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The Influence of Emotions and Word Frequency in First and Second Language Processing: Evidence From the Emotional Stroop Task

La influencia de las emociones y la frecuencia de las palabras en el procesamiento de la primera y la segunda lengua: evidencia de la tarea Stroop emocional

Diana Marcela Lizarazo Pereira
Purdue University, West Lafayette, USA & Universidad Nacional de Colombia, Bogotá, Colombia

Felicia Roberts
Purdue University, West Lafayette, USA

Ricardo M. Tamayo
Universidad Nacional de Colombia, Bogotá, Colombia

First (L1) and second (L2) language speakers process information differently. The current study explores whether L1 and L2 English language speakers process the emotional connotations of high and low-frequency words using the emotional Stroop task. With this task, we measure the reaction time required to name the color of words with positive, neutral, and negative valence. The sample was 100 participants, 50 L1 English speakers and 50 L2 English speakers. Our results show that L2 English speakers process words slower than L1 English speakers do. L1 English speakers processed positive words faster than negative words, but L2 English speakers displayed a reversed pattern, which indicates L2 emotional attenuation for negative words.

Keywords: emotional response, emotional Stroop task, second language learning, word frequency, word recognition

El presente estudio explora si hablantes nativos y extranjeros de inglés procesan de forma diferente las connotaciones emocionales de las palabras de alta y baja frecuencia, utilizando una tarea de Stroop emocional. Analizamos los tiempos de reacción ante palabras con valencia positiva, neutra y negativa. La muestra total fue de 100 participantes, 50 angloparlantes nativos y 50 angloparlantes extranjeros. Nuestros resultados muestran que los angloparlantes extranjeros procesan las palabras más lentamente que los angloparlantes nativos. Además, tanto los hablantes nativos como los extranjeros procesaron más rápido las palabras de alta frecuencia que las de baja frecuencia. Los hablantes nativos de inglés procesan las palabras positivas más rápido que las negativas, pero los hablantes extranjeros de inglés muestran un patrón inverso.

Palabras clave: aprendizaje de segundas lenguas, frecuencia de palabras, reconocimiento de palabras, respuesta emocional, tarea de Stroop emocional

Diana Marcela Lizarazo Pereira https://orcid.org/0000-0002-9284-3819 · Email: dmlizarazop@unal.edu.co
Felicia Roberts https://orcid.org/0000-0003-3427-9567 · Email: froberts@purdue.edu
Ricardo M. Tamayo https://orcid.org/0000-0002-8678-0145 · Email: rmtamayoos@unal.edu.co

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Introduction

A quarter of the world's population (1.75 billion people) uses English. There are at least three learners of English as a second language (L2) for each native speaker (L1; Maybin & Swann, 2010). Consequently, a substantial body of research aims to identify differences in understanding L1 and L2. One of the most interesting findings is the discovery of emotional differences in how L1 and L2 speakers process the meaning of words. The present study aims to investigate how the emotional connotation of words and word frequency influence processing speed for L1 and L2 speakers of English using an emotional Stroop task (EST). Previous research pointed out that L1 speakers tend to display stronger emotional reactions to negative and positive words than L2 speakers (i.e., Caldwell-Harris, 2015; Keysar et al., 2012). This so-called *foreign language effect* apparently leads to high emotional resonance in L1 and emotional attenuation in L2. In most cases, L1 speakers also display enhanced automaticity and speed in processing emotional words, whereas L2 speakers display decreased emotional automaticity and emotional attenuation (Pavlenko, 2012).

A fundamental explanation for emotional differences in L1 and L2 processing might reside in dual-system accounts of cognition (i.e., Kahneman, 2011; Parra & Tamayo, 2021, for a review). Dual system theories suggest that two different modes operate in parallel to process linguistic information. On the one hand, the implicit system is fast, automatic, and intuitive. On the other hand, the explicit system is slow, analytical, and rational. Accordingly, L2 information, predominantly processed by explicit mechanisms, demands more significant cognitive load and effort than L1, primarily processed by implicit strategies (Costa et al., 2014). Additionally, information implicitly acquired seems more persistent over time than explicit memories (Mitchell, 2006; Tamayo & Frensch, 2007, 2015).

Emotional Differences in L1 and L2

Today, the study of emotional differences between L1 and L2 processing involves behavioral (e.g., lexical decision task, EST), psychometric (e.g., questionnaires), neurophysiological (skin conductance responses, SCRs), and neuroimaging techniques such as functional magnetic resonance imaging (fMRI). Research concerned with emotional differences between L1 and L2 has suggested some interesting ways in which the emotional attenuation typically observed in L2 can facilitate the accuracy of moral judgments, reduce biases involved in decision-making, and increase the speed of single-word processing (Altarriba & Mathis, 1997; Costa et al., 2014; Keysar et al., 2012; Pavlenko, 2017).

One pioneer piece of research compared emotional processing in L1 and L2 (Bond & Lai, 1986). The researchers interviewed participants regarding embarrassing topics in their native and foreign languages. They found that the length and detail of answers in L2 were more significant than in L1, which suggests that talking about embarrassing topics is easier in L2 than in L1. Similarly, Dewaele (2004) reported a sizeable multilingual study (N = 1,039) including participants with different language backgrounds. He assessed the perceived emotional weight of swear words. The results showed that the perceived emotionality of swear words was higher in L1 and weaker in languages learned subsequently. Additionally, implicit physiological measures, such as SCRs, show that emotional activation is slightly higher when taboo words are processed in L1 than in L2 (Harris, 2004; Harris et al., 2003).

Interestingly, proficiency and experience seem to modulate emotional reactivity. For instance, studies about lying in L1 and L2 have shown that participants subjectively perceive higher emotionality in L1 than L2, but objective SCRs were greater in L2 than L1 (Caldwell-Harris & Ayçiçeği-Dinn, 2009). Thus, physiological reactions can depend on language proficiency. On the one hand, early learners and highly proficient speakers do not show differences in physiological measures. On the other hand, late learners and low-proficient individuals display increased SCRs. The reason is that it could be harder to respond in L2 than in L1, thus increasing participants' anxiety and emotional reactivity (Caldwell-Harris & Ayçiçeği-Dinn, 2009; Harris, 2004).

