Slevc, Davey, & Linck (2016) – Supplemental Materials

This document provides the supporting documentation of the modeling procedure and results (interim and final) for the analyses reported in Slevc, Davey, and Linck (*Journal of Cognitive Psychology*).

"Main Analysis of Language Switching" (Table 2)

We begin with the 2 (block) x 2 (switch condition) x 2 (language) omnibus analysis. The maximal random effects model (i.e., correlated random effects for the full 2 x 2 x 2 factorial combination of effects, varying by both subjects and items) failed to converge. As a next step, we tried fitting a simplified model with correlated random effects for the main effects only (i.e., dropping all random effects for the interactions); this model also failed to converge. Finally, we fit a model with uncorrelated random effects for the main effects, varying by subjects and items. This model successfully converged and was reported in Table 2 (a) of the manuscript.

2x2 subset analyses, separately for Univalent and bivalent blocks

In order to understand the 3-way interaction, we next conducted follow-up 2x2 analyses, fit separately for univalent and bivalent blocks. For both blocks, we began with the random effects structure from the omnibus analysis (i.e., uncorrelated random effects for the main effects only, varying by subjects and items). However, the univalent block model required further simplification, as detailed below.

Univalent blocks -- 2 (switch) x 2 (language) analysis. For the univalent block, a model with uncorrelated random effects for the main effects successfully converged. However, an examination of the random effect estimates suggested overfitting of the data with the switch condition factor, based on the fact that the **switch condition** random effects are estimated to be zero by Subject and very near zero by Item (see Table S1). Therefore we dropped all random slopes involving switch condition and refit the model. This simplified model converged successfully and showed no evidence of overfitting, as indicated by non-zero effects estimated for all random effects (see Table 2(b) in manuscript). Note that the fixed effects estimates in Table 2(b) look nearly identical to the more complex model in Table S1.

Table S1. Precursor to univalent block model reported in Table 2(b) in Slevc et al.

Parameter	Estimate	*SE*	t value		Item *SD*	Subject *SD*
(Intercept)	676.8	12.8	52.9	*	47.6	77.3
Switch condition	8.1	3.1	2.6	*	< 0.01	0.0
Language	107.6	15.6	6.9	*	84.8	74.6
Switch condition x Language	3.7	6.2	0.6			

Note. Model formula in lmer: rt ~ Switch condition * Language + (1 | Subj) + (0 + Switch condition | Subj) + (0 + Language | Subj) + (1 | Item) + (0 + Switch condition | Item) + (0 + Language | Item).

Bivalent blocks -- 2 (switch) x 2 (language) analysis: For the bivalent block, a model with uncorrelated random effects for the main effects successfully converged. This model was reported in Table 2(c).

English-only switch cost analysis (Table 3)

To examine whether block impacted switch costs in English, we analyzed switch and non-switch data from English naming trials within univalent and bivalent blocks. We began by fitting a maximal random effects model, with correlated random effects by subjects and items (see Table S2 below).

Table S2. Precursor to English-only switch cost model reported in Table 3 in Slevc et al. -- maximal random effects.

	Fixed effects				Random effects							
					By items				By subjects			
Parameter	Estimate	*SE*	*t* value		*SD*	Block	Switch	Block x Switch	*SD*	Block	Switch	Block x Switch
(Intercept)	752.7	19.7	38.2	*	89.5	0.942	-0.289	-0.370	110.1	0.512	0.294	0.185
Block	45.1	9.2	4.9	*	6.3		0.050	-0.036	59.9		0.081	0.487
Switch condition	14.9	4.8	3.1	*	15.6			0.996	17.9			0.846
Block x Switch condition	12.4	7.4	1.7		24.2				19.5			

Note. Model formula in lmer: rt ~ Block * Switch condition + (Block * Switch condition | Subj) + (Block * Switch condition | Item).

An examination of the random effects suggests that this model may be overfitting the data – specifically, there are near-perfect correlations between the by-item random effects of switch condition and the 2-way interaction between block and switch condition (*r* = .996), and between the by-item random effects of the intercept and block (*r* = .94). Therefore, we simplified the model by eliminating the by-item random effects of block and its interaction with switch condition. This model produced more stable random effect correlation estimates, with none greater than .84. Moreover, a comparison of the model fit statistics indicates that the more complex model with maximal random effects had larger values on two of the three standard criteria (AIC: max = 145,690, simpler = 145,684; BIC: max = 145,873, simpler = 145,816; but for deviance, max = 145,640, slightly smaller than the simpler model's deviance of 145,648). Because the two models differed only in random effects, a formal chi-square test was not justified (e.g., Gelman & Hill, 2005). However, based on the negligible decrease in deviance value and the *increase* in AIC and BIC values, we concluded that the more complex model did not provide an improved fit to the data (or alternatively, that the simpler model produced a similarly good fit to the data) and therefore we reported the simpler model in Table 3.

