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Emojis and affective priming in visual word recognition

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ABSTRACT

Emojis are frequently used in digital communication to supplement the lack of non-verbal cues, but their integration during reading has not been thoroughly examined. This study explores the interplay between language and emotion by testing the influence of emotional valence and face-status of emojis on visual word recognition. Two online experiments were conducted with 92 native English-speaking university students, examining priming effects between congruent (e.g. 😋 delicious) and incongruent (e.g. 😋 hate) prime-target pairs, varying the face-status of the emoji prime (face vs. non-face) and the valence (positive vs. negative) of the word target. Irrespective of valence, face emojis demonstrated a processing advantage over non-face emojis, implying automatic attention capture. Additionally, the results revealed an interaction between prime-target congruency and valence, with a facilitatory effect for positive, but not negative, items, suggesting a valence-specific mechanism of affective priming in the lexical decision task. The research suggests that the rapid integration of emoji content occurs during the early stages of visual word recognition, with heightened attentional sensitivity to both face-like and positive stimuli when reading digital communications.

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Face-to-face interactions encompass multiple informational signals beyond spoken words. Until the advent of emoticons in the early 1980s (Fahlman et al., 1982) and emojis in the late 1990s (Bellis, 2024), facial expressions and hand gestures, crucial in oral communication, were absent in written communication. The emergence of emoticons and emojis facilitated the digital expression of emotions. Emojis, small images conveying meaning or attitude in digital communication, have since become a prevalent aspect of our written culture (Bai et al., 2019). However, the cognitive mechanisms of emoji processing and online integration in reading have only recently started to be systematically explored through behavioural and neurophysiological experimental approaches (Barach et al., 2021; Yang et al., 2021; Yu et al., 2022). The present study's primary objective was to investigate the impact of emojis on visual word recognition using a well-controlled primed lexical decision paradigm.

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Important groundwork for the study comes from recent eye-tracking research reporting evidence of emoji congruency effects comparable to well-documented word congruency effects (Barach et al., 2021; Beyersmann et al., 2023). Word congruency effects are characterised by quicker and more efficient reading when the target word semantically aligns with the surrounding sentence (Ehrlich & Rayner, 1981). This efficiency arises because the semantic content of the congruent word is rapidly and automatically integrated into the ongoing interpretation of the text. Building on this, Barach et al. (2021) explored similar congruency effects for non-affective emojis in sentence-final positions. They found that semantically congruent emojis (e.g. "My tall coffee is just the right temperature ☕") led to shorter fixation times and fewer refixations compared to incongruent ones (e.g. "My tall coffee is just the right temperature 🍺"). Beyersmann et al. (2023) reported similar effects for affective emojis located in the middle of sentences. Participants read sentences containing an emotionally congruent or incongruent face emoji (e.g. "That's good news 😀 tell me more" vs. "That's good news 😔 tell me more"). A significant congruency effect in total reading time and dwell time revealed that integrating incongruent emojis incurred additional processing costs. These findings provide initial evidence for emoji integration during sentence reading but also underscore the need for further research on the speed and automaticity of this process.

Barach et al. (2021) reported higher skipping rates for semantically congruent emojis, suggesting that some level of processing might commence in the parafovea, even before direct fixation. Conversely, Beyersmann et al. (2023) reported high skipping rates irrespective of emoji-sentence congruency, leading to diverging interpretations. These varying outcomes could be attributed to the distinct types of emojis used: affective facial expressions in the case of Beyersmann et al. (e.g. 😀 😔) and non-affective, non-face emojis in Barach et al. (e.g. ☕🍺). To further explore these discrepancies, the present study manipulated emoji face-status and valence as variables between conditions.

In terms of the complex dynamics of valence, a fundamental question arises: How do positive and negative emotional cues differ in processing, and can priming modulate this distinction? To answer this, Comesaña et al. (2013) conducted an event-related potential (ERP) experiment. They varied three factors: the type of prime (emoji or word), the prime's valence (positive or negative) and prime-target affective congruency (matched or mismatched in valence). A representative trial involved a 50 ms exposure of a masked emotional prime – this could be a word such as "alegría" [happiness] versus "rabia" [rage], or emojis like 😄 versus 😖. Subsequently, participants encountered a target word, like "encanto" [charm] or "esclavo" [slave]. Participants' electroencephalographic activity was recorded as they judged the valence of the presented word to discern the ERP patterns elicited by emoji as opposed to word primes, and to examine the temporal trajectory of priming effects. Affective priming entailed assessing the influence of a briefly presented positive or negative prime on the subsequent processing of a positive or negative target word. For instance, a positive emoji prime followed by a positive target word might expedite recognition due to their congruency in affective content. Behavioural and electrophysiological results revealed quicker and more precise responses for targets congruent with emoji primes compared to those congruent with word primes. Such findings corroborate the emoji congruency effects on word recognition in an affective priming context and suggest more streamlined processing for affective emoji primes than for their word counterparts. Furthermore, a significant main effect of target valence was observed, with positive targets being recognised faster than negative targets. The phenomenon wherein positive words are processed more rapidly and efficiently than their negative or neutral counterparts is often termed "positivity bias" (Unkelbach et al., 2020). Comesaña et al. (2013) findings are thus consistent with a substantial body of research showing that positive words prompt quicker reaction times than negative words in lexical decision tasks (Sass et al., 2012; Scott et al., 2014).

The advantage associated with cognitive processing of positive words has been attributed to two main causes. First, according to the "density hypothesis" (Unkelbach et al., 2008), positive rather than neutral or negative information is clustered within memory more densely, suggesting its higher elaboration and stronger interconnectivity, which is evident in its enhanced processing. For instance, Crossfield and Damian (2021) employed an empirical approach to create sets of neutral (e.g. "situation"), positive (e.g. "spa"), and negative (e.g. "slave") words, matched on 28 attributes beyond just valence. Their findings from a lexical decision,

employing a mouse tracking paradigm, revealed that positive words were processed more efficiently compared to neutral and negative items. Additionally, Scott et al. (2014), through a series of lexical decision tasks, investigated the categorical nature of emotion word recognition, considering its interaction with frequency. Their results consistently demonstrated that positive words, like the low-frequency "cheer" and high-frequency "cash", elicited faster responses than neutral household items, such as the low-frequency "stool" and high-frequency "bench". Conversely, the recognition speed of negative words, like the low-frequency "snake" and high-frequency "cancer", did not differ from the neutral condition, but was influenced by word frequency, highlighting the complex nature of the negative category. These consistent patterns across studies suggest that the advantage for positive words may stem from their enhanced information density and semantic richness, implying that positive stimuli are not only represented more widely, but are also more accessible than their neutral or negative counterparts.

An alternative explanation of the positivity bias emphasises the distinctiveness of negative emotions, which are considered more multifaceted than positive emotions and thus more challenging to discern unambiguously (Kuperman et al., 2014). Supporting this, Rossell and Nobre (2004) probed affective semantic priming using various affective categories of related word pairs in a lexical decision task. Their results showed that while neutral (e.g. "pause–wait") and happy (e.g. "smile–grin") prime-target pairs produced significant semantic priming, fearful (e.g. "scream-shriek") pairs displayed a weaker facilitatory effect, and sad primes inhibited reactions to sad targets (e.g. "cry–weep"). These findings suggest that the associative mechanisms underpinning semantic priming for neutral words also apply to positive words but not necessarily to negative ones. The differentiation in associative mechanisms for negative valence words could indicate a heightened vigilance in adverse contexts or suggest distinct associative structures. In a related fMRI study, Sass et al. (2012) investigated how emotions impact the neural correlates of semantic priming. Both behavioural and neuroimaging data highlighted a valence-specific semantic priming effect (i.e. congruent > incongruent) for neutral (e.g. "can – cup") and positive (e.g. "heaven – angel"), but not for negative (e.g. "conflict – aggression") word pairs. This research concluded that while positive and neutral information share a common semantic network, negative relations can activate compensatory mechanisms, inhibiting the spread of activation between related concepts. Hence, while the existing literature reports evidence for a facilitatory effect of reading positive words relative to the more multifaceted nature of reading neutral or negative ones, the cognitive mechanisms involved in integrating emotional cues into reading are still poorly understood.

