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BRIEF REPORT

Parental Scaffolding during Book-Sharing Predicts Child General Intelligence

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Abstract

While much variance in general intelligence or *g* is genetic, a substantial environmental component suggests a possible role for parent-child interaction. In particular, previous evidence suggests the importance of parental scaffolding, or provision of cognitive structure to shape child behaviour. A role for scaffolding is consistent with the proposal that, in adult cognition, a critical aspect of *g* is decomposition of complex problems into a structure of simpler parts. Building on previous work, we recruited 162 parents attending Children's Centres with a child aged 2–4 years, and examined parental scaffolding during a book-sharing activity. Scaffolding was measured as the first principal component of a variety of parental behaviours, including sensitivity, focusing attention, extending comprehension, and promoting child participation. Child *g* was measured as the first principal component of a broad cognitive battery, including language, attention, working memory, and executive function. Importantly, we assessed contributions of the parent's own intelligence, education, and family income. Though these variables were all associated with both child *g* and parental scaffolding, scaffolding remained predictive of child *g* even once the influence of these variables was removed. In contrast to the correlation with cognitive proficiency, scaffolding did not predict child pro-social behaviour. We suggest that parental scaffolding supports the child's development of a broad skill of attentional structuring, promoting the across-the-board cognitive proficiency that is reflected in *g*.

Keywords Cognitive development · Spearman's *g* · Parent-child interaction · Scaffolding

Introduction

In psychometrics, the concept of general intelligence or Spearman's *g* (Spearman, 1904) is proposed to explain universal positive correlations between different cognitive tests; to some extent at least, a person doing well on any one test is also likely to do well on others. To measure *g*, one common approach uses a battery of different sub-tests, with *g* obtained simply by averaging performance, or by extracting scores on the first principal component (Crawford et al., 1990). The best known examples are traditional IQ tests such as the WAIS (Wechsler Adult Intelligence Scale; Wechsler, 1955), though principal components extracted from any diverse task battery will give largely similar results ("indifference of the indicator"; Spearman, 1904). A measurement of *g* can also be obtained using tests of novel problem-solving or "fluid intelligence", such as Raven's Progressive Matrices (Raven et al., 1988) and Cattell's Culture Fair (Institute for Personality and Ability Testing, 1973). Performance on these tests usually has strong loadings on the *g* factor extracted by factor analysis (Carroll, 1993; Institute for Personality and Ability Testing, 1973; though for a cautionary analysis, see Gignac, 2015). Though *g* has a large genetic contribution (Plomin & Deary, 2015; Plomin & von Stumm, 2018), there is also a substantial non-genetic component, suggesting important influences from experience. One strong possibility is a role for parent-child interaction, with parental input shaping development of broad cognitive skills in the child.

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A plausible candidate for such an input is parental scaffolding (Wood et al., 1976) during organized joint problem solving. In scaffolding, the parent structures the child's mental activity, focusing attention on useful parts within an overall problem, adjusting these parts as necessary to the child's ability and progress, and where possible promoting autonomy by handing control of the task to the child. Scaffolding occurs as a collaborative dialogue, requiring the parent to match their input to the level of the child's emerging ability, or what Vygotsky (1978) called their "zone of proximal development". Much research links effective parental scaffolding to strong executive functions in the child (e.g., Bernier et al., 2012; Castelo et al., 2022; Fay-Stammbach et al., 2014; Hughes & Devine, 2019; Lengua et al., 2014). Scaffolding is thought to promote the child's sense of agency in problem solving, enabling self-directed attention to critical task elements and sub-goals (Castelo et al., 2022). Strongly reminiscent of these proposals, recent work suggests that, in adult cognition, a core aspect of *g* is the ability to solve complex problems in a structure of simpler parts, with successive attention to useful parts leading to an effective, organized whole (Duncan et al., 2017; Duncan et al., 2020). In a standard fluid intelligence task, performance of low-*g* participants is radically improved if problems are pre-segmented into their parts (Duncan et al., 2017). Brain imaging and lesion findings link *g* to a specific "multiple-demand" network, with a central role in creating episodes of focused attention (Duncan et al., 2020). Other work shows much overlap between tests of fluid intelligence and executive function. For several classical executive tests, partialling out the change in fluid intelligence removes deficits in many patient groups, including those with frontal lobe lesions (Roca et al., 2010). A plausible hypothesis is that cognitive scaffolding teaches the child a broad skill of attentional structuring, promoting the across-the-board cognitive proficiency that is reflected in strong executive functions and *g*.

