

Literacy training of kindergarten children with pencil, keyboard or tablet stylus: The influence of the writing tool on reading and writing performance at the letter and word level

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Supplementary Material

1 Supplementary Tables

Supplementary Table 1.

Results of the letter reading task at the different time points of assessment

Letter reading	T2	T3
	Mean (SD) [Min – Max]	Mean (SD) [Min – Max]
Total	11.70 (4.31) [1 – 16]	11.91 (4.31) [1 – 16]
Pencil	11.54 (4.17) [2 – 16]	11.73 (4.27) [2 – 16]
Stylus	11.55 (4.08) [2 – 16]	11.75 (4.07) [2 – 16]
Keyboard	12.00 (4.75) [1 – 16]	12.28 (4.66) [1 – 16]

Note. T2 = assessment after training; T3 = assessment 4-5 weeks after training;

Supplementary Table 2.

Correlations of the dependent variables averaged across T2 and T3 with the control variables, separately for the different training groups

Dependent variables	Control variables					
	<i>Letter reading T1</i>			<i>Visuo-spatial skills T1</i>		
	<i>Pencil</i>	<i>Stylus</i>	<i>Keyboard</i>	<i>Pencil</i>	<i>Stylus</i>	<i>Keyboard</i>
<i>Letter recognition</i>	0.32*	0.11	0.22	0.55**	0.25	0.08
<i>Letter writing</i>	0.80**	0.81**	0.81**	0.31*	0.32*	0.37*
<i>Word reading</i>	0.70**	0.63**	0.77**	0.38**	0.16	0.21
<i>Word writing</i>	0.71**	0.69**	0.70**	0.33*	0.09	0.36*

Note. T1 = assessment before training; * indicate a significant correlation with $p < 0.05$; ** indicate a significant correlation with $p < 0.01$.

Supplementary Table 3.

Descriptive data of all dependent variables for the pencil group at the different time points of assessment

Pencil group	T1	T2	T3
	Mean (<i>SD</i>) [Min – Max]	Mean (<i>SD</i>) [Min – Max]	Mean (<i>SD</i>) [Min – Max]
Letter recognition (raw score)	7.00 (2.70) [1 – 11]	8.58 (2.02) [3 – 11]	8.53 (2.05) [4 – 11]
Letter writing (raw score)	6.56 (4.50) [0 – 16]	9.90 (4.17) [1 – 16]	10.21 (4.17) [2 – 16]
Word reading (raw score)	-- ¹	1.75 (1.80) [0 – 5]	1.76 (2.02) [0 – 5]
Word writing (raw score in %)	-- ¹	49.27 (33.00) [0 – 100]	52.00 (36.00) [4 – 100]
Visuo-spatial skills (raw score)	15.27 (5.57) [5 – 25]	17.35 (5.02) [6 – 24]	-- ²

Note. . T1 = assessment before training; T2 = assessment after training; T3 = assessment 4-5 weeks after training; --¹: variable was not quantified at T1; --²: variable was not quantified at T3.

Supplementary Table 4.

Descriptive data of all dependent variables for the stylus group at the different time points of assessment

Stylus group	T1	T2	T3
	Mean (SD) [Min – Max]	Mean (SD) [Min – Max]	Mean (SD) [Min – Max]
Letter recognition (raw score)	7.13 (2.19) [1 – 10]	8.51 (2.04) [3 – 11]	8.41 (2.14) [4 – 11]
Letter writing (raw score)	6.20 (3.06) [0 – 12]	9.77 (3.68) [3 – 15]	9.93 (3.90) [1 – 16]
Word reading (raw score)	-- ¹	1.17 (1.56) [0 – 5]	1.21 (1.50) [0 – 5]
Word writing (raw score in %)	-- ¹	41.94 (28.71) [0 – 100]	48.23 (30.14) [0 – 100]
Visuo-spatial skills (raw score)	15.96 (5.05) [5 – 23]	17.57 (4.12) [5 – 25]	-- ²

Note. . T1 = assessment before training; T2 = assessment after training; T3 = assessment 4-5 weeks after training; --¹: variable was not quantified at T1; --²: variable was not quantified at T3.

Supplementary Table 5.

