Journal of Child Language (2025), 1–22
doi:10.1017/S0305000925000054

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

Learning Irony in School: Effects of Metapragmatic Training

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(Received 13 August 2024; revised 20 December 2024; accepted 15 January 2025)

Abstract

Irony comprehension requires going beyond literal meaning of words and is challenging for children. In this pre-registered study, we investigated how teaching metapragmatic knowledge in classrooms impacts written irony comprehension in 10-year-old Finnish-speaking children ($n = 41$, 21 girls) compared to a control group ($n = 34$, 13 girls). At pre-test, children read ironic and literal sentences embedded in stories while their eye movements were recorded. Next, the training group was taught about irony, and the control group was taught about reading comprehension. At post-test, the reading task and eye-tracking were repeated. Irony comprehension improved after metapragmatic training on irony, suggesting that metapragmatic knowledge serves an important role in irony development. However, the eye movement data suggested that training did not change the strategy children used to resolve the ironic meaning. The results highlight the potential of metapragmatic training and have implications for theories of irony comprehension.

Keywords: language development; irony; eye movements; training; reading

Ironian ymmärtäminen edellyttää kykyä päästä sanojen kirjaimellisen merkityksen taakse, mikä on haastavaa lapsille. Tässä esirekisteröidyssä tutkimuksessa selvitimme, miten metapragmaattisen tiedon opettaminen kokonaiselle koululuokalle kerralla vaikuttaa kirjoitetun ironian ymmärtämiseen 10-vuotiailla suomenkielisillä lapsilla ($n = 41$, 21 tyttöä) verrattuna kontrolliryhmään (n = 34, 13 tyttöä). Alkumittauksessa lapset lukivat ironisia ja kirjaimellisia virkkeitä, jotka oli sisällytetty lyhyisiin tarinoihin. Samalla heidän silmänliikkeensä rekisteröitiin. Tämän jälkeen koeryhmälle pidettiin ironiaa käsittelevä oppitunti ja kontrolliryhmälle luetun ymmärtämistä käsittelevä oppitunti. Jälkimittauksessa lukutehtävä ja silmänliikerekisteröinti toistettiin. Ironian ymmärtämisen tarkkuus parani koeryhmällä oppitunnin jälkeen, mikä viittaa siihen, että metapragmaattisella tiedolla on tärkeä rooli

ironian ymmärtämisen kehittymisessä. Silmänliiketulokset viittasivat siihen, että yksittäinen oppitunti ei muuta strategiaa, jolla lapset ratkaisevat ironian merkityksen. Saadut tulokset osoittavat metapragmaattisen tiedon opettamisen lupaavuuden harjoitusmenetelmänä, ja tuovat uusia näkökulmia ironian ymmärtämisen teorioihin.

1. Introduction

In the novel Harry Potter and the Order of the Phoenix, Harry is angry at Draco Malfoy (Rowling, 2003, p. 242). Harry's friend Hermione says: "Harry, don't go picking a row with Malfoy, don't forget, he's a prefect now, he could make life difficult for you…" He answers: "Wow, I wonder what it'd be like to have a difficult life?" Those familiar with Harry Potter know that his life is far from easy and that he does not really mean what he is saying, but quite the opposite. Harry's response exemplifies verbal irony where something opposite is intended than what is literally said (Attardo, 2000). It is typically used to criticize *someone* or *something* (the former is called sarcasm; e.g., Kreuz & Link, 2002). In a broader sense, irony can be divided into verbal irony and situational irony (see Attardo, 2000 for an overview of the definition). Situational irony is a state of the world that is perceived as ironic (e.g., a fire station is on fire). In this paper, we will only focus on verbal irony, as it is more important in terms of language learning and social function. Ironic language is used often in communication, and even children encounter it frequently, for example, in family conversations (Recchia et al., 2010), classrooms (Piirainen-Marsh, 2011), cartoons (Dews et al., 1996), and online communication (Aguert et al., 2016).

Irony comprehension requires going beyond the literal phrasal meaning to recognize the intention of the speaker. It is therefore not surprising that irony comprehension is challenging for children and the ability improves until early adulthood (Fuchs, 2023; Pexman, 2023). Moreover, it does not develop at the same pace among all children. Children's irony comprehension varies greatly, even in middle childhood when language and perspective-taking skills should be sufficient for comprehension (Olkoniemi et al., 2023; Zajączkowska & Abbot-Smith, 2020). Irony comprehension is not only matter of language skills, as speakers use irony because it serves important social functions. It is most often used to strengthen bonds between friends and peers (e.g., Dews et al., 1995), starting in the early school years (Aguert et al., 2016; Pexman et al., 2009). Deficits in irony comprehension are associated with the experience of being socially excluded (Kim & Lantolf, 2018). School-age peer relations bear great importance as they relate to children's development (Hartup, 1996) and engagement with school (Wentzel & Caldwell, 1997), among other things. Although irony most often serves positive social functions, irony can also be used to tease and even to bully (e.g., Rutherford & Rissel, 2004). It is, thus, important to find ways to improve children's irony comprehension so that they can detect the ironic speaker's intent, accurately comprehend what they read, and fully participate in everyday communication.

Here, we explored whether teaching irony in the classroom can improve 10-year-old children's irony comprehension skills. In what follows, we describe the development of irony comprehension and review factors affecting use and comprehension of irony. We then introduce previous irony training and eye-tracking studies on written irony comprehension.

https://doi.org/10.1017/S0305000925000054 Published online by Cambridge University Press

1.1. Children's irony comprehension

Irony comprehension typically begins to emerge by the age of 6 (Fuchs, 2023; Pexman, 2023), and the comprehension of simple ironic utterances may occur even earlier (e.g., Loukusa & Leinonen, 2008). By this age, children have developed sufficient language and social skills to understand something of the intended meaning of irony (Fuchs, 2023). At this early stage of development, comprehension accuracy is low and children often misinterpret irony as literal language or as a lie (Demorest et al., 1984; Loukusa & Leinonen, 2008).

