

8. APPENDICES

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Appendix A

Additional Information on the Method-of-Loci TaskTable A.1. *Fixed Lists Lengths and Inter-Stimulus Intervals (ISIs) for the Method-of-Loci Task in the First Three Sessions of the Study*

		9-year olds		11-year olds		young adults	
Session	# of lists	List Length (# of items)	ISI (in ms)	List Length (# of items)	ISI (in ms)	List Length (# of items)	ISI (in ms)
1 (Pretest)	2	10	8 000	11	8 000	16	6 000
2 (Instruction)	3	12	<i>self-paced</i>	12	<i>self-paced</i>	16	<i>self-paced</i>
3 (Training 1)	3	10	10 000	11	10 000	16	8 000
3 (Training 2)	3	10	8 000	11	8 000	16	6 000

Table A.2. *Possible Combinations of List Length and Inter-Stimulus Intervals (ISIs) for the Method-of-Loci Task in the Adaptive and the Dual-Task Phase*

List Length (number of items)	ISI (in ms)
6	8500
7	7000
8	6000
9	5200
10	4000
11	3500
12	3200
13	2800
14	2500
15	2300
16	2100
17	2000
18	1800
19	1700
20	1600

Note. Maximum list length for children was 14 items.

Table A.3. *Method-of-Loci Adaptive Phase: List Length and 80% Correct-Recall*

List Length (in items)	Recall Performance for 80% Correct
20	15
19	14
18	13
17	13
16	12
15	11
14	10
13	10
12	9
11	8
10	7
9	7
8	6
7	5
6	4

Table A.4. *Method-of-Loci Adaptive Phase: Algorithm for Adjusting Task-Difficulty of the Following Trial*

Difference to 80 % Correct (in items)	Steps in the Adaptation Procedure
more than 2 above	- 2
1 or 2 above	- 1
0	- 1
1 or 2 below	+ 1
more than 2 below	+ 2

Note. A negative value in the second column indicates that the task will be more difficult (more items, shorter ISIs) in the following trial, a positive value indicates that the task will be easier (fewer items, longer ISIs) in the following trial.

Appendix B

Additional Information on the N-Back Task

Table B.1. *Fixed Lists Lengths and Inter-Stimulus Intervals (ISIs) for the N-back Task in the First Three Sessions of the Study*

Session	N-back Version	children			young adults		
		Number of Trials	List Length (# of items)	ISI (in ms)	Number of Trials	List Length (# of items)	ISI (in ms)
1	N-back 0	1	10	2500	1	10	2500
	N-back 1	3	11	2500	1	11	2500
	N-back 2	4	12	2500	2	12	2500
	N-back 3	-	-	-	3	13	2500
	N-back 4	-	-	-	3	14	2500
2	N-back 2	8	12	2500	-	-	-
	N-back 4	-	-	-	8	14	2500
3	N-back 2	3	12	2500	-	-	-
	N-back 2	3	19	1730	-	-	-
	N-back 4	-	-	-	3	14	2500
	N-back 4	-	-	-	3	19	1730

Note. During the training phase, trials with less than 3 (children) or 5 (adults) correct items were repeated, such that some participants occasionally worked on additional lists. The number of successive digits increased by one unit with N-back versions 0 (10 digits) to 4 (14 digits), such that the maximum correct score in each task was always “10”. An exception is the last block of the third session, in which 19 digits were presented in each age group, to accustom participants to longer trials in the adaptive phase.

Table B.2. *Possible Combinations of List Length and Inter-Stimulus Intervals (ISIs) for N-Back in the Adaptive and the Dual-Task Phase*

Number of Items Shown	Maximum Number of Correct Items for N-back 2	Maximum Number of Correct Items for N-back 4	ISI in ms
13	11	9	2500
16	14	12	2300
19	17	15	2000
22	20	18	1684
25	23	21	1454
28	26	24	1280
31	29	27	1142
32	30	28	1000

Table B.3. *N-Back Adaptive Phase: Algorithm for Adjusting Task-Difficulty of the Following Block*

Difference to 80 % Correct (in Percent)	Steps in the Adaptation Procedure
more than 20 % above	- 2
10 or 20 % above	- 1
about correct	- 1
more than 10 % below	+ 1

Note. A negative value in the second column indicates that the task will be more difficult (more items, shorter ISI) in the following trial, a positive value indicates that the task will be easier (fewer items, longer ISIs) in the following trial.

