Enhancing Preschoolers' Executive Functions through Embedding Cognitive Activities in Shared Book Reading

Abstract

Given evidence that early executive functioning sets the stage for a broad range of subsequent outcomes, researchers have sought to identify ways to foster these cognitive capacities. An increasingly common approach involves computerized 'brain training' programs, yet there are questions about whether these are well suited for fostering the early development of executive functions (EFs). The current series of studies sought to design, develop, and provide evidence for the efficacy of embedding cognitive activities in a commonplace activity – shared reading of a children's book. The book, *Quincey Quokka's Quest*, required children to control their thinking and behaviour to help the story's main character through a series of obstacles. The first study investigated effects of reading with embedded cognitive activities in individual and group contexts on young children's executive functions (EFs). The second study compared reading with embedded cognitive activities against a more-active control condition (dialogic reading) that similarly engaged children in the reading process yet lacked clear engagement of EFs. The third study sought to investigate whether the effect of reading the story with embedded EF activities changed across differing doses of the intervention and whether effects persisted 2 months post-intervention. Findings provide converging evidence of intervention effects on working memory and shifting in as little as 3 weeks (compared to more traditional reading) and maintenance of these gains 2 months later. This suggests the efficacy of embedding cognitive activities in the context of everyday activities, thereby extending the range of users and contexts in which this approach can be used.

Enhancing Preschoolers' Executive Functions through Embedding Cognitive Activities in Shared Book Reading

A child's ability to exert control over their thinking is central to their capacity to meet the mental, social, and emotional demands of life. These cognitive control processes, typically bundled as executive functions (EFs), enable us to activate, manipulate, and sustain information in mind (i.e., working memory), control urges, impulses, and resist distraction (i.e., inhibition), and flexibly shift our attention between information, processes, or tasks (i.e., shifting). Research suggests that early EFs set the stage for a broad range of developments in later life including, but not limited to, school readiness (Blair & Razza, 2007), academic achievement (Müller, Liebermann, Frye, & Zelazo, 2008), early literacy and numeracy skills (Bull, Espy, & Wiebe, 2008), social and emotional competence (Riggs, Jahromi, Razza, Dillworth-Bart, & Müeller, 2006), and physical health (Liang, Matheson, Kaye, & Boutelle, 2014; Reinert, Poe'e, & Barkin, 2013). Deficiencies in executive functioning have also been implicated in a number of developmental disorders (e.g. ADHD; Diamond, 2005; Fairchild et al., 2009; Lui & Tannokc, 2007). Even beyond childhood, the ability to exert self-control in the early years, for which EFs are essential (Hofmann, Schmeichel, & Baddeley, 2012), predicts achievement, health, wealth, and quality of life in adulthood (Moffitt et al., 2011). EFs thus are an interesting target for early intervention, with the potential to influence lifespan developmental trajectories across a range of academic, behavioural, social, emotional, and health outcomes.

Although some EF intervention efforts have sought to examine effects of existing activities on EFs (e.g., whether, and under what conditions, physical activity supports EF development), an increasingly common approach has involved computerized 'brain training' programs (a now more than $1 billion industry; Hayden, 2012). These programs (e.g., Cogmed working memory training; Klingberg, Forssberg, & Westerberg, 2002) administer computerized training tasks that progressively increase EF demands. Although results with these programs have been mixed (Diamond & Lee, 2011), a common result is improvement in trained EF abilities and more-limited transfer to untrained tasks and abilities (e.g., Bergman Nutley et al., 2011; Rueda, Rothbart, McCandliss, Saccomanno, & Posner 2005). Some studies have reported some transfer of computerized EF training effects to non-trained cognitive and EF tasks (e.g., attention, inhibition) and cross-domain tasks (e.g., visual-spatial

WM to verbal WM), in both typically and atypically developing children of varying ages (Holmes, Gathercole, & Dunning, 2009; Kirk, Gray, Riby, & Cornish, 2015; Klingberg et al., 2005; Klingberg et al., 2002; Titz & Karbach, 2014). Studies thus suggest the potential to modify EFs in childhood, although the various means for achieving this (e.g., the type, quantity, quality, and duration of intervention) remain debated.

There is also evidence that earlier EF interventions may yield more pronounced, stable, and lasting change (Wass, Scerif, & Johnson, 2012). Yet existing computerized EF training programs are often not designed for young children or are downward extensions of adult programs, with unclear consequences for their efficacy in the early years. For instance, in one of the few available preschool Cogmed studies, Thorell, Lindqvist, Bergman Nutley, Bohlin, and Klingberg (2009) trained 4-5 year olds in either Cogmed or an analogous computerized inhibition-training program for 5 weeks. Results indicated that children who received the Cogmed training showed significant improvement on non-trained attention, visual-spatial, and verbal working memory tasks (but not on inhibition, problem solving, or processing speed tasks). However, these effects could not be replicated in a later study (Bergman Nutley et al., 2011). Given the comparatively limited cognitive abilities of young children (e.g., duration, capacity and control of attention, limited ability to understand instructions and communicate a response; Howard & Okely, 2015), it has been suggested that computerized methods of training may be unsuitable to generate EF improvements in young children (Fernandez-Molina, Trella, & Barros, 2015; Lakes & Hoyt, 2004; Plowman & Stephen, 2003). To meaningfully engage in these programs participants require metacognitive awareness, technological expertise, and the ability to concentrate for prolonged periods (e.g., many training periods extend for upwards of 30-45 minutes) – abilities that are comparatively weaker among younger children.

Thus the question remains as to whether current computerized approaches are well suited to fostering the early development of EFs. In contrast, many existing activities and experiences of young children foster these cognitive control abilities (as exemplified by classroom activity and curricular approaches to EF development; Bodrova & Leong, 2007; Diamond, Barnett, Thomas, & Munro, 2007). If the relevant cognitive activities can be meaningfully embedded in everyday activities – earlier, and in a way that constantly challenges and extends young children's EFs – this would provide distinct advantages over computerized approaches. First, interventions could be designed for the unique needs of young children (e.g., sufficiently engaging and developmentally appropriate). Second, embedding cognitive challenge within existing everyday activities would create low- and no-cost means to foster EFs, making it more accessible to a greater number of children, families, and educators. At present, demands on time (e.g., current EF programs are often non-routine, with some training times in excess of 25 hours), costs (e.g., sometimes in excess of $2000), and technological availability render computerized programs inaccessible for much of the population, especially those most in need. This is problematic given the strong negative relationship established between socioeconomic status and EFs (Lawson, Hook, Hackman, & Farrah, 2015; Noble, Norman, & Farah, 2005), and that children with poorer EFs tend to benefit most from intervention (Diamond, 2013; Diamond & Lee, 2011). Lastly, efficaciously embedding EF activities within everyday practices, via the utilization of commonplace resources and requisite know-how, would greatly expand the range of settings, contexts, and activities for developing EFs.

The current series of studies sought to design, develop, and provide a 'proof of concept' for the efficacy of embedding cognitive activities in an everyday activity. Specifically, this initial series of studies are the first to evaluate whether cognitive activities embedded in a children's picture book (i.e., activities that require the child to control their thinking and behaviour to help a story's main character through a series of obstacles) have positive effects on their EFs. The first study investigated the effects of reading with embedded EF activities in both individual and group contexts on young children's executive functions (EFs) using a quasi-experimental design. The second study adopted a more-active control (i.e., dialogic reading) and experimental design to better evaluate the EF effects associated with integration of the EF activities. Finally, the third study sought to investigate whether the effect of reading the story with embedded EF activities changed across differing durations of the intervention, and whether effects persisted 2 months post-intervention (for a summary of the studies' characteristics, see Table 1). The overarching aim thus was to evaluate a range of contexts, durations, and intensities that would yield positive EF effects. In all cases, it was hypothesized that the children participating in the integrated EF activities would show better performance on non-trained EF tasks that shared few surface features with the trained EF activities. If successful, these results would represent an important advance/alternative to the ongoing proliferation of computerized EF and brain training, as well as providing initial efficacy data from which to further investigate (e.g., degree of transfer, longitudinal effects) this and other methods of EF training in the context of everyday activities. It is hoped that this would yield continued innovation of a more comprehensive range of low- and no-cost activities that parents and educators could integrate into their daily routines to promote young children's EF development. EF-promoting activities would thus no longer be restricted to computerized training, or even reading of this purpose-designed book, but instead could be conducted indoors or outdoors, in preschool or at home, in active or quiet time, individually or in a group.