A further key consideration in investigating reading with emojis is whether face and non-face emojis convey emotional content to the same extent. Face perception is an essential evolutionary skill (Schmidt & Cohn, 2001) and a vital visual ability for human social interactions (Haxby et al., 2000). A growing body of data from neuroscience and psychology underscores the rapidity of facial expression recognition and its potential to occur subconsciously (Tamietto et al., 2009). Notably, faces expressing emotions automatically capture our visual attention (Theeuwes & Van der Stigchel, 2006). Recent ERP research has shown that face emojis in text messaging trigger neural responses similar to those elicited by human faces during real-life interactions, such as the N170 component, known for its sensitivity to emotional content in faces (Gantiva et al., 2019). However, an EEG study by Dalle Nogare and Proverbio (2023) suggested different origins: unlike the face-related N170, generated in the face fusiform area, the emoji-related N170 did not activate this region. An fMRI study by Chatzichristos et al. (2020) explored memory recall triggered by emotionally congruent or incongruent word-emoji pairs. Similarly, they found activation in areas related to facial emotion interpretation, such as the amygdala and the right temporal pole, but provided limited evidence for the activation of the face fusiform area.

Fugate and Franco (2021) adapted the Facial Action Coding System (Ekman & Rosenberg, 1997) for emoji faces, showing that emojis, while sharing fundamental features with human faces, utilise fewer anatomical codes to express emotions. This reflects their more schematic nature and potentially simplifies the classification of their emotional content. Additionally, Częstochowska et al. (2022) found that face emojis can be more ambiguous than object emojis but less ambiguous than symbol emojis. In summary, while previous studies have noted variations in emoji effects during reading based on their face-like properties (Gantiva et al., 2019), it is yet to be established if the face-status of emojis modulates the reading of word targets.

Furthermore, the role of emojis in affective priming is still under debate. Neuroimaging studies using fMRI (Chatzichristos et al., 2020) and ERP analyses (Comesaña et al., 2013) indicate processing benefits for emotionally congruent emoji-word pairings over their incongruent counterparts. However, behavioural results from similar studies (Kaye et al., 2023) and sometimes from the same experiments (Comesaña et al., 2013; Yang et al., 2021) do not consistently show priming effects. For instance, in a study by Yang et al. (2021), participants performed a word valence judgment task with target words primed by emojis depicting positive (e.g. 😃), negative (e.g. 😩), or neutral (e.g. 🟡) emotions. This resulted in three semantic relationships: congruent (e.g. "😃 angel" and "😩 assassination"), incongruent (e.g. "😃 assassination" and "😩 angel"), and unrelated (e.g. "🟡 angel" and "🟡 assassination"). While behavioural results showed no priming effects, ERP data have indicated affective congruency effects in P2 and N400 amplitudes and early distinctions in the N1 component. These findings could suggest that emojis' emotional content might impact initial stages of lexical processing. However, most primes in the congruent and incongruent conditions were face emojis, whereas the only neutral prime was a non-face yellow circle, raising questions about whether the observed N1 effect was exclusive to face emojis or applicable to affective emojis more broadly. Additionally, the limited number of items (11 items across three conditions) and repetitive exposure (300 trials) might have facilitated associative learning, as suggested by the modulation of P2 and N400 responses, a phenomenon previously noted in studies on early emotional effects in word processing (Hinojosa et al., 2019). Similarly, small stimuli sets (i.e. one emoji per one experimental condition) potentially inducing involuntary associative learning were noted in studies by Comesaña et al. (2013) and Kaye et al. (2023), which also did not find behavioural effects of affective congruency. These inconsistencies in affective priming data with emojis raise further questions regarding the role of emojis in reading.

A further point to consider is that the nature of the experimental tasks used with emojis can inadvertently trigger emotional processing. For example, in the study by Chatzichristos et al. (2020), participants were asked to recall a specific memory in response to a combination of a word and an emoji; in Comesaña et al. (2013) and Yang et al. (2021), the task involved a valence judgment of positive versus negative target words; in Yu et al. (2022), participants judged emotional consistency with emotionally congruent versus incongruent targets. These tasks could inadvertently launch irrelevant emotional processing and increase the likelihood of semantic rather than affective priming (Heyman et al., 2015). When tasks did not require emotional processing (e.g. lexical decision), no congruency effects and only limited evidence of a positivity advantage were observed (Kaye et al., 2023). Contrary to previous evidence that emotionally positive picture stimuli can facilitate lexical decisions for both congruent positive and unrelated neutral targets in a priming paradigm (Kissler & Koessler, 2011), Kaye et al. (2023) Study 1 demonstrated the lack of a facilitatory lexical decision effect when emojis were displayed to the right of a letter string. Hence, the lexical decision task, which taps into rapid integration processes during visual word recognition, might offer deeper insights into emoji-word affective priming compared to other reading tasks.

The present study

The current study aimed to shed further light on the cognitive integration of emojis' content in reading by using a valence judgement task (Experiment 1), as well as an emoji-primed lexical decision task, in which target words were preceded by emoji primes (Experiment 2). Building on prior evidence for emoji congruency effects in reading (Barach et al., 2021; Beyersmann et al., 2023), we asked if emoji priming effects (measured by comparing congruent to incongruent prime-target pairs) are modulated by the emotional valence and the face-status of emoji primes. Additionally, we controlled for the psycholinguistic properties of the word material, the visual complexity of the emojis, and the associative strength between prime-target pairs to enhance the rigor and reproducibility of the research.

Experiment 1

In Experiment 1, we used a valence judgement task to (i) test if the positivity bias for word targets replicates within the context of our own word materials (i.e. faster responses to positive than negative words), (ii) examine whether positivity bias generalises to valence judgements performed on emoji targets (i.e. faster responses to positive than negative emojis), and (iii) use the outcomes of Experiment 1 to extract psycholinguistic baseline measures for the word and

emoji materials selected for the lexical decision task in Experiment 2.

Method

Participants

A total of 92 native English speakers (78 female, 14 male), aged 18–50 years ($M = 23.7$, $SD = 8.0$), all university students in Australia, participated for course credit. The sample size was estimated using G*power analysis (Faul et al., 2007) and based on a 0.3 medium effect size and a power of 0.8 (Cohen, 1992). Another 31 participants were excluded based on the pre-registered criteria (https://aspredicted.org/TLF_JP7) of having a native language other than English ($n = 12$), or self-reported language or literacy difficulties ($n = 7$), vision problems ($n = 9$), cognitive impairment ($n = 2$), or autism spectrum disorder ($n = 1$). Furthermore, to meet the pre-registered sample size, we excluded left-handed or ambidextrous ($n = 11$) participants. Although such inclusion criteria could limit the study's generalizability (Siritzky et al., 2023), the full dataset, including data from excluded participants, is available at (https://osf.io/deq4r/?view_only=22bf124526e24b4581c32d3b1693be4c) and demonstrates patterns consistent with the reported results. Finally, all respondents reported using emojis in texting and estimated the average number of emojis they used per message ($M = 0.9$, $SD = 1.0$).

Materials

A full list of stimuli can be found in the repository (https://osf.io/deq4r/?view_only=22bf124526e24b4581c32d3b1693be4c).

A total of 40 affective emojis was selected, guided by EmoTag, an emoji-emotion NLP resource based on the Twitter database containing approximately 20.8 million tweets (Shoeb & de Melo, 2020). Half of the stimuli represented face and half non-face emojis; half were positive, and half negative. Emojis were carefully chosen to ensure visual complexity was consistent across groups with positive and negative valences, as validated using sentiment (Kralj Novak et al., 2015) and valence (Ferré et al., 2022) scores from two widely used emoji databases.

The selection of word stimuli was informed by their co-occurrence frequencies with emojis in EmoTag (Shoeb & de Melo, 2020), ensuring an associative balance that controlled for semantic congruency effects distinct from affective priming (for details, see the Materials section for Experiment 2). Words were filtered by length ($n \geq 3$) and ranked according to the number of matches in the dataset. Among the top 100 associated words, the most appropriate one was selected manually so that each emoji was paired with one unique word of the same emotional valence, verified by the valence norms (Warriner et al., 2013). Moreover, the selection process aimed to mitigate confounding variables by matching positive and negative words in terms of length, orthographic neighborhood, and OLD20 (Levenshtein distance), based on findings that lexical processing sensitivities can confound with valence (Perea, 2015).

