### 1. Background

Language and cognitive control as well as neurocognitive adaptations are assumed to be affected by measures of individual bilingual experience. See, for instance, the UBET Model (DeLuca et al., 2020):

1. Duration of the bilingual experience $\leftrightarrow$ Efficiency
2. Intensity and diversity of language use $\leftrightarrow$ Executive control
3. Relative proficiency $\leftrightarrow$ Efficiency
4. Language switching $\leftrightarrow$ Executive control

Language switching experience requires measurement of many variables:

#### 1) The Language and Social Background Questionnaire (LSBQ; Anderson et al., 2018): excellent measure for language usage and proficiency. **Limitation:** limited capture of language switching.

#### 2) Code-Switching and Interaction Context Questionnaire (CSICQ; Hartanto & Yang, 2016, 2020; Yang et al., 2016;): various types of code-switching (in interaction contexts: Green & Abutaleb, 2013), training cognitive control differently: dual-language context (sentence-switching task) and dense code-switching context (within-sentence switching); **Limitation:** CSICQ does not capture the intentionality (control) of switches or the ACH interactional contexts.

#### 3) Bilingual Switching Questionnaire (Rodriguez-Fornells et al., 2012): captures contextuality and intentionality of the switch, which can indicate inhibitory control or the lack of it. **Limitation:** Does not capture the type of switch (e.g., between-sentence) or ACH interactional environments.

The SEEQ combines the above, measuring ACH contexts, intentionality/control and contextuality of switching and types of code-switching, across different ACH contexts and daily environments (e.g., at home vs. at work). It also includes important language proficiency and usage variables.

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### 2. Aims

**Aim 1:** To test the construct validity of the SEEQ and to test its internal reliability, through exploring its underlying factorial structure.

**Aim 2:** To explore how well the SEEQ factors represent an 8-factor latent variable structure based on the ACH (Green & Abutaleb, 2013), CPM (Green & Wei, 2014) and UBET (DeLuca et al., 2020): single-language, dual-language and dense code-switching environment under intentional switching, contextual switching, duration of the bilingual experience, relative proficiency and intensity/diversity of language use.

### 3. Participants

- 231 young healthy right-handed bilinguals living in the UK (187f, 42m), aged 19-30 (M = 21.2, SD = 3.15).
- Wide range of self-reported language proficiency. L1 = more proficient language (mean 98.0, SD = 4.7), L2 = less proficient language (mean 73.7, SD = 18.4).
- Most common L1: 1) English, 2) Chinese, 3) French and Spanish, 4) Polka, Greek and Cantonese, 5) Turkish, Romanian, Italian, German and Czech.

### 4. Methods and Analysis

- Participants filled in SEEQ questionnaire online on Qualtrics.
- Pearson correlations on variables computed from the questionnaires, to assess compatibility of these factors within latent variables.
- Confirmatory factor analysis (CFA) with 8 factors (see aims).

### 5. Results

**Correlations:** Five variables excluded based on very high correlations (r > .80). Four other included in the covariance terms, due to their importance.

**CFA:** Proposed 8-factor model did not converge, so simplified steppedwise, based on theoretical assumptions and model modification indices. Final standard model estimated using maximum likelihood estimation and robust standard errors and Satorra-Bentler scaled test statistic, for 4 latent variables (see Fig. 1):

1. Dominance/duration of bilingualism,
2. Intensity/diversity of language use,
3. Dense code-switching environment,
4. Dual-language environment.

### 6. Discussion

The four factors and their relevance for cognitive/language control:

1. **Dominance/duration of bilingualism:** Combines duration of being bilingual, relative (visual and auditory) proficiency (i.e., language dominance) and language use in the family.

   **References:**
   - The UBI T model (DeLuca et al., 2020) assumes that the duration of bilingualism affects efficiency.
   - Higher L2 proficiency related to increased top-down control and efficiency, due to the higher monitoring and inhibition requirements.

2. **Intensity/diversity of language use:** Combines measures mainly from the LSBQ (Anderson et al., 2018): language use in different social situations (e.g., with friends), language usage balance (L1/L2 ratio; visual and auditory), language entropy (higher values = balanced use of both languages; Gullifer et al., 2016; Gullifer & Trione, 2019).

   **Reference:** Effect of duration on efficiency is moderated by intensity/diversity of language use. Thus, prolonged use of both languages means higher efficiency but even more so if used more often and in more contexts.

3. **Dual-language environment:** Combines participants’ time spent in a dual-language environment across the four contexts of home, school, work and other.

   **Reference:** Model converged well with dual-language environment and dense code-switching as independent factors, supporting the ACH (Green & Abutaleb, 2013) that they are different contexts with different characteristics.

4. **Dense code-switching environment:** Combines all types of measures of unintended and contextual switching.

   **Reference:**
   - Unintended switching loaded positively: dense code-switching environment is likely related to less inhibition.
   - Model did not distinguish between unintended switching and contextual switching. Thus, switching by mistake happens a lot on contextual cues, which was also important for (positively related to) dense code-switching.

**Notes:** Single-language environment co-occurred (was very highly correlated) with dual-language environment, and was therefore removed from the model.

### 7. Future revisions

- Distinguish different types of code-switching, related to different cognitive control modes more finely, as suggested by Hofheiber et al. (2016) and the Control Process Model (Green & Wei, 2014;)
- Add speaker switching measure, suggested to incur additional cost (Peeters, 2003).
- Add objective proficiency measures (see Macbeth et al., 2022, Tomoshchuk et al., 2019).

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**Fig. 1. The CFA model. Note:** Standardized parameter estimates are displayed for each relationship. Solid single-headed arrows show factor loadings, while dashed lines indicate the covariance terms. The residual variance of each variable is indicated by a black solid double-headed arrow.

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**References**