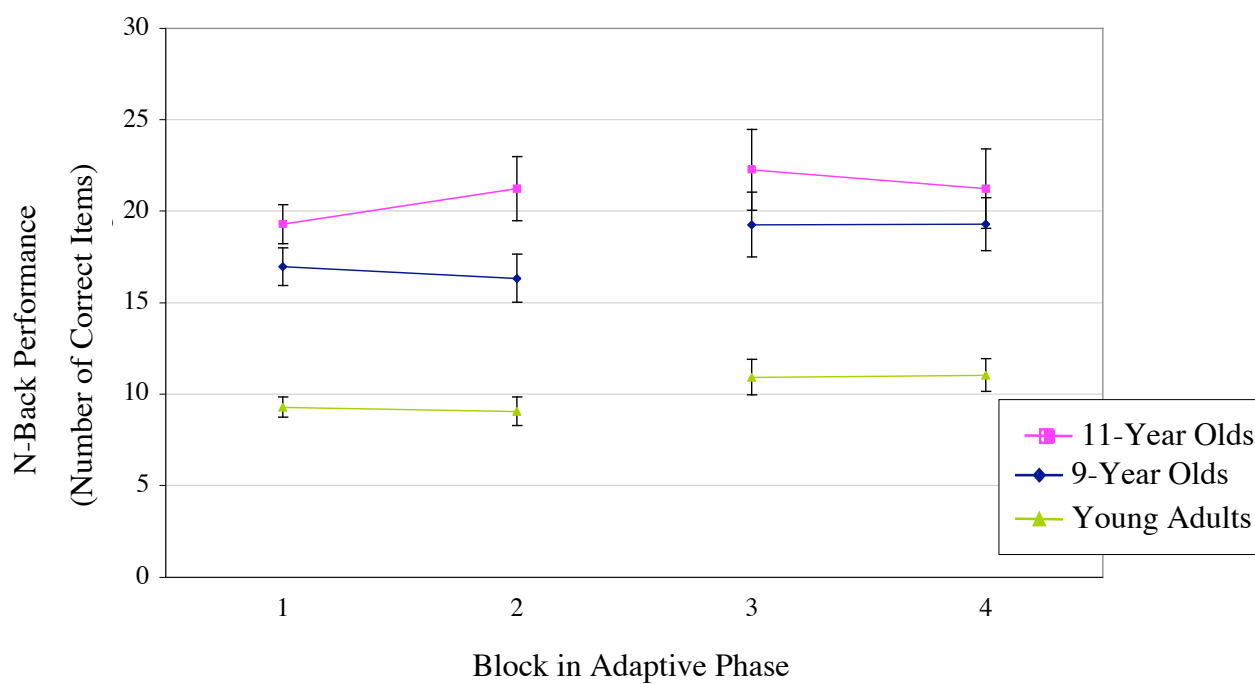


Figure B.1. Performance Raw Scores for the Adaptive Phase of the N-back Task

Note. Error bars depict standard errors of the mean.

Appendix C

Additional Information on the Differential-Emphasis PhaseTable C.1. *Reinforcement Scheme for the Differential-Emphasis Phase of the Study*

	Focus on Both Tasks	Focus on N- Back	Focus on Balance
Criterion Reached in the N-Back Task	2	3	1
Criterion Reached in the Balance Task	2	1	3
Maximum of Credit- Points in Each Trial	4	4	4

Note. Cells depict the number of credit points that can be achieved in one trial in a specific task domain. The maximum number of points that can be reached within one trial is always 4, but the weighting of the two task domains (balance vs. N-back) depends on the emphasis condition. If the criterion is not reached, participants receive 0 credit points for the respective condition.

Appendix D

Additional Information on the Study Design

Table D.1. *Detailed Description of the Sessions of the Study*

Session	Tasks
1	MOL pretest (2 trials) Balance on stable platform: 2 trials without ankle-disc board 2 trials on the board with deliberate movements 3 trials on the board with online feedback 3 trials on the board with offline feedback N-back training with different N-back conditions of increasing difficulty (8 or 10 trials)
2	MOL instruction (3 trials) Balance on stable platform on the board: 2 trials with online feedback 4 trials with offline feedback N-back training (8 trials)
3	MOL training (3 trials) N-back training (6 trials) Balance on the board: 4 trials on stable platform 1 warm-up trial on moving platform (difficulty 1) 3 trials on moving platform (difficulty 1) 1 warm-up trial on moving platform (difficulty 2) 3 trials on moving platform (difficulty 2) MOL training (3 trials)
4 and 5	MOL adaptive (3 trials) N-back adaptive (2 blocks with 3 trials each) Balance on the board: 2 trials on stable platform while reading numbers 1 warm-up trial on moving platform (difficulty 1) 2 trials on moving platform (difficulty 1) while reading numbers 1 warm-up trial on moving platform (difficulty 2) 2 trials on moving platform (difficulty 2) while reading numbers 2 trials on moving platform (difficulty 2) with animal voices 2 trials on moving platform (difficulty 1) with animal voices 2 trials on stable platform with animal voices MOL adaptive (3 trials)

(Table continues)

Table D.1 (continued). *Detailed Description of the Sessions of the Study*

Session	Tasks
6 to 8	<p>MOL single-task (1 trial)</p> <p>Balance on the board:</p> <p>2 warm-up trials</p> <p>2 trials single-task with reading numbers</p> <p>2 trials single-task with animal voices</p> <p>N-back single-task (2 trials)</p> <p>3 trials dual-task MOL with balance</p> <p>4 trials dual-task N-back with balance</p> <p>MOL single-task (1 trial)</p> <p>Balance on the board:</p> <p>2 trials single-task with reading numbers</p> <p>1 trial single-task with animal voices</p> <p>N-back single-task (2 trials)</p>
9	<p>MOL single-task (2 trials)</p> <p>Balance on stable platform on the board:</p> <p>2 warm-up trials</p> <p>2 trials single-task with reading numbers</p> <p>N-back single-task (3 trials)</p> <p>2 trials dual-task N-back with balance, focus on both tasks</p> <p>4 trials dual-task N-back with balance, focus on N-back task</p> <p>4 trials dual-task N-back with balance, focus on balance task</p> <p>2 trials dual-task N-back with balance, focus on both tasks</p> <p>Balance on stable platform on the board:</p> <p>2 trials single-task with reading numbers</p> <p>N-back single-task (3 trials)</p>

Note. In Sessions 2 to 8, the two-choice reaction-time task was assessed at the beginning and end of each session. For the N-back task, children worked on the N-back 2 version, and adults worked on the N-back 4 version from Session 2 on. For the balance task, task difficulty was operationalized by different angles of movement and depended on age groups (see Table 5). In the adaptive phase (Sessions 4 and 5), the order of secondary tasks for balance was reversed in the second adaptive session: Session 5 started the balance trials with the secondary task of detecting animal voices (instead of reading numbers). In the dual-task phase (Sessions 5 to 8), each of the 3 sessions was administered with a certain balance difficulty condition (stable platform, movement difficulty 1, and movement difficulty 2), and the order of these sessions was counterbalanced across participants. In Session 9, the order of the dual-task condition “focus on N-back” and “focus on balance” was counterbalanced across participants.

