511751806.022>
- Ohala, J. J. (1997). Sound symbolism. *Proceedings of the 4th Seoul International Conference on Linguistics (SICOL)*, 98–103.
- Okada, H. (1991). Japanese. *Journal of the International Phonetic Association*, 21(2), 94–96.
<https://doi.org/10.1017/S002510030000445X>

- Ota, M., Yamane, N., & Mazuka, R. (2018). The effects of lexical pitch accent on infant word recognition in Japanese. *Frontiers in Psychology*, 8, Article 2354.
<https://doi.org/10.3389/fpsyg.2017.02354>
- Pakosz, M. (1983). Attitudinal judgments in intonation: Some evidence for a theory. *Journal of Psycholinguistic Research*, 12, 311–326. <https://doi.org/10.1007/BF01067673>
- Pan, Y., & Schmitt, B. (1996). Language and brand attitudes: Impact of script and sound matching in Chinese and English. *Journal of Consumer Psychology*, 5(3), 263–277.
https://doi.org/10.1207/s15327663jcp0503_03
- Parise, C., & Spence, C. (2008). Synesthetic congruency modulates the temporal ventriloquism effect. *Neuroscience Letters*, 442(3), 257–261.
<https://doi.org/10.1016/j.neulet.2008.07.010>
- Parise, C., & Spence, C. (2012). Audiovisual crossmodal correspondences and sound symbolism: A study using the implicit association test. *Experimental Brain Research*, 220(3), 319–333. <https://doi.org/10.1007/s00221-012-3140-6>
- Paus, T. (2000). Functional anatomy of arousal and attention systems in the human brain. *Progress in Brain Research*, 126, 65–77.
[https://doi.org/10.1016/S0079-6123\(00\)26007-X](https://doi.org/10.1016/S0079-6123(00)26007-X)
- Peiffer-Smadja, N., & Cohen, L. (2019). The cerebral bases of the bouba-kiki effect. *NeuroImage*, 186, 679–689.
<https://doi.org/10.1016/j.neuroimage.2018.11.033>
- Peng, D., & Wang, C. (1997). Hanzi jiagong de jiben danyuan: Laizi bihuashu xiaoying he bujianshu xiaoying de zhengju [Basic processing unit of Chinese character recognition: Evidence

- from stroke number effect and radical number effect]. *Acta Psychologica Sinica*, 29(1), 9–17.
- Perlman, M. (2017). Debunking two myths against vocal origins of language. *Interaction Studies*, 18(3), 376–401.
<https://doi.org/10.1075/is.18.3.05per>
- Perlman, M. (2024). Iconic prosody is deeply connected to iconic gesture, and it may occur just as frequently. In O. Fischer, K. Akita, & P. Perniss (Eds.), *Oxford handbook of iconicity in language*. Oxford University Press.
- Perlman, M., & Cain, A. A. (2014). Iconicity in vocalization, comparisons with gesture, and implications for theories on the evolution of language. *Gesture*, 14(3), 320–350.
<https://doi.org/10.1075/gest.14.3.03per>
- Perlman, M., Clark, N., & Johansson Falck, M. (2015). Iconic prosody in story reading. *Cognitive Science*, 39(6), 1348–1368.
<https://doi.org/10.1111/cogs.12190>
- Perlman, M., Dale, R., & Lupyan, G. (2015). Iconicity can ground the creation of vocal symbols. *Royal Society Open Science*, 2(8), 150152. <https://doi.org/10.1098/rsos.150152>
- Perniss, P., Thompson, R., & Vigliocco, G. (2010). Iconicity as a general property of language: Evidence from spoken and signed languages. *Frontiers in Psychology*, 1, Article 227.
<https://doi.org/10.3389/fpsyg.2010.00227>
- Perry, L. K., Perlman, M., & Lupyan, G. (2015). Iconicity in English and Spanish and its relation to lexical category and age of acquisition. *PLoS ONE*, 10(9), 1–17.
<https://doi.org/10.1371/journal.pone.0137147>
- Pike, K. L. (1948). *Tone languages: A technique for determining the number and type of pitch contrasts in a language, with*

studies in tonemic substitution and fusion. University of Michigan Press.

- Pinti, P., Cardone, D., & Merla, A. (2015). Simultaneous fNIRS and thermal infrared imaging during cognitive task reveal autonomic correlates of prefrontal cortex activity. *Scientific Reports*, 5, 17471. <https://doi.org/10.1038/srep17471>
- Pinti, P., Scholkmann, F., Hamilton, A., Burgess, P., & Tachtsidis, I. (2019). Current status and issues regarding pre-processing of fNIRS neuroimaging data: An investigation of diverse signal filtering methods within a general linear model framework. *Frontiers in Human Neuroscience*, 12, Article 505. <https://doi.org/10.3389/fnhum.2018.00505>
- Pittayaporn, P., & Kirby, J. (2017). Laryngeal contrasts in the Tai dialect of Cao Bằng. *Journal of the International Phonetic Association*, 47(1), 65–85. <https://doi.org/10.1017/S0025100316000293>
- Poeppel, D. (2001). Pure word deafness and the bilateral processing of the speech code. *Cognitive Science*, 25(5), 679–693. https://doi.org/10.1207/s15516709cog2505_3
- Pollet, T. V., Stulp, G., Henzi, S. P., & Barrett, L. (2015). Taking the aggravation out of data aggregation: A conceptual guide to dealing with statistical issues related to the pooling of individual-level observational data. *American Journal of Primatology*, 77(7), 727–740. <https://doi.org/10.1002/ajp.22405>
- Posner, J., Russell, J. A., & Peterson, B. S. (2005). The circumplex model of affect: An integrative approach to affective neuroscience, cognitive development, and psychopathology.

- Development and Psychopathology*, 17(3), 715–734.
<https://doi.org/10.1017/S0954579405050340>
- Quaresima, V., Bisconti, S., & Ferrari, M. (2012). A brief review on the use of functional near-infrared spectroscopy (fNIRS) for language imaging studies in human newborns and adults. *Brain and Language*, 121(2), 79–89.
<https://doi.org/10.1016/j.bandl.2011.03.009>
- R Core Team. (2023). *R: A language and environment for statistical computing*. (Version 4.3.2) [Computer software].
<https://www.R-project.org/>
- Ramachandran, V. S., & Hubbard, E. M. (2001). Synaesthesia—A window into perception, thought and language. *Journal of Consciousness Studies*, 8(12), 3–34.
- Ramachers, S., Brouwer, S., & Fikkert, P. (2018). No perceptual reorganization for Limburgian tones? A cross-linguistic investigation with 6- to 12-month-old infants. *Journal of Child Language*, 45(2), 290–318.
<https://doi.org/10.1017/S0305000917000228>
- Ren, J., Cai, L., Jia, G., & Niu, H. (2024). Cortical specialization associated with native speech category acquisition in early infancy. *Cerebral Cortex*, 34(4), bhae124.
<https://doi.org/10.1093/cercor/bhae124>
- Revelle, W. (2023). *psych: Procedures for psychological, psychometric, and personality research* (Version 2.3.6) [Computer software]. <https://CRAN.R-project.org/package=psych>
- Robinson, M. D., Storbeck, J., Meier, B. P., & Kirkeby, B. S. (2004). Watch out! That could be dangerous: Valence-arousal interactions in evaluative processing. *Personality and Social*

Psychology Bulletin, 30(11), 1472–1484.