Study 1

To initially investigate the effects of reading a storybook with embedded cognitive activities on young children's EFs, a pilot study was conducted to compare the effects of embedded EF activities with traditional reading of the same story. Specifically, preschool-aged children were read a picture-based story twice per week for 5 weeks, in one of the following three conditions: (1) reading the story one-on-one, with embedded cognitive activities; (2) reading the story in a group, with embedded cognitive activities; or (3) reading the story in a group, without children performing the cognitive activities. This permitted initial evaluation of whether these sorts of cognitive activities, when explicitly and meaningfully integrated into everyday routines, would have a positive effect on children's subsequent EF performance.

Methods

Participants

Three participating preschools were randomly assigned to one of three conditions after the baseline data was collected: (i) reading the story one-on-one with embedded cognitive activities (one-on-one intervention; *n* = 24); (ii) reading the story in a group with embedded cognitive activities (group intervention; *n* = 29); or (iii) reading the story in a group without children performing the cognitive activities (control; *n* = 22). Analysis of 'Socio-Economic Index for Areas (SEIFA) Relative Advantage and Disadvantage' data – a composite index of socioeconomic status (e.g., typical income, education, employment, housing) for geographic areas adopted by the Australian Bureau of Statistics – indicated all preschools were in low-SES areas (SEIFA Deciles 1 to 3). Ten participants withdrew from the study, were absent from post-testing, or missed more than two readings. The final sample thus consisted of 65 children (M_{age} = 4.40, *SD* = 0.66; 58.5% female) from preschools randomly assigned to the one-on-one intervention (*n* = 22; 12 female), group intervention (*n* = 25; 16 female), or control condition (*n* = 18; 10 female). All participants spoke English as a first language and were without significant hearing or vision impairment, or known developmental delay.

Intervention

For the purposes of this research, the primary investigator teamed with a children's book writer, illustrator, and publisher to create a children's picture book with embedded EF activities (*Quincey Quokka's Quest;* Howard & Chadwick, 2015). The book incorporated nine EF activities (i.e., three each of working memory, inhibition, and shifting) that were integrated within the story as 'obstacles' the child must help the main character through. The EF intervention involved a single adult fieldworker with early childhood experience reading the purposefully designed book, either individually or in a group, and then instructing the child/group on how to complete the EF activity on each page using the in-book guidelines. The reader was only briefly trained in order to parallel the process a novice reader might undertake if they trialed the book independently. Specifically, training consisted of providing the reader with a copy of the book to read and review independently (the book contains user-friendly instructions for each activity, which the book suggests all readers should familiarize themselves with prior to reading with a child) and two fidelity checks to ensure activities would be administered in the manner intended (one prior to reading with the children and one whilst reading to children). In all cases, no modifications to the reading were necessary.

Each reading with EF activities involved the first or second half of the nine activities (i.e., the first story page, the first four or last five of the activities, and then the final story page) to constrain the total amount of reading time per sitting to ~15 minutes. This was also facilitated by the fact that the book was designed so that there was no noticeable loss of logic or sequence if particular activities were skipped. Activities ran for around 2-4 mins each, depending on the nature of the activity and how fast the child was able to complete it. Some examples include remembering a sequence of steps and then recalling them in backwards order (WM), saying "hiss" when the reader points to a frog and "ribbit" when they point to a snake (inhibition; Figure 1), and switching between following a path by color and then by shape. For all groups, the same book was read twice per week for 5 weeks. The incorporation of cognitive activities added approximately 8-10 minutes of additional 'reading' time to the intervention group compared to the control group (control: ~5-7 minutes; intervention: ~15 minutes), although this added time involved performance of the EF activities rather than additional reading.

Over time the embedded EF activities were systematically increased in difficulty (either in speed or number of items to be remembered) in order to challenge and extend children's EF abilities. During children's first encounter with each activity, their initial maximum threshold was established by increasing the difficulty level to the point at which the activity became too difficult for the child to complete, and noting the difficulty level just prior to that point. For activities where difficulty increases equated to increases in speed, general (not precise) speed was noted (e.g., slow, medium, fast, very fast). For each subsequent reading, difficulty levels were made to slightly exceed the child's last-established thresholds, with the child's new thresholds then noted. Records indicated that all intervention condition participants increased in performance on the book's EF activities across the intervention period.

Measures

To assess changes in EF, three measures from the iPad-based Early Years Toolbox (Howard & Melhuish, 2015) were selected. Specifically, a measure of visual-spatial WM, inhibition, and shifting were adopted. These tasks were designed to assess young children's EFs in an age-appropriate and engaging way, and have been validated in a large Australian sample ($N = 1764$) showing as-good or often better validity and reliability evidence than other comparable and widespread measures (e.g., NIH Toolbox) (Howard & Melhuish, 2015). This subset of tasks, described below, was selected to ensure that total administration time did not exceed 20 min per child, with each task taking around 5 min to administer. For all measures, higher scores were indicative of better EF performance.

Mr. Ant. This working memory (WM) task, following the protocols of Howard and Melhuish (2015), requires participants to remember the spatial locations of 'stickers' placed on a cartoon ant, and identify these locations after a brief retention interval. Test trials increase in difficulty as the task progresses, with three trials at each level of complexity (progressing from one to eight stickers). All trials progress as follows: (1) Mr. Ant presented with *n* colored stickers for 5 s (where *n* equals the current level of WM demand); (2) presentation of a blank screen for 4 s; then (3) an image of Mr. Ant without stickers, along with an auditory prompt to recall where the stickers were, repeated until the participant's response is complete. Participants responded by tapping the spatial locations on Mr. Ant that they deemed had previously held stickers. The task continued until the earlier of completion (at level 8, eight spatial locations to remember) or failure on all three trials at the same level of difficulty. Instruction and three practice trials serve to familiarize participants with task requirements. WM capacity was indexed by a point score (Howard & Melhuish, 2015; Morra, 1994), which was calculated as follows: beginning from level 1, one point for each consecutive level in which at least two of the three trials were performed accurately, plus 1/3 of a point for all correct trials thereafter.

Go/No-Go. This inhibition task, following established protocols (Howard & Melhuish, 2015; Howard & Okely, 2015), requires participants to respond to 'go' trials ('catch fish') and withhold responding on 'no-go' trials ('avoid sharks'). Because the majority of stimuli are 'go' trials (80% fish), this generates a pre-potent tendency to respond, thus requiring participants to inhibit this response on 'no-go' trials (20% sharks). Prior to commencing, participants are given instruction and practice as follows: go instructions; five practice 'go' trials; no-go instructions; five practice 'no-go' trials; combined go/no-go instructions; then a mixed block of 10 practice trials (80% go trials); and a recap of instructions. Feedback in the form of auditory tones and a point score was provided for all practice trials. The 75 test stimuli were divided evenly into three test blocks (each separated by a short break and a reiteration of instructions). Each trial involved presentation of an animated stimulus (i.e., fish or shark) for 1500 ms, each separated by a 1000 ms inter-stimulus interval. Inhibition was indexed by an impulse control score, which is the product of proportional 'go' (to account for the strength of the pre-potent response generated) and 'no-go' accuracy (to index a participant's ability to overcome this pre-potent response).

