8. Appendices

8.1 Appendix A. Levene's Tests of Equality of Error Variance in ANOVA Analyses of Processing Fluctuations in Postural Control

8.1.1 Moment-to-Moment Fluctuations

Levene's tests of the equality of error variances demonstrated significant age differences across all conditions and postural control measures: Simple standing baseline, $F(1,34) = 12.56$, $p < .05$, dual-task standing baseline, $F(1,34) = 36.49$, $p < .05$, simple standing daily average, $F(1,34) = 12.56$, $p < .05$, dual-task standing daily average, $F(1,34) = 10.99$, $p < .05$. This picture did not change when sex was introduced as an additional between-subject factor. Levene's tests revealed variance heterogeneity with respect to baseline single-task standing, $F(3,32) = 3.62$, $p < .05$, and average moment-to-moment fluctuations in simple standing across the 45 days, $F(3,32) = 4.90$, $p < .05$, and also detected inequality of variance with respect to baseline dual-task standing $F(3,32) = 5.35$, $p < .05$, and average moment-to-moment fluctuations in dual-task standing across the 45 days, $F(3,32) = 5.79$, $p < .05$.

8.1.2 Trial-to-Trial Fluctuations

The older age group was more heterogeneous than the younger sample in terms of trial-to-trial fluctuations in single-task standing, $F(1,34) = 14.94$, $p < .05$, and dual-task standing, $F(1,34) = 17.80$, $p < .05$. When sex was included as an additional factor in the ANOVA analyses, Levene's tests of equality-of-error variances found significant cell heterogeneity in single-task standing, $F(3,32) = 5.43$, $p < .05$, and dual-task standing, $F(3,32) = 5.38$, $p < .05$. Sample heterogeneity was not significant in simple standing trial-to-trial fluctuations after controlling for interindividual differences in moment-to-moment sway at baseline, $F(1,34) = .34$, $p >.10$. However, sample heterogeneity remained significant after controlling for interindividual differences in average moment-to-moment sway across the daily assessment period, $F(1,34) = 4.39$, $p < .05$. The older adult sample was more heterogeneous than the young adult sample in dual-task standing trial-to-trial fluctuations after controlling for interindividual differences in baseline sway, $F(1,34) = 4.94$, $p < .05$, and after controlling for interindividual differences in average sway across the daily assessment period, $F(1,34) = 13.61$, $p < .05$. In the analyses of within-individual residual trial-to-trial fluctuations the older adult group was more heterogeneous than the young adult group in single-task standing, $F(1,34) = 11.06$, $p < .05$, and marginally more diverse than the young group in dual-task standing, $F(1,34) = 3.59$, $p = .07$.

8.1.3 Day-to-Day Fluctuations:

Older adults were more heterogeneous than young adults in the amount of day-to-day fluctuations in single-task standing, $F(1,34) = 11.06$, $p < .05$. In terms of between-subject heterogeneity in the level of day-to-day fluctuations the two age groups were only marginally different in the dual-task standing condition, $F(1,34) = 3.59$, $p = .067$. Including sex as an additional factor in the analyses resulted in homogeneity of error variances in dual-task standing, $F(3,32) = 2.11$, $p > .10$ but not in single-task standing, $F(3,32) = 3.62$, $p < .05$. Error variances differed significantly between age groups after controlling for baseline moment-to-moment fluctuations, $F(1,34) = 4.76$, $p < .05$, and after controlling for moment-to-moment fluctuations averaged across days, $F(1,34) = 10.89$, $p < .05$. In contrast, the inclusion of control variables homogenized the age groups in terms of their residual dual-task standing scores. The Levene's tests of equality of error variances was not significant after the inclusion of baseline moment-to-moment fluctuations, $F(1,34) = 2.21$, $p > .10$, and after inclusion of the moment-to-moment fluctuations averaged across days, $F(1,34) = 2.15$, $p > .10$.

