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Adolescents' Cognitive and Verbal Demands During Online Irony Comprehension: An Eye-tracking Reading Study

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Abstract

This study investigates how adolescents process written irony and how individual differences in vocabulary knowledge and mentalizing abilities relate to comprehension. While prior research has focused primarily on adults, less is known about how developing readers integrate linguistic and contextual information to derive non-literal meaning. One hundred eighteen Spanish-speaking adolescents (16–18 years) read short texts containing ironic or literal utterances while their eye movements were recorded. Comprehension accuracy and reading-time measures were analyzed using mixed-effects models. Ironic utterances elicited longer regression-path durations and total reading times than literal statements, indicating increased integration and reanalysis demands. Comprehension accuracy was lower for ironic texts and was positively associated with vocabulary knowledge, although this effect did not differ by condition. Mentalizing abilities did not significantly predict performance. These findings suggest that written irony comprehension in adolescence involves increased processing demands and is associated with general linguistic proficiency, while evidence for a contribution of mentalizing abilities in this task remains limited.

Keywords: irony comprehension; eye-tracking; adolescence; vocabulary; reading; figurative language

Introduction

Irony is a pervasive feature of everyday communication, yet its interpretation depends critically on the ability to integrate linguistic meaning with contextual information and communicative intent (Grice, 1975; Harris & Pexman, 2003; Giora, 2003). While extensive research has examined how adults process ironic language, comparatively little is known about how adolescents comprehend irony during reading. This gap is theoretically important because adolescence is a period of continued development in both linguistic and socio-cognitive abilities that are directly implicated in irony comprehension (Filippova & Astington, 2008; Blakemore, 2008; Dumontheil et al., 2010). Vocabulary knowledge expands substantially during this stage, supporting the integration of implicit meaning during reading (Larsen & Nippold, 2007; Currie & Cain, 2015; Guerra & Kronmüller, 2024), while mentalizing abilities continue to refine, particularly in contexts involving ambiguity and non-literal language use (Blakemore, 2008; Dumontheil et al., 2010). Understanding how these developing capacities contribute to irony comprehension can inform broader accounts of how readers construct meaning beyond the literal level (Kendeou et al., 2009; Gibbs, 2002; Pexman, 2008).

Despite its ubiquity, irony is not directly encoded in linguistic form but rather emerges from a mismatch between

what is said and what is meant. Consider the utterance in (1), produced by a teenager after receiving an undesirable gift:

(1) “Nice, that was exactly what I wanted.”

This statement can be interpreted either as a sincere expression of appreciation or as conveying the opposite attitude. In spoken interaction, such distinctions are often supported by prosodic and paralinguistic cues, including intonation, emphasis, and facial expressions (Cutler, 1976; Rockwell, 2000; Bryant & Fox Tree, 2005). However, these cues are not always reliable and may vary across speakers and contexts (Bryant & Fox Tree, 2005). Successful irony comprehension therefore requires recognizing that the speaker’s intended meaning diverges from the literal content of the utterance (Grice, 1975; Winner & Leekam, 1991; Sperber & Wilson, 1986/2002).

While such cues can facilitate irony detection in spoken language, the situation is markedly different in written discourse. Written texts lack prosody, facial expressions, and gestures—signals that often guide pragmatic interpretation in speech. As a result, readers must rely primarily on linguistic information and contextual cues to infer non-literal meaning. This raises a central question: how do readers recognize irony when only the written context is available?

In written contexts, irony is often conveyed through contrasts between an utterance and its surrounding context. For example, in *Wuthering Heights* (Brontë, 2008), an apparently positive evaluation (“What a beauty! What a lovely, charming thing!”) is immediately followed by imagery associated with disgust (“Haven’t they reared it on snails and sour milk?”), making a literal interpretation implausible. In such cases, the ironic meaning arises from a clear mismatch between evaluative language and contextual information. More generally, readers can identify irony when they detect an incongruity between what is said and what is supported by the context.

