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Understanding Mathematical Story Problems in Students with Dyslexia In the Context of Artificial Intelligence

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ABSTRACT

This study was driven by the challenges dyslexic students face in understanding mathematical word problems, stemming from decoding, language processing, and neurological difficulties. The research aims to describe and examine how dyslexic students comprehend math word problems with support from the Game-Math TCM AI, which provides text-to-speech and visual manipulative features. This study employed a descriptive qualitative case study involving two sixth-grade students with dyslexia selected through screening tests. Before completing five addition and subtraction word problems, the students were introduced to the AI features used in the learning activities. Data were gathered from worksheets, screen recordings of student AI interactions, and semi-structured interviews. The analysis focused on four comprehension indicators: interpreting, classifying, inferring, and comparing. Findings show that text-to-speech assisted students in understanding the problem content (interpreting), while visual manipulatives supported their ability to identify and select the appropriate operations (classifying). Both features also helped students outline the steps toward conclusions (inferring), and the visual tools enabled them to verify their understanding (comparing). Overall, the combination of text-to-speech, visual manipulatives, and guided support reduced cognitive demands and strengthened dyslexic students' understanding of math word problems through the Game-Math TCM platform.

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1. INTRODUCTION

Mathematics is a compulsory subject at the basic education level and holds a significant role in human life [1]. This discipline cultivates skills in logical reasoning, symbolic representation, and abstract thinking. Its relevance extends beyond formal classroom instruction, as mathematical ideas are inherently linked to everyday experiences [2]. Mastery of mathematics, therefore, requires not only proficiency in numerical operations but also the ability to grasp underlying concepts and solve contextual problems presented in the form of word problems.

Word problems are viewed as more challenging than problems presented in direct mathematical form because they require students to interpret and convert contextual information into an appropriate mathematical model [3]. In completing such tasks, students are expected to fully grasp the narrative context, determine which information is relevant, and apply the suitable mathematical concepts. Nevertheless, many learners continue to struggle in understanding the story context, selecting essential information, and using the correct mathematical principles to solve the problems [4].

Students' challenges in understanding word problems stem from various contributing factors. One reason students struggle with mathematical story problems is their limited ability to listen attentively, which often leads them to perceive such problems as abstract and difficult to interpret [5]. Moreover, restricted reading abilities, weak reasoning skills, and other related barriers make it difficult for students to connect verbal information with mathematical symbols and representations [6]. These challenges become even more pronounced when encountered by students with dyslexia.

Dyslexia is a language-based disorder that particularly affects reading, causing children with this condition to experience specific challenges in recognising, interpreting, and differentiating letters [7]. Students with dyslexia also struggle with encoding both numerical and alphabetical symbols [8]. Consistent with this view, dyslexia is further described as a specific learning difficulty characterised by impairments in reading, writing, spelling, speaking, and sound processing, despite being unrelated to an individual's level of intelligence [9]. This difficulty directly influences the learning process, particularly when students must work with math word problems that demand simultaneous comprehension of verbal and symbolic information. It also affects their performance across the four key comprehension processes: interpreting the problem, classifying and identifying operations using keywords, determining the steps needed to reach a conclusion (inferring), and reviewing and comparing their answers.

Based on observations conducted at a State Special School (SLBN) in Jambi City, several sixth-grade students were found to exhibit reading difficulties consistent with dyslexia. These students showed low concentration during learning and struggled to recognise letters, numbers, and simple words, as well as to read and comprehend texts. Such challenges directly affected their ability to understand mathematical story problems. They continued to face obstacles in solving these problems, particularly in reading and interpreting the meaning of the questions. These findings indicate the need for assistive technology that can reduce the reading load and support dyslexic students in understanding mathematical story problems.

With ongoing technological developments, the integration of artificial intelligence presents new possibilities for supporting the learning of students with special needs. Artificial Intelligence (AI) can assist Students With Learning Disabilities (SWLD) by providing more adaptive, personalised learning experiences [10]. This suggests that technological innovations have the potential to address many of the challenges encountered in contemporary education. Findings from Maulidin's study further indicate that AI-based learning can significantly enhance the academic performance of students with special needs, accompanied by increased engagement and improved social interaction when compared to their typically developing peers [11].

