

**Caregivers fine-tune their speech to support children's word learning during shared book
reading**

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Abstract

The current study investigated whether caregivers adapt their communication to their child's individual lexical knowledge (fine-tuning) and whether such modulations facilitate children's word learning during shared book reading. It also examined the influence of book format (print vs. digital) on caregivers' communicative behaviours. English-speaking dyads ($N=78$; Child $M_{\text{age}} = 57.74$ months) were videorecorded during shared reading sessions with a print and a digital storybook. Caregivers' use of verbal and gestural scaffolds in relation to target words embedded in the storybooks was coded offline. Before the session, caregivers completed a vocabulary checklist to assess their child's knowledge of the target words. After the session, children's word learning was assessed using picture naming, definition, and comprehension tasks. Generalized Linear Mixed Models indicated that caregivers adjusted their verbal, but not gestural, scaffolds to their child's reported lexical knowledge. This verbal fine-tuning predicted children's word learning, as assessed through a definition task. Overall, caregivers provided significantly fewer scaffolds in the digital compared to the print format. Theoretical and practical implications of these findings are discussed in light of contemporary literacy practices.

Keywords: word learning, fine-tuning, child-directed language, scaffolding, gesture, digital media, shared book reading.

Caregivers fine-tune their speech to support children's word learning during shared book reading

Children learn new words at an incredible rate. Their vocabulary acquisition is enhanced by the rich multimodal cues provided by caregivers in play and conversation, and extended through encounters with written language during shared reading (Bojczyk et al., 2016; Nation et al., 2022; Pillinger & Vardy, 2022). In recent years, there has been an increasing interest in understanding the dynamic and interactive mechanisms that support children's word learning and language development (Donnellan et al., 2023; Fusaroli et al., 2023; Leung et al., 2021; Shi et al., 2022). This research highlights the importance of understanding the ecological niche in which language development unfolds and suggests that studying young children as isolated learners will provide, at best, an incomplete account of the mechanisms that support their language learning.

Caregivers consistently adapt their language when talking to children compared to adults (Fernald & Mazzie, 1991; Hills, 2013; Onnis et al., 2008). Both the prosodic and syntactic properties of child-directed language have been shown to support word learning in young children (Graf Estes & Hurley, 2013; Ma et al., 2011; Schwab & Lew-Williams, 2016). For instance, repetition of object labels in successive sentences, a common feature of natural child-directed language, has been shown to support word learning (Schwab & Lew-Williams, 2016). Crucially, the properties of child-directed language change as children age (Cox et al., 2023; Huttenlocher et al., 2010; Liu et al., 2009). For example, caregivers use more diverse vocabulary and more complex syntactic structures as children get older, suggesting that caregivers adapt their speech to children's developing language skills. This adaptive and flexible nature of caregivers' input is proposed to support language learning by providing children with input at the appropriate level of complexity (Snow, 1972), a view which is in line with the *scaffolding* principle (Wood et al., 1976) and the notion of the *zone of proximal development* (Vygotsky, 1978).

What is less established and deserves further investigation is whether caregivers modulate their communication at a fine-grained level as a function of their children's knowledge of specific

words (hereafter fine-tuning; see Leung et al. 2021), above and beyond adapting their communication to their children's general vocabulary knowledge (hereafter coarse-tuning; see Leung et al. 2021). Both forms of scaffolding could play an important functional role in supporting children's vocabulary development. They both operate within the zone of proximal development of the child, providing input that takes into account what the child already knows and what they can learn. Fine-tuning should be particularly powerful given the precise adjustment of the input to the child's knowledge of individual words. There has been little research investigating caregivers' fine-tuning, and there is a clear research gap in the shared reading context. This is surprising because shared book reading is an important context for vocabulary development (Dowdall et al., 2020; Noble et al., 2019). Understanding the role of fine-tuning is essential to shed light on the precise and sophisticated mechanisms that support word learning moment-to-moment through shared reading interactions. The focus of this study was therefore to examine caregivers' fine-tuning during shared reading, and its relation to children's learning of the meanings of unknown words. To reflect contemporary literacy practices, we also examined potential differences in shared reading experiences with print and basic digital books. This enhances the ecological validity and practical implications of our findings.

Fine-Tuning and Word Learning

The fine-tuning hypothesis proposes that caregivers adapt their communication to their children's individual lexical knowledge in a way that supports their word learning (Leung et al., 2021). For instance, Leung et al. (2021) showed that caregivers adjust the length and content of their speech according to their two-year-olds' individual lexical knowledge during a tablet-based reference game. Specifically, caregivers provided longer referring expressions (i.e., they produced more words on each trial before the child selected the target in the reference game) for words they thought their children did not know. Longer referring expressions predicted children's accuracy only for words that caregivers thought their children did not know, suggesting that caregivers' fine-tuning contributed to children's success in the reference game. The content of referring expressions also

differed by word knowledge: Caregivers provided more comparisons, descriptors, and superordinate category labels for unknown compared to known words, whilst the opposite was true for subordinate category labels.

In a study of toy-play interactions, Donnellan et al. (2023) found that caregivers' question asking and pointing gestures were also adapted to 3- to 4-year-olds' individual lexical knowledge and supported their vocabulary acquisition. Specifically, asking more questions about unknown words relative to known words supported immediate word learning. In contrast, the opposite was true for pointing gestures: Pointing more towards known than unknown words supported immediate word learning.

Therefore, emerging evidence suggests that caregivers fine-tune their verbal and gestural behaviours to their child's individual lexical knowledge to support word learning, but the pattern of results differs for linguistic and gestural cues (Donnellan et al., 2023). To the best of our knowledge, only a handful of studies have investigated caregivers' verbal and gestural fine-tuning and its relation to children's word learning (Donnellan et al., 2023; Motamedi et al., 2024). Our study examined, for the first time, whether verbal and gestural fine-tuning would generalise to shared book reading, a critical context for children's vocabulary development. We examine both verbal and gestural scaffolds based on the premise that word meaning acquisition is rooted in sensory-motor experiences, consistent with the theory of embodied cognition (Smith & Gasser, 2005).

