Emojis and Words Work Together in the Service of Communication

Laurie Beth Feldman,[1] Eliza Barach,[1] Vidhushini Srinivasan[2] and Samira Shaikh[3]
[1]University at Albany - SUNY
[2]Oracle Cloud Infrastructure, Seattle, WA
[3]University of North Carolina at Charlotte
samirashaikh@uncc.edu

Abstract

We describe an experimental approach to study the relation between emojis and online language use based on tweets from a public social media platform. The novel contribution of our work derives from the application of an entropy measure to compare lexical diversity (vocabulary richness) in messages with and without emojis. We find that lexical diversity is reliably attenuated when emojis are added to text. The pattern holds both when influence of tweet length or number of emojis is removed. That emojis serve to alter the lexical diversity of text in an online public context could demonstrate an interdependency between emojis and accompanying text in the service of communication. Our findings are consistent with the claim that the drop in lexical diversity may reflect a compensatory relation between emojis and words in communication. This outcome sets boundary conditions on the extent to which emoji patterning in isolation from text can qualify as a language.

Introduction

Online written communication once was considered a hopelessly impoverished medium both because immediate reactions could not be conveyed easily and longer term ambiguity could not be resolved quickly, while text production was ongoing. Participants were remote from one another, limiting both shared context and the modalities for interaction, severely constraining the potential to establish shared understanding (Holler and Wilkin 2009). Of particular relevance to the present work, nonverbal aspects of written communication like emotions and topic emphasis of content. Intonation had to be conveyed by means other than those available in face-to-face communication (Gill et al. 2008).

Traditional experimental measures of language comprehension and other aspects of language processing show a benefit when verbal and nonverbal content converge compared to when they do not. Tasks can require memory for words, either visual (Craik and Tulving 1975) or auditory (Heikkilä, Alho, and Tiippana 2017), for longer expanses of text (Bransford and Johnson 1972) or simple naming aloud of colors or of pictures (Starreveld and La Heij 2017). Influenced by such research, the consensus has shifted in recent years with a more nuanced understanding of how verbal and nonverbal content can complement each other in the service of written as well as spoken communication. Experimental results have shown how measures of comprehension and processing speed benefit when verbal and nonverbal content converge (Marchman and Fernald 2008).

In the present study, we examine how verbal and nonverbal content work together in online communication. We focus on how emoji presence can affect lexical diversity in the messages in which they are embedded. It is well documented that gestures aid thinking as well as communication (Goldin-Meadow 1999) and that gestures can even convey thought that does not appear in a speaker's verbal productions (Cooperrider et al. 2021). We draw from the literature linking emoticons and emojis with gesture (Feldman et al. 2017; Gawne and McCulloch 2019) to probe the manner in which emojis and language function together to enhance the efficiency of communication. In the present work, we do not attempt to compare or to differentiate between the emoticons and emojis in the present work.

Measures of vocabulary richness have been shown to be linked to measures of the overall frequency of a word's use as both entail ease of access to the meaning of a particular word, which depends on the cumulative experience of encountering and understanding that word across many contexts and usage patterns (Moscoso del Prado Martín 2017). One limitation of measuring vocabulary knowledge from type/token ratios is that such measures are sensitive to sample size. As a consequence, it can be difficult to make meaningful comparisons across different-sized samples.

To overcome limitations of basing measures of language patterning on a type/token ratio, Moscoso del Prado (2014) adapted an information-theoretical framework that is widely prevalent in biology (Gotelli and Chao 2013) to measure diversity within a corpus. This method is particularly powerful because the same measure can be applied not only to lexical but also to morphological (inflectional), and syntactic diversity, in that all diversities can be quantified as the entropy (Shannon 1948) of a distribution of frequencies of occurrence. In the present study, we apply two measures from the entropy framework to assess lexical diversity in online communication.

Related Work

We begin with a treatment of gestures in spoken language and then draw parallels between movement-based gestures and emojis.

