Emojis in Sentence Processing: An Electrophysiological Approach

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ABSTRACT

This paper discusses two multi-experiment studies using the ERP methodology to investigate neural correlates of processing linguistic emojis. The first study examined the use of wink emojis used to mark irony and found the same ERP response complex that has been found in response to word-generated irony. Contingent upon individual differences in interpretation, these emojis are processed the same way as ironic words. The second study investigated the prediction of non-face emojis substituted for nouns. When predictability was high, unexpected emojis elicited the same ERP response patterns as words. Overall, the results of these two studies suggest that emojis used linguistically are processed in the same way as words and that individuals can integrate input from multiple modalities into a holistic representation of a single utterance.

KEYWORDS

emojis, ERP, irony, language processing, linguistics, multimodality, prediction, psycholinguistics

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The purpose of this paper is to introduce to the emoji research community a project on the psycholinguistic processing of emojis. As emojis can perform a range of linguistic functions, it is a worthwhile endeavor to investigate how users and receivers interpret these in real time. Especially with various public claims about emojis becoming 'their own language,' it is important to compare the processing of emojis to the processing of their word-based counterparts. A wide range of psycholinguistic methodologies could be utilized to investigate the processing of emojis in different sentence contexts; selection of an appropriate methodology is dependent on the aims of the research question and the specific emoji usage to be studied. Psycholinguistic investigations of emojis can uncover lots about emojis and about human language, including the speed and ease of emoji interpretation, the effects of context, regions of neural activation, acquisition of emoji competency, and even manifestations of aphasia.

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This paper presents two studies of the processing of emojis using the Event-Related Potentials (ERP) methodology. In this methodology, electrical activity from the brain is recorded via EEG while participants process auditory or visual stimuli. Neural activity is time-locked to the onset of meaningful stimuli and averaged across many trials and multiple participants to produce a picture of what happens, on average, in response to stimuli in different conditions. This averaged activity from electrodes of interest within a given time window is compared across conditions. ERPs are great for their millisecond-level temporal resolution and are therefore an ideal methodology to investigate the timing of cortical activity. ERP components are typically identified by their polarity (positive or negative), time course (milliseconds after critical stimulus onset), and scalp topography (where on the scalp the electrical activity is measured). An ERP effect is said to be significant when there is a significant difference between the average waveforms in two or more conditions during a given time window. The two studies presented here will provide information about when and how emojis in different language contexts are processed in the brain.

Study 1 is an investigation of the processing of ironic wink emojis and Study 2 examines the predictive processing of non-face emojis. Both of these studies are 'emoji versions' of experiments with findings that are established in the non-emoji linguistic literature, so the results of these studies are interpreted with respect to that previous work. As this paper is a synopsis of work and an entranceway to a discussion about studying the psycholinguistic processing of emojis, the results are not analyzed in full detail here. For a more detailed discussion of the results of Study 1, see the full write-up in Weissman & Tanner (2018) [4] or see Tanner, Goldshtein & Weissman (2018) [2] for a special look at individual differences in the study. The full-length paper for Study 2 is currently under review as Weissman, Cohn & Tanner (under review) [3].

Study 1 was a three-experiment project designed to investigate neural responses to wink emojis used as markers of irony. The consensus from previous ERP studies of word-generated irony is a P200 effect followed by a P600 effect in cases of irony. The P600, often discussed in linguistics, is a relatively late component that is typically conceived of as an index of reanalysis or reprocessing. The P200, much less discussed with respect to language processing, is an early component typically elicited when attentional resources are allocated. Materials for all three experiments were sentences with an emoji at the end. Sentences could be followed by an emoji that matched the valence of the sentence (positive or negative), an emoji that mismatched the valence of the sentence, or a wink emoji that rendered the sentence ironic. Examples are listed in Table 1 (emojis from EmojiOne [1]).