Card Sorting. This shifting task, following the protocols of Howard and Melhuish (2015), requires children to sort cards (i.e., red rabbits, blue boats) first by one sorting dimension (i.e., color or shape), and then switch to the alternate sorting dimension. The task begins with a demonstration trial and two practice trials, after which children begin sorting by one dimension for six trials. In the subsequent post-switch phase, children are asked to sort cards by the other sorting dimension. For all test items, each trial begins by reiterating the relevant sorting rule and then presenting a stimulus for sorting. If the participant correctly sorts at least five of the six pre- and post-switch stimuli, they then proceed to a border phase of the task. In this phase, children are required to sort by color if the card had a black border or sort by shape if the card had no black border. After a demonstration trial and two practice trials, this sorting rule was reiterated prior to presenting the six sorting trials (consisting of three bordered stimuli and three non-bordered stimuli). For all phases, cards were ordered such that a particular stimulus was never presented more than twice in a row. Scores represent the number of correct sorts after the pre-switch phase.

Procedure

EF pre-testing was completed in a single session in the week prior to commencement of the intervention. This occurred in a quiet space in the child's preschool. Tasks were administered in the following same random order to all participants: Mr Ant, Go/NoGo, and Card Sorting. For the EF intervention, participating children were read the story individually in a quiet space in the preschool (for the individual reading condition) or in a group setting in the preschool's group reading area (for the group reading conditions). EF post-testing occurred in the week following training completion in the same manner as pre-testing. Because a single adult fieldworker conducted both data collection and reading, preschools were randomly assigned to a condition using a computer number generator after pre-testing was complete, thus eliminating potential for researcher bias at pre-test. Further, adoption of self-contained EF assessments meant that fieldworkers had little opportunity to influence a child's post-test task performance (i.e., standardized task instructions and performance-related feedback were delivered automatically via the iPad, responses were collected and scored by the iPad apps). Further, different fieldworkers with early childhood experience were used for each study to ensure consistency of findings across numerous fieldworkers.

Results

Preliminary Data Screening

Data were first screened to ensure the assumptions of planned statistical analyses were met. To ensure that all responses included in analyses were valid, Go/NoGo data were removed in cases of: overly fast responses (trials with response times < 300 ms, given that these were unlikely to be in response to the stimulus); indiscriminate responding (i.e., blocks with go trial accuracy > 80% and no-go trial accuracy < 20%); and non-responsiveness (i.e., blocks with go trial accuracy < 20% and no-go trial accuracy > 80%). This initial screening did not result in complete loss of any participants' data. Rather, in a limited number of cases (<5% in each study) it resulted in the removal of one of the three blocks of Go/No-Go data. In such cases the remaining two blocks were used to calculate an index of inhibitory control for that participant. Exploration of the data also identified two extreme data points, as indicated by boxplots. To evaluate the effects of these extreme data points, scores were winsorized (substituted with the next highest/lowest non-extreme value) and patterns of significance were then compared between the winsorized and original data. While some distributions were identified as skewed by significant Shapiro-Wilk statistics, none of the distributions showed extreme skewness ($z_{skewness} < 3$) before or after winsorization. Because subsequent analyses indicated identical patterns of significance for the winsorized and original datasets, results using the original data are reported. Eta squared (η^2) was calculated as a measure of effect size, with .01, .06, and .14 representing small, medium, and large effects, respectively (Cohen, 1969).

Evaluation of Intervention Effects

Descriptive statistics for all measures are provided in Table 2. To evaluate the efficacy of the intervention, EF data were analysed using a 2 (Time) x 3 (Condition) ANOVA with a within-subjects factor of Time (pre-test, post-test) and a between-subject factor of Condition (control group, group intervention, one-on-one intervention). Age was additionally included as a covariate given existing differences in pre-test scores across age groups (3, 4, or 5 years of age). For working memory, there was a significant main effect of Time, $F(1, 59) = 7.53$, $p = .008$, $\eta^2 = .10$, and Condition, $F(2, 59) = 6.34$, $p = .003$, $\eta^2 = .11$. Contrary to expectations, the Time x Condition interaction was non-significant, $F(2, 59) = 0.72$, $p = .489$, $\eta^2 = .02$. Post hoc analyses indicated that working memory scores were significantly higher at post-test ($M = 2.02$, $SD = 0.60$) compared to pre-test ($M = 1.69$, SD

= 0.81) and that the group condition had higher working memory scores compared to the individual or control conditions.

For shifting, results indicated the main effect of Time was non-significant, $F(1, 60) = 2.01$, $p = .161$, $\eta^2 = .03$. The main effect of Condition was also non-significant, $F(2, 60) = 1.38$, $p = .260$, $\eta^2 = .04$. As expected, these main effects were conditioned by a significant Time x Condition interaction, $F(2, 60) = 3.54$, $p = .035$, $\eta^2 = .10$. Post hoc analyses indicated that the group and individual conditions showed improved scores at post-test relative to pre-test, yet the control condition did not show a similar change over this period.

For inhibition, results indicated the main effect of Time was non-significant, $F(1, 59) = 1.40$, $p = .241$, $\eta^2 = .02$. The main effect of Condition was again non-significant, $F(2, 59) = 0.12$, $p = .888$, $\eta^2 = .00$. Contrary to expectations, however, the Time x Condition interaction was non-significant, $F(2, 59) = 0.11$, $p = .895$, $\eta^2 = .00$, suggesting there were no unique effects of the intervention on inhibition scores.

Study 1 Preliminary Conclusions

This study aimed to evaluate the effects of embedding cognitive activities in a children's picture book, read individually and in a group, on developing EF performance. Results indicated significant improvements in shifting in the intervention groups, in the context of individual and group reading. In contrast, the effects on inhibition were non-significant. While the effects of the intervention on working memory also appeared non-significant, this must be interpreted in the context of what was being measured – working memory capacity – and what level of gains could realistically be expected. That is, mental-attentional capacity (a causal component underlying developmental growth of working memory capacity) has been found to increase approximately one unit approximately every other year, from one unit at 3 years of age to seven units around 15 years of age (Morra, Gobbo, Marini, & Sheese, 2008). As such, the descriptive increase in the individual intervention group's working memory capacity of nearly half a unit (corresponding to a year of normal development) is, in practical terms, substantial. This is especially so given the short duration of the intervention. Moreover, the small sample size further limits the ability to detect potentially genuine change. To illustrate this point, it is notable that paired-samples t-tests for each group indicated a significant improvement in working memory capacity for only the one-on-one intervention group ($\eta^2 = .32$). Current results thus suggest integrating cognitive challenge into everyday activities may be a viable means for enhancing shifting and working memory in young children, although further research is required to replicate these results. The efficacy of this approach for improving inhibition is much less clear, such that the current study suggested no improvements beyond normal developmental change or practice effects. In fact, improvement of inhibition via EF training has been notoriously difficult in previous studies, and has been met with mixed success (e.g., Enge et al., 2014; Thorell et al., 2009). Further research with larger samples is needed to replicate and extend these findings. This research needs a closer-comparison control group (e.g., a one-on-one control condition) and a research design that permits stronger causal inferences to be drawn (e.g., given the current ability to control for factors such as clustering in preschools). This was the focus of Study 2.

