Wrist Movement during Purposeful Activities: Primary Analysis

Usman Rashid

13/10/2021

Contents

1 Statistical Analysis Plan **2**

2 Results of Primary Analysis **3**
2.1 Total Movement Volume 3

3 Statistical Models **4**
3.1 TMV Estimation and Hypothesis Tests 4
3.1.1 Model with Carry-over Effects 4
3.1.2 Test for Carry-over Effects 4
3.1.3 Model without Carry-over Effects 4
3.1.4 Model Diagnostics 4
3.1.5 Hypothesis Tests 5
3.1.6 Expected TAP with 95% CIs 5
3.1.7 Visualisation of Expected TAP 5
3.1.8 Overall Model Summary 6

References **8**

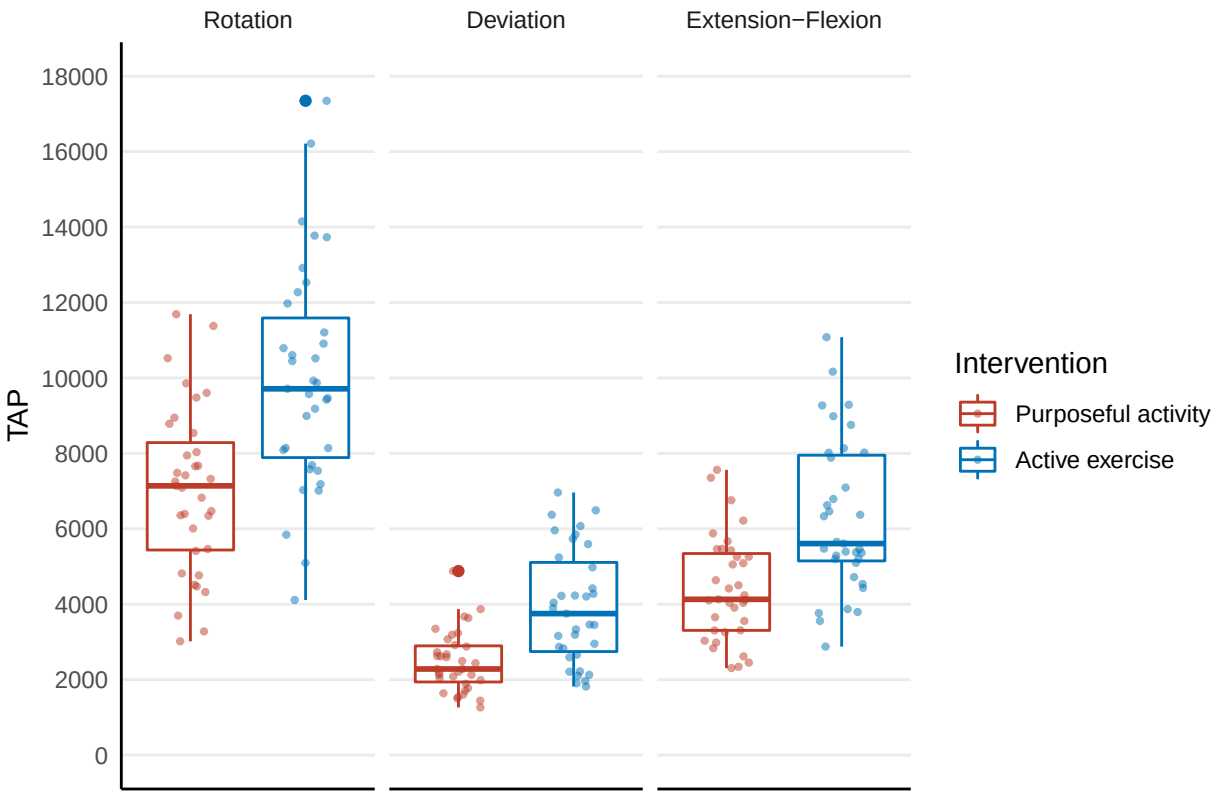
1 Statistical Analysis Plan

A statistical analysis consisting of linear mixed regression is conducted to evaluate the following primary null hypothesis: total movement volume (TMV) is equal across conditions under all movement categories. The linear mixed regression model regresses TMV on movement type, condition, and the interaction of movement type with condition. The model also includes a participant-wise random-intercept for each movement type without any constraints on the correlations across movements (a.k.a "unstructured"). This allows the model to account for the between-participant variance and within-participant correlations amongst the movement types. Moreover, to account for differences in error variance across movement types, the model is structured to estimate a separate error variance for each movement type. The normality and homogeneity of model residuals is evaluated with fitted values versus residuals plot, QQ-plot and histogram. The presence of carry-over effects is tested by including an interaction term between condition and period. This interaction term is dropped if it is not statistically significant. If it is significant, data from period 2 is dropped from analysis as it is considered contaminated with the carry-over effect. The null hypothesis is evaluated with pair-wise comparison of estimated TMV means across conditions. Statistical significance level is set at 0.05. TMV means across conditions under different movement types are reported with their 95% confidence intervals. The analysis is conducted in R using packages: nlme, lme4, r2glmm, emmeans, performance and ggplot2 (Bates, Mächler, Bolker, & Walker, 2015; Jaeger, 2017; Lenth, 2021; Lüdecke, Ben-Shachar, Patil, Waggoner, & Makowski, 2021; Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2021; R Core Team, 2021; Wickham, 2016).

2 Results of Primary Analysis

2.1 Total Movement Volume

The raw data for TMV is illustrated in the below figure in a box and scatter plot. Lower TMV is observed in condition PA compared to condition AE irrespective of the movement type.



No carry-over effect is detected in the data. The general trend observed in the raw TMV is confirmed by the statistical model. Condition PA has lower TMV irrespective of the movement type. The movement-wise difference between condition PA and AE is: ulnar deviation Δ = -1446 95% CI [-1807, -1085], t[170] = -7.914, p = < 0.0001; wrist extension/flexion Δ = -1878 95% CI [-2389, -1367], t[170] = -7.260, p = < 0.0001; forearm rotation Δ = -2943 95% CI [-3821, -2065], t[170] = -6.616, p = < 0.0001.

3 Statistical Models

3.1 TMV Estimation and Hypothesis Tests

3.1.1 Model with Carry-over Effects

```
Model <- lme(TMV ~ Movement*Intervention + Intervention*Period,
             random = ~ Movement|Participant,
             data = Datasource,
             weights = varIdent(form = ~1|Movement))
```