One of the artificial intelligence technologies used in this research is a web-based learning platform called Game-Math TCM, which integrates text-to-speech (TTS) and visual manipulatives. The platform is accessed on Android tablets while students work on mathematical story problems, providing multimodal support to aid text comprehension, such as enabling students to listen to the problem, visualise the objects involved, and revisit the information presented. The use of this technology is considered essential because students with dyslexia often struggle to read long passages. Previous studies have demonstrated that text-to-speech tools can enhance the reading abilities of children with dyslexia and reveal significant differences between those who use assistive technology and those who receive only verbal instruction at school [12]. These findings indicate that AI-based technologies provide meaningful benefits for students with dyslexia.

In addition to text-to-speech, visual manipulatives also support dyslexic students by helping them translate abstract ideas into more concrete representations. The use of manipulatives has been shown to positively influence student learning outcomes by promoting active engagement in mathematical activities, thereby increasing students' involvement in completing mathematical tasks. Furthermore, manipulatives can enhance students' conceptual understanding and overall achievement in mathematics [13].

Although text-to-speech features and visual manipulative tools have been widely applied to assist learners with dyslexia, research on how these two forms of support interact specifically within the context of mathematical word problems remains limited. In particular, there is still a limited understanding of how the combined use of text-to-speech and visual manipulatives supports dyslexic students' comprehension of math story problems.

Previous studies on the use of AI technology for students with dyslexia have generally emphasised final outcomes, such as gains in reading skills or improved answer accuracy, while paying little attention to the cognitive processes students engage in when solving mathematical story problems. In addition, no research has specifically described how dyslexic students make use of text-to-speech functions and visual manipulative media during the process of understanding math story problems based on the four indicators of story-problem comprehension: interpreting, classifying, inferring, and comparing. This gap highlights the need for more detailed investigations that explain how dyslexic learners process information when interacting with AI technology equipped with text-to-speech and visual manipulative features in the context of mathematical story problems.

Grounded in these identified gaps, this research explores in detail how AI technology and visual manipulative media facilitate dyslexic students' comprehension of mathematical story problems. Consequently, the study seeks to address the key question: In what ways do dyslexic students engage in interpreting, classifying, inferring, and comparing when understanding math story problems supported by AI equipped with text-to-speech and visual manipulative features?

Therefore, this study is anticipated to offer a detailed account of how dyslexic students comprehend mathematical story problems when supported by AI technology and to contribute to the advancement of inclusive learning approaches that integrate audio, visual, and digital manipulatives for students with reading challenges.

2. METHOD

This research employs a descriptive qualitative approach to portray and analyse dyslexic students' abilities to comprehend mathematical word problems in an artificial intelligence–based learning context. The study was conducted at SLBN Prof. Dr. Sri Soedewi Mascjchun Sofwan, Jambi, during the first semester of the 2025/2026 academic year. The investigation centred on students' word-problem worksheets, interview data, and the processes by which students completed the tasks, to illustrate how artificial intelligence supports dyslexic learners in understanding mathematical story problems. The study was further strengthened by systematic data analysis procedures and qualitative research techniques, which involved categorising, interpreting, and validating findings from field data.

Interventions and AI technology

The artificial intelligence used in this study is the Game-Math TCM web-based platform, accessed via an Android tablet. The AI system is equipped with several key features, including:

1. Text-to-speech (TTS)
   The AI system reads the story text at an adjustable speed, and students can replay the audio at any time, helping them manage difficulties in comprehending the written material.
2. Manipulative visual media
   Consists of visual objects that can be pressed and counted on the screen.

Research Instruments

The instruments employed in this study included a dyslexia screening questionnaire used to identify the research participants, as well as comprehension test items and interview guidelines.

1. The screening instrument adopted in this research was a questionnaire developed by [14], consisting of two forms: a student questionnaire and a teacher questionnaire. The scores from both instruments were compared, and students categorised as high risk on both were selected as the primary subjects. Meanwhile, students whose results differed between the two questionnaires were placed into a group requiring additional observation and were not included as the main participants.
2. Comprehension skill test items
   The assessment consists of five story-based items that require two-digit addition and subtraction. Each problem is presented using simple contexts, concise sentences, and familiar everyday vocabulary, and has been reviewed and validated by experts. To assess students' comprehension, the study utilised four indicators of understanding as outlined in [15], namely: (1) interpreting, (2) classifying, (3) inferring, and (4) comparing mathematical story problems.