Shared Reading and Word Learning

Shared reading is an important context for word learning for several reasons. First, the language of storybooks is lexically richer than conversation and, therefore, provides learning opportunities beyond child-directed language (e.g., Montag et al., 2015). Second, adults' mediation supports word learning from shared reading (for a meta-analysis, see Flack et al., 2018). Repetitions, definitions, and questions in extra-textual talk have been shown to support 3-to 6-year-olds' word learning from shared book reading (Blewitt et al., 2009; Flack et al., 2018; Lenhart et al., 2019). In line with embodied cognition accounts of word learning (e.g., Sadoski & Lawrence, 2023; Smith &

Gasser, 2005), gestures have also been shown to support word learning (Barnes et al., 2023; Flack et al., 2018; Flack & Horst, 2018). Deictic gestures such as pointing facilitate 3.5-year-olds' word learning from shared reading in experimental contexts (Flack & Horst, 2018). During naturalistic shared reading in the classroom, meaning-focused gestures, such as iconic and representational gestures, are associated with 4.5-year-olds' vocabulary development (Barnes et al., 2023).

In addition, scaffolding-like procedures, such as asking questions of gradually increasing complexity to the child over successive readings, have been shown to facilitate 2- to 4-year-olds' acquisition of elaborated word meanings from shared reading (Blewitt et al., 2009). This work underscores the importance of tailoring support to young children's developing lexical knowledge and suggests that fine-tuning may be an important mechanism for word learning in the shared reading context. Yet studies exploring whether and how caregivers adapt their support to children's individual lexical knowledge to facilitate word learning during shared reading are currently lacking.

Book Presentation Format

Contemporary reading experiences involve new media of story presentation, such as iPads and tablets, in addition to traditional print books (Kucirkova, 2019). This has opened the debate on the effectiveness of these new book formats relative to traditional print books. While a wealth of prior research has investigated this critical issue, recent meta-analyses contrasting comprehension and learning outcomes from print and digital text highlight a mixed and inconclusive set of findings (e.g., Clinton-Lisell et al., 2024). In relation to shared book reading with young children, previous research suggests that the digital format has a negative influence on the quality of caregiver-child interactions during shared reading with 2- to 6-year-olds (Korat & Or, 2010; Krcmar & Cingel, 2014; Munzer et al., 2019; Ozturk & Hill, 2020). For instance, digital books are associated with fewer communicative initiations, responses and less expanding talk by mothers (Korat & Or, 2010), and with lower social reciprocity between parent-toddler dyads (Munzer et al., 2019). Yet it should be noted that digital books have been reported to enhance communicative initiations, responsiveness, and visual attention in children (Korat & Or, 2010; Richter & Courage, 2017; Wainwright et al., 2020).

Against this mixed background, we examined whether book format influenced caregivers' multimodal scaffolding during word-learning episodes in the context of shared reading. By including both print and digital formats, our study offers important practical insights into similarities and differences between shared-reading interactions with print and digital books.

The Present Study

This study investigates scaffolding by English-speaking caregivers and their 4- to 5-year-olds' word learning during shared reading with print and digital books. Shared reading frequency has been shown to be an important predictor of vocabulary knowledge and growth in this age group (Mol & Bus, 2011; Sénéchal et al., 2008). However, the mechanisms underlying this association remain underspecified. Understanding which mechanisms and contextual factors support 4- to 5-year-olds' rapid vocabulary development is of critical importance for both theoretical and practical reasons. On the one hand, it contributes to a more nuanced and detailed account of the word-learning process during an important developmental period. In addition, it provides essential insights that can inform translational endeavours to promote children's vocabulary development. For example, taking into account what children already know may be an important ingredient of more personalised and effective shared reading interactions.

Here, we examined whether, to what extent, and how caregivers modulated their verbal and gestural scaffolds as a function of their child's individual lexical knowledge (i.e., fine-tuning) and book presentation format. We then assessed whether fine-tuning supported children's word learning across book formats. We used data from a corpus of video-recorded shared reading interactions and coded for caregivers' provision of verbal and gestural scaffolds in relation to target words. Our dataset included responses to a vocabulary checklist completed by each caregiver before the shared reading interaction, which provided an index of their child's knowledge of target words. Measures of each child's target word learning and concurrent vocabulary knowledge were collected after the interaction. Our research questions were as follows:

1. Do caregivers modulate their verbal and/or gestural scaffolding as a function of their child's individual lexical knowledge (fine-tuning) and book presentation format (print vs. digital) during shared reading?

If the fine-tuning hypothesis generalises to semi-naturalistic shared reading interactions, caregivers should display fine-tuning behaviours during shared reading; that is, they should modulate their scaffolds as a function of their children's lexical knowledge. Caregivers should provide more scaffolds for words that are unknown to their children, although this may vary between verbal and gestural scaffolds (Donnellan et al., 2023). We expected to find evidence of fine-tuning across verbal and gestural scaffolds (Donnellan et al., 2023; Leung et al., 2021). If the digital reading medium negatively affects dyads' social reciprocity (Munzer et al., 2019), and hinders caregivers' communicative initiations, responsiveness, and expansions (Korat & Or, 2010), we should observe less scaffolding with digital, compared to print, storybooks.

2. Does caregivers' fine-tuning enhance young children's word learning during shared reading with print and digital books?

If prior findings from a tablet-based reference game and toy-play interactions (Donnellan et al., 2023; Leung et al., 2021; Motamedi et al., 2024; Shi et al., 2022) generalise to the shared book reading context and an extended age range, fine-tuning should enhance children's word learning by providing input at the appropriate level of difficulty. If fine-tuning generalises to different shared reading contexts, it should be observed across book formats.