Appendix E

Reliabilities

Reliability coefficients (Cronbach's Alpha = average inter-item correlation) were calculated across repeated trials in the same conditions to assess whether the position of a score in a distribution of scores remains stable when measured several times.

Table E.1. *Stability of Measurement for Scores of the Method-of-Loci Task*

Task Condition	Number of Trials	Sample			
		9-year olds	11-year olds	young adults	total sample
Pretest	2	.74*	.81*	.83*	.92**
Training	6	.65*	.09	.76**	.96**
Adaptive Phase	12	.92**	.92**	.92**	.96**
Single-Task	8	.96**	.96**	.96**	.98**
Dual-Task, Stable Platform	3	.86**	.67*	.44	.82**
Dual-Task, Moving Platform	3	.88**	.94**	.91**	.95**
All Dual-Task Trials	6	.95**	.90**	.86**	.95**
MOL DTCs	2	.83*	.20	.35	.51*

Note. The “MOL DTCs” consist of the 2 values: DTCs on the stable and on the moving platform.

* $p < .05$, ** $p < .01$

Table E.2. *Stability of Measurement for Scores of the N-Back Task*

Task Condition	Number of Trials	Sample			
		9-year olds	11-year olds	young adults	total sample
Training Session 2, 10 Stimuli	8	.46	-1.51	.56*	.63**
Training Session 3, 10 Stimuli	3	.67*	-.43	.78**	.82**
Training Session 3, 19 Stimuli	3	.05	.53	.66*	.83**
Adaptive Phase	12	.81**	.90**	.86**	.95**
Single-Task	18	.82**	.96**	.95**	.98**
Dual-Task, Stable Platform	4	.25	.93**	.32	.93**
Dual-Task, Moving Platform	4	.45	.37	.45	.66**
Dual-Task DE, Focus on Both	4	.83**	.87**	-.11	.95**
Dual-Task DE, Focus on N-Back	4	.63*	.83**	.36	.91**
Dual-Task DE, Focus on Balance	4	.71**	.88**	.63*	.91**
All Dual-Task Trials	20	.83**	.95**	.77**	.97**
N-Back DTCs (Without DE Phase)	2	.44	-.63	.76*	.45
All N-Back DTCs	5	.75**	-2.10	.85**	.67**

Note. “DE” refers to the differential-emphasis phase. The “N-Back DTCs” consist of the 2 values: DTCs on the stable and on the moving platform. The “All N-Back DTCs” also include the DTCs of the differential-emphasis phase.

* $p < .05$, ** $p < .01$

Table E.3. *Stability of Measurement for Scores of the Balance Task*

Task Condition	Number of Trials	Sample			
		9-year olds	11-year olds	young adults	total sample
Online Feedback, Session 1	3	-.02	.49	.53	.67**
Offline Feedback, Session 1	3	.62*	.60	.86**	.74**
Offline Feedback, Session 2	4	.90**	.86**	.73**	.92**
Stable Platform, Session 3	4	.87**	.81**	.75**	.92**
Moving Platform, Session 3	3	.57	.85**	.87**	.87**
Adaptive Phase, Stable with Numbers	4	.66*	.76**	.16	.89**
Adaptive Phase, Moving with Numbers	4	.15	.79**	.81**	.82**
Adaptive Phase, Stable with Animals	4	.81**	.86**	.81**	.92**
Adaptive Phase, Moving with Animals	4	.86**	.86**	.94**	.92**
Single-Task, Stable with Numbers	8	.83**	.93**	.84**	.96**
Single-Task, Moving with Numbers	4	.85**	.82**	.93**	.92**
Single-Task, Stable with Animals	3	.12	.92**	.90**	.84**
Single-Task, Moving with Animals	3	.81**	.59	.89**	.87**
Dual-Task, Stable with N-Back	4	.85**	.78**	.67*	.88**
Dual-Task, Moving with N-Back	4	.87**	.83**	.95**	.92**
Dual-Task, Stable with MOL	3	.28	.82**	.72*	.91**
Dual-Task, Moving with MOL	3	.75**	.86**	.87**	.93**
Dual-Task DE, Focus on Both	4	.85**	.95**	.80**	.94**
Dual-Task DE, Focus on N-Back	4	.91**	.88**	.88**	.94**
Dual-Task DE, Focus on Balance	4	.88**	.90**	.82**	.93**
DTCs With N-Back	2	-.09	-.20	-.23	-.04

Table continues

Table E.3 (continued). *Stability of Measurement for Scores of the Balance Task*

Task Condition	Number of Trials	Sample			
		9-year olds	11-year olds	young adults	total sample
DTCs With MOL	2	.71*	.73*	.14	.60*
Balance DTCs	4	.52	.58*	-.34	.44*

Note. The balance scores have been square-root transformed before the analysis. “DE” refers to the differential-emphasis phase. The reliability coefficient for “Single-Task, Stable with Numbers” includes the single-task trials of the differential-emphasis phase. The “Balance DTCs” consist of 4 values: balance with MOL or with N-back on the stable platform and on the moving platform.

