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Speaking with the hands—fine motor skills, language, and the role of gestures

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Abstract

Previous investigations link fine motor skills (FMS) with language development. Studies also examined relations between motor actions and gestures, as well as between gestures and language. However, little research has systematically investigated fine motor skills, manual gestures, and language within the same study or investigated their unique associations. In this study, we examined FMS, receptive and expressive vocabulary, narrative skills, and gesture production, imitation, and use during storytelling in 130 children (aged 3–6). FMS significantly predicted receptive vocabulary and narrative skills but not expressive vocabulary. Including manual gestures in hierarchical linear regressions reduced the association between FMS and receptive vocabulary as well as narrative skills. Notably, greater gesture use during the narrative task negatively predicted receptive vocabulary and narrative skills. Mediation analyses revealed that gesture use significantly mediated the link between FMS and both receptive vocabulary and narrative skills, indicating that gestures partially explain how FMS relate to these language outcomes. The study discusses limitations, future research needs, and educational implications.

KEYWORDS

expressive vocabulary, fine motor skills, gestures, language development, oral narrative skills, receptive vocabulary

Motor development has been referred to as the Cinderella of Psychology—fundamental to children's experiences, yet often overlooked (Rosenbaum, 2005). Indeed, motor skills were once seen as developed through predetermined biological changes, with minimal influence from environmental or cognitive factors (e.g., Gesell & Amatruda, 1945). Therefore, few studies tested interconnections with

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Statement of Contribution

What is already known

- Fine motor skills are linked to children's language development.
- Gestures support language development.
- The role of gestures in motor-language links is unclear.

What the present study adds

- Examines fine motor skills, gestures, and language within a single study
- Fine motor skills relate to receptive vocabulary and narrative skills.
- Motor-language associations weaken after gesture measures are included.

child cognitive and, specifically, language development. However, a growing body of research indicates that motor skills play a significant role in children's language development (Iverson, 2010; Suggate et al., 2025; Walle, 2016). More specifically, fine motor skills (FMS) may relate to diverse language outcomes (Gonzalez et al., 2019).

Several overlapping explanations for the connection between motor and language development have been proposed. Motor advances may have a ripple effect on language learning and vice versa, providing cognitive challenges and chances for language acquisition (Iverson, 2010; Oaks & Rakison, 2019). Research shows that walking toddlers carry and share objects more often, resulting in increased linguistic interaction with caregivers (Karasik et al., 2011). Furthermore, neuroimaging studies demonstrate that motor and language processes often engage overlapping brain regions (Adamaszek & Kirkby, 2016; Kana et al., 2015), yet the mechanisms behind the consistent correlations between motor skills and language abilities remain ambiguous. Gestures may play a mediating role, both preceding and supporting spoken language (Iverson & Goldin-Meadow, 2005), being tied to FMS, and sharing motor planning, control, and coordination processes (e.g., Alcock & Krawczyk, 2010; Chien et al., 2009). Building on prior work linking FMS with vocabulary and narrative skills (Winter et al., 2024), the present study investigates whether manual gestures help explain the association between FMS and children's language development.

Fine motor skills

FMS can be characterized as 'small muscle movements requiring close eye-hand coordination' (Luo et al., 2007, p. 596). This is crucial in tasks like writing, page turning, or keyboard usage. FMS measures typically involve manipulating small objects, such as threading beads or tracing lines (Cameron et al., 2012). Growing FMS allow children to explore, manipulate, and engage with objects in their environment (Case-Smith, 2000). Given FMS's functional and foundational role, it is unsurprising that a substantial body of research links it to several areas of learning and development. For instance, a growing number of studies indicate that FMS are significantly associated with language outcomes (e.g., Gonzalez et al., 2019; Houwen et al., 2016; Muluk et al., 2014).

FMS and language

Research on links between FMS and language has largely focused on vocabulary, including receptive and expressive vocabulary (Suggate et al., 2025). Associations between FMS and vocabulary have been shown

in toddlers (e.g., Houwen et al., 2016; Kobaş et al., 2021) and kindergarten-aged children (e.g., Dellatolas et al., 2003; Pagani et al., 2010). Cameron et al. (2012), for example, identified a positive relation between FMS, requiring manual dexterity, and expressive vocabulary in three- and four-year-olds. Links have also been reported between FMS and embodied lexical items (Suggate & Stoeger, 2014, 2017; Winter et al., 2021). Furthermore, both expressive and receptive language tasks stimulate the motor cortices of both hands (Flöel et al., 2003). A meta-analysis reported small to moderate correlations between FMS and vocabulary, although receptive and expressive vocabulary were not examined separately (Suggate et al., 2025).

