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Intervention to Enhance Cognitive Development Underpinning Reading for Japanese Preschool Children

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Abstract

This study aimed to examine the effects of intervention through a cognitive educational program based on previous research and conducted it on a class of nursery preschoolers. To examine the effects of the intervention, two measures of cognitive abilities (Flanker task / PASS Rating Scale) were administered pre- and post-intervention. We analyzed the activity review sheets filled by children after each session. As a result, the size of interference effects on the response time of the Flanker task in post-intervention decreased compared with that in pre-intervention and the scores of the PASS Rating Scale in post-intervention were higher than that in pre-intervention. Additionally, analyses of the activity review sheets indicated that the descriptions of "content of activity" and "strategy" tended to increase as the sessions progressed. Changes in measures of cognitive abilities suggest that the intervention played an important part in enhancing preschoolers' cognitive abilities. The result of reflection suggests the fact that we actively provided opportunities to interact with instructors and classmates while verbalizing the contents and strategies of activities during sessions. These results suggest the positive impact of class-wide intervention of cognitive enhancement programs among preschoolers.

Keywords: preschool children, cognitive education, reflection on activities

Introduction

The significance of early detection and assistance for children with developmental disabilities and those who require learning support is crucial in establishing a link between early childhood cognitive abilities and academic learning. Several studies highlighting this correlation have stressed the importance of interventions to bolster cognition and subsequent academic success. They examined the effectiveness of various cognitive-enhancing programs for preschoolers and revealed that group programs are more effective than individual ones (Scionti et al., 2020), and that effective programs are characterized by an emphasis on interaction with others (Yoshikawa et al., 2013).

An instructional facilitation program featuring the above characteristics is Cognitive Enhancement Training (COGENT; Das, 2006) based on the PASS theory of intelligence (Das et al., 1994). This theory is based on Luria's (1966) theory of functional brain units and assumes four cognitive processes: planning, attention, simultaneous processing, and successive processing. These processes are interdependent, and previous studies have highlighted their connection to learning achievement. While all cognitive processes relate to learning, research suggests that challenges crucial to learning often arise in the presence of biases or difficulties in the information encoding styles, such as in simultaneous or successive processing (Das, 2009; Wang et al., 2012; Keat et al., 2020).

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COGENT, designed to enhance cognitive function, phonological awareness, and language function related to reading, focuses on children aged 4-7 with typical and at-risk development (Das, 2009). This system accommodates groups of up to 10 students and has been successfully employed by multiple instructors in classroom settings. Various instructional programs based on the PASS theory of intelligence have proven effective (Cordero-Arroyo et al., 2021), and the intervention effects of COGENT have been demonstrated in several studies. Das et al. (2006) and Hayward et al. (2007) reported improvements in reading achievement among 4- to 7-year-old orphaned children in India and indigenous children in Canada, respectively. In Japan, the implementation of a regular first-grade elementary school class (Hirai et al., 2009), and paired learning for preschoolers (Aoki et al., 2013) reported improvements in reading performance post-instruction.

Cognitive enhancement programs that emphasize social interaction include Tools of the Mind (TOOLS; Bodrova & Leong, 2007) based on Vygotsky's developmental theory suggesting the significance of self-regulation abilities for developing higher mental functions such as attention, memory, and thinking. Self-regulation and executive function are also related to the planning (Johnson & Maricle, 2022). According to Vygotsky, children develop external speech through social interaction, eventually internalizing it as a thinking tool. TOOLS does not directly teach preschoolers letters and other knowledge through drills and printouts but focuses on nurturing self-regulation during learning (Bodrova & Leong, 2007). Based on Vygotsky's theory, this program emphasizes verbal interaction to promote a child's self-regulation. One prominent activity within TOOLS reflecting these principles is Buddy Reading (Diamond et al., 2007).

Several reports have underscored the efficacy of TOOLS. Blair et al. (2018) implemented the program with preschoolers and found that when compared to a control group, problem behaviors and aggression were reduced and self-regulation, social-emotional competence, and positive teacher-child relationships were improved. Solomon et al. (2018) noted significantly higher executive functioning in 3- to 4-year-olds with ADHD compared to the control group after implementing the program. Additionally, Diamond et al. (2019) reported significant behavioral improvements in preschoolers following the intervention.