Around age 7–8, children start to understand the ironic speaker's intent (Pexman, 2023) and comprehension accuracy typically exceeds chance level (Fuchs, 2023; c.f., Olkoniemi et al., 2023; Zajączkowska & Abbot-Smith, 2020). This developmental phase has been linked to the emergence of several socio-cognitive and socio-emotional skills, such as theory of mind (i.e., ability to impute one's own and other people's mental states, Premack & Woodruff, 1978; see Quesque et al., 2024 for terminology on mental state attributions) and empathy (i.e., ability to understand and feel the emotional states of others; Riess, 2017). This also ties in with Piaget's concrete operational stage during which children overcome egocentrism and develop the ability to understand other people's intentions (Piaget, 1972). Although the development of socio-cognitive and irony comprehension skills seem to go hand in hand, the nature of the relationship between theory of mind (especially the ability to consider what people think about other people's thoughts, i.e., second-order theory of mind, Perner & Wimmer, 1985) and irony comprehension is not completely clear (Fuchs, 2023; Pexman, 2023). In addition, several other cognitive skills have been linked to children's irony comprehension, such as cognitive flexibility, inhibitory control, and working memory (Fuchs, 2023; Pexman, 2023). Of these, working memory has been shown to modulate irony comprehension even in adulthood (e.g., Olkoniemi & Kaakinen, 2021).

Socio-emotional and cognitive abilities are not the only factors contributing to the development of irony comprehension. Exposure to ironic language also serves an important role in this development (Banasik-Jemielniak et al., 2020; Loukusa & Leinonen, 2008; Pexman et al., 2009; Recchia et al., 2010). For example, Pexman et al. (2009) showed that the use of irony by 3- to 15-year-old children did not correlate with their general cognitive ability or vocabulary, but with the use of irony by their parents and siblings. Moreover, Recchia et al. (2010) showed that in family conversations 4- to 6-year-old children tended to use similar kinds of figurative expressions to those their parents used most often. Consistent with these findings, Banasik-Jemielniak et al. (2020) found that eight-year-old children's irony comprehension was associated with their mothers' higher use of irony toward the child. These findings are not surprising as children's communicative knowledge, and world knowledge, in general, develops by learning from others (e.g., Carpendale & Lewis, 2004; Newcomp 2013), for example, in early learning by mimicking (Piaget, 1972; see also Newcomp, 2013, for review on theories of cognitive development). Thus, it is logical that metapragmatic knowledge of irony (i.e., explicit knowledge of irony and its use; e.g., Bernicot et al., 2007) can be learned in interaction with family members. Although family is important for learning irony comprehension, there is evidence that irony comprehension can also be taught outside the family context. Before reviewing previous training studies, we will first describe the factors that are important for the use and comprehension of irony and thus of relevance for learners.

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1.2. Factors influencing the use and comprehension of irony

Irony is context-dependent (e.g., Ackerman, 1983; Grice, 1975). In the example from Harry Potter, above, knowledge about Harry's life is important context, contrasting with the literal meaning of Hermione's comment. Detecting this contrast is necessary for interpreting Harry's comment as ironic, and contrast with context is the most important factor for irony comprehension (e.g., Ackerman, 1983). Most irony comprehension theories emphasize the role of context (Fabry, 2021; Gibbs, 1994; Grice, 1975; Pexman, 2008; Sperber & Wilson, 1981). For example, the classical *standard pragmatic view* (e.g., Grice, 1975) states that the inconsistency between the literal meaning and the context in which it occurs is essential to irony processing. According to this theory, irony is comprehended via three consecutive steps: First, the reader interprets the phrase literally. Second, the reader realises that the literal interpretation does not fit the context. Third, the reader looks for an alternative interpretation and understands that the phrase is ironic. Because understanding the intended meaning of an ironic phrase is seen as a serial process, it is expected to be slower and more difficult than that of a literal phrase. Later theories of irony comprehension make a similar assumption that ironic phrases are harder and slower to comprehend, but only under certain conditions. For example, when it is not highly familiar as irony (e.g., "Yeah, right!"; *the graded salience view*, Giora, 2003) and/or when the previous context gives no indications of it (*the direct access view*, Gibbs, 1994). Experimental findings support these theoretical assumptions (see Olkoniemi & Kaakinen, 2021, for a review of eye-tracking studies on irony). Thus, the previous research suggests that the contrast between the context and the phrase is crucial for understanding irony. Therefore, learning about the contrasting nature of irony is of great importance for the development of irony comprehension.

Several other factors are important for comprehending irony. The *echoic mention theory* (Sperber & Wilson, 1981) suggests that when an ironic phrase echoes a previous contextual statement, processing of it is facilitated. For example, if Lisa mentions that the weather will be perfect for camping tomorrow and the next day it is pouring rain, Kathy's message "What a perfect weather for camping!" echoes Lisa's comment and makes it easier to recognise as irony. While the theory states that the echo does not need to be direct like in the example, it has been suggested that only direct echo would facilitate comprehension because it reduces the need for inferencing (e.g., Jorgensen et al., 1984). Empirical evidence supports the facitative role of direct echo, but the evidence on the role of indirect echo is unclear (e.g., Keenan & Quigley, 1999; Kreuz & Glucksberg, 1989). Most relevant for this study, Keenan and Quigley (1999) showed that 6- to 10-year-old children were more likely to detect an ironic statement when it explicitly echoed a previous statement than when it did not. Thus, echoic mention could be useful for children in learning to understand irony.

Speakers use vocal cues to signal irony, which is referred to as an ironic tone of voice (e.g., Bryant, 2010). Studies suggest that there is no specific ironic tone of voice and that speakers use a variety of ways to signal irony (Bryant & Fox Tree, 2005), which may be culture-specific (Cheang & Pell, 2009). The use of an ironic tone of voice aids in irony comprehension (Fuchs, 2023; Keenan & Quigley, 1999), but some studies suggest that it plays only a small role (e.g., Ackerman, 1983). Studies have shown that children's ability to understand irony can be improved by the use of an ironic tone of voice (see Fuchs, 2023, for review), but this benefit is not observed in younger (< ~ 7-year-old) children (Ackerman, 1983; Fuchs, 2023, cf., Glenwright et al., 2014). Thus, learning to pay attention to tone of voice may help school-aged children to better understand irony.

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Irony is often used to express something negative while the literal meaning of the phrase is positive (Kreuz & Glucksberg, 1989). The *tinge hypothesis* suggests that activating positive literal meaning reduces the perceived negativity of ironic criticism (Dews & Winner, 1995), which has been shown in several studies (e.g., Dews & Winner, 1995; Thompson et al., 2016). Despite this reduction in perceived negativity, both positive (humorous) and negative (critical) emotions are present in irony, (e.g., Pfeifer & Pexman, 2023; Roberts & Kreuz, 1994). However, children struggle to recognize the humour in irony and tend to interpret ironic phrases as more critical and mean than adults do (see Pexman, 2023, for review). The humour function is also among the last developing aspects of irony comprehension (Dews et al., 1996; Pexman, 2023). As humour and laughter are important features of irony (Bryant, 2010; Gibbs et al., 2014), it is essential for children to learn about the humorous intent behind irony. This should help them to better understand a speaker's motivation for using irony.