Another significant aspect of language is oral narrative skills, recognized as a robust and reliable measure of higher-level language proficiency (Massonnié et al., 2022). They refer to the capacity to create spoken stories or dialogues that convey details about characters, chronological order, events, or environments (Reese et al., 2010). Many researchers consider them a more natural way of investigating language acquisition than vocabulary tests (Schraeder et al., 1999). Evaluating narrative skills provides insights into several aspects of language, such as expressive vocabulary and grammar, as well as more complex language skills, such as story organization and character motivation (Schneider et al., 2006).

Few studies have directly assessed the link between FMS and narrative skills. Winter et al. (2024) examined typically developing children aged three to six, examining associations between FMS and receptive vocabulary, expressive vocabulary, and oral narrative skills. Findings demonstrated stronger correlations between FMS and children's narrative skills than between FMS and vocabulary, with the latter not mediating links between FMS and narrative skills. Nevertheless, the results demonstrated a connection between the ability to skillfully use one's hand and communicative speech. Interestingly, Florit-Pons et al. (2025) found that children's multimodal skills, including gesture use, predicted narrative language abilities, whereas basic motor skills did not. These findings suggest that motor-based communicative behaviours, most notably gestures, may play a key role.

FMS and gesture

Gestures often accompany verbal messages during communication. They can be defined as hand and arm movements that co-occur with speech (Kong et al., 2015) and are described as actions that carry meaning (Goldin-Meadow, 2005). They are crucial in enhancing the conveyance of information, even though they are not always consciously planned (McNeill, 1995). Manual gestures serve as forms of communication, including actions like clapping, pointing, and waving. Manual gestures are closely linked to FMS (Alcock & Krawczyk, 2010). Both rely on precise and controlled movements of the hands and fingers and are foundational to human communication and interaction. A pointing gesture, for example, depends on the ability to clearly control certain fingers. Conversely, pointing or reaching helps children explore their environment and refine their dexterity. Thus, inherent links between gestures and FMS have been proposed (Chien et al., 2009).

Moreover, neuroimaging studies suggest that FMS and gestures share overlapping neural substrates, including the premotor cortex and the inferior parietal lobule, which are activated during object manipulation and the production of communicative gestures (Montgomery et al., 2007), indicating behavioural and neural integration in both domains. This close link between FMS and gesture provides a compelling foundation for understanding how gestures also interface with language development. Apart from their motor foundation, gestures are a vital part of communication and play a fundamental role in supporting and enhancing verbal expression. Indeed, research indicates that gestures significantly contribute to language development and acquisition (Mayberry & Nicoladis, 2000).

Gesture and language

From early childhood, gestures and language develop together to support communication (Acredolo & Goodwyn, 1988). Gestures play a pivotal role in joint attention and early language (Tomasello

et al., 2007). Individuals instinctively gesture while speaking, integrating spontaneous hand and body movements into their interactions. Accordingly, human communication is facilitated not only through spoken language but also through gestures (Goldin-Meadow & Alibali, 2013). Manual gestures can draw listeners towards significant elements within their surroundings (deictic gestures) (Kita, 2013) or enrich speech through iconic or metaphoric gestures. Also, speakers may produce swift hand movements that correspond with the vocal emphasis, accentuating key points (beat gestures) (McNeill, 1995).

Gesturing typically emerges alongside children's comprehension of their initial words (Goldin-Meadow, 2005). Prior to developing expressive verbal skills, children use gestures as a means of communication and continue to employ them even after they begin to articulate words. Gestures enable children to articulate thoughts and ideas that they may not yet fully understand (Goldin-Meadow, 2015). Additionally, gestures can predict future vocabulary growth (Iverson & Goldin-Meadow, 2005), appearing approximately three months before lexical verbalizations. Furthermore, greater use of manual gestures, particularly pointing, is associated with larger expressive vocabularies [Acredolo & Goodwyn, 1988; see Colonnese et al., 2010 and Kirk et al., 2022 for meta-analyses] and improved narrative skills (Demir et al., 2015). Furthermore, enacting and observing gestures can improve vocabulary learning (Oppici et al., 2023). Research indicates that gestures support narrative development by enhancing both cognitive processing and communication (Goldin-Meadow, 2005). Iconic gestures can help organize narrative content by highlighting key story aspects to improve storytelling and coherence (Vilà-Gimenez & Prieto, 2021). Finally, substantial neural overlap exists between manual gestures and language, including Broca's area (Gentilucci & Dalla Volta, 2008) and the left middle frontal gyrus and the inferior frontal gyrus (Cacciantone et al., 2024).