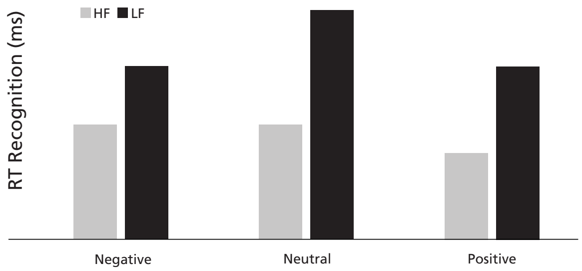
Emotional Word Processing

Researchers soon recognized that multiple variables (experience, motivation, competence, fluency, etc.) affect information processing in L1 and L2. Consequently, some scholars have focused on a more straightforward scenario, the processing of single words. Words differ from morphemes (the smallest unit in a language that can be assigned a meaning) because they can have a meaning uttered in isolation. All words have a form linked to a sound (a phonetic and a phonological code) and a grapheme (orthographic code). Additionally, every word has a meaning (semantic code) that can provide information about comprehensive knowledge of words (the generic form and function) and what the word refers to (the reference). Form and meaning are two intertwined systems representing a single word in our minds (Traxler, 2012). In this way, when we perceive a word, it can activate a cognitive meaning and trigger an emotional response related to the meaning (de Houwer & Hermans, 1994). Within this cluster of research, emotions are typically measured along two key dimensions: (a) valence, ranging from pleasant to unpleasant; and (b) arousal, ranging from calm to excited (Bradley & Lang, 1999).

Single-word processing studies have shown contradictory results in emotional processing. For instance, lexical decision task (LDT) studies that included positive words found faster processing for positive words than for neutral and negative words (Kuchinke et al., 2005; Recio et al., 2014). However, studies comparing L1 and L2 report faster reaction times (RTs) in processing emotional words (positive and negative) than neutral words for both L1 and L2 (Conrad et al., 2011). These differences are attributable to the rules used to construct non-words needed for most LTD experiments, which require similar construction schemes in L1 and L2 but affect the participants' ability to differentiate among them. In our view, this points out one shortcoming of LDT experiments: they require creating non-words based on a specifically predesigned set of rules. One reason for using an alternative experimental task in our study is that the EST (see below) does not require a lexical decision between words and non-words.

Notwithstanding, extant LDT studies have also investigated the relationship between emotion and word frequency. These experiments are relevant to the present study, although most are not necessarily centered on L1 and L2 differences (Kuchinke et al., 2007; Méndez-Bértolo et al., 2011; Nakic et al., 2006; Scott et al., 2009). High-frequency negative words are recognized faster than low-frequency and neutral words. Low-frequency negative words are recognized faster than low-frequency neutral ones, but there are no significant differences between high-frequency neutral and negative words (Méndez-Bértolo et al., 2011). Low-frequency words are processed slower than high-frequency, and highly negative words are processed faster than low-frequency negative and neutral words (Nakic et al., 2006). Additionally, when positive valence takes part in these studies, an advantage to high-frequency positive words relative to low-frequency words was found. High-frequency positive words are processed faster than high-frequency neutral and high-frequency negative words, whereas low-frequency positive and low-frequency negative words are processed more quickly than neutral ones (Kuchinke et al., 2007; Scott et al., 2009). Figure 1 presents a simplified summary of these findings.

Figure 1. Schematic Summary of Empirical Findings Reporting Advantages on Recognition Speed According to Emotionality and Word Frequency



Note. The Y-axis depicts reaction time (RT) of word recognition in milliseconds. The X-axis depicts type of word according to emotion and frequency. HF = high frequency, LF = low frequency.

Sheikh and Titone (2016) conducted an eye-tracker study focused on differences between L1 and L2. They found an interesting advantage in processing positive emotional words in L2 compared with neutral words but not for negative words and an emotional advantage in high-frequency positive words compared to low-frequency words. These results suggest an apparent effect of frequency: faster processing of high-frequency words compared to low-frequency ones.

Emotional Stroop in L1 and L2

As mentioned above, researchers use various measures to evaluate emotional processing. In the present study, we use the EST to assess emotional interference involved in word processing (Williams et al., 1996). In a typical EST, participants must name as quickly and accurately as possible the color of emotional words (e.g., *cancer*, *war*, *kill*) and neutral words (e.g., *street*, *lift*, *spoon*) printed in assorted colors. Typically, participants slow down when they name the color of emotional words compared to neutral words. Emotional words activate automatic connotations, divert attention from the printed color, and so slow participants' reaction time (Algom et al., 2004; Frings et al., 2010; Mackay et al., 2004). However, an earlier monolingual study has shown interference effects in the EST only for low-frequency negative words and null effects in high-frequency negative ones (Kahan & Hely, 2008).

The EST has also been used to compare the automaticity of word processing in L1 and L2 (i.e., Eilola et al., 2007; Fan et al., 2016; Sutton et al., 2007; Winskel, 2013). For instance, Sutton et al. (2007) focused on the emotional Stroop effect using only negative and neutral words in highly proficient Spanish-English bilinguals. They found similar levels of interference for both English and Spanish word processing. Eilola et al. (2007) assessed the processing speed of neutral, positive, negative, and taboo words in proficient Finish-English bilinguals. They found interference in both languages when negative and taboo words were presented, slowing the RT compared with neutral words. Neutral and positive words did not display this effect. Besides, there were no differences in the size of cross-interference between languages.