3. Interview guidelines

Research Subject

This study involved two research participants who were selected based on the results of dyslexia screening questionnaires completed by both teachers and students. The screening identified two sixth-grade students with a high likelihood of dyslexia.

Data Collection Technique

Data collection techniques form an essential component of the research process [16]. In this study, data were collected through a dyslexia screening test involving both student and teacher questionnaires, as well as through written assessments, interviews, observations, and documentation.

Data Analysis

The data in this study were examined using the analytical procedures outlined by Miles and Huberman, which encompass data reduction, data display, and conclusion formulation. Information obtained from students' written responses, interview transcripts, and screen recordings of their tablet-based problem-solving activities was organised into thematic categories aligned with the indicators of mathematical story-problem comprehension.

Data Validation

In this research, technical triangulation was applied, namely the process of validating data from identical sources through multiple data collection techniques [16]. The triangulation procedure involved comparing results from screen recordings, students' written responses to mathematical story problems, and interview data. This process strengthened the consistency and reliability of interpretations of students' comprehension abilities.

Research Procedure

The research procedure in this study went through stages, namely:

1. The pre-field phase involved preparing the research proposal, submitting it to the supervising lecturer for approval, selecting the research site (SLBN Prof. Dr. Sri Soedewi Masjchun Sofwan, S.H, Jambi), conducting initial observations through teacher interviews, developing the research instruments, and obtaining permission from the school to conduct the study.
2. The fieldwork phase commenced with administering a dyslexia screening test to identify the research participants, followed by an introduction to the use of AI technology. The students were then given mathematical word problems to solve, assisted by AI tools and manipulatives. Interviews were also conducted during this stage. Subsequently, the researcher examined the consistency of responses across AI outputs, written work, and verbal explanations obtained during the interviews, and continued with the analysis of all collected data.

3. The data analysis phase consisted of reducing data derived from observations, tests, and interviews, organising and presenting the information, and ultimately formulating the research conclusions.

3. RESULTS

3.1. Dyslexia Screening Test Questionnaire Results

The dyslexia screening questionnaire was utilised to determine the research subjects. The instrument comprised two sections: a student questionnaire and a teacher questionnaire, to obtain a comprehensive understanding of students' learning profiles. The questionnaire included indicators of reading difficulties, errors in letter recognition, slow processing of written information, and frequent requests for repetition. The results of the dyslexia screening test are presented in the following table.

Table 1. Dyslexia Screening Test Questionnaire Results

Subject	Teacher's score	Student score	Conclusion
S1	High	High	Selected
S2	High	High	selected
S3	Low	Observation	Not selected
S4	Observasi	High	Not selected
S5	Low	Observation	Not selected

Based on the analysis, two students demonstrated high and consistent dyslexia risk scores on both the teacher and student questionnaires and were therefore designated as Subjects 1 and 2. In contrast, students whose results differed between the two questionnaires were not included as research subjects. The outcomes of the dyslexia screening served as the foundation for selecting S1 and S2 as the primary participants whose comprehension of mathematical story problems assisted by artificial intelligence would be examined.

3.2. Presentation of Subject 1 Results

Screen recordings, answer sheets, and interview data reveal that the first participant (S1) relied heavily on replaying the AI-generated audio two to three times for almost every item to understand each story problem before responding. Because S1 has reading difficulties, the student's comprehension of the story questions depended almost entirely on the auditory support provided by the artificial intelligence system, as confirmed by the interview results.

P : "Can you read back what you wrote?"
S1 : "Mmm..." (difficulty reading)"
P : "So, do you know where it came from?"
S1 : "From Ai's voice"
P : "Do you feel that Ai's voice helps you understand the question?"
S1 : "Yes, it helps."

These findings indicate that difficulties in decoding written text lead S1 to rely heavily on AI-generated audio to grasp the narrative's key points. Once the AI reads the question aloud, S1 can then interpret or translate its content more effectively. This observation is also supported by S1's statements during the interview with the researcher.

P : "What was the question about?"
S1 : "About apples."
P : "From the question read by the AI, how many apples did she have?"
S1 : "Ani had three apples."
P : "Then what happened?"
S1 : "Her mother gave her three more apples."