Detecting and resolving such incongruities requires readers to integrate lexical meaning with contextual information and pragmatic expectations (Giora, 2003; Kendeou et al., 2009). When the literal interpretation of an utterance conflicts with the surrounding context, readers must revise their initial interpretation and construct a meaning that is compatible with the speaker’s intended attitude (Grice, 1975; Searle, 1979; Gibbs, 2002). This process places demands on both linguistic and cognitive resources and unfolds dynamically during reading, making it well suited to investigation using online measures such as eye tracking (Rayner, 1998; Filik et al., 2014; Olkonien & Kaakinen, 2021).

In addition to linguistic integration, irony comprehension may also involve socio-cognitive processes related to inferring the speaker's communicative intentions. Previous work has suggested that understanding irony can engage mentalizing abilities, particularly in situations where the speaker's intended meaning diverges from the literal content of the utterance (Happé, 1993; Spotorno & Noveck, 2014). However, the extent to which such processes contribute to online comprehension during reading remains debated. While some evidence links irony processing to Theory of Mind abilities, it is possible that their contribution depends on task demands and the availability of contextual cues (Sperber & Wilson, 2002).

Theoretical Accounts of Irony Comprehension

From a theoretical standpoint, models of irony comprehension differ in their assumptions about the time course of interpretation and the mechanisms involved. Early pragmatic accounts, such as the Standard Pragmatic View, propose a serial process in which the literal meaning is computed first and subsequently rejected if it conflicts with contextual information, predicting increased processing costs at later stages of comprehension (Grice, 1975; Searle, 1979). In contrast, the Direct Access View argues that non-literal meanings can be accessed immediately when the context is sufficiently constraining, predicting reduced or absent processing costs under supportive contexts (Gibbs, 2002). The Graded Salience Hypothesis offers a different perspective, proposing that the most salient meaning—whether literal or non-literal—is activated first, with processing difficulty arising when a salient interpretation must be overridden by a less salient but contextually appropriate one (Giora, 1997, 2003). More recent constraint-based accounts further suggest that interpretation emerges from the simultaneous integration of linguistic, contextual, and reader-related cues, including individual differences in cognitive and linguistic abilities (Pexman, 2008). These accounts generate distinct predictions regarding the timing and locus of processing difficulty. Serial and salience-based accounts predict increased processing costs at later stages of comprehension, reflecting reanalysis and integration, whereas direct access accounts predict reduced or absent processing costs when contextual support is strong. Eye-movement measures allow these predictions to be tested by distinguishing early from later stages of processing.

However, less is known about how these processes operate in adolescent readers. Recent work on adolescent pragmatic development suggests that the aspects of the neural and cognitive mechanisms supporting non-literal interpretation continue to mature during this period. For example, neuroimaging studies have shown that pragmatic language processing in adolescence recruits developing brain networks associated with both linguistic and socio-cognitive functions (Asaridou et al., 2019; Forbes Schieche & Uddén, 2025). At the same time, behavioral research in adults consistently reports increased processing costs for irony, particularly in

later stages of comprehension as reflected in eye-movement measures (Filik et al., 2014; Olkonien & Kaakinen, 2021). However, it remains unclear whether similar processing patterns characterize adolescent readers, and how individual differences in linguistic and socio-cognitive abilities shape these processes during development.

Taken together, these accounts and findings raise two related but distinct questions about irony comprehension during reading. The first concerns whether ironic statements impose additional processing costs relative to literal ones, and at what stage of processing these costs emerge. The second concerns whether individual differences in linguistic and socio-cognitive abilities modulate comprehension and processing. At the linguistic level, vocabulary knowledge may be associated with more efficient integration of lexical meaning with contextual information, facilitating the detection and resolution of incongruities (Kendeou et al., 2009; Larsen & Nippold, 2007). At the socio-cognitive level, mentalizing abilities have been proposed to support the attribution of communicative intentions, although their contribution may depend on task demands and the availability of contextual cues (Happé, 1993; Sperber & Wilson, 2002). Examining these two dimensions jointly can provide a more complete account of the mechanisms underlying irony comprehension during adolescence.