8.2 Appendix B. A Detailed Description of the Trend Estimation Procedure in Postural Control Performances

Trends in the postural control data across the 45 days were estimated with separate multi-level models for simple standing and dual-task standing. Time was defined as the order of occasions on which a participant was assessed. The time variable was centered at the individual's means and divided by 45. Parameters were tested for significance by means of χ^2-tests that were based on model comparisons with one degree of freedom. Polynomials of increasing order were fitted to the first level of analysis (i.e., the within-person level) to estimate the within-person trends. Parameters that were not statistically significant were omitted from the analyses in subsequent models. The exact sequence of models used to describe trends in simple standing and dual-task standing postural control is reported in the next two sections.

8.2.1 Trends in Simple Standing Postural Control

In single-task standing, first a fixed effect and than a random effect of a linear trend (Linear) were fitted to the data before the covariance between the random variances of the intercept and the linear trend was estimated. Secondly, a quadratic trend (Quadratic) was introduced in the model and its fixed and random effects were tested for statistical significance. The significances of covariations between the random variance of the quadratic trend with other random parameters were examined next. In a last step, the statistical significance of a cubic trend (Cubic) was examined. A cubic fixed effect and followed by a cubic random effect were inserted into the model.

In the following, results of the single parameter tests are displayed before the equations of the final model are presented and the final results are reported. Table B.1 shows the significance tests of model parameters specifying trends in simple standing postural control performance.

Table B1. *Multi-Level Modeling of Trends in Simple Standing Postural Control: Single Parameter Significance Tests.*

		Parameter	Model Change
Fixed Effects			
Average	Intercept	γ_{00}	
Linear	Intercept	γ_{10}	$\chi^2(1) = 104; p < .05$
Quadratic	Intercept	γ_{20}	$\chi^2(1) = 10.8; p < .05$
Cubic	Intercept	γ_{30}	$\chi^2(1) = 2.4; p >.10$
Random Effects (Variance Components)			
Level 1	Within-Person	σ_ε^2	
	In Average	σ_0^2	
	In Linear	σ_1^2	$\chi^2(1) = 79.6; p < .05$
	In Quadratic Trend	σ_2^2	$\chi^2(1) = 45.6; p < .05$
Level 2	In Cubic	σ_3^2	$\chi^2(1) = 0.6; p >.10$
	In Average by Linear	σ_{10}	$\chi^2(1) = 0; p > .10$
	In Average by Quadratic	σ_{20}	$\chi^2(1) = 3.2; p = .074$
	In Linear by Quadratic	σ_{21}	$\chi^2(1) = 7.7; p < .05$

From Table B.1 shows that the most parsimonious model of trends in simple standing postural control sufficiently described the data with linear and quadratic trends. Cubic trends were omitted from further analyses. The parameter values of the final model can be found in Table B.2.

The final model was arrived at by following equations:

First Level: $Y_{ij} = \pi_{0i} + \pi_{1i}(\text{Linear}) + \pi_{2i}(\text{Quadratic}) + \varepsilon_{ij}$

Second Level: $\pi_{0i} = \gamma_{00} + \zeta_{0i}$

$\pi_{1i} = \gamma_{10} + \zeta_{1i}$

$\pi_{2i} = \gamma_{20} + \zeta_{2i}$

Where $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$ and $\begin{bmatrix} \zeta_{0i} \\ \zeta_{1i} \\ \zeta_{2i} \end{bmatrix} \times \begin{bmatrix} \zeta_{0i} \\ \zeta_{1i} \\ \zeta_{2i} \end{bmatrix}^t \approx N \begin{bmatrix} \sigma_0^2 & 0 & 0 \\ 0 & \sigma_1^2 & \sigma_{12} \\ 0 & \sigma_{21} & \sigma_2^2 \end{bmatrix}$

Table B2. *Multi-Level Modeling of Trends in Simple Standing Postural Control: Final Model Parameter Values.*