The studies above did not find critical differences between L1 and L2 in automatic word processing. Nevertheless, recent studies contested these results, reporting a critical difference between negative and neutral words in proficient Thai-English bilinguals. An emotional Stroop effect was found in L1 (slow RT in emotional words) but not in L2 (Winskel, 2013). According to Winskel (2013), this difference

> is attributable to the proficiency levels in English of the Thai-English bilinguals and the context in which they had learned English, predominantly as a foreign language. For example, only 57% of the Thai participants had spent a brief period overseas, whereas 100% of the Finnish participants in Eilola et al.'s (2007) study had spent time overseas, and 44% of them had lived in an English-speaking environment for a year or longer. (p. 1096)

These findings suggest that higher expertise with L2 can lead to emotional reactions similar to those observed for L1.

More recently, EST effects were reported in a face-word Stroop paradigm in both L1 and L2 (Fan et al., 2016). This study showed higher interference for bilinguals' dominant language, which supports the view of emotional attenuation in L2. Using a different task to measure automaticity in word processing (the rapid serial visual presentation), L1 was more emotional than L2, apparently, due to an attention blink in L2 for English speakers (Colbeck & Bowers, 2012). In sum, previous EST studies have shown that proficiency, the context of learning, and expertise with L2 are critical variables involved in emotional interference in word processing (Costa et al., 2014; Eilola et al., 2007; Fan et al., 2016; Sutton et al., 2007). All these studies suggest that emotional words can lead to higher reactivity in L2 only after an extensive or an immersive experience with the non-dominant language. The shared explanation for this particular effect points to a higher degree of automaticity and fluency of emotional words achieved after extensive experience with L2.

There is a clear need to evaluate the influence of word frequency in the automaticity of emotional word processing for L2, considering the evidence summarized above. Mainly, word frequency can quantify a priori the amount of experience from L2 learners with specific words simply because frequent words can be assumed to be more familiar than infrequent words for L2 learners. Further, it is required to analyze the role of L2 exposure in emotional processing because none of the studies above has used the emotional Stroop paradigm to evaluate frequency effects in L1 and L2 as a complementary variable to understand the cognitive processing of words; although those previous studies indirectly suggest that frequency is an important variable that could influence emotional word processing in an EST paradigm. Therefore, we suggest assessing emotional differences between L1 and L2, considering the frequency of words. This is relevant to the field because previous EST studies concerning L1 and L2 differences did not simultaneously consider word frequency and emotion (negative, neutral, and positive). As mentioned above, some studies have considered the difference between L1 and L2, taking into account proficiency and expertise with the L2 (i.e., Winskel, 2013) but have yet to simultaneously consider word frequency. Others have studied word frequency (i.e., Kahan & Hely, 2008) but have yet to simultaneously analyze the influence of L1 and L2. However, others have considered all three factors (emotion, proficiency, and L1 and L2) but using a different methodology, such as an eye-tracker (i.e., Sheikh & Titone, 2016).

The Current Study

The current study considers: (a) emotion (positive, neutral, and negative), (b) word frequency (low, high), and (c) L1 and L2 as variables that influence English word processing in an EST experimental paradigm. Therefore, we intend to provide further insights into how emotion and frequency interact for L1 and L2 word processing. We recruited native English speakers (L1) and English as foreign language (EFL) learners (L2) living in the USA at the time the experiment took place. Consequently, our EFL speakers had a diverse L1 background, which minimizes the influence of the type of L1 on the experiment and emphasizes the influence of L2 exposure on word processing.

Question 1: Do high-frequency English words increase the emotional load and consequently differently slowdown RTs for L1 and L2 speakers? Based on previous evidence from the LDT paradigm (see Figure 1 for a summary), we hypothesize a slowdown in the RT for high-frequency words relative to low-frequency words.

Question 2: Do emotional words (negative and positive) slow down RTs compared to neutral words? Do L1 and L2 display the same pattern? We hypothesized an interference effect for emotional words (negative and positive), at least in the L1 group (i.e., Eilola et al., 2007). However, we do not predict a specific pattern for the L2 group because word frequency may play a more decisive modulating role than valence for word processing in L2 (see Sutton et al., 2007; Winskel, 2013). Emotional low-frequency words exert less influence on L2 participants because presumably they can easily ignore the emotional connotation of unfamiliar (low-frequency) words.

Method

Participants

One hundred students enrolled at Purdue University participated in this research. Fifty L1 English speakers (women = 27, mean age 20.4) and 50 L2 English speakers (women = 18, mean age 22.7). There were 66% Asians, 24% Latinos, and 10% other ethnicities in the L2 group. Their L1 was Mandarin ($n = 18$); Spanish ($n = 13$); Hindi ($n = 6$); Korean ($n = 3$); two Arabic, Bengali, French, and Marathi speakers; one Farsi and one Japanese. The average self-reported English skills on a 1–6 scale were writing (4.68), reading (4.92), listening (4.96), and speaking (4.66). All L1 and L2 were first- and second-year college students.

Participants earned extra credit for their participation. All participants had a normal or corrected vision and reported no color blindness. They provided written informed consent before participation in the study. The study and recruitment had approval from the IRB committee (Human Research Protection Program) at Purdue University.

Experimental Design and Materials

We used a mixed 2 x 2 x 3 design with language as the between-subjects factor (native, foreign) and word frequency (low, high) and emotion (positive, negative, and neutral) as the within-subjects factors.

Word stimuli varied according to valence, arousal, and word frequency. According to the British National Corpus, we selected 120 English words as stimuli, 60 high-frequency words, and 60 low-frequency words (https://www.english-corpora.org/bnc/). For each of these categories, we selected words according to their valence and arousal normative scores: 20 positive, 20 negative, and 20 neutral words (see Appendix). Closely modeled after Scott et al. (2009), we took valence and arousal values from the Affective Norms for English Words (Bradley & Lang, 1999)—a database of 1,000 words providing normative ratings both for arousal, ranging from 1 (*low*) to 9 (*high*), and for valence, ranging from 1 (*negative*) to 9 (*positive*). Based on Scott et al., we selected *emotional* words with arousal values greater than 6.0 and neutral words less than 5.45. Valence ratings greater than 6.0 for positive words and less than 4.0 for negative words. We took neutral words with valence values between 4 and 6.