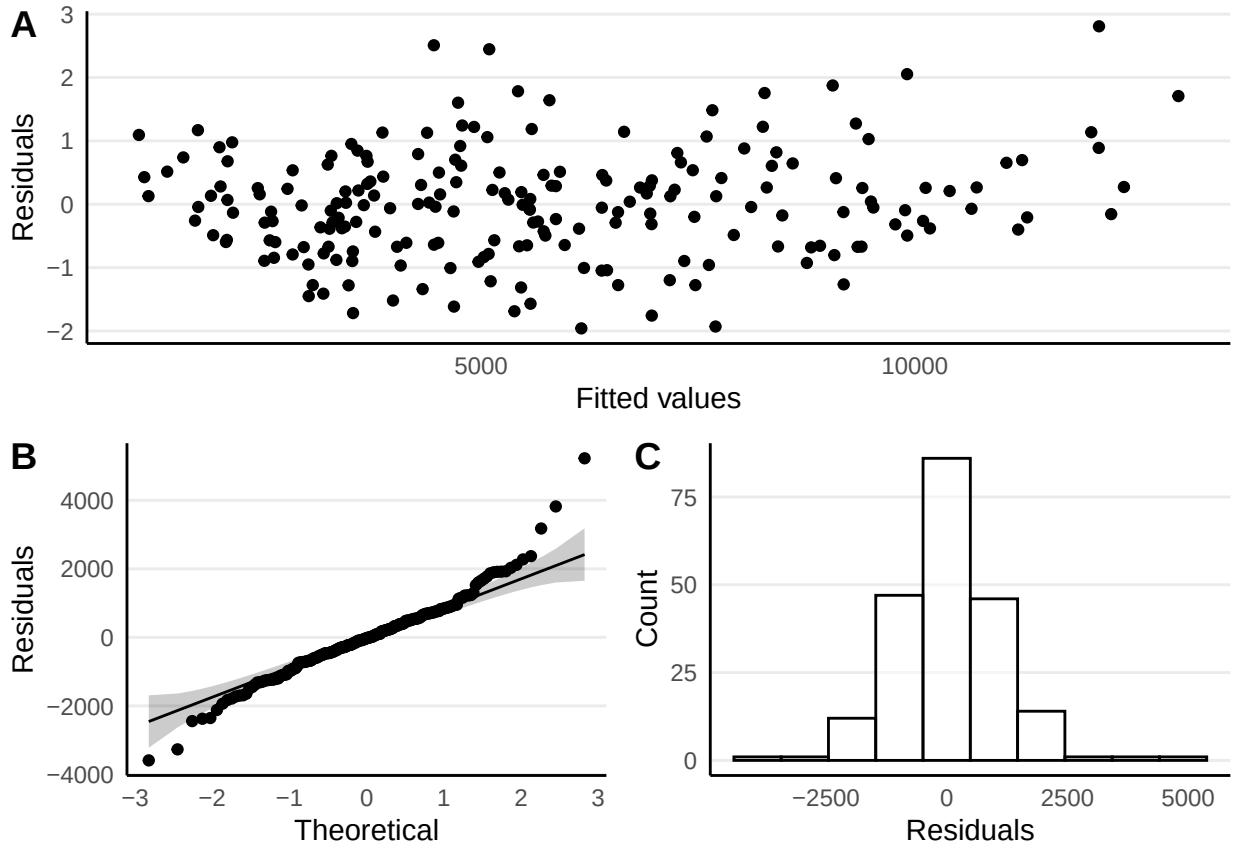
3.1.2 Test for Carry-over Effects

	Num. D.F.	Den. D.F.	F-value	P-value
Intervention:Period	1	168	0.255	0.614

3.1.3 Model without Carry-over Effects

```
Model <- lme(TMV ~ Movement*Intervention,
             random = ~ Movement|Participant,
             data = Datasource,
             weights = varIdent(form = ~1|Movement))
```

3.1.4 Model Diagnostics