1.3. Irony training studies

Development of irony comprehension is closely linked to the development of metapragmatic knowledge, which refers to conscious knowledge about social rules of language and the ability to apply them (e.g., Bernicot et al., 2007). In irony's case, this includes, for example, knowledge of what irony is, and how and why it is used. The importance of the development of metapragmatic knowledge in general is obviously not limited to the development of irony comprehension but has also been shown to be important, for example, in the development of understanding requests (Bernicot et al., 2007) and metaphors (Tonini et al., 2022).

As described earlier, children are exposed to ironic language in family conversations, and it is likely that the required metapragmatic knowledge would often come from these conversations (Banasik-Jemielniak, 2019; Banasik-Jemielniak et al., 2020; Pexman et al., 2009). Variability in children's irony comprehension accuracies, however, suggests that this is not the case for all. Moreover, Garfinkel et al. (2024) studied irony comprehension and metapragmatic awareness in eight-year-olds and showed that only 37% were able to give an explanation containing metapragmatic knowledge of irony. A few recent studies have explored how to overcome the lack of metapragmatic knowledge through training (Bouton, 1999; Kim & Lantolf, 2018, Persicke et al., 2013; Saban-Bezalel & Mashal, 2015). The majority have involved participants with a diagnosis of autism spectrum disorder (Persicke et al., 2013; Saban-Bezalel & Mashal, 2015) or second language speakers (Bouton, 1999; Kim & Lantolf, 2018). Most relevant for the current study, two studies explored the effect of irony training on typically developing children (Lee et al., 2021; Szücs & Babarczy, 2017).

First, Szücs and Babarczy (2017) investigated how three one-on-one training sessions teaching metapragmatic knowledge affected 4- to 7-year-old children's irony comprehension ($n = 20$) as compared to passive controls ($n = 19$). In the task, children listened to age-appropriate stories containing an ironic statement, for example, a father saying "What soft cookies!" after seeing burned cookies in the kitchen. After each story, children selected the correct interpretation for the target phrase from three alternatives (literal, deception, or irony). In the training, children were shown similar stories and were asked questions helping them to understand what is relevant for the interpretation. These questions concerned knowledge of the actual state of affairs, knowledge of the contrast between the literal phrasal meaning and the speaker's knowledge of the actual state of

https://doi.org/10.1017/S0305000925000054 Published online by Cambridge University Press

affairs, recognition of the inappropriateness of the deceptive interpretation, and consideration of ironic use of language. After training, all children were tested again on the same irony task that had been used prior to training. The training group children's accuracy in the irony task increased from 18% pre-test to 71% post-test, whereas the control group's accuracy was virtually unchanged (15% pre-test and 18% post-test). Szücs and Babarczy also measured children's language ability and theory of mind, but those measures did not correlate with irony comprehension. This finding suggests that the level of metapragmatic knowledge may be a more influential factor in explaining differences in irony comprehension among typically developed children than individual differences in language comprehension or theory of mind.

Second, Lee et al. (2021) investigated whether short (~15-minute) one-on-one training could improve 5- to 6-year-old children's ability to understand irony (n = 58) when compared to active controls (n = 53). In the training, children were given a definition of sarcasm (this term was used given the young age of the children, as in English the word sarcasm is acquired earlier than irony, Kuperman et al., 2012) and were shown a storybook containing illustrated stories in which ironic or literal comments were made. The experimenter read the stories aloud and explained cues and function of sarcasm: contrast between the phrase and the context, humour function of irony, and ironic tone of voice. After reading, children were given a summary of the taught content. For the controls, the experimenter read a non-ironic storybook. Prior to training, all children were shown five puppet shows of which three ended with an ironic statement. After each show, children were asked questions about the speaker's beliefs, intent, and humour. After the training, new puppet shows were presented to all children, the same set of questions was asked as in pre-test, and additionally irony detection accuracy was measured. Children who took part in the irony training and had low ability to interpret irony at pretest (<50% correct in questions concerning speaker's belief and intent) improved their accuracy in evaluating ironic speaker belief and intent and showed more accurate irony detection (N = 36; 68% accuracy) compared to the controls (N = 29; 51% accuracy). However, unlike the other measures, irony recognition accuracy was only measured at post-test, so we do not know to what extent it improved with training.

These studies show that one-on-one irony training is an effective way of improving children's irony comprehension. In the present study, we investigated the effect of irony training in a classroom setting. Moreover, we measured not only change in comprehension accuracy but also tested for change in processing irony by tracking children's eye movements while they read texts containing irony, before and after training.

1.4. Processing of written irony

Eye-tracking methodology allows detailed analysis of the time-course of reading without posing additional demands on the reader (Rayner, 2009). In recent years, it has been used to study how adults process irony (see Olkoniemi & Kaakinen, 2021, for review) and, very recently, in children (Olkoniemi et al., 2023). Adults' eye-tracking studies have shown that when the irony is unfamiliar or unsupported by context, it takes longer to process than its literal counterparts (e.g., Filik & Moxey, 2010). This slowdown has typically been seen in increased later rereading of (i.e., look-backs to) ironic phrases, as well as greater likelihood of rereading the context for ironic than for literal stories (Olkoniemi & Kaakinen, 2021). This rereading behavior is thought to reflect efforts to integrate the ironic meaning with the context, as predicted by theories of irony comprehension (e.g.,

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Grice, 1975). This interpretation is consistent with assumptions about the role of later rereading in reading comprehension, as it is thought to reflect conscious efforts to build a comprehensive representation of the text (e.g., Hyönä et al., 2002). However, processing of ironic statements is not static but changes over the course of an experimental session, which is referred to as the *trial effect* (Olkoniemi & Kaakinen, 2021) or *Early-Late effect* (Spotorno & Noveck, 2014). For example, Sportorno and Noveck (2014) presented adult participants short texts with ironic and literal statements. Participants read the texts sentence by sentence at their own pace. They spent more time reading ironic than literal statements, but this *irony effect* diminished towards the end of the experiment. A similar effect was also observed for the sentence following an ironic statement (i.e., spillover region). It seems that when readers repeatedly encounter irony, an expectation of forthcoming irony is created. This makes following ironic statements easier to process, and thus, more similar to that of literal statements.