Among the 40 chosen target words, 62.5% ($n = 25$) were adjectives, 22.5% ($n = 9$) were nouns, and 15% ($n = 6$) were adverbs. Of these 40 words, 97.5% ($n = 39$) also could function as adjectives. Descriptive statistics for both words and emojis are provided in Table 1, with detailed individual item scores and analysis

Table 1. Means and standard deviations (SD) for psycholinguistic properties of words, non-words and emojis by condition.

		Words		
Condition	N	Number of letters	Orthographic neighbours	Orthographic Levenshtein Distance 20
Positive	20	6.35 (1.39)	3.10 (4.66)	2.05 (0.63)
Negative	20	5.90 (1.45)	5.90 (6.97)	1.78 (0.54)
Non-words	40	5.63 (1.10)	2.68 (2.54)	1.98 (0.40)
		Emojis		
		Sentiment score[a]	Valence score[b]	Visual complexity[b]
Face positive	10	0.55 (0.17)	7.75 (0.43)	2.26 (0.55)
Face negative	10	−0.18 (0.25)	2.52 (0.69)	2.42 (0.75)
Non-face positive	10	0.54 (0.18)	6.68 (1.04)	1.99 (0.54)
Non-face negative	10	0.17 (0.33)	2.89 (0.80)	2.00 (0.74)

Note: The sentiment score varies between −1 (negative) and 1 (positive). The valence score varies between 1 (negative) and 9 (positive). The visual complexity score varies between 1 (simple) and 7 (complex).
[a]Retrieved from Emoji Sentiment Ranking 1.0 by Kralj Novak et al. (2015).
[b]Retrieved from Emoji-SP – The Spanish emoji database by Ferré et al. (2024).

accessible via https://osf.io/deq4r/?view_only=22bf124526e24b4581c32d3b1693be4c.

Procedure

Participants signed up through (Sona Systems, n.d.) to the experiment hosted at Gorilla (Anwyl-Irvine et al., 2019). Ethical approval has been obtained from the Macquarie University Human Research Ethics Committees (HRECs). After reading the project description, participants provided informed consent and filled out demographic and emoji experience questionnaires. Each participant performed two valence judgment tasks, on emojis and words. The order of tasks was counterbalanced across participants. Instructions were shown on the screen at the beginning of every task. Participants were instructed to answer by pressing one of two buttons, "J" for positive items, and "F" for negative ones. Each task was also preceded by a practice trial with accuracy feedback. After that, the stimuli were presented in one block in random order. Each task included 40 trials, and every trial began with a fixation cross for 500 ms, followed by a word or emoji exposed for 3000 ms or until the response. The task lasted approximately 15 min.

Analysis

Data and scripts can be found in the OSF repository (https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c). Analyses were conducted using the statistical software R (RStudio Team, 2021). Following the procedure outlined by Kralj Novak et al. (2015), we calculated valence scores for both words and emojis. After removing timeout responses, valence scores were determined by the difference in proportions of "J-Pressed" (negative) and "F-Pressed" (positive) responses.

Separately, mean reaction times and their standard deviations were calculated for each item. Error trials (4.1% of the word data and 4.3% of the emoji data) were removed from the reaction times analysis. To mitigate skewness in the data (Baayen et al., 2008), we employed a log transformation, determined by the Box–Cox procedure (Box & Cox, 1964) using the MASS package (Ripley et al., 2013). The transformed data was checked for normality, and outliers exceeding ±2.5 SD were trimmed, resulting in the removal of 2.3% of the word trials and 2.0% of the emoji trials. This threshold, originally suggested by (Leys et al., 2013) and commonly used in reaction time studies (Lachaud & Renaud, 2011), was pre-registered (https://aspredicted.org/TLF_JP7https://aspredicted.org/TLF_JP7). The trimmed data was analysed following (Matuschek et al., 2017) using linear mixed-effects models with the lme4 package (Bates et al., 2015) and the mediation package (Tingley et al., 2014) for the mediation analysis.

In word valence judgement, we scrutinised valence scores for outliers, specifically checking whether words initially labelled as positive or negative deviated significantly from their expected valence scores. Reaction times were also examined to confirm the presence of a positivity bias, as indicated by faster responses to words with positive valence. The final model included single fixed effect of word valence, random slope for word valence for participants, and random intercept for targets.

Similarly, for emoji valence judgement, we analysed valence scores for outliers and compared them with established emoji sentiment databases (Ferré et al., 2024; Kralj Novak et al., 2015). This comparison aimed to validate our findings against broader emoji sentiment trends and was conducted via calculating Pearson and Spearman correlation coefficients. We also investigated reaction times to assess positivity bias in emojis and to examine the influence of face-status and its interaction with emoji valence. The final model included fixed effects of emoji valence, face-status, the interaction between them, random slopes for emoji valence and face-status for participants, and random intercept for targets.

Results and discussion

After screening the proportion of correct responses by response option (positive or negative), we excluded one participant from both tasks due to non-discriminatory response patterns. Specifically, their responses showed a proportion of correct responses at the chance level for both responses, indicating random

Table 2. Means and standard deviations (SD) for reaction times and valence scores for words and emojis in Experiment 1 by condition.

	Words		
Condition	N	Reaction time	Valence
Positive	19	711.69 (57.72)	0.95
Negative	19	781.17 (75.75)	−0.89
	Emojis		
	N	Reaction time	Valence
Face positive	10	702.06 (42.47)	0.97
Face negative	10	742.89 (57.02)	−0.89
Non-face positive	10	781.14 (106.90)	0.87
Non-face negative	10	851.03 (105.28)	−0.92

Note: The valence varies between −1 (negative) and 1 (positive).

button presses. Additionally, one word, "trying", in the word analysis was removed owing to a mismatch with its assigned valence. Mean reaction times, valence scores, and standard deviations by condition are provided in Table 2 (data with individual scores accessible via https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c).

In the word analysis, the RT model revealed a significant fixed effect of valence ($b = -0.09$, $SE = 0.02$, $t(37.39) = -3.54$, $p = .001$). This finding confirms our hypothesis that positive rather than negative words elicit faster valence judgments.

In the emoji analysis, the RT model demonstrated a significant effect of emoji valence ($b < 0.001$, $SE < 0.001$, $t(38.53) = 2.65$, $p = .012$), indicating quicker responses for positive emojis over negative ones. Moreover, face emojis elicited faster responses than non-face emojis ($b < 0.001$, $SE < 0.001$, $t(37.84) = -4.10$, $p < .001$). However, the interaction between emoji valence and face-status did not yield a significant result ($b < 0.001$, $SE < 0.001$, $t(35.89) = -0.01$, $p = .994$), suggesting that these factors operated independently.

Finally, we assessed the correlation between our valence ratings and established databases, namely the emoji sentiment lexicon by (Kralj Novak et al., 2015) and Emoji-SP by (Ferré et al., 2022). The results of Pearson's ($r(31) = .80$, $p < .001$) and Spearman's ($rs(31) = .68$, $p < .001$) correlations with the first database indicated a significant positive association. Similarly, we observed a strong positive association with the Emoji-SP database, as evidenced by Pearson's ($r(31) = .95$, $p < .001$) and Spearman's ($rs(31) = .81$, $p < .001$) correlation. These results validated the consistency of our findings with established sentiment measures in the field.

Post-hoc analysis of emoji valence judgement

To validate the observed emoji valence effects, we conducted a set of non-preregistered post hoc analyses, available at OSF repository (https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c). Previous studies have shown that positive emojis tend to be more frequent and familiar than negative emojis (Scheffler & Nenchev, 2024), which could affect processing speed and potentially confound our results. Another possible confounder was clarity, defined as the degree to which an emoji conveys a single, unambiguous meaning. Face emojis, in particular, can be more ambiguous to participants than non-face objects (Częstochowska et al., 2022), contributing to potential variation in clarity ratings.

Therefore, the frequency, familiarity and clarity scores were extracted from Emoji-SP by Ferré et al. (2024) and tested for collinearity as potential nuisance variables in the emoji analysis. Due to high correlation between frequency and familiarity ($r(31) = .91$, $p < .001$), corroborated by variance inflation factor (VIF) above 5, the model was updated with z-scaled predictors of frequency and clarity, assuming the subjective nature of familiarity (Scheffler & Nenchev, 2024).

