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Executive function training for kindergarteners after the Great East Japan Earthquake: intervention effects

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Abstract
Japan's Social Thinking and Academic Readiness Training (START) program Academic Readiness (AR) lesson aims to improve self-regulation, executive function, and behavior problems in kindergarten children, but the effects of the START program AR lessons in unfavorable circumstances are unclear. Therefore, this study investigated the effects of the START program AR lesson in affected areas after the Great East Japan Earthquake. A cluster randomized trial was conducted with 111 5-year-old children in two kindergartens in Miyagi Prefecture to evaluate the effectiveness of the six-week AR lesson. One kindergarten was randomly chosen to implement the AR lesson, and the other maintained standard education. In the intervention group, trained classroom teachers provided the children with a 20-min AR lesson once a week. Executive function, behavioral self-regulation, and internalizing and externalizing problem behaviors were measured before and after the six-week intervention. The intervention group showed improved inhibitory control and enhanced behavioral self-regulation compared with the standard practice group. In addition, teachers' evaluations showed that children's internalizing and externalizing problem behaviors improved significantly. The results indicate that the START program AR lesson was effective in enabling teachers to help students improve executive function, self-regulation, and problematic behaviors. Therefore, educators and policy-makers should consider implementing the START program AR lesson in kindergartens after a disaster.

Keywords Executive function · Internalizing behaviors · Externalizing behaviors · START program · Great East Japan Earthquake · Kindergarten

There are several reports of problems in pre-school to kindergarten or kindergarten to elementary school transitions (Rimm-Kaufman et al., 2009; Ursache et al., 2012; van Lier &

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Deater-Deckard, 2016). These are widely reported as a first-grade elementary school problem in Japan. Children who have just entered the school exhibit behaviors such as walking around during the lesson, not concentrating on their studies, not listening to the teacher, and not returning to the classroom even after the break.

Several factors are assumed to cause or affect first-grade elementary school problems. Among them is children's poor self-regulation (Imai-Matsumura & Schultz, 2021). This self-regulating ability to control one's behavior, emotions, and thoughts is closely related to the development of executive function (EF) (Blair, 2002). EF is a capability required to control cognition and behavior, and it comprises multiple components related to goal-oriented behavior, attention control, and the organization of behavior (Duncan, 1986). EF comprises three elements: inhibitory control, working memory, and cognitive flexibility (Best & Miller, 2010; Miyake et al., 2000). Inhibitory control helps curtail impulsive behaviors, and behaviors that require self-control in favor of more adaptive ones (Ikeda et al., 2014; Rennie et al., 2004). In preschool children, poor inhibitory control is associated with internalizing and externalizing problem behaviors (Lonigan et al., 2017; Schoemaker et al, 2013; Utendale & Hastings, 2011).

Working memory helps keep information in mind and manipulate it to solve problems (Gathercole et al., 2008). Children with poor working memory are unable to function well socially (Schuiringa et al., 2017). Cognitive flexibility is related to acting quickly and flexibly in changing situations (Diamond et al., 2005). However, poor cognitive flexibility can interfere with problem-solving and result in aggressive or inappropriate behaviors (Diamond et al., 2005). EF acts as a cognitive control process that calms impulsive reactions and emotions (e.g., Blair, 2002). Therefore, it is considered to influence everyday situations (e.g., Baptista et al., 2016; Blair & Raver, 2012).

Pathways in the development of executive function

The development of EF has been investigated by measuring it with behavioral tasks. The development of EF is considered to be an important period, with its germination in early childhood and significant development in the preschool years (Zelazo & Müller, 2002). In a study of preschool children, scores on behavioral self-regulation, cognitive flexibility, inhibitory control, and working memory tasks improved significantly between the ages of 3 and 5. This indicates that abilities develop rapidly in the preschool years (McClelland et al., 2014). However, there are individual differences in their development: influence of family environment, mother's parenting style, mother's education, mother's mental health, and family income (Berthelsen et al., 2017; Sektnan et al., 2010). Therefore, there are individual differences in EF at the time of entering elementary school. It has been suggested that children with poor EF are more likely to exhibit difficulties in later school life (Calkins & Howse, 2004; Eisenberg et al., 2000; McClelland et al., 2000). However, previous studies have reported that EF can be improved by training (e.g., Diamond & Ling, 2020).

Executive function intervention program

Many intervention programs aimed at improving EF have been designed according to a model that improves children's EF, improves sociability, behavioral problems, and school adaptation (e.g., Bodrova & Leong, 2001; Diamond, 2012; Ford et al., 2009; Hughes &

Ensor, 2011; Keown et al., 2020; McClelland et al., 2019). Tools of the Mind, one of the programs available in schools, focuses on improving EF (especially self-control) and social-emotional skills. Tools of the Mind is a classroom curriculum designed to emphasize the role of the teacher. This program is used in preschools with 3- to 4-year-olds with hyperactivity and inattention tendencies to improve their inhibitory control (Solomon et al., 2018).