Gestures enrich spoken communication: Emoticons and emojis invite parallels with manual gestures in spoken language. We acknowledge that emoji use is increasing while that of emoticons is declining (Pavalanathan and Eisenstein 2015).

In face-to-face communication, nonverbal information coordinated with speech typically encompasses facial expressions, as well as head, hand and body movements in particular formations, all of which can supplement the verbal content and thereby enhance communication. These gestures provide information that can be iconic (e.g., arm movement for swimming), deictic (e.g., pointing), or emblematic (e.g., peace sign) (McNeill 1992). Iconic gestures are tightly linked to speech production both semantically and temporally and often aid comprehension. Semantic incompatibility of iconic gestures as well as word equivalents can elicit a signal in the brain whose temporal qualities reflect difficulty with semantic processing (Özyürek et al. 2007). Depending on whether they are compatible or incompatible with the message as a whole, accompanying nonverbal information may impact aspects of spoken language understanding (Kelly et al. 2014) and cognition in a variety of ways.

While it is often observed that many types of gestures serve to elaborate and enrich spoken language, there is no consensus how to define what is and is not a gesture, the categories by which to classify them or, most importantly, the degree of interdependency between spoken language and gesture (Goldin-Meadow and Brentari 2017; Gawne and McCulloch 2019).

Emojis function as gestures: Some have claimed that emojis function like gestures (see e.g., (Feldman et al. 2017; Gawne and McCulloch 2019) and have the potential to enhance written communication in ways that parallel coordination between gesture and speech.

Aside from rating data, eye-tracking measures, which can gauge processing difficulty for comprehension have revealed slowed processing time when emoji and text valence are incongruent or when emojis are absent compared to when they are present (Cohn et al. 2018). Emoji but not emoticons tend to be colored and oriented vertically. Many represent facial expressions and the face is often composed of multiple features inside a circle. By contrast, emoticons mainly capture facial expressions. (Rodrigues et al. 2018).

Emojis can appear in isolation. Emojis, especially those that depict faces, often appear as an isolated response and devoid of sentence context to endorse or disagree with judgments of others, for example about food products (Ares and Jaeger 2017), or disclose sentiment and mood as well as intentions (dos Reis et al. 2018). Those that are emblems like the peace sign or the heart can have meaning even in isolation from text (Gawne and McCulloch 2019). When emojis do combine, strings composed exclusively of emojis typically consist of multiple repetitions of a single element or of near synonyms (Gawne and McCulloch 2019).

Emojis enhance perception of message content as well as tone: There is a growing body of work that investigates the pragmatic functions of emoji (c.f. (Dainas and Herring 2021) for an in-depth review). It is well-documented in judgment tasks that unambiguous congruent emojis (or emoticons) can facilitate decisions about a text's tone (positive vs. negative) (Lo 2008) or judgments about tone intensity (Derks, Fischer, and Bos 2008). Emojis serve functions more varied than simply conveying emotional tone via facial expression. Not surprisingly, function seems to vary by context. For example, emoji use is less prevalent when contexts are task-oriented than social (Derks, Bos, and Von Grumbkow 2007). They are often coordinated with speaker intent so as to provide a social context to aid interpretation. Alternative functions in a professional setting include markers of agreement, humor or irony or hedges to strengthen or weaken the impact of a directive (Skovholt, Grønning, and Kankaanranta 2014).

In addition to valence, other common dimensions evaluated are aesthetic appeal, familiarity, visual complexity, concreteness, arousal, and meaningfulness (Rodrigues et al. 2018). Many such studies demonstrate the sensitivity of emoji rating data to social aspects of the context. A common conclusion is that emoji meaning can be ambiguous (Rodrigues et al. 2018) insofar as variations in the perceived meaning and emotionality of emojis can reflect something other than the speaker's intended emotionality (Derks, Fischer, and Bos 2008). Context-conditioned influences on ratings of emoji dimensions highlight the potential limitations of rating data to examine all of the ways in which emojis and language work together in the service of communication.