As noted in footnote 3, the two-way interaction (block x switching condition) was not significant in the maximal random effects model (*b* = 12.38, *t* = 1.67), whereas the interaction was significant in the model with the simplified random effects (*b* = 13.7, *t* = 2.05). This suggests that the roughly 12 ms difference in switch costs between univalent and bivalent conditions may not be a particularly robust difference. However, this interaction is not critical for our central research questions, and follow-up analyses of switch costs within each block indicated that significant switch costs were experienced by participants in both blocks – a finding that goes against the claims of the response-selection hypothesis of switch costs. Nonetheless, we reported this difference in fixed effect inferences here and in the paper for transparency.

Mixing costs for univalent (Character/English) and bivalent (Pinyin/English) blocks, analyzed separately.

To examine whether significant mixing costs were experienced in univalent and bivalent blocks, we conducted two separate analyses comparing the univalent and bivalent block non-switch trials to performance in the single-language blocks. We began with the maximal random effects structure for subjects and items. For the univalent block, the full random effects model successfully converged. Because one of the random effects correlations was very high (Intercept--Language by items, *r* = .91), we also fit a simplified model with uncorrelated random effects by items, but still maintaining correlated random effects by subjects. A comparison of information criteria for the two models suggests that dropping the random effect correlations significantly hurt the fit of the model to the data, as indicated by larger values for the simpler model on all three criteria (AIC: max = 215,586, simpler = 215,682; BIC: max = 215,779, simpler = 215,829; deviance: max = 215,536, simpler = 215,644). For the bivalent block, a maximal random effects model successfully converged, and all random effects estimates fell within reasonable limits. Therefore, we reported the maximal random effects model for both analyses in Table 5(a) and 5(b).

Script-switching costs for the Character/Pinyin mixed block.

Finally, we examined the effects of switch condition and script within the Chinese-only Character/Pinyin block. The maximal random effects model successfully converged. However, given some random effects correlations at or near 1.0 (Table 6), we also fit a simplified model with uncorrelated random effects. When random effects were forced to be uncorrelated (Table

S3), the interaction between script and switching condition was significantly different from zero (*b* = -16.88, *t* = -2.10). However, the more complex model appeared to be justified, as indicated by the smaller AIC, BIC, and deviance values for the maximal model (AIC: max = 145,858, uncorrelated = 146,023; BIC: max = 146,040, uncorrelated = 146,118; deviance: max = 145,808, uncorrelated = 145,997), therefore we reported the maximal random effects model in Table 6.

Table S3. Script-switching analysis for Character/Pinyin block, with uncorrelated random effects.

Parameter	Estimate	*SE*	t value		Item *SD*	Subject *SD*
(Intercept)	713.9	17.3	41.2	*	45.8	112.0
switch condition	-2.6	6.4	-0.4		36.3	17.2
script	221.1	24.9	8.9	*	96.2	147.8
switch condition x script	-16.8	8.0	-2.1	*	20.3	7.5

Note. Model formula in lmer: rt ~ Switch condition * Script + (1 | Subj) + (0 + Switch condition | Subj) + (0 + Script | Subj) + (0 + Switch condition * Script | Subj)) + ((1 | Item) + (0 + Switch condition | Item) + (0 + Script | Item) + (0 + Switch condition * Script | Item).

It is worth noting that although the *Switch condition x Script* fixed effect estimate was numerically similar in the two models (maximal model *b* = -14.4, uncorrelated model *b* = -16.8), the estimate only differed significantly from zero in the reduced, uncorrelated random effects model (*t* = -2.10). This may help to explain why the model inferences suggest there was no effect of switching, despite the apparent numerical switch *benefit* of 24ms in the Pinyin condition (computed across subjects). When the random effects structure fully models variability in the effects both between subjects and between items, the sample-level inferences indicate that the interaction effect is not stable.