Current study

Growing evidence links FMS to language, particularly receptive and expressive vocabulary, as well as narrative skills (Winter et al., 2024). Research also shows significant connections between gestures and language, including narrative skills. Together, these findings highlight the complex interactions among physical, cognitive, and communicative domains and warrant the examination of FMS, gestures, and language within a single study.

The current study pursued two main objectives. First, we aimed to replicate Winter et al. (2024) findings, while addressing two methodological limitations: their use of a non-standardized narrative measure and the absence of cognitive control variables. To improve generalizability and comparability, we used the standardized Edmonton Narrative Norms Instrument (ENNI; Schneider et al., 2005) and included several cognitive controls. Second, we examined manual gestures and their links to FMS and language skills. Although some studies have grouped manual gestures under the broader category of FMS (e.g., Chien et al., 2009), research directly assessing the relationship between FMS and manual gestures is limited, especially in typically developing children. We therefore examined whether gesture measures accounted for additional variance in language outcomes beyond FMS (see Iverson & Braddock, 2011), providing a more comprehensive picture of the relations among FMS, gestures, and language.

METHOD

Participants

The study involved 130 participants aged 36 to 79 months ($M=58.78$, $SD=9.09$ months), comprising 46.2% females and 53.8% males. Participants were recruited from five kindergartens located in a city in southern Germany (population ~179,000). Most children (83.1%) were right-handed, 13.7% left-handed,

and 3.2% ambidextrous. Around 22.3% of the children spoke a language other than German at home (mostly Russian, followed by Albanian and English). Regarding parental education, 33.1% of mothers and 45.5% of fathers held a university degree. This is higher than the German national average of 32% (OECD, 2022), indicating a sample with a slightly elevated level of education. A post-hoc power analysis indicated that the sample size had adequate power to detect a small to moderate effect ($r = .25$, power = 0.83).

Measures

Measures included demographics, language spoken at home, maternal education, handedness, number recall, reasoning, motor imitation, as well as FMS, receptive vocabulary, expressive vocabulary, oral narrative skills, and gestures.

Demographic information

As factors such as age, language spoken at home (Hoff, 2006), and maternal education (Frank et al., 2021) can influence language skills, we included them as control variables. A questionnaire evaluated demographic data, including age, place of birth, whether German was spoken at home, and level of maternal education. Maternal education was simplified to a binary measure (no university degree vs. university degree). Both maternal education (no university degree = 1; university degree = 2) and language spoken at home (German language dummy; other = 1, German = 2) were entered as dummy variables in the regression analyses.

Handedness

An assessment of hand preference was carried out by having the participants demonstrate (a) brushing their teeth and (b) drawing a picture using a pen or pencil. A research assistant recorded the hand used to complete the two imaginary tasks as the dominant hand.

Cognitive variables

To derive an intelligence estimate and establish a general measure of IQ, three cognitive subtests (reasoning, number recall, and motor imitation) were administered. Reasoning and recall were selected because they: (a) do not necessitate FMS for responses, (b) encompass one task from both verbal and spatial domains, and (c) are not closely related to vocabulary or gestures. The motor imitation task was chosen as a non-verbal working memory task and to control for motor skill differences.

Reasoning

Participants' reasoning abilities were assessed using the matrices subtest of the Wechsler Preschool and Primary Scale of Intelligence – German Adaptation (WPPSI-GA; Petermann & Lipsius, 2014). The test required participants to complete partial patterns by selecting the missing part out of five potential matches. The test increased in difficulty and ended after three successive errors or until all items were completed. The test manual showed good split-half reliability ($r = .83$).

Number recall

Verbal working memory was assessed using the number recall subtest of the German version of the Kaufman ABC II (K-ABC-II; Kaufman & Kaufman, 2015). Participants repeated increasingly long

number sequences, starting with two and ending with nine digits. Testing ended after three consecutive errors or completion of all items. According to the test manual, the test demonstrated good split-half reliability ($r = .81$).

Motor imitation

To assess non-verbal working memory and ensure participants could perform the motor movements necessary for gesture production, we administered the manual motor sequences task from the Developmental Neuropsychological Assessment (NEPSY; Korkman et al., 2007). The test included 12 motor sequences that increased in difficulty. The motor sequences combined unimanual and bimanual sequences, different hand positions, as well as using hands simultaneously or alternately (e.g., in sequence: clap, right hand in a fist, left palm down). The task started with simple sequences, such as right hand in a fist, then right palm down, and progressively became more complex and longer (e.g., left hand in a fist, right hand palm to the side, left palm down, right hand in a fist). Each sequence was demonstrated three times and then repeated five times by the participant, scoring one point per correct repetition (maximum 5 per item, 60 in total). Testing continued until the participant scored zero on four consecutive items or completed all items.

