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 164 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 child g , their links to parental scaffolding were weaker, and 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 .

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, Cochrane, Besson, Parker, & Stewart, 1990). The best known examples are traditional IQ tests such as the WAIS (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, Court, & Raven, 1988) and Cattell's Culture Fair (Institute for Personality and Ability Testing, 1973). Performance on these tests alone correlates strongly with the first principal component obtained from a diverse task battery (Carroll, 1993). 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.

Recent work suggests that, in adult cognition, a core aspect of g is the ability to divide complex problems into a structure of simpler parts, with successive attention to useful parts leading to an effective, organized whole (Duncan, Chylinski, Mitchell, & Bhandari, 2017; Duncan, Assem, & Shashidhara, 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, proposed to integrate brain activity in focused attention (Duncan et al., 2020). This link between g and attentional segmentation is strongly reminiscent of the concept of parental scaffolding (Wood, Bruner, & Ross, 1976). In scaffolding, the parent structures the child's mental activity, focusing attention on useful parts within an overall problem, and adjusting these parts as necessary to the child's ability and progress. 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". Given these characteristics of scaffolding, a plausible hypothesis is that this form of parental support teaches the child a broad skill of attentional structuring, promoting the across-the-board cognitive proficiency that is reflected in *g*. Indeed, research shows that effective parental scaffolding is correlated with different aspects of child cognition, including tests of executive control (Fay-Stammbach, Hawes, & Meredith, 2014; Hughes & Devine, 2019; Lengua et al., 2014), classroom behaviour (Neitzel & Stright, 2003), and verbal and performance IQ (Obradovic, Yousafzai, Finch, & Rasheed, 2016).

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, Schlackman, Eskeles Gottfried, & Boutin-Martinez, 2015). In particular, scaffolding during book-sharing has been found, in a low-income Pakistani community, to predict child intelligence (Obradovic et al., 2016). 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).

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 cognitive 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*. In this study, the follow-up test showed no significant difference in child

cognition between trained and control groups (Murray et al., submitted). One potential reason is the relatively brief period allowed for follow-up (Murray et al., submitted). Further, the intervention was delivered at an age when language and cognitive skills are beginning to stabilise (Murray et al., 2016), in contrast to some with younger children studies which have found large effects (e.g. Cooper et al., 2014; Vally, Murray, Tomlinson, & Cooper, 2015). Independent of this null result, here we used book-sharing simply as a vehicle for assessing spontaneous variations in scaffolding. We assessed parental behaviour during book-sharing interactions (observed before any training took place) using a coding scheme specifically designed to measure cognitive scaffolding components, and 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. For example, common genetic influences might produce correlations between parent and child intelligence, and more broadly, many factors might contribute to correlations between child cognition and family circumstances, such as parental education and income. If such factors were also strong predictors of parental book-sharing behaviour, they could be the source of any correlation between book-sharing and child cognition. 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, attentional focus, enrichment, 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 behaviour 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 control trial of a book-sharing intervention, the Impact of Early Years Provision in Children's Centres (EPICC) study (Murray et al., 2018). 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 3 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 minutes with breaks for refreshment. Between the baseline and post assessment, participants from half the Children's Centres received 7 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) 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, complete data for present purposes were obtained from 164 (90 and 74 respectively in the control and intervention groups). All analyses were based on these 164 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 Alburgh) in the way they would at home. Interactions were filmed, and utterances from parent and child later transcribed. Five minutes of the interaction were scored from the time it started. For each variable, a single member of the research team

scored all interactions, having previously been trained to reliability. For present purposes we extracted a total of 7 scores, aiming to address the key components of cognitive scaffolding: sensitivity to the child, attentional focussing, cognitive enrichment/complexity, and encouragement of child involvement.

Sensitivity was coded on a 5-point overall rating scale 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/complexity concerned the parent extending the child's understanding of the relationship between individual book elements and their wider context. We used two scores. The first (Enrichment) 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"). The second (Complexity) was the number of complex verbal constructions used by the parent that set elements of the book-content in relation to each other. These comprised contrasts (e.g. "The monkey is splashing, but his mummy says he must stop"), causes (e.g. "The mummy monkey tells the baby to stop because it's bed time"), and sentential complements (e.g. "The baby monkey thinks that the elephant will splash 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.

Cognitive assessment

The cognitive assessment consisted of 10 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 Language Fundamentals (CELF-2; Wiig, Secord, & Semel, 2004)). The score was the mean percentage correct from 3 subscales, “sentence structure”, “concepts and following directions”, and “basic concepts”.