* $p < .05$, ** $p < .01$

Tables E.1 to E.3 present the reliability coefficients obtained for the data of this study, with Table E.1 presenting the coefficients for the MOL scores, Table E.2 for the N-back scores, and Table E.3 for the balance data, namely the square-root transformed COP areas. Please note that the absolute performance scores have been used for MOL and N-back, and not the percent correct scores. Each tables includes the coefficient for each age group separately, and for the overall sample. For the MOL task, reliability coefficients ranged from $r = .09$ (training in the 11-year olds) to $r = .98^{**}$ (single-task in all three age groups). For the N-back task, reliability coefficients ranged from $r = -2.0$ (N-back DTCs in the 11-year olds) to $r = .98^{**}$ (e.g. single-task in all three age groups).¹⁹ For the balance task, reliability coefficients ranged from $r = -.47$ (DTCs with N-back in the young adults) to $r = .96^{**}$ (single-task, stable with numbers for all three age groups). In general, stability coefficients tended to be high, with values for the overall sample naturally higher than for single age groups. Furthermore, reliability coefficients for the dual-task costs were sometimes very low or even negative, which is probably influenced by the fact that dual-task costs are difference scores and therefore tend to show decreased reliability (see Cohen & Cohen, 1983; Madden, Pierce, & Allen, 1993; Wittmann, 1988).

¹⁹ Negative values smaller than -1 can occur, because Cronbach’s Alpha ranges from $-\infty$ to 1 , and they are more likely to occur when the sample size is small (van Zyl, Neudecker, & Nel, 2000).

Appendix F

Method-of-Loci Task: Changes in Percent Correct Performance During the Adaptive Phase

Two mixed- design ANOVAs with age group (2) as between-subjects factor and adaptive trial (6) as within-subjects factor were conducted, for each session of the adaptive phase separately. Performance in percent correct was the dependent variable in these analyses. For trials 1 to 6, the children's performance differed significantly from the young adults, $F(1,24) = 7.67$, $MSE = 438.32$, $p < .05$, $\eta^2 = .242$, whereas the difference between 9- and 11-year olds did not reach significance, $F(1,24) = 3.17$, $MSE = 438.32$, $p = .088$, $\eta^2 = .117$. The linear trend for the trial effect turned out significant, $F(1,24) = 49.40$, $MSE = 162.46$, $p < .001$, $\eta^2 = .673$, and there was no interaction of this trend with the age contrast comparing children to young adults. However, the age contrast comparing 9-year olds to 11-year olds interacted with the linear trend, $F(1,24) = 7.79$, $MSE = 162.46$, $p < .05$, $\eta^2 = .245$. This indicates that the young adults still showed higher recall performance than the two children's groups in the first adaptive session, maybe because they started with a larger difference between their actual performance and the 80 % correct level, and the difficulty manipulation required a couple of trials to actually decrease young adults' performance sufficiently. The mixed-design ANOVA of trials 7 to 12 yielded similar results, except that the age contrasts did not reach significance, suggesting that the difficulty manipulation actually led to comparable percent correct performance scores across groups. The linear trend for the trial effect reached significance again, $F(1,24) = 5.70$, $MSE = 324.93$, $p < .05$, $\eta^2 = .192$, and it didn't interact with the age contrasts.

Table F.1. *Method-of-Loci List Length in the Dual-Task Phase*

	9-year olds	11-year olds	young adults
MOL List Length			
<i>M</i>	9.56	12.22	17.00
<i>SD</i>	2.01	2.28	2.96
<i>Max</i>	12	14	20
<i>Min</i>	7	8	13

At the end of the adaptive phase, a specific MOL task parameter setting (combination of list length and ISI) was chosen for each participant individually according to the performance in

the adaptive phase. Table F.1 presents the mean list length used in the dual-task phase, along with the standard deviation and minimum and maximum values for each age group. To investigate age differences in the task difficulty for MOL after the adaptive phase, an ANOVA with age group (3) as between-subjects factor was conducted, with each participant's list length as the dependent variable. A significant main effect of age group was found, $F(2,24) = 21.37$, $p < .001$, and difference contrasts comparing 9- to 11-year-olds detected significant differences ($p < .05$), as well as significant differences between these two groups and the young adults ($p < .001$).

Appendix G

N-Back Task: Parameter Setting at the End of the Adaptive Phase

Like for the MOL task, task parameters for the dual-task phase of N-back were selected at the end of Session 5 for each participant individually. Table G.1 shows the average list length, its standard deviation, and its minimum and maximum for each age group. An ANOVA with list length of the dual-task phase as dependent variable and age group (3) as between-subjects factor revealed a significant effect of age group, $F(2,24) = 20.03$, $p < .001$, and difference contrasts comparing 9-year olds to 11-year olds showed that these two groups did not differ significantly ($p = .335$), whereas there was a significant difference between the two children's groups and young adults ($p < .001$). This was again due to the fact that adults were working on the more difficult version of the task (N-back 4 instead of N-back 2).

Table G.1. *N-back List Length in the Dual-Task Phase*

	9-year olds (N-back 2)	11-year olds (N-back 2)	young adults (N-back 4)
N-back List Length			
<i>M</i>	27.56	29.33	18.67
<i>SD</i>	3.24	4.36	3.81
<i>Max</i>	32	32	28
<i>Min</i>	22	22	16

Appendix H

Practice in the Balance Task During the Adaptive Phase

Did participants improve their balance performance in Sessions 4 and 5, in which the secondary tasks of reading numbers and of detecting animal voices were introduced?

Table H.1. *Centre-of-Pressure Areas for Balance Trials with Reading Numbers as Secondary Task in Sessions 4 and 5*

		Sample		
Balance Condition		9-year olds	11-year olds	young adults
stable platform	Trial 1			
	<i>M</i>	16.92	14.09	10.86
	<i>SD</i>	3.02	2.36	1.48
	Trial 2			
	<i>M</i>	18.23	13.85	11.18
	<i>SD</i>	4.45	3.11	1.60
	Trial 3			
	<i>M</i>	17.38	14.03	10.38
	<i>SD</i>	4.04	2.81	2.17
	Trial 4			
	<i>M</i>	16.96	13.59	9.23
	<i>SD</i>	2.99	2.35	1.56
moving platform	Trial 1			
	<i>M</i>	43.93	36.65	32.41
	<i>SD</i>	6.57	7.17	3.37
	Trial 2			
	<i>M</i>	46.77	36.15	29.93
	<i>SD</i>	4.76	8.25	3.97
	Trial 3			
	<i>M</i>	43.71	30.92	28.52
	<i>SD</i>	14.72	5.54	5.95
	Trial 4			
	<i>M</i>	39.51	29.47	28.88
	<i>SD</i>	4.89	3.36	6.45

Note. COP area scores for each trial have been square-root transformed.