Study 2

Despite these positive results, several limitations hinder interpretation and generalisability of the pilot study's findings. First, given that the control condition was standard *group* reading, the effects of one-on-one reading may have simply been because this form of reading was inherently more beneficial for development (e.g., it involves greater engagement of children's EFs). Thus, a control condition that more closely approximates the intervention was needed to further evaluate the efficacy of this EF training method. This is especially important given previous studies that have found unique benefits of their active control condition (Thorell et al., 2009). While no EF benefits were expected of the active control condition in the current study, we nevertheless wanted to ensure the fairest possible non-EF control condition (same book, active reading) to ensure that effects could be better attributed to the EF activities. Further, the intervention duration was extended to 7 weeks in case the previous lack of working memory and inhibition effects were due to insufficient training opportunities.

The present study thus compared one-on-one reading of the children's book with embedded EF activities relative to an active control that similarly engaged children in the book-reading process, yet lacked clear engagement of EFs. Specifically, the current study adopted an experimental design in which participants were individually read the same book, once per week for 7 weeks, in one of two conditions: (1) reading the story one-on-one, with embedded cognitive activities (intervention condition); or (2) reading the book without embedded cognitive activities, instead using interactive dialogic reading (active control condition). Dialogic reading was selected as a comparison control condition because, like the intervention condition, it more actively involves children in storytelling than typical shared reading, yet it would not be expected to improve children's EF abilities. Originally purposed for improving children's language development, dialogic reading involves collaborative storytelling, in which the reader identifies and poses problems to the child, and then scaffolds their answers (Whitehurst et al., 1988).

Methods

Participants

Participants were 46 children from a single preschool centre, randomly assigned to the intervention (n = 23) or active control condition (n = 23). The SEIFA index for the centre indicated it was in a high-SES area (SEIFA Decile 9). Two participants withdrew from the study after random assignment and four participants were excluded due to absence from post-testing or missing more than two reading sessions. The final sample therefore consisted of 40 children (M_{age} = 4.41, SD = 0.53; 52.5% female) in either the intervention (n = 19; 11 female) or active control condition (n = 21; 10 female). All participants spoke English as a first language and were without significant hearing or vision impairment, or known developmental delay.

Intervention

The EF intervention in this study was identical to that for the one-on-one intervention condition in the first study, except that the book was only read once per week. The primary change from the first study was the use of an active control condition that involved one-on-one reading (compared to the group control condition in the first study) and the use of dialogic reading principles in the control condition to actively engage the children in the book reading (albeit without EF activities). Given the highly similar nature of the EF intervention, only the control condition will be described here.

Active Control Condition (Dialogic Reading). Dialogic reading involves readers adopting the "PEER" sequence, requiring the reader to prompt (P) a child with questions about a book's story and pictures, evaluate (E; praise correct responses, offer alternatives for incorrect responses) and expand (E) upon a child's response with more information, and then, where appropriate, encourage the child to repeat (R) their expansion (Whitehurst et al., 1994; Whitehurst et al., 1988). This sequence was used to design prompts that were focused on potential problems in the book. Examples of such prompts include "How should the animals escape from the spider's web?", and "How can he [Quincey] get across the river?". Thus, whilst reading the story, instead of engaging the child in the embedded EF activities, the adult reader would identify a potential obstacle preventing goal attainment in the story and ask the child how they think this problem could be overcome. Then they would discuss and expand the child's answer, offering other potential resolutions, and in doing so, model more sophisticated approaches. Further, prompts were designed to gradually increase in difficulty over time (i.e., problems became harder to "solve") with progressive readings. Five sets of prompts were developed (one for each week of training), each containing at least 12 prompts. Children were never presented with the same set of prompts more than once over the course of the training period. Prompts were adhered to unless the child showed interest in a certain feature of the book. In these cases, the feature of interest was briefly discussed before the child's attention was redirected to the next prompt. Use of dialogic reading served to roughly equate the amount of reading time (~15 minutes) between the two conditions, albeit with different activities undertaken in that time.

Measures and Procedure

All EF measures and procedures were identical to Study 1, except that all reading occurred in an individual reading session, rather than in a group reading format for some participants. A single adult fieldworker with early years experience again conducted all reading and data collection, with identical validity controls as per Study 1 (e.g., random assignment after pre-test, standardization of tasks), but was not the same fieldworker as in Study 1 (to ensure consistency of findings across fieldworkers).

Results

Preliminary Data Screening

Data were screened using the same procedures as Study 1 to ensure they met assumptions of planned statistical analyses (i.e., removing invalid cases in Go/No-Go data, which again did not result in removal of complete data for any participant). Exploration of the data identified five extreme data points, as indicated by boxplots. To evaluate the effects of the extreme data points, these scores were winsorized (substituted with the next highest/lowest non-extreme value) and patterns of significance were compared for these and the original data. While some distributions were identified as skewed by significant Shapiro-Wilk statistics, none of the distributions were extremely skewed ($z_{skewness} < 3$) before or after winsorization. Because subsequent analyses indicated identical patterns of significance for the winsorized and original datasets, results using the original data are reported.

Evaluation of Intervention Effects

Descriptive statistics for all measures are provided in Table 3. To evaluate the efficacy of the intervention, EF data were analysed using a 2 (Condition) x 2 (Time) ANOVA with a within-subjects factor of Time (pre-test, post-test) and a between-subject factor of Condition (control, intervention). A covariate of age was again included due to pre-existing age differences. For working memory scores, there was a significant main effect of Time, $F(1, 37) = 9.34$, $p = .004$, $\eta^2 = .16$, such that scores were significantly higher at post-test ($M = 2.17$, $SD = 0.67$) than pre-test ($M = 1.83$, $SD = 0.70$). However, the main effect of Group was non-significant, $F(1, 37) = 1.67$, $p = .205$, $\eta^2 = .04$. In line with expectations, main effects were conditioned by a significant Time x Condition interaction, $F(1, 37) = 4.39$, $p = .043$, $\eta^2 = .08$. Post hoc analyses to examine this interaction effect indicated that intervention condition scores improved from pre- to post-test, $t(18) = -3.51$, $p = .003$, $\eta^2 = .41$, whereas the control condition showed no significant change over this period, $t(20) = -0.57$, $p = .573$, $\eta^2 = .02$.

For shifting, results indicated the main effect of Time was non-significant, $F(1, 37) = 0.05$, $p = .828$, $\eta^2 = .00$. The main effect of Group was again non-significant, $F(1, 37) = 0.00$, $p = .998$, $\eta^2 = .00$. As expected, however, these main effects were conditioned by a significant Time x Condition interaction, $F(1, 37) = 13.73$, $p = .001$, $\eta^2 = .27$.. Post hoc analyses suggested that the intervention condition similarly improved from pre-test to post-test, $t(18) = -5.69$, $p < .001$, $\eta^2 = .64$, whereas the control condition did not significantly change from pre- to post-test, $t(20) = -0.59$, $p = .561$, $\eta^2 = .02$.

For inhibition, results indicated the main effect of Time was non-significant, $F(1, 37) = 1.70$, $p = .201$, $\eta^2 = .04$. Once again, the main effect of Condition was non-significant, $F(1, 37) = 0.69$, $p = .412$, $\eta^2 = .02$. Contrary to expectations, however, the Time x Condition interaction was non-significant, $F(1, 37) = 1.29$, $p = .264$, $\eta^2 = .03$, suggesting that there were no unique effects of the intervention on inhibition scores.

Study 2 Preliminary Conclusions

This study aimed to replicate and extend the results of Study 1, but with a more active and closely comparable control condition. Results largely paralleled those of Study 1, such that there were effects of embedded cognitive activities over and above dialogic reading on shifting and working memory, but no unique effects on inhibition. More than a replication of the findings of Study 1, particularly notable is the consistency of these results when compared with individual shared reading as an active control condition, despite the relative brevity of the intervention in Study 2 (i.e., 70-105 minutes of intervention engagement, compared to 100-200 minutes in Study 1). In contrast, many other successful EF interventions have involved substantially higher time commitments (i.e., 6 to 25 hours; Kirk et al., 2015; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2011; Traverso, Viterbori, & Usai, 2015). The current results thus provide converging evidence for EF activities embedded in everyday routines having a positive effect on working memory and shifting. Still unclear, however, are the trajectories of change associated with the intervention (e.g., whether improvements are continuous and linear, or whether brief intervention generates similar benefits) and the extent to which these acute EF improvements are maintained after a period of time without the reading intervention.