Though the parent may help to structure a child's mental activity in any complex setting, here we focus on scaffolding in the context of book-sharing. This context provides excellent opportunities for joint attention and cognitively enriching parental support. The essence of good book-sharing practice is that the adult follows the child's focus of interest, elaborating on it and linking it to the child's own experience and developmental capacity, and facilitates the child's active participation and engagement with the book content. In studies of community samples, the extent to which parents read to their children has been found to be a strong predictor of child language and educational outcomes (Fletcher & Reese, 2005; Gottfried et al., 2015). A causal role of good book-sharing practices is supported by evidence for substantial gains in child development (language, attention) arising from parental book-sharing training (Dowdall et al., 2020), mediated by improvements in parental sensitivity and in reciprocal parent-child engagement (e.g., Cooper et al., 2014; Murray et al., 2016). Of particular relevance to the current work, one study in a low-income, rural Pakistani community linked child intelligence to an assessment of parental scaffolding during book-sharing (Obradovic et al., 2016).

Here, we build on these findings. The context is a broader study of the effects of book-sharing on child development in a UK sample, including a parent training programme for some participants (Murray et al., 2018). In this study, we assessed parental behaviour during book-sharing interactions (observed before any training took place) using a coding scheme specifically designed to measure scaffolding components. At a follow-up test, administered approximately 6 months after the training programme, we employed an extensive cognitive battery to assess aspects of child language, attention, working memory, and executive function, and we used the first principal component of the battery to measure child *g*. Effects of the intervention are presented and discussed elsewhere (Murray et al., 2023), though in this study effects were small overall and in the main non-significant. Here we used book-sharing simply as a vehicle for assessing spontaneous variations in scaffolding. Expanding on the previous study of Obradovic et al. (2016) in a very different cultural context, we asked whether the quality of scaffolding would be a predictor of child *g* extracted from our cognitive battery.

Of course, correlation between parental behaviour and child cognition need not reflect causation. A broad range of common influences might affect both, from genetic influences affecting both parent and child, to environmental circumstances such as parental education and family income. To assess the role of such potential confounding factors, we measured associations between book-sharing behaviour and parental intelligence, education and income, and partialled out their impact before correlating book-sharing with child *g*.

In scaffolding accounts, the parent not only focuses the child's attention on important task content, where possible supporting them to structure the activity for themselves, but sensitively adjusts their input to the requirements of the child. Accordingly, we coded a broad set of parent behaviours, including sensitivity, guiding the child's attentional focus, enrichment of the child's understanding, and promotion of child involvement. Further, to distinguish the influence of the quality, as compared to the quantity, of book-sharing, we also asked parents to report on the amount of time they typically spent reading books with the child. Finally, to determine whether cognitive scaffolding during book-sharing specifically affects child cognitive ability, we assessed its impact on a standard measure of child pro-social behaviour.

Method

Overview

Data were collected in the context of a randomised controlled trial of a book-sharing intervention, the Impact of Early Years Provision in Children's Centres (EPICC) study (Murray et al., 2018, 2023). Participants were recruited from Children's Centres in the town of Reading, UK, the majority of which are situated in areas of relative economic deprivation. Testing in EPICC took place in three phases: baseline, post (2–3 months after baseline), and follow-up (9–10 months after baseline). Baseline and post sessions were conducted within the Children's Centres, while follow-up testing was conducted at the University of Reading. Test sessions lasted approximately 90–120 min, with breaks for refreshment. Between the baseline and post assessment, participating parents from half the Children's Centres received seven weekly sessions of training in book-sharing (for details, see Murray et al., 2018).

For the present study, data on the quality of book-sharing were taken from the baseline session, since we wished to assess spontaneous behaviour prior to training. All other data (cognitive measures, child pro-social behaviour, estimated time per week reading to the child before the study began, parent IQ) were taken from the follow-up session, when cognitive testing was most extensive. The full content of each test session is described in Murray et al. (2018). Ethical approval was obtained from the University of Reading Research Ethics Committee, reference number N15/09/084.