Diamond et al. (2007) suggested the integration of TOOLS initiatives into daily activities, advocating a combined approach with COGENT tasks under TOOLS instructional policy. Additionally, they proposed a class-wide implementation of this program in nursery schools where interaction with the teacher and other children is frequent. From a practical standpoint, expanding cognitive enhancement programs to reach more children is crucial. While Japan has conducted surveys to foster children’s cognition (National Institute for Educational Policy Research, 2023), there is a lack of studies in Japan demonstrating the effectiveness of class-wide interventions utilizing COGENT or TOOLS for preschoolers.

This study implemented an instruction program combining TOOLS and COGENT to enhance cognitive development in preschoolers. Specifically, COGENT tasks were implemented in class-wide instruction while focusing on relating to children in TOOLS. The purpose of this study was to examine the effectiveness of cognitive-enhancing instructions by evaluating the learning and cognitive abilities before and after intervention implementation by analyzing the sheets completed by the children.

Method

Participants

The study involved 20 preschoolers (M=68.5 months, SD＝3.09) from a private nursery school. This group excluded children with diagnosed developmental disabilities or children whose native language was not Japanese. The nursery program involved daily activities, including printouts of letters, numbers, figures, and flashcards featuring letters and words. These activities aim to provide consistent exposure to letters as part of the children's daily routine.

Evaluation Before and After the Program

Assessment of learning: The participants' reading and writing ability was assessed using the Japanese reading ability test for preschoolers and pupils (edited by Yoshonen Kenkyujo, 1973). The test assesses the ability to learn to read and recite letters and sentences. It comprises six subtests, which measure the level of letter-reading ability, passive vocabulary, understanding of shapes, and phonological awareness. A reading ability T-score is calculated from the subtests' results.

Assessment of cognitive background (EF): Following Diamond et al. (2007), we evaluated EF by conducting a flanker task developed for preschoolers by modifying the one proposed by Rueda et al. (2004). It was administered to assess self-regulation. A fixation displayed in the center of the screen was presented for 2,000 ms; then, each stimulus was presented for up to 12,000 ms. In the task, the congruent and incongruent stimuli were randomly presented 20 times each. Each stimulus was controlled using Super Lab 4.5 (Cedrus Corporation) and displayed on a laptop or PC.

The children responded by pressing the key for the direction (left or right) that the middle fish was facing. Diamond et al. (2007) recommended that participants should not rush their responses. The test administrator provided verbal feedback regarding the children's responses for each test session. The children were offered a chance to practice their responses before beginning the task.

Assessment of cognitive background (cognitive processing): The nursery teacher answered questions from the PASS rating scale (PRS; Naglieri & Pickering, 2003) to assess cognitive traits. The teacher rated 18 items concerning children's attention, and simultaneous and successive processing (six items each) on a four-point scale: 0 (Never), 1 (Sometimes), 2 (Often), and 3 (Frequent).-Since planning abilities are less developed than the other three cognitive processing measures in early childhood, our assessment focused on simultaneous processing, successive processing, and attention. PRS is an informal rating scale; thus, this assessment was used to compare scores before and after intervention.

Program Tasks

We selectively conducted Modules 1 (Squeeze and Say) and 2 (Clap and Listen) of the five COGENT task modules for enhancing self-regulation, and simultaneous and successive processing with high impact on reading difficulty (for details, see Das et al., 2006). As per the guidelines, module 1 requires a response to the presented stimulus: for example, "clap your hands when a picture of an animal is shown," or "do not clap your hands when a picture of a fruit is shown." Module 2 requires a response to a specific stimulus from a series of sounds or words. Initially, both modules required only a motor response; afterwards, both motor and verbal responses were required. Finally, only a motor response was required for more complex stimuli. Thus, the level of difficulty increased as the task became more complex.

Program Process

Duration and frequency of sessions: Two to three sessions were conducted per month from June to October, 20XX, amounting to1 pre-session and 10 full sessions. Each session lasted about 30 minutes, during which several tasks were performed. The first author acted as the main instructor and requested assistance from the nursery teacher as needed.