Study 3

Although the initial two studies provide converging evidence for the efficacy of embedded EF activities in the context of reading, there remains limited research regarding the optimal dose and frequency of EF training tasks (Diamond, 2013). Wass et al.'s (2012) critical review of EF training programs highlights this point, demonstrating the variability in training frequency (e.g., ranging from one session/week to five sessions/week; Kloo & Perner, 2003; Rueda et al., 2005), training intensity (e.g., training times ranging from 30 minutes to 25 hours over the intervention period; Kloo & Perner, 2003; Holmes et al., 2009) and program duration (e.g., ranging from 2 weeks to 8 weeks; Kloo & Perner, 2003; St Clair Thompson, 2007). Further, most EF interventions have administered an intensive phase of training with only pre- and post-test assessments of EF (Wass et al., 2012). As a consequence, there remains no clear guidance for the optimal dosage, frequency, or intensity of EF interventions. The current study thus sought to investigate whether the effect of reading the story with embedded EF activities changed across differing doses of the intervention. Given the previous lack of difference in effects between a passive and active reading control condition, and resource constraints (e.g., time per week made available by preschools, financial), a passive reading control condition was again adopted. Specifically, participants were read the story one-on-one, once per week for 9 weeks, either with (intervention group) or without (control group) performing the cognitive activities. This longer intervention period permitted an ability to establish whether inhibition effects could be found with a longer intervention duration, as well as conduct multiple mid-intervention evaluations. That is, in order to investigate potential differences in intervention efficacy with continued administration, participants were assessed on EF measures after every 3 weeks of reading to provide initial insight into the dose-response effect of the embedded EF activities. These measures were again administered 2 months post-intervention to investigate the extent to which acute EF improvements were maintained after a period of time without the reading intervention.

Methods

Participants

Participants were 43 children from two preschool centres, which were randomly assigned to one of two conditions after baseline data collection: reading a story one-on-one, with embedded cognitive activities (intervention; n = 21); or reading the story one-on-one, without embedded cognitive activities (control; n = 21). The SEIFA index for these preschools indicated they were in a moderate-SES area (SEIFA Decile 6). EF data was not collected for nine participants due to their dropout or absence from at least one EF data collection session. The final sample thus included 34 children (M_{age} = 4.29, SD = 0.53; 61.8% female) who had been randomly assigned to either the intervention (n = 19; 12 female) or control group (n = 15; 9 female). Two-month follow-up EF assessments were conducted (M = 59.26 days; range = 55 – 67) for all but one intervention group child and two control group children who were absent during follow-up data collection. All participants spoke English as a first language and were without significant hearing or vision impairment, or known developmental delay.

Intervention

The EF intervention in this third study was identical in delivery to that in the second study, except that the book was read once per week for a total of 9 weeks. Moreover, given that there were no effects of dialogic reading in Study 2, the control condition in this study were simply read the book (without cognitive activities) with the same frequency as the intervention condition. All other circumstances of reading paralleled those of the second study.

Measures and Procedure

All measures were identical, and administered in an identical manner, as in Studies 1 and 2. The protocols for reading in this study were also identical to Study 2, except reading occurred over a longer intervention period (9 weeks) and was separated by EF assessments after each 3-week reading block. This allowed evaluation of the trajectory of change across the intervention period. A single adult fieldworker with early years experience again conducted all reading and data collection, with identical validity controls as per Studies 1 and 2, and was again a different fieldworker from these previous studies (to ensure consistency of findings across fieldworkers).

Results

Preliminary Data Screening

Data were screened using the same procedures as Studies 1 and 2 to ensure they adhered to the assumptions of the planned statistical analyses (i.e., removing invalid cases in Go/No-Go data, which again resulted in no complete data being removed for any participant). Exploration of the data identified four extreme data points, as indicated by boxplots. To evaluate the effects of the extreme data points, these scores were winsorized (substituted with the next highest/lowest non-extreme value) and patterns of significance were compared for these and original data. While one distribution (i.e., Inhibition Time 4) was extremely skewed as indicated by $z_{skewness} > 3$, after winsorizing no distributions were extremely skewed. Subsequent analyses indicated identical patterns of significance for the winsorized and original datasets. As such results using the original data are reported. Because Mauchly's test of sphericity indicated that the assumption of sphericity remained violated for shifting measures, an adjusted degrees of freedom analysis of variance (i.e., Greenhouse-Geisser) was conducted for this analysis.

Evaluation of Intervention Effects

Descriptive statistics for all measures are provided in Table 4. To evaluate the efficacy of the intervention, EF data were analysed using a 2 (Condition) x 4 (Time) ANOVA with a within-subjects factor of Time (i.e., baseline, 3 weeks, 6 weeks, 9 weeks/post-test) and a between-subject factor of

Condition (i.e., control, intervention). Age was again included as a covariate due to pre-existing EF differences by age. For working memory, there were no significant main effects of Time, $F(3, 93) = 0.45$, $p = .720$, $\eta^2 = .01$, or Condition, $F(1, 31) = 2.92$, $p = .097$, $\eta^2 = .07$. There was, however, a significant interaction, $F(3, 93) = 4.34$, $p = .007$, $\eta^2 = .12$. One-way repeated measures ANOVAs indicated a significant effect of Time in the intervention condition, $F(3, 54) = 6.35$, $p = .001$, $\eta^2 = .26$, but not the control condition, $F(3, 42) = 0.36$, $p = .786$, $\eta^2 = .02$. Post hoc analyses indicated that working memory scores improved across all time points for the intervention condition, except between 3 to 6 weeks.

For shifting, an adjusted degrees of freedom Greenhouse-Geisser ANOVA indicated no main effects of either Time, *G-G* $F(2.46, 76.17) = 0.92$, $p = .420$, $\eta^2 = .02$, or Condition, $F(1, 31) = 2.72$, $p = .109$, $\eta^2 = .07$. However, these non-significant main effects were conditioned by a significant interaction, *G-G* $F(2.46, 76.17) = 5.37$, $p = .004$, $\eta^2 = .14$. One-way repeated measures ANOVAs indicated a significant effect of Time in the intervention condition, $F(3, 54) = 4.06$, $p = .011$, $\eta^2 = .18$, but not the control condition, $F(3, 42) = 2.78$, $p = .053$, $\eta^2 = .17$. Post hoc analyses indicated shifting scores were significantly higher at 6 weeks than at baseline, with no significant improvements after only 3 weeks or from 6 weeks to 9 weeks.

For inhibition, there was a significant main effect of Time, $F(3, 93) = 6.61$, $p < .001$, $\eta^2 = .02$. Post hoc analyses indicated that inhibition scores improved across all time points ($M_B = 0.61$, $SD = 0.24$; $M_3 = 0.70$, $SD = 0.20$; $M_6 = 0.75$, $SD = 0.19$), except from 6 to 9 weeks ($M_9 = 0.77$, $SD = 0.19$). There was no main effect of Condition, $F(1, 31) = 0.02$, $p = .969$, $\eta^2 = .00$. Contrary to expectations, there was no significant interaction conditioning these main effects, $F(3, 93) = 0.52$, $p = .647$, $\eta^2 = .01$. As such, and consistent with Study 2, there were no effects of the intervention on inhibition scores at any measurement time point.