Table H.2. *Centre-of-Pressure Areas for Balance Trials with Detecting Animal Voices as Secondary Task in Sessions 4 and 5*

		Sample		
Balance Condition		9-year olds	11-year olds	young adults
stable platform	Trial 1			
	<i>M</i>	23.42	19.53	13.66
	<i>SD</i>	8.14	2.88	2.92
	Trial 2			
	<i>M</i>	24.60	21.63	12.43
	<i>SD</i>	5.21	5.78	2.84
	Trial 3			
	<i>M</i>	24.99	18.00	14.46
	<i>SD</i>	7.96	5.60	2.97
	Trial 4			
	<i>M</i>	23.43	19.14	12.31
	<i>SD</i>	5.37	5.78	3.01
moving platform	Trial 1			
	<i>M</i>	50.35	42.52	34.53
	<i>SD</i>	11.01	8.51	4.18
	Trial 2			
	<i>M</i>	56.70	42.62	34.76
	<i>SD</i>	13.01	10.69	5.47
	Trial 3			
	<i>M</i>	52.16	47.26	33.10
	<i>SD</i>	13.96	16.32	5.54
	Trial 4			
	<i>M</i>	56.28	41.10	33.79
	<i>SD</i>	9.41	7.88	6.24

Note. COP area scores for each trial have been square-root transformed.

Table H.1 depicts the balance performance for balancing while reading numbers for each trial separately, in the first part of the table for balancing on the stable platform, and in the second part for balancing on the moving platform. Table H.2 presents the same kind of data for balance trials while detecting animal voices. In order to investigate whether there were further improvements of the COP areas with practice, balance performance for all four trials of each condition was investigated, for the two different balance difficulties (stable vs. moving platform) and for the two different secondary tasks (reading numbers vs. detecting animal voices) separately.²⁰

²⁰ Please note that there were two cases in which not all four trials of each condition could be collected, resulting in missing data for these age groups in the analyses.

For balancing on the stable platform while reading numbers, a mixed-design ANOVA with trial (4) as the within-subjects factor and age group (2) as the between-subjects factor was conducted. Neither the linear nor the quadratic trend for the trial effect reached significance, and these effects also did not interact with the age contrasts, indicating that the balance performance under that specific condition remained rather stable over the course of Sessions 4 and 5. Not surprisingly, adults showed superior balance performance than children, $F(1,22) = 32.38$, $MSE = 16.85$, $p < .001$, $\eta^2 = .595$, and the 9-year olds differed significantly from the 11-year-olds, $F(1,22) = 12.96$, $MSE = 16.85$, $p < .01$, $\eta^2 = .371$. For balancing on the stable platform while detecting animal voices, the mixed-design ANOVA presented a similar pattern of findings: no linear or quadratic trend in the data, and no interaction of this effect with the age contrasts. In this condition, children again showed significantly larger COP areas than young adults, $F(1,22) = 23.03$, $MSE = 71.92$, $p < .01$, $\eta^2 = .511$, and 9-year olds had larger COP areas than 11-year olds, $F(1,22) = 5.81$, $MSE = 71.92$, $p < .05$, $\eta^2 = .209$.

The same kind of mixed-design ANOVA was calculated for the balance trials on the moving platform. For the secondary task of reading numbers, the linear trend for the trial effect reached significance, $F(1,22) = 14.65$, $MSE = 28.56$, $p < .01$, $\eta^2 = .400$, and that effect did not interact with any of the age contrasts. That indicates that performance improved over the course of the four trials in that condition, and it improved in all three age groups. The age contrasts revealed that children's COP areas differed significantly from young adults', $F(1,22) = 14.37$, $MSE = 85.24$, $p < .01$, $\eta^2 = .395$, and that 9-year olds' COP areas differed from 11-year olds', $F(1,22) = 21.90$, $MSE = 85.23$, $p < .001$, $\eta^2 = .499$. For the analysis of the balance data on the moving platform while detecting animal voices, the ANOVA did not detect any linear or quadratic trend in the data, and the age contrasts did not interact with this effect. As in the other conditions, significant differences were found between the balance performances of children and young adults, $F(1,23) = 14.77$, $MSE = 297.01$, $p < .01$, $\eta^2 = .391$, and between 9- and 11-year olds, $F(1,23) = 6.68$, $MSE = 297.01$, $p < .05$, $\eta^2 = .225$.

Appendix I

Stability of the Balance Baseline Performance in the Dual-Task Phase

Table I.1. *Centre-of-Pressure Areas for Balance Trials with Reading Numbers in the Dual-Task Phase*