In recent years, intervention programs focusing on EF have been developed in kindergartens and elementary schools in Japan (Imai-Matsumura, 2011; Imai-Matsumura & Schultz, 2021). Social Thinking & Academic Readiness Training (START) program consists of 6 Academic Readiness (AR) lessons and 12 Social thinking (ST) lessons (Imai-Matsumura, 2011; Imai-Matsumura & Schultz, 2021). AR lesson is designed to improve EF and self-regulation. ST lesson is designed to improve interpersonal relationships. These programs can be conducted by the homeroom teachers as school readiness for the children. Lesson is generally conducted in one session per week for 6 weeks for AR lesson and 12 weeks for ST lesson. Furthermore, after each lesson, teachers should continue to provide START instruction and children should use START behaviors in a variety of situations.

In Imai-Matsumura and Schultz (2021), the effectiveness of the program was verified by cluster-randomized participants. A total of 171 children from 11 classes, one class each from the average Japanese kindergarten class of 5-year-olds, were assigned to the START program AR lesson group and the standard practice group. The results of the A separate mixed ANOVA showed that the AR lesson implementation group improved self-regulation (effect size $\eta^2 = 0.02$) and responsiveness to teacher instructions (effect size $\eta^2 = 0.11$) compared to the standard practice group. In Imai-Matsumura et al. (2017), 216 Japanese children from kindergarten classes for 5-year-olds participated in START program AR lessons. After implementation, the attention and aggression problem behaviors, evaluated by the teacher, improved. In summary, kindergarten children's externalizing behavioral problems, which were borderline or clinical, improved to normal levels after the START program AR lesson (Imai-Matsumura et al., 2017).

Situation of children in a disaster

The START program AR lesson proved effective for average Japanese children. However, it has not been assessed with children exposed to a high degree of adversity after a natural disaster. In Japan, natural disasters such as landslides caused by earthquakes and hurricanes occur frequently (Cabinet Office, 2021). After the Great East Japan Earthquake, many children in the lower grades are restless, unable to concentrate in class, and walk about during lesson, similar to behaviors of elementary school students in the first-grade problems. Moreover, an increasing number of students showed emotional and communication problems, such as fights with friends, crying often, and an inability to communicate well with teachers and friends (Miyagi Prefectural Children's Center, 2016).

Four years after the Hanshin-Awaji earthquake with a magnitude of 7.3 occurred in Japan in 1995, emotional and behavioral problems (difficulty in focusing, irritability, and aggressive behavior) were frequently reported in schools (Hyogo Prefectural Board of Education, 2011). There was concern that children's internalizing behaviors such as anxiety and depression and externalizing behaviors such as aggression would continue at schools for several years after a major disaster (Miyagi Prefectural Children's Center, 2016).

In Vernberg et al.'s (1996) integrated conceptual model to predict a child's response to a natural disaster, problem behaviors were shown to be related to children's coping skills. One such coping skill is EF, which improves emotional and behavioral control (e.g., Masten, 2007). Eight months after Hurricane Katrina, in Louisiana, USA, elementary school students were assessed for factors that protect them from disaster-related stress (Terranova et al., 2009). EF helps children and adults exercise their coping skills after dangerous situations (e.g., Masten & Narayan, 2012; Terranova et al., 2009).

Intervention study for children after a disaster

Children affected by disasters are often complex and multifaceted, and may experience other problems (e.g., sadness, depression, and anxiety) along with posttraumatic stress symptoms (La Greca & Silverman, 2009). For this reason, coping with grief and anxiety and anger management are considered to be important components of interventions to promote recovery from disasters (La Greca & Silverman, 2009). EF, one of the protective factors against stress from disasters, is also essential for social competence, such as social problem-solving, emotional regulation, and attention focus (Blair, 2002). The START program AR lesson includes information on improving EF and emotional control. Therefore, it is conceivable that AR lessons could be beneficial for children affected by disasters.

The purpose of this study

In this study, the START program AR lesson (Imai-Matsumura & Schultz 2021; Imai-Matsumura et al., 2017) was used to examine whether EF and behavioral problems in children affected by the Great East Japan Earthquake improved. In Japan, education is compulsory from elementary school onward, and preschool education is not compulsory, but since almost all children attend preschool facilities (94.8% of 3-year-olds, 97.3% of 4-year-olds, and 98.3% of 5-year-olds) (Ministry of Education, Culture, Sports, Science and Technology, 2020), we thought that intervention in preschool facilities would reach all children. Therefore, in this study, an intervention and a standard practice group were created for each kindergarten in the areas affected by the Great East Japan Earthquake.

This study addresses two research questions. First, does participation in the START program AR lesson promote the EF of kindergarten children in the disaster area? Since EF is a relatively variable cognitive ability (e.g., Blair & Raver, 2014), we predicted that the intervention group would show significant improvement in EF, compared with the standard practice group.