Descriptive data of all dependent variables for the keyboard group at the different time points of assessment

Keyboard group	T1	T2	T3
	Mean (<i>SD</i>) [Min – Max]	Mean (<i>SD</i>) [Min – Max]	Mean (<i>SD</i>) [Min – Max]
Letter recognition (raw score)	7.13 (2.02) [2 – 11]	8.00 (2.22) [3 – 11]	7.48 (2.01) [2 – 11]
Letter writing (raw score)	7.74 (4.49) [0 – 15]	11.76 (4.19) [2 – 16]	11.27 (4.32) [1 – 16]
Word reading (raw score)	-- ¹	1.98 (1.85) [0 – 5]	2.26 (1.88) [0 – 5]
Word writing (raw score in %)	-- ¹	56.78 (34.66) [0 – 100]	58.83 (34.16) [0 – 100]
Visuo-spatial skills (raw score)	16.11 (4.76) [5 – 24]	16.15 (4.57) [4 – 22]	-- ²

Note. . T1 = assessment before training; T2 = assessment after training; T3 = assessment 4-5 weeks after training; --¹: variable was not quantified at T1; --²: variable was not quantified at T3.

Supplementary Table 6.

Results of estimated LMMs for the variable letter recognition (T1 vs. T2)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	7.06 (.30)	274.26	23.27	<.001	6.46	7.65
T3 (Reference=T1)	1.56 (.41)	141.60	3.78	<.001	.74	2.37
Stylus group	.10 (.43)	274.11	.23	.821	-.75	.94
Keyboard group	-.02 (.43)	274.13	-.04	.968	-.87	.83
Visuo-spatial skills (at T1)	.06 (.03)	139.35	2.20	.029	.01	.11
Letter reading (at T1)	.11 (.03)	139.33	4.11	<.001	.06	.16
T3 * stylus group	-.20 (.58)	140.87	-.34	.738	-1.35	.96
T3 * keyboard group	-.71 (.59)	140.88	-1.21	.230	-1.87	.45
Reference: keyboard group						
Intercept	7.04 (.31)	274.08	22.95	<.001	6.43	7.64
T3 (Reference=T1)	.58 (.42)	140.18	2.03	.044	.02	1.68
Stylus group	.11 (.43)	274.02	.27	.791	-.74	.96
Pencil group	-.02 (.43)	274.13	.04	.968	-.83	.87
Visuo-spatial skills (at T1)	.06 (.03)	139.35	2.20	.029	.01	.11
Letter reading (at T1)	.11 (.03)	139.33	4.11	<.001	.06	.16
T3 * stylus group	.51 (.59)	140.17	.87	.386	-.65	1.68
T3 * pencil group	.71 (.59)	140.88	1.21	.230	-.45	1.87

Supplementary Table 7.

Results of estimated LMMs for the variable letter recognition (T2 vs T3)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	8.63 (0.29)	224.57	29.97	<.001	8.07	9.20
T3 (Reference=T2)	-0.05 (.30)	133.67	-.17	.867	-.64	.54
Stylus group	-0.16 (.41)	222.89	-.40	.693	-.97	.65
Keyboard group	-0.72 (.41)	224.50	-1.74	.083	-1.53	.09
Visuo-spatial skills (at T1)	.10 (.03)	140.00	3.15	.002	.04	.16
Letter reading (at T1)	.05 (.03)	139.21	1.56	.121	-.01	.11
T3 * stylus group	-.30 (.56)	134.88	-.26	.799	-.96	.74
T3 * keyboard group	-1.15 (.56)	135.59	-1.00	.319	-1.28	.42
Reference: keyboard group						
Intercept	7.92 (.29)	224.83	26.85	<.001	7.34	8.50
T3 (Reference=T2)	-.48 (.31)	137.34	-1.55	.125	-1.10	.13
Stylus group	.56 (.42)	223.31	1.34	.182	-.26	1.38
Pencil group	.72 (.41)	224.50	1.74	.083	-.09	1.53
Visuo-spatial skills (at T1)	.10 (.03)	140.00	3.15	.002	.04	.16
Letter reading (at T1)	.05 (.03)	139.21	1.56	.121	-.01	.11
T3 * stylus group	.32 (.44)	136.70	.73	.464	-.55	1.19
T3 * pencil group	.43 (.43)	135.59	1.00	.319	-.42	1.28

Supplementary Table 8.