The RT model of emoji valence judgement, controlled for frequency and clarity confirmed the effect of face-status ($b < 0.001$, $SE < 0.001$, $t(27.87) = -2.68$, $p = .012$) with faster responses for face than non-face emojis. However, the effect of emoji valence ($b < 0.001$, $SE < 0.001$, $t(28.12) = 1.13$, $p = .269$) did not reach significance. The mediation of the emoji valence effect was estimated using nonparametric bootstrap with 1,000 Monte Carlo draws to compute the bias-corrected and accelerated (BCa) confidence intervals. The indirect effect of frequency accounted for 53.8% of the total effect ($ACME = -32.75$, 95% CI [−42.19, −22.90], $p < .001$, sensitivity (ρ) = −0.1), and the indirect effect of clarity accounted for 32.4% of the total effect ($ACME = -13.45$, 95% CI [−18.86, −8.19], $p < .001$, sensitivity (ρ) = 0.1).

In sum, Experiment 1 revealed a positivity advantage for word targets, whereby participants responded faster to positive than negative stimuli. For emoji targets, after controlling for emoji frequency and emoji clarity, there was a significant effect of face-status with faster responses for face than non-face emojis. Furthermore, the results from Experiment 1 were instrumental in informing the selection of a matched set of prime-target pairs for Experiment 2.

Experiment 2

Building on the insights gained from the valence judgement task, Experiment 2 aimed to investigate the influence of emoji on visual word recognition using an emoji-primed lexical decision task. Here, we employed a $2 \times 2 \times 2$ factorial design considering the emoji face-status (face or non-face, e.g. "😊" or "🏆"), target word valence (positive or negative, e.g. "champion" or "hate"), and prime-target congruency. The congruency conditions were created by a match or mismatch in the emotional valence between prime and target, producing congruent combinations like "😊champion" or "👍hate" and incongruent pairs

such as "😊hate" or "👍champion". Our hypotheses were three-fold. First, if the information conveyed by emojis can be rapidly integrated into the reading process, it should result in a congruency effect, that is, facilitated responses to congruent rather than incongruent prime-target pairs. Second, we expected faster and more accurate responses for the positive than negative target words, that is, a significant effect of valence. Furthermore, according to Sass et al. (2012), valence-specific priming effects should be significant for positive items only. If that is the case, we would expect a congruency effect for positive rather than negative congruent prime-target pairs, evidenced by a significant interaction between congruency and target word valence. Finally, we assessed whether the lexical decision is sensitive to the face-status of an emoji prime. If the information conveyed by face emojis can be integrated faster than their non-face counterparts, we should see a larger congruency effect for items with face than non-face emojis, manifested in a significant interaction between congruency and emoji type. Alternatively, face emojis may elicit a greater attentional response than non-face ones, but this arousal may not interact with the emotional or lexical processing. If this is the case, we should see an effect of face-status in the absence of interaction with congruency or valence. These hypotheses were pre-registered, along with the experimental design and data analysis plan (https://aspredicted.org/TLF_JP7).

Method

Participants

The participants were the same as in the first experiment.

Materials

A full list of stimuli can be found in the repository (https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c).

Emoji primes and word targets tested in Experiment 1 were combined to form 40 congruent (positive-positive or negative-negative) prime-target pairs. The same stimuli were used to create 40 incongruent (positive–negative or negative–positive) items by pairing each emoji with a word of the opposite emotional valence (see Table 3). Hence, each emoji (and word) appeared for a participant twice, in a congruent (e.g. 😊 delicious) and in an incongruent (e.g. 😰 delicious) condition. To minimise the effects of potential semantic priming, we controlled the associative strength in prime-target pairs by matching the normalised co-occurrence frequencies (Shoeb & de Melo, 2020) between the experimental conditions (i.e. congruency, valence and face status), thus allowing us to address the impact of affective priming, our primary research question.

Finally, the 80 resulting experimental items were matched with 80 fillers, comprising an equal number of face and non-face emotionally neutral emojis followed by non-words. Non-words were balanced with the targets in terms of length, orthographic neighborhood, and Levenshtein distance (Rastle et al., 2002). In total, each participant made LD on 160 unique prime-target pairs.

Procedure

The task was a lexical decision on words primed by emojis. Instructions were shown on the screen at the beginning of every task. Participants were instructed to answer by pressing "J" for words and "F" for non-words. Following a practice with accuracy feedback, the main task consisted of 160 trials, each starting with a fixation cross for 500 ms, followed by an emoji prime exposed for 100 ms. A word stimulus was presented immediately afterwards for 3000 ms or until the response, as shown in Figure 1. The stimuli were presented in a random order. The task lasted approximately 30 min.

Analysis

Data and scripts can be found in the OSF repository (https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c). All statistical analyses were performed in R (RStudio Team, 2021) using (generalised)

Table 3. Examples of prime-target pairs in Experiment 2 by condition.

	Congruent		Incongruent		Control
Condition	Positive & positive	Negative & negative	Positive & negative	Negative & positive	Neutral & non-word
Face	😊delicious	😰scared	😊hate	😰delicious	🛒strozed
Non-face	🏆champion	👍hate	🏆scared	👍champion	👔daaroid

Note: Emoji stimuli were extracted from Apple iOS 15.4, Version 14.0 in the size of 320 × 320 px.

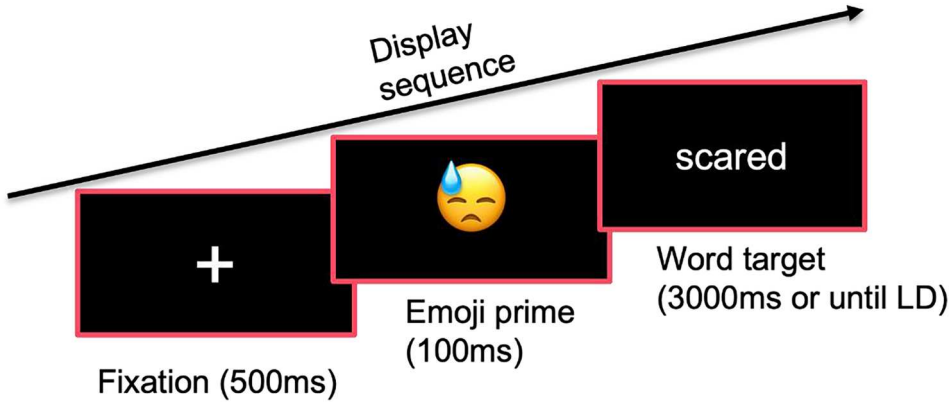

Figure 1. The trial sequence of emoji-primed lexical decision in Experiment 2.

linear mixed-effects models (Baayen et al., 2008) in the lme4 package (Bates et al., 2015), the mediation package (Tingley et al., 2014) for the mediation analysis and the car (Fox et al., 2012) and eMmeans (Lenth, 2024) packages for anova and post hoc contrasts.

In line with our pre-registration, maximal models for reaction times and error rates initially included random intercepts and slopes for participants and items (Barr et al., 2013). These models incorporated fixed effects of face-status (face or non-face), target word valence (positive or negative), prime-target congruency (congruent or incongruent), and two interactions: one between congruency and emoji face-status, and another between congruency and target word valence. Since models were overfitted, the random intercepts models were run next, and random effects for participants and targets were added one at a time (Matuschek et al., 2017). The final models included random slopes for congruency and target valence for participants, and an intercept-only random effect for targets, as each target was presented in each condition.

Error trials (5.3% of the data) were excluded from the reaction times analysis. Latencies were right-skewed, and following a Box–Cox test, a square root transformation was applied to reduce skewness. The resulting distribution was checked for normality, and scaled residuals beyond ±2.5 *SD* (3.3% of the data) were trimmed, adhering to our pre-registration (https://aspredicted.org/TLF_JP7). No data points were removed in the error rate analysis.

