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The Effectiveness of Visual-Auditory Perception Training on Working Memory and Attention in Children with Dyslexia

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ABSTRACT

Background: Attention and working memory are impaired as reading correlates in children with dyslexia. This study was conducted with the aim of determining the effectiveness of auditory-visual perception training on attention and working memory in these children.

Methods: The present research was a quasi-experimental study using a pretest-posttest design. The statistical population consisted of students referred to the learning disorders centers of Afagh, Shahid Hosseinzadeh, and Arvandroud in Birjand during the academic year 2024–2025. A total of 30 dyslexic students were selected through convenience sampling and randomly assigned into experimental group (n=15) and a control group (n=15). The experimental group participated in 16 sessions of auditory-visual perception training, while the control group received no intervention. To collect data, the Diagnostic Questionnaire for Specific Learning Disorders, the abbreviated form of the Stanford-Binet Intelligence Scale (ABIQ), the N-Back test, and the Continuous Performance Test (CPT) were used. Finally, data were analyzed using multivariate analysis of covariance (MANCOVA).

Results: The results indicated a significant improvement in working memory ($F = 73.97$, $p < .001$) and attention scores ($F = 43.61$, $p < .001$) in the experimental group compared to the control group in posttest.

Conclusions: These findings suggest that auditory-visual perception training can be effectively used as an intervention method to enhance attention and working memory in children with dyslexia.

Keywords: Attention, Auditory-Visual Perception, Dyslexia, Working Memory

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Introduction

Dyslexia impairs accurate and fluent reading, comprehension, and spelling (Roitsch & Watson, 2019). The American Psychiatric Association (2013) defines it by difficulties in word recognition, decoding, and spelling, not attributable to intellectual disability, sensory, or other neurological impairments. In Iran, its prevalence is estimated at 7.5% (Sakhai et al., 2025). Its significant impact on academic achievement, self-esteem, and quality of life, highlights the critical need for intervention (Sakhai et al., 2025). Consequently, the implementation of effective educational and interventional methodologies to ameliorate the difficulties experienced by individuals with dyslexia is imperative.

Core deficits in dyslexia often involve working memory and attention, which are crucial executive functions and prerequisites for reading acquisition; their deficits contribute to the persistence of dyslexia into adulthood (Farah et al., 2021). Targeting these components is a promising intervention strategy. Regarding attention, various models have been proposed. For instance, the theory by Mayer and Kieras (1997) conceptualizes attention as comprising three fundamental dimensions: sustained attention, selective attention, and focused attention, which also encompass higher-level aspects like divided and alternating attention. Furthermore, based on (Bundesen,1990) Theory of Visual Attention (TVA), visual attention capacity involves low-level, bottom-up (stimulus-driven) and high-level, top-down (goal-directed) processes. From a research perspective, attentional deficits in children with dyslexia have been demonstrated in numerous studies (Bagheri Nia et al., 2022; Perry & Long, 2022; Valdois et al., 2022). Thus, improving attention is considered a prerequisite for enhancing reading skills.

Another key correlate of reading skill, is working memory. Various theoretical models highlight its pivotal role in reading (Baddeley, 2000; Hitch et al., 2021). For example, (Daneman & Carpenter's, 1980) model suggests that individual differences in reading comprehension reflect differences in working memory capacity, specifically the trade-off between processing and storage; inefficient cognitive processes in poor readers reduce the information maintained in working memory. The Working Memory Flexibility model (Bouchcourt & Buschman, 2019) explains how the brain maintains various types of information flexibly despite capacity limits. Research consistently shows dysfunctional working memory in dyslexia (Dos santos & Carvalho, 2024; Kim, 2021; Sinha et al., 2024). Therefore, working memory and attention can be improved through targeted educational and interventional strategies. One potential instructional method is audiovisual perceptual training.