The present study

The present study investigates how Spanish-speaking adolescents process ironic and literal statements during silent reading. Eye movements were recorded while participants read short texts in which the same target utterance was preceded by either an ironic or a literal context. To capture different stages of processing, we analyzed first-pass reading times, regression-path durations, and total reading times, along with comprehension accuracy for each item. In addition, participants completed independent measures of receptive vocabulary (TEVI-R) and mentalizing abilities (MMQ) to examine how individual differences relate to both online processing and offline comprehension.

This study addresses two questions. First, do ironic statements impose greater processing costs than literal ones during reading, and at what stage of processing do these costs emerge? Second, do individual differences in vocabulary knowledge and mentalizing abilities modulate comprehension and processing? Based on prior theoretical accounts, we hypothesized that ironic statements would elicit increased processing costs, particularly in later measures (e.g., regression-path duration and total reading time) reflecting reanalysis and integration. We further predicted that vocabulary knowledge would relate to higher accuracy and more efficient reading overall. Condition-specific vocabulary effects were examined exploratorily, given the added integration demands of irony. Mentalizing effects were

also treated as exploratory, given mixed prior evidence and the self-report nature of the MMQ.

Method

Participants A total of 118 Spanish-speaking adolescents (81 females; 16–18 years, $M = 16.93$, $SD = 0.88$) participated; 114 contributed usable eye-tracking data. Individual-difference data were available for TEVI-R ($N = 110$) and MMQ ($N = 110$), with 109 participants having complete data for both measures. All participants were high school students enrolled in the 3rd or 4th grade of secondary education. They reported normal or corrected-to-normal vision and no history of reading or neurological disorders. Written informed consent was obtained from parents or legal guardians, and written assent was provided by the adolescents. The study was approved by the Ethics Committee of the Faculty.

Materials and design We constructed 45 short texts, including 30 experimental items and 15 fillers. Each item had an ironic and a literal version, differing only in the context preceding an identical target utterance (Table 1). The target utterance was the region of interest because its interpretation depended on the preceding context. Each item was followed by a yes/no comprehension question (e.g., “Does Carlos think that Javier is funny?”) to test whether participants understood the text as ironic or literal.

Table 1: Example of experimental materials

	Region	Story content
Literal	Introduction	Javier and Carlos work in a circus. Tonight’s show sold out immediately.
	Critical Context	When Javier is on stage, the audience seems cheerful and laughs throughout the performance. When Javier finishes his act, he receives a standing ovation.
	Target Utterance	“What a clown you are!”
	Spillover Region Ending	shouts Carlos. Later, Carlos asks Javier if he would like to go to the movies.
Ironic	Introduction	Javier and Carlos work in a circus. Tonight’s show sold out immediately.
	Critical Context	When Javier is on stage, the audience seems bored, and even some people yawn. When Javier finishes his act, he receives only a couple of claps.
	Target Utterance	“What a clown you are!”
	Spillover Region Ending	shouts Carlos. Later, Carlos asks Javier if he would like to go to the movies.

Text length ranged from 41 to 65 words. The experiment employed a within-subjects repeated-measures Latin square design, ensuring each participant saw only one version of

each item in a pseudorandomized order. Individual differences were assessed with the TEVI-R, a receptive vocabulary task (Echeverría et al., 2002), and the MMQ, a self-report mentalizing questionnaire (Aldunate et al., 2024). Higher scores indicated greater vocabulary knowledge and self-reported mentalizing ability, respectively. Raw scores were centered and scaled for analysis. Descriptive statistics were: TEVI-R, $N = 110$, $M = 79.65$, $SD = 12.07$, range = 53–102; MMQ, $N = 110$, $M = 43.44$, $SD = 5.09$, range = 28–55.