As we have illustrated in this section from related literature, similar to gestures while talking, emojis in text appear to influence retrieval of word meaning when producing a text message. ***However, almost all of the studies delineating emoji use cited above elicit ratings on messages that include emojis.*** By contrast, our work is data-driven and based on data collected from spontaneous message produced on an online social media platform. We focus on the relation between emojis and word choice by analyzing corpora with and without emojis from spontaneous online productions in response to a shared event.

Hypotheses and Data Collection

Our central question is: ***Does the inclusion of emojis predict diversity of word choice?*** To investigate, we conduct two separate analyses, centered around two key hypothesis.

Hypotheses. We hypothesize that the presence of emojis in tweets is associated with reduced lexical diversity when compared to tweets where emojis are absent (**H1**). We do not differentiate among types of emojis. Next, we ask whether lexical diversity is stable across different types of emojis defined by their function (**H2**). We demonstrate that emojis serve to alter the composition of written text and introduce the possibility that not all types of emojis function comparably. We describe the data that we use to conduct our investigation next. Our investigation is centered around two corpora of tweets from Twitter, one for a weather-related

	Tweet Length (# of words)	Sample Size	Lexical Diversity	Confidence Interval (95%)	Perplexity
A: Original					
Full Corpus	13.25	3831522	10.807	10.805-10.808	1791.56
No Emoji	13.24	3754892	10.788	10.787-10.790	1768.12
With Emoji	13.44	76630	**10.72**	10.71-10.73	1686.71
B: Bootstrap: No replacement					
Full Corpus	9.35	43000	9.46	9.44-9.47	704.28
No Emoji	9.52	40500	9.41	9.39-9.44	680.29
With Emoji	9.32	40500	**9.34**	9.33-9.37	648.07
C: Bootstrap: With Replacement					
Full Corpus	9.55	42500	9.48	9.46-9.51	714.11
No Emoji	9.65	39000	9.45	9.43-9.46	699.41
With Emoji	9.41	39000	**9.37**	9.35-9.39	661.68

Table 1: Average Tweet Length, three estimates of Lexical diversities and confidence intervals (CI) and perplexities for all English tweets (Full) and for those with and without emojis from Hurricane Irma. Bolded values represent lower Lexical Diversity in tweets with emojis vs. those without, and provide support for hypothesis **H1**

event and another for the COVID-19 pandemic. Overall descriptive statistics of both corpora are shown in Table 1 and Table 2 (Column: Sample size).

Data collection Irma: We collected tweets from Twitter that contained the keyword *irma* and were posted between the time Irma became an intense storm (September 6th, 2017) and when it weakened over Mississippi on September 12th, 2017. Tweets were downloaded using the Twitter streaming API. Because we examine the influence of emojis on word choice, we chose a crisis event where a range of emoji valence values would arise. For example, positive emojis would be used as an expression of support and negative emojis as an emotional reaction to destruction. In this way, we seek to offset the general bias for positive emojis (Novak et al. 2015). We excluded retweets and tweets in languages other than English and formed two subsets, one with and one without emojis. Of the approx. 4 Million English tweets, 2% included an emoji and 98% did not.

Data collection COVID. We use the repository of tweets related to COVID-19 made available by Chen et al. (2020). This repository contains an ongoing collection of tweet IDs starting January 28, 2020 downloaded using the Twitter streaming API. Of the approx. 4 million English tweets, about 10% included an emoji and 90% did not.

Method

Lexical Diversity. To investigate our hypotheses, we frame the questions around **lexical diversity**, an information-theoretic measure of the richness of word choice. Typically, variability in word choice or vocabulary richness is assessed by comparing words that differ along some variant of a type-token ratio of the frequencies with which words appear in an expanse of text. By contrast, the information theoretical framework we use in our work uses uncertainty (entropy as average number of bits per word).