Fine motor skills

FMS were assessed using the FMS tasks from the German version of the Movement Assessment Battery for Children (M-ABC 2; Petermann et al., 2011). This included coin posting, bead threading, and maze tracing. In coin posting, participants placed six (3- to 4-year-old) or 12 (5- to 6-year-olds) yellow plastic coins through a slit at the top of a small plastic box. Participants completed the task after a demonstration, with a second trial being allowed after an error or non-completion within the specified time frame (12–25 s, age-dependent). The test was then repeated with the non-dominant hand. In bead-threading, participants were asked to thread six (aged 3–4) or 12 (aged 5–6) beads one at a time onto a short shoelace-like thread. Two attempts were allowed if the first exceeded the age-specific time limit (41–73 s). For maze tracing, participants traced a path between two lines using a pencil without crossing the boundaries. Two trials were conducted, depending on whether the participant stayed within the lines, with no time limit. All results were converted into age-adjusted standard scores. The test manual reported test–retest reliability of $r \geq .93$ for coin posting, $r = .92$ for maze tracing, and $r \geq .66$ for maze tracing.

Language

Receptive vocabulary. The Peabody Picture Vocabulary Test—German Adaptation (PPVT; Lenhard et al., 2015) assessed children's receptive vocabulary by having them select a matching picture from a set of four options after hearing a word. Difficulty increased until a ceiling criterion of 8 incorrect responses within a set of 12 items was met or completion of all 216 items. The test manual demonstrated excellent internal consistency, Cronbach's $\alpha = .97$.

Expressive vocabulary. The expressive vocabulary task in the German adaptation of the Kaufman ABC II (K-ABC-II; Kaufman & Kaufman, 2015) assessed participants' expressive vocabulary. This assessment consisted of a one-word vocabulary test, wherein the child named each of the 39 pictures presented in a stimulus book. Items increased in difficulty, and the task continued until the participant provided four consecutive incorrect responses or completed all items. According to the German manual, the split-half reliability coefficient for this assessment was $r = .89$.

Narrative skills. Oral narrative skills were assessed using the Edmonton Narrative Norms Instrument (ENNI; Schneider et al., 2005), which prompts children to narrate a story based on a picture book. A practice story and the picture book A3 were used in the current study. Picture

book A3 included 13 pictures, four characters, and three events. Participants viewed the pictures and were subsequently encouraged to tell the story while looking at them again. In order to enable the children to gesture, the experimenter held the picture book and turned the pages at all times. Participants' stories were video-recorded, transcribed, and scored in accordance with the ENNI scoring framework on story grammar (Schneider et al., 2005), with points allocated for the inclusion of essential elements such as setting, characters, initiating event, internal responses and plans, outcomes, and reactions (maximum of 40 points). Thus, compared to counting word tokens or utterances, the scores indicated retell without extraneous additions (e.g., repetitions, filler words, incorrect information). Partial credit was given for minor inaccuracies. Interrater reliability was estimated for 35% of the transcripts by a trained research assistant and the first author, yielding an agreement of 90%, $\kappa = .79$.

Gestures

Gesture production

Children's ability to generate meaningful gestures was assessed using the elicited gesture task (Wray et al., 2016). Children were instructed to convey the meanings of eight distinct words without speaking (train, guitar, sleepwalking, sad, climbing a ladder, monkey, painting, and sword fight). This task was scored on two criteria: whether the child produced any gestures and whether they were representative of the word. A maximum of 16 points could be obtained, with two points for each word (one for production, one for representation). Interrater reliability was estimated for 15% of the transcripts by a trained research assistant and the first author, yielding 79% agreement, $\kappa = .93$.

Gesture quantity

To evaluate gesture usage during the oral narrative skills tasks, participants were recorded during the ENNI. Gesture movements were discerned from the recorded video and documented in the transcription. A gesture was defined as the duration from the initiation of a movement until the hand(s) returned to their resting position (McNeill, 1995).

Procedure

Prior to participation, consent forms, parent questionnaires, and details regarding the testing procedure were distributed to parents via the kindergartens. Based on the number of returned consent forms, the participation rate was approximately 50%. Children were tested individually in their kindergartens over two sessions of around 35 min and 1 week apart, to reduce the likelihood of concentration difficulties.

The first session contained the handedness test, followed by the PPVT, bead threading, expressive vocabulary, number recall, and coin posting. The second session included the motor imitation task, maze tracing, the ENNI, and the gesture production task. Upon completion of each task, children were rewarded with a sticker. The experiment was overseen by the first author, along with trained undergraduate education students, and conducted in accordance with the university's ethics procedure.