Apparatus

We invited participants to the Brian Lamb School of Communication Laboratory at Purdue University. We used Inquisit software web version 5.0 for data collection. We also adapted the EST described by Smith and Waterman (2003) using the manual keyboard responding variant for the present study. Additionally, we included a demographic questionnaire. Participants sat at a viewing distance of approximately 65 cm from the screen monitor. Keyboard responses were A, S, K, and L keys on a standard QUERTY keyboard. Stimuli appeared on a white background in low case. A fixation cross appeared before each word for 500 ms; after each wrong response, a red cross emerged for 400 ms.

Procedure

Participants voluntarily took part in the study through a research participation system website. This system offers students extra credit in registered courses for participation in research. Other students were recruited through flyers on campus. Initially, participants received general instructions about the nature of the experiment. Subsequently, participants followed the instructions on the screen by themselves. The instructions prompted participants to respond as fast and accurately as possible by pressing the corresponding key color of each word.

Words had four colors (green, blue, red, and yellow). Participants had to press keyboard keys mapped onto each color to register their response to each stimulus. Depending on the word color, participants had to press a specific key. For example, the word "joy" was printed in green, and the green key was mapped onto the "A" key. Therefore, the participant had to press the key "A" to match the color of the word. The RT for each response was recorded in milliseconds. The task had three parts. First, a practice block presented numbers from 1 to 10 printed in four colors to familiarize participants with key-color mapping. Second, there was an experimental block in which participants had to respond to the target stimuli. The experimental software assigned each word to four colors and randomly presented a different order for each participant in a single block. Finally, in the third block, participants had to complete a brief survey with questions about their expertise in the English language.

Results

Fifty L2 English speakers participated in this study. Regarding immersion in an English-speaking country, 18 reported having lived less than one year in an English-speaking country (36%), 21 lived between one and five years (42%), and 11 reported having lived more than five years (22%). Concerning the age of acquisition (AoA), 17 said it started before six years (early learners, 34%), and 33 reported their AoA after six years (late learners, 66%). Regarding English language proficiency, all L2 participants obtained 80 or higher scores in the TOEFL iBT (a general undergraduate admission requirement for Purdue University). Additionally, we asked participants to rate their reading English proficiency subjectively: 12 reported an intermediate English proficiency (24%), 21 reported an advanced English level (42%), and 17 were not sure about their proficiency (34%). Regarding language preference, 36% of participants preferred to use English in their daily lives, and the remaining percentage preferred to use their native language. Finally, about the use of English, 28% of participants reported spending less than half of their daily life using the English language, whereas 72% of participants reported using it most of the time in their everyday life.

We performed a linear regression to explore correlations between the above variables with RTs. There was a significant negative correlation between the immersion time and RT. The more time living in an English-speaking country, the faster the RT ($R = -.341$, $P = (.065, 90\%)$. Besides, there was a positive correlation between AoA and the RT; the later the learning of L2, the slower the RT ($R = -.351$, $P > 0.001$). Finally, there was a negative correlation between English and the RT; the more use of English, the faster the RT ($R = -.366$, $P > .001$). There was no correlation between language preference and the RT ($R = .008$, $P = .511$). These results suggest that higher exposure and use of L2 leads to faster word processing.

Analysis of Errors

We also analyzed the proportion of errors for each cell of our experimental design (see Table 1).

Table 1. Percentage of Errors in Each of the Six Categories of Stimuli for L1 and L2

	L1		L2	
	HF	**LF**	**HF**	**LF**
Negative	3.9	2.9	3.9	3.0
Neutral	3.6	4.5	2.9	3.9
Positive	3.9	4.4	3.8	4.5

Note. The error accounted for 3.8% of the total data (L1 = 3.9%; L2 = 3.7%). HF = high frequency, LF = low frequency.

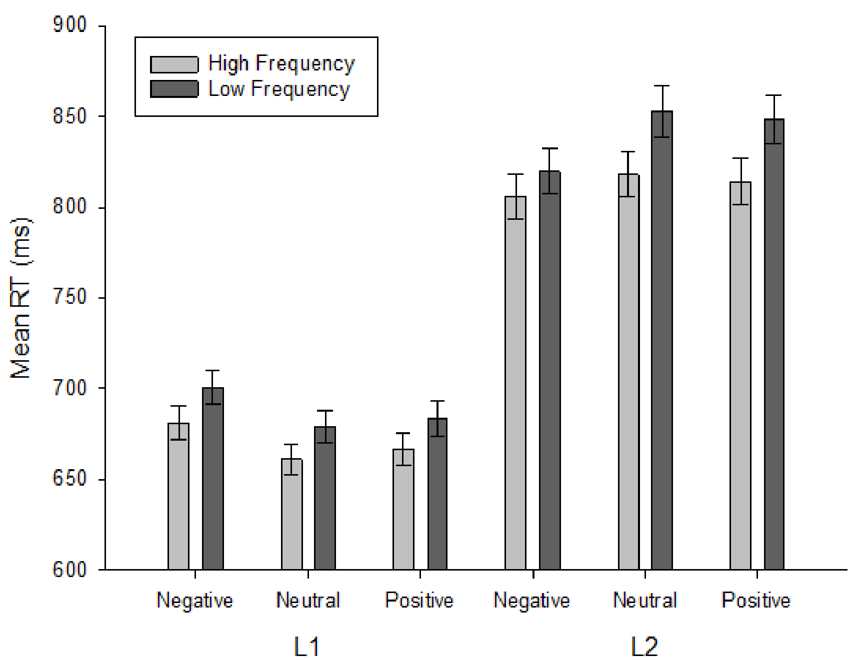
We ran a two-way analysis of variance (ANOVA) for errors with category and group as factors. There were no statistically significant category differences (emotion, frequency) $F(5, 433) = 1.745$, $p = .121$ or group $F(1, 433) = .283$, $p = .595$.