Results of estimated LMMs for the variable letter writing (T1 vs. T2)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	6.90 (.32)	257.47	21.45	<.001	6.27	7.53
T2 (Reference=T1)	3.37 (.39)	139.95	8.69	<.001	2.61	4.14
Stylus group	-.10 (.45)	256.61	-.22	.828	-.99	.79
Keyboard group	.37 (.46)	257.44	.81	.420	-.54	1.28
Visuo-spatial skills (at T1)	.04 (.03)	139.45	1.42	.157	-.02	.10
Letter reading (at T1)	.66 (.03)	139.12	21.20	<.001	.59	.72
T2 * stylus group	.30 (.55)	139.94	.55	.584	-.78	1.39
T2 * keyboard group	.62 (.56)	140.01	1.12	.263	-.47	1.72
Reference: keyboard group						
Intercept	7.27 (.33)	257.45	22.11	<.001	6.62	7.92
T2 (Reference=T1)	4.00 (.40)	140.07	10.07	<.001	3.21	4.78
Stylus group	.47 (.46)	256.53	-1.03	.306	-1.37	.43
Pencil group	-.37 (.46)	257.44	-.81	.420	-1.28	.54
Visuo-spatial skills (at T1)	.04 (.03)	139.45	1.42	.157	-.02	.105
Letter reading (at T1)	.66 (.03)	139.12	21.20	<.001	.59	.72
T2 * stylus group	-.32 (.56)	139.99	-.58	.563	-1.42	.78
T2 * pencil group	-.62 (.56)	140.01	-1.12	.263	-1.72	.475

Supplementary Table 9.

Results of estimated LMMs for the variable letter writing (T2 vs. T3)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	10.25 (.37)	169.53	27.56	<.001	9.52	10.99
T3 (Reference=T2)	.16 (.24)	129.85	.63	.528	-.33	.64
Stylus group	.10 (.53)	169.53	.19	.852	-.95	1.14
Keyboard group	1.13 (.53)	169.48	2.12	.035	.08	2.18
Visuo-spatial skills (at T1)	.09 (.04)	139.35	2.22	.028	.01	.18
Letter reading (at T1)	.60 (.04)	137.80	14.04	<.001	.51	.68
T3 * stylus group	-.09 (.35)	130.73	-.24	.808	-.79	.61
T3 * keyboard group	-.47 (.35)	130.46	-1.33	.185	-1.17	.23
Reference: keyboard group						
Intercept	11.38 (.38)	169.68	29.93	<.001	10.63	12.13
T3 (Reference=T2)	-.32 (.26)	131.02	-1.24	.217	-.82	.19
Stylus group	-1.03 (.44)	169.65	-1.93	.056	-2.09	.03
Pencil group	-1.13 (.44)	169.48	-2.12	.035	-2.18	-.08
Visuo-spatial skills (at T1)	.09 (.04)	139.35	2.22	.028	.010	.18
Letter reading (at T1)	.60 (.04)	137.80	14.04	<.001	.51	.68
T3 * stylus group	.39 (.36)	131.29	1.07	.287	-.33	1.10
T3 * pencil group	.47 (.35)	130.46	1.33	.185	-.23	1.17

Supplementary Table 10.