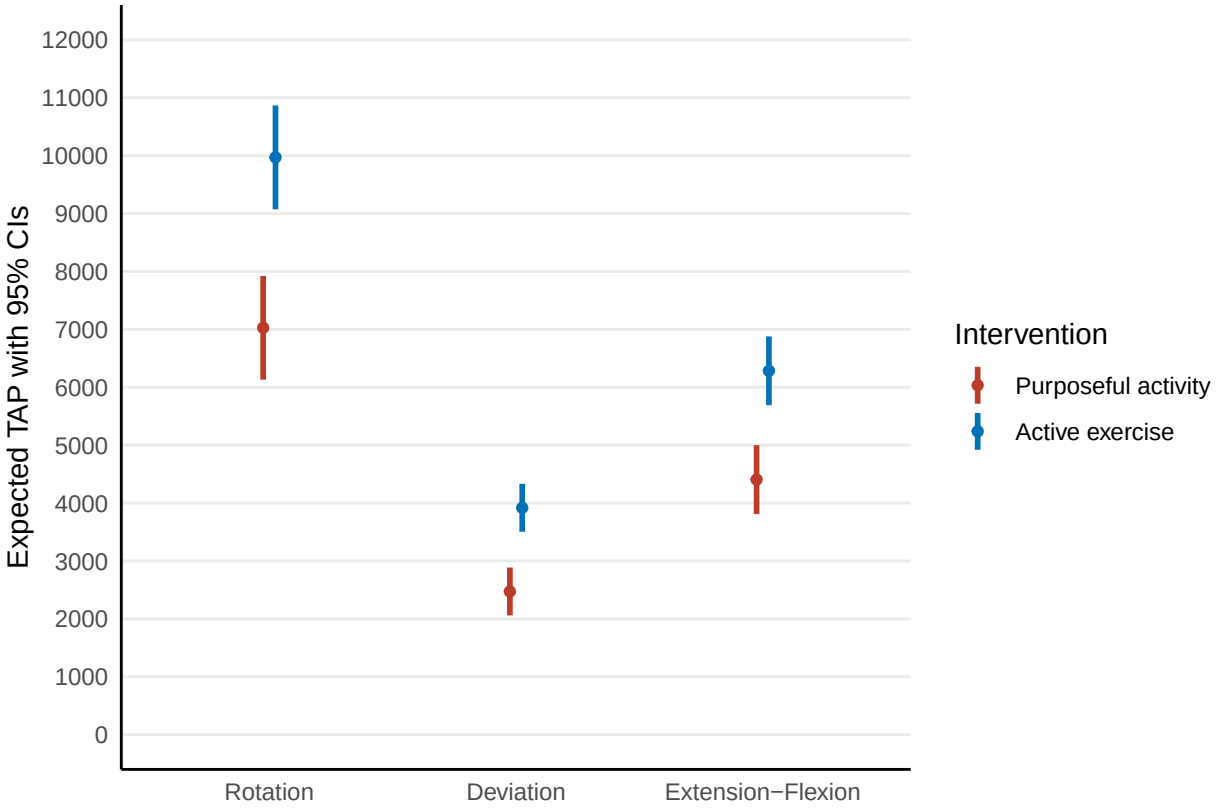
3.1.5 Hypothesis Tests

Contrast	Movement	Difference	SE	D.F.	95% CI Lower	95% CI Upper	T-value	P-value
Purposeful activity - Active exercise	Rotation	-2943	445	170	-3821	-2065	-6.616	<0.001
Purposeful activity - Active exercise	Deviation	-1446	183	170	-1807	-1085	-7.914	<0.001
Purposeful activity - Active exercise	Extension-Flexion	-1878	259	170	-2388	-1367	-7.260	<0.001