Table 1: Study 1 - Example Stimuli

Sentence	Condition
The stress was overwhelming 😕	Match
The stress was overwhelming 🙂	Mismatch
The stress was overwhelming 😉	Irony

Across the three experiments, both the P200 and P600 effects were reliably found to the ironic wink emojis. Since there was such a range of non-literal response rates to the comprehension questions, the relationships between ERP difference waves (formed by subtracting the Irony condition from the Match condition) and response rates across all three experiments were analyzed, uncovering a significant correlation with P600 amplitude ($r = .28, p = .004$). The higher an individual's non-literal response rate, the larger the P600 effect; this finding is consistent with the P600 as an index of reanalysis and indicates the robustness of the effect.

Study 2 was a two-experiment study focusing on cross-modal prediction of non-face emojis. Materials for this study consisted of sentences in which the last word could have an emoji substitution. Experiment 2a presented the sentences 'traditionally' with words only; Experiment 2b presented the sentences with the emoji substitutions. This study utilized two levels of sentence constraint: high and low, as determined by Cloze norming - a measure of predictability of a given word in a sentence. High constraint (high predictability) sentences could have either the expected completion or an unexpected yet plausible completion; low constraint sentences could have either a plausible (yet low predictability) or an implausible completion. Example stimuli are shown in Table 2.

Experiment 2a served as a (successful) replication of the previous studies that have examined the effects of sentence constraint, expectancy, and plausibility on traditional (word) sentences, finding an N400 effect to unexpected completions and an additional Late Frontal Positivity (LFP; 600-1000ms) when the completion is plausible albeit unexpected. The functional significance of the N400 effect is debated, but it is generally understood as index of the difficulty of semantic processing; the LFP has been suggested to be a reflection of discourse revision. The relevant effects in high constraint - the N400 and LFP - were significant to sentence-final emojis in Experiment 2b. Scalp distributions to the high constraint emoji completions, like those to word completions, were as expected for each effect - posterior for the N400, anterior for the LFP. In low constraint sentences, there was a significant difference between plausible and implausible emojis in the N400 time window, but this emoji-elicited negativity displayed a more anterior distribution than the word-based N400. It is hypothesized that high predictability, established during a sentence, facilitates the lexical access of emojis, hence the greater degree of similarity to word-elicited effects under high constraint.

A trial-level analysis found a significant correlation between the Cloze expectancy of a given completion and N400 amplitude to that emoji, replicating a correlation that has been shown to be present to words. Similar analyses were run with visual, conceptual, and semantic similarity (between expected emoji and actual emoji); that none of these correlations were significant indicates participants were anticipating lexical forms as opposed to visual, conceptual, or semantic features.

Table 2: Study 2 - Example Stimuli

Sentence	Constraint	Condition
She put more paper into the 🖨️	High	Expected
She put more paper into the 👞	High	Unexpected
His favorite animal is the 🐬	Low	Plausible
His favorite animal is the 🚒	Low	Implausible

A central finding across both studies is that emojis not only can serve linguistic purposes but also get processed in largely the same way as words when they do. This evidence counters various pop culture claims that emojis are 'their own language' and instead suggests a domain-general language processing system that can pull from multiple modalities. Wink emojis used ironically generated the same neural response as words used ironically, and emoji substitutions are lexically predicted and subject to the same constraint-based considerations as words. In both of these instances, emojis and sentences are combining to form a single, holistic utterance that pulls from two modalities; the neural evidence suggests that our mental representations of these occasions are holistic as well. Evidence from Study 2 suggests that high constraint facilitates the lexical access of emojis, indicating an interaction between the emojis and their linguistic environments.

These two studies have begun to provide insights into the neural correlates of processing emojis. With so many different uses of emojis and so much variability in their uses and interpretations, there is a lot of room for further research in the processing domain. The preponderance of ERP language studies allows for the comparison of many types of emoji uses to their non-emoji linguistic counterparts, including syntactic, lexical, and pragmatic phenomena. Less high-tech methodologies like eye-tracking and self-paced reading can also be used to investigate these topics, and more high-tech methods like fMRI can be used to provide more spatial information about neural activity in processing. Psycholinguistic methods can be used to investigate cross-cultural and cross-linguistic differences in emoji interpretations, including in second language learners. Studies of the processing of linguistic emojis in aphasic patients can reveal more about the language processing system in patients and in the nonaphasic population. Such explorations will not only advance our knowledge about emojis but also knowledge about our language processing and domain-general communicative systems.

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