Results and discussion

The statistics for participants' RT and ER scores by experimental condition are illustrated in Figure 2. The adjusted RT model indicated a significant fixed effect of congruency ($b = -0.33$, $SE = 0.07$, $t(1391.32)$

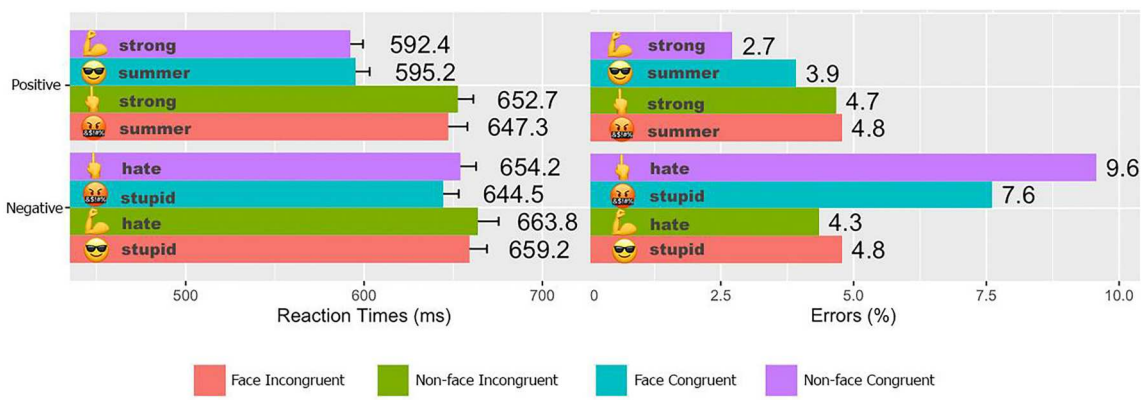

Figure 2. Mean reaction times (left) and error rates (right) by condition in Experiment 2. Error bars represent the SEM.

= −5.07, $p < .001$), confirming faster lexical decisions for congruent compared to incongruent prime-target pairs. Additionally, faster responses were observed for positive versus negative target words ($b = -0.47$, $SE = 0.10$, $t(41.84) = -4.64$, $p < .001$) and for words preceded by face versus non-face emojis ($b = 0.14$, $SE = 0.07$, $t(6529.27) = 2.16$, $p = .031$). A significant interaction was found between congruency and target word valence ($b = -0.95$, $SE = 0.13$, $t(6531.44) = -7.28$, $p < .001$) indicating a notable prime-congruency effect for positive ($EMM = -0.95$, $SE = 0.12$, $t(84.1) = -7.83$, $p < .001$), but not for negative words ($EMM = -0.003$, $SE = 0.12$, $t(83) = -0.03$, $p = .979$). The interaction between congruency and face-status was not significant ($b = -0.04$, $SE = 0.19$, $t(36.99) = -0.21$, $p = .838$).

In the error rate analyses, no effects were observed for congruency ($b = 0.28$, $SE = 0.15$, $z = 1.86$, $p = .063$) or face-status ($b = -0.01$, $SE = 0.11$, $z = -0.10$, $p = .922$). However, a significant effect was found for target word valence, with fewer errors on positive than negative words ($b = -0.52$, $SE = 0.17$, $z = -3.12$, $p = .002$). The interaction between target word valence and congruency was significant ($b = -1.17$, $SE = 0.24$, $z = -4.95$, $p < .001$) showing that the congruency effect was absent for positive words ($EMM = 0.31$, $SE = 0.21$, $z = 1.51$, $p = .132$), whereas there was an inhibitory congruency effect for negative words ($EMM = -0.86$, $SE = 0.17$, $z = -5.03$, $p < .001$), where participants made more errors responding to negative words preceded by a congruent rather than incongruent emoji prime. The interaction between congruency and face-status was not significant ($b = 0.12$, $SE = 0.27$, $z = 0.43$, $p = .668$).

Post-hoc analysis

To ensure the robustness of the findings, we conducted a set of non-preregistered additional analyses (https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c). Similar to Experiment 1, z-scaled predictors of frequency and clarity were added as covariates to the reported models. The RT model was updated without other changes in the effects structure. In the ER model, following the model comparison, the random slope for target valence for participants was removed to achieve convergence.

The updated RT model verified significant fixed effects of congruency ($b = -0.37$, $SE = 0.08$, $t(836.00) = -4.89$, $p < .001$), target word valence ($b = -0.45$, $SE = 0.09$, $t(39.44) = -4.89$, $p < .001$), and the interaction between them ($b = -0.45$, $SE = 0.18$, $t(419.64) = -2.56$, $p = .011$), with significant effect for positive ($EMM = -0.59$, $SE = 0.12$, $t(314) = -5.13$, $p < .001$), but not negative targets ($EMM = 0.14$, $SE = 0.12$, $t(323) = 1.23$, $p = .219$). The only difference between the main analyses and the post-hoc analysis was a change in the main effect of face-status. While the effect of face-status remained significant ($b = -0.18$, $SE = 0.08$, $t(379.36) = -2.15$, $p = .032$), its direction changed, indicating an advantage for words preceded by non-face rather than face emojis. The mediation of the face status effect was estimated using nonparametric bootstrap with 1,000 Monte Carlo draws to compute BCa confidence intervals. The indirect effect of frequency accounted for 10.1% of the total effect ($ACME = 0.20$, 95% CI [0.11, 0.29], $p < .001$, sensitivity (ρ) = −0.1).

The error rate analyses confirmed the significant effect of valence ($b = -0.47$, $SE = 0.14$, $z = -3.46$, $p < .001$) and the interaction between valence and congruency ($b = -0.80$, $SE = 0.31$, $z = -2.62$, $p = .009$), showing that the congruency effect was absent for positive words ($EMM = -0.26$, $SE = 0.25$, $z = -1.01$, $p = .311$), whereas there was an inhibitory congruency effect for negative words ($EMM = -0.55$, $SE = 0.22$, $z = -2.47$, $p = .013$).

To further investigate the facilitatory effects with positive emojis in reaction times and the inhibitory effects with negative emojis in error rates, accounting for the speed-accuracy trade-off (Vandierendonck, 2017), Inverse Efficiency Scores (IES) and the Linear Integrated Speed Accuracy Scores (LISAS) were calculated. IES is a commonly recognised non-linear measure that combines reaction time and accuracy into a single efficiency metric. In turn, LISAS adjusts reaction time to accommodate the number of incorrect responses, balancing the contribution of speed and accuracy to the composite score. Both IES (calculated as RT divided by 1 minus the proportion of errors) and LISAS (computed as the participant's mean RT adjusted for the proportion of errors, weighted by the standard deviation ratio of RT and error rates) were calculated according to Vandierendonck (2017) guidelines.

Subsequent re-analysis was performed using IES and LISAS as dependent variables in two separate Linear Mixed Effects (LME) models. The converged IES and LISAS models maintained same structure with fixed effects of face-status, valence, congruency, two interactions: between congruency and face-status, and between congruency and valence, z-scaled covariates of frequency and clarity, and

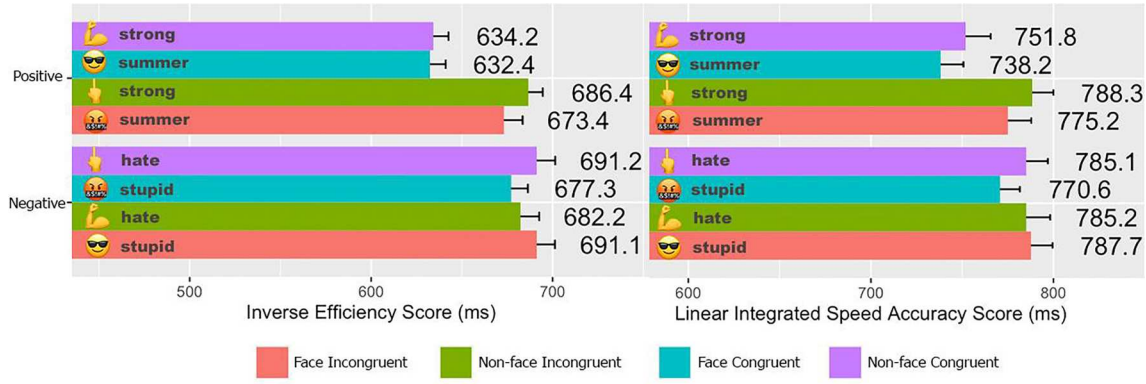

Figure 3. Mean inverse efficiency score (left) and linear integrated speed accuracy score (right) by condition in Experiment 2. error bars represent the SEM.

random intercepts for targets and participants. All response variables underwent a transformation as indicated by the Box–Cox test to meet the assumptions of normality. The descriptive statistics for IES and LISAS scores are displayed in Figure 3.