Methods

Participants

Seventy-eight British English-speaking caregiver-child dyads provided eligible data for this study. Data was collected between January and June 2023 in the context of a larger study (anonymised for review) which included 100 dyads. Overall, a small proportion of data relevant to the research aims of this paper was missing (5.8 %), and largely due to difficulties in performing the behavioural coding of specific video recordings, either due to equipment failure (the video recording

was corrupted), or inaudible speech (see Figure S1 and S2 in the Supplementary Materials for the patterns of missingness). Previous studies addressing similar research questions with analogous analytic approaches have included 38 to 41 dyads (Leung et al., 2021; Shi et al., 2022). Therefore, we are confident that our sample of $N = 78$ provides sufficient power to detect the effects under investigation, as stated in our pre-registration (anonymous link for review: https://osf.io/4cm73/?view_only=37ff877cb13a491bb424e2b07aebb0a5).

Children were typically developing, as reported by their caregivers, and aged between 48 to 71 months ($M_{age} = 57.74$; $SD = 7.00$; 43 girls). Caregivers were aged 29 to 45 years ($M_{age} = 37.69$; $SD = 3.67$; 74 self-reported as females; 4 as men) and were predominantly highly educated, with 63 achieving an undergraduate degree or higher. All the caregivers reported to be the parents of the child. The socio-economic status (SES) of our participants was derived through their postcode (Government of the UK, 2019). We obtained a composite score, The Index of Multiple Deprivation, reflecting seven domains of deprivation, which include income, employment, health, education, barriers to housing and services, crime, and living environment (Ministry of Housing Communities and Local Government, 2019). We report the distribution of our sample according to the Index of Multiple Deprivation Decile in Figure 1. We note that according to the Index of Multiple Deprivation, 24% of our sample was below the 5th decile, 64 % was above the 5th decile, and the remaining 12 % was within the 5th decile.

The vast majority of dyads were White, reflecting the ethnic composition of the North West of England (85.6% White, 8.4 % Asian, 2.3% Black, 2.2% Mixed, 1.5% Other; Government of the UK, 2022). Participants were recruited via the university database, which covers a broad demographic, social media advertisements, and flyers distributed in public book libraries in a middle-sized town in the North West of England. This was complemented by a snowball strategy, where participating caregivers were asked to share the study flyer with their own social networks. Written informed consent was obtained from caregivers prior to data collection. Children received a book and

caregivers received a travel reimbursement for their participation. This research received ethical approval from (anonymised).

Storybook Materials

Two storybooks with embedded low-frequency words were designed to ensure the novelty of the storyline and that all target words were of comparable salience. Storybooks were formatted in both print and digital format so that, in a within-subjects design, each story served as the print condition for half of the participating dyads, and the digital condition for the other half. The order of story and format presentation was counterbalanced across participants. There were no additional features embedded in the digital books (pages were static). The size of the book was controlled across formats (single page size: 126 x 113 mm; open book / iPad screen size: 126 x 226 mm). Each target word was depicted in the visual storyline and appeared on two successive pages. Target words were repeated three times in the text (across two successive pages) and accompanied by an adjective on one occasion. Storybook materials can be found on OSF (anonymous link for review https://osf.io/g9dw8/?view_only=baf843ea9dae49b5a45077460d6f4214) under Creative Commons Attribution 4.0 International.

The selection of the low-frequency target words was guided by the need to ensure high levels of ecological validity. Thus, we selected real words, likely to be unfamiliar to children in our age range. Our selection was informed by several criteria (see Lenhart et al., 2020 and Sarı et al., 2019 for a similar approach), including their frequency in the SUBLEX corpus of children's tv programs (van Heuven et al., 2014) and their age of acquisition (Kuperman et al., 2012). We selected concrete nouns for animals (*myna*, *okapi*, *sloth*, *toucan*) and tools (*clamp*, *valve*, *chisel*, *screw*). We included one word in each category that was more likely to be known by children (i.e., *toucan*, *screw*) to support motivation and engagement with the storyline. Each story contained four target words. Words across the stories were closely matched on psycholinguistic features such as age of acquisition and frequency. Psycholinguistic properties of the target words and accompanying adjectives are reported in Table S1 in the Supplementary Materials.

Measures

Behavioural Coding Scheme

A coding scheme, with non-mutually exclusive codes, was developed to quantify the presence and degree of caregivers' use of verbal and gestural scaffolds in relation to target words (adapted from Hadley & Dickinson, 2019). For each unique target word-child combination (hereafter observation), several behaviours were coded: (1) the number of word repetitions by the caregiver in extra-textual talk; (2) whether definitional information, including synonyms, perceptual (e.g., "it looks like a zebra" or "stripy legs"), or conceptual (e.g., "it's a kind of bird") information, was provided by the caregiver in extra-textual talk; (3) the number of comments and questions related to the target word in extra-textual talk (e.g., "Look at that!" "Can you find the [X]?"); and (4) gestural behaviour for each observation, specifically, the presence of pointing and iconic gestures (i.e., a gesture that illustrates word meaning such as opening and closing one's hand with fingers straight to mimic a clamp). A detailed codebook is available in Table S2 in the Supplementary Materials.

Two student assistants, blinded to our hypotheses, independently coded the video recordings of the shared reading interactions. Student assistants were trained by the first author on a pilot dataset, which was separate from the dataset included in the study. Training took place over two weeks and consisted of joint observation of videos, discussions of codes, independent coding by student assistants, discussions of disagreements, and refinement of the coding scheme, before the actual coding began. To assess inter-rater reliability, 20% of videos were double-coded. Cohen's kappa was computed for each measure. Levels of agreement ranged from *substantial* to *almost perfect*: repetition (Cohen's $k = .74$), definition (Cohen's $k = .84$), question (Cohen's $k = .69$), pointing (Cohen's $k = .80$), iconic gesture (Cohen's $k = .78$). The code comment was excluded from further analyses as the agreement was only moderate (Cohen's $k = .51$).