Second, does participation in the START program AR lesson reduce internalizing and externalizing behaviors, as evaluated by teachers? Post-disaster, children's internalizing and externalizing problem behaviors are increasing (Miyagi Prefectural Board of Education, 2019). Previous studies on the START program (Imai-Matsumura et al., 2017), even in the affected areas after the Great East Japan Earthquake, predicted that the intervention group would show significantly improved internalizing and externalizing behaviors, compared with the standard practice group.

Method

Intervention study design

This study was conducted four years after the Great East Japan Earthquake. The participating kindergartens were located 130 km from the earthquake's epicenter, which was heavily damaged during the Great East Japan Earthquake (Rifu Town, Miyagi District, Miyagi Prefecture, 2011). We requested the cooperation of the four kindergartens under the jurisdiction of the local board of education in Miyagi Prefecture. Only two of the kindergartens consented. The kindergarten director and five teachers of the classes for 5-year-olds received oral explanations from the researchers and agreed to participate.

A cluster randomized controlled trial was conducted in two kindergartens. Each kindergarten was assigned to a cluster: one with an intervention program and one with standard practice. After the post-test, the cluster 2 standard practice group received training lectures and materials so that they could later implement the START program AR lesson. The homeroom teachers who conducted the START program were unaware of the study hypothesis but were informed of the basic purpose of the study, which was to examine changes in children before and after the program. The teachers of the standard practice group were not informed of their role as control groups, with the aim of observing the development of children in September and December in the standard practice of kindergartens. EF performance and classroom behavior were compared between the clusters before and after the intervention.

Great East Japan Earthquake

The Great East Japan Earthquake occurred on March 11, 2011; at a magnitude of 9.0, it is the fourth largest worldwide. It triggered various disasters, such as catastrophic tsunamis, large-scale power outages, fuel shortages, and nuclear accidents. The damage in Miyagi Prefecture was enormous. The National Police Agency reported 9,543 deaths, 1,216 missing, and 4,145 injured in the tsunami (National Police Agency, 2021). Eight months after the disaster, 43% of children from kindergarten to junior high school in the tsunami-affected coastal areas showed flashbacks; physical symptoms such as loss of appetite, headache, and abdominal pain; and problematic behaviors such as inability to concentrate, attention deficit, and anxiety (Usami et al., 2012). The kindergartners continued to have the same symptoms 20 months later (Usami et al., 2014). In a study of maternal mental health in Miyagi Prefecture, 50% of mothers who gave birth before or after the disaster showed symptoms of physical anxiety, which was considerably higher than the Japanese average of 14%. Furthermore, this condition continued for the next four years (Sato et al., 2016).

Participants

All five classes of 5-year-olds who participated in the full-day program from two kindergartens were targeted. The classes included children who were five years old on or before April 1. They receive kindergarten and elementary schooling in the same grade. In the middle of the kindergarten year (i.e., September), an invitation to participate in the study was distributed to parents of 113 children at the participating kindergartens. Parents received a document explaining the nature and purpose of the study and they could oppose their participation. Consent forms were collected from 111 families.

The intervention group comprised 64 children from one kindergarten (31 boys, 33 girls; *M*age = 71.4 months, *SD* = 3.6), and the consent rate was 100%. The standard practice group comprised 47 children from another kindergarten (26 boys, 21 girls, *M*age = 71.5 months, *SD* = 3.5), and the consent rate was 96%.

Parents reported the children's gender, birthdate, and residential area. All the participants were Japanese. As 98% of the Japanese population has graduated from high school (Ministry of Education, Culture, Sports, Science and Technology, 2011), the children's parents were assumed to have at least a high school education. The socioeconomic status of the sample was primarily middle class, established through the Japan Census (Ministry of Internal Affairs & Communications, 2015). Children were enrolled in kindergartens that provided education according to national curriculum guidelines. We confirmed with the principal that neither kindergarten had an educational program designed to strengthen EF.

Procedure

Study phases

The study was divided into three phases: pre-test (September), intervention (October–November), and post-test (December).

During the *pre-test* phase, children's EF was assessed over one week. Research assistants, who participated in a half-day training, assessed the children in a quiet space at their school, separate from their usual classroom. Each assessment lasted 15–20 min. EF tasks were recorded using a video camera. The teachers evaluated the children using a behavioral checklist.

The *START program implementation procedure* is as follows: During the intervention phase, one kindergarten with three classrooms was used and the three teachers of the intervention classrooms were trained in the START program AR lesson by the program developer (last author). The training lasted 90 min. After the training, teachers in the intervention group practiced using the manual.

Each session included 25 or 26 children and one teacher and occurred in the children's regular classrooms. The intervention sessions were scheduled on the same day and at the same time every week, as chosen by the classroom teachers. Lessons were approximately 20 min, once per week. Students absent from sessions were taught directly by their homeroom teachers. Furthermore, the contents of the AR lessons were not only applicable to that time, but also to daily activities. For example, when the teacher was speaking, the children looked at the teacher and listened to what she had to say. When they wanted to speak, they raised their hands and spoke only after being nominated. They received substantial praise from teachers when they performed START program tasks correctly.