3.1.6 Expected TAP with 95% CIs

Intervention	Movement	Expected TMV	95% CI Lower	95% CI Upper
Purposeful activity	Rotation	7027	6131	7923
Active exercise	Rotation	9970	9074	10867
Purposeful activity	Deviation	2472	2059	2886
Active exercise	Deviation	3918	3504	4332
Purposeful activity	Extension-Flexion	4406	3812	5000
Active exercise	Extension-Flexion	6284	5690	6877

3.1.7 Visualisation of Expected TAP



3.1.8 Overall Model Summary

```
Linear mixed-effects model fit by REML
  Data: Datasource
       AIC      BIC    logLik
  3610.146 3659.918 -1790.073

Random effects:
 Formula: ~Movement | Participant
 Structure: General positive-definite, Log-Cholesky parametrization
                         StdDev    Corr
(Intercept)              1827.9470 (Intr) MvmntD
MovementDeviation        1756.8338 -0.866
MovementExtension-Flexion 2012.8400 -0.758  0.978
Residual                  764.3095

Variance function:
 Structure: Different standard deviations per stratum
 Formula: ~1 | Movement
 Parameter estimates:
       Deviation Extension-Flexion          Rotation
        1.000000          1.415756          2.434950
Fixed effects:  TMV ~ Movement * Intervention
                                                        Value Std.Error  DF
(Intercept)                                          7027.343  440.9379 170
MovementDeviation                                   -4555.029  451.4789 170
MovementExtension-Flexion                           -2621.457  498.1664 170
InterventionActive exercise                          2943.114  444.8774 170
MovementDeviation:InterventionActive exercise       -1497.257  480.9335 170
MovementExtension-Flexion:InterventionActive exercise -1065.229  514.6103 170
                                                       t-value p-value
(Intercept)                                          15.937261  0.0000
MovementDeviation                                   -10.089128  0.0000
MovementExtension-Flexion                            -5.262212  0.0000
InterventionActive exercise                           6.615562  0.0000
MovementDeviation:InterventionActive exercise        -3.113231  0.0022
MovementExtension-Flexion:InterventionActive exercise -2.069971  0.0400
 Correlation:
                                                    (Intr) MvmntD MvmE-F
MovementDeviation                                   -0.896
MovementExtension-Flexion                           -0.813  0.879
InterventionActive exercise                         -0.504  0.493  0.447
MovementDeviation:InterventionActive exercise        0.467 -0.533 -0.413
MovementExtension-Flexion:InterventionActive exercise 0.436 -0.426 -0.517
                                                    IntrAe MD:IAe
MovementDeviation
MovementExtension-Flexion
InterventionActive exercise
MovementDeviation:InterventionActive exercise       -0.925
MovementExtension-Flexion:InterventionActive exercise -0.864  0.800

Standardized Within-Group Residuals:
        Min          Q1         Med          Q3         Max
-1.95856578 -0.60535476 -0.02874106  0.50111168  2.80800841
```

```
Number of Observations: 210
Number of Groups: 35
```

References

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 1–48. https://doi.org/10.18637/jss.v067.i01

Jaeger, B. (2017). *r2glmm: Computes r squared for mixed (multilevel) models*. Retrieved from https://CRAN.R-project.org/package=r2glmm

Lenth, R. V. (2021). *Emmeans: Estimated marginal means, aka least-squares means*. Retrieved from https://CRAN.R-project.org/package=emmeans

Lüdecke, D., Ben-Shachar, M. S., Patil, I., Waggoner, P., & Makowski, D. (2021). performance: An R package for assessment, comparison and testing of statistical models. *Journal of Open Source Software*, *6*(60), 3139. https://doi.org/10.21105/joss.03139

Pinheiro, J., Bates, D., DebRoy, S., Sarkar, D., & R Core Team. (2021). *nlme: Linear and nonlinear mixed effects models*. Retrieved from https://CRAN.R-project.org/package=nlme

R Core Team. (2021). *R: A language and environment for statistical computing*. Retrieved from https://www.R-project.org/

Wickham, H. (2016). *ggplot2: Elegant graphics for data analysis*. Retrieved from https://ggplot2.tidyverse.org