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Sources of variation in preschoolers' relational reasoning: The interaction between language use and working memory

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A B S T R A C T

Previous research has suggested the importance of relational language and working memory in children's relational reasoning. The tendency to use language (e.g., using more relational than object-focused language, prioritizing focal objects over background in linguistic descriptions) could reflect children's biases toward the relational versus object-based solutions in a relational match-to-sample (RMTS) task. In the lack of any apparent object match as a foil option, object-focused children might rely on other cognitive mechanisms (i.e., working memory) to choose a relational match in the RMTS task. The current study examined the interactive roles of language- and working memory-related sources of variation in Turkish-learning preschoolers' relational reasoning. We collected data from 4- and 5-year-olds (*N* = 41) via Zoom in the RMTS task, a scene description task, and a backward word span task. Generalized binomial mixed effects models revealed that children who used more relational language and background-focused scene descriptions performed worse in the relational reasoning task. Furthermore, children with less frequent relational language use and focal object descriptions of the scenes benefited more from working memory to succeed in the relational reasoning task. These results suggest additional working memory demands for object-focused children to choose relational matches in the RMTS

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task, highlighting the importance of examining the interactive effects of different cognitive mechanisms on relational reasoning.

Introduction

Relational reasoning is the ability to reason based on the similarity of the relations between objects instead of the similarity in objects' properties. For example, a boat *under* a bridge should be judged to be relationally similar to a cat *under* a table because of the relative position of the boat and the cat, despite the perceptual dissimilarities between the boat and the cat as well as between the bridge and the table. Although relational reasoning is an essential predictor of several domains such as spatial skills (e.g., Turan et al., 2021) and mathematical skills (e.g., Starr et al., 2023), preschool children mainly focus on objects in relational reasoning tasks, displaying a limited understanding of relational rules (e.g., Hochmann et al., 2017). The development of working memory and language can help children overcome their challenges in relational reasoning tasks (Christie, 2021; Gentner, 2016; Richland et al., 2006). However, what aspects of working memory and language are associated with relational reasoning has not been specified yet. Furthermore, these factors (i.e., working memory and language) have been predominantly examined in isolation, and the joint contributions of them are unknown. This study fills these gaps by investigating the interplay between children's language use and working memory in explaining their relational reasoning abilities.

The development of relational reasoning

The essential component of relational reasoning is the ability to represent links between objects, which is observed starting from infancy (Anderson et al., 2018; Hochmann et al., 2016). For example, 3-month-olds looked longer at a pair of different objects (e.g., XY) after being habituated to the different pairs of the same objects (e.g., AA, BB), suggesting the ability to detect relations (Anderson et al., 2018). Early in development, children could use relational representations in decision-making, such that 18- to 30-month-old children could detect that a machine works if a pair of identical (or different) objects was placed on it (Walker et al., 2016). Contrary to the performance level of 18- to 30-month-olds, 30- to 48-month-old children failed to understand this rule and could not make the machine work (Walker et al., 2016). In the preschool age group, the relational match-to-sample (RMTS) task is widely used to measure relational reasoning (Premack, 1983). In this task, children are presented with a card depicting a pair of identical (or different) objects from which they are expected to infer relations. They are asked to match the card depicting the *sameness* relation with the presented card regardless of the objects displayed in the choice cards. Children aged 2 to 4 years failed to match the cards based on relations even when the objects were less salient (i.e., basic geometric shapes such as *square* and *circle;* Christie & Gentner, 2014). This failure in the RMTS task extended to 5-year-olds, using complex stimuli composed of abstract shapes that children are unfamiliar with (Carvalho et al., 2018; Hochmann et al., 2017). After 6 years of age, children could reliably show relational reasoning in various versions of the RMTS task (Hochmann et al., 2017; Serraille and Hochmann, 2023). Thus, children seem to have difficulty in relational reasoning during the preschool period.

The developmental trajectory of relational reasoning gives rise to a major question: What is happening during preschool ages when we observe a decrease in the ability to use relational representations in reasoning? The *relational shift hypothesis* asserts that preschoolers mainly focus on objects and have a strong tendency to compare physical features of objects with each other (Gentner, 1988). This way, they reliably learn how to compare objects and transfer this developed skill to understand the similarity between relations (Christie, 2021). Furthermore, the developmental change in children's executive functions during preschool years may help children inhibit their prepotent object focus and allow them to represent multiple objects and relations simultaneously (Richland et al., 2006). Although these two accounts differ in their mechanism for change (i.e., shift in comparison domain vs. development of domain-general skills), they converge on the initial cause of failure in relational reasoning due to the prepotent object focus. Moreover, object focus could differ across contexts and children (Carstensen & Frank, 2021). These contextual and individual differences in object versus relational focus could influence how salient objects are represented in children's minds, which in turn determines how children perform in a relational reasoning task (Carstensen & Frank, 2021). Thus, examining the differences in children's attention toward objects or relations could help us understand the sources of variation in relational reasoning.

Individual differences in relational reasoning and language use

Recent studies revealed that object focus may be variable across individuals, which in turn relates to children's relational reasoning skills (Guarino et al., 2021). Guarino and colleagues (2021) examined the role of object focus with a scene analogy task. In this task, children were presented with some scenes (e.g., a dog is chasing a cat) and were asked to find the relational equivalent of an agent (e.g., the dog–the chaser) in another scene presenting the same relation with different agents (e.g., a girl chasing a boy) and an object match (e.g., a dog apart from the chasing relation) (Richland et al., 2006). They found that children who looked longer at the object match (i.e., the dog) performed worse in finding the relational equivalent of the source agent (i.e., the chaser). In addition, children who looked longer at the relations performed better in relational reasoning tasks where children were asked to complete the missing part of the pair (food: banana–eater: ?) based on a complete pair (food: nut–eater: elephant) (Starr et al., 2018). Consequently, children vary in their attention to objects and relations. Furthermore, while solving the RMTS task, children who spontaneously labeled the color or shape of the objects showed a decrease in their performance (Esmer et al., 2023). Thus, object focus seems to vary across children during preschool years, which is also related to children's relational reasoning performance.

Beyond the individual level, object focus might differ across different linguistic or cultural groups, such that preschoolers from East Asia and the United States behave differently in relational reasoning tasks (Christie et al., 2020). In a modified version of the RMTS task, Chinese preschoolers understood that a machine works when a pair of two identical (or different) objects were placed on it even in the presence of an object match, whereas their counterparts in the United States mainly chose object matches to make the machine work (Carstensen et al., 2019). Chinese children also performed better than their peers in the United States when multiple relations were presented to them in relational reasoning tasks (Richland et al., 2010). Furthermore, Japanese children performed better than their peers in the United States when richly detailed objects were used in the task (e.g., clock, key, television) but not when simple objects were used (e.g., square, circle) (Kuwabara & Smith, 2012).

Christie and colleagues (2020) provided two potential sources that could result in cross-cultural differences in preschoolers' object focus and relational reasoning. First, examining an object in relation to a context might lead to biases toward perceiving relations, easing reasoning about relations. In that sense, East Asian individuals are found to be more sensitive to the background when examining an object, whereas Western individuals might focus directly on the focal object (e.g., physical feature of a fish) with less elaboration on the background (e.g., the fish's relation with the aquarium) (Varnum et al., 2010). Thus, the advantage of East Asian children in relational reasoning might stem from their attentional biases toward the background. However, preschoolers' attention to the focal objects and background is comparable across cultures and displayed considerable individual differences within cultures (Senzaki et al., 2016). If attention to background is a prominent factor in East Asian children's relational reasoning performance, one might expect a correlation between individuals' attention to background and their relational reasoning performance. Thus, the first aim of this study was to test whether attention to background versus focal objects was associated with children's relational reasoning.

The second source of difference discussed by Christie and colleagues (2020) was about the trajectory of relational language learning (e.g., verbs, prepositions). Due to the difficulty of individuating relational referents (e.g., events requiring at least an agent to perform them; Gentner & Boroditsky, 2001; Golinkoff & Hirsh-Pasek, 2008), children learn verbs (i.e., relational referents) later than nouns for individual objects (Gentner, 1982). However, children who acquire languages with rich verb inflections and using verbs in salient positions in sentences (e.g., Japanese, Korean, Mandarin, Turkish) show reduced noun bias (Chan et al., 2011; Kauschke et al., 2007; Özcan et al., 2016; Setoh et al., 2021). Children learning these verb-privileged languages need less contextual information to map a verb onto an event (Arunachalam et al., 2013). They also hear more verbs in their parents' language input (Choi & Gopnik, 1995; Tardif et al., 1997). As a result, these children might develop a relation focus instead of an object focus.