The researchers *confirmed the implementation status of the program* with the chief instructor telephonically weekly and visited the program for one day. Implementation status was recorded in the kindergarten instruction records. The program was implemented successfully. On the other hand, two classes in the standard practice group received regular education according to the national curriculum guidelines.

During the *post-test*, EF assessments were re-administered to all the children. The teachers evaluated the children using a behavioral checklist.

START program AR lessons (Imai-Matsumura & Schultz, 2021)

(1) Rules for speaking in class: This lesson focuses on the rules for listening and speaking in class. The teacher teaches the children to raise their hands when they want to speak. Children should not automatically shout out answers to the teacher's questions, but raise their hands and wait to be called on. The aim is to help children develop inhibitory control.
(2) Paying attention: This lesson focuses on paying attention. Use posters that focus attention on the teacher in class. Using that behavior as a model, children encourage their teachers to focus their attention.
(3) Sustaining attention and ignoring distractions: This lesson focuses on teaching children how to maintain attention during classroom instruction. Children practice ignoring interruptions when they are concentrating their attention.
(4) Shifting attention and following directions: This lesson will help you learn to "stop" and then switch behaviors. Ensure that children are able to respond quickly to the teacher's instructions. Moving on to the next action also requires working memory capacity.
(5) Emotional regulation of excitement and (6) emotional regulation of frustration and anger focus on the control of emotions. Practice stopping, taking deep breaths, and calming your mind during a fun and exciting activity. In the same way, practice self-control when you are frustrated or angry.

Activities similar to these lesson contents are also conducted in commonly used classroom activities. However, the START program is intended to make children aware of their EF and self-regulation skills and to strengthen their capacities.

Measures

The Fruit/Vegetable Stroop test was used to test *inhibitory control* (Archibald & Kerns, 1999; Loher & Roebers, 2013). This task consists of four A4-size sheets of paper. The first sheet shows 25 squares in four colors; the children are able to recognize the colors swiftly and correctly. The second questions the children about the colors of 25 fruit of four types. The third, printed in black and white, shows the same fruit and the original color is asked. The last sheet is printed with 25 fruits of different colors and the children are instructed to provide the original color. Reaction times are recorded as the dependent variable for each condition. Faster reaction times are interpreted as reflecting higher abilities in resistance to stimulus incompatibility. A previous study demonstrated that this task has good reliability and construct validity in 5–8-year-olds (Loher & Roebers, 2013).

The *auditory working memory task* was the backward digit recall task of the Wechsler Intelligence Scale for Children-IV (WISC-IV). In this task, the inspector reads a random series of single-digit numbers (0–9) and the child is asked to repeat them backwards. In the current study, the task started with two digits, and if the answer was correct, another digit was added. This task was halted when the children failed to provide the correct answers twice consecutively. The number of correct answers was used as the auditory working memory score. This task has shown good reliability and construct validity for participants aged 5–16 years (Japanese WISC-IV Publication Committee, 2010).

The hand movement task from the Kaufman Assessment Battery for Children II (KABC-II) was used to assess *visuospatial working memory* (Japanese KABC-II

Publication Committee, 2013). In this task, the inspector shows their fist, palm, and sides of the hand. The child replicates it. The number of three random combinations increases when the answer is correct. The score is in the range of 0–23 points for all 23 questions. This task has shown good reliability and construct validity for participants aged 3–18 years old (Japanese KABC-II Publication Committee, 2013; Lichtenberger et al., 2006).

Moreover, the head-toes-knees-shoulders (HTKS) task (Ponitz et al., 2008) was used to assess inhibitory control, cognitive flexibility, and working memory of EF. The task consists of three parts. In part 1, when children are asked to touch their toes, they touch their heads; when asked to touch their heads, they touch their toes. In part 2, the shoulders and knees are added. When children are asked to touch their shoulders, they touch their knees. In part 3, the experimenter changes the rules. When children are asked to touch their heads, they should instead touch their knees. When asked to touch their toes, the children touch their shoulders. We used the number of correct answers for the test trial: two points for a correct answer and one point when the child notices a mistake and starts over. This task has shown good reliability and construct validity for children aged 3–8 years (McClelland et al., 2014). The Cronbach's α of the behavioral self-regulation task was 0.950 (pre-test) and 0.980 (post-test).