After listening to the AI-generated audio and attempting to interpret the problem, S1 remained uncertain about which mathematical operation to apply. Consequently, the researcher employed guiding questions and provided visual representations, both of which supported S1 in identifying the appropriate operation.

P : "Given" means what? Increased or decreased?
S1 : "Increased."
P : "Well, if the question earlier said it came again, what does that mean?
S1 : "Added."

S1 exhibited strong reasoning abilities. S1 systematically outlined the steps for solving each problem and successfully reached the correct solutions, as reflected in the answers provided.

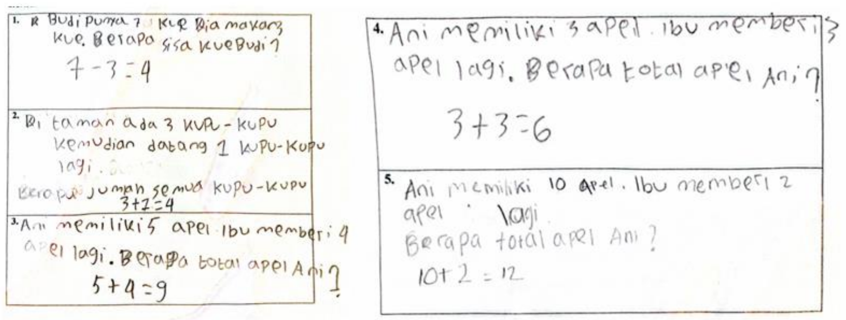

Figure 1. Results of S2 Answers at the Stage of Carrying out Research

S1 demonstrates the ability to identify given information, respond to questions, outline the steps for solving a problem, and produce accurate answers. Nevertheless, S1 often rewrites the entire problem exactly as it is read by the AI and shown on the tablet.

After completing the answers, S1 verifies their work using manipulatives. S1 recalculates the results with the support of visual manipulative tools to ensure the accuracy of the chosen answers.

3.3. Presentation of Subject 2 Results

From the screen recordings, written work, and interview results, the second subject (S2) appeared to have reasonably good reading skills, as evidenced by S2's ability to spell out sentences, although quite slowly. Even so, S2 still found it challenging to interpret the information that was read. S2 tried to understand the story problems by replaying the AI voice one or two times for almost every question before giving an answer. With support from the AI narration, S2 was able to grasp and interpret the questions, as confirmed during the interview.

P : *"Do you find it helpful when the AI reads the questions aloud?"*
S2 : *"Yes."*
P : *"When you read them yourself, how do you feel? Do you find it difficult?"*
S2 : *"Yes, it is difficult."*

This indicates that difficulties in decoding text lead S2 to depend on the AI's voice to grasp key information in the story, even though S2 can read by spelling. When the AI reads the questions aloud, S2 feels supported in interpreting their meaning. S2 then restates all the information they have understood from the questions. These observations are consistent with the findings from the interview with S2.

P : *"Did you hear what the AI read?"*
S2 : *"There were 10 butterflies."*
P : *"Then what else did it say?"*
S2 : *"8 butterflies came."*

After listening to the AI's narration and interpreting the question, S2 can promptly associate the key terms with the mathematical operation required. When the AI uses the phrase "come again," S2 can immediately infer that the appropriate operation is addition. S2 also demonstrates sound reasoning, as shown by the ability to outline procedural steps and produce the correct solution. Nevertheless, a reasoning error remains evident in S2's response to question number 1.

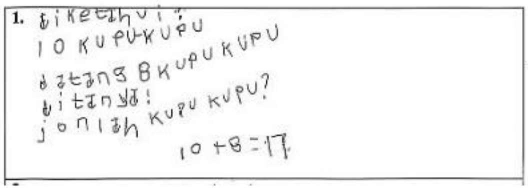

Figure 2. Results of S2 Answers at the Stage of Carrying out Research

It appears that S2 can identify the given information and respond to the questions by interpreting their meanings and outlining the steps needed to solve them. However, S2's responses still contain inaccuracies in the final conclusions. The written answers also show that S2 frequently omits certain letters when writing.