		Sample		
Balance Condition		9 years	11 years	young adults
stable platform	Trial 1			
	<i>M</i>	16.91	14.10	10.30
	<i>SD</i>	3.32	3.22	2.03
	Trial 2			
	<i>M</i>	19.08	17.06	10.25
	<i>SD</i>	2.78	4.97	2.01
	Trial 3			
	<i>M</i>	20.50	15.14	9.45
	<i>SD</i>	4.58	3.99	2.04
	Trial 4			
	<i>M</i>	17.78	14.76	9.86
	<i>SD</i>	2.89	3.94	1.69
	Trial 5			
	<i>M</i>	17.24	14.11	9.51
	<i>SD</i>	4.06	3.05	1.74
	Trial 6			
	<i>M</i>	19.13	14.04	9.56
	<i>SD</i>	5.14	3.83	1.50
	Trial 7			
	<i>M</i>	16.43	12.94	9.54
	<i>SD</i>	4.85	2.55	1.60
	Trial 8			
	<i>M</i>	16.81	13.73	9.58
	<i>SD</i>	4.85	3.99	3.80
moving platform	Trial 1			
	<i>M</i>	43.06	33.37	29.06
	<i>SD</i>	10.17	5.50	6.24
	Trial 2			
	<i>M</i>	40.84	33.16	27.62
	<i>SD</i>	7.61	7.07	6.10
	Trial 3			
	<i>M</i>	36.62	33.93	26.39
	<i>SD</i>	3.78	6.15	5.67
	Trial 4			
	<i>M</i>	37.56	33.76	27.20
	<i>SD</i>	8.43	5.79	5.56

Note. COP area scores for each trial have been square-root transformed. Trials 5 to 8 on the stable platform were collected in the last session of the study.

Table I.2. *Centre-of-Pressure Areas for Balance Trials while Detecting Animal Voices in the Dual-Task Phase*

		Sample		
Balance Condition		9-year olds	11-year olds	young adults
stable platform	Trial 1			
	<i>M</i>	30.66	19.41	12.73
	<i>SD</i>	11.08	3.79	3.01
	Trial 2			
	<i>M</i>	26.98	22.04	12.54
	<i>SD</i>	9.34	7.61	2.93
	Trial 3			
	<i>M</i>	25.36	21.02	12.42
	<i>SD</i>	4.49	6.70	2.08
moving platform	Trial 1			
	<i>M</i>	51.67	43.78	31.20
	<i>SD</i>	12.58	13.50	5.71
	Trial 2			
	<i>M</i>	44.86	39.95	30.54
	<i>SD</i>	9.25	8.70	4.39
	Trial 3			
	<i>M</i>	47.48	40.30	29.30
	<i>SD</i>	11.22	6.40	4.60

Note. COP area scores for each trial have been square-root transformed.

Appendix J

Task Performances Under Single- and Dual-Task Conditions and Dual-Task Costs

Tables J.1, J.2, and J.3 present the average raw performances under single- and dual-task conditions, for MOL (Table J.1), N-back (Table J.2), and balance (Table J.3), for each age group and the two balance difficulty conditions separately.

Dual-task costs for the three tasks are presented in Table J.4, for each age group and the two balance difficulty conditions separately.

Table J.1. *Method-of-Loci Performance Raw Scores Under Single- and Dual- Task Conditions*

	9-year olds	11-year olds	young adults
Single-Task			
<i>M</i>	7.44	10.15	14.40
<i>SD</i>	2.45	2.76	3.18
Dual-Task, Stable Platform			
<i>M</i>	6.56	8.89	12.67
<i>SD</i>	2.25	2.65	2.78
Dual-Task, Moving Platform			
<i>M</i>	6.44	9.89	13.04
<i>SD</i>	2.13	2.86	3.21

Table J.2. *N-Back Performance Raw Scores Under Single- and Dual-Task Conditions*

	9-year olds	11-year olds	young adults
Single-Task			
<i>M</i>	21.41	23.22	10.67
<i>SD</i>	3.12	6.59	3.19
Dual-Task, Stable Platform			
<i>M</i>	22.92	21.50	9.86
<i>SD</i>	2.97	9.26	1.79
Dual-Task, Moving Platform			
<i>M</i>	17.75	18.91	9.47
<i>SD</i>	4.74	6.03	2.07

Table J.3. *Balance Performance (Centre-of-Pressure Areas) with Different Secondary Tasks Under Different Balance Conditions*

Condition	Secondary Task	9-year olds	11-year olds	young adults
Baseline-Task, Stable Platform	Reading Numbers			
<i>M</i>		329.51	218.29	97.17
<i>SD</i>		98.70	97.68	29.41
Dual-Task, Stable Platform	N-back			
<i>M</i>		315.84	213.06	110.58
<i>SD</i>		200.88	97.20	43.29
Baseline-Task, Moving Platform	Reading Numbers			
<i>M</i>		1599.91	1147.70	785.68
<i>SD</i>		559.22	342.32	310.21
Dual-Task, Moving Platform	N-back			
<i>M</i>		1297.68	1045.81	792.56
<i>SD</i>		449.04	339.63	365.80
Baseline-Task, Stable Platform	Detecting Animal Voices			
<i>M</i>		790.15	438.22	163.24
<i>SD</i>		299.88	211.50	58.59
Dual-Task, Stable Platform	MOL			
<i>M</i>		649.51	356.69	155.68
<i>SD</i>		140.60	148.27	30.65
Baseline-Task, Moving Platform	Detecting Animal Voices			
<i>M</i>		2383.65	1758.49	938.40
<i>SD</i>		948.29	642.89	286.10
Dual-Task, Moving Platform	MOL			
<i>M</i>		2231.65	1345.51	950.98
<i>SD</i>		607.61	367.47	294.70

Note. COP area scores for each condition have been square-root transformed, averaged, and then squared again.