RESULTS

Four participants were absent from the second session, resulting in missing data for maze-tracing, narrative skills, gesture measures, motor imitation, and reasoning. Age-adjusted standard scores were used when available (FMS, vocabulary, number recall, reasoning); otherwise, we used raw scores and

controlled for age in the multivariate analyses. Descriptive statistics for all variables are presented in Table 1. The corresponding distributions, skewness, and kurtosis values ranged from -1.82 to 1.63 and thus were considered acceptable (Gravetter & Wallnau, 2014). An exception was gesture quantity, which was highly skewed (skewness = 8.58 ; kurtosis = 7.04) and therefore recoded into three categories: 1 = no gestures, 2 = 1–3 gestures, and 3 = 4+ gestures.

To examine associations between FMS and language, gesture, and cognitive variables, age-corrected correlations were calculated between FMS, receptive vocabulary, expressive vocabulary, narrative skills, gesture production, gesture quantity, number recall, motor imitation, and reasoning (Table 2). FMS correlated positively with receptive vocabulary and oral narrative skills, but not expressive vocabulary, and negatively with gesture quantity, suggesting that stronger FMS were associated with fewer gestures used during storytelling. Gesture quantity also showed negative correlations with all language measures. Gesture production was positively correlated with oral narrative skills. Positive correlations were found between FMS and number recall, motor imitation, and reasoning. Furthermore, both receptive and expressive vocabulary showed a significant positive correlation with oral narrative skills and with each other. Across the sample, 22.3% of participants spoke a language other than German at home. A t -test comparing receptive and expressive vocabulary scores between native and non-native speakers revealed significant group differences. Native speakers scored higher on receptive vocabulary, $t(125) = 3.62, p < .001$, and on the expressive vocabulary measure, $t(125) = .52, p < .001$. An additional t -test indicated no significant difference between native and non-native speakers in overall gesture production ($p > .05$). To ensure that language background did not confound the results, German language was included as a dummy-coded variable in subsequent analyses.

To estimate the role of FMS and gestures for the different language variables, three hierarchical linear regressions were conducted, predicting receptive vocabulary, expressive vocabulary, and oral narrative skills. Each model tested whether FMS explained variance beyond cognitive and environmental control variables. Furthermore, two gesture measures were added to examine their contribution beyond FMS and control factors. Results are summarized in Table 3.

TABLE 1 Descriptive statistics for FMS, receptive vocabulary, expressive vocabulary, oral narrative skills, gesture measures, and cognitive control variables.

Measured variable	M	SD	<i>n</i>	Range
Age (in months)	58.78	9.09	130	36–79
FMS (sum)	27.38	6.9	126	6–40
Coin-posting	10.03	2.54	130	2–14
Bead-threading	10.11	2.75	130	3–15
Maze-Tracing	7.25	3.81	126	1–13
Receptive vocabulary	47.13	9.58	130	27–73
Expressive vocabulary	10.47	2.80	130	5–19
Narrative skills	13.95	6.36	126	1–28
Gesture measures				
Gesture production	10.75	2.91	126	2–16
Gesture quantity—raw	2.81	4.10	126	0–17
Gesture quantity—coded	1.80	.83	126	0–3
Cognitive control variables				
Number recall	10.95	3.19	130	2–18
Motor imitation	25.42	11.63	126	0–55
Reasoning	9.27	3.11	126	2–16

Note: Gesture quantity categories (1 = no gestures, 2 = 1–3 gestures, 3 = 4+ gestures).

TABLE 2 Correlation coefficients between FMS, receptive vocabulary, expressive vocabulary, oral narrative skills, gesture production, gesture quantity, and the control variables number recall, motor imitation, and reasoning, all corrected for age.

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1)	FMS	-	.23*	.09	.23*	-.10	-.31***	.27**	.35***	.21*
(2)	Receptive vocabulary		-	.68***	.42***	.11	-.33***	.44***	.28**	.27**
(3)	Expressive vocabulary			-	.40***	.16	-.18*	.41***	.09	.17
(4)	Oral narrative skills				-	.25**	-.29**	.22*	.15 ^a	.15
(5)	Gesture production					-	-.04	-.03	-.01	.20*
(6)	Gesture quantity-coded						-	-.28**	-.21*	-.10
(7)	Number recall							-	.34***	.23**
(8)	Motor imitation								-	.32***
(9)	Reasoning									-

p* < .05. *p* < .01. ****p* < .001.

^a*p* < .10.