For questions two through five, S2 was able to note the known information and interpret the questions, although several letter errors were still present in the written work, particularly with letters such as "m" and "n." Despite these writing difficulties, S2 successfully selected the appropriate operation and correctly described the steps to solve the problems. The researcher's interview with S2 supported these findings.

P : *"Now, try to calculate how much is left?"*
S2 : *"2"*

P : "How did you calculate that?"
S2 : "I pressed the visual image until it turned yellow 5 times, then subtracted 3."
P : "So how many yellow visual images are there?"
S2 : "2."

After completing the answer, S2 reviews it again using the AI-provided manipulative images. S2 performs a second calculation using the visual aids to verify the accuracy of the selected answer.

4. DISCUSSION

4.1 Interpreting: The process of understanding initial information

Based on the findings, S1 replayed the audio several times for each item to grasp the information in the story problems, whereas S2 also repeated the audio, but far less frequently than S1. In their written responses, both S1 and S2 occasionally omitted certain letters when noting the given information or writing their solutions. This pattern reflects difficulties in decoding text. Students with dyslexia commonly encounter challenges in reading, writing, and encoding letters and numbers [17]. This was evident in both subjects, suggesting that the AI voice played a significant role in their interpretation of the questions.
The reliance of S1 and S2 on the AI narration further demonstrates that text-to-speech support can lessen the decoding burden and enhance reading comprehension for learners with dyslexia [12].

This indicates that the text-to-speech feature in the artificial intelligence system helps students interpret the questions more clearly. This feature is particularly beneficial for students with limited processing and translation abilities, as well as those who struggle with reading skills [18]. AI support through text-to-speech features not only assists S1 and S2 in translating the questions, but researcher guidance also contributes to their comprehension. Consequently, the interpretive abilities of S1 and S2 emerge from the combined influence of the text-to-speech system and the researcher's scaffolding.

4.2 Classifying: Selecting Operations Based on Language and Visual Content

In identifying the appropriate mathematical operations, S1 and S2 exhibited different approaches. S1 required additional support and relied on the visual representations provided by the artificial intelligence system. This need suggests that students with dyslexia benefit from visual cues to strengthen the link between action words and mathematical operations [19]. Through AI features that present text, visual images, and spoken instructions, S1 was better able to classify the required operations for each problem.

In contrast, S2 demonstrated greater independence in determining the operations. S2 relied on linguistic cues, connecting specific keywords directly to the corresponding operations. However, this process was not always consistent, as S2 occasionally depended on intuitive language patterns rather than a full understanding of the context. This occurred when S2 inferred the operation from the final word in a sentence or focused only on a single part of the question. Such tendencies align with common characteristics of dyslexia, where information is sometimes processed quickly and in fragments, increasing the likelihood of missing contextual details [9].

These findings indicate that artificial intelligence provides valuable support to children with dyslexia by offering language, visual, and auditory assistance tailored to their needs. This aligns with the multisensory approach, which integrates visual and auditory input to effectively support students with dyslexia in reading and learning [20]. In this context, the classification process for both students was influenced by the text-to-speech feature in the AI, as well as by the researcher's intervention when students were unsure how to represent their actions.

4.3 Inferring: Accuracy in Generating Final Answers

S1 and S2 demonstrated strong capabilities in presenting step-by-step problem-solving procedures coherently and logically. Both students used the AI's audio narration and the provided visual manipulative tools. The AI's integration of voice and text feedback supports cognitive processing, facilitating students' comprehension of problem sequences [21].

For S1, visual representations play a critical role in verifying calculations and guiding problem-solving. The combination of visual and auditory cues assists in deconstructing abstract mathematical concepts, enabling students to understand content that might otherwise be challenging through a structured, adaptive approach [22]. In contrast, S2 primarily relied on auditory input and progressed more rapidly to symbolic computation. Nevertheless, S2 exhibited occasional inaccuracies in drawing conclusions, consistent with the characteristic difficulties in phonological processing and lexical retrieval often observed in students with dyslexia, which can impede reading comprehension [23].

Artificial intelligence mitigates such errors by offering consistent numerical displays and supportive visual aids; however, its effectiveness depends on the students' engagement with these tools. In S1's case, both visual and concrete manipulatives were consistently employed, reinforcing understanding of procedural steps in mathematical problem solving [24].