Hearing and using language with more syntactical emphasis on relations can support children's focus on relations because the linguistic labels for relations provide a different representation that is abstracted away from the objects. In turn, these linguistic labels ease the process of flexibly using relational representations in reasoning (Gentner, 2016). One source of evidence supporting this view comes from studies using novel linguistic labels (e.g., dax) when presenting the relations, which enhances children's reasoning performances (Christie & Gentner, 2014; Gentner et al., 2011; Loewenstein & Gentner, 2005). Moreover, children who lack relational language showed difficulties in nonlinguistic spatial tasks, such that deaf children who lack the knowledge of conventional signs to communicate spatial relations failed in spatial reasoning tasks (Gentner et al., 2013). Similarly, children who knew more spatial relational words (e.g., on, under) performed better in spatial reasoning tasks than children who knew few spatial relational words (Turan et al., 2021). Using relational language might also alter children's focus on relations. For example, Hoyos and colleagues (2016) asked children to either name an object (e.g., pencil) or an event (e.g., jumping) before the completion of the RMTS task. Children who named objects before the RMTS task performed worse in this task than those who named events. Therefore, using verbs more frequently might also create a spontaneous focus on relations, which is why children might easily understand the relational structures in relational reasoning tasks. Thus, the second aim of the current study was to examine whether children's relational language use was associated with their relational reasoning performance.

The role of working memory

Working memory, an aspect of executive functions, is the ability to maintain and manipulate a breadth of information in mind (Diamond, 2013). In the context of relational reasoning, working memory provides a representational space wherein objects and relations are maintained and manipulated. For example, increased working memory capacity can help children maintain multiple relations simultaneously (Morrison et al., 2011; Richland et al., 2006). Furthermore, in the context of the RMTS task, children need to infer the relation presented in the standard card and compare the standard card with the choice cards, requiring the ability to manipulate information in their minds. Supporting this argument, working memory tasks requiring children to maintain and manipulate information in mind (e.g., backward digit span) have been found to be a significant predictor of relational reasoning (Miller et al., 2016; Simms et al., 2018).

Furthermore, the association between working memory and relational reasoning might depend on children's relational language use and object focus. Relational language can help children represent a relation without referring to the objects. For example, when children see two same squares depicted in a card, they can refer to that card by just saying "same" without the need to say "squares." Thus, using relational language in a description might reduce the number of items children need to focus on, which in turn can reduce working memory demands. Similarly, children who provide object-based descriptions may experience increased working memory needs given that the weight of objects in their representations could limit the room available for representing relations. In the case of the RMTS task, relation-focused children might easily use the presented sameness relation as a single unit in reasoning, whereas object-focused children might consider two objects per relation (e.g., two squares). Thus, any relational comparison between a standard card and a choice card would involve more units for object-focused children. Following this logic, the third aim of the current study was to investigate the effect of the interaction between children's language use (relational vs. object-focused and focal vs. background) and working memory on their relational reasoning performances.

The current study

Low relational reasoning performance of 4-year-olds from the United States has been attributed to children's object focus, which shows a high degree of variability across individuals and populations, possibly due to the variance in children's relational language. Considering the individual differences in children's object focus (e.g., Esmer et al., 2023; Guarino et al., 2021) and relational reasoning (Turan et al., 2021), we aimed to investigate the variance in children's relational language learning within a single linguistic community, namely in a Turkish-speaking sample of 4- and 5-year-old preschoolers. In a previous study, Turkish-speaking 4- and 5-year-olds showed chance-level performance in the version of the RMTS task testing only for sameness relations without object matches as options (Turan et al., 2021). Therefore, we used the same version of the RMTS task to observe individual differences and to prevent a floor effect due to additional demands (testing multiple relations and providing object matches).

Turkish-speaking children around these ages also showed variance in their use of relational language (i.e., directional and spatial relations; Gentner et al., 2013). Therefore, we focused on how children use relational language in a novel scene description task. We used a novel task because we also investigated how children talked about different focal objects within different backgrounds. This way, we could test the roles of both relational language and attention to focal object versus background in the scenes. Moreover, the current study delved into the specific associations between working memory components and relational reasoning by taking children's relational language use into account.

The first aim of the study was to examine whether children's relational language use in the scene description task was associated with their relational reasoning performance. Relational language includes the use of verbs, prepositions, and conjunctions that causally or temporally relate two events. For children to be able to use these structures in their descriptions, each scene in the scene description task had two moving items moving at the same time. Because using relations spontaneously and frequently in their language could help children produce an initial bias toward relations to represent relations easier, we expected the frequent use of relational language in the scene description task to increase the probability of choosing the relational match in the RMTS task (Hypothesis 1a [H1a]) after controlling for children's age, average length of sentences, and working memory. The scene description task also had different backgrounds, including various static objects semantically related to the contexts. Given that spontaneously and frequently naming these objects in descriptions might reveal children's object focus, we expected that using more object names in the scene description task would decrease the probability of choosing the relational match in the RMTS task (H1b) after controlling for children's age, average length of sentences, and working memory.

The second aim of the study was to examine whether children's descriptions for focal object and background in the scene description task were associated with their relational reasoning performance. Each video in the scene description task had one moving item that was bigger and placed in a more central position (i.e., focal dynamic object), whereas the other moving item that was smaller and placed in a more peripheral position (i.e., background dynamic object). In addition, each video had different backgrounds and static items that could be seen naturally in the context the scene depicted. This allowed us to calculate two different scores for descriptions for focal events and background events. Due to the lack of previous research on how children talk about focal and background information in Turkish-speaking samples, we did not have a clear expectation regarding how these scores differ. We expected that the scores would vary across participants and this variance might explain some variance in their relational reasoning performance.

Given that attention to background information is closely related to the ability to establish connections between focal objects and their surrounding context, we predicted that higher background description scores in the scene description task would increase the probability of choosing relational match in the RMTS task (H2a) after controlling for children's age, average length of sentences, and working memory. Furthermore, because focusing on the focal object more could imply attention toward a specific object, we expected higher focal description scores in the scene description task to decrease the probability of choosing relational match in the RMTS task (H2b) after controlling for children's age, average length of sentences, and working memory.

The last aim of the study was to investigate whether the association between working memory and relational reasoning performance would depend on how children described the scenes. Children's language use might reveal their initial biases toward relations, which might help represent relations more saliently and decrease the cognitive load while using the relational representations in reasoning. Specifically, the association between working memory and the probability of choosing a relational match would be weaker for children who used more relational language (H3a) and would be stronger for those who used more object-focused language (H3b) in their descriptions of a scene. Similarly, we predicted that the association between working memory and the probability of choosing a relational match would be weaker for children who talked more about the background (H3c) and would be stronger for those who talked more about focal objects (H3d) when describing a scene.

Method

Participants

The data were collected online via Zoom from 42 Turkish-learning preschoolers (M_{age} = 59.01 months, *SD* = 6.41, range = 48–71). The sample size was similar to the previous studies testing children's performance in an RMTS task (20–25 children per age group; see Christie & Gentner, 2014; Hochmann et al., 2017) and studies investigating individual differences (25–60 children; Guarino et al., 2021; Starr et al., 2018; Turan et al., 2021). One participant was excluded due to a problem with the participant's computer screen. All but 1 participant had regularly attended a preschool at the time of testing. On average, participants had a monthly family income (in Turkish lira) of ₺19000 (*SD* = ₺12000, range = ₺4000–₺50000) at the time of testing. In addition, most of the participants' parents had a college degree (26 mothers and 29 fathers). Thus, the sample mainly represented middle to high socioeconomic status. Participants received a certificate of attendance and an e-gift card worth ₺50 for their participation. The procedures used in this study were approved by the institutional review board of Koç University.

Materials and procedure

All materials used in this study can be accessed via the Open Science Framework (https://osf.io/rzw5p/?view_only=ec100b1784d1471884730b3f0223740c).

The data used in this study were part of a larger project. Before the study session, all parents filled out a Qualtrics survey, which included an informed consent form and demographic information. The study was conducted online via Zoom, and all participants gave their consent to be recorded. All tasks in the study (except Turkish word span) were conducted by sharing the experimenter's screen with children. The study started with a warm-up task where children watched a short cartoon video clip depicting a story of two octopuses and were asked to narrate the story afterward. Children's performance in this task was not included in the study. Then, the primary study tasks were administered in three blocks. After each block, a short break lasting 3 min was given, within which a sticker selection activity was done as a filler task. From the first block, we used data from the RMTS task. From the second block, we used the scene description and storytelling tasks. From the last block, we used the Turkish word span task. The entire procedure took approximately 45 min. The task order (i.e., RMTS, scene description, storytelling, and Turkish word span) was fixed across participants.

RMTS task

The RMTS task was used to examine children's relational reasoning skills (Premack, 1983). In each trial, children were first presented with a standard card depicting a pair of two identical geometric shapes (square–square; AA). Then, they saw two choice cards. One of these cards depicted two identical geometric objects that were different from the standard card (star–star; BB). The other choice card depicted two different geometric shapes (diamond–circle; CD). The task consisted of 12 test trials, 6 of which presented objects familiar to children (i.e., triangle, circle, square, diamond, star, and heart) and the remaining 6 of which were unfamiliar to children (i.e., rotated rectangle, rotated obtuse triangle, parallelogram, trapezoid, hexagon, and ellipsis). Children's performance in the RMTS task did not differ based on stimuli familiarity (see Esmer et al., 2023, for results and a detailed discussion). Children's performance on each test trial was scored binary (1 if the relational match was chosen and 0 if the non-relational foil was chosen). Fig. 1 presents an example display of a trial from the RMTS task.