<https://doi.org/10.1177/0146167204266647>

Rojczyk, A. (2011). Sound symbolism in vowels: Vowel quality, duration and pitch in sound-to-size correspondence. *Poznań Studies in Contemporary Linguistics*, 47(3), 602–615.

<https://doi.org/10.2478/psicl-2011-0030>

Russell, J. A. (1980). A circumplex model of affect. *Journal of Personality and Social Psychology*, 39(6), 1161–1178.

<https://doi.org/10.1037/h0077714>

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, 110(1), 145–172.

<https://doi.org/10.1037/0033-295X.110.1.145>

Sakamoto, M., & Watanabe, J. (2018). Bouba/kiki in touch: Associations between tactile perceptual qualities and Japanese phonemes. *Frontiers in Psychology*, 9, Article 295.

<https://doi.org/10.3389/fpsyg.2018.00295>

Sato, Y., Sogabe, Y., & Mazuka, R. (2007). Brain responses in the processing of lexical pitch-accent by Japanese speakers.

NeuroReport, 18(18), 2001–2004.

<https://doi.org/10.1097/WNR.ob013e3282f262de>

Sato, Y., Sogabe, Y., & Mazuka, R. (2010a). Development of hemispheric specialization for lexical pitch-accent in Japanese infants. *Journal of Cognitive Neuroscience*, 22(11), 2503–

2513. <https://doi.org/10.1162/jocn.2009.21377>

Sato, Y., Sogabe, Y., & Mazuka, R. (2010b). Discrimination of phonemic vowel length by Japanese infants. *Developmental Psychology*, 46(1), 106–119.

<https://doi.org/10.1037/a0016718>

- Schacht, A., & Sommer, W. (2009). Time course and task dependence of emotion effects in word processing. *Cognitive, Affective, & Behavioral Neuroscience*, 9(1), 28–43.
<https://doi.org/10.3758/CABN.9.1.28>
- Scheff, S. W. (2016). Nonparametric statistics. In *Fundamental statistical principles for the neurobiologist* (pp. 157–182). Academic Press. <https://doi.org/10.1016/B978-0-12-804753-8.00008-7>
- Scherer, K. R. (1979). Nonlinguistic vocal indicators of emotion and psychopathology. In C. E. Izard (Ed.), *Emotions in personality and psychopathology* (pp. 493–529). Springer.
https://doi.org/10.1007/978-1-4613-2892-6_18
- Scherer, K. R. (1989). Vocal correlates of emotional arousal and affective disturbance. In H. Wagner & A. Manstead (Eds.), *Handbook of social psychophysiology* (pp. 165–197). John Wiley & Sons.
- Scherer, K. R., Johnstone, T., & Klasmeyer, G. (2003). Vocal expression of emotion. In R. J. Davidson, K. R. Scherer, & H. H. Goldsmith (Eds.), *Handbook of affective sciences* (pp. 433–456). Oxford University Press.
- Scherer, K. R., & Oshinsky, J. S. (1977). Cue utilization in emotion attribution from auditory stimuli. *Motivation and Emotion*, 1(4), 331–346. <https://doi.org/10.1007/BF00992539>
- Schirmer, A., & Kotz, S. A. (2006). Beyond the right hemisphere: Brain mechanisms mediating vocal emotional processing. *Trends in Cognitive Sciences*, 10(1), 24–30.
<https://doi.org/10.1016/j.tics.2005.11.009>

- Schmidtke, D., Conrad, M., & Jacobs, A. M. (2014). Phonological iconicity. *Frontiers in Psychology*, 5, Article 80.
<https://doi.org/10.3389/fpsyg.2014.00080>
- Shafer, V. L., Yu, Y. H., & Garrido-Nag, K. (2012). Neural mismatch indices of vowel discrimination in monolingually and bilingually exposed infants: Does attention matter? *Neuroscience Letters*, 526(1), 10–14.
<https://doi.org/10.1016/j.neulet.2012.07.064>
- Shang, N., & Styles, S. J. (2017). Is a high tone pointy? Speakers of different languages match Mandarin Chinese tones to visual shapes differently. *Frontiers in Psychology*, 8, Article 2139.
<https://doi.org/10.3389/fpsyg.2017.02139>
- Shang, N., & Styles, S. J. (2023). Implicit association test (IAT) studies investigating pitch-shape audiovisual cross-modal associations across language groups. *Cognitive Science*, 47(1), e13221. <https://doi.org/10.1111/cogs.13221>
- Shih, S. S., Ackerman, J., Hermalin, N., Inkelas, S., Jang, H., Kavitskaya, D., Kawahara, S., Oh, M., Starr, R. L., & Yu, A. (2019). Cross-linguistic and language-specific sound symbolism: Pokémonastics. *Manuscript*.
<https://ling.auf.net/lingbuzz/004725>
- Shintel, H., Nusbaum, H. C., & Okrent, A. (2006). Analog acoustic expression in speech communication. *Journal of Memory and Language*, 55(2), 167–177.
<https://doi.org/10.1016/j.jml.2006.03.002>
- Shrum, L. J., Lowrey, T. M., Luna, D., Lerman, D. B., & Liu, M. (2012). Sound symbolism effects across languages: Implications for global brand names. *International Journal of*

- Research in Marketing*, 29(3), 275–279.
<https://doi.org/10.1016/j.ijresmar.2012.03.002>
- Sidhu, D. M. (2025). Sound symbolism in the lexicon: A review of iconic-systematicity. *Language and Linguistics Compass*, 19(1), e70006. <https://doi.org/10.1111/lnc3.70006>
- Sidhu, D. M., & Pexman, P. M. (2018). Five mechanisms of sound symbolic association. *Psychonomic Bulletin & Review*, 25(5), 1619–1643. <https://doi.org/10.3758/s13423-017-1361-1>
- Sidhu, D. M., Vigliocco, G., & Pexman, P. M. (2022). Higher order factors of sound symbolism. *Journal of Memory and Language*, 125, 104323. <https://doi.org/10.1016/j.jml.2022.104323>
- Singh, L., Rajendra, S. J., & Mazuka, R. (2022). Diversity and representation in studies of infant perceptual narrowing. *Child Development Perspectives*, 16(4), 191–199. <https://doi.org/10.1111/cdep.12468>
- Sluijter, A. M. C., & van Heuven, V. J. (1996). Spectral balance as an acoustic correlate of linguistic stress. *The Journal of the Acoustical Society of America*, 100(4), 2471–2485. <https://doi.org/10.1121/1.417955>
- Spence, C. (2011). Crossmodal correspondences: A tutorial review. *Attention, Perception, & Psychophysics*, 73(4), 971–995. <https://doi.org/10.3758/s13414-010-0073-7>
- State Language Commission. (1988). *Xiandai hanyu changyong zibiao [List of frequently used characters in modern Chinese]*. Yuwen Publishing House.
- State Language Commission. (2013). *Tongyong guifan zibiao [List of commonly used characters in modern Chinese]*. The Commercial Press.