4.4 Comparing: Verification Mechanism and Accuracy

S1 demonstrated a higher level of proficiency and consistency in monitoring and verifying their work. The student employed dual concrete representations, including visual images on the screen and physical manipulatives, to ensure the accuracy of calculations. This finding is consistent with prior research suggesting that manipulative media enhance students' precision in verifying numerical information [25], indicating that S1 strategically integrated these tools into their problem-solving process.

Conversely, S2 exhibited a distinct pattern. Although S2 also engaged with the AI-provided visual images, a degree of hesitation was evident during the verification process. S2 required more time to perform recalculations, and while comparison activities were present, they were less systematic and decisive compared to S1. These observations suggest that S2 continues to benefit from intensive guidance and repeated practice of the fundamental steps to consolidate the answer verification process effectively.

The differences in comparison skills between S1 and S2 underscore the significance of a learning approach grounded in hands-on experience and the use of concrete tools.

Manipulative media, such as visual images and counting sticks, not only facilitate students' understanding of operational processes but also enhance their ability to evaluate the accuracy of their answers. This aligns with research indicating that direct interaction with tangible tools can improve both precision and reflective skills in students when verifying their understanding [25]. These findings suggest that the integrated support of text-to-speech features, AI-based visual media, and concrete objects influences the comparatively stronger comparison skills demonstrated by S1 relative to S2. Such multimodal assistance appears essential in fostering greater independence among students with learning difficulties when validating their solutions.

4.5 Research Limitations

This study presents several limitations. First, it involved only two sixth-grade students from a single school, making the findings highly context-specific and unsuitable for broad generalisation. In addition, the study did not include a comparison group that worked without AI support, which limits the ability to distinguish the individual effects of each AI feature, such as text-to-speech, visual manipulatives, or researcher assistance. Consequently, the results should be interpreted as an in-depth portrayal of the learning processes of the two subjects, rather than evidence that can be extended to a wider population.

4.6 Practical Implications and Future Research Directions

The findings of this study offer practical implications for students with dyslexia's learning process. The integration of AI equipped with text-to-speech features supports students in comprehending story problems, while repeated voice playback and information retrieval strengthen their understanding. Additionally, the use of visual, concrete manipulatives helps students ensure the accuracy of their calculations. Teachers are also encouraged to introduce structured checking routines, particularly for students who still exhibit uncertainty at the comparing stage.

Aligned with these implications, this study opens avenues for further investigation. Future research is advised to involve a larger number of participants to obtain a more extensive depiction of comprehension dynamics and students' responses to AI-based support. The research scope may also be extended to various mathematical domains to evaluate the contribution of AI assistance across different types of problem contexts. Moreover, incorporating metrics such as the frequency of audio replays or task-completion duration may provide a more objective representation of students' cognitive processes. Consequently, future research directions have the potential to strengthen the understanding of the effectiveness and operational mechanisms of AI technology in supporting mathematics learning for students with dyslexia.

5. CONCLUSION

Based on findings from two students with dyslexia, this study shows that integrating artificial intelligence with text-to-speech features, visual manipulatives, and researcher guidance significantly supports the comprehension of mathematical story problems. The text-to-speech function reduces the cognitive load associated with decoding, the visual manipulative media clarify quantitative representations, and the researcher's guidance assists students when they encounter confusion. Each of these components contributes in different ways to the indicators of story-problem comprehension: text-to-speech facilitates the interpretation of problem content (interpreting), visual manipulative media aid in identifying information and determining the required operations (classifying), both text-to-speech and visual manipulative tools support students in outlining the steps needed to draw conclusions (inferring), and visual manipulative media help reaffirm understanding (comparing). These results reinforce the potential of adaptive, technology-assisted learning for students with dyslexia.

However, this study has several limitations, including a small sample size, the absence of a non-AI control group, and the potential influence of the technology's novelty and researcher assistance. Nonetheless, the findings provide practical insights for schools supporting students with dyslexia, particularly regarding the use of text-to-speech for story problems and the use of visual or physical manipulatives. Future research should involve larger, more varied samples, compare conditions with and without AI, and incorporate application-based interaction data, such as replay frequency or completion time, to deepen understanding of students' cognitive processes. Overall, this study contributes to the development of more inclusive and targeted instructional strategies for learners with dyslexia.

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