Visual perception is the interpretation and organization of visual information for identifying stimuli (Patel etal., 2015), while auditory perception involves the reception and analysis of auditory stimuli (Dawes & Bishop, 2009). Several theories highlight visual and auditory perceptual deficits in dyslexia. For instance, the Auditory Processing Deficit Hypothesis and the Phonological Deficit Hypothesis (Tallal, 1980) propose that problems processing rapid acoustic changes impair phoneme identification and reading acquisition. In general, audiovisual perception, attention, and memory are interactive cognitive processes for detecting, selecting, storing, and processing multisensory information, all requiring direct training in children with dyslexia (Ho et al., 2024; Breadmore et al., 2024).

Several studies have employed direct audiovisual perceptual training to enhance reading skills in dyslexia (Afruzeh et al.,2022). Findings from (Siahkalroodi et al., 2009; Bucci, 2021) indicate visual perceptual training enhances reading skills. Other studies also show audiovisual perceptual training strengthens reading performance (Vatandoust et al., 2013; Magnan & Ecalle, 2009; Peters et al., 2019). While the effectiveness of this training on reading skills is well-studied, investigating its efficacy on the essential prerequisites of attention and working memory is crucial. Relatively few studies exist in this specific

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area. Among them (Ren et al., 2023; Zhao et al., 2019) found that training bottom-up and top-down attention improved visual attention capacity and reading skills. Therefore, this study's objective was to determine the effectiveness of audiovisual perceptual training on attention and working memory in children with dyslexia.

Methods

The present research was a quasi-experimental study using a pretest-posttest design. The statistical population consisted of all dyslexic male and female students in Birjand who had referred to the Afaq, Shahid Hosseinzadeh, and Arvandroud Learning Disorder Centers between November 2024 and February 2025. From this population, a sample of 30 participants was selected via convenience sampling and was randomly assigned to either an experimental group (n=15) or a control group (n=15). The experimental group underwent 16 sessions of audiovisual perceptual training, whereas the control group received no intervention. The sample size was determined based on a power analysis for Multivariate Analysis of Covariance (MANCOVA), considering an alpha level of 0.05, two assessment time points, and a statistical power of 0.95. In this study, all ethical principles were observed. Parents and participants were fully informed about the research objectives and procedures. They were also assured of the confidentiality of their information and were free to withdraw from the study at any time. Written informed consent was obtained from all the participants/parents, and the study was approved by the Ethics Committee of the University of Birjand.

The inclusion criteria were as follows: diagnosis of dyslexia by a specialist examiner based on the DSM-V diagnostic criteria; confirmation of a dyslexia diagnosis based on the Specific Learning Disorder Diagnostic Questionnaire and teacher interviews; an IQ score greater than 85 according to the short form of the Stanford-Binet Intelligence Scales, Fifth Edition; absence of physical and neuropsychological disorders; completion of the consent form; and absence of a diagnosis of Attention-Deficit/Hyperactivity Disorder based on interviews with parents/teachers. The exclusion criteria included: the child's unwillingness to cooperate or irregular attendance in the sessions, lack of parental consent and cooperation, and concurrent receipt of other psychological interventions during the study period.

Initial screening of the children was conducted through interviews with teachers/parents, administration of the Specific Learning Disorder Diagnostic Questionnaire, review of DSM-V diagnostic criteria, and assessment of reading performance via the oral reading of a standardized text from the Exceptional Education Organization of Iran, as well as several passages from various sections of their textbooks.

During the first session, initial assessments and pretests were administered. The experimental group subsequently received 16 sessions of individual visual-auditory perception training, while the control group received no intervention. A posttest was conducted at the final training session. After the completion of the research, the control group received 5 free visual-auditory perception training sessions. It should be noted that one participant from the experimental group was lost to attrition during the study and was replaced by another individual. The attrition occurred after the 10th session, and the participant dropped out due to relocation to another city, which made continued attendance in the in-person sessions impossible.

Intervention

The training package was developed based on exercises and the protocol established by Vatandoust et al. (2013). Additionally, the content validity of the package was assessed by 8 psychology experts using the Content Validity Ratio (CVR) and Content Validity Index (CVI), which yielded values of 0.79 and 0.88, respectively. Each session had aduration of 60 minutes. The intervention was administered over a period of 8 weeks, with a frequency of two sessions per week. Table 1 shows the content of audiovisual perceptual training sessions (Table 1).