- Stefanics, G., Háden, G. P., Sziller, I., Balázs, L., Beke, A., & Winkler, I. (2009). Newborn infants process pitch intervals. *Clinical Neurophysiology*, 120(2), 304–308.
<https://doi.org/10.1016/j.clinph.2008.11.020>
- Stel, M., Dijk, E. van, Smith, P. K., Dijk, W. W. van, & Djalal, F. M. (2012). Lowering the pitch of your voice makes you feel more powerful and think more abstractly. *Social Psychological and Personality Science*, 3(4), 497–502.
<https://doi.org/10.1177/1948550611427610>
- Storbeck, J., & Clore, G. L. (2008). Affective arousal as information: How affective arousal influences judgments, learning, and memory. *Social and Personality Psychology Compass*, 2(5), 1824–1843. <https://doi.org/10.1111/j.1751-9004.2008.00138.x>
- Styles, S. J., & Gawne, L. (2017). When does Maluma/Takete fail? Two key failures and a meta-analysis suggest that phonology and phonotactics matter. *I-Perception*, 8(4), 1–17.
<https://doi.org/10.1177/2041669517724807>
- Sučević, J., Savić, A. M., Popović, M. B., Styles, S. J., & Ković, V. (2015). Balloons and bavoons versus spikes and shikes: ERPs reveal shared neural processes for shape–sound–meaning congruence in words, and shape–sound congruence in pseudowords. *Brain and Language*, 145–146, 11–22.
<https://doi.org/10.1016/j.bandl.2015.03.011>
- Sun, X., Li, X., Ji, L., Han, F., Wang, H., Liu, Y., Chen, Y., Lou, Z., & Li, Z. (2018). An extended research of crossmodal correspondence between color and sound in psychology and cognitive ergonomics. *PeerJ*, 6, e4443.
<https://doi.org/10.7717/peerj.4443>

- Svantesson, J.-O. (2017). Sound symbolism: The role of word sound in meaning. *Wiley Interdisciplinary Reviews: Cognitive Science*, 8(5), e1441. <https://doi.org/10.1002/wcs.1441>
- Swoboda, P. J., Morse, P. A., & Leavitt, L. A. (1976). Continuous vowel discrimination in normal and at risk infants. *Child Development*, 47(2), 459–465. <https://doi.org/10.2307/1128802>
- Taga, G., Asakawa, K., Maki, A., Konishi, Y., & Koizumi, H. (2003). Brain imaging in awake infants by near-infrared optical topography. *Proceedings of the National Academy of Sciences*, 100(19), 10722–10727. <https://doi.org/10.1073/pnas.1932552100>
- Tarte, R. D. (1982). The relationship between monosyllables and pure tones: An investigation of phonetic symbolism. *Journal of Verbal Learning and Verbal Behavior*, 21(3), 352–360. [https://doi.org/10.1016/S0022-5371\(82\)90670-3](https://doi.org/10.1016/S0022-5371(82)90670-3)
- Telkemeyer, S., Rossi, S., Nierhaus, T., Steinbrink, J., Obrig, H., & Wartenburger, I. (2011). Acoustic processing of temporally modulated sounds in infants: Evidence from a combined near-infrared spectroscopy and EEG Study. *Frontiers in Psychology*, 2, Article 62. <https://doi.org/10.3389/fpsyg.2011.00062>
- Tervaniemi, M., & Hugdahl, K. (2003). Lateralization of auditory-cortex functions. *Brain Research Reviews*, 43(3), 231–246. <https://doi.org/10.1016/j.brainresrev.2003.08.004>
- The ManyBabies Consortium. (2020). Quantifying sources of variability in infancy research using the infant-directed-speech preference. *Advances in Methods and Practices in*

Psychological Science, 3(1), 24–52.

<https://doi.org/10.1177/2515245919900809>

Thompson, A. L. (2018). Are tones in the expressive lexicon iconic?

Evidence from three Chinese languages. *PloS ONE*, 13(12),

e0204270. <https://doi.org/10.1371/journal.pone.0204270>

Thompson, A. L., & Do, Y. (2019). Defining iconicity: An articulation-

based methodology for explaining the phonological structure

of ideophones. *Glossa: A Journal of General Linguistics*, 4(1),

Article 72. <https://doi.org/10.5334/gjgl.872>

Toet, A., & van Erp, J. B. F. (2019). The EmojiGrid as a tool to assess

experienced and perceived emotions. *Psych*, 1(1), Article 1.

<https://doi.org/10.3390/psych1010036>

Tse, C.-S., Yap, M. J., & Chan, Y.-L. (2024). Neighborhood in Chinese

lexicon: A megastudy analysis of lexical decision and naming

of two-character Chinese words. *Journal of Experimental*

Psychology: Learning, Memory, and Cognition, 50(9), 1489–

1515. <https://doi.org/10.1037/xlm0001357>

Tsuji, S., & Cristia, A. (2014). Perceptual attunement in vowels: A

meta-analysis. *Developmental Psychobiology*, 56(2), 179–191.

<https://doi.org/10.1002/dev.21179>

Tsushima, T., Takizawa, O., Sasaki, M., Shiraki, S., Nishi, K., Kohno,

M., Menyuk, P., & Best, C. (1994). Discrimination of English

/r-l/ and /w-y/ by Japanese infants at 6-12 months:

Language-specific developmental changes in speech

perception abilities. *3rd International Conference on Spoken*

Language Processing, 1695–1698.

<https://doi.org/10.21437/ICSLP.1994-438>

Vainio, L., Kilpeläinen, M., Wikström, A., & Vainio, M. (2023). Front

is high and back is low: Sound-space iconicity in Finnish.

- Language and Speech*, 67(4), 1001–1019.
<https://doi.org/10.1177/00238309231214176>
- Vainio, L., Wikström, A., Repetto, C., & Vainio, M. (2023). Sound-symbolic association between speech sound and spatial meaning in relation to the concepts of up/down and above/below. *Language and Cognition*, 15(4), 884–903.
<https://doi.org/10.1017/langcog.2023.31>
- van Lancker, D. (1980). Cerebral lateralization of pitch cues in the linguistic signal. *Paper in Linguistics*, 13(2), 201–277.
<https://doi.org/10.1080/08351818009370498>
- Vannasing, P., Florea, O., González-Frankenberger, B., Tremblay, J., Paquette, N., Safi, D., Wallois, F., Lepore, F., Béland, R., Lassonde, M., & Gallagher, A. (2016). Distinct hemispheric specializations for native and non-native languages in one-day-old newborns identified by fNIRS. *Neuropsychologia*, 84, 63–69.
<https://doi.org/10.1016/j.neuropsychologia.2016.01.038>
- Vigneau, M., Beaucousin, V., Hervé, P. Y., Duffau, H., Crivello, F., Houdé, O., Mazoyer, B., & Tzourio-Mazoyer, N. (2006). Meta-analyzing left hemisphere language areas: Phonology, semantics, and sentence processing. *NeuroImage*, 30(4), 1414–1432.
<https://doi.org/10.1016/j.neuroimage.2005.11.002>
- Visser, I., Kucharský, Š., Levelt, C., Stefan, A. M., Wagenmakers, E.-J., & Oakes, L. (2024). Bayesian sample size planning for developmental studies. *Infant and Child Development*, 33(1), e2412. <https://doi.org/10.1002/icd.2412>
- Walker, P. (2012). Cross-sensory correspondences and cross talk between dimensions of connotative meaning: Visual

angularity is hard, high-pitched, and bright. *Attention, Perception, & Psychophysics*, 74(8), 1792–1809.
<https://doi.org/10.3758/s13414-012-0341-9>

Walker, P., Bremner, J. G., Mason, U., Spring, J., Mattock, K., Slater, A., & Johnson, S. P. (2010). Preverbal infants' sensitivity to synaesthetic cross-modality correspondences. *Psychological Science*, 21(1), 21–25.
<https://doi.org/10.1177/0956797609354734>

Walker, P., & Smith, S. (1985). Stroop interference based on the multimodal correlates of haptic size and auditory pitch. *Perception*, 14(6), 729–736. <https://doi.org/10.1068/p140729>

Wang, X. (2021). Sound symbolism in Chinese children's literature. *Cognitive Linguistics*, 33(1), 95–120.
<https://doi.org/10.1515/cog-2021-0019>

Wang, Y., Zhou, L., & Luo, Y. (2008). The pilot establishment and evaluation of Chinese Affective Words System. *Chinese Mental Health Journal*, 22(8), 608–612.