Only one previous study investigated children's written irony comprehension and compared that to adults (Olkoniemi et al., 2023). That study found that comprehending written irony was more challenging for 10-year-old children than for adults, although for both groups it was more difficult than comprehending literal language. Processing of ironic stories was similar for children and adults in most respects. Both groups showed increased rereading of target phrase and critical context for irony (i.e., sentence that made the target phrase ironic) and showed trial effects. The main differences were that children's reading focused more on immediate (i.e., first-pass reading) and adults on later rereading (i.e., look-backs and look-froms). This is consistent with studies showing that when reading for comprehension, younger readers tend to spend more time on first-pass reading than adults (Kaakinen et al., 2015). Moreover, children did not show similar sensitivity to the correct comprehension of target phrase as adults, meaning that reading patterns were the same when the irony was comprehended and when it was not. Furthermore, children who were more accurate irony comprehenders showed faster reading times, whereas the opposite was true for adults (Olkoniemi et al., 2023). It seems that as adult reading is automatic and fluent, and literal language is generally expected, a prediction error caused by reading an ironic phrase interrupts this process and requires rereading. For children, however, the reading process is not as fluent and automatic as for adults, and predictions of text are not as accurate. This is reflected in slower reading in general and focusing more on the first-pass reading. In this process, better recognition of irony reduces the load on the interpretive process in general, which is reflected in faster reading times.

1.5. Aims of the study

In the present pre-registered study, we aimed to test, for the first time, whether teaching metapragmatic knowledge of irony in the classroom can improve 10-year-old children's comprehension of irony. To assess improvement, we used a pre-post test design and measured children's comprehension of stories containing ironic and literal target statements. Additionally, we used eye-tracking to explore how training affected the efficiency of children's processing of irony. In the metapragmatic knowledge training, we taught children about factors affecting irony comprehension: the definition of irony and sarcasm, the significance of contrast, the humor function, ironic tone of voice, use of echoic mention, and with whom people might use irony. The active control group received training on reading comprehension. We hypothesized that irony training would improve

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irony comprehension for the training group so that at post-test, they would show more accurate comprehension and faster processing of ironic meaning than the controls. Olkoniemi et al. (2023) found that more accurate irony comprehension in children was associated with faster first-pass reading time of the ironic target phrase and the spillover region. Therefore, the training group was expected to show improvement in these measures.

2. Method

2.1. Transparency and openness

Prior to data collection, the planned hypotheses, sample size, materials, and the analyses were pre-registered on the Open Science Framework (OSF) (https://osf.io/z3xyc). The materials used in training, data, and analysis scripts are available via OSF https://osf.io/48bem/

2.2. Participants

Altogether 82 fourth-grade children (40 females, M = 10;5 years, SD = 0;3, range 9;11–10;10) from four classrooms in two Finnish schools from North Ostrobothnia and Southwest Finland were recruited for the study. In both schools, the first class to be tested was selected as a control and the last as a training group (more details in 'Training and Control Lessons' section). This resulted in 35 children in the control group, and 45 children in the training group.

Eight participants (five controls and three training participants) were absent from school due to illness during the training/control lesson. Out of these, the control group participants were kept in the data as passive controls[1] to retain adequate statistical power. The absent training group participants were excluded from the data, as it is possible that their classmates had informed them about the content of the training lesson. Moreover, one training group participant was excluded due to poor eye-tracking data quality.

To ensure that the participants were within the typical range of abilities that might affect their irony comprehension (Fuchs, 2023; Pexman, 2023) and that the results would reflect normative development, we assessed their working memory (Digit Span subtest of WISC-IV, Wechsler, 2010), level of reading comprehension (Maze task, Ronimus et al., 2022), technical reading skill (Word Fluency subtest of Lukilasse II, Häyrinen et al., 2013), and empathy skill (Finnish translation of Index of Empathy for Children and Adolescents, Bryant, 1982; Olkoniemi et al., 2023). One control group participant had lower than expected span performance for the age group (i.e., < -2 SD), and their data were excluded from analyses. For participants included in the analyses, descriptive statistics for the background measures are presented in Table 1. In total, we had 34 participants in the control group and 41 in the training group, which was higher than the number of participants required ($\geq$ 30/group) to have adequate statistical power (power =.8, α = .05, see pre-registration for more details). Training and control group participants did not differ on the background measures, all ps > .05 (see Appendix S1 in the Supplementary materials for detailed results).

[1]The pattern of all the results reported remains the same when the training group is compared only to the active controls. Models with only the active controls are available via OSF https://osf.io/48bem/

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Table 1. Descriptive data of the participant groups

	Control group	Training group
n	34	41
Gender (F/M/Other)	14/20/0	22/19/0
Age (Years:Months)	10;4 (0;3)	10;5 (0;3)
Lukilasse	80.43 (15.05)	86.42 (10.58)
Maze	35.29 (7.94)	35.73 (10.22)
Digit Span	12.56 (1.79)	13.08 (2.57)
Empathy Index	14.51 (2.40)	13.16 (3.51)

Note. Values reported for Age, Lukilasse, Maze, Digitspan, Empathy Index are mean scores, and their respective *SD*s are reported in parentheses. Lukilasse = measure of technical reading skill, Maze = measure of reading comprehension, Digit Span = measure of working memory capacity, and Empathy Index = measure of empathy skill.

All children had no known reading difficulties, were Finnish native speakers, and had normal or corrected-to-normal vision. At the time of testing, they had received approximately three years and three months of formal reading instruction. Children's parents signed a written consent form, and verbal consent was obtained from each child. For their participation, children received candy or stickers. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee for Human Sciences at the University of Turku.

2.3. Apparatus

Eye movements were recorded using EyeLink Portable Duo and EyeLink 1000 Plus eye-trackers (SR Research Ltd. Ontario, Canada) using 500Hz sampling frequency. With Portable Duo, the stimuli were presented on a 17.3" Asus ROG G752V laptop screen, with participants seated 60 cm from the screen. With EyeLink 1000 Plus, the stimuli were presented on a 24" Asus VG248QE monitor, with participants seated 92 cm from the screen. Both monitors were set to a resolution of 1920 × 1080 pixels and a 120 Hz refresh rate. Participants' heads were stabilized using a chin-and-forehead rest.