Analysis of Response Latencies

We excluded all errors for further analysis (3.8%). Additionally, RTs from practice trials and RTs slower than 2.5 and faster than 2.5 standard deviations, and RTs < 250 ms were removed. We conducted a repeated-measures ANOVA and a linear regression model for the primary analysis. The main effect of the group was significant, $F(1, 98) = 44.35$, $p < .001$. L1 responses were faster ($M = 658$ ms) than L2 ($M = 801$ ms). This result confirms a cognitive advantage in speed processing for L1 vs. L2 speakers. There was also a significant main effect of frequency $F(1, 98) = 13.565$, $p < .001$. High-frequency words were processed faster ($M = 719$ ms) than low-frequency words ($M = 740$ ms). This finding supports the frequency effect: Processing high-frequency words was easier than low-frequency ones. This result suggests that despite high-frequency words being experienced more frequently, their possible emotional connotations do not produce interference effects in the EST. Finally, there was no significant difference between group and frequency, $F(1, 98) = .75$, $p = .784$.

Valence was no significant per se, $F(2, 196) = 57$, $p = .564$; however, there was a significant main effect of valence and group, $F(2, 196) = 6.74$, $p < .001$. L1 speakers processed negative words slower ($M = 667$ ms) than neutral ($M = 658$ ms) and positive words ($M = 647$ ms). The RTs for negative words were marginally more prolonged than for neutral words (+8.9 ms). Conversely, L2 speakers responded faster to negative words ($M = 787$ ms) than neutral ($M = 807$) and positive words ($M = 808$). The average difference between negative and neutral words was -19.8 ms. This finding suggests an opposite effect in processing emotional words in both groups. Plainly, whereas L1 speakers show a marginal emotional interference for negative words, L2 speakers display relative facilitation in color naming. Thus, L2 speakers invert the interference effect. The overall interaction between frequency, valence, and group was not significant. Figure 2 summarizes these findings.

Figure 2. Main Results for Reaction Times



Note: Mean Reaction Time (processing speed) in the emotional Stroop task for high frequency vs. low-frequency words according to emotional valence (negative, neutral, and positive) for L1 and L2 speakers of the English language. Error bars depict +/- 1 standard error of the mean.

Discussion

The present study investigated how L1 and L2 English speakers process individual words according to their emotional valence and frequency in the EST. We expected to find an emotional Stroop effect for high-frequency words due to greater familiarity and, thus, higher emotional interference than low-frequency words, especially for the L1 group (Costa et al., 2014). This hypothesis was not supported. The frequency of words was more relevant than the emotional influence. As the frequency effect suggests, participants processed high-frequency words faster for both L1 and L2. Therefore, although high-frequency words are experienced more frequently, their possible emotional connotation does not produce interference effects, as assessed through the EST.

Additionally, we predicted longer RTs for the L2 group than for the L1 due to the foreign language effect (i.e., Caldwell-Harris, 2015; Keysar et al., 2012). Indeed, L2 English speakers were slower, while L1 English speakers had faster RTs. The overall difference between RT in L1 and L2 can be explained by a combination of the dual-system theory (Kahneman, 2011) and the trade-off between L1 and L2 processing. From this point of view, System 1, which is automatic and faster, was predominantly used by L1 speakers because words present in their L1 enhanced their automated processing. On the other hand, System 2 was mainly used by L2 speakers because words presented in a less automatized language required more cognitive recourses and, thus, led to slower RTs.

More importantly, we found a Stroop facilitation for negative words in the L2 group compared with the L1 group. This result supports the view of a unique mechanism for accessing the lexical meaning of negative words in L2, probably related to other emotional attenuation effects reported for L2 (i.e., Keysar et al., 2012). From our sample of 50 L2 English speakers, only 14 had the Latin alphabet in their native language (13 Spanish and one French), and none of them spoke Germanic or Nordic languages as L1, which probably minimized the influence of cognates as an intervening variable and facilitated the expression of emotional attenuation in our sample.

In contrast with Sutton et al. (2007) and Eilola et al. (2007), our results show a difference in L1 and L2 processing in the emotional Stroop paradigm. However, their studies focused on highly proficient bilinguals, while our sample had both early and late AoA, wider differences in proficiency, different L1 backgrounds, and various immersion times in L2. Additionally, our results contradict previous research that found substantial interference in L1 (Fan et al., 2016; Winskel, 2013). Although present, our study found slight interference of negative words for L1 speakers mainly driven by low-frequency words, a result previously reported but challenging to explain with current models of lexical and emotional access (see Kahan & Hely, 2008).

However, we found strong facilitation for negative words for L2 speakers. Our findings suggest a difference in automatic word processing in L1 and L2. On the one hand, L1 facilitated faster and automated color naming across all emotional word categories (negative, neutral, and positive). Negative emotional words slowed down reaction time more than neutral and positive words. On the other hand, L2 involves less automatic emotional processing. We believe that negative words pose an unavoidable attentional demand for all participants. However, L2 speakers can more quickly deal with the color and neglect the negative emotional connotation because fewer automatic cognitive resources are available in L2 to process negative emotional words, which would explain why the processing of negative connotations was faster by L2 speakers than by L1 speakers.

Regarding frequency effects, a previous study reported that monolinguals process low-frequency negative words slower than high-frequency negative words (Kahan & Hely, 2008). In the present study, we found the same directionality but did not replicate a similar statistical significance. However, both results are consistent with the Parallel Distributed Processing Model. When a low-frequency word is processed, the cognitive system needs more time to get all the lexical information. At this point, semantic activation will have more time to influence word processing and, thus, increase interference effects (Cortese & Schock, 2012).

In the present study, we also tested the influence of word frequency on L2 speakers. While we found slower processing speed in low-frequency negative words for L1 speakers, low-frequency negative words were processed faster by L2. Following the bilingual cognitive advantage hypothesis (i.e., Bialystok, 2001), bilinguals usually tend to outperform interference effects in a standard Stroop paradigm compared with monolinguals. According to this perspective, bilinguals activate both languages in parallel; however, cognitive mechanisms must exert control over the non-necessary language leading to an enhancement in the executive process that improves the overall performance in cognitive tasks.