Flow of each session: (1) Reviewing the previous session: the instructor prompted the children to reflect on their prior tasks and strategies. They were asked to recall their activities from the previous session and assess their improvement. The instructor facilitated an open discussion, emphasizing verbal expression to allow the children to articulate their thoughts and experiences. (2) Performing the tasks: all the children performed the tasks in the COGENT modules simultaneously under the guidance of the instructor. Before beginning the task in each session, the instructor explained the task and asked the children what activity they were about to undertake and how they could approach it effectively

(repeating these questions after the task as well), thereby allowing the children to respond to questions in words. Based on the "Buddy Reading" (Diamond et al., 2007) approach from TOOLS, the instructor made arrangements for the children to easily understand their respective roles. Each child participating in the activity wore a card with an illustration. The child who responded and listened to the question similarly hung a card with an illustration of a mouth and ear, respectively. In the first half of the intervention period, the instructor asked questions, and the children listened and responded to them. In the second half, the instructor provided the children with the opportunity to play the role of questioner, thereby facilitation a situation in which the children could experience a role change. (3) Filling out the activity review sheet: Bodrova and Leong (2007) recommended that activities be documented in the form of pictures or words. Thus, after each session ended, the instructor asked the children to write the activities they had performed during the session on a blank A4 sheet ("the activity review sheet") along with how they could have performed better. No restrictions were placed on the expressive means or entry form of the response.

Principles of interaction with children: In principle, the instructor (a) avoided teaching children how and what to do directly; (b) the instructor attempted to be aware of the children's Zone of Proximal Development (ZPD; Vygotsky, 1987), which COGENT and TOOLS emphasize, by asking questions such as "What do you do next?" or "Can you do it in different ways?"; and (c) depending on the children's responses to the task questions, they emphasized attention to others (e.g., "How are your friends doing it?"), presented a model (e.g., "You did it this way before?"), or framed a choice (e.g., "Which do you think is the better way, A or B?").

Analysis

Before and after the program, several measures were gauged. These included the reading ability T-score of the class, and the mean and standard deviation for the reading ability step-ratings for each item. Moreover, a t-test of the T-score and step-ratings was conducted. In the flanker task, the percentage of correct responses, response time, mean, and standard deviation were calculated pre- and post-program for the congruent and incongruent stimuli. Additionally, a t-test was conducted. Furthermore, the size of interference effects in the percentage of correct responses and response time (Holmes & Pizzagalli, 2007) were calculated, and a t-test was conducted. The mean and standard deviation in the PRS were also calculated, and Wilcoxon signed-rank sum test was conducted. SPSS Statistics ver. 27 was used for statistical processing.

To analyze signs of development in planning abilities, the children's responses in the children's activity review sheets were categorized and the percentage of responses falling within each category was calculated (the number of children who described a specific response divided by the number of children × 100 (%)). Drawing from Das and Misra's work (2014), children's responses were categorized into four content types: (1) content of the activity, (2) strategy for doing well, (3) schedule from the whiteboard, and (4) feeling about the activity. Furthermore, they were categorized into three description methods: (a) letter-only description, (b) picture-only description, and (c) both letter and picture description.

Ethical Considerations

This research was approved by the Research Ethics Committee of the authors' institution (Approval No. Tsuk29-167). The study purpose and methods were explained both orally and in writing to the participants' caregivers and the principal of the nursery school. Subsequently, written consent was obtained from them. The authors have no competing interests to declare. Due to the nature of the research and the pertaining ethics, supporting data is not available.

Results

Japanese Reading Ability Test for Preschoolers and Pupils

Table 1. Result of Japanese Reading Ability Test for Preschoolers and Pupils

	pre-assessment		post-assessment		significant difference	effect size (d)
	M	SD	M	SD		
Japanese reading ability test						
T-score	62.6	5.29	60.75	4.98	NS	0.37
Subtest						
1. Word understanging	3.3	.80	3.5	0.61	NS	-0.2
2. Undestanding of shapes	4.2	.75	4.4	0.75	NS	-0.29
3. Separation of syllables	4.2	1.11	4.3	1	NS	-0.04
4. Identification of syllables	4.0	.65	3.5	1	NS	0.39
5. Letter recognition	4.4	.81	4.3	0.79	NS	0.13
6. Understanding of sentences	4.0	.76	4.1	0.6	NS	-0.22

* p＜.05 ** p＜.01

Table 1 shows the pre-and post program reading ability test results. The meaning of the reading ability T-score and the means of the step-rating scores for each subtest before and after the program indicate no significant difference and a small effect size.