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Table 1. Visual-auditory perception training package for working memory and attention in dyslexic children

Session No.	Session content	Session goals	Sample task
1	Visual-auditory attention and focus	Enhancing attention	**Visual:** Counting words, short and long sentences with and without word omissions. **Auditory:** Counting the number of claps or taps on the table with eyes open and closed.
2	Visual-Auditory discrimination	Enhancing visual-auditory sensitivity	**Visual:** Finding a specific shape/image/object among other shapes/images/objects. **Auditory:** Identifying environmental (non-verbal) sounds.
3	Visual-auditory constancy	Stabilizing visual-auditory processing	**Visual:** Showing geometric shapes and letters in different positions and orientations. **Auditory:** Discriminating sounds heard from different directions.
4	Visual-auditory figure-ground perception	Discriminating shape and sound from Background	**Visual:** Finding a specific shape among overlapping shapes; Visualizing objects and their background. **Auditory:** Focusing on a noisy environment and identifying a specific sound among the heard sounds.
5	spatial relations	Enhancing spatial relations	**Concrete:** Generalizing left and right to surrounding objects based on the child's body axis. **Semi-concrete:** Discriminating the spatial position of images and shapes relative to each other (e.g., ability to discern that a square is above a triangle and is placed diagonally).
6	spatial relations	Enhancing spatial relations	**Concrete:** Recognizing relationships and lines in alphabet letters and numbers. **Semi-concrete:** Recognizing the position of objects relative to each other (concepts of left and right, before and after).
7	direct visual memory and sequence (recognition and recall)	Enhancing visual working memory	**Recognition memory without sequence:** Identify and separate 3 previously seen images from among 6 images. **Recognition memory with sequence:** Separate 3 previously seen images from among 6 images and arrange them in order. **Recall without sequence:** Show 6 images, then after 30 seconds, name them. **Recall with sequence:** Show 6 images, then after 30 seconds, name them in order.
8	reverse visual memory and sequence (recognition and recall)	Enhancing visual working memory	**Reverse Visual processing Sequence:** Arrange the following sequence of words from the last letters of the alphabet to the first. **Reverse working memory:** Remember and state the last image of each row from three rows of four shapes. **Reverse recall without sequence:** Separate 3 previously seen images from among 6 images and arrange them in reverse order without maintaining the original sequence.
9	direct auditory memory and sequence (recognition and recall)	Enhancing auditory working memory	**Simple memory:** Stating the sequence of played non-verbal sounds. **Direct sequence Memory:** Stating the sequence of played non-verbal sounds in order.

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Table 1. Visual-auditory perception training package for working memory and attention in dyslexic children

Session No.	Session content	Session goals	Sample task
10	reverse auditory memory and sequence (recognition and recall)	Enhancing auditory working memory	**Recognition memory:** From 6 presented words, recognize and identify the third word. **Recall memory:** The child is asked to repeat a set of 4 items after hearing them. **Reverse sequence memory:** Stating the played non-verbal sounds in reverse order.
11	concept formation (categorization)	Combining and integrating visual-auditory input	**Visual:** Finding a common feature in a group of objects or images (e.g., chair). **Auditory:** Ability to combine several words and form a sentence.
12	Visual-auditory-tactile coordination	enhancing Sensory integration	Hopping and jumping on specific markers (e.g., markers with a dot) and words.
13	auditory-motor coordination	Enhancing sensory integration	Moving forward-backward and left-right according to the instructor's count from 1 to 10 and vice versa.
14	visual-auditory closure	Enhancing visual-auditory closure	**Visual:** Completing incomplete images and shapes; solving puzzles; drawing shapes by connecting dots; playing tangrams. **Auditory:** Completing heard words, sentences, and stories.
15	visual-auditory patterning	Discriminating visual-auditory patterns	**Visual:** Using images, objects, geometric shapes, and numbers. **Auditory:** Discriminating auditory patterns, finding phonetic patterns.
16	Post-treatment assessment	assessment	

Data collection instruments: The data collection instruments used in this study included The Stanford-Binet Intelligence Scales-Fifth (SB-5), the Continuous Performance Test, the N-back, and the Specific Learning Disorder Diagnostic Questionnaire.