2.4. Materials

Each participant was shown 44 experimental stories to read on a computer screen (font: Courier New, font size: 27, line height: 3). Twenty-six stories were from Olkoniemi et al. (2023), and 18 new stories were created for this experiment. New stories were pre-tested to ensure that they were equivalent to the original stories (see Appendix S2 in the Supplementary materials for more details). Each story had a literal and ironic version (44 stories × 2 story types, resulting in 88 experimental stories). There were 20–41 words (M_{Words} = 29.65, SD_{Words} = 4.28) in each story across 4–5 sentences (see Table 2 for an example). Each story started with one or two background sentences that were the same across the story versions. These were followed by a context sentence that made the following target phrase either ironic or literal (i.e., critical context). The target phrase was identical in both story versions and was followed by a spillover region (Rayner, 2009) describing who had said the phrase. Each story had a final neutral sentence that described

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Table 2. An example of an experimental story and inference and text memory questions translated from Finnish

Region	Version	Content
Beginning		Emma is going out and it's raining, and Emma's mother has told her to put on her rain gear.
Critical Context	Literal	She comes home in the evening dry, wearing her raincoat.
	Ironic	She comes home in the evening soaking wet and without the raincoat.
Target Phrase		"It's great that you wore your rain gear!"
Spillover Region		mother exclaims.
End		Emma goes directly to the sauna because it has just been heated.
Inference Question		Was mother disappointed by what Emma was wearing?
Text Memory Question		Was it raining when Emma went out?

how the events of the story ended. The spillover region and the final sentences were the same between the story versions. After reading of each story, participants were asked a text memory question to test their memory for the story content and an inference question to test their comprehension of the intended meaning of the target phrase (see Table 2 for examples). For both types of questions, the proportion of correct answers was computed.

Each participant read 22 experimental stories at both the pre-test and post-test. Participants were shown only one version of each story, and they did not read the same story twice. Presentation of the stories was counterbalanced, so that each story was shown equally often in the pre-test and post-test phases, and the presentation order of the stories was randomized within each testing phase. New and original stories were mixed so that equal proportions of new and original items were presented in pre- and post-test phases.

2.5. Training and control lessons

Both training and control lessons were designed to be in line with the Finnish National Core Curriculum for Basic Education and to be delivered to the whole classroom in a typical 45-minute school lesson, so that they could be easily implemented in the education system. The materials are consistent with several objectives in the core curriculum, for example, 'acting in interactive situations', 'interpreting texts', and 'understanding language, literature and culture' (Finnish National Board of Education, 2016).

Training lesson. In the lesson, the different aspects of irony were taught by showing children example stories containing irony, each presenting a new theme that was discussed with children. These themes were: (1) What irony is, (2) importance of contrast in irony, (3) humour function of irony, (4) difference between irony and sarcasm, (5) ironic tone of voice, (6) how people might use echoic mention while being ironic, and (7) with whom people might use irony. We wanted the children to actively participate in the lesson, and involvement was implemented through various tasks. First, each example story was discussed with children, and when discussing the use of ironic tone of voice, children practiced this in pairs. Second, in the middle of the lecture children filled out a questionnaire where they had to choose which of the six short stories presented were ironic (3/6 stories were ironic). After filling the questionnaire, each story was discussed

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with the group by asking whether this was ironic or not, and why did they think so. In the questionnaire, we also asked two binary (yes/no) questions: (1) Had you heard about irony prior to this lesson? (2) Have you learned something new during this lesson? Third, at the end of the lesson, children were to make up a short story in pairs, in which someone says something ironic. These stories were shared in the group, and each of the stories were discussed. Last, a Finnish translation of coloring book *Sydney Gets Sarcastic*, designed to help children understand sarcasm (Pexman & Bitterman, 2021), was given to all the pupils in the class, and they were encouraged to try to recognize the use of irony in their everyday lives.

Control lesson. The control group children were taught about: (1) eye movements and reading, (2) reading strategies to improve reading comprehension, and (3) the benefits of reading. These topics were chosen to serve reading learning purposes and to make the children in the control group feel that the topics were relevant to the experiment but clearly not related to irony so that they would not affect the results (similarly to Lee et al., 2021). Similarly to the training lesson, the subject was taught in an interactive manner. Examples of each theme were shown and discussed with the whole class. This included trying out how the hand starts to lose sharpness when it moves away from foveal vision, exploring in pairs how eye movements look when reading, and in the end of the lesson, discussing the benefits of reading and what each of them had read recently. As homework, children were asked to find and read any book that interests them.

2.6. Procedure

In each school, testing was performed one class at a time. The first class tested was assigned as the control group, and the second as the training group. Testing always started with the control group to avoid the information about the content of the training lesson spreading before the controls were tested. The experiment was blinded: the undergraduate students performing the testing were not told which class was assigned as control and which as the training group, and they did not test the class during the day a lesson was given. Children were told not to talk about the content of the lesson with the experimenter. All the lessons were given by the first author.

The study consisted of four phases. During the pre-test, participants were tested individually. Upon arrival, participants were informed that the experiment would assess reading. They were then introduced to the eye-tracking system and the experimental procedure. After the introduction, the eye tracker was set up and calibrated using a nine-point calibration. Participants were asked to read for comprehension. They read each story at their own pace and pressed spacebar on the keyboard when finished. Each story was shown on a single screen. After reading the story, text memory and inference questions were presented – one at a time – to which they responded by pressing designated "Yes" and "No" keyboard buttons. The next story was presented after both questions had been answered. Digit Span, Lukilasse, and Index of Empathy for Children and Adolescents were performed after the reading task. Each pre-test session lasted about 45 minutes, and all the children in the class were tested within two weeks.

After all the children in the class had participated in the pre-test, the first author gave the class either the control or the training lesson. Starting from the day after the lesson, the post-test was executed. The post-test was similar to the pre-test, except that only the reading task with eye-tracking was performed. The post-test session lasted for about 20 minutes. All the children in the class were tested in the post-test phase within 1–13 days

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after the lesson. The average delay from the lessons to post-test was three days for the controls (*SD* = 2.27, range: 1–6) and five days for the training group (*SD* = 2.86, range: 1–13). The average delay between pre- and post-test was 10 days for the controls (*SD* = 3.19, range: 3–16) and 14 days for the training group (*SD* = 5.77, range: 4–27).

Last, after the two school classes had completed the post-test, the Maze task was carried out by the children in their own class. Children were rewarded with candy or stickers for their participation and the specific nature of the experiment was explained to them. Control group participants were also given the Finnish version of the *Sydney Gets Sarcastic* coloring book that was part of the irony training. This final session took about 30 minutes.

3. Results

3.1. Analyses

Statistical analyses were performed with linear mixed-effects models (Baayen et al., 2008) using the *lme4* package (Bates et al., 2015) in the R statistical software (Version 4.1.2; R Core Team, 2021). Dependent variables with a high number of zero values (i.e., number of first-pass rereading fixations on the target phrase, probability to look-back to the target phrase, probability to initiate a look-from the target phrase, and probability to look-back to critical context) were analyzed using *glmmTMB* package (Version 1.1.7.; Brooks et al., 2017). More detailed descriptions of the eye movement measures, task performance, preprocessing of the data, and the analyses are reported in Appendix S3 in Supplementary materials. Separate models were built for each eye movement measure for the different text regions (i.e., target phrase, critical context, and spillover region) and for the accuracy of the inference and text memory questions. Descriptive statistics of the measures are reported in Table 3. For the eye movement analyses, we used a similar exclusion criterion for comprehension accuracy as Olkoniemi et al. (2023), namely, that participants should have correctly comprehended more than one ironic item (i.e., > 10% correct; see preregistration). Three participants (1 from the control and 2 from the training group) had irony comprehension accuracy *below acceptable levels.* Their data were excluded from the analyses, leaving a total of 72 participants (32 control group and 40 training group participants).[2] Moreover, only correctly comprehended items were included when analyzing reading.