Children were randomly assigned to one of the two conditions differing only in the trial order. The order of trials was determined quasi-randomly, ensuring that the relational match did not appear on the same choice card (i.e., left or right) for 5 consecutive trials. In the beginning of the task, children saw a screen where a blank card appeared at the location of either of the two choice cards, and children were asked to raise their hand corresponding to the card's location (e.g., raising right hand if the blank card appeared on the right side of the screen). This process was repeated until the experimenter accurately understood which hand's raise would indicate the response card the child meant to indicate. Children were then shown an example matching trial in which the standard card was a cat and the option cards were a mouse and a dog. Children were asked to indicate which card matched the standard card better. The experimenter asked the children whether they chose the dog or mouse according to children's hand raise. This step was done to ensure that (a) children raised their hand to indicate the card they preferred and (b) the experimenter accurately predicted which card children chose from their hand raise. After this trial, 12 test trials were presented. Each trial was administered similarly, such that the experimenter showed the standard card and said, "Bu karta bak bakalım" [Let's look at this card]. Then the choice cards appeared, and the experimenter asked children, "Sence ilk kartla hangisi daha iyi eşleşir?" [Which card do you think matches better with the first card?]. Given that this prompt asked for children's opinion on which card matched better with the standard, it implied that there was no objective correct answer. The prompt was repeated if children were not responsive to this question. After the children responded to the second prompt, the experimenter proceeded to the following trials. If the children did not respond to the second prompt, the experimenter proceeded to the next trials. Children were not provided with any corrective feedback on the test trials.

Scene description task

This task was used to understand the variability in how children used relational language and how they described focal and background events. There were eight video clips in this task, each lasting approximately 6 s. The video clips were designed in Microsoft PowerPoint. In each video clip, there were two dynamic objects and a background. The movement of dynamic objects was incorporated into the scenes by adding an animation path to the selected objects. Half of the video clips included inanimate dynamic objects (e.g., boat, ball, toy train) and the remaining half had animate dynamic objects (e.g., dog, frog, squirrel) to increase variability. There was one focal and one background dynamic object in each video that differed according to (a) their position in the scenes, (b) the relative size of the dynamic object, and (c) the relative size of the area within which the action was performed. The grounds were also different, such that half of them depicted indoor scenes and the remaining half depicted outdoor scenes. As a result, there were two scenes for each composition: outdoor–animate (Fig. 2A), outdoor–inanimate (Fig. 2B), indoor–animate (Fig. 2C), and indoor–inanimate (Fig. 2D). In addition to the dynamic objects, other static objects were distributed across the center and periphery. All static objects were considered as background objects.

Children were randomly assigned to two conditions that differed only in the randomized order of trials. In the beginning of the task, children were first instructed to watch short video clips and were asked to describe each video when they saw a blank screen. Before starting each video, the experimenter said, "Bakalım bu sahnede neler olacak, neler göreceksin" [Let's see what will happen in this scene and what you will see in the scenes]. Children watched the first trial and were then asked to describe what they saw in the video. If they did not respond to the first prompt, the prompt was repeated once again. If there was still no response from the children after the second prompt, the experimenter proceeded to the subsequent trial. The same procedure was applied to all trials.

Storytelling

The number of words that a child typically uses might influence how many object-focused and relational words the child uses in the scene description task. Therefore, we assessed the number of

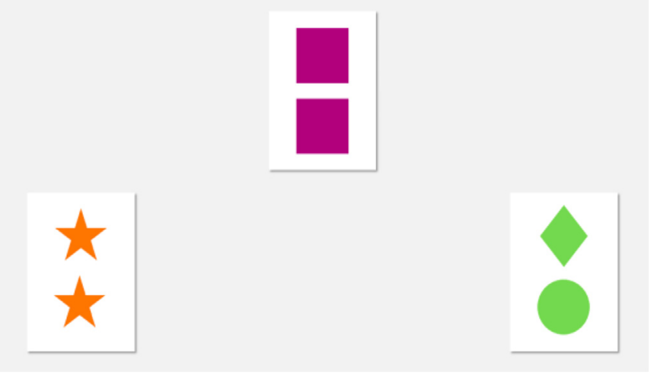

Fig. 1. An example display from the relational match-to-sample task.

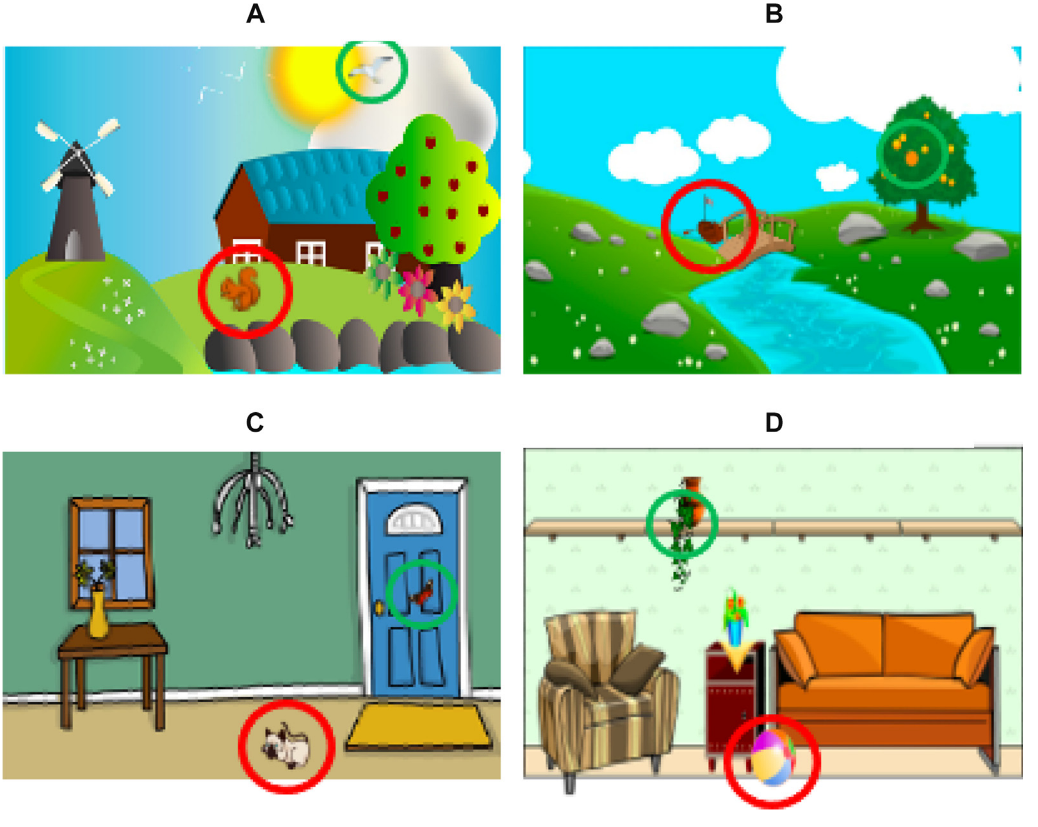

Fig. 2. First displays from videos of the scene description task. Focal dynamic objects are indicated with red circles, and background dynamic objects are indicated with green circles. These circles were not present in the original task. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

words children typically use in the storytelling task to control for children's general linguistic skills. In the storytelling task, children were expected to narrate two stories (i.e., Shipwreck and Late for School; Gillam & Pearson, 2004) based on the five pictures they were presented with for each story. From the stories children told, the mean number of words they used in a sentence was calculated to control for the general language skills in the main analyses. Before calculating the number of words in each sentence, we excluded filled pauses, repetitions, and story-unrelated utterances from the transcripts.

Turkish word span task

This task was used to measure verbal working memory in two different ways: forward word span and backward word span (Adıgüzel, 2021). In the forward and backward span tasks, children were instructed to reproduce the words spoken by the experimenter in the same order and reversed order, respectively. There were 2 training and 8 test trials in each task. In the training trials, children were tested with two words with two syllables. Test trials could be classified in terms of four difficulty levels (with 2 trials per difficulty level). The first 2 trials included two words with one syllable (e.g., *fil–taş* [elephant–rock]), and the second difficulty level again included two words but with two syllables (e.g., *yangın–şeker* [fire–sugar]). The third level asked children to repeat three words with three syllables (e.g., *süpürge–şemsiye–telefon* [broom–umbrella–telephone]). Finally, the fourth level investigated children's ability to repeat four words with four syllables (e.g., *battaniye–matematik–kalorifer–televizyon* [blanket–mathematics–radiator–television]).