Flanker Task

Table 2. Result of Flanker Task

	pre-assessment		post-assessment		significant difference (p)	effect size (d)
	M	SD	M	SD		
percentage of correct responses [%]						
congruent	99.3	1.83	98.3	3.73	NS	.26
incongruent	94.0	14.56	96.3	4.83	NS	-.15
response time [ms]						
congruent stimuli	1310.10	515.42	980.43	246.09	**	.68
incongruent stimuli	1649.97	867.57	1066.63	298.54	**	.83

* p＜.05 ** p＜.01

Table 2 shows the pre- and post-program flanker task results. The percentage of correct responses to the congruent and incongruent stimuli before and after the program shows no significant difference and a small effect size. The interference effect size was 5.3 (SD = 14.19) before and 2.0 (SD = 4.10) after the program, showing no significant difference ($p > .05$) and a small effect size ($d = 0.24$).

The response time for the congruent stimuli before and after the program shows significant differences and a medium effect size. The response time for the incongruent stimuli before and after the program shows a significant difference and a large effect size. The interference effect size was 339.87 (SD = 553.29) before and 86.20 (SD = 123.28) after the program, showing a significant difference ($p < .05$) and medium effect size ($d = .50$).

PASS Rating Scale

Table 3. Result of PASS rating scale

	pre-assessment		post-assessment		significant difference	effect size (r)
	M	SD	M	SD		
Simultaneous processing	15.5	3.5	17.1	1.3	*	0.47
Successive processing	15.0	3.7	17.3	1.5	*	0.57
Attention	15.0	3.4	14.5	3.5	NS	0.11

* $p<.05$ ** $p<.01$

Table 3 shows the PRS results pre- and post-program. The simultaneous processing scores before and after the program indicate significant differences and a medium effect size. The successive processing scores before and after the program suggest significant differences and a large effect size. The attention scores before and after the program indicate no significant difference and a small effect size.

The Activity Review Sheets

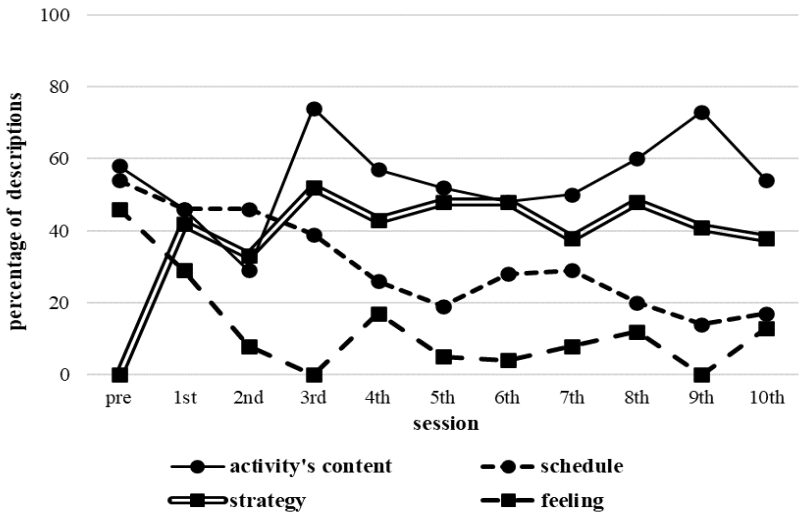

Figure 1. The transitions of the description contents of the children's activity review sheet responses

Figure 1 illustrates the transitions in the description contents of the children's responses in the review sheet activity after each session. After the pre-session, the instructor asked them to describe what they had done. As instructed, 56% of children described the activity's contents; however, 44% described their feelings about the activities, and 52% recorded the schedules described on the whiteboard.