Procedure Participants were tested individually in a laboratory setting. Eye movements were recorded using an EyeLink Portable Duo system at a sampling rate of 500 Hz. Participants were seated 60–70 cm from the monitor, and a 9-point calibration was performed. Participants were instructed to read at their own pace and press a key to proceed. A yes/no comprehension question followed each text. After the reading task, participants completed the vocabulary and mentalizing assessments in a counterbalanced order.

Data analysis Data were cleaned to remove track loss, short fixations (<80 ms), and reading-time outliers (>1.5 IQR). The target utterance was the region of interest, where first-pass reading time, regression-path duration, and total reading time were computed. Accuracy was analyzed with GLMMs and reading times with LMMs in R. Condition was sum-coded, and TEVI-R and MMQ scores were centered and scaled. Models included Condition, Vocabulary, Mentalizing, and their interactions with Condition, with random intercepts for participants and items. More complex random-effects structures were not retained due to convergence issues, so condition-related effects should be interpreted cautiously.

Results

Comprehension Accuracy Descriptive statistics indicated a ceiling effect for literal texts, whereas accuracy for ironic texts was considerably lower. Statistical models confirmed lower accuracy for ironic than literal items and a significant main effect of Vocabulary, indicating better overall performance among adolescents with higher lexical knowledge. The Condition × Vocabulary interaction was not significant, suggesting that this vocabulary effect did not differ reliably by condition. Mentalizing did not significantly predict accuracy or interact with Condition.

Table 2:

	β	se	z-value	p-value
(Intercept)	1.88	0.18	10.17	<.001
Condition	-2.49	0.18	-14.11	<.001
Vocabulary (TEVI)	0.35	0.16	2.16	0.03
Mentalizing (MMQ)	-0.08	0.16	-0.49	0.63
Condition × TEVI	0.18	0.16	1.13	0.26

Condition × MMQ	-0.10	0.16	-0.60	0.55
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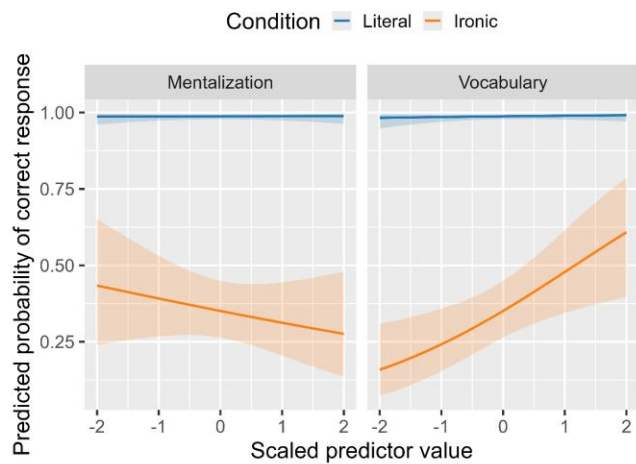


Figure 1. Predicted probability of correct response as a function of Mentalizing (left) and Vocabulary (right) by Condition. Shaded areas represent 95% confidence intervals.

Analysis of eye movements revealed distinct processing costs for irony (see Figure 2 and Table 3).

First-pass reading times showed no reliable effect of Condition, although higher vocabulary scores tended to predict shorter initial reading times.

Regression path durations, which reflect reanalysis, showed a reliable main effect of Condition, with ironic statements eliciting longer reading times than literal statements. Vocabulary showed a marginal tendency toward shorter regression-path durations overall. The Condition × Vocabulary interaction was significant, suggesting that vocabulary-related differences in processing varied by condition.

Total reading times showed a reliable main effect of Condition, with ironic statements requiring longer reading times than literal statements.