Stanford-Binet Intelligence Scales, Fifth Edition (SB-5): The SB-5 was developed by Roid in 2003. This instrument is utilized for assessing the intelligence of individuals aged 2 to 85 and comprises ten subtests. The overall mean composite score is 100, with subtest means set at 10, and standard deviations of 15 and 3, respectively. The SB-5 measures two domains, verbal and nonverbal, each of which contains five subtests: fluid reasoning, knowledge, quantitative reasoning, visual-spatial processing, and working memory. The reliability coefficients for the ten subtests range from 0.84 to 0.89 (Gibbons & Warne, 2019). The Abbreviated Battery IQ (ABIQ) of the Stanford-Binet Intelligence Scales consists of two scales: verbal knowledge (vocabulary) and nonverbal fluid reasoning (object series/matrices). The correlation between the ABIQ and the Full Scale IQ has been reported as r = 0.89 (Twomey et al., 2018). In the present study, the abbreviated form was employed to estimate IQ, and the Cronbach's alpha for the ABIQ in this study was 0.87.

Specific Learning Disorder Diagnostic Questionnaire: This scale was developed and standardized by (Alizadeh et al., 2023). The questionnaire consists of two sections with yes/no response options, where a score of 1 is assigned to "yes" and 0 to "no." The first section comprises 9 items; if a student exhibits at least one of the symptoms described in these 9 items for a minimum duration of six months, they are identified by the teacher as having a specific learning disorder. The second section includes 30 items based on indicators of specific learning disorders in mathematics, written expression, and reading. A positive response to at least one item in

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the second section indicates the presence of the respective learning disorder(s) (reading, writing, or mathematics). Furthermore, the reported Cronbach's alpha coefficients for the first and second sections were 0.72 and 0.87, respectively (Alizadeh et al., 2023). The Cronbach's alpha for this questionnaire in this study was 0.89.

Continuous Performance Test (CPT): The Continuous Performance Test was developed by (Hadianfard et al., 2001) and used for children aged 6 and older. This computer-administered test comprises two sets of stimuli (either pictures or numbers), each consisting of 150 images. The scores derived from this test include the number of correct responses, commissions (responses to non-target stimuli), omissions (failures to respond to target stimuli), and reaction time in milliseconds. In this study, the number of correct responses was measured. The test-retest reliability coefficients for various components of the test over a 20-day interval ranged from 0.59 to 0.93, all of which were significant at the $p < 0.001$ level. Furthermore, its discriminant validity in differentiating typically developing students from those with attention-deficit/hyperactivity disorder has been confirmed (Hadianfard et al., 2001). The Cronbach's alpha for the overall score in this study was 0.82.

N-Back Test: This test was initially introduced by Krchner in 1958 for the assessment of working memory. While it can be adapted, its core paradigm is suitable for school-aged children and adolescents. The Persian version of this test comprises 120 numbers. In this task, numbers from 1 to 9 are presented randomly on a screen with a 2-second interval. The participant is required to determine, across multiple levels, whether the currently presented stimulus matches the stimulus presented 'n' trials back; and increasing the 'n' value increases task difficulty. At the 1-back level, if the presented stimulus matches the one immediately preceding it, the participant presses the right key; otherwise, the left key is pressed. At the 2-back level, the comparison is made with the stimulus presented two trials earlier. Due to the young age of the participants in this study, the more difficult level (3-back) was not administered. The total score is derived from the sum of correct responses, with incorrect responses and omissions subtracted. According to studies by (Kane et al., 2007) the Cronbach's alpha for this test ranges between 0.54 and 0.84, indicating acceptable validity. The estimated Cronbach's alpha for this test in Iran is 0.78 (Nahravanian et al., 2018). The Cronbach's alpha for the overall score in this study was 0.80.

Data analysis was performed using Multivariate Analysis of Covariance (MANCOVA) in SPSS software version 26.