In the backward word span task, children were instructed to repeat the words that the experimenter produced in a reversed order. Before the training for backward span, the experimenter introduced the task nature with an example by saying "Mesela, ben eğer bardak–kalem dersem, sen bana kalem–bardak diyeceksin. Yani tam tersini söyleyeceksin" [For example, if I say cup–pen, you will say pen–cup. That means you will say the exact opposite]. Then, in the training trials, children were corrected if they failed to repeat the words. If they answered inaccurately in the training, they were repeated the initial introduction before proceeding to the test phase. After that, children were told that they understood the task and could continue to do the task without any correction. In the test trials, children did not need an additional prompt; thus, the experimenter only told the words to the children. If children did not produce any trials in a difficulty level, they did not proceed to the subsequent difficulty levels.

In the study, children were first provided with the forward word span task, where they were asked to repeat the words the experimenter said in the same order. This was followed by the backward word span task. In this study, we only considered the number of correctly reproduced trials for the backward span task.

Coding

Relational and object-focused language

Using the scene description task, we coded how many relational and object-focused words were used. Relational words included verbs (e.g., *takip etmek* [chasing], *yürümek* [walking], *gitmek* [going]), postpositions (e.g., *doğru* [toward], *altında* [under], *yakınında* [near]), conjunctions that conveyed causal relations (e.g., *çünkü* [because], *için* [for]) and temporal relations (e.g., *sonra* [after], *önce* [before]), and adverbs that conveyed manner of motion (e.g., *zıp zıp* b[y jumping], *yavaşça* [slowly]) and temporal relations between events (e.g., *aynı anda* [at the same time]). Object-focused words included nouns that referred to objects (e.g., *vazo* [vase], *top* [ball], *hindistan cevizi* [coconut]) and grounds (*duvar* [wall], *orman* [forest], *yer* [ground]). Each word was counted with a score of 1 for the corresponding category. Phrases, such as words combined with auxiliary verbs (e.g., *takip etmek* [chasing]), duplications (e.g., *zıp zıp* [by jumping]), and compound words referring to a single entity (e.g., *hindistan cevizi* [coconut]) were counted as a single unit receiving a score of 1. The coding was completed for each trial, and the mean number of relational and object-focused words for each participant was calculated. Table 1 shows examples of the coding.

After we scored the relational and object-focused words in each sentence, we calculated the mean score of all trials for each participant in each category (i.e., object and relation). We used these measures separately in our analyses to account for the distinction between children who used more relations with more objects and children who used fewer relations with fewer objects. If proportions were used, there would be no distinction in children's descriptions between the second example (i.e., the seagull was flying) and the third example (i.e., the seagull was flying toward the windmill) presented

Table 1
Examples of relational and object-focused language coding

Example in Turkish	English translation	Object	Relation
Martı gördüm	I saw a **seagull**	1	0
Martı uçuyordu	The **seagull** was flying	1	1
Martı değirmene doğru uçuyordu	The **seagull** was flying toward the **windmill**	2	2
Sincap uyandıktan sonra **değirmen**e doğru gitti	After the **squirrel** woke up, it went toward the **windmill**	2	4

Note. The example descriptions are based on the scene presented in Fig. 1A. Bold font denotes object-focused words, and underlines denote relational words.

in Table 1. However, the third example involved a more fine-grained explanation with additional relational details compared with the second example. To accommodate such variability in our analyses, we separately included relational and object-focused language variables.

A native speaker of Turkish coded all the data, and another native speaker of Turkish coded 22.5% of the data (71 trials from 9 participants) chosen randomly for reliability checks. The reliability analysis was conducted for relational language and object-focused language use with a two-way random model, absolute agreement, and single measures (Koo & Li, 2016). Results revealed excellent reliability for relational language (intraclass correlation coefficient [ICC] = .928, $p < .001$) and good reliability for object-focused language (ICC = .878, $p < .001$) based on the criteria provided by Koo and Li (2016).

Focal and background language

We coded how children talked about objects and events occurring in various locations within the scenes based on children's responses from the scene description task. Children's descriptions regarding the focal dynamic objects were coded as focal language. The remaining descriptions were categorized as background language. The coding scheme was adapted from studies that used picture description tasks (e.g., Imada et al., 2013; Masuda & Nisbett, 2001). Different from the word-by-word coding in the relational and object-focused language, focal-background coding is a description-level score-based coding scheme. Thus, children did not get a focal-background language score per focal and background objects they provided in their descriptions. Rather, the scheme had three levels: (1) whether the child's first word referred to focal or background objects (0 or 1), (2) how many descriptive words were used for background objects (e.g., adjectives, words detailing an object), and (3) how many relational words were used to explain the background object (e.g., verbs, prepositions). Based on these three levels, we calculated scores for focal and background language. As a result, children got focal/background scores only if they referred to them first in their descriptions as well as uttered descriptive and relational words to detail those objects.

If the first word of a child's description referred to or was attributed to the focal object, the child would receive a score for *focal/first word level* or else the child would receive a score for *background/first word level.* If a child's description included an adjective describing the focal object (e.g., *küçük* sincap [*small* squirrel]) or a word specifying the focal object (e.g., *oyuncak* tren; [*toy* train]), the child would receive a score for *focal/descriptive level* depending on the number of descriptors the child used. If such descriptive words were used for the items in the background of the scenes (e.g., *çirkin* martı; [*ugly* seagull]), the number of such words would be reflected in the child's score for the *background/descriptive level.* Finally, the relational level included the spatial relations or events (i.e., verbs and postpositions). Each verb and postposition resulted in a score of 1. If the landmark of a postposition that was used in the description was the focal object or the verb referred to the action of the focal object, the points would be counted for *focal/relational level.* For example, the child would get 2 points for the *focal/relational level* for a description such as "*sincap öne* yürüyordu" [the squirrel was walking toward *(its) front*]. Similarly, the point would be counted for the *background/relational level* if a verb referred to the background object's action and if the landmark of a postposition was on the background. For example, if a child described a scene as "*sincap değirmenin önüne* yürüyodu" [the squirrel was walking to the front of the windmill], the child would get a score of 1 for the *background/relational* *level* (i.e., *değirmenin önü* [the front of the windmill]) and 1 for the *focal/relational level* (i.e., *sincap yürüyordu* [the squirrel was walking]). More examples for this coding scheme are provided in the supplementary material.

After we calculated children's scores in each level (i.e., first word, descriptive, and relational), we summed up these scores to yield single scores for focal and background descriptions. In calculating the background scores, we considered all static items in a video as background items. Higher scores in focal descriptions would indicate how much focal information was prioritized. Similarly, higher scores in background descriptions would indicate how much background information was prioritized.

Results

Descriptive statistics and preliminary results

The descriptive statistics and the correlations between the study variables are presented in Table 2 and Table 3, respectively.

To understand the overall performance level of our sample, we conducted a one-sample t test examining whether the sample performed above the chance level (.50 because there were two choice cards) in the RMTS task. Performance in the RMTS task (percentage of trials where a child chooses a relational match) was significantly above the chance level (M = .69, SD = .23), $t(40) = 5.39$, $p < .001$. In addition, the order of trials, $t(39) = -0.399$, $p = .692$, and the familiarity of the objects were not related to children's relational reasoning performance, $F(1, 39) = 1.017$, $p = .320$.

We then investigated how children used relational and object-focused words in the scene description task. Children used more object-focused words (M = 3.18, SD = 0.96) than relational words

Table 2
Descriptive statistics of the study variables

Variable	*M*	*SD*	Min	Max
Age	59.10	6.46	47.80	71.00
RMTS	0.69	0.23	0.25	1.00
Object	3.18	0.96	1.43	5.75
Relation	2.24	1.21	0.00	4.50
Focal	1.52	0.60	0.00	2.75
Background	2.04	0.90	0.43	3.63
# of words	3.61	0.93	1.89	5.58
Forward	5.85	1.06	4.00	8.00
Backward	2.63	1.96	0.00	6.00

Note. RMTS, percentage relational match chosen; # of words, mean number of words used in sentences.

Table 3
Correlations among the study variables

Variable	1	2	3	4	5	6	7	8
1. Age	–							
2. RMTS	.304	–						
3. Object	.446**	.166	–					
4. Relation	.069	−.268	.235	–				
5. Focal	−.087	−.134	−.014	.876***	–			
6. Background	.265	−.242	.447**	.835***	.542***	–		
7. # of words	.310	.157	.339*	.307	.122	.454**	–	
8. Forward	.263	.025	.333*	.369*	.284	.410**	.517***	–
9. Backward	.477**	.328*	.431**	.007	−.049	.142	.372*	.442**

Note. RMTS, percentage relational match chosen; # of words, mean number of words used in sentences.
* $p < .05$.
** $p < .01$.
*** $p < .001$.