In the first session, the children were also asked to describe the strategies. Forty percent of the children described the strategies (which had not been described after the pre-session). In the third session, the children were presented with activity review sheets completed by their peers in the previous session. Consequently, 74% of children wrote about the activity's contents and 52% wrote about strategies. Subsequently, approximately 40–50% of children continued describing the activity contents and strategies with minor fluctuations. In the eighth session, prior to completing the activity review sheets, the children were asked what they would write when expressing themselves. Subsequently, 58% of children described the activity contents, and 46% focused on the strategies, showing a slight increase compared to earlier sessions. In the ninth session, the instructor interacted with the children and presented activity review sheets of their peers, resulting in 70% of the children describing the activity contents. Throughout the sessions, the proportion of children discussing activities and strategies remained consistently high, displaying some fluctuations, whereas the number

of children addressing schedules and feelings decreased progressively throughout.

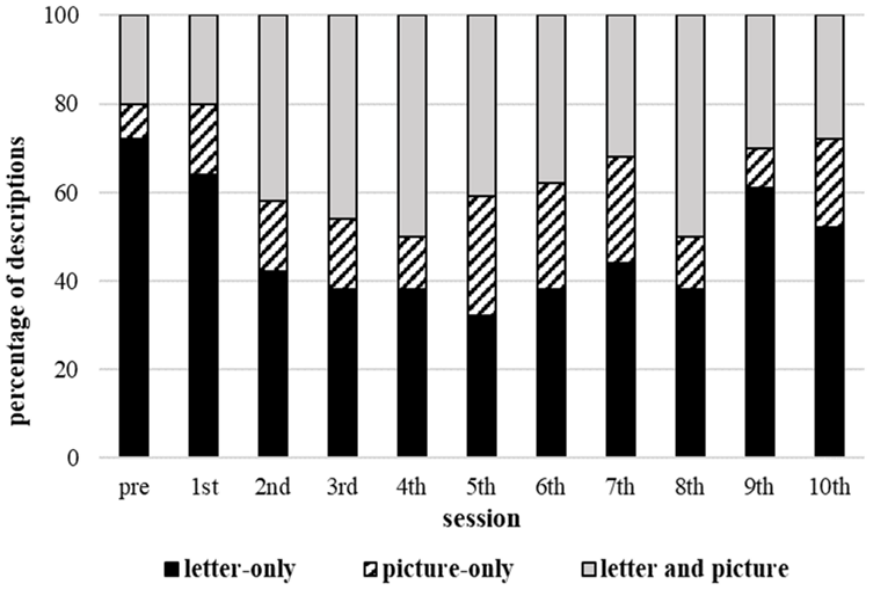

Figure 2. The transitions of the description methods of the children's activity review sheet responses

Figure 2 shows the transitions of the description methods in the children's activity review sheet responses after each session. In the pre-session, 72% of children described the letter-only approach. Subsequently, the percentage of descriptions by "picture-only" and "both letters and pictures" increased, although there were some differences depending on each session.

Discussion

Effectiveness of the Program in Enhancing Cognitive Development

In this Japanese study, the intervention involved children who already had daily exposure to reading and writing in nursery school prior to the program. Regarding learning and cognitive assessment, a ceiling effect was observed, with there being no significant difference after the program. The cognitive assessment showed reduced size for the interference effect on the flanker task response time and an increase in the PRS scores.

For the learning assessment, the Japanese reading ability test for preschoolers and pupils was administered before and after the program, and no significant difference was observed in the test results post-program. Previous studies (Das et al., 2006; Diamond et al., 2019) did record noticeable improvement in the learning ability (reading) of the participants after the program as compared to the control group; whereas, in this study, the children achieved high scores before and after the program, suggesting that they had already achieved a certain level of reading and writing prowess before implementing the program.

The study results indicate that the children's performance in both the flanker task and PRS administered to assess their cognitive ability for learning improved after the program. Unlike previous studies, the duration and total hours of the program for this study were shorter; however, similar to the studies by Diamond et al. (2019) which examined the effects of class-wide instruction, and by Aoki et al. (2013) which examined the effects of pair-learning, this study's program showed a reasonable level of effectiveness.

Early childhood is a time of great development in the ability for attention (Rueda & Conejero, 2020). While the attention score measured by PRS remained unchanged before and after the intervention, there was a noteworthy increase in the scores related to the two styles of encoding information: simultaneous and successive processing. This change could

potentially be attributed to the specific focus on the COGENT activities within Module 1 aimed to enhance simultaneous processing and those in Module 2 aimed to enhance successive processing. Thus, results obtained in previous studies (Das, 2009; Wang et al., 2012) record significant effects on reading performance in simultaneous and successive processing. The program in this study thus succeeded in enhancing both simultaneous and successive processing, even when the participants comprised preschoolers with a certain level of reading ability.