Caregivers' Ratings of Children's Individual Word Knowledge

A vocabulary checklist was designed after The MacArthur Communicative Development Inventories (Fenson et al., 2002). Before the shared reading activities, caregivers completed the

vocabulary checklist as an indicator of their child's knowledge of target words (see Shi et al., 2022 for a similar approach). For each target word, caregivers stated whether their child understood (receptive knowledge), or understood and produced (receptive and expressive knowledge) the target word or not. One point was assigned for a positive response (if either receptive, or receptive and expressive knowledge were indicated); otherwise, 0 was assigned. Thus, 1 point could be awarded per item.

Word Learning Measures

After the shared reading interactions, word learning was assessed with three tasks tapping into phonological and semantic representations. A five-minute delay between the shared reading and the assessment of word learning was introduced to assess retention (in line with Hartley et al., 2020). A picture-naming task was developed to assess phonological recall (Adlof et al., 2021; Blewitt et al., 2009). Pictures of target words were shown either on screen or on paper of identical size (126 x 226 mm), congruent with the book format (print or digital) in which the words were introduced during the shared reading. To assess generalisation to different exemplars, we followed the approach by Blewitt and colleagues (2009) and selected different pictures to those in the story. These were coloured child-friendly pictures selected from Canva Pro. The researcher asked the child, "Tell me what this is called". Four familiar words (dog, cat, pencil, spoon) were interspersed among the eight target words to maximise the opportunity for children to experience success during testing. Each correct response for a target word was assigned 1 point.

A definition task was designed to assess semantic recall, using the child-friendly procedure adopted in previous research (Blewitt & Langan, 2016). Children were introduced to a stuffed animal named "Toby." and told that "Toby does not know very many words.". For each target word, children were asked "Can you tell Toby what a [target] is?" After their initial responses, follow-up prompts were given such as "What else can you tell Toby about a [target]?" and continued until children could add no more information. Children were familiarised with the task via four practice trials with familiar words (i.e., dog, cat, spoon, pencil). For each word, children receive 1 point for

each unit of relevant information provided (e.g., object function, physical properties). Inter-rater reliability was computed via an intra-class correlation (ICC) analysis with absolute agreement (ICC = .95), representing excellent agreement (Cicchetti, 1994).

To assess comprehension, children were asked to identify referents of the target words in a multiple-choice task (see Blewitt et al. (2009) for a similar approach). Children were asked to “Find the [target, e.g., clamp]” on a page of four pictures. Each page depicted the target item and three distractors: an item from the same superordinate category as the target, an item from the story, and an item from the same superordinate category as another story word. Target words were represented by different pictures from those presented in the story. There were four practice trials using familiar non-target words (i.e., dog, cat, spoon, pencil). For each target item, children received 1 point for a correct response. Chance level in this task was 25%.

In line with previous literature (Adlof et al., 2021), the word learning measures were administered in a fixed order: picture-naming task, definition task, and multiple choice task. This order was adopted to minimise testing effect, which is highest in the multiple-choice task (where children can use mutual exclusivity), lowest when children need to name a picture (without hearing the label), and in between when children need to define a given label (without any visual cues).

Concurrent Vocabulary Knowledge

Children completed the Word Classes subtest of the Clinical Evaluation of Language Fundamentals – Preschool-2 (CELF-P2; Wiig et al., 2004). In this standardised assessment, children are shown three to four pictures (e.g., apple, shoe, bread), while the experimenter names each picture aloud. Children are instructed to identify the two words that go together best (e.g., apple and bread) and explain how they go together (e.g., both are food). Children get 1 point for each correct response, summed to provide a total vocabulary score which captures the breadth and depth of vocabulary knowledge.

Procedure

Data collection took place in an observation room located within the child-friendly testing facilities of a University campus. This enabled non-intrusive audio and video recording of caregiver-child shared reading interactions. First, caregivers completed the vocabulary checklist. Then, caregiver-child dyads were instructed to read the two storybooks: *"I would like you to read together as you would do at home. Please take your time, I will be back when you are finished"*. Each dyad read one of the two books presented on paper and the other book presented on an iPad, with the order of book and format presentation counterbalanced across participants. Books were read successively. After the shared reading activity, the child was administered the target vocabulary learning measures and the standardised vocabulary assessment. A detailed description of the full sessions is available [REDACTED FOR BLIND REVIEW].

Analytical Plan

Statistical Models

We fit Generalized Linear Mixed Models (GLMM; Baayen et al., 2008) specifying binomial error structure and logit link function for binary outcomes, and Poisson family, for count data. We included the full random effect structure supported by the data (Matuschek et al., 2017). Convergence issues were addressed by increasing the number of iterations, using different optimisers, and simplifying the random effect structure.

To investigate whether caregivers fine-tuned their communication to children's knowledge of specific words and examine whether book format influenced caregivers' scaffolds, we contrasted the following full-null models with a likelihood ratio test:

- Scaffold ~ prior vocabulary knowledge + age of acquisition + book format + *vocabulary checklist* + random effect structure
- Scaffold ~ prior vocabulary knowledge + age of acquisition + book format + random effect structure

Analyses were conducted at the item level. For each target word, the caregiver's scaffolding was modelled as a function of the child's reported lexical knowledge for that target word (key test

predictor), the book format in which the target word was presented, controlling for the child's general vocabulary knowledge, and the age of acquisition of the target word.

To examine whether caregiver fine-tuning supported children's word learning, we contrasted the following models.

- Word learning $\sim$ prior vocabulary knowledge + *scaffold* * *vocabulary checklist* + random effect structure
- Word learning $\sim$ prior vocabulary knowledge + random effect structure

Again, analyses were conducted at the item level. That is, the child's accuracy for each target word was modelled as a function of the interaction between their caregiver's provision of scaffolds for that specific word and the child's reported (by their caregiver) knowledge of that specific word. In this way, we examined fine-tuning at the level of specific words rather than coarse-tuning at the level of general vocabulary development. Critically, our analyses controlled for each target word's age of acquisition and the child's broader vocabulary knowledge.