Participants

Parents attending one of the 12 study Children's Centres with a child aged 28–45 months were approached to participate. Inclusion criteria were regular use of English at home, and absence of significant developmental disorder. A small gratuity was given for participation. Of 218 participants originally recruited into the study, suitable data on book-sharing (baseline), child cognition (follow-up) and covariates (see Results) were obtained from 162 (88 and 74, respectively, in the control and intervention groups). All analyses were based on these 162 parent-child pairs.

Book-Sharing

For the book-sharing assessment, parents were asked to share a text-light book with their child ("Yes" by Jez Alborough) in the way they would at home. Interactions were filmed, and utterances from parent and child later transcribed. The interaction was scored from start to finish, with a maximum cut-off of five minutes. For each variable, a single member of the research team scored all interactions. For present purposes we extracted a total of six scores, aiming to address the key components of parental scaffolding: sensitivity to the child, attentional focussing, cognitive enrichment, and encouragement of child involvement.

Sensitivity was rated 1–5 from the video, and concerned the parent's ability to adjust their responses to the child's "zone of proximal development" (Vygotsky, 1978), that is, their awareness of the child's direction of attention, behaviour, and verbalisations, and their appropriate, well-attuned and timely responsiveness. Sensitivity sets the general context for specific techniques used to scaffold the child's attention and understanding.

Attentional focussing concerned the extent to which the parent identified individual elements of the book content for the child, and comprised the number of book elements explicitly mentioned in the parent's speech. Separate scores were obtained for story events (Attention: Events), for utterances by story characters (Attention: Speech), and for reference to characters' mental states (Attention: Mental States).

Enrichment concerned the parent extending the child's understanding of the relationship between individual book elements and their wider context. The score was the percentage of child utterances to which the parent responded with a cognitively enriching extension (e.g., Child: "He's in the pond." Parent: "Yes, the baby's in the pond and the mummy is trying to catch him").

To capture encouragement of child involvement, we used a single score, Elicitation. This was the number of times the parent encouraged the child to participate, either by asking them a question or by inviting them to complete an utterance.

Manuals were used to define each score, and for each one, the rater was first trained to reliability. After a master session with an expert scorer, samples of pilot data were scored, starting with small numbers of records and discussion of any discrepancies, and then iterating this process for larger numbers of records until the two raters were consistently in good agreement. To check reliability, two raters provided independent scores for a subsample of 15 records (16 for sensitivity). Inter-rater reliability for all scores was excellent (for Enrichment, ICC = 0.84; all others, ICC > 0.93).

Cognitive Assessment

The cognitive assessment consisted of ten tests, each giving a single score of child performance. These were:

Vocabulary, using the vocabulary sub-test of the Early Years Toolbox (EYT; Howard & Melhuish, 2017). The score was total number of correct items.

Comprehension, using the Clinical Evaluation of Langage Fundamentals (CELF-2; Wiig et al., 2004). The score was

the mean percentage correct from three subscales, "sentence structure", "concepts and following directions", and "basic concepts".

Sustained attention, using the Early Child Vigilance Task (ECVT; Goldman et al., 2004; Vally et al., 2015). The score was the percentage of time the child attended to the stimulus over 7 min, coded from a video recording.

Play quality, using the Three Toy Play Task (Cooper et al., 2014; Kannass et al., 2006). The child was presented with three age-appropriate toys, and their play video-recorded for 2.5 min. Quality of attention (0–4 scale) was rated every 30 s. The score was the mean of these ratings.

Inhibition, using the EYT go-no-go task. The score was the proportion of correct no-go trials minus the proportion of incorrect go trials.

Persistence, using the frustration task of the Laboratory Temperament Assessment Battery (Goldsmith & Rothbart, 1993). The child was given the wrong set of keys to open a perspex box containing an attractive toy. Child behaviour was filmed for 4 min, and the quality of their persistence rated in 20-s time blocks on a 5-point scale (from 0 = disengaged/aimless to 5 = uses systematic strategy). The score was the mean rating.

Digit span, using the procedure of Alloway (2007). The child was asked to repeat back strings of numbers presented in blocks of six trials, each block increasing by one digit to a maximum of nine, or until the child failed on three or more of the six trials at a given length. The score was the number of correct trials.

Block design, using the Block Design subtest from the Wechsler Preschool and Primary Scale of Intelligence (Wechsler, 2012). The total score was computed following standard methods.