The overall accuracy in the flanker task remained consistently high, exceeding 90% before and after the implementation of the program. Concerning response time, a significant reduction was observed in the size of the interference effect, and a medium effect size was observed afterward. This change is noteworthy, particularly considering McDermott's (2007) findings that indicated no notable differences in reaction time between 5- and 6-year-olds during the flanker task in young children. This study demonstrates significant changes within a short duration.

The study by Diamond et al. (2007) reveals that this change is an improvement in EF within TOOLS enhanced by the sessions conducted. Additionally, the implementation of the program enhanced children's self-regulation, as emphasized in TOOLS and COGENT, and increased the processing speed, with no reduction in accuracy. This study emphasized the percentage of correct responses with reference to the previous study (Diamond et al., 2007) and encouraged children to take their time and respond thoughtfully. This approach likely alleviated the pressure on children's reaction speed, leading to a reduced trade-off between response accuracy and response time.

As mentioned in the introduction, self-regulation and executive functions correlate with planning. Additionally, within the PASS theory's cognitive processing scales, self-control and executive functions intersect with information encoding styles such as simultaneous and successive processing. The observed improvement in simultaneous and successive processing, indicated in PRS and flanker tasks, can be linked to the improvement in EF and self-regulation.

Significance of Involvement and Review in Enhancing Cognitive Development through Class-Wide Instruction

In this study, a group of children with a certain level of reading and writing proficiency before the program was selected and encouraged to use private speech through activity review sheets. Throughout the cognitive enhancement sessions, the children were provided the opportunity to describe activities and strategies using these sheets.

Subsequently, over ten sessions, there was a decline in the percentage of children who described schedules and feelings, while those describing the activities and strategies required for better performance increased. This result could signify the impact of the development of planning abilities through the implementation of the program. It can likely be attributed to children gaining strategic awareness. These changes indicate that they externalized their understanding of the tasks and strategies by describing the activity's contents and strategies on the activity review sheets.

The changes were similar to those observed by Aoki et al. (2016). Comparing the transitions, it was found that the verbal interaction between the instructor and the children and that among the children themselves related to the description on the sheets. Especially, the instructor's verbal interaction with their awareness of the children's ZPD may have influenced the responses. Furthermore, to encourage interaction between the children, they were offered the opportunity to change roles, from "asking a question" to "responding to the question," and then, to "listening to the question and the response." This facilitated an environment bolstering interpersonal interaction. Thus, the study results indicate that the children enjoyed various forms of interaction that enhanced their understanding of the program tasks and strategies through shared classroom activities, suggesting the significance of group instruction.

Limitations

Future studies must take into account several factors, especially the following five.

First, as children from a single preschool class participated in the study, the possibility of natural development could not be eliminated from the assessment results. Comparison with a control group must be conducted in the future.

Second, we recruited children with a certain level of reading and writing proficiency to participate in this study. However, to assess the effectiveness of the program, future studies should include a group with a risk of reading and writing proficiency.

Third, this study provided only 10 sessions. Future studies should conduct more sessions and assess the effectiveness of the program.

Fourth, in the Discussion section, we suggested that the involvement of an instructor with awareness of the children's ZPD might have influenced the results. To properly investigate this, it will be necessary to exhaustively analyze the interaction between the instructor and the children and that among the children themselves.

Last, in this study, PRS, an informal rating scale, was used to conduct cognitive assessment. It is necessary to assess the cognitive ability of the participants by using the rating scale with norms. Furthermore, it will be possible to analyze reading and writing abilities more accurately by using other assessments.

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Conclusion

In this study, the COGENT and TOOLS cognitive enhancement programs, based on Luria and Vygotsky's theory, were implemented in class-wide instruction, and the results showed an increase in performance after the intervention. The res

ults of the analysis of the intervention process showed that the children's attitudes toward the tasks changed as the program progressed.

In conclusion, the present study demonstrated that cognitive educational approaches for preschoolers are effective and provide new insights into educational psychology for them.

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Declaration of Interest Statement

The authors have no competing interests to disclose