(M = 2.24, SD = 1.21), $t(39)$[1] = 4.41, p < .001. Similar to the raw scores, the proportion of object-focused words was significantly more than the proportion of relational words, $t(39)$ = 4.33, p < .001. Overall, children uttered more object-focused words for the dynamic objects (M = 2.07, SD = .55) than for the static objects (M = 1.10, SD = .96) in the scenes. Children's relational and object-focused word use did not differ across trials depicting animate dynamic objects (object: M = 3.11, SD = 1.06; relational: M = 3.23, SD = 1.09) and inanimate dynamic objects (object: M = 2.17, SD = 1.34; relational: M = 2.23, SD = 1.20), $ts(39)$ = 0.76, ps > .45. In addition, neither relational nor object-focused word use was significantly correlated with the percentage of relational match chosen (see Table 3 for correlations).

Furthermore, we investigated children's focal and background description scores from the scene description task. Children's focal language scores (M = 1.52, SD = 0.60) were significantly lower than their background language scores (M = 2.04, SD = 0.90), $t(39) = -4.37$, p < .001. More specifically, at the relational level, children had lower scores for focal objects (M = 0.94, SD = 0.48) than for background objects (M = 1.50, SD = 0.87), $t(39) = -5.69$, p < .001. However, they scored similarly in focal and background descriptions for first-word level (focal: M = 0.06, SD = 0.10; background: M = 0.07, SD = 0.09) and descriptive level (focal: M = 0.52, SD = 0.21; background: M = 0.48, SD = 0.21). Children's background scores did not differ across trials depicting animate dynamic objects (M = 2.04, SD = 0.99) and inanimate dynamic objects (M = 2.04, SD = 0.99), $t(39)$ = 0.03, p = .97. However, children scored higher in their focal descriptions in scenes with animate dynamic objects (M = 1.63, SD = 0.62), than in scenes with inanimate dynamic objects (M = 1.41, SD = 0.67), $t(39)$ = 2.82, p = .007. In addition, neither background nor focal scores were significantly correlated with the percentage of relational match chosen. More results regarding our scene description task are provided in the supplementary material.

We also investigated performance in the backward word span task. Overall, children recalled around 3 of 8 words (M = 2.63, SD = 1.96). Moreover, children's backward word span scores were significantly and positively correlated with their relational reasoning performance, $r(40)$ = .328, p = .036.

Main results

To test our main research questions, we built two generalized binomial mixed effects models (*glmer*) using the "lme4" package (Bates et al., 2015) in R (R Core Team, 2022). In both models, the dependent variable was relational match performance per trial (1 = relational match chosen, 0 = non-relational foil chosen). To eliminate the random variance that might be related to participants and unmeasured properties of the RMTS task trials (e.g., stimulus color, shape), we added random intercepts for participants and trials. All variables entered into the models as fixed effects were continuous and standardized.

We first built two full models. In Model 1, we included our main language variables (i.e., relational and object-focused), backward word span scores, all control variables (i.e., number of words and age), and two interaction variables between our language measures and backward word span scores. In Model 2, we used a similar approach but included focal and background language scores as the language measures. Then, we consecutively excluded the nonsignificant fixed effects to enhance the model fit (i.e., decreasing Akaike information criterion [AIC]). For the models that did not converge in the first run, we added an optimizer (i.e., BOBYQA*;* Powell, 2009) to increase the number of iterations to find the best-fitting model. Table 4 presents the fixed effect estimates, AIC, and R^2 values of the best-fitting models. The R^2 values were calculated using the "MuMIn" package in R (Barton, 2015) based on the calculations provided by Nakagawa et al. (2017).

First, we tested the fixed effects of relational language use, object-focused language use, backward word span scores, number of words in a sentence, age, and the interaction between language and backward word span scores on the probability of choosing a relational match per trial (Model 1). The results of the best-fitting model revealed that relational language use was negatively ($\beta = -.480$, SE = .210, p = .022) related to the probability of choosing a relational match. In addition, the interaction between backward word span scores and relational language use was also significant ($\beta = -.475$, SE = .201, p = .018). No other fixed effects and interactions were significant (all ps > .05).

[1] One additional participant was excluded from the analyses due to a lack of data in the scene description task.

Table 4
Fixed effects estimates of the *glmer* models for the probability of choosing relational match

Fixed effect	Model 1	Model 2
	β (*SE*)	β (*SE*)
Language		
Object	Excl	
Relation	−.480 (.210)*	
Focal		.141 (.230)
Background		−.636 (.256)*
Backward word span	.386 (.221)	353 (.212)
Other control variables		
Age	.326 (.222)	.552 (.239)*
Number of words	Excl	
Interaction terms		
Object * Backward	Excl	
Relation * Backward	−.475 (201)*	
Focal * Backward		−.527 (.227)*
Background * Backward		Excl
Akaike information criterion	537.7	537.7
R^2	.378	.379

Note. Excl, excluded nonsignificant effects that decreased the model fit.
* $p < .05$.

Visual inspection of the interaction plot for Model 1 (i.e., the interaction between relational language use and backward word span scores; Fig. 3A) showed that the relation between the backward word span scores and the probability of choosing a relational match was stronger for children who used relational language less frequently.

Second, we tested the fixed effects of focal description scores, background description scores, backward word span scores, number of words in a sentence, age, and the interaction between focal-background scores and backward word span scores on the probability of choosing a relational match per trial (Model 4). The results of the best-fitting model revealed that background description use was negatively ($\beta = -.636$, $SE = .256$, $p = .013$) related and age was positively ($\beta = .552$, $SE = .239$, $p = .021$) related to the probability of choosing relational match. In addition, the interaction between focal description use and working memory was also significant ($\beta = -.527$, $SE = .227$, $p = .020$). No other fixed effects or interactions were significant (all *ps* > .05). Visual inspection of the interaction plot for Model 4 (i.e., the interaction between focal description use and backward word span scores; Fig. 3B) showed that the relation between the backward word span scores and the probability of choosing a relational match was stronger for children who use fewer focal object descriptions.

Discussion

The current study investigated how Turkish-learning preschoolers' language use and working memory were related to their relational reasoning performance. In particular, we focused on the relation between relational reasoning and (a) how children used relational and object-focused language, (b) how children described focal objects and backgrounds, and (c) children's working memory and language use. We found that children's use of relational language and their descriptions of backgrounds were negatively associated with their relational reasoning. More important, the association between working memory (i.e., backward word span) and relational reasoning was stronger for children who used relational language and focal object descriptions less frequently.

Overall, our sample performed above the chance level in the RMTS task, suggesting that Turkish-learning 4- and 5-year-olds were able to infer and reason based on the *sameness* relation. Using the scene description task, we found that the children in our sample used object-focused words (e.g., nouns) more frequently than relation-focused words (e.g., verbs, prepositions) and prioritized

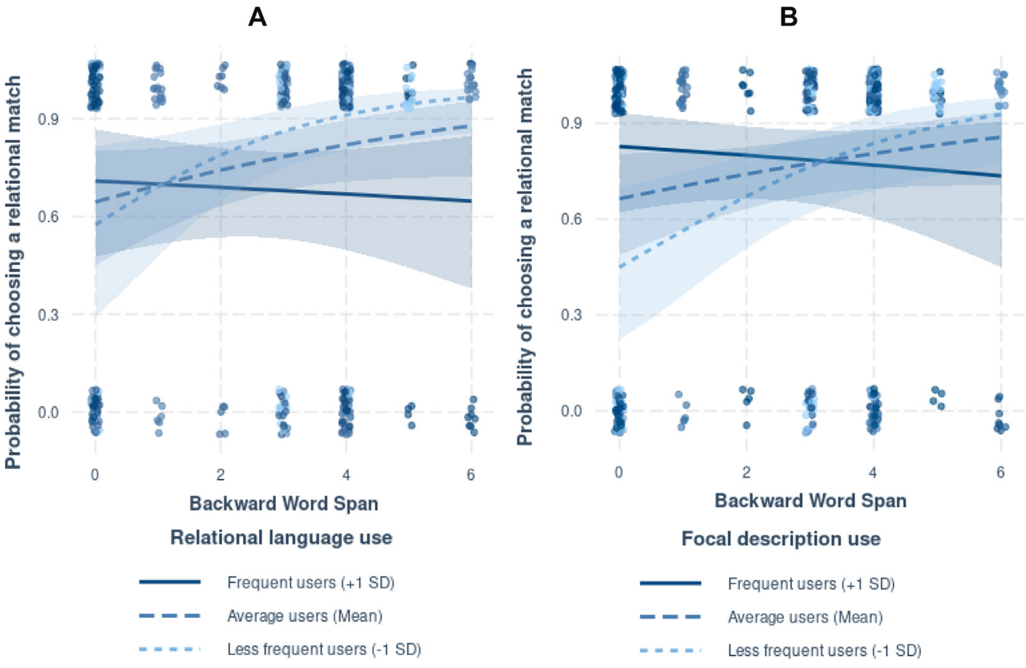

Fig. 3. Interaction plots depicting the relation between working memory and relational reasoning across different levels of children's relational language use (A) and focal description use (B).

background information compared with focal information. This pattern (e.g., background descriptions, successful relational reasoning) might be similar to the East Asian children's performance (e.g., Carstensen et al., 2019; Imada et al., 2013). However, in our scene description task, there were more background items in the videos, making the background descriptions richer. Therefore, in the following sections, as in our main analyses, we discuss the relations between the language measures we calculated from the scene description task and RMTS task in detail.