Inference Criteria

We compared our full models with null models lacking our test predictors but being otherwise identical using the likelihood ratio test to evaluate the significance of the contribution of our test predictors, whilst avoiding multiple testing (Forstmeier & Schielzeth, 2011). Beta coefficients with $p < .05$ were interpreted as significant. Null hypothesis significance testing was complemented by an examination of odds ratios (for binary outcomes), incidence rate ratios (for count outcomes) and relative confidence intervals. Marginal effects were plotted to guide the interpretation of more complex models including interactions (Lüdtke, 2018). Significant interaction terms accompanied by improvement in the model fit, as indicated by a significant likelihood ratio test, supported the presence of conditional effects. Marginal R^2 illustrated the proportion of variance explained by the fixed effects, while conditional R^2 illustrated the variance explained by both the fixed and random effects.

Transformations

We created a composite score for verbal and gestural scaffolds respectively. This resulted in a count variable for verbal scaffolds, where repetitions, definitions and questions were summed for each target word-child combination. For the gestural scaffold composite score, we created a binary variable which reflected the presence/absence of pointing or iconic gestures per each target word-child combination. These composites were used in our analyses to reduce issues associated with multiple testing. We provide descriptive statistics broken down by scaffold type below.

Implementation

The models were implemented in R version 4.1.3 (2022-03-10) with the function `glmer` of the R package `lme4` (version 1.1-33) (Bates et al., 2015). Predicted probabilities were computed using the function `ggpredict` of the R package `ggeffects`, version 1.3.2 (Lüdtke, 2018).

Results

Descriptive Statistics

The average reading time was comparable for print ($M = 4.65$ minutes; $SD = 2.44$) and digital format ($M = 4.70$ minutes; $SD = 2.91$). Across 550 observations analysed, 53% of the target words were reported to be known and 47% to be unknown to children. On average, children correctly labelled 27% of the items in the picture naming task, produced .88 units of meaningful information per item in the definition task, and correctly identified 74% of the items in the comprehension task (chance level of 25%). Caregivers provided no scaffold in only 10.4% of observations, at least one scaffold in 89.6% of observations, and more than one scaffold in 75.3% of observations. The means and standard deviations for verbal and gestural scaffolds, grouped by children's knowledge of the target words, are reported in Table 1. Verbal scaffolds were more frequent for unknown than known words, and a similar pattern was observed across different types of verbal scaffolds, namely repetitions, definitions, and questions. There was comparable use of gestural scaffolds for unknown and known words.

The means and standard deviation of caregivers' verbal and gestural scaffolds grouped by book format are reported in Table 2. Verbal and gestural scaffolds were more frequent in print than

in the digital reading condition. Means, standard deviations and correlations between all quantitative variables can be consulted in Table S3 in the Supplementary Materials.

Do Caregivers Modulate Their Verbal and/or Gestural Scaffolding as a Function of their Child's Individual Lexical Knowledge (Fine-Tuning) and Book Presentation Format (Print vs. Digital) During Shared Reading?

Verbal Scaffolds

The results of the likelihood ratio test indicated that our full model was a significantly better fit to the data compared to the null model ($\chi^2 = 8.59$, $df = 1$, $p = .003$). This result indicates a significant contribution of a child's knowledge of a target word to a caregiver use of verbal scaffolds. Our full model suggests that caregivers calibrated their verbal scaffolds and provided significantly fewer scaffolds for words that they thought their child already knew ($\beta = -0.19$, $CI = -0.32 - -0.07$, $p = 0.003$). Importantly, the model controlled for the age of acquisition of the target word, which was no longer significant once children's individual lexical knowledge was included in the model ($\beta = 0.04$, $CI = -0.01 - 0.08$, $p = 0.099$), and children's broader vocabulary knowledge, which was not significant ($\beta = 0.01$, $CI = -0.05 - 0.07$, $p = 0.672$). In other words, for each target word, the amount of scaffolding provided by a caregiver was predicted by their child's reported knowledge of that specific word, but not the age of acquisition of the word, or the child's broader vocabulary knowledge. This provides strong evidence of fine-tuning (modulations that are contingent on child's knowledge of individual words), but not coarse-tuning (modulations that are contingent on the child's general vocabulary development). Results also revealed that caregivers provided significantly fewer verbal scaffolds when reading a digital compared to a print book ($\beta = -0.13$, $CI = -0.23 - -0.02$, $p = 0.017$). Model results are reported in Table 3. Incidence rate ratios can be consulted in Table S4 in the Supplementary Materials.

Gestural Scaffolds

The likelihood ratio test indicated that the full model was not a significantly better fit compared the null model ($\chi^2 = 0.846$, $df = 1$, $p = 0.358$). This result indicates that there was no

significant contribution of a child's knowledge of a target word to the caregiver gestural scaffold. In contrast to the results reported above for verbal scaffolds, there was no evidence that caregivers modulated their gestural scaffolds for target words according to their perception of their child's knowledge of individual words ($\beta = 0.27$, $CI = -0.31 - 0.85$, $p = 0.359$). As in our previous analysis, the control predictors of the age of acquisition of target words and children's general vocabulary knowledge were not significant ($\beta = 0.04$, $CI = -0.14 - 0.23$, $p = 0.643$; $\beta = -0.01$, $CI = -0.17 - 0.15$, $p = 0.870$, respectively). In line with the results for verbal scaffolds, there was evidence that caregivers provided significantly fewer gestural scaffolds when reading a digital compared to a print book ($\beta = -1.20$, $CI = -1.68 - -0.71$, $p < 0.001$). Model results are reported in Table 4. Odds ratios can be consulted in Table S5 in the Supplementary Materials.

Does Caregivers' Fine-Tuning Enhance Young Children's Word Learning During Shared Reading With Print and Digital Books?