Table J.4. *Dual-Task Costs (DTCs) for the Different Tasks and Balance-Difficulty Conditions*

	9-year olds	11-year olds	young adults
MOL, Stable Platform			
<i>M</i>	11.87	12.42	11.59
<i>SD</i>	13.25	9.82	7.92
MOL, Moving Platform			
<i>M</i>	12.96	1.71	9.38
<i>SD</i>	15.67	17.12	14.13
N-Back, Stable Platform			
<i>M</i>	-7.42	9.52	2.01
<i>SD</i>	6.05	24.07	25.80
N-Back, Moving Platform			
<i>M</i>	15.43	17.75	7.38
<i>SD</i>	25.91	12.53	26.29
Balance+ MOL, Stable Platform			
<i>M</i>	-10.44	-12.74	4.13
<i>SD</i>	27.67	22.95	31.05
Balance+ MOL, Moving Platform			
<i>M</i>	0.90	-19.20	2.12
<i>SD</i>	31.81	19.62	19.35
Balance + N-Back, Stable Platform			
<i>M</i>	-17.39	0.76	9.20
<i>SD</i>	16.92	29.31	27.69
Balance+ N-Back, Moving Platform			
<i>M</i>	-16.89	-7.76	-1.13
<i>SD</i>	20.98	17.62	13.65

Appendix K

Correlations Among Measures of the Present Study with Measures of the Screening SessionTable K.1. *Correlations of Cognitive Variables of the Screening Session and the Present Study*

	<i>MS Forward</i>	<i>MS Backward</i>	<i>Words</i>	<i>MOL ST</i>	<i>N-Back ST</i>	<i>Cognitive DTCs</i>	<i>RTs</i>
<i>Digit Symbol</i>	.385*	.446*	-.472*	.700*	-.759**	.032	-.691**
<i>Memory Span Forward</i>	-	.725**	-.130	.367	-.173	.065	-.479*
<i>Memory Span Backward</i>		-	-.314	.272	-.442*	-.116	-.571**
<i>Word Meanings</i>			-	-.280	.373	-.007	.352
<i>MOL Single-Task</i>				-	-.422*	-.003	-.652**
<i>N-Back Single-Task</i>					-	.262	.498**
<i>Cognitive Dual-Task Costs</i>						-	.097

Note. * $p < .05$, ** $p < .01$. Variables in italics were assessed in the screening session. The single-task values (ST) for MOL and N-back refer to the raw scores, and not to the percent correct scores. Reaction times (RTs) were assessed with a two-choice reaction-time task at the beginning and end of sessions 2 to 8.

Table K.1 presents the correlations of cognitive performance measures of the current study with the cognitive performances of the screening session for the entire sample. Since raw scores instead of percent correct values were used for the MOL and N-back single-task performances, the correlations of the N-back single-task scores with the other cognitive measures are difficult to interpret, because young adults had lower scores in N-back than

children due to differences in task difficulties. It is noteworthy that the score on the “Digit Symbol Substitution Test” correlated highly with the other cognitive measures. Furthermore, cognitive dual-task costs did not correlate significantly with any of the other measures.

Table K.2. *Correlations of Sensorimotor Variables of the Screening Session and the Present Study*

	<i>Balance Moving</i>	<i>FSB</i>	Balance, Stable, Numbers	Balance, Moving, Numbers	Balance, Stable, Animals	Balance, Moving, Animals	Balance DTCs
<i>Balance Stable</i>	.542**	.204	.318	.167	.384*	.220	-.235
<i>Balance Moving</i>	-	.158	.424*	.415*	.471*	.416*	-.295
<i>Functional Stability Boundary (FSB)</i>		-	.236	.264	.139	.150	.090
Balance, Stable, Numbers			-	.719**	.886 **	.759**	-.429*
Balance, Moving, Numbers				-	.802**	.893**	-.482*
Balance, Stable, Animals					-	.884**	-.624**
Balance, Moving, Animals						-	-.736**

Note. * $p < .05$, ** $p < .01$. Variables in italics were assessed in the screening session. “Balance Stable” and “Balance Moving” were assessed while standing on the platform without using the ankle-disc board. “FSB” denotes the “Functional Stability Boundary” areas.

Table K.2 presents the correlations of the sensorimotor performance measures of the present study and of the screening study. The correlations of the balance single-task measures of the present study and the balance dual-task costs were reliable and negative, indicating that participants who already swayed a lot under single-task conditions had smaller dual-task costs in the balance domain under dual-task conditions (see Discussion for details). Furthermore,

balance on the moving platform during the screening session, when participants were not using the ankle-disc board, was related to all the single-task balance measures of the present study, when participants were balancing on the ankle-disc board.

Appendix L

Expressing Balance Performance in Percent of Functional Stability Boundary Area Used

In the screening session, a measure of functional stability was assessed, by measuring the COP area that results when people lean as far as possible in four different directions, namely in the anterior-posterior, the lateral, and the two diagonal directions (FSB area). The resulting areas for each age group are presented in Table L.1.

Table L.1. *Functional Stability Boundary (FSB) Areas and Percentage of FSB Areas Used in Different Balance Conditions*

	FSB Area	% of FSB in Stable with Numbers	% of FSB in Stable with Animals	% of FSB in Moving with Numbers	% of FSB in Moving with Animals
9-year olds					
<i>M</i>	26341	1.32	3.23	6.33	9.77
<i>SD</i>	4382	.46	1.51	2.84	5.20
11-year olds					
<i>M</i>	20241	1.27	2.76	6.79	9.89
<i>SD</i>	9401	.64	1.72	3.07	4.20
young adults					
<i>M</i>	23455	.47	.76	3.44	4.43
<i>SD</i>	7740	.09	.32	1.01	2.23

Note. The first column presents the average FSB areas, and the following columns depict which percentage of each individual's FSB area has been used in the different balance single-task conditions in each age group.

A percent value was calculated for each participant representing the proportion of the individual's area of Functional Stability Boundary (FSB) that was used in a specific balance task on the ankle-disc board (e.g. a participant who has a FSB area of 20.000 mm² and who produces an average area of 400 mm² when balancing on the stable platform while reading numbers uses 2 % of his personal functional stability area). The percent values refer to the balance single-task performance under different conditions.