Furthermore, the *evaluation by teachers* was as follows: We asked teachers to fill out the Child Behavior Checklist-Teacher Report Form (CBCL-TRF) for each of the participating children (Achenbach, 1991; Itani et al., 2001). This questionnaire, standardized in Japan, can be used to evaluate children aged 5–18 years. It comprises a list of statements about the child's everyday behaviors, and teachers are asked to rate the statements on a 3-point Likert scale: "not applicable" (0) to "applies more or less or sometimes" (1) to "always applicable" (2). The CBCL-TRF can produce eight measures of mental health for each participant: social withdrawal (nine items), somatic complaints (9 items), anxiety/depression (18 items), social problems (13 items), emotional reactivity (8 items), attention problems (20 items), delinquent behavior problems (9 items), and aggressive behavior problems (25 items). In this study, we used the internalizing and externalizing problems scales. The internalizing problems scale comprises social withdrawal, somatic complaints, and anxiety/depression minus one item (depressed). The externalizing problem scale comprises delinquent behavior and aggressive behavior. The range of scores is 0–70 points for the internalizing problem scale and 0–68 points for the externalizing problem scale. The Cronbach's α of the internalizing problem scale was 0.835 (pre-test) and 0.740 (post-test). The Cronbach's α of the externalizing problem scale was 0.906 (pre-test) and 0.751 (post-test).

Ethical considerations

All study participants provided informed consent, and the study was conducted in accordance with the Code of Ethics of the World Medical Association (Declaration of Helsinki).

Statistical analyses

We removed the data corresponding to five absent children and one child who had moved on the day of the post-test (intervention group: three children and standard practice group: three children). The inhibitory control task was accurately answered by most children. Therefore, the reaction time was used for the analysis. Four children who could not answer the original color were excluded (intervention group: three children and standard practice group: one child). The teacher's assessment excluded one person who had moved out of

the standard practice group. Little's test confirmed that the data were completely randomly missing ($p > 0.05$). All statistical tests were two-tailed, and a p of 0.05 was employed. Data were analyzed using IBM SPSS for Windows, version 26 (IBM, Armonk, NY, USA).

Results

Table 1 shows the average age, gender, and pre-test. A t-test was performed in two independent groups to examine whether there was a significant difference between the intervention group and the standard practice group in age, gender, and pre-test. There were no significant differences in age (t (109) = 0.01, p = 0.989, d = 0.00) or gender (t (109) = 0.71, p = 0.478, d = 0.00) between the intervention and standard practice groups. Similarly, there were no significant differences in pretest scores between the intervention group and standard practice group in the inhibitory control task (t(105) = 0.57, p = 0.573, d = 0.00), auditory working memory task (t(109) = 0.64, p = 0.524, d = 0.00), visuospatial working memory task (t(109) = 0.08, p = 0.938, d = 0.00), internalizing problem behavior (t(109) = 0.35, p = 0.728, d = 0.00), and externalizing problem behavior (t(109) = 1.85, p = 0.067, d = 0.03). Performance in the behavioral self-regulation task differed between the intervention and

Table 1 Means (SD) for the START and standard practices groups

	START			Standard			Group comparisons		
	n	*M*	*(SD)*	*n*	*M*	*(SD)*	*t*	*p*	*d*
Child's age	64	71.44	(3.64)	47	71.45	(3.52)	0.01	.989	.00
Child's gender	64	.48	(.50)	47	.55	(.50)	0.71	.478	.00
Pre inhibitory control	61	35.83	(20.21)	46	33.92	(12.53)	0.57	.573	.00
Post inhibitory control	61	29.63	(11.45)	45	35.99	(19.78)			
Difference in inhibitory control	58	−6.71	(18.70)	43	2.31	(20.74)			
Pre auditory working memory	64	3.95	(1.86)	47	3.70	(2.26)	0.64	.524	.00
Post auditory working memory	61	4.66	(1.55)	45	4.40	(1.64)			
Difference in auditory working memory	61	0.66	(1.67)	45	0.78	(1.81)			
Pre visuospatial working memory	64	8.47	(2.87)	47	8.43	(2.89)	0.08	.938	.00
Post visuospatial working memory	61	8.90	(2.77)	45	8.38	(2.86)			
Difference in visuospatial working memory	61	0.34	(2.70)	45	−0.04	(2.74)			
Pre behavioral self-regulation	64	34.81	(14.64)	47	28.04	(18.56)	2.07	.041	.04
Post behavioral self-regulation	61	45.56	(8.18)	45	37.91	(15.34)			
Difference in behavioral self-regulation	61	10.93	(15.49)	45	10.18	(12.95)			
Pre internalizing behavior	64	3.33	(3.27)	47	3.62	(5.44)	0.35	.728	.00
Post internalizing behavior	64	0.78	(1.16)	46	2.72	(3.19)			
Difference in internalizing behavior	64	−2.55	(3.11)	46	−0.98	(3.67)			
Pre externalizing behavior	64	2.78	(4.36)	47	4.85	(7.36)	1.85	.067	.03
Post externalizing behavior	64	0.80	(1.45)	46	2.87	(5.41)			
Difference in externalizing behavior	64	−1.98	(3.37)	46	−1.93	(3.61)			

Note. Child's gender: 0 = female, 1 = male

standard practice group, t (109) = 2.07, p = 0.041, d = 0.04. The intervention group had a higher score than the standard practice group.