Language and relational reasoning

Language, specifically relational language, can provide children with the grounds to represent relations in a way that is abstracted away from the objects they include (Gentner, 2016). Knowing relational words can enhance children's reasoning skills across different domains such as spatial (e.g., Gentner et al., 2013; Turan et al., 2021) and mathematical reasoning (e.g., Frank et al., 2008; Turan & De Smedt, 2022). In terms of relational reasoning, knowing the words *same* and *different* helped children choose relational matches in the RMTS task (Hochmann et al., 2017; Serraille & Hochmann, 2023), suggesting an advantage of specific relational terms in relational reasoning. Beyond the advantage of specific words, children who were asked to label relational words (i.e., verbs) before taking the RMTS task performed better than those who were asked to label object words (i.e., nouns; Hoyos et al., 2016). Building on these studies, we investigated whether children's relational language use in a scene description task, where we could obtain a variety of relational language use, could predict their performance in relational reasoning tasks. Contrary to our expectations, we found a significant negative association between children's relational language use and their relational reasoning performance.

Considering the overall performance level of our sample in relational reasoning (above chance level), this negative association does not mean that children failed to reason relationally. As Fig. 3A indicates, the probability of choosing a relational match was above 60% for the children who used relational language more frequently. Thus, our results revealed that despite the successful performance of children who used relational language more frequently, their accuracy in the RMTS task was lower than the those who used relational language less frequently. This result might have been observed due to two reasons. First, although these children frequently used relational language (i.e., verbs and postpositions), they might not have known the specific relational words (i.e., *same* and *different*) that were being used in the RMTS task. Given that these children tended to use relational language frequently, they might benefit more from relational terms to perform better in the task. Second, unlike Hoyos and colleagues (2016), children solved the RMTS task first and were presented with the scene description task, where they used relational language, afterward. Thus, in our study relational language use did not prime children to a "relational mindset" (Simms & Richland, 2019) to help them succeed in the RMTS task. Rather, the tendency to use relational language, as we measured from the scene description task, might have interacted with different processes in its relations with the RMTS task performance. Hence, the strength of a general tendency to use relational language might not robustly reveal itself in every context.

Regarding children's use of object-focused words, we found no significant associations with relational reasoning. We measured children's object-focused language in a separate task subsequent to the relational reasoning task, as opposed to the previous studies that measured it in terms of object property words used in the RMTS task (i.e., color and shape names; Esmer et al., 2023) and object-based explanations for children's choices in the RMTS task (Hochmann et al., 2017). Similar to the case of relational language use, the general tendency to label objects more might not be as powerful as the contextual constraints posed by the task itself.

Another aspect of language possibly relevant to children's relational reasoning is the descriptions of focal objects and backgrounds. Previous studies revealed a cross-cultural difference in preschoolers' relational reasoning (i.e., East Asian children outperformed their Western counterparts; Carstensen et al., 2019; Kuwabara & Smith, 2012; Richland et al., 2010), possibly due to the cultural differences in individuals' attention to focal objects and background (Christie et al., 2020). However, no study has investigated whether there was a direct relation between children's attention style (i.e., background and focal object) and relational reasoning performance. By measuring children's attention toward their descriptions of visual scenes (as in Imada et al., 2013; Senzaki et al., 2016), we found no significant association of relational reasoning with focal object descriptions, whereas a significant negative association was present with background descriptions.

Considering the successful performance level of our sample in the RMTS task, this finding once again implies a less robust level of success for children who used more background descriptions. Compared with the standard cards in the RMTS task, the scene description task involved more objects. It could be that extracting relations between two objects might be a different process than describing different relations of a focal object and its backgrounds. For example, children who described different areas of a scene might switch back and forth between these areas. Conversely, it has been found that switching back and forth between different cards instead of focusing solely on a single card resulted in poorer performance levels in the RMTS task (Carvalho et al., 2018). To infer the relational structure in the RMTS task, focusing more on the background might hinder sustaining attention to the relevant objects (i.e., objects in the standard card), and this tendency would decrease the robustness of children's performance levels.

In sum, children's general tendency to use relational language did not help them directly in the RMTS task, possibly because this tendency did not necessarily indicate children's knowledge of the relation asked in the RMTS task (i.e., sameness). It could also be due to the task order, such that their tendency to use relational language might not have primed relation representations in the RMTS task. Children's descriptions of the background, on the other hand, might indicate their attentional switch between different objects in a larger area in their perceptual array, potentially decreasing their success in inferring relations from the standard card.

Working memory and relational reasoning

Within the context of relational reasoning, working memory has been investigated as an indicator of the ability to hold and map multiple relational information in mind (Richland et al., 2006). Recent research also showed the predictive power of working memory measures that required children to not only maintain but also manipulate the information in their minds (e.g., backward digit span), indicating the advantage of the ability to manipulate information in relational reasoning (Miller et al., 2016; Simms et al., 2018). Building on these findings, we examined the link between backward word span scores (i.e., the ability to both maintain and manipulate information in mind) and relational reasoning. Different from the previous studies, we examined the interaction between working memory and children's object–relation focus as a window to see the additional cognitive load of relational reasoning for object-focused children.

Our results revealed that the association between children's relational reasoning and working memory (i.e., backward word span) depended on how children used language. First, we confirmed our hypothesis that the association between working memory and relational reasoning was weaker for children who used more relational language and stronger for children who used less relational language. According to the graded representations of relations account, relation representations also involve objects, and the relative salience of relations over objects might determine children's performance in relational reasoning tasks (Carstensen & Frank, 2021). Children could form more robust and finer-grained relational concepts through language (Gentner, 2016). Thus, relational language users might be more prone to benefit from language in forming these concepts compared with other cognitive processes. Given that relational language users can efficiently represent the relation, reasoning would place a lighter demand on working memory, making the link between working memory and reasoning weaker. On the other hand, children who do not use relational language much can still infer the relations. Although they might not benefit from the power of relational terms in their relational reasoning process, their reasoning might still involve the objects and the corresponding relations at the same time. Holding and manipulating all this information in their minds might lead to a higher cognitive load for these children, which could be overcome by enhanced working memory capacity. Thus, having a better working memory might work for those children who use relational language less frequently. These results suggest that choosing a relational match might have an additional working memory load for object-focused children (as indexed by less relational language use), revealing a novel way to consider the role of working memory in relational reasoning.

The association between children's working memory and relational reasoning also depended on children's tendency to use focal descriptions. Whereas working memory was more important for children with fewer focal descriptions, it was not much more important for those with frequent focal descriptions. Talking more about focal objects might indicate children's ability to sustain their attention to the central information, which was the standard card in the RMTS task. Increased sustained attention to the standard card was found to be related to children's relational reasoning performance (Carvalho et al., 2018). In addition, relational information could be obtained by focusing on objects first, which helps develop the cognitive mechanisms responsible for inferring relations such as comparison (Christie, 2021). Thus, children using more focal descriptions might successfully sustain attention on the central information (i.e., standard card in the RMTS task) and effectively compare it with the additional information (i.e., comparison between choice cards). In addition, in our study the focal object was dynamic, whose actions were inherently relational (i.e., a certain direction and in a certain manner). Thus, children who provided more focal descriptions possibly talked about every possible relation the focal object had, suggesting that these children inferred the relations depicted in the center of attention. This might indicate how children sustain their attention toward the central relational information even in the presence of competing objects and other actions. Therefore, these children potentially solved the relational rule in the RMTS task by attending to the standard card. In contrast, children who used fewer focal descriptions might be distracted more by non-central information. These distractions might increase their cognitive load during relational reasoning, requiring higher working memory capacity to attain better relational reasoning. Alternatively, children with fewer focal descriptions might not attend to the relational information or might not be able to convey the relational information the focal objects had. Therefore, these children might require more working memory capacity to represent relations with the objects they include.

In sum, children's ability to both maintain and manipulate information has a critical role in their relational reasoning. First, it might provide children who use relational language less frequently with a representational space wherein they could infer relations in the presence of objects. Second, working memory could also provide those children who get easily distracted by the background information with the ability to hold information from all over the perceptual array. Therefore, children with higher object focus (as indexed by less relational language use) or children who were distracted with multiple object information could still consistently choose relational matches thanks to their enhanced working memory capacities.