Instruction following, following procedures based on Jaroslawska et al. (2014). The child was instructed to perform actions (pick up or touch) on five types of object arranged before them, each object being one of three colours. Instructions were given in blocks of six trials, with the number of actions increasing by one in each block (e.g., in Block 1 – "pick up the red brick"; in Block 2 – "touch the green pencil, then pick up the blue spoon". Overall score was computed from the total number of correct elements (actions, objects, colours).

Shifting, using the EYT Card Sort task. The total correct score was used.

Pro-Social Behaviour

To assess the child's pro-social behaviour, we used a standard parent report, the pro-social subscale of the Strengths and Difficulties Questionnaire (SDQ; Goodman, 2001).

Parent IQ

To assess parent IQ we used a standard measure of *g*, the Cattell Culture Fair, Scale 2 Form A. The 20-min test involves novel problem solving using nonverbal materials, with four timed sub-tests (series completions, odd one out, matrices, topological relations). The standard paper and pencil version was adapted for presentation on a laptop computer. The parent completed the test while the child completed other assessments with the researcher.

Results

Demographic and other data on the participant sample are shown in Table 1. The data show the expected multi-ethnic sample, with broad ranges of parental IQ, education and income. For present purposes, child age, child gender and percentage of time non-English was used at home were all considered nuisance variables, and covaried out of all scores before calculating correlations. As noted above, child cognition variables showed few significant differences between trained and untrained groups (Murray et al., 2023). Data from the two groups were accordingly combined, but to account for possible differences, group was also covaried from all scores.

Correlations between the six parental book-sharing measures, with the above factors covaried out, are shown in Table 2. Positive correlations between all these measures suggest individual differences in a broad skill of cognitive scaffolding during book-sharing. In line with this, principal component analysis showed a strong first component, accounting for 52.8% of the variance – over three times the variance (16.2%) explained by the second component. To index scaffolding quality, accordingly, we used scores on the first principal component. Loadings of the different

Table 1 Participant sample

Child male %	60.5
Child age (months) at baseline: mean (s.d.)	34.6 (5.5)
Child age (months) at follow-up: mean (s.d.)	44.0 (4.5)
Parent IQ: mean (s.d.)	102.3 (15.1)
Parent education[1]: mean (s.d.)	3.4 (1.4)
Family income[2] : mean (s.d.)	3.2 (1.3)
Family multilingual %	29.6
Percent of time other language spoken: mean (s.d.)	11.9 (19.5)

Notes: 1. Scale (highest qualification): 0 = none, 1 = GCSE, 2 = A level, 3 = post-school qualification (not degree), 4 = undergraduate degree, 5 = postgraduate degree. 2. Scale (£ per annum): 1 = <16k, 2 = 16–25k, 3 = 25–33k, 4 = 33–50k, 5 = >50k

s.d. standard deviation

Table 2 Correlations between book-sharing scores

	1	2	3	4	5
1. Sensitivity					
2. Attention: Events	.47				
3. Attention: Speech	.46	.62			
4. Attention: Mental states	.44	.49	.43		
5. Enrichment	.30	.27	.20	.26	
6. Elicitation	.53	.27	.33	.34	.29

Table 3 Loading on first principal components

Book-sharing		Child cognition	
Sensitivity	.45	Vocabulary	.42
Attention: Events	.45	Comprehension	.45
Attention: Speech	.44	Sustained attention	.14
Attention: Mental states	.42	Play quality	.11
Enrichment	.30	Inhibition	.31
Elicitation	.38	Persistence	.06
		Digit Span	.38
		Block design	.36
		Instruction following	.32
		Shifting	.34

book-sharing variables on this first component are shown in the left column of Table 3.

Similar data for child cognition variables are shown in Table 4. In line with the usual evidence for a general or *g* factor, the great majority of correlations were positive. A partial exception concerns the two quality ratings (play quality and persistence), which showed generally low correlations with other scores. Again, principal component analysis suggested a strong first component, accounting for 34.7% of the variance, as compared to only 11.0% for the second component. Following standard methods for measuring *g*, we took scores on the first principal component as our measure of child cognition. Loadings of individual test scores on this first component are shown in the right column of Table 3.