Table 3:

First-pass reading times	β	se	t	p
(Intercept)	633.29	29.51	21.46	<0.001
Condition	11.01	6.18	1.78	0.08
Vocabulary (TEVI)	-35.31	17.50	-2.02	0.05
Mentalizing (MMQ)	-5.10	17.81	-0.29	0.78
Condition × TEVI	9.21	6.23	1.48	0.14
Condition × MMQ	2.41	6.25	0.39	0.70
Regression path duration				
(Intercept)	817.18	38.04	21.48	<0.001
Condition	26.32	7.41	3.55	<0.001
Vocabulary (TEVI)	-37.73	19.38	-1.95	0.05
Mentalizing (MMQ)	8.20	19.03	0.43	0.67
Condition × TEVI	15.63	7.46	2.10	0.04
Condition × MMQ	1.10	7.46	0.15	0.88
Total reading times				
(Intercept)	1013.22	46.73	21.68	<0.001
Condition	24.48	8.87	2.76	0.01
Vocabulary (TEVI)	-28.66	26.74	-1.07	0.29
Mentalizing (MMQ)	-31.07	26.47	-1.17	0.24
Condition × TEVI	2.09	8.93	0.23	0.81
Condition × MMQ	0.61	8.92	0.07	0.95

Discussion

The present study examined written irony comprehension in adolescents, a developmental period characterized by ongoing refinement in both linguistic and socio-cognitive abilities (Blakemore, 2008; Dumontheil et al., 2010; Larsen & Nippold, 2007). Specifically, we asked whether written irony imposes additional processing costs during reading and whether individual differences in vocabulary and mentalizing abilities are associated with comprehension and online

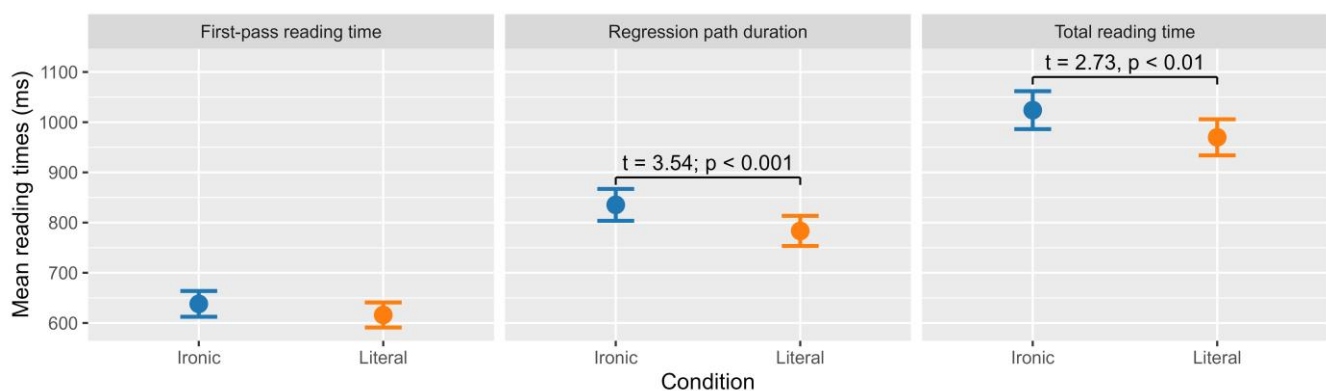


Figure 2. Mean reading times (ms) for First-pass, Regression path, and Total reading time by Condition (Irony vs. Literal). Error bars represent CI95% adjusted for within-subject designs.

processing. By combining eye-tracking with individual-difference measures, we tested whether irony-related costs emerge during early reading or later integration, a distinction central to debates contrasting serial, literal-first accounts (Grice, 1975; Searle, 1979) with more integrative approaches to irony comprehension (Gibbs, 2002; Pexman, 2008).