The IES model revealed the pattern of fixed effects and interactions aligning with the updated reaction time analyses. Specifically, a significant fixed effects of congruency ($b = -0.03$, $SE = 0.01$, $t(1916) = -4.71$, $p < .001$), valence ($b = -0.04$, $SE = 0.01$, $t(34.53) = -6.21$, $p < .001$), and their interaction ($b = -0.04$, $SE = 0.01$, $t(415.6) = -2.83$, $p = .005$), with facilitatory congruency effect for positive ($EMM = -0.05$, $SE = 0.01$, $t(675) = -5.21$, $p < .001$) but not for negative ($EMM = 0.01$, $SE = 0.01$, $t(688) = 0.92$, $p = .357$) words. The effect of face-status was also significant ($b = -0.02$, $SE = 0.01$, $t(392.7) = 2.19$, $p = .029$), with an advantage for words preceded by non-face emojis.

The LISAS analysis revealed similar results with significant fixed effects of congruency ($b < 0.001$, $SE < 0.001$, $t(2075) = 3.94$, $p < .001$), valence ($b < 0.001$, $SE < 0.001$, $t(34.12) = 6.10$, $p < .001$) and the interaction between them ($b < 0.001$, $SE < 0.001$, $t(389.4) = 2.34$, $p = .020$), showing that there was a moderate inhibitory congruency effect for negative words ($EMM < 0.001$, $SE < 0.001$, $t(365) = 2.24$, $p = .003$), with facilitatory congruency effect for positive ($EMM < 0.001$, $SE < 0.01$, $t(681) = 4.33$, $p < .001$) but not for negative ($EMM < 0.001$, $SE < 0.001$, $t(680) = -0.74$, $p = .459$) words. The effect of face-status was also significant ($b < 0.001$, $SE < 0.001$, $t(349.8) = 2.39$, $p = .018$), with an advantage for words preceded by non-face emojis.

In sum, a facilitatory priming effect for positive prime-target pairs remained robust across analyses. The inhibitory congruency effect for negative items was present only in error rates, and while this effect was controlled for frequency and clarity covariates, the IES and LISAS models did not confirm its significance. Notably, the inclusion of the covariates changed the direction of the face-status effect, indicating an advantage for words preceded by non-face emojis, also supported by the IES and LISAS analyses.

General discussion

This study explored the effects of emojis' valence and face-status on valence judgment and lexical decision tasks. In Experiment 1, valence judgments on word targets confirmed the anticipated processing advantage for positive stimuli over negative ones. Although initial analyses of valence judgments on emoji targets showed similar results, this effect was confounded by factors of frequency and clarity, leaving our findings inconclusive about whether the positivity advantage in word processing (Unkelbach et al., 2020) can be generalised to emojis. However, when these covariates were controlled for, the advantage of face emojis over non-face emojis remained significant. This phase also validated the psycholinguistic properties of the materials used in Experiment 2, where participants made lexical decisions on words primed by affectively congruent or incongruent emojis.

In Experiment 2, our findings largely confirmed the preregistered hypotheses. We anticipated that emojis would be rapidly integrated, thereby affecting lexical decision processes, particularly by enhancing the processing of positive words. Consistent with prior research (Comesaña et al., 2013; Sass et al., 2012), we observed facilitated lexical decisions for positive

words compared to negative words, and for congruent prime-target pairs compared to incongruent ones. Moreover, the interaction between valence and congruency effects demonstrated that facilitation in affective priming was significant only for positive items, reinforcing our hypothesis that the initial stages of lexical processing are influenced by the emotional valence of preceding emojis. This heightened sensitivity of lexical decision to emoji valence was evidenced by similar performances in the two incongruent conditions, showing that in the affective priming paradigm, the processing advantage for positive words can be counteracted by priming with negative emojis. Furthermore, when controlling for emoji frequency and clarity, analyses demonstrated better performance in lexical decisions on words preceded by non-face primes compared to face primes.

Overall, the results suggest that the factors of emoji face-status and valence operate independently. The valence judgment task showed a clear advantage for face over non-face emojis, although the positivity advantage was confounded by frequency and clarity. Conversely, in the lexical decision task, we found that frequency mediated the effect of face-status, masking the facilitated performance for words preceded by non-face rather than face emojis, while the positivity advantage remained robust across analyses. Together, these findings imply that valence effects depend on the cognitive demands of the task, suggesting that positivity bias in lexical decision and word valence judgment may rely on distinct cognitive mechanisms.

The results from both experiments indicate an enhanced attentional response to face stimuli, supporting previous evidence that the face processing advantage also applies to face emojis (Gantiva et al., 2019). In the valence judgment task, this involuntary attentional allocation was expected to make face emojis easier to categorise. This was confirmed by the observed advantage for face items, although this effect was partially mediated by frequency and clarity. Conversely, in the emoji-word priming task, responses were facilitated for words preceded by non-face rather than face primes. This suggests that the automatic attention capture by face emojis may incur additional perceptual load (Forster & Lavie, 2021), affecting word processing in subsequent lexical decisions. The absence of interaction between congruency and emoji type suggests that the nature of the emoji – whether face or non-face – does not differentially influence congruency effects. Thus, we propose that this face effect may be linked to increased attention levels rather than being specific to lexical processing.

Furthermore, the interaction between congruency and valence demonstrated robust facilitative priming exclusively for congruent positive pairings, corroborating the existence of a valence-specific processing mechanism, as suggested in the literature (Rossell & Nobre, 2004). At the same time, congruent negative items revealed an inhibition effect in accuracy, indicating that negative words primed by negative emojis led to higher error rates than their incongruent counterparts. This phenomenon may be attributed to the increased vigilance required in processing negative stimuli, as posited by Kauschke et al. (2019). Their review highlighted the evolutionary importance of negative stimuli (Vaish et al., 2008), suggesting that the enhanced memorability of negative content (Santaniello et al., 2018) could prolong attention disengagement (Estes & Adelman, 2008).

To scrutinise this possibility, we conducted IES and LISAS analyses, accounting for the speed-accuracy tradeoff. Results from both tests demonstrated facilitative priming for positive items but did not confirm the significance of inhibition for negatives. Hence, except for the error rates, performance for congruent negatives did not differ from incongruent conditions. According to Jiang et al. (2016), this absence of effects could stem from the simultaneous influence of two opposing forces: negative interference and congruent facilitation. This dual influence suggests that while lexical decision may be accelerated by prime-target affective associations, performance is simultaneously hindered by negative sentiment.

Comparing our findings with those of Kaye et al. (2023), who utilised a similar design but did not observe facilitatory effects of emojis on word processing, it appears that the priming paradigm – with emoji primes and word targets in the lexical decision task – is crucial for eliciting affective congruency effects. In Kaye et al. (2023), any potential affective congruency effects might have been negated by the placement of emojis to the right of words, which could allow participants to make a lexical decision before fully processing the emoji. Although presenting emojis before words is less common in natural digital communication (Cramer et al., 2016), they may still be perceived before the preceding message due to the visual saliency and attention capture of face stimuli. Furthermore, although the emoji used for the neutral condition (i.e. 😐) in Kaye et al. (2023) was categorised as neutral according to

database by Rodrigues et al. (2018), the same emoji was rated as negative in the databases that we used for stimuli selection (Ferré et al., 2022; Kralj Novak et al., 2015). This discrepancy highlights the challenge in replicating facilitative effects across different experimental setups. Nevertheless, Kissler and Koessler (2011) found that positive picture primes can facilitate lexical decisions even for unrelated neutral words. It is therefore possible that the positivity advantage observed in our study might stem from priming attentional or decision-making processes rather than directly influencing the lexical processing.