Lexical diversity (LD) captures the uncertainty that arises when many words are equally likely to appear. It is computed as the log (base 2) of the inverse probabilities for words then weighted for the probability of each. Thus, diversity reflects both richness and evenness of a distribution of word frequencies. A related measure is perplexity, where uncertainty is described in terms of the number of equiprobable word types in a corpus so as to maintain the same amount of Shannon entropy. Thus, a distribution with high richness and even frequencies for many words would show high entropy. On the other hand, a distribution with low richness and evenness would have a lower entropy. In addition, a distribution with high richness but uneven frequencies would have lower entropy than when both are high. (Rajaram, Castellani, and Wilson 2017).

Bootstrapping with and without replacement: Evidently, the corpora are heavily imbalanced in the number of tweets that contain emojis vs. those that do not. If we simply measure the differences in entropy in these subset directly, the results may not be valid. Thus, we need a method to account for differences in corpus size between tweets with and without emojis. To do so, we bootstrap to estimate lexical diversity and confidence intervals by sampling. This method avoids differences in number of tweets and tweet length within samples. In essence, we sample from the corpus of tweets without emoji so as to create a new distribution, comparable in size and tweet length, to that with emojis (Chao, Wang, and Jost 2013).

Finally, because consensus on how to best estimate population from sample diversity is lacking, we report calculations both with and without replacement. Sampling with replacement purportedly gives a more biased estimate of LD compared to sampling without replacement (Marcon and Hérault 2015).

	Tweet Length (# of words)	Sample Size	Lexical Diversity	Confidence Interval (95%)	Perplexity
A: Original					
Full Corpus	22.86	4058558	12.12	12.09-12.15	4457.84
No Emoji	20.99	3708802	11.989	11.987-11.990	4064.92
With Emoji	21.90	349756	**11.620**	11.618-11.623	3149.50
Face Emoji	19.71	171254	11.323	11.318-11.330	2563.16
Object Emoji	24.54	68755	11.791	11.784-11.798	3543.97
Gesture Emoji	22.01	109747	11.561	11.556-11.569	3022.99
B: Bootstrap: No replacement					
Full Corpus	20.40	58000	10.82	10.815 - 10.83	1809.46
No emoji	19.60118	55500	10.771	10.761 - 10.781	1747.52
With Emoji	19.41	55500	**10.52**	10.51 - 10.53	1469.37
Face Emoji	17.33	33000	10.21	10.20 - 10.23	1186.37
Object Emoji	22.27	9000	10.52	10.51 - 10.53	1469.33
Gesture Emoji	20.55	21000	10.340	10.33 - 10.342	1295.34
C: Bootstrap: With Replacement					
Full Corpus	21.92	56500	10.98	10.97 - 11.00	2021.14
No emoji	20.35	51000	10.95	10.94- 10.97	1979.58
With Emoji	19.4	51000	**10.882**	10.876 - 10.893	1887.41
Face Emoji	17.61	29000	10.42	10.41 - 10.43	1371.21
Object Emoji	21.44	8000	10.621	10.616 - 10.632	1574.99
Gesture Emoji	20.32	18000	10.49	10.47 - 10.49	1435.28

Table 2: Average Tweet Length, three estimates of Lexical diversities and confidence intervals (CI) and perplexities for all English tweets (Full) and for those with and without emojis from the COVID corpus. Bolded values represent lower Lexical Diversity in tweets with emojis vs. those without, and provide support for hypothesis **H1**

Classifying Emojis in Categories: Existing literature has shown that different types of emojis interact with text in different ways. Thus in a tweet, object emojis such as 🔑 or 🍕 can replace a word (i.e., *key* or *pizza*) whereas face emojis such as 🙃 or gesture emojis such as 🙏 are more likely to accompany it (Na'aman, Provenza, and Montoya 2017). Indeed, there is now a growing body of evidence to suggest that not all emojis interact with the accompanying text in the same manner and that it may be possible to classify emojis by the way in which they impact the accompanying verbal message (Gawne and McCulloch 2019). We follow the classification method of Barach (Barach et al. 2020). In their work, Barach et al. (2020) categorized emojis as the following: • face emojis (e.g., 😢); • gesture emojis (e.g., 💪); • object emojis (e.g., 🔥).