Our previous analyses indicated that caregivers fine-tune their verbal, but not gestural, scaffolds. Therefore, we examined the link between *verbal* fine-tuning and word learning. The effect of book format on word learning was investigated as a separate research question in a larger sample, including participants contributing data to this study (anonymised for review). Results of those analyses revealed no significant main effect of book format on word learning. Further, preliminary analyses confirm that there was no main effect of book format on word learning in the current subsample (see Supplementary Materials, Tables S9, S10, and S11). For these reasons, book format is not included in the following analyses. Word learning was evidenced by children's performance in three tasks: picture naming, definition, and comprehension tasks. The results for each outcome are reported below.

Picture naming

The likelihood ratio test indicated that our full model was a better fit to the data than our null model ($\chi^2 = 166.72$, $df = 3$, $p < 0.001$). However, the coefficients of the full model (Table 4) did not indicate a significant interaction between individual lexical knowledge and verbal scaffolds ($\beta =$

0.09, $CI = -0.23 - 0.40$, $p = 0.597$), suggesting no clear benefit of fine-tuning for picture naming.

Knowledge of target words was significantly and positively related to picture naming ($\beta = 3.07$, $CI = 2.06 - 4.08$, $p < 0.001$) and the same was true for general vocabulary knowledge ($\beta = 0.11$, $CI = 0.02 - 0.19$, $p = 0.014$). Model results are reported in Table 5. Odds ratios can be consulted in Table S6 in the Supplementary Materials.

Definition task

The likelihood ratio test indicated that our full model was a better fit to the data than our null model ($\chi^2 = 160.46$, $df = 3$, $p < 0.001$). Further, the coefficients of the full model (Table 5) supported the presence of a significant interaction between individual lexical knowledge and verbal scaffolds ($\beta = -0.08$, $CI = -0.15 - -0.01$, $p = 0.024$). Verbal scaffolds predicted performance in the definition task only for words that caregivers thought their child did not know, supporting the contribution of caregivers' fine-tuning to children's semantic recall. Because we modelled child performance at the item level, these results indicate that the child's accuracy for each target word was predicted by the interaction between the caregiver's provision of scaffolds for that specific word and the child's reported knowledge of that word. This result implies that scaffolding behaviour surrounding specific unknown words supported the acquisition of the semantic features for those same words. One could also look at this interaction from another perspective, noting that the difference in a child performance between reported known and unknown words was reduced when the caregiver provided more scaffolds. Paralleling our previous analysis on picture naming, a child's individual lexical knowledge was positively related to performance in the definition task ($\beta = 1.61$, $CI = 1.28 - 1.95$, $p < 0.001$) and the same was true of general vocabulary knowledge ($\beta = 0.12$, $CI = 0.05 - 0.19$, $p = 0.001$). Model results are reported in Table 6. Incidence rate ratios can be consulted in Table S7 in the Supplementary Materials.

As a robustness check, we assessed the relation between fine-tuning and performance in the definition task following an alternative analytic approach. For each caregiver, a global fine-tuning index was computed as the ratio between the number of scaffolds provided for unknown relative to

known words. This fine-tuning ratio had a significant, albeit small, positive correlation with children's definition of unknown words, $r(67) = .32, p = .007$, supporting the link between fine-tuning and word learning assessed through definition. We note that observations with zero at the denominator were excluded from this robustness check because they would result in infinite values of the fine-tuning ratio. We also note that there was considerable variability between caregivers: The fine-tuning ratio ranged from 0 to 13 ($M = 1.70; SD = 2.12$).

Comprehension

The likelihood ratio test indicated that our full model was a better fit to the data than our null model ($\chi^2 = 32.18, df = 3, p < 0.001$). However, the coefficients of the full model (Table 6) did not indicate a significant interaction between individual lexical knowledge and verbal scaffolds ($\beta = 0.07, CI = -0.12 - 0.26, p = 0.484$). In line with previous analyses, a child's knowledge of specific target words was significantly and positively related to performance in the comprehension task ($\beta = 1.10, CI = 0.45 - 1.76, p < 0.001$) and the same was true of vocabulary knowledge ($\beta = 0.18, CI = 0.07 - 0.29, p = 0.002$). Model results are reported in Table 7. Odds ratios can be consulted in Table S8 in the Supplementary Materials.

Discussion

The present study investigated whether and how caregivers display fine-tuning behaviours during shared reading interactions and whether this supports children's word learning. We also examined whether book presentation format affected caregivers' scaffolding. Caregivers adjusted their communication as a function of their child's knowledge of target words. This was apparent for verbal, but not gestural, scaffolds. There was evidence that fine-tuning supported word learning assessed with a definition task. Finally, caregivers provided significantly fewer verbal and gestural scaffolds in the digital, relative to the print, reading condition. We discuss each of these findings and their theoretical and practical implications in the following sections.

Verbal Fine-Tuning

Replicating and extending prior research (Donnellan et al., 2023; Leung et al., 2021; Shi et al., 2022), these findings provide the first empirical evidence that caregivers fine-tune their verbal behaviour during shared book reading interactions. By demonstrating that fine-tuning behaviour extends beyond tablet-based reference game and toy play interactions (Donnellan et al., 2023; Leung et al., 2021; Shi et al., 2022), this study supports our prediction that fine-tuning would generalise to the shared reading context. This has important theoretical implications as it provides further evidence of a caregiver's ability to precisely tailor their language to their child's lexical knowledge. Given the central role of shared book reading for early vocabulary development, these findings have also important practical implications. Adapting support to a child's individual word knowledge during shared book reading may be a promising way to reduce their cognitive load and optimise learning across a range of ability levels (Sadoski & Lawrence, 2023).