Our critical question was whether the quality of parental scaffolding contributes to child cognition, over and above the influence of other background variables including parental intelligence. As expected, child cognition was related to parental IQ, parental education and family income, r = 0.25, 0.27 and 0.24, respectively. These variables were also predictive of parental scaffolding, r = 0.23, 0.30 and 0.25, respectively. Before partialling out these variables, the raw correlation between scaffolding and child cognition was 0.35; after partialling, it was somewhat reduced but still strongly significant, r = 0.26, p =.001 (Fig. 1).

For comparison, we also examined relations between the quality of parental scaffolding and a measure of child social behaviour (SDQ pro-social scale), again removing nuisance variables as well as parental IQ, education and income. In this case, the correlation was close to zero, r = -.02, significantly below the correlation for child cognition, p < .01.

Next we asked whether child cognitive ability could be predicted by a measure of book-sharing quantity rather than quality. For this we used the parent's estimate of

Table 4 Correlations between child cognition scores

	1	2	3	4	5	6	7	8	9
1. Vocabulary									
2. Comprehension	.70								
3. Sustained attention	.10	.12							
4. Play quality	.12	.06	.07						
5. Inhibition	.27	.35	.16	.04					
6. Persistence	.04	.10	.00	-.01	.07				
7. Digit span	.47	.49	.12	.16	.34	.08			
8. Block design	.34	.50	.13	.22	.28	.02	.40		
9. Instruction following	.43	.39	.09	-.01	.22	.00	.32	.28	
10. Shifting	.37	.40	.17	.09	.39	.05	.23	.32	.30

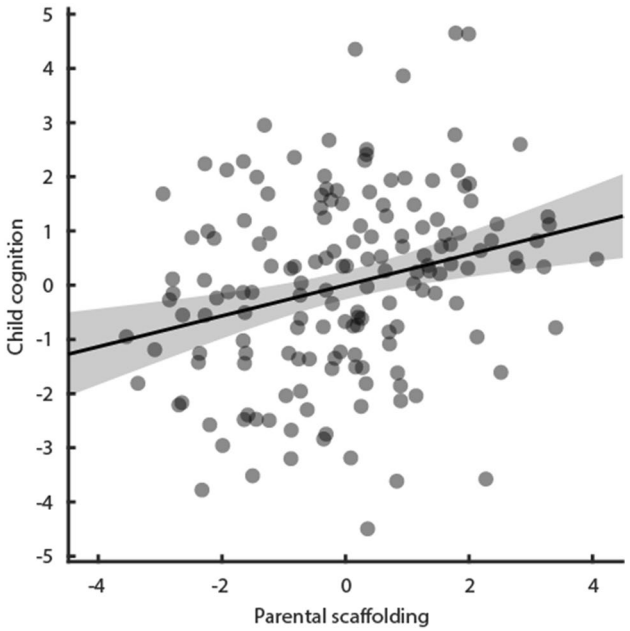

Fig. 1 Scatterplot relating child cognition to parental scaffolding. Data are residuals after partialling effects of parent IQ, income and education

how much time was spent reading to the child before the study began. The mean time per week was 94.5 min, with a standard deviation of 69.8 min. Removing nuisance variables as well as parental IQ, education and income, the correlation with child cognition was significant, $r = 0.20$, $p < .02$, below the correlation for scaffolding, but not significantly so, $p = .49$.

While effects of child age were removed from all correlations, it is possible that parental book-sharing could be influenced by a child's maturity, either in cognition or personality, which would only be partially captured by age. To examine this possibility, we repeated the principal component analyses, this time not removing the effect of child age, and then asked how scaffolding and child cognition were related to age. For child cognition, as expected, there was a strong positive correlation, $r = 0.51$, but there was no relationship between scaffolding and child age, $r = -.01$. These data show that a parent's book-sharing behaviour is unrelated to the age of the child, at least within the range used here, and thus unlikely to be influenced by further, unmeasured, differences in child maturity.

Discussion

In this study, we examined the link between parental cognitive scaffolding during book-sharing and a broad assessment of child cognition. To assess scaffolding, we used detailed scores of sensitivity, attention focusing, enrichment and elicitation of child involvement. A pattern of positive correlations suggested a broad skill of parental scaffolding, and to index this, we took the first principal component of scaffolding scores. To assess child cognition, we extracted the first principal component from a broad battery of cognitive tests, in line with standard methods for measuring general intelligence or *g*. As predicted by the proposal that parental scaffolding teaches a broad skill of attentional structuring, we found a significant relationship between these two scores. Our results add to growing evidence linking parental scaffolding to various aspects of child cognition, executive function and general intelligence (Bernier et al., 2010; Castelo et al., 2022; Obradovic et al., 2016; Fay-Stammbach et al., 2014; Neitzel & Stright, 2003).