		Parameter	Value	Model Change
Fixed Effects				
Average	Intercept	γ_{00}	246.08	
Linear	Intercept	γ_{10}	-54.72	$\chi^2(1) = 104; p < .05$
Quad-ratic	Intercept	γ_{20}	65.40	$\chi^2(1) = 10.8; p < .05$
Random Effects (Variance Components)				
Level 1	Within-Person	σ_ε^2	3016.63	
	In Average	σ_0^2	35230	
	In Linear	σ_1^2	3643.95	$\chi^2(1) = 79.6; p < .05$
Level 2	In Quadratic Trend	σ_2^2	32595	$\chi^2(1) = 45.6; p < .05$
	In Linear by Quadratic	σ_{21}	-6275.19	$\chi^2(1) = 7.7; p < .05$

Table B.2, shows that, on average, moment-to-moment processing fluctuations in simple standing postural control were reduced by 54.72 mm^2 across the 45 days of assessment. The significant quadratic term shows that learning gains were on average more pronounced at the beginning of the assessment and leveled of towards the end. More interestingly, significant interindividual differences were found in the linear slope parameter as well as in the quadratic curvature parameter. The strength of the linear slope and the quadratic trend covaried negatively.

8.2.2 Trends in Dual-Task Standing Postural Control

Multilevel models examining trends in dual-task standing were conducted in the following order. First, a fixed effect and than a random effect of a linear trend (Linear) were fitted to the data before the covariance between the random variances of intercept and linear trend was estimated. Second, a quadratic trend (Quadratic) was introduced in the model and its fixed effect and random effect were tested for statistical significance. The significances of covariations between the random variance of the quadratic trend and other random parameters were examined next. Third, a cubic trend's (Cubic) fixed effect and then a cubic trend's random effect were inserted in the model. The significance of the covariances between the random variance of the cubic term and other random parameters in the model was evaluated in the following. Finally, a polynomial of the fourth order (Fourth Order) was introduced and fixed and random effects were statistically tested one after the other.

The results of the single parameter tests are displayed first before the equations of the final model are presented and the final results are reported. Table B3 shows the significance tests of model parameters specifying trends in dual-task postural control performance.

Table B3. *Multi-Level Modeling of Trends in Dual-Task Standing Postural Control: Single Parameter Significance Tests.*

		Parameter	Model Change
Fixed Effects			
Average	Intercept	γ_{00}	
Linear	Intercept	γ_{10}	$\chi^2(1) = 126.8; p < .05$
Quadratic	Intercept	γ_{20}	$\chi^2(1) = 43.0; p < .05$
Cubic	Intercept	γ_{30}	$\chi^2(1) = 2.4; p >.10$
Fourth Order	Intercept	γ_{40}	$\chi^2(1) = 0.3; p > .10$
Random Effects (Variance Components)			
Level 1	Within-Person	σ_ε^2	
	In Average	σ_0^2	
	In Linear	σ_1^2	$\chi^2(1) = 145.2; p < .05$
	In Quadratic	σ_2^2	$\chi^2(1) = 59.0; p < .05$
	In Cubic	σ_3^2	$\chi^2(1) = 5.6; p < .05$
	In Fourth Order	σ_3^2	$\chi^2(1) = 0.1; p > .10$
Level 2	In Average by Linear	σ_{10}	$\chi^2(1) = 8.5; p < .05$
	In Average by Quadratic	σ_{20}	$\chi^2(1) = 0.6; p > .10$
	In Average by Cubic	σ_{30}	$\chi^2(1) = 1.0; p > .10$
	In Linear by Quadratic	σ_{21}	$\chi^2(1) = 8.6; p < .05$
	In Linear by Cubic	σ_{31}	$\chi^2(1) = 4.8; p < .05$
	In Quadratic by Cubic	σ_{32}	$\chi^2(1) = 0.1; p < .05$

As can be seen in Table B3, trends in dual-tasking postural control were sufficiently described by linear, quadratic, and cubic functions. Polynomials of higher order were omitted from the model. This model is referred to in the following as the trend model of dual-task standing. The parameter values of the final model can be found in Table B4.