These results also demonstrate, for the first time, that caregivers display fine-tuning behaviour with 4- to 5-year-olds, an older age group compared to those examined in prior research (Donnellan et al., 2023; Leung et al., 2021; Shi et al., 2022). Whilst certain properties of child-directed language have been documented to change as children age (Huttenlocher et al., 2010), our data suggest that caregivers' fine-tuning is robust and evident in 4- to 5-year-olds. Together with other research, this indicates the presence of fine-tuning across an extended period in child development; from toddlerhood (Leung et al., 2021) until, at least, five years of age (as illustrated in the current study).

While this modulation in scaffolding was only moderate, it has practical significance, especially when considering that it is likely to have a cumulative effect over time and shared reading experiences. Our data provide support for fine-tuning rather than coarse tuning: Children's knowledge of the target words, but not their vocabulary size, predicted caregivers' verbal scaffolding. One possible explanation for the lack of coarse tuning in our study is that caregivers may struggle to detect (and adapt to) differences in their child's vocabulary size, especially in our age

group where the vocabulary size is already quite large, estimated to be around 3,000 words (e.g., Anglin et al., 1993).

Gestural Fine-Tuning

Contrary to our predictions and the findings of Donnellan and colleagues (2023), we did not find evidence that caregivers modulated their gestures as a function of their child's knowledge of target words. There are different possible interpretations for these contradictory findings. First, it should be noted that pointing and iconic gestures were treated as the same gestural composite in our analyses to minimise the false discovery rate associated with multiple testing. Donnellan and colleagues (2023) differentiated between pointing and representational gestures and found evidence that caregivers modulated pointing but not representational gestures. It is possible that fine-tuning is operational only for certain kinds of gestures, which would make our composite measure unsuitable for studying fine-tuning. Yet our descriptive statistics do not support such an interpretation, as they show similar levels of both pointing and iconic gestures across known and unknown words.

An alternative possibility is that pointing was particularly important in the specific toy-play interactions studied by Donnellan et al. (2023) because three unknown word-object associations were presented simultaneously. In contrast, in our shared reading materials, unknown word-object associations were presented one page at a time, making the identification of the referent less challenging. Future studies investigating different learning and interactional contexts with varying degrees of referential ambiguity are needed to clarify the conditions under which caregivers modulate their use of gestures (Cheung et al., 2021). It is also possible that gestures play a differential role at different stages of development, and a direct comparison of different age groups is a crucial target for future research. We cannot entirely rule out the possibility that the different pattern of results we observed for verbal and gestural scaffolds is due to the binary nature of gesture scaffolds, which makes them less sensitive compared to the verbal ones. However, we note

that the effect of book format was evident for both verbal and gestural scaffolds, indicating that our binary gesture variable was sensitive to study manipulations.

Book Format and Scaffolding

In line with our prediction, caregivers were less likely to provide both verbal and gestural scaffolds when reading a digital compared to a print book. These findings replicate and extend prior research on interaction quality during print-based and digital-based shared reading (Korat & Or, 2010; Munzer et al., 2019; Ozturk & Hill, 2020). These findings may be explained by caregivers' greater familiarity with, and preference for, print formats, as reported in previous survey research (Strouse & Ganea, 2017). We contend that highlighting the potential of digital shared book reading to supplement, rather than substitute, print-based experiences through science communication could attenuate the adverse effects of the digital format on caregiver scaffolding observed in the present study and in prior research. These results also align with recent work underscoring the importance of considering the conversational context (Brinchmann et al., 2023) and features of books (O'Rear et al., 2023) when examining the properties of caregivers' input. Given that early literacy experiences are rapidly changing, and digital books are increasingly prevalent in children's lives (Kucirkova, 2019), these findings provide much-needed information to inform recommendations for users of research.

Overall, caregivers provided fewer scaffolds when reading a digital compared to a print book. However, fine-tuning of verbal scaffolds was observed after controlling for book format. Follow-up analyses were conducted to check whether fine-tuning was conditional on the book presentation format and revealed that this was not the case (see Supplementary Materials, Table S12). It is important to note that our findings refer to basic (static) digital books, that is, ones that did not include any additional features. Those books are likely very useful for caregivers who would like to read to their children in situations where many print books are not available (e.g., displaced families or financial restrictions).

Further research is needed to explore the contribution of specific digital features to support fine-tuning behaviours. For example, digital prompts that encourage children to identify the picture of the target word on the page may support caregivers in identifying precisely children's knowledge gaps of label-object associations. Once this link is established, prompts of increasing complexity and multimodal enhancements (e.g., Diprossimo et al., 2023) may encourage caregiver-child dyads to elaborate on word meaning, providing an opportunity to build a richer semantic representation of novel words over time. On the other hand, digital features that over-emphasise extraneous elements, or words already known by the child, may distract from the main message of the story and take cognitive resources away from learning opportunities.

The outcome of this scaffolding process critically depends on the interplay between characteristics of digital features, the child, and the caregiver, as emphasised in a recent developmental framework (Carranza-Pinedo & Diprossimo, 2025). This implies that contemporary research endeavours should pay close attention to the interactions between all those elements to provide insights for practice and policy and increase the chance that all individuals can benefit from scaffolding interactions.

Fine-Tuning and Word Learning

Our study is the first study of shared reading to include three different measures of word learning to capture complementary aspects of phonological and semantic representations. We found that fine-tuning predicted definition, but not picture naming or comprehension. Whilst the relation between fine-tuning and word learning, in general, is in line with prior research (Donnellan et al., 2023; Leung et al., 2021; Shi et al., 2022), the specific measures of word learning for which this relation was found differ: definition in the current study vs. comprehension in prior research. This difference could be explained, at least in part, by the inclusion of older children in our study. For our age group and learning context, the benefits of fine-tuning may have become apparent only when assessing children's deeper knowledge of word meaning through definition. Indeed, prior work also suggests that the positive effect of a scaffolding-like procedure during shared reading becomes

evident only when considering a definition task (Blewitt et al., 2009). Relative to the binary word learning measures, the definition measure contains more information making it sensitive to incremental changes in knowledge of a given word, and capturing differences between robust, detailed, knowledge of a word's meaning and a more superficial understanding. Further, the broader word-learning literature also finds that certain associations are measure-specific (e.g., Gathercole et al., 1997), likely because learning new words involves multiple distinct cognitive processes to acquire the sound and meaning of a word, which are assessed with different tasks. From a theoretical standpoint, the identification of a specific link between verbal fine-tuning and performance in the definition task is in line with the notions of scaffolding (Wood et al., 1976) and zone of proximal development (Vygotsky, 1978): By taking into account children's individual lexical knowledge, caregivers provide just the right level of support that enables children to efficiently acquire the semantic features of new words encountered during shared reading.