Table 2 shows the bivariate correlations between each task score. Age was significantly correlated with auditory working memory and behavioral self-regulation. In addition, since gender was also correlated with externalizing problem behavior, it was judged appropriate to include it as a covariate. The elements of the EF were correlated with each other. Internalizing and externalizing problem behaviors were also correlated. Intervention status was correlated with the difference of inhibitory control, pre-behavioral self-regulation, and the difference of internalizing problem behaviors.

Multiple regression analysis was used to verify the effects of the intervention. In the multiple regression analysis, the difference between the groups was used as the independent variable, and the increase in the score of each measurement task (post-score minus press score) was the dependent variable. The results are shown in Table 3. Diagnosis of multicollinearity was not problematic, with tolerance ranging from 0.882 to 0.997 and VIF from 1.005 to 1.133.

Inhibitory control task

The results of the multiple regression analysis were significant for the inhibitory control task, F (4, 96) = 22.27, $p < 0.001$, $R^2 = 0.48$. The lower the inhibitory control task score, the higher the ability. Participation in the START program was a significant predictor of reduced inhibition control task ($\beta = -0.18$, $p = 0.019$).

Auditory and visuospatial working memory task

The results of the multiple regression were significant for the auditory working memory tasks, F (4, 101) = 19.46, $p < 0.001$, $R^2 = 0.44$. However, participation in the AR lesson was a no significant predictor of increased auditory working memory tasks ($\beta = 0.02$, $p > 0.05$). The results of the multiple regression were significant for the visuospatial working memory task, F (4, 101) = 9.35, $p < 0.001$, $R^2 = 0.27$. However, participation in the AR lesson was a no significant predictor of increased visuospatial working memory tasks ($\beta = 0.08$, $p > 0.05$).

Behavioral self-regulation task

The results of multiple regression analysis were significant for the behavioral self-regulation task, F (4, 101) = 29.62, $p < 0.001$, $R^2 = 0.54$. Participation in the START program was a predictor of increased behavioral self-regulation tasks ($\beta = 0.18$, $p = 0.011$).

Internalizing and externalizing problem scale

The results of the multiple regression analysis of internalizing problem behavior were significant, F (4, 105) = 81.50, $p < 0.001$, $R^2 = 0.76$. Participation in the START program was a significant predictor of reduced internalizing problem behavior ($\beta = -0.26$, $p < 0.001$) (Table 4).

The results of the multiple regression analysis of externalizing problem behavior were significant, F (4, 105) = 51.44, $p < 0.001$, $R^2 = 0.66$. Participation in the START

Table 2 Correlations among key study variables

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Child's age	——														
2. Child's gender	.055	——													
3. Pre inhibitory control	−.103	.119	——												
4. Difference inhibitory control	−.083	.018	**−.649****	——											
5. Pre auditory working memory	**.267****	−.020	**−.244***	−.073	——										
6. Difference auditory working memory	−.127	−.032	.004	.104	**−.655****	——									
7. Pre visuospatial working memory	.157	.015	**−.241***	.009	**.416****	−.062	——								
8. Difference visuospatial working memory	.019	−.118	−.076	−.051	.005	.015	**−.487****	——							
9. Pre behavioral self-regulation	**.234***	−.129	**−.284****	.015	**.372****	**−.248***	.184	.042	——						
10. Difference behavioral self-regulation	−.057	.046	.142	−.137	−.144	**.262****	.046	.127	**−.702****	——					
11. Pre internalizing behavior	.001	.043	−.011	.027	−.097	−.005	−.017	−.049	.037	−.009	——				
12. Difference internalizing behavior	.018	.063	.098	−.060	−.050	.043	−.028	.051	−.135	.021	**−.826****	——			
13. Pre externalizing behavior	−.100	**.245****	−.041	**.224***	−.053	.024	−.082	.035	**−.273****	.227*	**.264****	**−.242***	——		
14. Difference externalizing behavior	−.003	−.164	.059	−.188	.030	−.105	−.053	.051	**.298****	**−.313****	−.175	**.225***	**−.795****	——	
15. Intervention	−.001	−.068	.059	**−.224***	.061	−.035	.007	.071	**.202***	.026	−.033	**−.227***	−.175	-.0077	——

Note. Child's gender: 0 = female, 1 = male

Intervention: 0 = standard practices, 1 = START

* $p < .05$; ** $p < .01$; *** $p < .001$

Table 3 Estimated effects for the START vs standard practices on exceptive functions