In summary, this experiment marks one of the first instances of utilising a lexical decision paradigm to study the impact of emoji primes on subsequent word processing. The results demonstrate a valence-specific congruency priming effect, indicating rapid integration of emotional information from emojis in primed lexical decisions. Additionally, the data support the notion that face-like stimuli elicit heightened attention affecting subsequent lexical processing. However, our study's use of a 100 ms prime exposure duration did not conclusively address the automaticity of emoji integration, suggesting that future research employing shorter prime durations, or a masked priming paradigm could provide deeper insights. Future research will need to more closely examine the facilitatory and inhibitory effects of emotional content in emojis by incorporating diverse research designs, such as masked priming, eye-tracking, and electrophysiological measures. These methodological extensions are crucial for a more comprehensive understanding of the cognitive processes involved in the integration of multimodal elements like emojis into digital discourse, thereby enhancing our grasp of their complex interplay in digital communication.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Data availability statement

Data, scripts and materials for the experiment are available (anonymized) at https://osf.io/deq4r/?view_only = 22bf124526e24b4581c32d3b1693be4c

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References

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2019). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388–407. https://doi.org/10.3758/s13428-019-01237-x

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

Bai, Q., Dan, Q., Mu, Z., & Yang, M. (2019). A systematic review of emoji: Current research and future perspectives. *Frontiers in Psychology*, *10*, 2221. https://doi.org/10.3389/fpsyg.2019.02221

Barach, E., Feldman, L. B., & Sheridan, H. (2021). Are emojis processed like words?: Eye movements reveal the time course of semantic processing for emojified text. *Psychonomic Bulletin & Review*, *28*(3), 978–991. https://doi.org/10.3758/s13423-020-01864-y

Barr, D. J., Levy, R., Scheepers, C., & Tily, H. J. (2013). Random effects structure for confirmatory hypothesis testing: Keep it maximal. *Journal of Memory and Language*, *68*(3), 255–278. https://doi.org/10.1016/j.jml.2012.11.001

Bates, D., Maechler, M., Bolker, B., Walker, S., Christensen, R. H. B., Singmann, H., Dai, B., Grothendieck, G., Green, P., & Bolker, M. B. (2015). Package 'lme4'. *Convergence*, *12*(1), 2. https://cran.r-project.org/web/packages/lme4/lme4.pdf

Bellis, M. (2024). Who invented emoticons and emoji? Retrieved June 25, from https://www.thoughtco.com/emoticons-and-emoji-1991412

Beyersmann, E., Wegener, S., & Kemp, N. (2023). That's good news ☹. *Journal of Media Psychology*, *35*(1), 17–27. https://doi.org/10.1027/1864-1105/a000342

Box, G. E. P., & Cox, D. R. (1964). An analysis of transformations. *Journal of the Royal Statistical Society Series B: Statistical Methodology*, *26*(2), 211–243. https://doi.org/10.1111/j.2517-6161.1964.tb00553.x

Chatzichristos, C., Morante, M., Andreadis, N., Kofidis, E., Kopsinis, Y., & Theodoridis, S. (2020). Emojis influence autobiographical memory retrieval from Reading words: An fmri-based study. *PLoS ONE*, *15*(7), e0234104. https://doi.org/10.1371/journal.pone.0234104

Cohen, J. (1992). Statistical power analysis. *Current Directions in Psychological Science*, *1*(3), 98–101. https://doi.org/10.1111/1467-8721.ep10768783

Comesaña, M., Soares, A. P., Perea, M., Piñeiro, A. P., Fraga, I., & Pinheiro, A. (2013). Erp correlates of masked affective priming with emoticons. *Computers in Human Behavior*, *29*(3), 588–595. https://doi.org/10.1016/j.chb.2012.10.020

Cramer, H., De Juan, P., & Tetreault, J. (2016). *Sender-intended functions of emojis in us messaging*. Proceedings of the 18th International Conference on Human-Computer Interaction with Mobile Devices and Services. https://doi.org/10.1145/2935334.2935370

Crossfield, E., & Damian, M. F. (2021). The role of valence in word processing: Evidence from lexical decision and emotional stroop tasks. *Acta Psychologica*, *218*, 103359. https://doi.org/10.1016/j.actpsy.2021.103359

Częstochowska, J., Gligorić, K., Peyrard, M., Mentha, Y., Bień, M., Grütter, A., Auer, A., Xanthos, A., & West, R. (2022). On the context-free ambiguity of emoji. *Proceedings of the*

International AAAI Conference on Web and Social Media, *16*(1), 1388–1392. https://doi.org/10.1609/icwsm.v16i1.19393

Dalle Nogare, L., & Proverbio, A. M. (2023). Emojis vs. Facial expressions: An electrical neuroimaging study on perceptual recognition. *Social Neuroscience*, *18*(1), 46–64. https://doi.org/10.1080/17470919.2023.2203949

Ehrlich, S. F., & Rayner, K. (1981). Contextual effects on word perception and eye movements during Reading. *Journal of Verbal Learning and Verbal Behavior*, *20*(6), 641–655. https://doi.org/10.1016/S0022-5371(81)90220-6

Ekman, P., & Rosenberg, E. L. (1997). *What the face reveals: Basic and applied studies of spontaneous expression using the facial action coding system (facs)*. Oxford University Press. https://books.google.nl/books?id = fFGYs079-7YC.

Estes, Z., & Adelman, J. S. (2008). Automatic vigilance for negative words in lexical decision and naming: Comment on larsen, mercer, and balota (2006). *Emotion*, *8*(4), 441-444; Discussion 445–457. https://doi.org/10.1037/1528-3542.8.4.441

Fahlman, S., Baird, J., & Jones, M. (1982). *Original bboard thread in which:-) was proposed*. Retrieved June 30, 2024, from https://www.cs.cmu.edu/~sef/Orig-Smiley.htm.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/10.3758/BF03193146

Ferré, P., Haro, J., Pérez-Sánchez, M. Á, Moreno, I., & Hinojosa, J. A. (2022). Emoji-sp, the spanish emoji database: Visual complexity, familiarity, frequency of use, clarity, and emotional valence and arousal norms for 1031 emojis. *Behavior Research Methods*, *55*(4), 1715–1733. https://doi.org/10.3758/s13428-022-01893-6

Ferré, P., Haro, J., Pérez-Sánchez, M. A., Moreno, I., & Hinojosa, J. A. (2024). *Emoji-sp – the spanish emoji database: Visual complexity, familiarity, frequency of use, clarity, and emotional valence and arousal norms for 1,031 emojis*. https://osf.io/dtfjv.

Forster, S., & Lavie, N. (2021). Faces are not always special for attention: Effects of response-relevance and identity. *Vision Research*, *189*, 1–10. https://doi.org/10.1016/j.visres.2021.08.002

Fox, J., Weisberg, S., Adler, D., Bates, D., Baud-Bovy, G., Ellison, S., Firth, D., Friendly, M., Gorjanc, G., & Graves, S. (2012). Package 'car'. *Vienna: R Foundation for Statistical Computing*, *16*(332), 333. https://CRAN.R-project.org/package = car.

Fugate, J. M. B., & Franco, C. L. (2021). Implications for emotion: Using anatomically based facial coding to compare emoji faces across platforms. *Frontiers in Psychology*, *12*, 605928. https://doi.org/10.3389/fpsyg.2021.605928

Gantiva, C., Sotaquirá, M., Araujo, A., & Cuervo, P. (2019). Cortical processing of human and emoji faces: An erp analysis. *Behaviour & Information Technology*, *39*(8), 935–943. https://doi.org/10.1080/0144929X.2019.1632933

Haxby, J. V., Hoffman, E. A., & Gobbini, M. I. (2000). The distributed human neural system for face perception. *Trends in Cognitive Sciences*, *4*(6), 223–233. https://doi.org/10.1016/S1364-6613(00)01482-0

Heyman, T., Van Rensbergen, B., Storms, G., Hutchison, K. A., & De Deyne, S. (2015). The influence of working memory load on semantic priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *41*(3), 911–920. https://doi.org/10.1037/xlm0000050

Hinojosa, J. A., Moreno, E. M., & Ferré, P. (2019). Affective neurolinguistics: Towards a framework for reconciling language and emotion. *Language, Cognition and Neuroscience*, *35*(7), 813–839. https://doi.org/10.1080/23273798.2019.1620957

Jiang, Z., Qu, Y., Xiao, Y., Wu, Q., Xia, L., Li, W., & Liu, Y. (2016). Comparison of affective and semantic priming in different soa. *Cognitive Processing*, *17*(4), 357–375. https://doi.org/10.1007/s10339-016-0771-8