Results of estimated LMMs for the variable letter writing (T1 vs. T3)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	6.90 (.33)	245.63	20.61	<.001	6.24	7.56
T3 (Reference=T1)	3.55 (.39)	137.12	9.19	<.001	2.78	4.31
Stylus group	-.10 (.47)	244.55	-.21	.838	-1.03	.83
Keyboard group	.38 (.48)	245.64	.80	.425	-.56	1.33
Visuo-spatial skills (at T1)	.05 (.03)	147.03	1.51	.133	-.02	.12
Letter reading (at T1)	.65 (.03)	141.84	19.68	<.001	.59	.72
T3 * stylus group	.26 (.55)	139.10	.48	.632	-.83	1.36
T3 * keyboard group	.18 (.56)	138.60	.33	.745	-.92	1.28
Reference: keyboard group						
Intercept	7.28 (.34)	245.63	21.27	<.001	6.60	7.95
T3 (Reference=T1)	3.73 (.40)	140.05	9.31	<.001	2.94	4.52
Stylus group	-.48 (.48)	244.47	-1.00	.316	-1.42	.46
Pencil group	-.38 (.48)	245.64	-.80	.425	-1.33	.56
Visuo-spatial skills (at T1)	.05 (.03)	147.03	1.51	.133	-.02	.12
Letter reading (at T1)	.65 (.03)	141.84	19.68	<.001	.59	.72
T3 * stylus group	.08 (.56)	140.46	.15	.882	-1.03	1.20
T3 * pencil group	-.18 (.56)	138.60	-.33	.745	-1.28	.92

Supplementary Table 11.

Results of estimated LMMs for the variable word writing (T2 vs. T3)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	49.29 (3.43)	163.77	14.37	<.001	42.51	56.06
T3 (Reference=T2)	3.42 (1.96)	132.85	1.74	.084	-.46	7.31
Stylus group	-5.62 (4.88)	162.89	-1.15	.251	-15.25	4.01
Keyboard group	3.75 (4.91)	163.79	.76	.446	-5.94	13.44
Visuo-spatial skills (at T1)	.37 (.40)	141.07	.92	.360	-.42	1.16
Letter reading (at T1)	4.33 (.40)	139.39	10.89	<.001	3.54	5.11
T3 * stylus group	2.65 (2.84)	133.49	.93	.352	-2.96	8.26
T3 * keyboard group	1.38 (2.85)	133.59	.48	.629	-4.26	7.03
Reference: keyboard group						
Intercept	53.04 (3.51)	163.89	15.13	<.001	46.11	59.96
T3 (Reference=T2)	4.80 (2.07)	134.24	2.32	.022	.71	8.90
Stylus group	-9.37 (4.93)	162.92	-1.90	.059	-19.11	.37
Pencil group	-3.75 (4.91)	163.79	-.76	.446	-13.44	5.94
Visuo-spatial skills (at T1)	.37 (.40)	141.07	.92	.360	-.42	1.16
Letter reading (at T1)	4.33 (.40)	139.39	10.90	<.001	3.54	5.11
T3 * stylus group	1.27 (2.91)	134.15	.44	.664	-4.49	7.03
T3 * pencil group	-1.38 (2.85)	133.59	-.48	.629	-7.03	4.26

Supplementary Table 12.

Results of estimated LMMs for the variable word reading (T2 vs. T3)

	Estimate (SE)	df	t-Score	p-Value	CI 95%	
					Lower	Upper
Reference: pencil group						
Intercept	1.78 (.18)	183.70	9.62	<.001	1.41	2.14
T3 (Reference=T1)	-.003 (.14)	131.26	-.02	.981	-.30	.28
Stylus group	-.47 (.26)	182.39	-1.81	.072	-.99	.04
Keyboard group	-.02 (.26)	181.95	-.07	.948	-.54	.50
Visuo-spatial skills (at T1)	.01 (.02)	139.76	.59	.559	-.03	.05
Letter reading (at T1)	.30 (.03)	137.84	11.72	<.001	.25	.35
T3 * stylus group	.06 (.21)	132.33	.31	.760	-.34	.47
T3 * keyboard group	.36 (.21)	132.46	1.74	.085	-.05	.77
Reference: keyboard group						
Intercept	1.76 (.19)	180.90	9.34	<.001	1.39	2.13
T3 (Reference=T1)	.36 (.15)	133.55	2.37	.019	.06	.66
Stylus group	-.46 (.26)	180.75	-1.72	.086	-.97	.07
Pencil group	.02 (.26)	181.95	.07	.948	-.50	.54
Visuo-spatial skills (at T1)	.01 (.02)	139.76	.59	.559	-.03	.05
Letter reading (at T1)	.30 (.03)	137.84	11.72	<.001	.25	.35
T3 * stylus group	-.30 (.21)	133.47	-1.41	.160	-.72	.12
T3 * pencil group	-.36 (.21)	132.46	-1.74	.085	-.77	.05