Evaluation of the Maintenance of Intervention Effects

To examine the maintenance of gains at 2-month follow-up, shifting and working memory scores were analysed using a 2 (Condition) x 3 (Time) ANOVA with a within-subjects factor of Time (i.e., baseline, post-test/9 weeks, 2-month follow-up) and a between-subjects factor of Condition (i.e., control, intervention), with planned contrasts on Time comparing baseline to post-test, and post-test to

2-month follow-up. For working memory scores, a planned contrast revealed that the Time effect differed between Conditions from baseline to post-test, $F(1,29) = 6.54$, $p = .016$, $\eta^2 = .18$, such that the intervention condition showed a higher score at post-test ($M_B = 1.61$, $SD = 0.85$; $M_9 = 2.41$, $SD = 0.70$), whereas the control condition showed a lower score at post-test ($M_B = 1.95$, $SD = 0.65$; $M_9 = 1.82$, $SD = 0.99$). An additional planned contrast revealed that the Time effect did not differ between conditions from post-test to the 2-month follow-up, $F(1,29) = 0.53$, $p = .475$, $\eta^2 = .02$ (Intervention: $M_B = 2.41$, $SD = 0.70$; $M_{FU} = 2.46$, $SD = 0.64$; control $M_B = 1.82$, $SD = 0.99$; $M_{FU} = 2.05$, $SD = 1.10$). This suggests that the working memory gains were maintained by the intervention group 2 months post-intervention.

For shifting, a planned contrast revealed that the Time effect differed between Conditions from baseline to post-test, $F(1, 29) = 4.24$, $p = .049$, $\eta^2 = .13$, with the intervention condition showing a higher score at post-test ($M_B = 5.11$, $SD = 4.68$; $M_9 = 7.94$, $SD = 4.01$) and the control condition showing a lower score at post-test ($M_B = 6.23$, $SD = 4.46$; $M_9 = 5.92$, $SD = 4.46$). Also, a planned contrast revealed that the Time effect did not differ between conditions from post-test to the 2-month follow-up, $F(1,29) = 0.56$, $p = .460$, $\eta^2 = .02$ (Intervention: $M_B = 7.94$, $SD = 4.01$; $M_{FU} = 7.89$, $SD = 3.82$; control $M_B = 5.92$, $SD = 4.46$; $M_{FU} = 6.53$, $SD = 4.98$). As with working memory, the shifting gains were maintained by the intervention group even 2 months post-intervention.

Study 3 Preliminary Conclusions

This study sought to extend the results of Studies 1 and 2 by replicating the EF effects of those previous studies and evaluating whether trajectories of EF improvement were consistent over the course of the intervention and whether intervention effects persisted after a period of time without the intervention. Results again paralleled Studies 1 and 2, such that there were significant effects of embedded cognitive activities on working memory and shifting, but not on inhibition. Further, results indicated that these benefits did not constantly and uniformly increase over a longer intervention period. Rather, the benefits in shifting appeared to be most pronounced in the initial three week reading period, after which these benefits were maintained (i.e., remained above control levels, but did not show further significant improvements). Working memory similarly showed its greatest gains in the first three weeks of the intervention period, although there were further improvements in working memory scores after the final three weeks of the intervention. It is also notable that working memory and shifting gains of the intervention group persisted even 2 months post-intervention. While further research is needed to explore different manipulations to intervention frequency and duration, these results suggest that brief EF intervention may be sufficient to yield change. The extent to which the subsequent intervention period is necessary for longer-term maintenance of gains, and the conditions under which this subsequent training period may yield further improvements, require further study.

Overall Discussion

The current study provides converging evidence for the efficacy of embedding EF activities, in the context of shared book reading, on preschoolers' working memory and shifting abilities. Specifically, the results of the first study identified that shifting benefits occurred in the context of individual and group reading, yet working memory benefits occurred only in the context of individual reading. The second study replicated these findings in the context of a more rigorous experimental design (with random assignment at the individual level) and a more-comparable, dialogic reading control condition. The third study suggested that the benefits demonstrated in these initial two studies were unlikely to occur continuously over the course of the intervention. Instead, EF improvements were more pronounced initially, after which these gains were largely maintained (although working memory also showed a smaller subsequent increase). Further, rather than acute EF effects, these intervention group gains continued to persist after 2 months post-intervention. Together, these results provide a 'proof of concept' for the efficacy of embedding cognitive activities in the context of everyday routines, thereby extending the range of users (e.g., to parents, caregivers, educators) and contexts in which this approach can be used (e.g., active and quiet play, indoors and outdoors, at home and in early childhood education and care settings).

The significant effects of this EF intervention corroborates extensive research supporting the ability to support, foster, and enhance children's EFs more broadly (e.g., Diamond & Lee, 2011), and in particular shifting (e.g., Kray, Karbach, Haenig, & Freitag, 2012; Röthlisberger et al., 2011; Traverso et al., 2015) and working memory (Klingberg et al., 2005; Röthlisberger et al., 2011; Thorell et al., 2009; Traverso et al., 2015). However, current approaches to EF training are constrained by their targeted age groups (typically older children, adolescents, and adults), accessibility (e.g., technological requirements), and their resource-intensive nature (e.g., time, money). The current approach, in contrast, represents a low-cost non-computerized EF training method, the principles of which can be extended to a no-cost 'menu' of EF training options that can be embedded into everyday practice. Moreover, another advance of the current intervention is its relative brevity (with benefits seen after only 42-63 minutes of intervention engagement, compared to upwards of 25 hours with other EF training approaches; Kirk et al., 2015; Rothlisberger et al., 2011; Traverso et al., 2015). That is, although previous EF training studies are often conducted over a similar number of weeks as the present studies, training in previous studies tends to be more intense, featuring longer and more weekly training sessions. In contrast, EF training using *Quincey Quokka's Quest* appeared to generate a sufficient level of challenge to yield similar (and in some cases stronger) EF benefits relative to computerized EF training approaches. Further, that the three studies yielded highly consistent results with young children sits in stark contrast to the often-inconsistent EF improvements that other approaches have tended to generate with this age group (e.g., Bergman Nutley et al., 2011).

The magnitude of these effects is also striking. In terms of working memory gains, for instance, improvements by the intervention group ranged anywhere from a quarter-unit increase in functional working memory capacity (for the group intervention condition of Study 1) to an approximately half-unit increase (for the one-to-one intervention groups in Studies 1 and 2) or even a 0.81-unit increase after a 9-week intervention. Given that mental-attentional capacity (a causal component underlying developmental growth of working memory) has been found to increase around one unit approximately every other year (Morra et al., 2008), this increase is, in practical terms, rather substantial. Whereas a single-unit increase in mental-attentional (or working memory) capacity would be expected to occur over the course of a full year of normal development (for further support from developmental norms for the current tasks, see Howard & Melhuish, 2015), the current studies found the equivalent of 3- to 9-months of normal development in as little as one month. Although these gains are likely functional rather than structural in nature, the ability to coordinate additional information in working memory as a result of EF training could nevertheless have important impacts for children's learning and learning-related abilities (e.g., literacy, numeracy, school readiness; Blair & Razza, 2007; Bull et al., 2008). In fact, these gains in EF performance approach levels found to separate preschoolers performing at the 25th and 50th percentiles, and between those at the 50th and 75th percentiles, for their age (Howard & Melhuish, 2015). This is also the case for shifting, in which the gains found in the current studies – ranging from 1.48 units to 5.84 units (the latter equated to successful performance at a full level higher in complexity) – is in line with the difference between young children lower and average, or average and higher, in performance on this shifting task.