Additionally, the bilingual L2 lexical disadvantage hypothesis predicts a lexical disadvantage in the less dominant language (L2). According to this hypothesis, the difference in negative word processing in both high-frequency and low-frequency by L2 speakers can be explained by the fact that information processing in L2 has weaker lexical access than in L1. Therefore, the meaning of words would not be easily accessible, and consequently, it would imply a more negligible or null emotional interference. Compared to L1, L2 would produce a negative shift in interference effects, facilitating the processing of emotional words and, thus, faster responses (Coderre et al., 2013; Gollan et al., 2008). According to the prediction of the bilingual L2 lexical disadvantage hypothesis, L2 participants had facilitation on the processing of negative words. L2 speakers have weaker lexical access to L2 representations, also more inefficient access to semantic code, hence fewer interference effects.

Although these previous hypotheses explain why there was a shift in negative word processing in both groups, it does not explain why it occurred only for negative words but not for positive words. The mobilization-minimization hypothesis (Taylor, 1991) suggests that faster physiological, cognitive, emotional, and social responses to negative stimuli are followed by a minimization stage intended to reduce unpleasant reactions and dampen the negative stimuli's impact. Additionally, this hypothesis proposes an asymmetry in negative–positive events: a weaker and less common association in memory for negative words but an easier recognition and processing fluency for positive words. Both variables, frequency and valence, contribute to differential word processing. In a previous study on the effects of valence, arousal, and frequency, positive valence speeds up word processing in LDT. It implies slower RTs for negative words and faster RTs for positive ones (Kuperman et al., 2014). Positive words thus would automatically facilitate word recognition. Relative to negative words, elaborating positive information is easier because it links semantic and lexical codes that broaden the scope of the cognitive-emotional system (Kuchinke et al., 2005). The enhancement of automaticity for positive words would not lead to interference costs because the lexical connections are already well established.

Finally, concerning the role of L2 exposure, we observed a negative correlation between RT and high proficiency, immersion time, and L2 daily use. Hence, the higher proficiency, immersion, and use of English, the faster the processing of English words. Conversely, the later the age of English acquisition as L2, the slower the processing of English words. Longitudinal studies suggest that different cerebral pathways process L1 and L2 lexical and affective features during early learning stages (Sianipar et al., 2015), but that with increasing L2 exposure, lexical and semantic networks become strongly interconnected across L1 and L2. Therefore, more prolonged exposure to L2 can enhance the processing speed of L2 to a level similar to the processing speed of L1.

In sum, the current work used an EST to identify differences in emotional valence and frequency for

L1 and L2 speakers. As predicted, we found critical cognitive and emotional differences between both groups. L1 speakers displayed faster processing than L2 speakers. There was a significant effect on word frequency: overall, our participants processed high-frequency words faster. Nevertheless, there was no significant interaction between the L1 and L2 groups. Our correlation analyses support the view that RTs become faster with greater exposure to L2.

The main finding of the present study was a significant difference between group and valence. Whereas L1 speakers showed a regular Stroop interference effect, L2 speakers showed an opposite effect: no interference effect; alternatively, we observed facilitation in negative word processing independently of the word frequency. This opposite effect is consistent with the bilingual L2 lexical disadvantage hypothesis. It suggests weaker lexical access in L2 that leads to weaker semantic access to L2 and a reverse pattern in interference when the task demands the participant to focus on the color of words but not on their meaning, speeding up negative word processing. We confirm with an alternative method (the EST) that L2 speakers are less sensitive to negative emotional connotations than L1 speakers. Future research should aim to replicate the present findings with other implicit cognitive measures and to keep word frequency as a variable of interest.

The present study had some fundamental limitations. First, the conclusions of the present study are hardly generalizable to other tasks (affective priming, flanker, Simon tasks, etc.) and domains (e.g., full sentences, spoken vs. written words). For instance, it is unclear if complete emotional vs. neutral sentences in L1 and L2 are also susceptible to the facilitation effect we report here.

Second, a recent EST study (Crossfield & Damian, 2021) reported no interference effects in monolinguals when emotional stimuli matched conceptual variables such as contextual diversity and sensory experience. Therefore, it remains an open question to investigate the involvement of this kind of conceptual variable in L1.

Finally, our study suggests two important implications for teaching English as a second language. On the one hand, teachers can take advantage of the reported fact that beginner and intermediate L2 students might learn faster and remember more accurately the meaning of words involving strong positive and negative emotional connotations.

On the other hand, we consider that L2 students should also be made explicitly aware of the fact that, in real-world interactions, L1 speakers tend to interpret negative words more strongly than L2 learners and that it might take some time to read the adequate context and usage of emotional expressions.

References

Algom, D., Chajut, E., & Lev, S. (2004). A rational look at the emotional Stroop phenomenon: A generic slowdown, not a Stroop effect. *Journal of Experimental Psychology: General*, *133*(3), 323–338. https://doi.org/10.1037/0096-3445.133.3.323

Altarriba, J., & Mathis, K. M. (1997). Conceptual and lexical development in second language acquisition. *Journal of Memory and Language*, *36*(4), 550–568. https://doi.org/10.1006/jmla.1997.2493

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition*. Cambridge University Press. https://doi.org/10.1017/CBO9780511605963

Bond, M. H., & Lai, T.-M. (1986). Embarrassment and code-switching into a second language. *Journal of Social Psychology*, *126*(2), 179–186.

Bradley, M. M., & Lang, P. J. (1999). *Affective norms for English words (ANEW): Instruction manual and affective ratings* (Technical report C-1). The Center for Research in Psychophysiology, University of Florida.