Results

The mean age of the control and experimental groups was 9.33 ± 1.54 and 9.87 ± 1.59, respectively. Furthermore, the mean IQ of the control and experimental groups was 92.27 ± 5.25 and 90.60 ± 1.85, respectively. Additionally, the mean education level of the control and experimental groups was 3.33 ± 1.34 and 3.07 ± 1.49, respectively. Independent samples t-tests indicated no significant differences between the two groups in the demographic variables of age ($t = 0.81$, $p = 0.697$), IQ ($t = 0.51$, $p = .651$), and education level ($t = 0.82$, $p = 0.603$). Regarding gender, 60% (n=9) of the control group and 66.7% (n=10) of the experimental group were male, with no significant difference between the groups ($X^2 = 0.14$, $p = .705$). Descriptive indicators show that the mean scores of working memory and attention for the experimental group increased more in the post-test stage compared to the control group (Table 2).

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Table 2. Descriptive statistics for research variables at pre-test and post-test stages

Dependent variable	Measurement stage	Groups	Mean (standard deviation)
Attention	Pre-test	Experimental	264.80 (12.57)
	Pre-test	Control	263.66 (11.52)
	Post-test	Experimental	280.60 (11.38)
	Post-test	Control	265.66 (10.74)
Working memory	Pre-test	Experimental	71.20 (10.44)
	Pre-test	Control	73.20 (10.48)
	Post-test	Experimental	92.73 (9.26)
	Post-test	Control	74.00 (7.69)

Subsequently, the assumptions of MANCOVA were examined: univariate normality assessed via the Kolmogorov-Smirnov test showed only the working memory variable for the experimental group at post-test was not normal ($p < .05$), leading to a Box-Cox transformation; multivariate normality assessed via Mahalanobis distances was met (max distance = 12.13 < critical 18.47); the homogeneity of variance-covariance matrices assessed via Box's M test was violated ($p < .0001$), leading to the use of Pillai's Trace instead of Wilks' Lambda; the homogeneity of variances assessed via Levene's test was not violated for attention and working memory ($p > .05$); and finally, the assumption of regression slope homogeneity was met, as there was no significant interaction between group membership and the covariate ($p > .05$).

In the final stage, MANCOVA was conducted. A significant difference was found in the linear combination of working memory and attention between the experimental and control groups (Pillai's Trace = 0.88, $F_{(2, 25)} = 41.98$, $p < .001$) (Table 3).

Table 3. Results of MANCOVA for group effects on working memory and attention

Effects	Multiple tests	Value	F	Hypothesis df	Error df	Sig.	Eta squared
Pre-test memory	Pillai's Trace	0.77	19.40	2	25	0.001	0.77
	Wilks' Lambda	0.23	19.40	2	25	0.001	0.77
	Hotelling's Trace	3.37	19.40	2	25	0.001	0.77
	Roy's Largest Root	3.37	19.40	2	25	0.001	0.77
Pre-test attention	Pillai's Trace	0.79	21.61	2	25	0.001	0.79
	Wilks' Lambda	0.21	21.61	2	25	0.001	0.79
	Hotelling's Trace	3.76	21.61	2	25	0.001	0.79
	Roy's Largest Root	3.76	21.61	2	25	0.001	0.79
Group	Pillai's Trace	0.88	41.98	2	25	0.001	0.88
	Wilks' Lambda	0.12	41.98	2	25	0.001	0.88
	Hotelling's Trace	7.30	41.98	2	25	0.001	0.88
	Roy's Largest Root	7.30	41.98	2	25	0.001	0.88

To determine which specific variable(s) contributed to the significant difference, follow-up univariate Analyses of Covariance (ANCOVAs) were conducted. As shown in Table 4, after controlling for pre-test scores, significant differences were found between the experimental and control groups in working memory ($F_{(1, 26)} = 73.97$, $p < .001$, partial $\eta^2 = 0.74$) and attention ($F_{(1, 26)} = 43.61$, $p < .001$, partial $\eta^2 = 0.62$). Eta squared shows that 74% and 62% of the difference between the two groups in the variables of working memory and attention, respectively, are due to the intervention provided (Table 4).