Results

We are interested in differences in word choice in tweets differentiated by the presence vs. absence of emojis.

To test **H1**, for each data collection, we divide tweets based on presence or absence of an emoji, and form two distributions. We examine results from the Irma and the COVID corpora and establish that lexical diversity was lower in the presence of emojis. Results are summarized in Table 1 and Table 2, respectively. We contrast diversity in tweets with and without emojis so that differences between corpora (and thus coverage of word types) are estimated in three ways.

First by ignoring the difference in size (Table 1, Section A) then by sampling without replacement to construct an estimate of uncertainty from confidence intervals (Table 1, Section B) and then by sampling with replacement (Table 1, Section C). In essence we provide three estimates of vocabulary richness that take into account relative frequency of use and sample size (Moscoso del Prado Martín 2017).

In the Irma data in Table 1, because of its limited size, all tweets with emojis are considered together. Consensus is lacking as to how to compare the diversity of distributions that differ in the number of elements they encompass (see (Rajaram, Castellani, and Wilson 2017)). Our approach is thus to sample from the corpus of tweets without emoji so as to create a new distribution of comparable size and tweet length to that with emojis. While the constructed distribution is not representative of all tweets without emojis and thus departs from a pure information-theoretical framework, it does allow us to examine the effect of emoji presence on lexical

	Tweet Length (# of words)	Sample Size	Lexical Diversity	Confidence Interval (95%)	Perplexity
A: Original					
No Emoji	11.49	2158325	11.67	11.65-11.68	3258.517
One Emoji	11.46	115262	10.83	10.82-10.85	1820.35
B: Bootstrap: No replacement					
No Emoji	10.65	335000	10.94	10.92-10.96	1964.573
One Emoji	10.62	3500	10.57	10.56-10.58	1520.152
C: Bootstrap: With Replacement					
No Emoji	10.78	335000	11.23	11.21-11.24	2401.966
One Emoji	10.78	3500	10.66	10.64-10.68	661.68

Table 3: Lexical diversity and perplexity in length matched tweets with and without one emoji in COVID corpus.

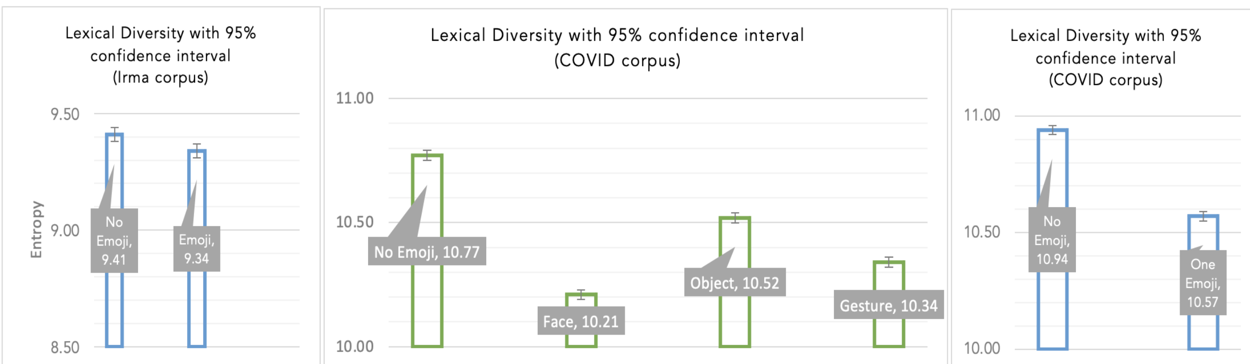

Figure 1: Lexical diversity with 95% confidence intervals for Irma and COVID corpus. All three plots represent the condition Bootstrap with no replacement from Tables 1, 2 and 3

diversity in the accompanying text. In each analysis, we see that both lexical diversity with its confidence intervals and perplexity (number of equiprobable words) is lower when emojis are present. This is not easily interpreted as a consequence of differences between the size of corpora. Nonetheless, replication of this result in another context would enhance confidence in the outcome. Thus, we seek convergent validity of our finding in the second corpus. The results on COVID data are summarized in Table 2. We find that the drop in lexical diversity in the presence, as contrasted with the absence, of emojis is replicated.