The final model was arrived at by following equations:

First Level: $Y_{ij} = \pi_{0i} + \pi_{1i}(\text{Linear}) + \pi_{2i}(\text{Quadratic}) + \pi_{2i}(\text{Cubic}) + \varepsilon_{ij}$

Second Level: $\pi_{0i} = \gamma_{00} + \zeta_{0i}$

$\pi_{1i} = \gamma_{10} + \zeta_{1i}$

$\pi_{2i} = \gamma_{20} + \zeta_{2i}$

$\pi_{3i} = \gamma_{30} + \zeta_{3i}$

Where $\varepsilon_{ij} \sim N(0, \sigma_\varepsilon^2)$ and $\begin{bmatrix} \zeta_{0i} \\ \zeta_{1i} \\ \zeta_{2i} \\ \zeta_{3i} \end{bmatrix} \times \begin{bmatrix} \zeta_{0i} \\ \zeta_{1i} \\ \zeta_{2i} \\ \zeta_{3i} \end{bmatrix}^t \approx N \begin{bmatrix} \sigma_0^2 & \sigma_{01} & 0 & 0 \\ \sigma_{10} & \sigma_1^2 & \sigma_{12} & \sigma_{13} \\ 0 & \sigma_{21} & \sigma_2^2 & 0 \\ 0 & \sigma_{31} & 0 & \sigma_3^2 \end{bmatrix}$

Table B4. *Multi-Level Modeling of Trends in Dual-Task Standing Postural Control: Final Model Parameter Values.*

		Parameter	Value	Model Change
Fixed Effects				
Average	Intercept	$\boldsymbol{\gamma_{00}}$	209.53	
Linear	Intercept	$\boldsymbol{\gamma_{10}}$	-34.33	$\chi^2(1) = 126.8; p < .05$
Quadratic	Intercept	$\boldsymbol{\gamma_{20}}$	95.99	$\chi^2(1) = 43.0; p < .05$
Cubic	Intercept	$\boldsymbol{\gamma_{20}}$	-90.65	$\chi^2(1) = 2.4; p > .10$
Random Effects (Variance Components)				
Level 1	Within-Person	$\boldsymbol{\sigma_\varepsilon^2}$	1618.60	
	In Average	$\boldsymbol{\sigma_0^2}$	17780	
	In Linear	$\boldsymbol{\sigma_1^2}$	4632.23	$\chi^2(1) = 145.2; p < .05$
	In Quadratic	$\boldsymbol{\sigma_2^2}$	21959	$\chi^2(1) = 59.0; p < .05$
Level 2	In Cubic	$\boldsymbol{\sigma_3^2}$	101487	$\chi^2(1) = 5.6; p < .05$
	In Average by Linear	$\boldsymbol{\sigma_{10}}$	-2199.25	$\chi^2(1) = 8.5; p < .05$
	In Linear by Quadratic	$\boldsymbol{\sigma_{21}}$	-4653.37	$\chi^2(1) = 8.6; p < .05$
	In Linear by Cubic	$\boldsymbol{\sigma_{31}}$	-12846	$\chi^2(1) = 4.8; p < .05$

Table B4 shows that moment-to-moment processing fluctuations in dual-task standing postural control were reduced on average by 34.33 mm^2 across the 45-day assessment period. Learning gains were on average more pronounced at the beginning than at the end of that period as indicated by the significant quadratic trend. Significant interindividual differences were found in the linear slope parameter as well as in the curvature parameter. The significant random variance in the cubic trend parameter indicates that some participants showed more than one phase of increase or decrease of performance across the whole assessment period. The significant covariance parameters of the linear slope indicated that participants with better average performance showed less learning and that more learning during the early measurement occasions was associated with lower quadratic and cubic trends.