Concerning the average FSB areas, independent samples t-tests revealed that children did not differ from the young adults, $t(24) = -.106$, $p = .916$, and that 9-year olds did not differ

from 11-year olds, $t(15) = 1.67$, $p = .114$. However, the values for the proportion of the individual's FSB area used in certain balance conditions differed significantly between children and adults ($t(24) = 4.28$, $p < .001$ on the stable platform while reading numbers; $t(24) = 4.11$, $p < .001$ on the stable platform while listening to animal voices; $t(24) = 3.13$, $p < .01$ on the moving platform while reading numbers; and $t(24) = 3.33$, $p < .01$ on the moving platform while listening to animal voices), with children always using a larger proportion of their FSB area on the ankle-disc board than adults. 9-year olds did not differ from 11-year olds in that respect.

Appendix M

Correlations Among Dual-Task Costs

Are there significant correlations between the dual-task costs of different conditions in the present study? Correlation coefficients across all three age groups are presented in Table M.1. Balance and cognitive DTCs were aggregated over balance difficulty and cognitive task, and four different values were included for the differential-emphasis phase of the study. Correlation coefficients were rather low, with the exception of the correlations between different balance dual-task costs. This indicates that the behavioral tendency to prioritize the balance domain occurred consistently in different dual-task situations.

Table M.1. *Correlations Between Cognitive Dual-Task Costs and Balance Dual-Task Costs (DTCs)*

	Balance DTCs	N-Back DTCs, Focus Cognition	N-Back DTCs, Focus Balance	Balance DTCs, Focus Cognition	Balance DTCs, Focus Balance
Cognitive DTCs	.009	.299	.222	-.077	-.099
Balance DTCs	-	.219	.319	.354	.404*
N-Back DTCs, Focus on Cognition		-	.240	.064	.339
N-Back DTCs, Focus on Balance			-	-.002	.134
Balance DTCs, Focus on Cognition				-	.679**

Note. * $p < .05$, ** $p < .01$.

Appendix N

Overview of Neuroimaging Studies Using the Dual-Task Methodology

Dual-task situations have been used in PET studies to create interference with the task-specific brain areas under investigation (Fletcher, Frith, Grasby, Shallice, Frackowiak, & Dolan, 1995; Fletcher, Shallice, & Dolan, 1998). Dual-task situations have also been used in order to specify certain brain areas that might be responsible for the coordination of two concurrent tasks, underlying theoretical concepts like the central executive system and the supervisory attentional system. A study by D'Esposito, Detre, Alsop, Shin, Atlas, and Grossman (1995) investigated a specific brain region for the central executive system of working memory. The central executive system controls attention and information flow to and from verbal and spatial short-term memory buffers. Using fMRI, the authors could show that the area under investigation in prefrontal cortex could only be activated when a verbal and spatial passive working memory task were performed concurrently, but not when the tasks were performed separately. However, other studies did not find evidence for a specific brain area used in these executive processes. Bunge, Klingberg, Jacobsen, and Gabrieli (2000) measured coordination processes in working memory (wm) by fMRI with tasks that were specifically designed to measure executive working memory. Subjects performed the task of sentence reading or short-term memory for words either separately or concurrently, and dual-task performance activated frontal-lobe areas to a greater extent than performance of either task in isolation. However, no new area was activated beyond those activated by either component task. The authors interpret this data as supporting a resource theory of wm executive processes in the frontal lobes. Similar results were obtained by Adcock, Constable, Gore, and Goldman-Rakic (2000), who used different combinations of two cognitive tasks. Activated areas varied with the component tasks, and all of the areas activated during dual-task performance were also activated during the component tasks. The surplus activation within activated areas during dual-task conditions was parsimoniously accounted for by the addition of the second task. The authors argue that executive processes may be mediated by interactions between anatomically and functionally distinct systems engaged in performance of component tasks, as opposed to an area dedicated to a generic executive system.

Another option would be to use the research on a specific brain region to predict dual-task interference in task combinations in which both tasks need that specific area for their performance (see Barinaga, 1996, for the involvement of the cerebellum in different motor and cognitive tasks). Some imaging studies have investigated the brain regions used for performing the same or similar tasks as the ones used in the present study, like for example

the regions used in standing balance (Ouchi, Okada, Yoshikawa, Nobezawa, & Futatsubashi, 1999), or the regions that are activated when performing the N-back task (Awh, Jonides, Smith, Schumacher, Koeppe, & Katz, 1996; Smith & Jonides, 1999).

In the context of the present study, which compares children to young adults, it is not only important to know which brain areas are used for certain tasks, but also how these areas develop and how these developmental changes influence dual-task performance. Casey, Giedd, and Thomas (2000) summarize MRI studies on structural and functional changes in the developing human brain and their relation to changes in cognitive processes. The studies are largely limited to the domain of prefrontal functioning and its development, and they lend support for a continued development of attention and memory both behaviorally and physiologically throughout childhood and adolescence. Specifically, the magnitude of activity observed in these studies was greater and more diffuse in children relative to adults. According to the authors, these findings are consistent with the view that increasing cognitive capacity during childhood may coincide with a gradual loss rather than formation of new synapses and presumably a strengthening of remaining synaptic connections. However, these findings might also be related to the topic of task difficulty often referred to in resource theories. Children might activate more and more widely diffused brain areas when working on a specific task, simply because it is more difficult for them. However, the question whether additional activation of brain areas really is an efficient way of dealing with difficult tasks (compensation), or whether it rather is a sign of severe performance reductions and therefore maladaptive, is hotly debated in the literature (Cabeza, Grady, Nyberg, McIntosh, 1997; Jonides, Marshuetz, Smith, Reuter-Lorenz, Koeppe, 2000; Klingberg, O'Sullivan, Roland, 1997; Reuter-Lorenz, 2002). From my point of view, many interesting findings will improve the understanding of these mechanisms in the future, and dual-task research using brain imaging data is one promising way to investigate these questions.