As potential confounding factors, we examined the influence of parental *g*, education and income. For multiple reasons, genetic as well as environmental, we expect parent and child intelligence to be correlated with one another. Similarly, multiple factors may link child *g* to family circumstances indexed by education and income. If these variables also predict the quality of scaffolding, they might produce a correlation between scaffolding and child *g*, independent of any direct effect of scaffolding itself. In our sample, both child *g* and parental scaffolding were somewhat predicted by parental *g*, education, and income. Given the rather weak effects of these potential confounding variables, however, removing their effects only slightly reduced the key correlation between scaffolding and child *g*. Inevitably, any measure of confounders is imperfect, and accordingly, partialling these variables will not fully remove the true effects. Still, our correlation between scaffolding and child *g*, obtained after removing the measured effect of these potential confounds, is consistent with the proposal that scaffolding itself promotes the child's cognitive development.

Of course, correlational evidence alone cannot confirm a causal influence of parental behaviour. For example, the direction of influence could potentially be reversed, with the more able child leading the parent into improved scaffolding. Evidence against this possibility comes from our finding that the parental scaffolding score was independent of child age. Additional evidence that scaffolding is causal comes from previous trials of book-sharing training, which implicitly promote parental scaffolding, and have consistently shown benefit to child cognition (Dowdall et al., 2020), including evidence that such benefit is mediated by improvements in book-sharing practice (Murray et al., 2016). These previous findings contrast with results of the current intervention, which showed significant gains just for vocabulary, and only in a per protocol analysis (Murray et al., 2023). More work is needed to pursue variability in training effects across different environments and cultural contexts.

Scaffolding measures, we argue, capture elements of attentional structuring, enrichment, and promotion of child

involvement that play a specific role in the child's cognitive development. In line with our prediction of a specific influence on cognitive proficiency, we found no correlation between such scaffolding and a measure of child pro-social behaviour. This is not to say that aspects of parental behaviour during book-sharing are not relevant to child social development, only that scaffolding has a specific impact on child intelligence. This is consistent with our previous research showing "specificity of effects", whereby we found parental scaffolding (in this case, explaining components of maths problems in relation to a superordinate concept) to predict child IQ, but not behavioural adjustment; and, conversely, the latter child outcome was predicted by parental emotional support during the task, but not scaffolding (Murray et al., 2006).

Our data also provide some suggestion that the quantity of book-sharing may be less important than the quality for promoting child cognitive development. Though the number of hours spent reading to the child did also predict child *g*, this correlation was somewhat weaker than the correlation for our scaffolding measure, albeit not significantly so. Further work is needed to better separate these factors.

Despite much overlap between measures of executive function and *g*, there is also much evidence that different aspects of executive function are partially distinct (Friedman & Miyake, 2017). Future work might address the influence of parental scaffolding on separate and shared components of executive function. Further work is also needed to identify the most important aspects of scaffolding. Some research, for example, gives an especially strong role to the promotion of child autonomy in problem solving (Bernier et al., 2012; Castelo et al., 2022). Here we measured scaffolding just in the context of book-sharing, and more work is needed to compare different contexts of parent-child interaction.

Elsewhere we have argued that, in all thought and behaviour, complex activities must be organized into a structure of component parts. In large part, *g* may reflect the ability to assemble such a structure, allowing attention to be focused on useful parts within the complex whole (Duncan et al., 2017; Duncan, 2020). Though we measured scaffolding during book-sharing, a particularly propitious context (Murray et al., 2022), it seems likely that the parental skill measured during this activity reflects a broader style of interaction with the child. Across many complex activities, effective scaffolding may be a means by which the parent promotes a skill of attentional structuring in the child, shaping the broad cognitive proficiency reflected in general intelligence.

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Data Availability The data are available on OSF at https://osf.io/v6zuf/.

Declarations

Results reported here come from an independent analysis of data originally gathered for a preregistered trial (https://doi.org/10.1186/s13063-018-2700-x).

Conflict of Interests None.

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