Warriner, A. B., Kuperman, V., & Brysbaert, M. (2013). Norms of valence, arousal, and dominance for 13,915 English lemmas. *Behavior Research Methods*, 45(4), 1191–1207.
<https://doi.org/10.3758/s13428-012-0314-x>

Warriner, A. B., Shore, D. I., Schmidt, L. A., Imbault, C. L., & Kuperman, V. (2017). Sliding into happiness: A new tool for measuring affective responses to words. *Canadian Journal of Experimental Psychology / Revue Canadienne de Psychologie Expérimentale*, 71(1), 71–88.
<https://doi.org/10.1037/cep0000112>

- Werker, J. F. (2018). Perceptual beginnings to language acquisition. *Applied Psycholinguistics*, 39(4), 703–728.
<https://doi.org/10.1017/S0142716418000152>
- Werker, J. F. (2024). Phonetic perceptual reorganization across the first year of life: Looking back. *Infant Behavior and Development*, 75, 101935.
<https://doi.org/10.1016/j.infbeh.2024.101935>
- Werker, J. F., & Polka, L. (1993). Developmental changes in speech perception: New challenges and new directions. *Journal of Phonetics*, 21(1–2), 83–101. [https://doi.org/10.1016/S0095-4470\(19\)31322-1](https://doi.org/10.1016/S0095-4470(19)31322-1)
- Werker, J. F., & Tees, R. C. (1984). Cross-language speech perception: Evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, 7(1), 49–63.
[https://doi.org/10.1016/S0163-6383\(84\)80022-3](https://doi.org/10.1016/S0163-6383(84)80022-3)
- Wernicke, C. (1874). *Der aphasische Symptomencomplex: Eine psychologische Studie auf anatomischer Basis*. Cohn & Weigert.
- Westbury, C. (2005). Implicit sound symbolism in lexical access: Evidence from an interference task. *Brain and Language*, 93(1), 10–19. <https://doi.org/10.1016/j.bandl.2004.07.006>
- Whalen, D., & Xu, Y. (1992). Information for Mandarin tones in the amplitude contour and in brief segments. *Phonetica*, 49(1), 25–47. <https://doi.org/10.1159/000261901>
- Whissell, C. (2003). The emotional symbolism of two English e-sounds: /I/ as in “cheap” is pleasant and /I/ as in “chip” active. *Perceptual and Motor Skills*, 96(1), 149–165.
<https://doi.org/10.2466/pms.2003.96.1.149>

- Wilcox, T., & Biondi, M. (2015). fNIRS in the developmental sciences. *WIREs Cognitive Science*, 6(3), 263–283.
<https://doi.org/10.1002/wcs.1343>
- Winter, B., Lupyan, G., Perry, L. K., Dingemanse, M., & Perlman, M. (2023). Iconicity ratings for 14,000+ English words. *Behavior Research Methods*, 56, 1640–1655.
<https://doi.org/10.3758/s13428-023-02112-6>
- Winter, B., Oh, G. E., Hübscher, I., Idemaru, K., Brown, L., Prieto, P., & Grawunder, S. (2021). Rethinking the frequency code: A meta-analytic review of the role of acoustic body size in communicative phenomena. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 376(1840), 20200400. <https://doi.org/10.1098/rstb.2020.0400>
- Winter, B., & Perlman, M. (2021). Iconicity ratings really do measure iconicity, and they open a new window onto the nature of language. *Linguistics Vanguard*, 7(1), 20200135.
<https://doi.org/10.1515/lingvan-2020-0135>
- Winter, B., Perlman, M., Perry, L. K., & Lupyan, G. (2017). Which words are most iconic? Iconicity in English sensory words. *Interaction Studies. Social Behaviour and Communication in Biological and Artificial Systems*, 18(3), 443–464.
<https://doi.org/10.1075/is.18.3.07win>
- Witteman, J., Goerlich-Dobre, K. S., Martens, S., Aleman, A., Van Heuven, V. J., & Schiller, N. O. (2014). The nature of hemispheric specialization for prosody perception. *Cognitive, Affective, & Behavioral Neuroscience*, 14(3), 1104–1114.
<https://doi.org/10.3758/s13415-014-0255-1>
- Witteman, J., van IJzendoorn, M. H., van de Velde, D., van Heuven, V. J. J. P., & Schiller, N. O. (2011). The nature of hemispheric

- specialization for linguistic and emotional prosodic perception: A meta-analysis of the lesion literature. *Neuropsychologia*, 49(13), 3722–3738.
<https://doi.org/10.1016/j.neuropsychologia.2011.09.028>
- Wong, K. W. Y., & Kang, Y. (2019). Sound symbolism of gender in Cantonese first names. In S. Calhoun, P. Escudero, M. Tabain, & P. Warren (Eds.), *Proceedings of the 19th International Congress of Phonetic Sciences* (pp. 2129–2133).
- Xiao, W., & Treiman, R. (2012). Iconicity of simple Chinese characters. *Behavior Research Methods*, 44(4), 954–960.
<https://doi.org/10.3758/s13428-012-0191-3>
- Xu, D. (2012). Reduplication in languages: A case study of languages of China. In *Plurality and Classifiers across languages in China* (pp. 43–62). <https://hal.science/hal-01386244>
- Xu, X., Li, J., & Chen, H. (2022). Valence and arousal ratings for 11,310 simplified Chinese words. *Behavior Research Methods*, 54(1), 26–41. <https://doi.org/10.3758/s13428-021-01607-4>
- Xu, Y. (1997). Contextual tonal variations in Mandarin. *Journal of Phonetics*, 25, 61–83.
- Xu, Y., Gandour, J., Talavage, T., Wong, D., Dziedzic, M., Tong, Y., Li, X., & Lowe, M. (2006). Activation of the left planum temporale in pitch processing is shaped by language experience. *Human Brain Mapping*, 27(2), 173–183.
<https://doi.org/10.1002/hbm.20176>
- Yao, Y., Lin, J., & Huang, C.-R. (2013). *Lexicalized emotion? Tonal patterns of emotion words in Mandarin Chinese*. The 25th North American Conference on Chinese Linguistics.
- Yap, D., Casasanto, L. S., & Casasanto, D. (2014). Metaphoric iconicity in signed and spoken languages. *Proceedings of the*

Annual Meeting of the Cognitive Science Society, 36, 1808–1813.

Yeung, H. H., Chen, K. H., & Werker, J. F. (2013). When does native language input affect phonetic perception? The precocious case of lexical tone. *Journal of Memory and Language*, 68(2), 123–139. <https://doi.org/10.1016/j.jml.2012.09.004>

Yip, M. (2002). *Tone*. Cambridge University Press.