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Table 4. Results of ANCOVA for each dependent variable

dependent variable	Source	Sum of squares	df	Mean squares	F	Sig.	Eta squared
Working memory	Pre-test	750.58	1	750.58	19.07	0.001	0.42
	Group	2910.70	1	2910.70	73.97	0.001	0.74
	Error	1023.12	26	39.35			
Attention	Pre-test	2469.26	1	2469.26	72.13	0.001	0.73
	Group	1489.11	1	1489.11	43.61	0.001	0.62
	Error	887.21	26	34.15			

Discussion

This study aimed to determine the effectiveness of audiovisual perceptual training on the working memory and attention of dyslexic children. The findings revealed that audiovisual perceptual training led to a significant improvement in the working memory and attention of dyslexic children. This finding can be contextualized by comparing it with other intervention studies. For instance, a meta-analytic review by (Peters et al., 2019) on visuo-attentional interventions reported moderate effect sizes on cognitive measures related to reading. The large effect size observed in the present study suggests that the integrated audiovisual perceptual training protocol, which simultaneously targets both visual and auditory modalities, may be particularly potent for enhancing working memory and attention in dyslexia compared to interventions focusing on single modality. However, direct comparisons should be made cautiously due to variations in intervention protocols, sample characteristics, and outcome measures across studies.

The findings of this study regarding attention improvement are consistent with previous research, such as the studies by (Ren et al.,2023; Zhao et al.,2019) which indicated that audiovisual attention training can enhance the attentional capacity of children with dyslexia. Furthermore, the results are partially aligned with the findings of (Afrouz et al., 2022; Same, 2009) who reported that audiovisual perceptual training leads to improvements in reading and comprehension performance. According to (Bundesen, 1990), the exercises employed in this research (e.g., detecting visual stimuli in cluttered arrays or identifying specific sounds in noisy environments) directly increase the sensitivity of the attentional system to salient stimuli.

The second finding of this study revealed that audiovisual perceptual training led to a significant improvement in the working memory. The results provided empirical support for the proposed mechanisms in previous studies. Specifically, studies by (Vatandoust et al., 2013; Magnan & Ecalle, 2009; Bucci, 2021; Peters et al., 2019) demonstrated that audiovisual perceptual training enhances reading skills in children with dyslexia, suggesting that improvement in working memory may be a contributing factor. The findings directly confirm this proposition by showing a significant, training-induced enhancement in working memory performance itself. This outcome can be explained by (Baddeley, 2000; Hitch et al., 2021). and the model of working memory flexibility (Bouchacourt & Buschman , 2019). The models posit that working memory is a dynamic system that can be strengthened through targeted training.

This study had several limitations: First, the relatively small sample size, selected via convenience sampling from a specific geographical region (Birjand), limits the statistical power and restricts the generalizability of the findings to the broader population of children with dyslexia. Second, the lack of control for certain confounding variables, such as home environment and other educational methods, could have influenced the outcomes. Additionally, the absence of a follow-up period limited the ability to investigate the long-term efficacy of this intervention. Consequently, it is recommended that future studies employ larger and more diverse samples from different geographical regions to enhance the generalizability of the findings. Furthermore, it is

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suggested that a follow-up period be incorporated to assess the long-term stability of the intervention effects. Also, the impact of combining this method with other cognitive and educational interventions, such as phonological awareness training, structured literacy approaches (e.g., the Orton-Gillingham method), or other executive function training, on the reading and writing skills of dyslexic children should be investigated.

Conclusion

The findings of this study demonstrate that audiovisual perceptual training is an effective intervention for significantly improving both working memory and attention in children with dyslexia. These results underscore the potential of audiovisual perceptual training as a valuable non-pharmacological approach to address the underlying cognitive deficits associated with dyslexia. By enhancing these fundamental skills, such interventions can contribute to improving reading acquisition and overall academic outcomes for affected children.

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Conflict of interest

The researchers declared no conflict of interest.

Ethical considerations

All ethical considerations have been observed.

Code of ethics

IR.BIRJAND.REC.1404.007

Authors' Contributions

N.S and M.R conceived the idea presented in this paper and developed the theory and performed the calculations. M.HS and M.R validated the analytical methods. N.S. was involved in the investigation of a specific aspect and supervised the findings of this study. All authors discussed the results and contributed to the final manuscript.

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