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

Play quality, using the Three Toy Play Task (Cooper et al., 2014; Kannass, Oakes, & Shaddy, 2006). The child was presented with three age-appropriate toys, and their play video-recorded for 2 ½ minutes. Quality of attention (0-4 scale) was rated every 30 seconds. 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 four minutes, and the quality of their persistence rated in 20-second time blocks on a five-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, Gathercole, Logie, & Holmes, 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”; and 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

Parent IQ was assessed during the follow-up session. For this purpose 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 cognitive and social measures did not differ between training and control groups (Murray et al., submitted), data from the two groups were combined, but for extra protection, group was also covaried from all scores.

Correlations between the seven 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 59.2% of the variance – over four times the variance (12.1%) explained by the second component. To index scaffolding quality, accordingly, we used scores on the first principal component. Loadings of the different 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. An exception concerns the two quality ratings (play quality and persistence), which showed very low correlations with other scores. Again, principal component analysis suggested a strong first component, accounting for 35.3% of the variance, as compared to only 10.8% 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 book-sharing contributes to child cognition, over and above the influence of other background variables. As expected, child cognition was related to parental IQ, parental education, and family income, $r = 0.23, 0.32$ and 0.23 respectively. Interestingly, these variables were less predictive of parental scaffolding, $r = 0.19, 0.08$ and 0.13 respectively. Partialling out these variables, the correlation between scaffolding and child cognition was strongly significant, $r = 0.26, p = .001$.

For comparison, we also examined relations between the quality of cognitive 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, $r = -.02$.

Next we asked whether child cognitive ability could be predicted by a measure of book-sharing quantity rather than quality, the reported time spent reading to the child, before the study began. The mean time per week was 94.5 minutes, with a standard deviation of 69.8 minutes. Again, removing nuisance variables as well as parental IQ, education, and income, the correlation with child cognition was significant, $r = 0.20, p = .01$, though below the correlation for book-sharing quality.

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 book-sharing and child cognition were related to age. For child cognition, as expected, there was a strong positive correlation, $r = 0.49$, but there was no relationship between book-sharing and child age, $r = -.02$. 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 (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, however, parental g , education, and income were only weakly related to the quality of scaffolding during book-sharing. These relations were, perhaps, somewhat weaker than those previously reported for other cultural contexts (Obradovic et al., 2016) or for scaffolding during more active joint problem solving (Carr & Pike, 2012). Our correlation between scaffolding and child g ,

obtained after removing the weak effects of these potential confounds, is consistent with the proposal that scaffolding itself promotes the child's cognitive development. The weak correlation between scaffolding and parent g is important for a further reason. Inevitably, any measure of parent g is imperfect, and accordingly, partialling out the obtained score will not fully remove the true effects. Even a perfect measure of parental g , however, would not likely explain the link between scaffolding and child g , given that in our sample, parental g and scaffolding were only weakly related.

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).

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 cognitive 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.

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, 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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Table 1. Participant sample.

Child male %	60.4
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 (15.0)
Parent education ¹ : mean (s.d.)	3.5 (1.4)
Family income ² : mean (s.d.)	3.2 (1.3)
Family multilingual %	29.3
% time other language spoken: mean (s.d.)	11.7 (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.

Table 2. Correlations between book-sharing scores.

	1	2	3	4	5	6
1. Sensitivity						
2. Attention: Events	.62					
3. Attention: Speech	.58	.71				
4. Attention: Mental states	.56	.59	.52			
5. Enrichment	.34	.29	.27	.36		
6. Complexity	.54	.54	.51	.79	.39	
7. Elicitation	.65	.36	.42	.42	.34	.44

Table 3. Loading on first principal components.

Book-sharing		Child Cognition	
Sensitivity	.41	Vocabulary	.41
Attention: Events	.40	Comprehension	.46
Attention: Speech	.39	Sustained attention	.15
Attention: Mental states	.41	Play quality	.07
Enrichment	.27	Inhibition	.32
Complexity	.41	Persistence	.06
Elicitation	.34	Digit Span	.39
		Block design	.38
		Instruction following	.32
		Shifting	.32

Table 4. Correlations between child cognition scores.

	1	2	3	4	5	6	7	8	9
1. Vocabulary									
2. Comprehension	.70								
3. Sustained attention	.15	.22							
4. Play quality	.08	-.01	.01						
5. Inhibition	.26	.38	.16	.02					
6. Persistence	.00	.05	.00	.01	.05				
7. Digit span	.50	.54	.14	.11	.34	.08			
8. Block design	.37	.53	.13	.18	.30	.07	.44		
9. Instruction following	.35	.36	.07	-.04	.25	.03	.32	.30	
10. Shifting	.30	.33	.14	.10	.40	.02	.23	.32	.32

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