Yu, C. S.-P., McBeath, M. K., Glenberg, A. M., & Benjamin, A. S. (2021). The gleam-glum effect: /I:/ versus /λ/ phonemes generically carry emotional valence. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 47(7), 1173–1185. <https://doi.org/10.1037/xlm0001017>

Yuan, J., & Chen, Y. (2014). 3rd tone sandhi in Standard Chinese: A corpus approach. *Journal of Chinese Linguistics*, 42(1), 218–236.

Yücel, M. A., Lühmann, A. v, Scholkmann, F., Gervain, J., Dan, I., Ayaz, H., Boas, D., Cooper, R. J., Culver, J., Elwell, C. E., Eggebrecht, A., Franceschini, M. A., Grova, C., Homae, F., Lesage, F., Obrig, H., Tachtsidis, I., Tak, S., Tong, Y., ... Wolf, M. (2021). Best practices for fNIRS publications. *Neurophotronics*, 8(1), 012101. <https://doi.org/10.1117/1.NPh.8.1.012101>

Zatorre, R. J., & Belin, P. (2001). Spectral and temporal processing in human auditory cortex. *Cerebral Cortex*, 11(10), 946–953. <https://doi.org/10.1093/cercor/11.10.946>

Zatorre, R. J., Evans, A. C., Meyer, E., & Gjedde, A. (1992). Lateralization of phonetic and pitch discrimination in speech processing. *Science*, 256(5058), 846–849. <https://doi.org/10.1126/science.256.5058.846>

- Zatorre, R. J., & Gandour, J. T. (2008). Neural specializations for speech and pitch: Moving beyond the dichotomies. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 363(1493), 1087–1104.
<https://doi.org/10.1098/rstb.2007.2161>
- Zhang, F., Gervain, J., & Roeyers, H. (2022). Developmental changes in the brain response to speech during the first year of life: A near-infrared spectroscopy study of Dutch-learning infants. *Infant Behavior and Development*, 67, 101724.
<https://doi.org/10.1016/j.infbeh.2022.101724>
- Zheng, T., Levelt, C. C., & Chen, Y. (2024). The adaptive value of Mandarin tones for affective iconicity. *Proc. Speech Prosody 2024*, 562–566.
<https://doi.org/10.21437/SpeechProsody.2024-114>
- Zheng, T., Levelt, C. C., & Chen, Y. (2025). The affective iconicity of lexical tone: Evidence from standard Chinese. *The Journal of the Acoustical Society of America*, 157(1), 396–408.
<https://doi.org/10.1121/10.0034863>
- Zheng, T., Levelt, C. C., & Chen, Y. (under revision). *The affective iconicity of phonemes and tonemes in Standard Chinese*.
- Zhou, X., & Marslen-Wilson, W. (1995). Morphological structure in the Chinese mental lexicon. *Language and Cognitive Processes*, 10(6), 545–600.
<https://doi.org/10.1080/01690969508407114>

Appendices

Appendix A. Affective iconicity in Standard Chinese: Related studies overview and supplementary results

Table A1

An overview of studies on pitch iconicity.

Citation	Language	Pitch parameters	Main finding
Lester (1974)	American English	Mandarin tones (presented by visual symbols ˊˋˋˋ)	No significant recognition of Mandarin tones presented visually (52% correct)
Marks (1974)	English	Pitch height	Higher-pitched sounds were associated with brighter lights.
Tarte (1982)	English	Pitch height	Low tones were perceived as large, heavy, slow, dull, low, and masculine, whereas high tones were perceived as small, light, fast, sharp, high, and feminine.
Walker & Smith (1985)	English	Pitch height	Participants responded more slowly when pitch was incongruent with the multimodal features of test words.

Citation	Language	Pitch parameters	Main finding
Marks (1987)	English	Pitch height	Response times were faster when auditory and visual stimuli were congruent (e.g., high-pitched beeps with fast-flashing lights).
Marks et al. (1987)	English	Pitch height	Children and adults matched high pitch with brightness and low pitch with dimness. Pitch-size associations emerged around age 11.
Melara & O'Brien (1987)	English	Pitch height	Participants classified dot location and tone height faster in congruent conditions (e.g., a high tone with a dot at a high location).
Melara (1989)	English	Pitch height	Faster and more accurate responses when pitch and colour were congruent (e.g., high-pitched tones with white dots).
Lapolla (1995)	Mandarin Chinese	Mandarin tones	High-level tones were linked to “coarse” and “wide,” while falling tones were associated with “largeness.”

Citation	Language	Pitch parameters	Main finding
Lapolla (1995)	Cantonese	Cantonese tones	Mandarin speakers linked high-level tones with “smallness” and falling tones with “largeness.”
M. K. M. Chan (1996)	Chinese	Overall pitch or pitch register	Across Standard Cantonese, Xiamen, and Wu dialects, higher pitch (Yin register) was linked to lightness, while lower pitch (Yang register) was linked to heaviness.
Ohala (1984, 1994, 1997)	Ewe, Yoruba, Cantonese	Tones in West African languages	High tones were associated with smallness and low tones with largeness.
Mondloch & Maurer (2004)	(Canada) English	Pitch height	Children reliably matched higher-pitched sounds with smaller, lighter objects.
Gallace & Spence (2006)	English	Pitch height	Participants reacted faster when a low-frequency sound was paired with a larger disk.
Shintel et al. (2006)	American English	Pitch height	Speakers described an upward-moving dot with a higher fundamental frequency.

Citation	Language	Pitch parameters	Main finding
Parise & Spence (2008)	English	Pitch height	High-pitched sounds were associated with smaller sizes, and low-pitched sounds with larger sizes.
Crisinel & Spence (2009)	British English	Pitch height	Faster responses to congruent pitch-taste pairings (e.g., high-pitched notes with sweet tastes).
Crisinel & Spence (2010a)	English	Pitch height	Sweet and sour tastes were associated with high-pitched sounds; bitter and salty tastes lacked a clear association with low pitch.
Crisinel & Spence (2010b)	English	Pitch height	Non-synesthetes showed systematic associations between tastes and musical notes (e.g., bitterness with lower-pitched notes, sweetness with higher-pitched notes).
Evans & Treisman (2011)	English	Pitch height	Pitch spontaneously mapped onto visual position, size, and spatial frequency but not contrast.
Perniss et al. (2010)	NA	NA	Pitch functions as a form of iconicity in sound symbolism and signed

Citation	Language	Pitch parameters	Main finding
			languages (e.g., prosodic marking).
Walker et al. (2010)	English	Pitch height	Infants looked longer at animations where pitch changed congruently with motion (e.g., rising pitch for rising objects).
Ludwig et al. (2011)	NA	Pitch height	Chimpanzees and humans performed better in congruent pitch-colour associations (e.g., high pitch with white, low pitch with black).
Rojczyk (2011)	Polish	Pitch height	Lowered pitch did not significantly influence size ratings, except for the vowel /u/.
Spence (2011)	NA	Pitch height	High pitch corresponded with smaller objects, higher elevation, brighter colours, angular shapes, higher spatial frequency, and upward motion.
Chiou & Rich (2012)	English	Pitch height	Matching auditory pitch facilitated visual elevation judgments, suggesting

Citation	Language	Pitch parameters	Main finding
			pitch-location mapping at an attentional level.
Chang et al. (2021)	Mandarin Chinese	Mandarin tones	Tone was more often matched with rounded shapes and large size, and tone with angular shapes and small size.
Crisinel et al. (2012)	English	Pitch height	Taste perception was influenced by background music (e.g., toffee tasted more bitter with low-pitched sounds).
Parise & Spence (2012)	British English	Pitch height	High pitch was linked to smaller, sharper shapes, while low pitch was linked to larger, more rounded shapes.
Stel et al. (2012)	NA	Pitch height	Lowering one's voice pitch increased feelings of power, but only when self-produced.
Walker (2012)	English	Pitch height	High-pitched words were associated with angular shapes and low-pitched words with curved shapes.