For receptive vocabulary, FMS was a significant predictor in Step 1. However, after adding gesture-related variables in Step 2, this association became marginally significant. Gesture quantity was a significant negative predictor, whereas gesture production was not. After including cognitive variables in Step 3, number recall became a significant predictor, and gesture quantity remained significant, whereas FMS was no longer a significant predictor. Adding demographic controls in Step 4 revealed both the German language dummy and maternal education as significant predictors, indicating that participants who spoke German at home and whose mothers had a university degree had higher receptive vocabulary scores.

For expressive vocabulary, neither FMS nor gestures were significant predictors; only number recall (Step 3) and the German language dummy (Step 4) emerged as significant.

For oral narrative skills, FMS was a significant predictor in Step 1. In Step 2, gesture production was a strong positive predictor, and gesture quantity was a significant negative predictor. These findings remained significant after adding cognitive and demographic controls in Steps 3 and 4, whereas FMS became non-significant, suggesting that gestures play a more substantial role in explaining variance in oral narrative skills. No other variables emerged as significant.

DISCUSSION

The present study investigated how children's FMS related to their language development beyond cognitive and environmental controls, as well as the role of gestures. Specifically, by analysing both gesture production and quantity, we explored the potential contribution of children's FMS to the development of more efficient or compensatory communication methods that influence their language learning. Notably, this study is the first to simultaneously examine FMS, different aspects of gesture use, and multiple language dimensions (receptive vocabulary, expressive vocabulary, narrative skills) while controlling for cognitive and environmental variables.

FMS and language

Initial steps of the regression analyses indicated significant relations between FMS and both receptive vocabulary and oral narrative skills. More specifically, children with stronger FMS demonstrated better receptive vocabulary outcomes and oral storytelling. These initial associations are broadly in

TABLE 3 Linear regression analysis testing links between FMS, gesture, and different language tests over and above cognitive variables (number recall, motor imitation, and reasoning) and environmental variables (age, maternal education, and German language dummy).

Predictors	Receptive vocabulary					Expressive vocabulary					Oral narrative skills				
	B	SE B	β	R ²	ΔR ²	B	SE B	β	R ²	ΔR ²	B	SE B	β	R ²	ΔR ²
Step 1															
Constant	38.24	3.51		.05	.05*	9.50	1.04		.01	.01	9.15	2.35		.04	.04*
FMS	.33	.13	.23*			.04	.04	.09			.18	.08	.19*		
Step 2															
Constant	43.38	5.73		.13	.08**	9.31	1.74		.05	.04	6.17	3.63		.22	.18***
FMS	.23	.13	.13 ^a			.03	.04	.06			.14	.08	.15*		
Gesture production	.32	.28	.10			.13	.09	.14			.73	.18	.33***		
Gesture quantity-coded	−3.18	1.03	−.28**			−.52	.34	−.15			−2.07	.66	−.27**		
Step 3															
Constant	30.71	5.84		.29	.16***	5.75	1.77		.21	.16***	3.82	4.03		.23	.02
FMS	.07	.12	.05			−.01	.04	−.02			.10	.09	.11		
Gesture production	.28	.27	.09			.16	.08	.16 ^a			.71	.19	.32***		
Gesture quantity-coded	−2.53	.96	−.22**			−.38	.30	−.11			−1.90	.67	−.25**		
Number recall	1.10	.26	.36***			.37	.08	.42***			.19	.18	.09		
Motor imitation	.02	.07	.03			−.02	.02	−.09			.04	.05	.07		
Reasoning	.39	.27	.13			.06	.08	.07			.03	.19	.01		
Step 4															
Constant	19.42	8.76		.40	.11***	−.86	2.56		.39	.18***	−5.07	6.48		.26	.03
FMS	.05	.12	.04			.00	.04	.01			.12	.09	.13		

TABLE 3 Continued

Predictors	Receptive vocabulary					Expressive vocabulary					Oral narrative skills				
	B	SE B	β	R ²	ΔR^2	B	SE B	β	R ²	ΔR^2	B	SE B	β	R ²	ΔR^2
Gesture production	.31	.26	.09			.13	.08	.13			.64	.19	.29**		
Gesture quantity-coded	-2.30	.91	-.20*			-.28	.27	-.08			-1.64	.68	-2.13*		
Number recall	.88	.26	.29**			.34	.08	.38***			.28	.19	.14		
Motor imitation	.10	.07	.13			-.01	.02	-.02			.01	.06	.01		
Reasoning	.16	.25	.05			-.02	.08	-.02			-.01	.19	-.00		
Age	-.05	.10	-.05			.02	.03	.07			.13	.07	.18 ^a		
Maternal education	3.75	1.59	.19*			.64	.48	.11			.92	1.18	.07		
German language dummy	6.37	1.77	.27***			2.77	.52	.41***			-.06	1.32	-.00		

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

^a $p < .10$.

line with previous research linking FMS to oral narrative skills (Winter et al., 2024) and receptive vocabulary (e.g., Pagani et al., 2010; Winter et al., 2024). However, contrary to our hypothesis, FMS showed no clear association with expressive vocabulary once additional control variables were included in the model. This finding is surprising given previous research findings (e.g., Dellatolas et al., 2003). However, not all prior research has shown a positive correlation between language and FMS (e.g., Suggate & Stoeger, 2014, 2017).