Kauschke, C., Bahn, D., Vesker, M., & Schwarzer, G. (2019). The role of emotional valence for the processing of facial and verbal stimuli—positivity or negativity bias? *Frontiers in Psychology*, *10*, 1654. https://doi.org/10.3389/fpsyg.2019.01654

Kaye, L. K., Rocabado, J. F., Rodriguez-Cuadrado, S., Jones, B. R., Malone, S. A., Wall, H. J., & Duñabeitia, J. A. (2023). Exploring the (lack of) facilitative effect of emoji for word processing. *Computers in Human Behavior*, *139*, 107563. https://doi.org/10.1016/j.chb.2022.107563

Kissler, J., & Koessler, S. (2011). Emotionally positive stimuli facilitate lexical decisions—an erp study. *Biological Psychology*, *86*(3), 254–264. https://doi.org/10.1016/j.biopsycho.2010.12.006

Kralj Novak, P., Smailović, J., Sluban, B., & Mozetič, I. (2015). Sentiment of emojis. *PLoS ONE*, *10*(12), e0144296. https://doi.org/10.1371/journal.pone.0144296

Kuperman, V., Estes, Z., Brysbaert, M., & Warriner, A. B. (2014). Emotion and language: Valence and arousal affect word recognition. *Journal of Experimental Psychology: General*, *143*(3), 1065–1081. https://doi.org/10.1037/a0035669

Lachaud, C. M., & Renaud, O. (2011). A tutorial for analyzing human reaction times: How to filter data, manage missing values, and choose a statistical model. *Applied Psycholinguistics*, *32*(2), 389–416. https://doi.org/10.1017/S0142716410000457

Lenth, R. (2024). *emmeans: Estimated marginal means, aka least-squares means_*. In (Version 1.10.3). https://CRAN.R-project.org/package=emmeans

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. *Journal of Experimental Social Psychology*, *49*(4), 764–766. https://doi.org/10.1016/j.jesp.2013.03.013

Matuschek, H., Kliegl, R., Vasishth, S., Baayen, H., & Bates, D. (2017). Balancing type i error and power in linear mixed models. *Journal of Memory and Language*, *94*, 305–315. https://doi.org/10.1016/j.jml.2017.01.001

Perea, M. (2015). Neighborhood effects in visual word recognition and reading. In A. Pollatsek & R. Treiman (Eds.), *The Oxford handbook of reading* (pp. 76–87). Oxford University Press. https://doi.org/10.1093/oxfordhb/9780199324576.013.7

Rastle, K., Harrington, J., & Coltheart, M. (2002). 358,534 nonwords: The arc nonword database. *The Quarterly Journal of Experimental Psychology Section A*, *55*(4), 1339–1362. https://doi.org/10.1080/02724980244000099

Ripley, B., Venables, B., Bates, D. M., Hornik, K., Gebhardt, A., Firth, D., & Ripley, M. B. (2013). Package 'mass'. *Cran r*, *538*, 113–120. http://www.stats.ox.ac.uk/pub/MASS4/

Rodrigues, D., Prada, M., Gaspar, R., Garrido, M. V., & 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. https://doi.org/10.3758/s13428-017-0878-6

Rossell, S. L., & Nobre, A. C. (2004). Semantic priming of different affective categories. *Emotion*, *4*(4), 354–363. https://doi.org/10.1037/1528-3542.4.4.354

RStudio Team. (2021). *Rstudio: Integrated development environment for r* (Version 4.4.0). RStudio, PBC. http://www.rstudio.com/

Santaniello, G., Ferré, P., Rodríguez-Gómez, P., Poch, C., Eva, M. M., & Hinojosa, J. A. (2018). Recognition memory advantage for negative emotional words has an early expiry date: Evidence from brain oscillations and erps. *Neuropsychologia*, *117*, 233–240. https://doi.org/10.1016/j.neuropsychologia.2018.06.006

Sass, K., Habel, U., Sachs, O., Huber, W., Gauggel, S., & Kircher, T. (2012). The influence of emotional associations on the neural correlates of semantic priming. *Human Brain Mapping*, *33*(3), 676–694. https://doi.org/10.1002/hbm.21241

Scheffler, T., & Nenchev, I. (2024). Affective, semantic, frequency, and descriptive norms for 107 face emojis. *Behavior Research Methods*. https://doi.org/10.3758/s13428-024-02444-x

Schmidt, K. L., & Cohn, J. F. (2001). Human facial expressions as adaptations: Evolutionary questions in facial expression research. *American Journal of Physical Anthropology*, *116* (S33), 3–24. https://doi.org/10.1002/ajpa.20001

Scott, G. G., O'Donnell, P. J., & Sereno, S. C. (2014). Emotion words and categories: Evidence from lexical decision. *Cognitive Processing*, *15*(2), 209–215. https://doi.org/10.1007/s10339-013-0589-6

Shoeb, A. A. M., & de Melo, G. (2020, November 8). Emotag1200: Understanding the association between emojis and emotions. *Proceedings of the 2020 conference on empirical methods in natural language processing (EMNLP)*. 8957–8967. https://doi.org/10.18653/v1/2020.emnlp-main.720

Siritzky, E. M., Cox, P. H., Nadler, S. M., Grady, J. N., Kravitz, D. J., & Mitroff, S. R. (2023). Standard experimental paradigm designs and data exclusion practices in cognitive psychology can inadvertently introduce systematic "shadow" biases in participant samples. *Cognitive Research: Principles and Implications*, *8* (1), 66. https://doi.org/10.1186/s41235-023-00520-y

Sona Systems. (n.d.). *Sona systems: Cloud-based participant management software*. Sona Systems, Ltd. https://www.sona-systems.com/

Tamietto, M., Castelli, L., Vighetti, S., Perozzo, P., Geminiani, G., Weiskrantz, L., & de Gelder, B. (2009). Unseen facial and bodily expressions trigger fast emotional reactions. *Proceedings of the National Academy of Sciences*, *106*(42), 17661–17666. https://doi.org/10.1073/pnas.0908994106

Theeuwes, J., & Van der Stigchel, S. (2006). Faces capture attention: Evidence from inhibition of return. *Visual Cognition*, *13* (6), 657–665. https://doi.org/10.1080/13506280500410949

Tingley, D., Yamamoto, T., Hirose, K., Keele, L., & Imai, K. (2014). Mediation: R package for causal mediation analysis. *Journal of Statistical Software*, *59*(5), 1–38. https://doi.org/10.18637/jss.v059.i05

Unkelbach, C., Alves, H., & Koch, A. (2020). Negativity bias, positivity bias, and valence asymmetries: Explaining the differential processing of positive and negative information. In B. Gawronski (Ed.), *Advances in experimental social psychology* (Vol. 62, pp. 115–187). Elsevier. https://doi.org/10.1016/bs.aesp.2020.04.005

Unkelbach, C., Fiedler, K., Bayer, M., Stegmüller, M., & Danner, D. (2008). Why positive information is processed faster: The density hypothesis. *Journal of Personality and Social Psychology*, *95*(1), 36–49. https://doi.org/10.1037/0022-3514.95.1.36

Vaish, A., Grossmann, T., & Woodward, A. (2008). Not all emotions are created equal: The negativity bias in social-emotional development. *Psychological Bulletin*, *134*(3), 383–403. https://doi.org/10.1037/0033-2909.134.3.383

Vandierendonck, A. (2017). A comparison of methods to combine speed and accuracy measures of performance: A rejoinder on the binning procedure. *Behavior Research Methods*, *49*(2), 653–673. https://doi.org/10.3758/s13428-016-0721-5

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

Yang, J., Yang, Y., Xiu, L., & Yu, G. (2021). Effect of emoji prime on the understanding of emotional words – evidence from erps. *Behaviour & Information Technology*, *41*(6), 1313–1322. https://doi.org/10.1080/0144929X.2021.1874050

Yu, L., Xu, Q., Cao, F., Liu, J., Zheng, J., Yang, Y., & Zhang, L. (2022). Emotional violation of faces, emojis, and words: Evidence from n400. *Biological Psychology*, *173*, 108405. https://doi.org/10.1016/j.biopsycho.2022.108405