Limitations and future directions

Overall, the current study suggested the possibility of different pathways to perform better in relational reasoning tasks. Specifically, our approach in examining the joint contributions of language use and working memory yielded important conclusions regarding how object-focused children can also choose relational matches (i.e., by using working memory). However, there were still some limitations that should be addressed. First, the general performance level was above chance in our sample, which might indicate that the task was relatively easy for children (see also Turan et al., 2021, for chance-level performance in a similar task). This is especially important for the interpretation of our finding showing that using relational language and background descriptions was negatively related to relational reasoning performance. This pattern might have been observed merely due to the ease of the task. The RMTS task used in the current study was adapted from Christie and Gentner (2014). The task involved basic geometric shapes (e.g., square, triangle) that possibly enhanced relational reasoning (Esmer et al., 2023; Shivaram et al., 2023; Son et al., 2011) and presented a non-relational foil instead of a competing object match as a choice card. Furthermore, the task exclusively assessed sameness relations, potentially reducing the cost associated with switching between relations used for reasoning, an essential aspect of relational abstraction. This easy version of the RMTS task was used to make object-focused children succeed and to identify which object-focused children performed better. Yet, this version might not effectively target relation-focused children. For these children, the presented sameness relation might have been so obvious that they might have suspected they were tasked with identifying other relations. Thus, to unravel the potential benefits of relational language use, future studies should vary the difficulty level of the RMTS task by incorporating complex objects as stimuli, object matches as choice cards, and trials measuring different types of relations (e.g., both sameness and difference).

Second, the way we measured relational language use did not necessitate children to use terms (i.e., *same* and *different*) that are relevant to children's performance in the RMTS task (Hochmann et al., 2017; Serraille & Hochmann, 2023). However, knowledge of these specific relational words could outweigh the role of the general tendency to use relational language. If knowledge of these words does not relate to children's language use in the scene description task, lack of investigating children's knowledge of these words could result in an increased unexplained variability in the relational reasoning task. Besides, children who do not know the words *same* and *different* might not use the same cognitive mechanisms to perform better in the RMTS task as children who know those words. Therefore, investigating these factors can allow researchers to disentangle the joint contributions of language and other cognitive processes on relational reasoning in a more refined way.

Last, our measure of language use included only verbal descriptions. Yet, language use in other modalities (e.g., gestures) should also be considered. Gestures can compensate for children's difficulty in communicating relational concepts (for a review, see Özer & Göksun, 2020). For example, one major type of relational language used in the scene description task was spatial relational terms (i.e., postpositions). In the communication of spatial relations, children's gesture use provides additional information (Karadöller et al., 2022; Sauter et al., 2012). Any potential additional information children provided to express relations might indicate their understanding of the relational concepts. The current study collected data via Zoom, which made it difficult to examine children's gestures. Future studies should also investigate children's co-speech gestures while using relational language.

Conclusion

The current study investigated the roles of language use and working memory in children's relational reasoning. Considering the joint contributions of these factors, we also examined potential interactions between working memory and language use through which children succeed in relational reasoning tasks. Our results suggested that children's use of relational language and background descriptions were negatively related to the probability of choosing a relational match. More important, we found that children who use fewer relational language and focal descriptions need working memory resources for successful relational reasoning. These results suggest that examining the joint contributions of different factors that affect children's relational reasoning could unravel the precise roles of the underlying cognitive mechanisms in relational reasoning.

Data availability

We provided OSF link.

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Data availability

The materials and data used in this study can be accessed at the Open Science Framework (https://osf.io/rzw5p/).

Author contributions

Şeref Can Esmer: conceptualization, data curation, formal analysis, investigation, methodology, project administration, software, visualization, writing–original draft, and writing–review & editing; **Eylül Turan:** conceptualization, methodology, resources, and writing–review & editing; **Dilay Z. Karadöller:** software, validation, supervision, and writing–review & editing; **Tilbe Göksun:** conceptualization, funding acquisition, methodology, project administration, supervision, and writing–review & editing.

Appendix A. Supplementary material

Supplementary material to this article can be found online at https://doi.org/10.1016/j.jecp.2024.106149.

References

Adıgüzel, Z. (2021). *Are children mindful decision makers? Investigating underlying mechanisms of Turkish-learning children's recency bias* [Unpublished Master's Thesis]. Koç University.

Anderson, E. M., Chang, Y.-J., Hespos, S., & Gentner, D. (2018). Comparison within pairs promotes analogical abstraction in three-month-olds. *Cognition, 176*, 74–86. https://doi.org/10.1016/j.cognition.2018.03.008.

Arunachalam, S., Leddon, E. M., Song, H., Lee, Y., & Waxman, S. R. (2013). Doing more with less: Verb learning in Korean-acquiring 24-month-olds. *Language Acquisition, 20*(4), 292–304. https://doi.org/10.1080/10489223.2013.828059.

Barton, K. (2015). Package 'MuMIn'. *Version, 1*(18).

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software, 67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01.

Carstensen, A., & Frank, M. C. (2021). Do graded representations support abstract thought? *Current Opinion in Behavioral Sciences, 37*, 90–97. https://doi.org/10.1016/j.cobeha.2020.10.009.

Carstensen, A., Zhang, J., Heyman, G. D., Fu, G., Lee, K., & Walker, C. M. (2019). Context shapes early diversity in abstract thought. *Proceedings of the National Academy of Sciences of the United States of America, 116*(28), 13891–13896. https://doi.org/10.1073/pnas.1818365116.

Carvalho, P. F., Vales, C., Fausey, C. M., & Smith, L. B. (2018). Novel names extend for how long preschool children sample visual information. *Journal of Experimental Child Psychology, 168*, 1–18. https://doi.org/10.1016/j.jecp.2017.12.002.
Chan, C. C. Y., Tardif, T., Chen, J., Pulverman, R. B., Zhu, L., & Meng, X. (2011). English- and Chinese-learning infants map novel labels to objects and actions differently. *Developmental Psychology, 47*(5), 1459–1471. https://doi.org/10.1037/a0024049.
Choi, S., & Gopnik, A. (1995). Early acquisition of verbs in Korean: a cross-linguistic study. *Journal of Child Language, 22*(3), 497–529. https://doi.org/10.1017/S0305000900009934.
Christie, S. (2021). Learning sameness: object and relational similarity across species. *Current Opinion in Behavioral Sciences, 37*, 41–46. https://doi.org/10.1016/j.cobeha.2020.06.010.
Christie, S., Gao, Y., & Ma, Q. (2020). Development of analogical reasoning: a novel perspective from cross-cultural studies. *Child Development Perspectives, 14*(3), 164–170. https://doi.org/10.1111/cdep.12380.
Christie, S., & Gentner, D. (2014). Language helps children succeed on a classic analogy task. *Cognitive Science, 38*(2), 383–397. https://doi.org/10.1111/cogs.12099.
Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64*(1), 135–168. https://doi.org/10.1146/annurev-psych-113011-143750.
Esmer, Ş. C., Turan, E., Karadöller, D. Z., & Göksun, T. (2023). Object focus and preschoolers' relational reasoning. In M. Goldwater, F. Angorro, B. Hayes, & D. Ong (Eds.), *Proceedings of the 45th annual conference of the cognitive science society*. Cognitive Science Society.
Frank, M. C., Everett, D. L., Fedorenko, E., & Gibson, E. (2008). Number as a cognitive technology: evidence from Pirahã language and cognition. *Cognition, 108*(3), 819–824. https://doi.org/10.1016/j.cognition.2008.04.007.
Gentner, D. (1982). Why nouns are learned before verbs: linguistic relativity versus natural partitioning. In S. Kuczaj (Ed.). *Language development: language, thought, and culture* (Vol. 2, pp. 301–334). Lawrence Erlbaum.
Gentner, D. (1988). Metaphor as structure mapping: the relational shift. *Child Development, 59*(1), 47–59. https://doi.org/10.2307/1130388.
Gentner, D. (2016). Language as cognitive tool kit: how language supports relational thought. *American Psychologist, 71*(8), 650–657. https://doi.org/10.1037/amp0000082.
Gentner, D., Anggoro, F. K., & Klibanoff, R. S. (2011). Structure mapping and relational language support children's learning of relational categories: structure mapping and relational language. *Child Development, 82*(4), 1173–1188. https://doi.org/10.1111/j.1467-8624.2011.01599.x.
Gentner, D., & Boroditsky, L. (2001). Individuation, relativity, and early word learning. *Language Acquisition and Conceptual Development, 3*, 215–256. https://doi.org/10.1017/CBO9780511620669.010.
Gentner, D., Özyürek, A., Gürcanli, Ö., & Goldin-Meadow, S. (2013). Spatial language facilitates spatial cognition: evidence from children who lack language input. *Cognition, 127*(3), 318–330. https://doi.org/10.1016/j.cognition.2013.01.003.
Gillam, R. B., & Pearson, N. A. (2004). *TNL: Test of Narrative Language*. Pro-Ed.
Golinkoff, R. M., & Hirsh-Pasek, K. (2008). How toddlers begin to learn verbs. *Trends in Cognitive Sciences, 12*(10), 397–403. https://doi.org/10.1016/j.tics.2008.07.003.
Guarino, K. F., Wakefield, E. M., Morrison, R. G., & Richland, L. E. (2021). Exploring how visual attention, inhibitory control, and co-speech gesture instruction contribute to children's analogical reasoning ability. *Cognitive Development, 58*. 101040. https://doi.org/10.1016/j.cogdev.2021.101040.
Hochmann, J.-R., Mody, S., & Carey, S. (2016). Infants' representations of same and different in match- and non-match-to-sample. *Cognitive Psychology, 86*, 87–111. https://doi.org/10.1016/j.cogpsych.2016.01.005.
Hochmann, J.-R., Tuerk, A. S., Sanborn, S., Zhu, R., Long, R., Dempster, M., & Carey, S. (2017). Children's representation of abstract relations in relational/array match-to-sample tasks. *Cognitive Psychology, 99*, 17–43. https://doi.org/10.1016/j.cogpsych.2017.11.001.
Hoyos, C., Shao, R., & Gentner, D. (2016). In D. Grodner, D. Mirman, A. Papafragou, & J. Trueswell (Eds.), *Proceedings of the 38th annual conference of the cognitive science society* (pp. 2507–2512). Cognitive Science Society.
Imada, T., Carlson, S. M., & Itakura, S. (2013). East–West cultural differences in context-sensitivity are evident in early childhood. *Developmental Science, 16*(2), 198–208. https://doi.org/10.1111/desc.12016.
Karadöller, D. Z., Sümer, B., Ünal, E., & Özyürek, A. (2022). Sign advantage: Both children and adults' spatial expressions in sign are more informative than those in speech and gestures combined. *Journal of Child Language*. https://doi.org/10.1017/S0305000922000642. Advance online publication.
Kauschke, C., Lee, H.-W., & Pae, S. (2007). Similarities and variation in noun and verb acquisition: a crosslinguistic study of children learning German, Korean, and Turkish. *Language and Cognitive Processes, 22*(7), 1045–1072. https://doi.org/10.1080/01690960701307348.
Koo, T. K., & Li, M. Y. (2016). A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *Journal of Chiropractic Medicine, 15*(2), 155–163. https://doi.org/10.1016/j.jcm.2016.02.012.
Kuwabara, M., & Smith, L. B. (2012). Cross-cultural differences in cognitive development: attention to relations and objects. *Journal of Experimental Child Psychology, 113*(1), 20–35. https://doi.org/10.1016/j.jecp.2012.04.009.
Loewenstein, J., & Gentner, D. (2005). Relational language and the development of relational mapping. *Cognitive Psychology, 50*(4), 315–353. https://doi.org/10.1016/j.cogpsych.2004.09.004.
Masuda, T., & Nisbett, R. E. (2001). Attending holistically versus analytically: comparing the context sensitivity of Japanese and Americans. *Journal of Personality and Social Psychology, 81*(5), 922–934. https://doi.org/10.1037/0022-3514.81.5.922.
Miller, M. R., Rittle-Johnson, B., Loehr, A. M., & Fyfe, E. R. (2016). The influence of relational knowledge and executive function on preschoolers' repeating pattern knowledge. *Journal of Cognition and Development, 17*(1), 85–104. https://doi.org/10.1080/15248372.2015.1023307.
Morrison, R. G., Doumas, L. A. A., & Richland, L. E. (2011). A computational account of children's analogical reasoning: balancing inhibitory control in working memory and relational representation: Development of analogical reasoning. *Developmental Science, 14*(3), 516–529. https://doi.org/10.1111/j.1467-7687.2010.00999.x.
Nakagawa, S., Johnson, P. C., & Schielzeth, H. (2017). The coefficient of determination R^2 and intra-class correlation coefficient from generalized linear mixed-effects models revisited and expanded. *Journal of the Royal Society Interface, 14*(134). 20170213. https://doi.org/10.1098/rsif.2017.0213.