Gesture findings: Production vs. quantity

A key novel finding is the clear but contrasting roles that manual gestures play across different language measures. Interestingly, our results suggest that gestures function in two distinct ways, rather than acting as a uniform concept. On the one hand, gesture production (the ability to accurately represent words or actions with one's hands) showed positive associations with oral narrative skills, even after including cognitive and environmental variables in the models. This suggests that for children with richer narrative skills, gesture production may extend their spoken thoughts. On the other hand, gesture quantity was negatively correlated with language skills, meaning that frequent gesturing during storytelling was associated with lower receptive vocabulary skills and oral narrative skills. This finding indicates that children with weaker language abilities rely more on gestures, perhaps to compensate for linguistic gaps. This interpretation aligns with previous work showing heightened gesture use in children with language delays (Goldin-Meadow, 2015) and with findings of Pronina et al. (2023), who similarly reported positive associations between language and gesture production along with negative associations between language and gesture rate. It is important to note, however, that oral narrative skills capture more than language ability alone. Successful storytelling relies not only on vocabulary and grammar, but also on organization, or working memory, to name a few. Thus, the observed associations may also reflect broader cognitive and linguistic demands rather than language proficiency in isolation.

Beyond examining the quantity of gestures produced during the narrative task, analysing their specific forms and functions can provide further insight into how children use gestures to support communication. Children in this study primarily used *deictic gestures*, frequently pointing to objects in the ENNI drawings. These gestures mostly *replaced* the spoken word when the correct word could not be retrieved or was unknown to the child. This finding further supports the interpretation that children with stronger language skills tend to use gestures extending speech, whereas children with weaker language skills rely more heavily on gestures to compensate for lexical gaps. Gestures thus act as a support system for the speaker, helping to organize ideas and expressions in the manner of a cognitive support tool.

Interestingly, although FMS were initially a significant predictor of both oral narrative skills and receptive vocabulary, they became statistically redundant when adding gestures into the models. Therefore, gestures seem to influence the relation between FMS and narrative skills. Thus, FMS may affect language abilities more indirectly, primarily through their impact on gesture use. Children with stronger FMS may be better able to produce communicative gestures, such as pointing, which in turn may support early language development by enhancing social interaction (Goldin-Meadow, 2005).

Cognitive findings

The current findings also shed light into links between cognitive variables and their connection to FMS, language, and gestures. Number recall (digit span) showed a moderate association with receptive and expressive vocabulary, respectively, but not with oral narrative skills. This may reflect the different cognitive demands of the tasks. Single-word vocabulary tasks require fast and accurate access to individual lexical items. Better working memory might support more effective retrieval; therefore, making it easier to recognize or produce words (Gray et al., 2022). Narrative production, on the other hand, requires a

more complex integration of various cognitive and linguistic processes; therefore, relying less on processes associated with digit-span working memory (Youse & Coelho, 2005).

Limitations

Despite valuable insights into the link between FMS and language abilities, there are some methodological and conceptual limitations. First, gesture quantity and narrative skills stem from the same task, making their association partly dependent. This issue is mirrored in other studies, as many studies measured both variables simultaneously (e.g., Florit-Pons et al., 2023; Zampini et al., 2016).

Second, expressive vocabulary was assessed only via the expressive vocabulary subtest of the KABC-II (Kaufman & Kaufman, 2015), which, despite being widely used, contains a limited number of items and is prone to potential ceiling effects (Cohen et al., 2013). Furthermore, compared with the PPVT, the expressive vocabulary subtest also has a smaller range of possible scores, which may have contributed to the reduced variability observed in the expressive language scores.

Third, we focused exclusively on FMS, excluding gross motor skills. Although FMS show stronger and more consistent links to language and gesture (e.g., Iverson & Goldin-Meadow, 2005; Winter et al., 2021, 2024), gross motor skills incorporate certain movements, such as arm and swinging motions, that can play an important role in gesturing (Iverson & Goldin-Meadow, 2005).