To test **H2**, we compared the lexical diversities of the tweets that contain each category of emoji (viz. face, gesture and object). It was possible to test **H2** in the COVID corpus due to its larger size. Our results shown in Table 2. Face emojis tend to be associated with lower lexical diversity than object or gesture emojis. It is also the case, however, that those tweets tend to contain fewer words, introducing the possibility that face emojis appear in more stereotyped contexts and require less disambiguation. Conversely, object emojis are accompanied by more diverse contexts and tend to appear in longer tweets.

To assure ourselves that the presence of multiple emojis could not account for the drop in lexical diversity, we conducted a final comparison restricted to COVID tweets with a single emoji. Results are summarized in Table 3. Again we see a drop in lexical diversity in the presence of even a single emoji. This post hoc analysis confirmed that the drop in lexical diversity remains reliable when tweet length is controlled. As can be seen in Table 3, we ensured that the length of the tweet in number of words was equivalent across both samples (No emoji tweet length = 11.49 vs. one emoji tweet length = 11.46). Even when tweet length is controlled in this manner, we find that the lexical diversity shows the consistent drop in the presence of emojis. The plots for lexical diversity with 95% confidence intervals are shown in Figure 1.

Discussion

In the present study, in separate analyses of the Irma and the COVID corpora, we applied measures adapted from the framework of information theory and reported that lexical diversity when communicating about a shared event, was lower in the presence than the absence of emojis. Depending on the online event and the composition and longevity of the community of tweeters, ten or fewer percent of tweets in the corpora we have examined typically include emojis. Therefore, efforts to offset or at least mitigate effects of relative corpus size when comparing lexical diversity in corpora are important. With the relevant adjustments that we have introduced, emoji presence in tweets remained associated with a less rich vocabulary relative to tweets without emojis.

Our analyses of corpora show an association between emoji use and word choice and thus support **H1**. Individuals tend to use less elaborated language and less differentiated word use when including emojis in their written communication on Twitter than when foregoing them. This finding invites an extension of the claim that gestures work to facilitate lexical retrieval to include emojis as well as movement gestures. Furthermore, this finding is consistent with the claim that gestures may influence the manner in which we think as well as how we express ourselves (Goldin-Meadow 1999; Cooperrider et al. 2021). Finally, it provides new insights into the ways in which our verbal and nonverbal semantic codes interrelate.

In addition, the lexical diversity associated with different categories of emojis appears to differ, thus supporting **H2**. This may reflect the extent to which meaning within a category tends to be ambiguous and thus the degree to which ambient context helps to reduce message uncertainty. Also relevant to any characterization of effects of emojis on factors such as lexical diversity is the familiarity and typicality of the intended message in which the emojis appear. By extension, attempts to probe the adequacy of purely emoji-based communication will need to assess efficacy when messages are novel and unpredictable. Emoji translations of famous texts provide a less than compelling proof of concept of the communicative adequacy of emojis without text (Wicke and Cunha 2020).

In the interpretation above, we have assumed that the behavior of emojis taps into a general principle of cognition. Of course, it is also possible that the pattern we observe is more revealing about differences between individuals and the style(s) in which they communicate.

The general theme would be that those who choose to write with emojis have access to a more restricted vocabulary than those who do not. In essence the systematic difference in lexical diversity with and without emoji could arise from differences in word knowledge among individual tweeters. Of course, the underlying assumption would be that individuals have a stable tweeting style that they apply over different online contexts.