While the lack of significant effects on inhibition was not expected, it is at least somewhat consistent with previous research. Inhibition training effects have been at best mixed, such that some studies have found improvements (Röthlisberger et al., 2011; Traverso et al., 2015) while others have been largely unsuccessful (Enge et al., 2014; Thorell et al., 2009). To explain this, Thorell et al. (2009) suggested that the comparatively lower success rate of inhibition training programs relative to working memory training (which has a comparatively stronger record of success) may reflect the difficulty in making inhibition training programs sufficiently adaptive. As evidenced by studies such as Klingberg et al.'s (2002), adapting program difficulty to ensure tasks provide an adequate level of challenge is an essential characteristic of efficacious training programs. For working memory activities, difficulty may be continuously adjusted by increasing the number of items to be remembered, manipulating the order in which items are recalled (i.e., random, consecutive, reverse order), or increasing the time that information must be retained prior to recall (Kirk et al., 2015). In contrast, increasing the difficulty of inhibition tasks often involves manipulating the speed with which a pre-potent response must be overcome, or the salience and number of distracting stimuli. In the context of *Quincey Quokka's Quest*, however, the imprecise increase in speed introduced by the reader may have been insufficient to set the level of inhibitory challenge just beyond the child's current level of ability.

An interesting question is whether the same effects would be expected if this EF approach was adopted by parents or educators, given evidence from a recent meta-analysis suggesting that many researcher-generated effects were not replicable when implemented by non-researchers (Mol, Bus, & De Jong, 2009). Unique to the current series of studies is our adoption of a different fieldworker for each study, all of whom had experience in early childhood education and care contexts (with two of the three having experience as preschool educators). While this does not ensure that results can be generalized to reading by parents and educators, it suggests greater promise than if these same results had been found using highly trained researchers. Nevertheless, the extent to which these findings generalize to use by parents and educators is an important question for future research. Future research would also benefit from consideration of additional participant characteristics (e.g., prior experience with books, enjoyment of reading), inclusion of measures to examine the breadth of benefits (e.g., if the positive effects of shared book reading are maintained, whether benefits transfer to abilities such as problem solving, planning, and self-regulation), and the extent to which these EF effects impact longitudinal outcomes (e.g., school readiness, academic performance). Prior research, indicates there is likely an important relationship (mediator, moderator, bi-directional) between language development and EF growth (e.g., Hughes, 1998; Marton, 2008), which may be especially important for reading-based EF training. Future research would also benefit from examining why trajectories of change from EF training are not steady and consistent across all EFs (e.g., a result of insufficient challenge, biological ceiling, etc.)

These results must also be interpreted within the context of the limitations of the current studies. For one, there were unexpected yet consistent differences in baseline EF scores for the control group across all three studies. It is noted that random assignment of centres (in Study 1) or participants (in Studies 2 and 3) did not occur until after pre-testing, and was conducted by a computerized random number generator. Further, it is noted that few of these differences represented statistically significant pre-existing differences between groups (this was only significant for working memory in Studies 1 and 2). It is also notable that in most cases that the gains of the intervention group not only closed the performance gap with the control group, but also in most cases surpassed the control group's pre- and post-test performance (that is, there were significant condition effects at post-test for working memory and shifting for all but shifting in Study 3). As such, the effects of the intervention did not simply remove pre-existing differences in performance. Nevertheless, future research would benefit from adopting stratified random sampling (especially in the context of smaller sample sizes, for which random assignment is less robust) to ensure initial group equivalence.

There was also a degree of instability in EF outcome scores, such that across the three studies the extent of change (e.g., shifting gains ranged from 1.48 to 5.84 correct card sorts), pre-test scores (e.g., working memory capacity scores ranging from 1.55 to 2.00), and post-test scores were not perfectly consistent. One potential explanation is the use of only a single measure of each EF, which is not a pure measure of the latent ability of interest (the notorious 'task impurity problem'). That is, given that no task can be a pure measure of the EF of interest, it is plausible that the results of a single task are spurious (e.g., due to situational or motivational factors), transitory (e.g., due to temporary practice effects), or the product of enhancements to non-EF processes. The first two appear unlikely as a result of converging evidence across these studies, as well as the strong validity and reliability evidence for the adopted EF tasks (Howard & Melhuish, 2015). Nevertheless, the current data is unable to conclusively determine that improvements in EF performance necessarily resulted from enhancements to the targeted EFs. For instance, motivation could be a common factor underlying performance increments in the intervention group. However, it is notable that improvements were not found for inhibition, thus making this explanation unlikely.

Another possible explanation is the inability to blind data collectors to participants' experimental condition introducing tester bias. While possible, it is noted that extensive validity controls were put in place to minimize this possibility (e.g., randomization after pre-testing, adoption of standardized and self-contained EF assessments with little opportunity to influence a child's task performance). Attribution of the results to tester bias also becomes increasingly implausible when considering the consistency in findings across the different data collector for each study. A perhaps more plausible alternative is the difference in SES across the samples, which could at least begin to account for the between-study differences and instability in EF scores (e.g., baseline inhibition scores ranged from .54-.58 in the lowest SES group, from .59-.63 in the moderate-SES group, and from .60-.67 in the high-SES group). As such, consistent with research establishing a negative relationship between SES and EFs and potential for increased gains among low-EF groups (e.g., Diamond, 2013; Diamond & Lee, 2011; Lawson et al., 2015; Noble et al., 2005), differences in baseline scores and degree of change in the current study may be at least partly a product of between-study differences in children's

SES. Still, future research would benefit from examining these possibilities through investigation of EF effects by socio-economic sub-group and adopting multiple measures for the outcomes of interest.

While not a limitation, further research is required to examine the longer-term maintenance and real-world impacts of these improvements (e.g., on young children's subsequent school readiness, academic success, ADHD symptomology). EFs remain a promising target for intervention given their potential broad and apparent lifelong impact but few studies have established that altering these developmental trajectories yield a similar degree of change (or change at all) in these longitudinal outcomes. As such, this is an area that is desperately under-researched. Finally, while the restricted sample size and demographics of these studies limit the strength of their respective conclusions, that the results were highly consistent across the three studies strengthens the case for the authenticity of these EF effects.

These studies show promising support for the trainability of shifting and working memory in a way that can be readily administered by parents and educators, at low to no cost. That is, embedding cognitive challenge within everyday activities requires only the capacity to engage children's EFs and sufficiently open-ended resources to permit flexibility in their use. While *Quincey Quokka's Quest* (Howard & Chadwick, 2015) has been shown to be an effective example of this, these benefits are by no means expected to be restricted to this book. Rather, this approach allows for EF training to be seamlessly integrated into children's existing home and preschool routines, unlike the majority of existing interventions that represent an "additional more" that must be accommodated and incorporated into a child's (and parent's) day. Whereas high-cost computerized interventions have more recently dominated the EF training space, the accessibility of this approach opens up opportunities for EF training that can be more widely accessed, especially by less-advantaged populations that tend to show relatively poorer EF abilities (Diamond, 2013; Diamond & Lee, 2011). It also creates an opportunity for a broader range of users. That is, rather than necessitating administration by a professional or researcher, the current EF approach can be implemented by parents and educators alike. Such strategies for integrating cognitive challenge offers researchers, parents, and educators multiple accessible low- and no-cost methods to engage and improve children's EFs.