In mixed-effects models, there is a problem in determining *p*-values because it is difficult to define exact degrees of freedom for the *t*- and *z*-statistics (Baayen et al., 2008). Consequently, we do not report *p*-values; statistical significance at the .05 level is indicated by values of $|t|$ and $|z| > 1.96$. For the sake of brevity, only significant effects are reported in the text and model estimates for interactions are illustrated in figures. All the model summaries are reported in Appendix S3 Tables S3 – S10 in the Supplementary materials.

3.2. Inference and text memory questions

Children's accuracy in the pre- and post-test on text memory questions was near ceiling, suggesting that they were attentive to the task. As children showed a ceiling effect, the planned model for text memory questions was not analyzed to avoid overfitting. The t-test

[2]After removal, we reanalyzed differences in control measures between the control and training groups. There were no significant differences between the groups in any of the measures (all ps > .050).

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Table 3. Descriptive statistics of the reading and comprehension measures for both story types and groups

		Control Group				Training Group			
		Literal		Ironic		Literal		Ironic	
Region	Measure	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Questions	Memory accuracy	.93 (.26)	.93 (.26)	.94 (.23)	.93 (.25)	.93 (.26)	.92 (.27)	.94 (.24)	.94 (.23)
	Inference accuracy	.93 (.25)	.91 (.29)	.43 (.50)	.48 (.50)	.90 (.29)	.90 (.30)	.45 (.50)	.66 (.47)
Target Phrase	First-pass reading time	1830 (1182)	1732 (1116)	1933 (1125)	1822 (1140)	1683 (925)	1624 (977)	1726 (943)	1593 (965)
	Forward-fixation time	1401 (648)	1328 (634)	1460 (678)	1375 (623)	1337 (605)	1268 (634)	1314 (554)	1238 (617)
	Number of first-pass rereading fixations	2.70 (2.82)	2.75 (2.90)	3.05 (3.31)	2.81 (2.72)	2.47 (2.00)	2.60 (2.42)	2.72 (2.64)	2.70 (2.57)
	Probability to first-pass reread	.66 (.47)	.60 (.49)	.67 (.47)	.65 (.48)	.61 (.49)	.59 (.49)	.68 (.47)	.58 (.49)
	Probability to look-back	.18 (.39)	.14 (.35)	.23 (.42)	.15 (.36)	.17 (.38)	.20 (0.40)	.24 (.43)	.16 (.37)
	Probability to look-from	.13 (.34)	.11 (.32)	.19 (.40)	.11 (.31)	.12 (.32)	.13 (.34)	.16 (.37)	.16 (.32)
Spillover Region	First-pass reading time	994 (686)	941 (675)	1038 (689)	930 (611)	979 (661)	865 (559)	937 (550)	851 (573)
Critical Context	Probability to look-back	.22 (.41)	.16 (.37)	.21 (.41)	.15 (.36)	.21 (.41)	.22 (.41)	.23 (.42)	.16 (.37)

verified that the control and training groups did not significantly differ on text memory question accuracy, $t(73) = 0.25$, $p = .807$, $d = 0.06$.

The model for *inference question accuracy* showed two main effects (see Table S3). First, there was an effect of the Story Type, indicating that the intended meaning of ironic phrases was harder to comprehend than that of literal phrases, $\beta = -3.18$, *95% CI* [−3.56, −2.80], $z = -16.40$. Second, there was an effect of Time, indicating that the inference question accuracy was overall higher at the post-test than at pre-test, $\beta = 0.26$, *95% CI* [0.16, 0.36], $z = -5.04$. These main effects were qualified by a three-way interaction between Story Type, Group, and Time, $\beta = 0.92$, *95% CI* [0.52, 1.33], $z = 4.45$ (see Figure 1a). This interaction indicates that the training group showed higher inference question accuracy for ironic items at post-test, but the groups did not differ at pre-test. Additionally, the groups did not differ at either timepoint for literal items. The interaction is supported by the observed values presented in Figure 1b and the questionnaire responses of the training group at the lesson. Questionnaire results showed that only 49% of the training group participants (*SD* = 50%) reported having heard about irony

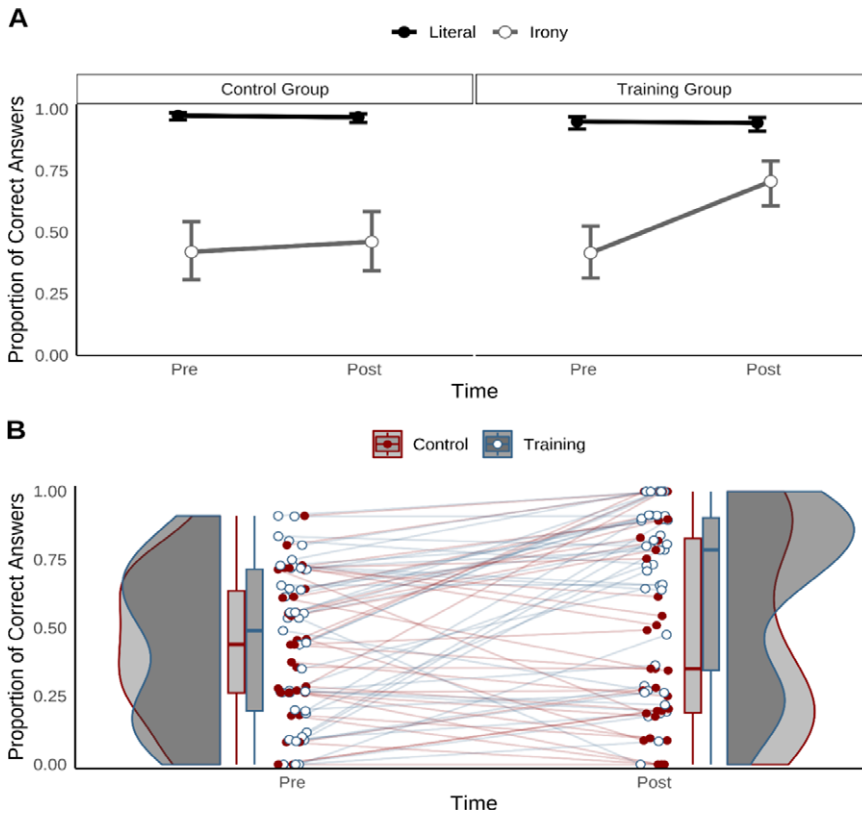

Figure 1. Inference question accuracy in pre- and post-test phase.
Note. Panel A: Model estimates for the inference question accuracy. Model values are back-transformed from log-values. Error bars represent 95% confidence intervals. Panel B: Observed inference question accuracies for ironic items in pre- and post-test phase. Lines in the middle represent the direction of change for each participant between the groups.