Citation	Language	Pitch parameters	Main finding
Deroy & Spence (2013)	NA	Pitch height	Higher pitch was consistently matched to brightness, small size, high elevation, angularity, and upward movement.
Yao et al. (2013)	Mandarin Chinese	Mandarin tones	Words expressing sadness had higher tonal levels, while joy and anger had steeper tonal contours.
Perlman & Cain (2014)	English	Pitch average: fundamental frequency in Hz; Pitch range: the absolute value of the difference between the maximum and minimum <i>f₀</i> ; Pitch change: the ordered difference between the maximum and minimum <i>f₀</i> .	Smooth textures are vocalised with higher pitch than rough ones. Downward space corresponds to falling and lower pitch, while upward space aligns with higher pitch. Sharp shapes elicit higher pitch than dull shapes. Positive appraisals have a wider pitch range and higher pitch than negative ones. Male voices are lower with less pitch decrease than female voices. Only hearing children consistently used pitch for magnitude, unexpectedly associating larger items with higher

Citation	Language	Pitch parameters	Main finding
			pitch, contrary to previous English-speaking findings.
Fernández-Prieto et al. (2015)	English	Pitch height	Crossmodal pitch-size correspondence effects emerged in 6-month-old infants but not in younger ones.
Perlman, Dale, et al. (2015)	English	Pitch height	Readers used lower pitch when narrating “big” stories compared to “small” ones.
Perlman, Dale, et al. (2015)	English	Pitch height Pitch range	Smooth textures are vocalised with higher pitch. Downward space corresponds to falling and lower pitch, while upward space aligns with higher pitch. Positive appraisals have a wider pitch range and higher pitch than negative ones.
Lowe & Haws (2017)	English	Pitch height	Lower pitch in voice or music led consumers to infer larger product sizes.
Perlman (2017)	English	Pitch height Pitch contour Pitch range	Iconic vocalisations in vocal charades followed these pitch patterns: smooth-higher, downward-

Citation	Language	Pitch parameters	Main finding
			falling/lower, sharp-higher, good appraisal-larger range/higher, male-lower/less decrease, cut action-higher.
Shang & Styles (2017)	Mandarin Chinese	Mandarin tones	Native speakers: T1-curvy, T4-pointy. English speakers: T1-pointy, T3-curvy. Bilinguals: bivalent pattern.
Svantesson (2017)	NA	High vs. low tone	Kammu, Yoruba, and Ewe onomatopoeic ideophones followed the frequency code (higher pitch = smaller size).
Getz & Kubovy (2018)	English	Pitch height	AVCs rely on both bottom-up and top-down processing. Top-down influence was strongest for size, weakest for height, while bottom-up effects were strongest for height, weakest for brightness.
Hamilton-Fletcher et al. (2018)	NA	Pitch height	Blind individuals showed reduced pitch-shape correspondence but maintained pitch-size and pitch-weight associations.

Citation	Language	Pitch parameters	Main finding
Nielsen & Rendall, (2018)	NA	Pitch height	Pitch-affect connections, often labelled as synesthetic, were also observed in non-synesthetes.
Shih et al. (2019)	Japanese, English, Mandarin, Cantonese, Korean, and Russian	Mandarin tones, Cantonese tones	In Mandarin, tone was linked to male names and powerful Pokémon attributes. In Cantonese, tone was negatively correlated with height and power.
Sidhu & Pexman (2018)	NA	Pitch height	High-pitched sounds were perceived as brighter, sharper, and faster.
Sun et al. (2018)	NA	Pitch height	High pitch was associated with red and yellow, while low pitch was linked to blue and orange.
Thompson (2018)	Mandarin, Cantonese, and Taiwanese	Mandarin tones, Taiwanese tones, and Cantonese tones	Across Mandarin, Cantonese, and Taiwanese, sound symbolic strata were skewed toward specific tonal categories.

Citation	Language	Pitch parameters	Main finding
Anikin & Johansson (2019)	English	Pitch height ²	High pitch showed weak associations with blue, light grey, high saturation, and high luminance.
Wong & Kang (2019)	Cantonese	Cantonese tones	Rising tones showed a significant preference for female names.
Matsui (2020)	Japanese Chinese	Pith height	Vowels /u/ and /o/ were responded for low frequencies, /i/ for high frequencies across speakers of different languages. There are common relationships between the pitch of pure tones and onomatopoeic expressions.
Akita (2021)	Japanese	Japanese pitch accent	Low-pitched quotatives after exclamatory quotations and ideophonic adverbs in Japanese serve as backgrounding depiction markers, suppressing description while

² In this article, the authors pointed out that pitch is usually considered a metathetic dimension, in the sense that higher pitch is not "larger" or "greater" than low pitch, but qualitatively different.

Citation	Language	Pitch parameters	Main finding
			highlighting depiction. Ideophone pitch contours, including HLL and HHL patterns, carry partial semantic motivation.
X. Wang (2021)	Chinese	Mandarin tones	Nature: rising tones (T35) were more common in human names than in animal or monster names, though post hoc analysis showed no significant difference. Gender: rising tones (T35) were more frequent in male names than female names. Personality traits: high-level tones (T55) were prevalent in positive character names, while negative characters often featured rising tones. Size: no significant tonal distinctions were found.
Winter et al. (2021)	Japanese, English, Catalan, Spanish, Dutch, Korean,	Pitch height	A meta-analysis of speech production experiments across multiple languages (Korean, Japanese, Chinese, Catalan, Austrian German, German, Russian) found

Citation	Language	Pitch parameters	Main finding
	German, Austrian, Russian, Chinese		that speakers lower their pitch when addressing an imagined superior compared to a friend or peer.
Ekström et al. (2022)	NA	Pitch height	Motion-prosody congruent pairings, particularly those with a declining <i>f₀</i> , were more readily selected than incongruent ones, except for Turkish-speaking participants.
González-Alvarez & Sos-Peña (2022)	Spanish	Pitch height	Listeners more accurately perceived the speaker's body size when <i>f₀</i> was raised.
Shang & Styles (2023)	Mandarin	Pitch height	All language groups exhibited basic pitch-height congruence (high-pointy, low-curvy) for the non-linguistic stimuli.
Vainio, Kilpeläinen, et al. (2023)	Finnish	Pitch height	The results reveal a novel sound-space symbolism phenomenon, where spatial concepts of forward/front and backwards/back are iconically linked to high-

Citation	Language	Pitch parameters	Main finding
			and low-pitched speech sounds.
Vainio, Wikström, et al. (2023)	Finnish	Pitch height	This study replicated the pitch-elevation effect, showing an increase in vocalisation pitch when responding to an up-directed stimulus.

Table A2

Summary of inferential statistics for LOOCV for arousal in the DCAWS dataset.