Fourth, we included working memory (verbal and non-verbal) and reasoning, both of which are relevant for language and FMS. However, other cognitive variables may play a role in the interconnectedness of motor skills, gestures, and language, such as fluid intelligence (Martzog et al., 2019) or executive functions (e.g., inhibitory control or cognitive flexibility). Also, our non-verbal working memory task (motor imitation) involved increasingly complex unimanual and bimanual hand movement sequences. Recent work has suggested that different forms of object manipulation and hand actions may themselves be linked to language development (e.g., Contino et al., 2024, 2025). This raises the possibility that specific characteristics of the motor imitation task may have contributed to the observed associations, which warrants caution in interpreting these findings.

Finally, approximately one-fifth of the participants spoke a language other than German at home. Because the narrative task, as well as the receptive and expressive vocabulary tasks, were administered in German, differences in German language exposure may have acted as a confounding factor. To account for this, spoken language at home was added as a variable to the analysis. Moreover, gesture use and interpretation can be influenced by cultural conventions (e.g., Kita, 2009; Naidu et al., 2026), meaning that gesture analyses may also be susceptible to cultural biases. Our coding system was designed to minimize such bias by focusing on the presence and communicative meaning of gestures, rather than specific gesture forms. Nevertheless, future studies should consider children's language background and proficiency in more detail to better separate the effects of language background and culture from the association of FMS, gestures, and language abilities. This is particularly relevant for narrative assessment, as previous research has shown that monolingual and multilingual children may display different patterns across vocabulary and narrative measures (e.g., Boerma et al., 2016; Hipfner-Boucher et al., 2015; Uccelli & Páez, 2007).

Implications and future research

The current findings point towards educational implications, emphasizing the close link between motor and language development (Iverson, 2010). In light of our and previous studies, applications arise for early interventions. Language improvement programs might benefit from including activities that foster FMS and gesture use. Encouraging children to use gestures while telling a story could aid them in their language and fine motor development (Demir et al., 2015). By including

activities that encourage gestural communication, such as oral storytelling combined with hand movements, children have the opportunity for multimodal learning (Liu et al., 2023), which in turn can help them connect physical actions with verbal communication. This could help children communicate their thoughts more clearly and strengthen the language network by incorporating motor processes. Incorporating movement is especially important given the ever-increasing time spent in a stationary or sedentary position, which comprises approximately 80% of the school day (Nielsen-Rodríguez et al., 2021).

Our findings also have implications for research. Adding gestures to the assessment of FMS and oral narrative skills has revealed a nuanced picture. Higher scores in gesture production are positively correlated with more pronounced narrative skills, whereas greater overall gesture use was associated with lower narrative skills. These findings suggest that gestures should not be treated as a uniform concept but rather should be differentially considered according to their various facets and integrated into assessments of language as well as gesture usage.

The findings point to the importance of future research exploring relations between FMS, gestures, and language in a more differentiated way. In the current sample, meaningful analyses of gesture types and their influence were not possible due to limited variability in gesture types (354 coded gestures, including 291 deictic, 13 iconic, 18 beat, and 36 unclassified gestures). Future studies could explore how different types of gestures (iconic, deictic, etc.) contribute to various aspects of language, such as syntax, vocabulary, and sentence formation. In addition, future research could consider complementary measures of narrative language production, such as word quantity or lexical diversity, to better distinguish links between gesture use and different aspects of storytelling. Such measures may help clarify whether gesture production is more closely related to narrative quality, language quantity, or both.

Furthermore, longitudinal research could examine how gestural changes relate to changes in FMS and narrative development. Investigating how gestures support FMS learning and language in different linguistic and cultural contexts might also be a fascinating avenue to explore, as it may reveal both universal and culture-specific mechanisms in the integration of FMS and language development. Future research may also benefit from incorporating gross motor skills to provide a more comprehensive understanding of the role motor skills play in the development of language and gestures. Finally, this foundational research is important for identifying potential mechanisms but needs to inform the development of intervention designs, combining FMS and gestures into language interventions.

CONCLUSION

The current study contributes to a growing body of research demonstrating the interconnectedness of motor and language development and highlights gestures as a key aspect in early childhood development. Our findings underscore the importance of FMS for receptive vocabulary and oral narrative skills. Crucially, gestures emerged as a key factor in this connection, offering both important insights into the relationship and a potential bridge in connecting FMS and language.

AUTHOR CONTRIBUTIONS

Sebastian P. Suggate: Conceptualization; writing – review and editing; supervision; formal analysis; methodology. **Heidrun Stoeger:** Conceptualization; writing – review and editing; supervision; resources. **Rebecca E. Winter:** Conceptualization; investigation; writing – review and editing; formal analysis; project administration; methodology; writing – original draft.

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CONFLICT OF INTEREST STATEMENT

There are no relevant financial or non-financial competing interests to report.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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