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prior to the training, and 86% (*SD* = 35%) reported learning something new during the lesson. On average, they correctly detected 2.83 out of 3 (89%) ironic stories (*SD* = 0.37) and gave false positives (i.e., misidentified literal stories as ironic) only 0.33 out of 3 (11%) literal stories (*SD* = 0.64).

3.3. Reading of the Ironic and Literal Stories

The model for *first-pass reading time on the target phrase* revealed two main effects (see Table S4). First, there was an effect of the Story Type, indicating that children showed higher first-pass reading times for ironic than for literal target phrases, $\beta = 0.04$, 95% CI [0.002, 0.07], $t = 2.08$. Second, there was an effect of Time, indicating that children read target phrases faster in the post-test phase than in the pre-test phase, $\beta = -0.08$, 95% CI [−0.11, −0.05], $t = -5.62$. The model did not show an effect of Group or any interactions.

The model for *forward-fixation time on the target phrase* revealed a main effect of Time (see Table S5). Children, in both the control group and the training group, showed faster forward-fixation time in the post- than in pre-test phase, $\beta = -0.07$, 95% CI [−0.09, −0.05], $t = -6.31$. The model showed no effect of Story Type, Group, nor any interactions.

The model for the *number of first-pass rereading fixations on the target phrase* showed a main effect of Time (see Table S6). This effect indicates that children made less first-pass rereading in the post-test than in pre-test phase, $\beta = -0.14$, *95% CI* [–0.21, −0.07], $z = -3.90$. This effect was qualified by an interaction between Story Type and Time, $\beta = -0.17$, *95% CI* [–0.31, −0.03], $z = -2.36$ (see Figure 2a). The interaction indicates that children did more first-pass rereading for ironic than literal target phrases at pre-test but showed no difference at post-test. The model did not show any effect of Group.

The model for *probability of look-back fixations to target phrase* revealed a main effect of Time (see Table S7). Children showed lower probability to look-back to the target phrase in the post- than pre-test phase, $\beta = -0.48$, *95% CI* [−0.73, −0.24], $z = -3.85$. Additionally, the model revealed an interaction between Story Type and Time, $\beta = -0.94$, *95% CI* [−1.43, −0.44], $z = -3.73$ (see Figure 2b). This interaction indicates that children showed a higher probability to initiate a look-back to ironic than the literal target phrase in the pre-test phase but showed no difference between story types in the post-test phase. The model did not show any effect of Group.

The model on *probability to initiate a look-from fixation from the target phrase* revealed a main effect of Time (see Table S8). This effect indicates that children showed a lower probability to initiate look-from fixation from the target phrase in the post- than pre-test phase, $\beta = -0.31$, *95% CI* [−0.59, −0.04], $z = -2.23$. The model showed no effect of Story Type, Group, or any interaction.

The model on *first-pass reading time on the spillover region* revealed a main effect of Time (see Table S9), indicating that children showed faster reading times in the post- than pre-test phase, $\beta = -0.12$, *95% CI* [−0.16, −0.09], $z = -7.01$. The model did not show any effects of Story Type, Group, or any interactions. Finally, the *model on probability to look-back to critical context* showed a main effect of Time (see Table S10), indicating that children showed lower probability to look back to critical context in the post- than pre-test phase, $\beta = -0.62$, *95% CI* [−0.48, −0.80], $z = -3.74$. The model showed no effects of Story Type, Group, or any interactions.

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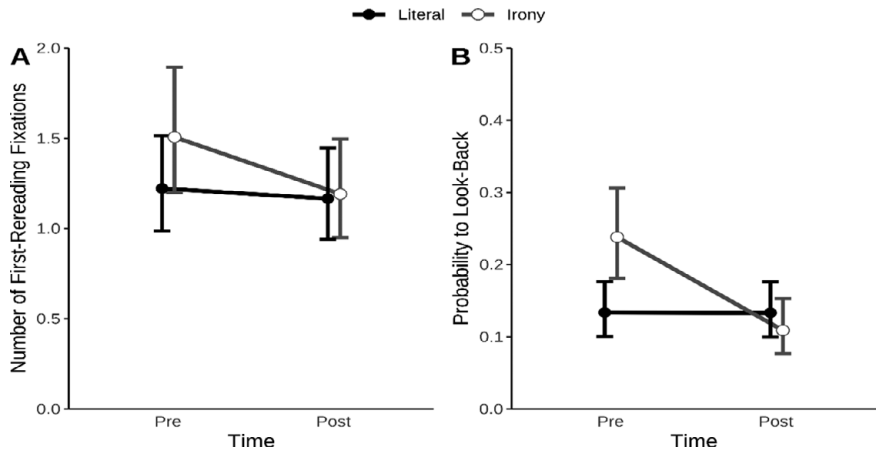

Figure 2. Interactions on reading measures between Story Type and Time.
Note. Panel A: Model estimates for the number of first-pass rereading fixations on the target phrase. Panel B: Model estimates for the probability to look-back to the target phrase. Model values are back-transformed from log-values. Error bars represent 95% confidence intervals.

4. Discussion

We investigated whether 10-year-old children's irony comprehension skills can be improved by teaching irony in the classroom. We hypothesized that at post-test, the irony training group would surpass the controls by showing better learning, in terms of more accurate comprehension and faster processing of ironic meaning. Moreover, we assumed that children's better irony comprehension accuracy would be associated with faster first-pass reading time of the ironic target phrase and the spillover region.

4.1. Effect of training on comprehending irony

The results showed that, as hypothesized, teaching irony in the classroom effectively improved children's irony comprehension. This is consistent with the previous training studies (Lee et al., 2021; Szücs & Babarczy, 2017) but extends the training effect to a group learning context. The results suggest that irony-specific metapragmatic knowledge is crucial for the development of irony comprehension. This is also consistent with studies showing that irony use in families is associated with children learning irony earlier (e.g., Pexman et al., 2009; Recchia et al., 2010) and having better irony comprehension (Banasik-Jemielniak et al., 2020), suggesting that some children learn the needed metapragmatic knowledge at home. When this knowledge is not yet learned, teaching it in school seems to be an effective way to fill the knowledge gap.