Limitations

In this comparison of lexical diversity in tweets with as contrasted without emojis, we have focused on the interaction between emojis and words in the service of communication. Another possibility is that adding emojis to text reflects style differences among people – some include emojis and others do not. If proportion of tweets parallels different writing styles across people, then most tweeters communicate without emojis whereas only a subset of tweeters communicate with emojis. In this case, the implication would be that differences in verbal ability associated with vocabulary are primarily responsible for the drop in lexical diversity in the presence of emojis. One approach to try to differentiate contributions of the individual and verbal ability from the more general emoji-text interactions, would be to analyze only those tweets contributed by people who tweet both with and without emojis. In addition, since the data are curated from Twitter, there is the possibility that there are spurious accounts that are included in our data collection (e.g. bots). As part of future work, we wish to examine the extent to which these differences reflect a division of labor between the communicative contributions of words and emojis as contrasted with differences in tweeting style across people and account for the presence of bots in the corpora.

Our analysis is limited to analysis of lexical diversity and perplexity measures, and whether they vary under the presence of emoji in text. While this method provides some evidence to test our hypotheses, we acknowledge that more robust forms of statistical analysis, for example using Bayesian linear models with random effects of tweets to predict lexical diversity and effects of emojis should allow us to strengthen our conclusions. We will also explore this line of investigation in our future work.

Acknowledgements

We thank the anonymous reviewers for their careful reading of the earlier version of our manuscript. We feel that their feedback has resulted in a stronger publication.

References

Ares, G.; and Jaeger, S. R. 2017. A comparison of five methodological variants of emoji questionnaires for measuring product elicited emotional associations: An application with seafood among Chinese consumers. *Food Research International* 99: 216–228.

Barach, E.; Srinivasan, V.; Fernandes, R.; Feldman, L. B.; and Shaikh, S. 2020. It's not Just What you Tweet, it's how you Tweet It. In *7th European Conference on Social Media ECSM 2020*, 52.

Bransford, J. D.; and Johnson, M. K. 1972. Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of verbal learning and verbal behavior* 11(6): 717–726.

Chao, A.; Wang, Y.; and Jost, L. 2013. Entropy and the species accumulation curve: a novel entropy estimator via discovery rates of new species. *Methods in Ecology and Evolution* 4(11): 1091–1100.

Chen, E.; Lerman, K.; and Ferrara, E. 2020. Tracking social media discourse about the covid-19 pandemic: Development of a public coronavirus twitter data set. *JMIR Public Health and Surveillance* 6(2): e19273.

Cohn, N.; Roijackers, T.; Schaap, R.; and Engelen, J. 2018. Are emoji a poor substitute for words? Sentence processing with emoji substitutions. In *CogSci*.

Cooperrider, K.; Fenlon, J.; Keane, J.; Brentari, D.; and Goldin-Meadow, S. 2021. How pointing is integrated into language: Evidence from speakers and signers. *Frontiers in Communication* 6: 27.

Craik, F. I.; and Tulving, E. 1975. Depth of processing and the retention of words in episodic memory. *Journal of experimental Psychology: general* 104(3): 268.

Dainas, A.; and Herring, S. 2021. *Approaches to internet pragmatics*.

Derks, D.; Bos, A. E.; and Von Grumbkow, J. 2007. Emoticons and social interaction on the Internet: the importance of social context. *Computers in human behavior* 23(1): 842–849.

Derks, D.; Fischer, A. H.; and Bos, A. E. 2008. The role of emotion in computer-mediated communication: A review. *Computers in human behavior* 24(3): 766–785.

dos Reis, J. C.; Bonacin, R.; Hornung, H. H.; and Baranauskas, M. C. C. 2018. Intenticons: Participatory selection of emoticons for communication of intentions. *Computers in Human Behavior* 85: 146–162.

Feldman, L. B.; Aragon, C. R.; Chen, N.-C.; and Kroll, J. F. 2017. Emoticons in text may function like gestures in spoken or signed communication. *Behavioral and Brain Sciences* 40.

Gawne, L.; and McCulloch, G. 2019. Emoji as digital gestures. *language @ internet* 17(2).

Gill, A. J.; French, R. M.; Gergle, D.; and Oberlander, J. 2008. The language of emotion in short blog texts. In *Proceedings of the 2008 ACM conference on Computer supported cooperative work*, 299–302.