Variable	Inhibitory control ($N=101$)		Auditory working memory ($N=106$)		Visuospatial working memory ($N=106$)		Behavioral self-regulation ($N=106$)	
	β	*SE*	β	*SE*	β	*SE*	β	*SE*
Intervention	$-.18^{*}$	2.98	.02	0.26	.08	0.47	$.18^{*}$	2.00
Child's age	−.14	0.41	.06	0.04	.12	0.07	.13	0.28
Child's gender	.09	2.97	−.06	0.26	−.12	0.46	−.06	1.97
Baseline score	$-.66^{***}$	0.08	$-.67^{***}$	0.07	$-.51^{***}$	0.08	$-.78^{***}$	0.06
R^2		.48		.44		.27		.54

Note. Intervention: 0 = standard practices, 1 = START

Child's gender: 0 = female, 1 = male

* $p<.05$; ** $p<.01$; *** $p<.001$

Table 4 Estimated effects for the START vs standard practices on internalizing and externalizing behaviors

Variable	Internalizing behavior ($N=110$)		Externalizing behavior ($N=110$)	
	β	*SE*	β	*SE*
Intervention	$-.26^{***}$	0.33	$-.15^{*}$	0.40
Child's age	.03	0.05	−.10	0.06
Child's gender	.07	0.33	.04	0.41
Baseline score	$-.84^{***}$	0.04	$-.84^{***}$	0.04
R^2		.76		.66

Note. Intervention: 0 = Standard practices, 1 = START

Child's gender: 0 = female, 1 = male

$^{*}p<.05$; $^{***}p<.001$

program was a significant predictor of reduced externalizing problem behavior ($\beta=-0.15$, $p=0.013$).

Discussion

This study aimed to investigate the effect of the START program AR lesson implemented in Miyagi Prefecture after the Great East Japan Earthquake. The intervention group showed significant improvement in scores for inhibitory control. Methods to improve control of inhibition include freeze games to stop body movements and attention training (Bodrova & Leong, 2001; Volckaert & Noël, 2015). The START program AR lesson included similar training. Similarly, long-term tragic experiences of children have been shown to cause diverse problems in the areas of the brain involved in EF development (Blair, 2017). The impact of the 2010 Chile earthquake (magnitude 8.8) on the EF of 4-year-old children after the Chilean earthquake was lower than that of children of the same age before the earthquake (Gomez & Yoshikawa, 2017). Situations in which stress stimulation is too high or persistent affect the development of EF in children (Blair, 2017). For this reason, AR

lesson with improved control of inhibition may be particularly important in the field of disaster.

Furthermore, similar to a previous study by Imai-Matsumura and Schultz (2021), there was an effect of the START program AR lesson on behavioral self-regulation associated with elements of EF. In the AR lesson, behavioral self-regulation improved by focusing attention, stopping what one wanted to do, and smoothly switching to the next activity. Self-regulation is drawing attention regarding resilience (Masten, & Obradovic, 2008; Sciaraffa et al., 2018). At ages 8–17 years, self-regulation that controls one's thoughts, emotions, and behaviors supports adaptation toward higher school levels and better mental health, even in stressful situations (Buckner et al., 2003). However, the development of behavioral self-regulation varies among people, and in the absence of early intervention, low levels in children continue for a long time (Wanless et al., 2016). Therefore, it is considered necessary to effectively increase self-regulation.

Effects on internalizing and externalizing problem behavior

After a natural disaster, children demonstrate internalizing and externalizing problem behaviors for a long time in any country (Chen et al., 2020; Rubens et al., 2018). Participants in this study had higher internalizing and externalizing problem behaviors in the pre-test condition than kindergarten children in western Japan who were unaffected by the Great East Japan Earthquake (Imai-Matsumura et al., 2017). Thus, we suggest that the high internalizing behaviors observed by teachers in the children in our sample may have been heavily influenced by the Great East Japan Earthquake disaster.

Children's problem behavior in disaster areas has been found to correlate with mothers' post-traumatic stress symptoms, anxiety, and depression (Yagi et al., 2016). Disasters also affect the minds of teachers. Stress among kindergarten teachers remained high after the Great East Japan Earthquake (Wakashima et al., 2019). In Miyagi Prefecture, there were many cases where severely injured teachers were engaged in the care and education of children without having the opportunity or time to care for their wounds. Hurt and exhaustion of teachers may affect the way they see and respond to children's problems, leading to worsening of the child's condition (Gilliam & Shahar, 2006). Furthermore, it has been reported that as time passes after a disaster, children themselves often express their residual fears and feelings of helplessness through problematic behaviors (Miyagi Prefectural Children's Center, 2016; Raccanello et al., 2017). Feelings of fear and anger may be reflected in conflicts and quarrels with other children and defiant attitudes toward teachers. They may respond with an attitude of escape and avoidance of situations that elicit anxiety and fear.