Sub set	GLMM F (HLM, ΔR^2) coefficients	Significance of multiple comparisons: <i>p-values in GLMM (HLM)</i>				
		FF-RL	FF-RR	HF-RL	HL-RL	FH-RL
1	36.7	0	0.006	0.006	0.007	0.014
	(0.016)	(0)	(0.014)			
2	31.1	0	0.008	0.058	0.018	<i>n.s.</i>
	(0.015)	(0.001)	(0.037)			
3	33.1	0	0.007	0.015	0.022	<i>n.s.</i>
	(0.015)	(0)	(0.031)			
4	29.1	0	0.012	0.048	0.048	<i>n.s.</i>
	(0.014)	(0.002)	(0.051)			
5	31.2	0	0.005	0.041	0.060	<i>n.s.</i>
	(0.015)	(0.003)	(0.028)			
6	32.4	0	0.005	0.052	0.050	0.046
	(0.015)	(0)	(0.027)			
7	33.9	0	0.004	0.016	0.026	0.038
	(0.016)	(0)	(0.018)			
8	34.0	0	0.003	0.042	0.013	<i>n.s.</i>
	(0.017)	(0)	(0.014)			
9	34.4	0	0.004	0.016	0.015	0.038
	(0.016)	(0)	(0.019)			
10	31.5	0	0.004	0.031	<i>n.s.</i>	<i>n.s.</i>
	(0.016)	(0)	(0.014)			

The HLM indicated that the ratings of emotional valence were not significantly influenced by the lexical tonal sequence. Additionally, the impact of the lexical tonal sequence on emotional valence seems comparatively minor when contrasted with its influence on emotional arousal. Table A3 indicates the detailed R-squared coefficients.

Table A3

ΔR^2 of lexical tonal sequences in explaining emotional arousal and valence across all corpora.

Corpus	Emotional arousal	Emotional valence
CAWS	2.22%***	0.88%
NORM	0.44%***	0.22%
DCAWS	1.60%**	0.84%

Note. The differential R-squared coefficients (ΔR^2) were obtained by subtracting the R^2 of the two-block HLM models in each corpus analysis.

Appendix B. Pseudowords formulation and their wordlikeness ratings in Dutch and Japanese

A set of pseudowords was created based on the shared phonotactic rules of Dutch and Japanese. First, phonemes that exist in both languages were identified. These phonemes were then composed into pseudowords with vowel (V) or consonant-vowel (CV) syllabic structures. The pseudowords were subsequently manipulated and recorded by a bilingual speaker fluent in both Japanese and Dutch. Finally, native speakers of Japanese and Dutch evaluated the pseudowords for their wordlikeness in each language. More details are shown as follows.

Phonemes

Six co-existing phonemes, i.e., /p/, /t/, /k/, /s/, /i/, and /a/, were selected (Gussenhoven, 1992 for Dutch; Okada, 1991 for Japanese). Specifically, /p/ is a voiceless bilabial plosive consonant, /t/ a voiceless alveolar plosive, /k/ a voiceless velar plosive, and /s/ a voiceless alveolar fricative. Furthermore, the vowel /i/ is a close (or, high), front, and unrounded vowel, while /a/ open (or, low), front and unrounded vowel.

Words composition

All pseudowords were created according to the phonotactic rules of both languages, based on previous studies of acceptability judgments for pseudowords (Bailey & Hahn, 2001; Needle et al., 2022). The chosen phonotactic framework followed a (C)VCV disyllabic structure. Six distinct syllabic constituents (i.e., /i/, /pi/, /pa/, /ta/, /ka/, and /sa/) were concatenated to make ten disyllabic pseudowords, including

/ipa/, /kapi/, /pasa/, /pika/, /pipa/, /pisa/, /pita/, /sapa/, /sapi/, and /tapi/.

Words recording

Two pitch patterns, High-Low (HL) and Low-High (LH), were used for all pseudowords during recording. All stimuli were recorded in isolation with a Sennheiser MKH416T microphone (sample size 44.1 kHz, 16 bit) at Leiden University's Phonetics Lab by a female native speaker of Japanese (from the Tokyo area) who is proficient in Dutch. The speech signals were digitised at a 44.1 kHz sampling rate with 16-bit resolution. She was asked to produce the stimuli as a statement without any emphasis. The stimuli were recorded three times, with the stimulus list randomised for each recording. Tokens judged to be most clearly articulated by the first author were selected for further manipulations.

Words manipulation

To optimise the stimuli for use in both languages, the pseudowords were further resynthesised. All steps were performed using Praat (Boersma & Weenink, 2024).

Segmentation

Since all target words contained a second syllable starting with an obstruent onset, segmentation was relatively straightforward. The acoustic waveforms, accompanied by corresponding spectrograms and auditory verification, provided clear cues of spectral shifts in a zoomed-in display to identify reliable syllable boundary locations.

The first syllables had either a stop onset (/p/, /k/, /t/), a fricative onset (/s/), or a vowel onset (/i/), which is often preceded by a phonetic

glottal closure. We marked the onset of the first syllable at the first positive-going zero crossing in the waveform for the vowel /i/, right before the noise burst for the release of a stop closure (/p/, /k/, /t/ and /ʔ/), or at the start of the medium amplitude noise for /s/.

The end of the first syllable was marked at the last negative-going zero crossing for both the vowel and the nasal coda before the closure for the following stop onset.

We took the end of the first syllable as the start of the following syllable, while the offset of the second syllable was marked as the last negative-going zero crossing for both the vowel and nasal coda.

Annotation

After segmenting the sounds, we cut them into monosyllables using TextGrid files and moved the start and end of each monosyllable to the nearest zero crossings. According to phoneticians and phonologists' consultations, some of the syllables were manipulated in length or replaced with better-recorded ones.

Duration modification

To enhance the experimental parameters, we further manipulated the duration lengths of the concatenated words, given that duration proved the most reliable correlate of stress in Dutch and can be exploited for recognising spoken words (Cutler & van Donselaar, 2001; Sluijter & van Heuven, 1996). Based on studies of vowel discrimination, the durations of V syllables were calibrated to 220 ms, the CV syllables to 250 ms, and the pause interval between syllables, if any, was adjusted to 100 ms (De Klerk et al., 2019; Shafer et al., 2012; Swoboda et al., 1976). Note that /s/ was adjusted to 150 ms to avoid harsh sound

effects. All pseudowords were evaluated as natural as real words in two languages by phoneticians and phonologists.

Ratings on the pseudowords

After manipulating the lexical items, we conducted an online rating task using Qualtrics (Provo, UT, USA. Copyright © 2020 Qualtrics. <https://www.qualtrics.com>) to evaluate their perceived qualities. Native speakers of Japanese and Dutch assessed all pseudowords to determine the extent to which they resonated with the auditory characteristics of actual Dutch or Japanese vocabulary. Participants rated each word on a 5-point scale, where 5 indicated that a word sounded very much like a possible Dutch/Japanese word, and 1 indicated that a word did not sound like a possible Dutch/Japanese word at all.