Goldin-Meadow, S. 1999. The role of gesture in communication and thinking. *Trends in cognitive sciences* 3(11): 419–429.

Goldin-Meadow, S.; and Brentari, D. 2017. Gesture, sign, and language: The coming of age of sign language and gesture studies. *Behavioral and Brain Sciences* 40.

Gotelli, N. J.; and Chao, A. 2013. Measuring and estimating species richness, species diversity, and biotic similarity from sampling data .

Heikkilä, J.; Alho, K.; and Tiippana, K. 2017. Semantically congruent visual stimuli can improve auditory memory. *Multisensory Research* 30(7-8): 639–651.

Holler, J.; and Wilkin, K. 2009. Communicating common ground: How mutually shared knowledge influences speech and gesture in a narrative task. *Language and cognitive processes* 24(2): 267–289.

Kelly, S. D.; Hirata, Y.; Manansala, M.; and Huang, J. 2014. Exploring the role of hand gestures in learning novel phoneme contrasts and vocabulary in a second language. *Frontiers in Psychology* 5: 673.

Lo, S.-K. 2008. The nonverbal communication functions of emoticons in computer-mediated communication. *Cyberpsychology & behavior* 11(5): 595–597.

Marchman, V. A.; and Fernald, A. 2008. Speed of word recognition and vocabulary knowledge in infancy predict cognitive and language outcomes in later childhood. *Developmental science* 11(3): F9–F16.

Marcon, E.; and Hérault, B. 2015. entropart: An R package to measure and partition diversity. *Journal of Statistical Software* 67(1): 1–26.

McNeill, D. 1992. *Hand and mind: What gestures reveal about thought*. University of Chicago press.

Moscoso del Prado, F. 2014. Grammatical change begins within the word: Causal modeling of the co-evolution of Icelandic morphology and syntax. In *Proceedings of the Annual Meeting of the Cognitive Science Society*, volume 36.

Moscoso del Prado Martín, F. 2017. Vocabulary, grammar, sex, and aging. *Cognitive Science* 41(4): 950–975.

Na'aman, N.; Provenza, H.; and Montoya, O. 2017. Varying linguistic purposes of emoji in (Twitter) context. In *Proceedings of ACL 2017, Student Research Workshop*, 136–141.

Novak, P.; Smailović, J.; Sluban, B.; and Mozetič, I. 2015. Sentiment of emojis. *PloS one* 10(12): e0144296.

Özyürek, A.; Willems, R. M.; Kita, S.; and Hagoort, P. 2007. On-line integration of semantic information from speech and gesture: Insights from event-related brain potentials. *Journal of cognitive neuroscience* 19(4): 605–616.

Pavalanathan, U.; and Eisenstein, J. 2015. Emoticons vs. emojis on Twitter: A causal inference approach. *arXiv preprint arXiv:1510.08480* .

Rajaram, R.; Castellani, B.; and Wilson, A. 2017. Advancing Shannon entropy for measuring diversity in systems. *Complexity* 2017.

Rodrigues, D.; Prada, M.; Gaspar, R.; Garrido, M. V.; and Lopes, D. 2018. Lisbon Emoji and Emoticon Database (LEED): Norms for emoji and emoticons in seven evaluative dimensions. *Behavior research methods* 50(1): 392–405.

Shannon, C. E. 1948. A mathematical theory of communication. *The Bell system technical journal* 27(3): 379–423.

Skovholt, K.; Grønning, A.; and Kankaanranta, A. 2014. The communicative functions of emoticons in workplace e-mails::-. *Journal of Computer-Mediated Communication* 19(4): 780–797.

Starreveld, P. A.; and La Heij, W. 2017. Picture-word interference is a Stroop effect: A theoretical analysis and new empirical findings. *Psychonomic bulletin & review* 24(3): 721–733.

Wicke, P.; and Cunha, J. M. 2020. An Approach for Text-to-Emoji Translation .