Özcan, F. H., Altinkamiş, F., & Gillis, S. (2016). Early lexical composition of Turkish–Dutch bilinguals: nouns before verbs or verbs before nouns. *Poznan Studies in Contemporary Linguistics, 52*(4), 583–604. https://doi.org/10.1515/psicl-2016-0023.
Özer, D., & Göksun, T. (2020). Gesture use and processing: a review on individual differences in cognitive resources. *Frontiers in Psychology, 11*. 573555. https://doi.org/10.3389/fpsyg.2020.573555.
Powell, M. J. (2009). *The BOBYQA algorithm for bound constrained optimization without derivatives* (Cambridge NA Report NA2009/06). University of Cambridge.
Premack, D. (1983). The codes of man and beasts. *Behavioral and Brain Sciences, 6*(1), 125–136. https://doi.org/10.1017/S0140525X00015077.
R Core Team (2022). *R: a language and environment for statistical computing*. R Foundation for Statistical Computing.
Richland, L. E., Chan, T.-K., Morrison, R. G., & Au, T.-K.-F. (2010). Young children's analogical reasoning across cultures: similarities and differences. *Journal of Experimental Child Psychology, 105*(1–2), 146–153. https://doi.org/10.1016/j.jecp.2009.08.003.
Richland, L. E., Morrison, R. G., & Holyoak, K. J. (2006). Children's development of analogical reasoning: insights from scene analogy problems. *Journal of Experimental Child Psychology, 94*(3), 249–273. https://doi.org/10.1016/j.jecp.2006.02.002.
Sauter, M., Uttal, D. H., Alman, A. S., Goldin-Meadow, S., & Levine, S. C. (2012). Learning what children know about space from looking at their hands: the added value of gesture in spatial communication. *Journal of Experimental Child Psychology, 111*(4), 587–606. https://doi.org/10.1016/j.jecp.2011.11.009.
Senzaki, S., Masuda, T., Takada, A., & Okada, H. (2016). The communication of culturally dominant modes of attention from parents to children: a comparison of Canadian and Japanese parent–child conversations during a joint scene description task. *PLoS One, 11*(1). e147199. https://doi.org/10.1371/journal.pone.0147199.
Serraille, E., & Hochmann, J.-R. (2023). Changes in inductive biases alone cannot account for the development of analogical reasoning. *Poster presentation at Budapest CEU conference on cognitive development, Budapest, Hungary*.
Setoh, P., Cheng, M., Bornstein, M. H., & Esposito, G. (2021). Contrasting lexical biases in bilingual English–Mandarin speech: verb-biased mothers, but noun-biased toddlers. *Journal of Child Language, 48*(6), 1185–1208. https://doi.org/10.1017/S0305000920000720.
Shivaram, A., Shao, R., Simms, N., Hespos, S. J., & Gentner, D. (2023). When do children pass the relational-match-to-sample task? In M. Goldwater, F. Angorro, B. Hayes, & D. Ong (Eds.), *Proceedings of the 45th annual conference of the cognitive science society*. Cognitive Science Society.
Simms, N. K., Frausel, R. R., & Richland, L. E. (2018). Working memory predicts children's analogical reasoning. *Journal of Experimental Child Psychology, 166*, 160–177. https://doi.org/10.1016/j.jecp.2017.08.005.
Simms, N. K., & Richland, L. E. (2019). Generating relations elicits a relational mindset in children. *Cognitive Science, 43*(10). e12795. https://doi.org/10.1111/cogs.12795.
Son, J. Y., Smith, L. B., & Goldstone, R. L. (2011). Connecting instances to promote children's relational reasoning. *Journal of Experimental Child Psychology, 108*(2), 260–277. https://doi.org/10.1016/j.jecp.2010.08.011.
Starr, A., Leib, E. R., Younger Project iLead Consortium, J. W., Uncapher, M. R., & Bunge, S. A. (2023). Relational thinking: an overlooked component of executive functioning. *Developmental Science, 26*(3). e13320. https://doi.org/10.1111/desc.13320.
Starr, A., Vendetti, M. S., & Bunge, S. A. (2018). Eye movements provide insight into individual differences in children's analogical reasoning strategies. *Acta Psychologica, 186*, 18–26. https://doi.org/10.1016/j.actpsy.2018.04.002.
Tardif, T., Shatz, M., & Naigles, L. (1997). Caregiver speech and children's use of nouns versus verbs: a comparison of English, Italian, and Mandarin. *Journal of Child Language, 24*(3), 535–565. https://doi.org/10.1017/S030500099700319X.
Turan, E., & De Smedt, B. (2022). Mathematical language and mathematical abilities in preschool: a systematic literature review. *Educational Research Review, 36*. 100457. https://doi.org/10.1016/j.edurev.2022.100457.
Turan, E., Kobaş, M., & Göksun, T. (2021). Spatial language and mental transformation in preschoolers: does relational reasoning matter?. *Cognitive Development, 57*. 100980. https://doi.org/10.1016/j.cogdev.2020.100980.
Varnum, M. E., Grossmann, I., Kitayama, S., & Nisbett, R. E. (2010). The origin of cultural differences in cognition: the social orientation hypothesis. *Current Directions in Psychological Science, 19*(1), 9–13. https://doi.org/10.1177/0963721409359301.
Walker, C. M., Bridgers, S., & Gopnik, A. (2016). The early emergence and puzzling decline of relational reasoning: effects of knowledge and search on inferring abstract concepts. *Cognition, 156*, 30–40. https://doi.org/10.1016/j.cognition.2016.07.008.