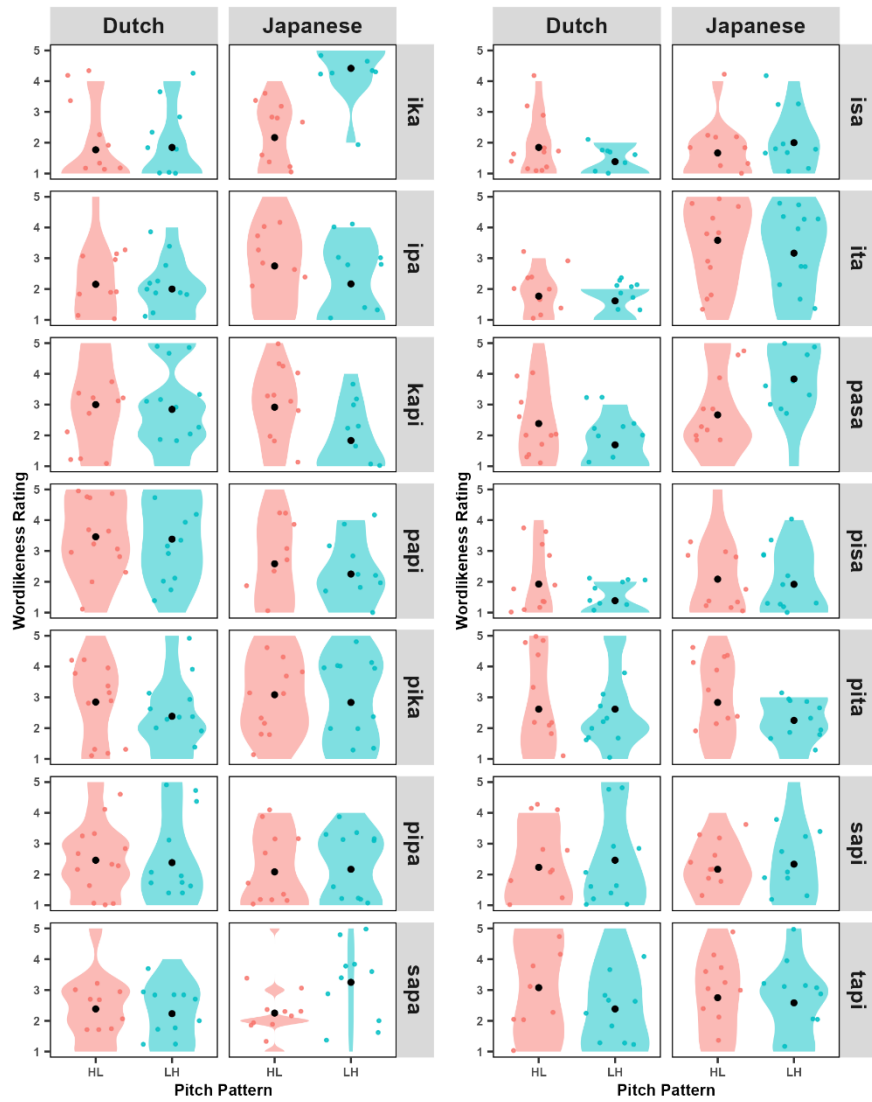
Table B1

The demographics information of Dutch and Japanese raters.

Rater	Male	Female	Age range	Mean age
Dutch	3	10	20–73	55.70
Japanese	5	7	19–48	35.50

Figure B1

The likeness rating on all words by native language speakers in Japanese and Dutch.



Appendix C. Outcomes from all fNIRS data preprocessing pipelines in Experiments 2 and 3 of Chapter 5

This table summarises the outcomes of all preprocessing pipelines and datasets, including dataset inclusion counts and hemispheric response patterns for pitch processing from 4 months (4m) to 10 months (10m).

- Pipeline-Dataset: Represents the pipeline and dataset numbers (e.g., 1-2 indicates Pipeline 1 applied to Dataset 2).
- Inclusions (4m/10m): Indicates the number of datasets included in statistical analyses (e.g., 21/27 means 21 datasets for 4m and 27 for 10m).
- Hemispheric Response (4m–10m): Shows dominant hemisphere patterns for PT and Word conditions. For example, RH-BH under “Word” indicates a shift from right-hemispheric (RH) dominance at 4m to bilateral (BH) response at 10m. “n.s.” (non-significant): Indicates that the interaction effect of Condition $\times$ Hemisphere $\times$ Age was not statistically significant, meaning no clear hemispheric dominance was observed.

Table C1

Summary of outcomes across pipelines and datasets.

Pipeline -Dataset	Inclu- sions 4m/ 10m	NL		Inclu- sions 4m/ 10m	JP	
		Hemispheric response			Hemispheric response	
		4m-10m			4m-10m	
		PT	Word		PT	Word
1-1	21/27	RH-RH	RH-BH	16/14	BH-RH	LH-LH
1-2	21/27	RH-RH	RH-BH	16/14	BH-RH	LH-LH

Pipeline -Dataset	Inclu- sions 4m/ 10m	NL		Inclu- sions 4m/ 10m	JP	
		Hemispheric response			Hemispheric response	
		4m-10m			4m-10m	
		PT	Word		PT	Word
1-3	20/26	RH-RH	RH-BH	16/14	BH-RH	LH-LH
1-4	18/26	RH-RH	RH-BH	16/14	RH-n.s.	LH-n.s.
2-1	21/27	RH-RH	RH-BH	16/14	BH-RH	LH-LH
2-2	21/27	RH-RH	RH-BH	16/14	BH-RH	LH-LH
2-3	20/26	RH-RH	RH-BH	16/14	BH-RH	LH-LH
2-4	17/24	RH-RH	RH-LH	16/14	n.s.-RH	n.s.-LH
3-1	21/27	RH-BH	LH-LH	8/2	LH-LH	LH-BH
3-2	21/27	RH-BH	LH-LH	7/2	LH-LH	LH-BH
3-3	21/27	RH-RH	LH-RH	7/2	LH-LH	LH-RH
3-4	17/26	RH-RH	LH-RH	7/2	LH-LH	LH-RH
4-1	21/27	RH-BH	LH-LH	7/2	LH-LH	LH-BH
4-2	21/27	RH-BH	LH-LH	7/2	LH-LH	LH-BH
4-3	21/27	RH-RH	LH-RH	7/2	LH-LH	LH-RH
4-4	16/26	RH-RH	LH-BH	7/2	BH-LH	RH-RH
5-1	20/26	RH-RH	RH-LH	16/9	BH-RH	LH-BH
5-2	20/26	RH-RH	RH-LH	16/9	BH-RH	LH-BH
5-3	20/26	RH-RH	RH-LH	16/9	RH-RH	LH-BH
5-4	16/24	RH-RH	RH-LH	16/9	RH-RH	LH-RH
6-1	20/26	RH-RH	RH-LH	16/9	BH-RH	LH-BH
6-2	20/26	RH-RH	RH-LH	16/9	BH-RH	LH-BH
6-3	19/24	RH-RH	RH-LH	16/9	BH-RH	LH-BH
6-4	16/24	RH-RH	RH-LH	16/9	BH-RH	LH-LH
7-1	21/27	RH-BH	BH-LH	8/2	LH-LH	BH-RH
7-2	21/27	RH-BH	BH-LH	8/2	LH-LH	BH-RH
7-3	21/26	RH-BH	BH-LH	8/2	LH-LH	BH-RH
7-4	17/24	RH-RH	BH-BH	8/2	LH-BH	BH-RH

Pipeline -Dataset	Inclu- sions 4m/ 10m	NL		Inclu- sions 4m/ 10m	JP	
		Hemispheric response 4m-10m			Hemispheric response 4m-10m	
		PT	Word		PT	Word
8-1	21/27	RH-BH	BH-LH	8/2	LH-LH	BH-RH
8-2	21/27	RH-BH	BH-LH	8/2	LH-LH	BH-RH
8-3	21/26	RH-BH	BH-RH	8/2	BH-LH	BH-RH
8-4	16/24	RH-RH	BH-LH	6/2	BH-RH	BH-RH