The results revealed distinct patterns in offline comprehension and online processing. Ironic texts elicited lower accuracy than literal texts, as well as longer regression-path durations and total reading times. This pattern suggests that the processing cost of irony emerged primarily during later stages of reading, consistent with increased integration and reanalysis demands rather than immediate difficulty during first-pass reading. Importantly, ironic texts elicited more comprehension errors than literal texts, while vocabulary knowledge predicted overall accuracy across conditions. This suggests a general association between vocabulary and coherent interpretation during reading, rather than a vocabulary advantage specific to irony. In contrast, mentalizing abilities did not significantly predict comprehension accuracy or processing times, nor did they interact with Condition.

Theoretical Implications of Processing Costs Ironic utterances elicited longer regression-path durations and total reading times than literal statements, indicating increased late-stage processing demands. This pattern is consistent with accounts that predict reanalysis when contextual information conflicts with an initial interpretation, including literal-first approaches (Grice, 1975; Searle, 1979) and the Graded Salience Hypothesis (Giora, 1997, 2003). The absence of robust first-pass effects suggests that difficulty emerged mainly during later integration rather than during initial reading, providing limited support for a strong direct-access account under the present task conditions (Gibbs, 2002). Longer regression-path durations may reflect sensitivity to contextual incongruity, such as the mismatch between “What a clown you are!” and the preceding boredom context, consistent with prior eye-tracking evidence of reanalysis during irony comprehension (Filik et al., 2014; Olkonienmi & Kaakinen, 2021).

The Role of Vocabulary and Mentalizing The individual-differences results suggest different patterns for vocabulary and mentalizing abilities in this task. In this written reading task, vocabulary knowledge was more clearly associated with comprehension and aspects of online processing than self-reported mentalizing abilities. Vocabulary knowledge was associated with better overall comprehension and showed some evidence of modulating regression-path durations, suggesting a role in lexical-contextual integration. However, the accuracy results do not support a vocabulary advantage specific to ironic texts. This is consistent with the idea that richer lexical knowledge may support readers’ sensitivity to mismatches between what is said and what is implied by the context (Guerra & Kronmüller, 2024; Kendeou et al., 2009; Larsen & Nippold, 2007).

Conversely, MMQ scores did not significantly predict comprehension or reading times. This suggests that, in the present written reading task, self-reported mentalizing abilities were not reliably associated with adolescents’ irony comprehension, despite prior evidence linking irony processing to mindreading abilities (Happé, 1993; Spotorno & Noveck, 2014). In a silent reading task without prosodic or facial cues (Bryant & Fox Tree, 2005), participants may have relied more strongly on lexical and contextual information to detect incongruity, which may have made self-reported mentalizing abilities less predictive of performance. These findings suggest that, in this task, detecting lexical-contextual incongruity may have been more closely associated with adolescents’ performance than individual variation in self-reported mentalizing abilities.

Limitations and Future Directions While these findings highlight the role of vocabulary in adolescent reading, there are limitations to consider. The study relied on written texts, which inherently lack the paralinguistic cues available in spoken interaction, potentially minimizing the role of socio-cognitive cues (Bryant & Fox Tree, 2005; Cutler, 1976; Rockwell, 2000). Moreover, because the MMQ is a self-report measure, it may capture adolescents’ perceived socio-cognitive tendencies rather than their online ability to infer others’ mental states during language comprehension. This is particularly relevant because previous studies linking irony comprehension to mindreading have used different approaches, including online processing measures and performance-based Theory of Mind tasks, rather than self-report questionnaires (Spotorno et al., 2013; Ronderos, Tomlinson, & Noveck, 2024). Thus, the absence of MMQ effects should be interpreted cautiously and should not be taken as evidence that mentalizing is irrelevant for irony comprehension. Future research could investigate whether the null result for mentalizing persists in multimodal contexts, where prosody and facial expressions are available, and whether similar patterns emerge with performance-based ToM tasks. Additionally, longitudinal designs could clarify whether vocabulary-related variability shifts as readers transition into adulthood. Finally, investigating different types of irony beyond sarcastic criticism could reveal whether the observed reliance on linguistic-contextual integration is specific to the “semantic clash” structure used in these materials (Lee & Katz, 1998).

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