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Table 1

Summary of study characteristics

	Study 1	Study 2	Study 3
Demographics			
Participants' Age			
Mean (*SD*)	4.40 (*0.66*)	4.41 (*0.53*)	4.29 (*0.53*)
Range	3.00 – 5.76 years	2.99 – 5.16 years	3.18 – 5.23 years
Percent girls	58.5%	52.5%	61.8%
SES (SEIFA Decile)	Deciles 1-3	Decile 9	Decile 6
Intervention			
EF Training Dose	2 times/wk	1 time/wk	1 time/wk
EF Training Duration	5 weeks	7 weeks	9 weeks
Conditions	**Control Group:** Passive Group Reading	**Control Group:** Active (Dialogic) 1:1 Reading	**Control Group:** Passive 1:1 Reading
	Intervention Groups: 1:1 EF book activities Group EF book activities	**Intervention Group:** 1:1 EF book activities	**Intervention Group:** 1:1 EF book activities

Table 2

Descriptive statistics by condition (Study 1)

	Control		**Group**		**One-on-One**	
	Pre-test M (*SD*)	Post-test M (*SD*)	Pre-test M (*SD*)	Post-test M (*SD*)	Pre-test M (*SD*)	Post-test M (*SD*)
Working memory	1.55 (*0.80*)	1.83 (*0.51*)	2.00 (*0.75*)	2.25 (*0.55*)	1.44 (*0.82*)	1.89 (*0.65*)
Shifting	3.56 (*3.82*)	3.56 (*3.60*)	2.76 (*3.76*)	6.04 (*3.69*)	2.09 (*3.21*)	3.57 (*4.03*)
Inhibition	0.54 (*0.20*)	0.64 (*0.17*)	0.55 (*0.22*)	0.69 (*0.26*)	0.58 (*0.22*)	0.69 (*0.18*)

Table 3

Descriptive statistics by condition (Study 2)

	Control		**Intervention**	
	Pre-test M (*SD*)	Post-test M (*SD*)	Pre-test M (*SD*)	Post-test M (*SD*)
Working memory	1.86 (*0.87*)	1.95 (*0.68*)	1.81 (*0.45*)	2.40 (*0.58*)
Shifting	5.67 (*4.39*)	6.24 (*4.41*)	2.84 (*4.21*)	8.68 (*3.43*)
Inhibition	0.67 (*0.14*)	0.79 (*0.15*)	0.60 (*0.21*)	0.78 (*0.12*)

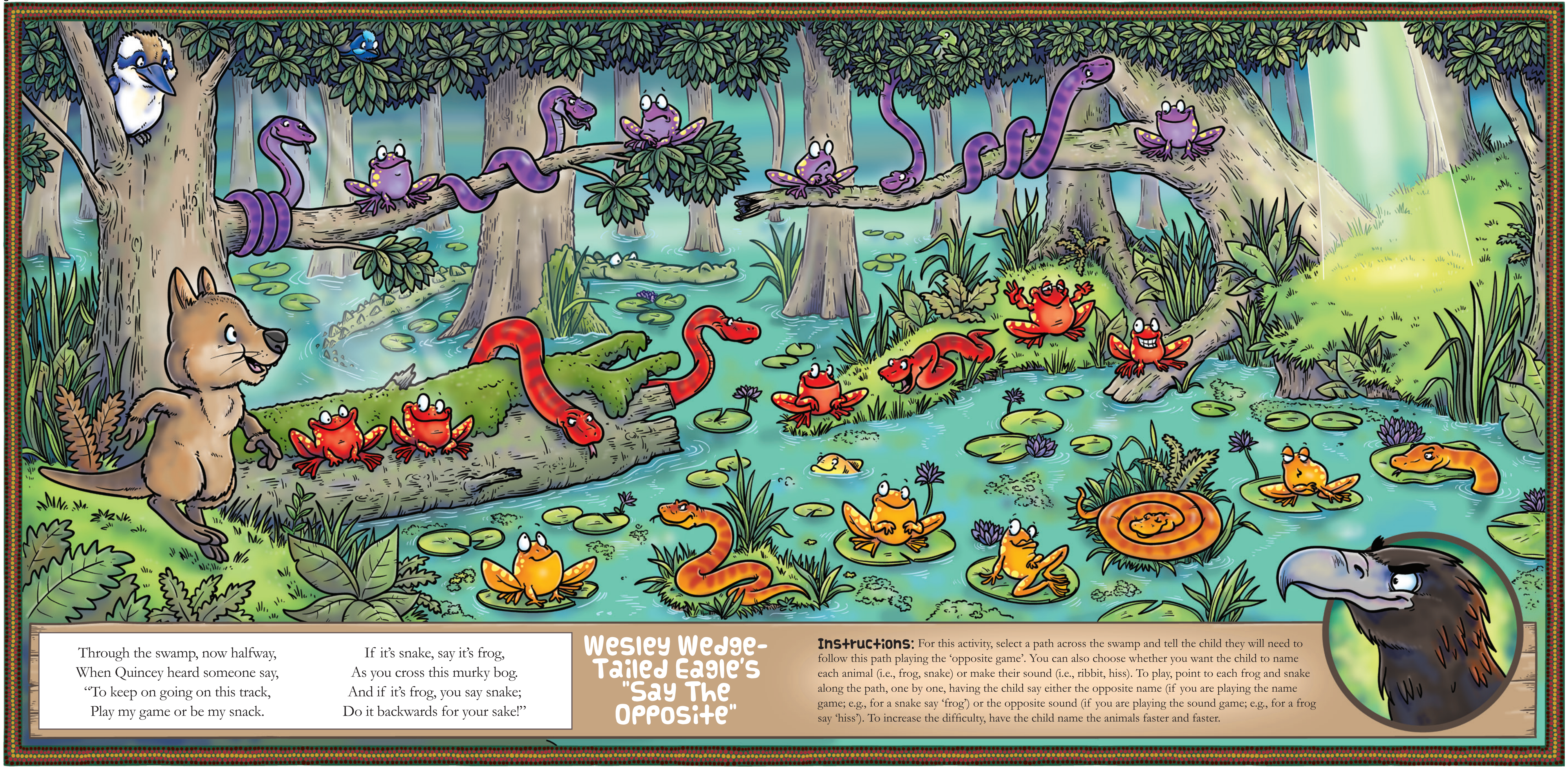
Table 4

Descriptive statistics by condition (Study 3)

	Baseline		**3 Weeks**		**6 Weeks**		**9 Weeks**		**2 Mo Follow-Up**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Control Group										
WM	1.82	0.79	1.71	0.70	1.64	0.93	1.67	1.01	2.05	1.10
Shifting	6.47	4.19	4.33	3.68	4.60	4.52	5.73	4.37	6.54	4.98
Inhibition	0.63	0.21	0.69	0.23	0.74	0.21	0.76	0.18	0.77	0.19
Intervention Group										
WM	1.58	0.84	2.14	0.71	2.04	0.52	2.39	0.69	2.46	0.64
Shifting	4.84	4.69	7.26	4.00	7.74	3.56	8.05	3.92	7.89	3.82
Inhibition	0.59	0.27	0.70	0.19	0.76	0.18	0.77	0.21	0.78	0.15

Figure 1. *Sample activity from Quincey Quokka's Quest. In this activity, the reader points along a row of snakes and frogs at a speed that challenges the child's impulse control. The child is asked to say 'hiss' when the reader points to a frog or 'ribbit' when the reader points to a snake, thus having to overcome the pre-potent response of saying the sound the target animal makes. The activity's difficulty is increase by increasing the speed with which the reader points to the frogs and snakes along a row.*

Figure


Through the swamp, now halfway,
When Quincey heard someone say,
“To keep on going on this track,
Play my game or be my snack.
If it’s snake, say it’s frog,
As you cross this murky bog.
And if it’s frog, you say snake;
Do it backwards for your sake!”
Wesley Wedge-Tailed Eagle’s "Say The Opposite"
Instructions: For this activity, select a path across the swamp and tell the child they will need to follow this path playing the ‘opposite game’. You can also choose whether you want the child to name each animal (i.e., frog, snake) or make their sound (i.e., ribbit, hiss). To play, point to each frog and snake along the path, one by one, having the child say either the opposite name (if you are playing the name game; e.g., for a snake say ‘frog’) or the opposite sound (if you are playing the sound game; e.g., for a frog say ‘hiss’). To increase the difficulty, have the child name the animals faster and faster.