One mechanism through which fine-tuning might enhance learning is through a reduction in overall cognitive load by directing and focusing learners' attention on relevant features in the environment. Repetitions, for example, help to direct and focus attention to a picture and its name, thereby making unknown words more salient. Questions and definition-based expansions surrounding unknown words would reduce the inferential load on the child, an important predictor of older children's word learning from text (Cain et al., 2004). We note that gestural fine-tuning was not observed in our context and age group, but it should not be dismissed or overlooked in future studies. Future research might usefully seek to disentangle the contributions of fine-tuning for scaffolds that direct attention from those that provide additional multimodal support for phonological and semantic representations of the word, to understand better the mechanisms that underpin different aspects of word learning.

Limitations and Future Directions

We acknowledge some study limitations and suggestions for further research, in addition to those already noted. The first set of limitations relates to the study design. We note that the study

materials comprised a relatively small set of words, and these were all concrete nouns. Future research should include a range of word types, including adjectives and verbs, to establish if our results generalise to words other than concrete nouns. Second, retention of the new words was measured with only a short (5 minute) delay. Whilst this delay is appropriate to go beyond fast mapping (Hartley et al., 2020), we may find poorer long-term retention (and a lower learning rate) over a longer delay. Related to this, our study enabled us to observe learning at a single timepoint. Future research should examine the role of fine-tuning over longer time scales, for instance, by including longitudinal measures of vocabulary development (Shi et al., 2022). This would allow researchers to investigate the potential dynamic and reciprocal relations between fine-tuning and children's learning to illuminate the role of both caregivers and children in this process across different timescales.

Another set of limitations concerns the use of caregiver reports of their child's word knowledge. Parent-report measures have been used widely in research on children's word learning (Donnellan et al., 2023; Leung et al., 2021; Shi et al., 2022). For 2- to 7-year-olds, parent reports of vocabulary show strong concurrent and predictive validity (Libertus et al., 2015), indicating that caregivers can reliably track their child's vocabulary development up to at least age seven. However, these reports tend to be less reliable at the level of individual word items (Łuniewska et al., 2024). We note that in our study, parent report predicted performance at the individual item level in all of our word learning assessments, suggesting that this measure meaningfully captured children's prior word knowledge. When parents have inaccurate beliefs about their child's word knowledge, they have been shown to revise their beliefs dynamically during the interactions based on their child's behaviour (Leung et al., 2021; Shi et al., 2022). Furthermore, the word learning process is incremental and parents may tailor scaffolds to a child's developing knowledge of specific words, making fine-tuning a graded and dynamic process. Examining this dynamic interplay in greater detail is an important target for future research to provide insights into word learning during shared reading, and also to test further the validity of parent reports.

A final set of limitations concerns the generalisability of our findings to other cultural, socio-economic, and learning contexts. Our participants were recruited within travelling distance of our child assessment labs and consisted primarily of highly educated caregivers. However, the distribution of the Index of Multiple Deprivation Decile indicated variability in the broader socioeconomic conditions of our participants (i.e., income, employment, health, education, barriers to housing and services, crime, and the living environment). Therefore, while the findings may not generalise to caregivers from other geographical contexts or with lower levels of formal education, they may still be representative of experiences across a range of socioeconomic contexts. Replication with other populations is warranted. The present study provides the first evidence of fine-tuning in shared reading, but future work is needed to examine the role of fine-tuning across different interactional contexts (e.g., toy play, shared reading, mealtime conversations). This will identify similarities and differences in use and effectiveness for learning across different activities. It remains unclear whether fine-tuning will be observed in non-dyadic contexts, for example, during shared book reading in the classroom. Prior research suggests that teachers adapt their speech to individual preschoolers' language proficiency during classroom activities, including story time (Chan et al., 2022), but future work could usefully clarify whether teachers modulate their speech at the level of individual lexical items. Such work would provide much-needed information to inform our understanding of how fine-tuning operates across different learning activities.

Conclusions

The importance of caregivers' mediation to enhance word learning from shared reading is well established. Here, we showed for the first time that caregivers adapt their verbal communication to their children's individual lexical knowledge during shared reading and that this supports children's learning of new word meanings. These results suggest that caregivers' mediation is particularly effective when it is tailored and individualised to the child's current knowledge of specific words. We also identified fewer caregiver scaffolds with the digital book format. This indicates the need for further research to determine which features of digital books can enhance

caregiver-child interactions and support children's learning and development in our increasingly digital ecology. This area of inquiry may be fruitfully informed by caregivers' fine-tuning behaviours.

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The data and analytic code necessary to reproduce the analyses presented in this paper are publicly accessible, as are the materials necessary to attempt to replicate the findings presented here. Data, analytic code, and materials are available on the project's OSF repository:

https://osf.io/g9dw8/?view_only=baf843ea9dae49b5a45077460d6f4214. The analyses presented

here were preregistered after data collection and descriptive statistics were performed on a subsample ($n = 42$). The pre-registration is available at the following URL:

https://osf.io/4cm73?view_only=37ff877cb13a491bb424e2b07aebb0a5.

Credit

(anonymised): Conceptualization, Formal analysis, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. (anonymised): Conceptualization, Writing – review & editing, Supervision, Funding acquisition.

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