The number of violent acts in the lower grades of elementary school increased sharply five years after the Great East Japan Earthquake. Two years later, the number of violent acts by elementary school students continued to be higher than the national average (Miyagi Prefectural Board of Education, 2019). Bullying and truancy remained high seven years after the disaster as well (Miyagi Prefectural Board of Education, 2019). Immediately after a disaster, teachers were aware of the need to care for children, but in a disaster of the scale of the Great East Japan Earthquake, they did not know how long they would need to care for them (Miyagi Prefectural Children's Center, 2016). As time went on, the teachers could not tell whether the problems shown by the children were caused by the disaster or whether they had emerged regardless (Hyogo Prefectural Board of Education, 2011; Miyagi Prefectural Children's Center, 2016). The background of the children's problematic behaviors was thought to be complicated by the passage of time and the intertwining of factors such

as family environment, kindergarten environment, and the children themselves that had changed due to the disaster (Miyagi Prefectural Children's Center, 2016).

AR lessons includes an information regarding emotional control, during which teachers taught children how to stop their thoughts, take deep breaths, and control their physical tension. It is suggested that learning these strategies decreases children's internalizing behaviors (Kar, 2009). Internalizing behaviors in childhood are negatively related to future sociability, school adaptiveness, stress, and anxiety, which have been shown to impair EF and school success (Blair & Diamond, 2008). Therefore, it is necessary to acquire skills to eliminate anxiety when preparing for school readiness (Blair & Diamond, 2008; Chen & Li, 2000). In the future, it is expected that the mental illness of children in Miyagi Prefecture will be reduced, and school adaptation will be promoted.

In addition, the START program improved externalizing behavior problems. Stressful life events during preschool predict externalizing behavior problems in preschool and elementary school (Mesman & Koot, 2001). It is expected that children will improve their externalization problem behavior in elementary school by learning how to deal with excited emotions. Improving children's externalizing problem behaviors also leads to better teacher–child relationships (Jeon et al., 2019). It is possible that the START program AR lesson will calm the classroom, build a good relationship between teachers and children, and decrease teachers' stress.

Improvement of START program for the future

Our study showed no significant impact of the START program AR lesson on working memory, which concurs with results of Imai-Matsumura and Schultz (2021). Participants in this study had lower visual working memory scores during pre-and post-measurements than kindergarten children in western Japan who were unaffected by the Great East Japan Earthquake (Imai-Matsumura et al., 2017). Working memory is necessary to improve academic ability (Alloway, 2006). The START program AR lesson does not include working memory training, and inhibitory and emotional control training does not affect children's working memory. Children experiencing trauma following a disaster often have academic difficulties (Gomez & Yoshikawa, 2017); therefore, working memory training should be added to the START program AR lesson.

Limitation

To our knowledge, this is the first study to examine an intervention to improve EF in kindergarten students from a disaster-stricken area. Despite interest in the relationship between children's EF and socio-psychological adaptation, few studies have aimed to improve EF as an intervention in mitigating internalizing and externalizing problem behaviors after a disaster. After a major disaster, post-traumatic stress disorder has received much attention, and expert intervention has been considered (e.g., Kar, 2009; Seiden et al., 2021). There are few studies of interventions aimed at improving internalizing and externalizing problem behaviors and enhancing EF in all children after a disaster.

However, our study has several limitations. First, the number of participants in this study was small, only two kindergartens in one town. Post-disaster intervention studies are considered very difficult because schools cannot afford them and teachers do not want to remember the disaster (Chemtob et al., 2002). In the future, it will be necessary to increase the number of participating schools in larger towns.

Second, the teachers knew that they were participating in a study. The new program may have been effective due to the teachers' expectation that the children would change (Diamond & Ling, 2020).

Third, the EF task was a laboratory-based task. We would have needed to use an objective measure in a real classroom situation.

Fourth, we evaluated the AR lesson over a relatively short period (six weeks). Further improvement may be possible if the teacher continues the self-control training or compliments children's behaviors. Hence, future studies should focus on long-term implementation of the START program AR lesson.

Conclusions

The results suggest that the START program AR lesson is effective in improving control of inhibition control, self-regulation, and problem behavior. Large-scale disasters can cause long-term behavioral problems in children. However, it takes personnel and money for mental health professionals to implement interventions in each educational facility after a large-scale disaster. Therefore, START programs that are designed and tested to be delivered by familiar teachers in safe schools are valuable. It will be necessary to effectively disseminate this program through training sessions for teachers and teacher training institutions.

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Author contribution Noriko Yamamoto: Investigation, writing—original draft, visualization. Kyoko Imai-Matsumura: Conceptualization, methodology, investigation, writing—review and editing, supervision, funding acquisition.

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Availability of data and material The dataset analyzed in this study will be disclosed by the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors declare no competing interests.

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Current themes of research:

Development of executive function and self-regulation; Eye-tracking study in educational practice.

Most relevant publications in the field of Psychology of Education:

Stites, M.L., Sonnenschein, S., Chen, Y., Imai-Matsumura, K., Gürsoy, H. (2021). Facilitating Preschool Children's Mathematics Development in Chinese, Japanese, and the United States: Is the Classroom Library Considered? *Educ. Sci. 11*, 792. https://doi.org/10.3390/educsci11120792.

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