The improvement we observed in irony comprehension accuracy was consistent with the measured improvement in children's awareness of their knowledge of irony: slightly under half of the training group children reported that they had heard about irony before, and the majority (86%) reported that they learned something new during training. The initial level of knowledge of irony is in line with a previous study, which showed that only 37% of eight-year-olds were able to give a metapragmatic explanation of irony

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(Garfinkel et al., 2024). Although the majority of the training group exhibited improved irony comprehension, there were a few training group children whose comprehension accuracy dropped after the lecture. One possible reason could be that despite our best efforts, not all the pupils remained motivated throughout the course of the whole experiment. Their decreased performance at post-test could reflect boredom and inattention.

There was no indication that metapragmatic or control group training affected childrens' reading comprehension in general. Both the control and training groups showed a ceiling effect on the text memory and comprehension questions for literal items in the pre- and post-test phases. Furthermore, the reading comprehension task administered after the post-test showed that reading comprehension scores were almost the same between the groups. Thus, the only training-related change was the improvement in irony comprehension in the experimental group. The fact that there were no other changes between pre- and post-test is not surprising as, firstly, the reading performance of 10-year-olds is already similar to that of adults for the reading of literal texts, although children are slower in general (see Blythe & Joseph, 2011, for a review). Secondly, Finnish children develop their decoding skills relatively early (Seymour et al., 2003) and their literacy skills are high compared to children in many other linguistic communities (e.g., Schroeder et al., 2022).

In the previous training studies (Lee et al., 2021; Szücs & Babarczy, 2017), children's learning was assessed immediately after training. Our study differs from that practice as the children were not tested within the same training session, but within a two-week-period after the training. The fact that training effects were observable after this delay indicates that training effects persist beyond the initial training day. Our results suggest that teaching metapragmatic knowledge of irony in early elementary school would be a feasible way of improving children's irony comprehension and that the effect of this training would likely not wear off immediately. However, the present results leave open how well the training effect withstands longer periods of time, a topic that should be addressed in future studies. While the irony training lesson was designed to be in line with the Finnish National Core Curriculum (Finnish National Board of Education, 2016), it should be feasible to implement in other countries' educational systems as well.

Pre-test irony comprehension accuracy for both training and control groups was similar to that reported by Olkoniemi et al. (2023) who also used written irony as materials but lower than in several previous studies using non-written materials (Fuchs, 2023). The present results confirm the assumption made by Olkoniemi et al. that lower accuracies for written irony are observed because it sets higher demand for the interpreter. In the absence of facial and tone of voice cues, the written form might require more knowledge of what irony is to be able to interpret it reliably.

4.2. Effect of training on processing irony

In their reading times, children showed higher rates of first-pass rereading fixations on ironic target phrases at pre-test, but no difference at post-test. Although this is partly consistent with our hypothesis, this effect was observed for both the control and the training group. As both groups showed improvement, it seems likely that this reflects a trial or test-retest effect. These results are similar to the trial effect observed in previous eye-tracking studies, which would also explain why the effect was observed not only in early (i.e., first-pass rereading) but also in late measures (i.e., probability to look-back)

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(see Olkoniemi & Kaakinen, 2021, for a review). In other words, when the reader repeatedly encounters ironic phrases, there will be an expectation of forthcoming irony and readers adjust to the experimental context. This makes the processing of ironic phrases easier and, consequently, more similar to that of literal phrases. It seems that even an untrained reader makes adjustments over time for ironic expressions.

Contrary to our hypothesis, we did not observe improvement in irony processing in the training group. Although this was unexpected, this is consistent with studies on adults showing that online (i.e., reading times) and offline (i.e., comprehension questions) measures are not always directly linked (see Rapp & Mensik, 2011, for review). There are at least two possible reasons for this null effect. First, children who just learned about irony may take longer to process its intended meaning than those who were already familiar with it. This might level out the expected improvement in reading times, hiding the learning effect and leaving the more general trial effect observed. Second, it is possible that variability in children's eye movements rendered the measures too noisy to detect the improvement in reading times. As suggested by Olkoniemi et al. (2023), it is possible that as 10-year-olds still need to invest more resources to reading in general, therefore some effects may not be as evident as they are for adults for whom reading is already automatized. Future studies are needed to further investigate children's irony processing and to adjudicate between these possibilities.

Our reliance on eye-tracking to analyze written materials limits the inferences that can be drawn. It is unclear whether teaching the recognition of ironic tone of voice would have increased efficiency in recognizing irony from speech. This is also a general issue with the studies conducted thus far – we do not know which parts of training are necessary for improving comprehension accuracy and facilitating processing. Future studies should explore the active ingredient(s) in irony training.

5. Conclusions

The present study showed that teaching metapragmatic knowledge of irony to a whole classroom in one lesson can improve children's irony comprehension. Most of the previous studies of irony development have focused on how the emergence of cognitive and socio-emotional abilities, such as theory of mind, are associated with irony comprehension. Our intervention study shows that metapragmatic knowledge also plays a crucial role in development of irony comprehension, and it can be effectively taught in school.

This study was not designed to differentiate between theories of irony comprehension, and those theories do not explicitly take into account developmental changes. However, theories that consider individual differences, such as *the parallel constraint-satisfaction framework* (Pexman, 2008) and *the predictive processing account of irony* (Fabry, 2021), can best explain our results. When irony comprehension ability is still developing, there will be variability in how it is processed and understood. The present findings suggest that a useful addition to any theoretical model would be a detailed learning component that enables the derivation of testable hypotheses on the acquisition of irony. Future studies should refine and test these theories to determine which social and cognitive skills and aspects of metapragmatic knowledge are most related to children's irony processing. While training studies have not been the norm in the irony literature, we believe that they can significantly advance the field by testing which aspects of social-cognitive development are most related to children's irony comprehension at different stages of development.

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Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/S0305000925000054.

Acknowledgments. This study was supported by Research Council of Finland grant #338712 awarded to Henri Olkoniemi. We thank Dr. Seppo Vainio for his help in creating the stories, Dr. Minna Sääskilahti and primary teacher education students for the valuable feedback for improving the lessons and materials, and Mr. Atte Räinä for his help in the data collection.

Competing interest. The author(s) declare none

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Cite this article: Olkoniemi, H., Häikiö, T., Merinen, M., Manninen, J., Laine, M., & Pexman, P.M. (2025). Learning Irony in School: Effects of Metapragmatic Training. *Journal of Child Language* 1–22, https://doi.org/10.1017/S0305000925000054