Caldwell-Harris, C. L. (2015). Emotionality differences between a native and foreign language: Implications for everyday life. *Current Directions in Psychological Science*, *24*(3), 214–219. https://doi.org/10.1177/0963721414566268

Caldwell-Harris, C. L., & Ayçiçeği-Dinn, A. (2009). Emotion and lying in a non-native language. *International*

Journal of Psychophysiology, *71*(3), 193–204. https://doi.org/10.1016/j.ijpsycho.2008.09.006

Coderre, E. L., Van Heuven, W. J. B., & Conklin, K. (2013). The timing and magnitude of Stroop interference and facilitation in monolinguals and bilinguals. *Bilingualism: Language and Cognition*, *16*(2), 420–441. https://doi.org/10.1017/S1366728912000405

Colbeck, K. L., & Bowers, J. S. (2012). Blinded by taboo words in L1 but not L2. *Emotion*, *12*(2), 217–222. https://doi.org/10.1037/a0026387

Conrad, M., Recio, G., & Jacobs, A. M. (2011). The time course of emotion effects in first and second language processing: A cross cultural ERP study with German–Spanish bilinguals. *Frontiers in Psychology*. https://doi.org/10.3389/fpsyg.2011.00351

Cortese, M. J., & Schock, J. (2012). Imageability and age of acquisition effects in disyllabic word recognition. *The Quarterly Journal of Experimental Psychology*, *66*(5), 946–972. https://doi.org/10.1080/17470218.2012.722660

Costa, A., Foucart, A., Arnon, I., Aparici, M., & Apesteguia, J. (2014). "Piensa" twice: On the foreign language effect in decision making. *Cognition*, *130*(2), 236–254. https://doi.org/10.1016/j.cognition.2013.11.010

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

de Houwer, J., & Hermans, D. (1994). Differences in the affective processing of words and pictures. *Cognition & Emotion*, *8*(1), 1–20. https://doi.org/10.1080/02699939408408925

Dewaele, J.-M. (2004). The emotional force of swearwords and taboo words in the speech of multilinguals. *Journal of Multilingual and Multicultural Development*, *25*(2–3), 204–222. https://doi.org/10.1080/01434630408666529

Eilola, T. M., Havelka, J., & Sharma, D. (2007). Emotional activation in the first and second language. *Cognition & Emotion*, *21*(5), 1064–1076. https://doi.org/10.1080/02699930601054109

Fan, L., Xu, Q., Wang, X., Zhang, F., Yang, Y., & Liu, X. (2016). Neural correlates of task-irrelevant first and second language emotion words: Evidence from the emotional face-word Stroop task. *Frontiers in Psychology*, *7*, 1672. https://doi.org/10.3389/fpsyg.2016.01672

Frings, C., Englert, J., Wentura, D., & Bermeitinger, C. (2010). Decomposing the emotional Stroop effect. *Quarterly Journal of Experimental Psychology*, *63*(1), 42–49. https://doi.org/10.1080/17470210903156594

Gollan, T. H., Montoya, R. I., Cera, C., & Sandoval, T. C. (2008). More use almost always means a smaller frequency effect: Aging, bilingualism, and the weaker links hypothesis. *Journal of Memory and Language*, *58*(3), 787–814. https://doi.org/10.1016/j.jml.2007.07.001

Harris, C. L. (2004). Bilingual speakers in the lab: Psychophysiological measures of emotional reactivity. *Journal of Multilingual and Multicultural Development*, *25*(2–3), 223–247. https://doi.org/10.1080/01434630408666530

Harris, C. L., Ayçiçeği, A., & Gleason, J. B. (2003). Taboo words and reprimands elicit greater autonomic reactivity in a first language than in a second language. *Applied Psycholinguistics*, *24*(4), 561–579. https://doi.org/10.1017/S0142716403000286

Kahan, T. A., & Hely, C. D. (2008). The role of valence and frequency in the emotional Stroop task. *Psychonomic Bulletin & Review*, *15*(5), 956–960. https://doi.org/10.3758/PBR.15.5.956

Kahneman, D. (2011). *Thinking, fast and slow* (1st ed.). Farrar, Straus and Giroux.

Keysar, B., Hayakawa, S. L., & An, S. G. (2012). The foreign-language effect: Thinking in a foreign tongue reduces decision biases. *Psychological Science*, *23*(6), 661–668. https://doi.org/10.1177/0956797611432178

Kuchinke, L., Jacobs, A. M., Grubich, C., Võ, M. L.-H., Conrad, M., & Herrmann, M. (2005). Incidental effects of emotional valence in single word processing: An fMRI study. *NeuroImage*, *28*(4), 1022–1032. https://doi.org/10.1016/j.neuroimage.2005.06.050

Kuchinke, L., Võ, M. L.-H., Hofmann, M., & Jacobs, A. M. (2007). Pupillary responses during lexical decisions vary with word frequency but not emotional valence.

International Journal of Psychophysiology, *65*(2), 132–140. https://doi.org/10.1016/j.ijpsycho.2007.04.004

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

Mackay, D. G., Shafto, M., Taylor, J. K., Marian, D. E., Abrams, L., & Dyer, J. R. (2004). Relations between emotion, memory, and attention: Evidence from taboo Stroop, lexical decision, and immediate memory tasks. *Memory & Cognition*, *32*(3), 474–488. https://doi.org/10.3758/BF03195840

Maybin, J., & Swann, J. (Eds.). (2010). *The Routledge companion to English language studies*. Routledge. https://doi.org/10.4324/9780203878958

Méndez-Bértolo, C., Pozo, M. A., & Hinojosa, J. A. (2011). Word frequency modulates the processing of emotional words: Convergent behavioral and electrophysiological data. *Neuroscience Letters*, *494*(3), 250–254. https://doi.org/10.1016/j.neulet.2011.03.026

Mitchell, D. B. (2006). Nonconscious priming after 17 years: Invulnerable implicit memory? *Psychological Science*, *17*(11), 925–929. https://doi.org/10.1111/j.1467-9280.2006.01805.x

Nakic, M., Smith, B. W., Busis, S., Vythilingam, M., & Blair, R. J. R. (2006). The impact of affect and frequency on lexical decision: The role of the amygdala and inferior frontal cortex. *Neuroimage*, *31*(4), 1752–1761. https://doi.org/10.1016/j.neuroimage.2006.02.022

Parra, J. A., & Tamayo, R. M. (2021). Medidas implícitas en cognición: una aproximación al estudio de la automaticidad. *Revista Colombiana de Psicología*, *30*(1), 89–110. https://doi.org/10.15446/rcp.v30n1.85106

Pavlenko, A. (2012). Affective processing in bilingual speakers: Disembodied cognition? *International Journal of Psychology*, *47*(6), 405–428. https://doi.org/10.1080/00207594.2012.743665

Pavlenko, A. (2017). Do you wish to waive your rights? Affect and decision-making in multilingual speakers. *Current Opinion in Psychology*, *17*, 74–78. https://doi.org/10.1016/j.copsyc.2017.06.005

Recio, G., Conrad, M., Hansen, L. B., & Jacobs, A. M. (2014). On pleasure and thrill: The interplay between arousal and valence during visual word recognition. *Brain and Language*, *134*, 34–43. https://doi.org/10.1016/j.bandl.2014.03.009

Scott, G. G., O'Donnell, P. J., Leuthold, H., & Sereno, S. C. (2009). Early emotion word processing: Evidence from event-related potentials. *Biological Psychology*, *80*(1), 95–104. https://doi.org/10.1016/j.biopsycho.2008.03.010

Sheikh, N. A., & Titone, D. (2016). The embodiment of emotional words in a second language: An eye-movement study. *Cognition and Emotion*, *30*(3), 488–500. https://doi.org/10.1080/02699931.2015.1018144

Sianipar, A., Middelburg, R., & Dijkstra, T. (2015). When feelings arise with meanings: How emotion and meaning of a native language affect second language processing in adult learners. *PLoS ONE*, *10*(12), e0144576. https://doi.org/10.1371/journal.pone.0144576

Smith, P., & Waterman, M. (2003). Processing bias for aggression words in forensic and nonforensic samples. *Cognition & Emotion*, *17*(5), 681–701. https://doi.org/10.1080/02699930302281

Sutton, T. M., Altarriba, J., Gianico, J. L., & Basnight-Brown, D. M. (2007). The automatic access of emotion: Emotional Stroop effects in Spanish–English bilingual speakers. *Cognition & Emotion*, *21*(5), 1077–1090. https://doi.org/10.1080/02699930601054133

Tamayo, R., & Frensch, P. A. (2007). Interference produces different forgetting rates for implicit and explicit knowledge. *Experimental Psychology*, *54*(4), 304–310. https://doi.org/10.1027/1618-3169.54.4.304

Tamayo, R., & Frensch, P. A. (2015). Temporal stability of implicit sequence knowledge: Implications for single-system models of memory. *Experimental Psychology*, *62*(4), 240–253. https://doi.org/10.1027/1618-3169/a000293

Taylor, S. E. (1991). Asymmetrical effects of positive and negative events: The mobilization-minimization hypothesis. *Psychological Bulletin*, *110*(1), 67–85. https://doi.org/10.1037/0033-2909.110.1.67

Traxler, M. J. (2012). *Introduction to psycholinguistics: Understanding language science* (1st ed.). Wiley-Blackwell.

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin*, *120*(1), 3–24. https://doi.org/10.1037/0033-2909.120.1.3

Winskel, H. (2013). The emotional Stroop task and emotionality rating of negative and neutral words in late Thai–English bilinguals. *International Journal of Psychology*, *48*(6), 1090–1098. https://doi.org/10.1080/00207594.2013.793800

About the Authors

Diana Marcela Lizarazo Pereira is a Research Assistant at the Department of Psychology, University of Oslo. She holds an MA in Social and Cultural Psychology (2021) from the University of Oslo (Norway), the University of Limerick (Ireland), and ISCTE (Portugal). She obtained her BA in Psychology (2018) from Universidad Nacional de Colombia.

Felicia Roberts is a Professor of Communication in the Brian Lamb School of Communication at Purdue University (USA). She was Associate Head of the School from 2017–2022 and director of the Linguistics Program (School of Interdisciplinary Studies 2012–2016). She obtained her PhD in English Language and Linguistics (1996) from the University of Wisconsin, Madison.

Ricardo M. Tamayo is an Associate Professor at the Department of Psychology, Universidad Nacional de Colombia. He was a lecturer for Psychology at Jacobs University Bremen (Germany, 2010–2012) and a postdoctoral researcher at Akademie Schloss Solitude (Stuttgart, Germany, 2009–2010). He obtained his PhD in Psychology from Humboldt University of Berlin (Germany, 2008).

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Appendix: Details of Word Stimuli Used in the Emotional Stroop Task

	High frequency			Low frequency		
	Positive	Neutral	Negative	Positive	Neutral	Negative
	joy	odd	mad	lust	hawk	demon
	fun	book	gun	fame	muddy	rage
	car	tool	war	champ	truck	venom
	win	wine	rape	thrill	wamp	annoy
	sex	rock	hate	dazzle	rattle	tumor
	kiss	cold	fear	riches	limber	betray
	song	glass	panic	elated	clumsy	sinful
	happy	clock	angry	aroused	icebox	insult
	heart	hotel	fight	affection	coarse	hatred
	lucky	paint	pain	ecstasy	whistle	leprosy
	couple	shadow	danger	intimate	pamphlet	wicked
	pretty	avenue	horror	treasure	skeptical	hostile
	passion	market	guilty	sunlight	nonsense	intruder
	travel	gender	trouble	fireworks	repentant	slaughter
	memories	journal	tragedy	nude	trumpet	outrage
	romantic	teacher	victim	astonished	sheltered	disloyal
	birthday	fabric	accident	triumphant	nonchalant	assassin
	success	context	disaster	flirt	lighthouse	humiliate
	holiday	medicine	nervous	millionaire	trunk	cockroach
	beautiful	reserved	suspicious	intercourse	thermometer	unfaithful
Length	6	6	6	7	7	7
Frequency	62	66	50	8	7	8
Valence	8	5	2	8	5	3
Arousal	7	4	7	7	4	7

Note. Mean values. Length in the number of letters, frequency in occurrences per million, arousal rating range 1 (*low*) to 9 (*high*), valence rating range 1 (*negative*) to 9 (*positive*)