Cognitive processing in multilinguals explained by individual variability in language switching proficiency: an fMRI study
E. Struys & G. Mohades
Vrije Universiteit Brussel, TALK, CLIN, MuRe

Aim
The aim of this study is to look at the effects of language switching proficiency on cognitive control in the brains of multilinguals.

We have investigated congruency and switching effects in an event-related fMRI Simon task. The population consisted of four groups of balanced and non-balanced bilinguals who were either low or high proficient in language switching.

Argument
Balanced multilinguals have been shown to score better on cognitive control tasks than monolinguals because of their constant need to inhibit the non-target language and to switch between language systems (Bialystok et al., 2004). However, some researchers have not been able to replicate this multilingual cognitive advantage. Such contradictory results have usually been explained by differences in methodology (type of tasks, sample selection) or in the sociolinguistic context (Costa et al., 2009).

Another cause might be that individual differences in language switching proficiency have been overlooked. Prior & Gollan (2011) already found a link between multilinguals’ self-reported frequency of language switching and their performance on a cognitive control task.

If this degree of switching translates into a language switching skill, we hypothesized that individual performance on tests of language switching would explain individual variability on cognitive control tests within a group of multilinguals.

We further hypothesized that language switching proficiency would more significantly correlate with cognitive control performance than the fact of being a balanced bilingual or not.

Method & Results
Participants
24 right-handed, healthy Dutch-French bilinguals (12 balanced bilinguals, mean age: 18.42, SD: 1.9 and 12 non-balanced bilinguals, mean age: 18.33, SD: 2.1).

Procedure
Behavioural data were gathered in a bilingual verbal fluency task: In 1 min. the participants had to say as many words as possible constantly switching between Dutch and French. Neuroimaging data were acquired in an fMRI scanner during an experiment with an event-related design. A Simon task was employed as a measurement of cognitive control and the task’s trials (congruent and incongruent, see Fig. 1) were synchronized with the scanning trials.

Results
On the basis of the language switching scores, the participants were divided into two groups: above and below average switchers (see Table 1). RTs were analysed using a mixed-model ANOVA including Switch (Switch vs Non-switch) and Congruency (Congruent vs Non-congruent) as Within-Subjects factors in 2 separate analyses and Balancedness (Balanced vs Non-balanced bilinguals) and Switching Proficiency (Above-average vs Below-average switchers) as Between-Subjects factors. A Main Effect for Switching Proficiency was highly significant for Switch (F(1,23)=7.82, p<0.01) and significant for Congruency (F(1,23)=6.62, p<0.05). No Main Effect for Balancedness or Interaction Effects were found.

Full factorial design analysis of neural activation in SPM showed significant additional activity in the Right Anterior Cingulate Gyrus for high proficient language switchers during the Switch trials vs Non-switch trials (see Figure 2; MNI coordinates 16, 4, 38; T=4.51, k>33, p<0.001 uncorrected).

Table 1. Distribution of the balanced and non-balanced bilinguals according to their switching scores.

<table>
<thead>
<tr>
<th></th>
<th>below av</th>
<th>above av</th>
<th>total</th>
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<tbody>
<tr>
<td>balanced</td>
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<td>8</td>
<td>12</td>
</tr>
<tr>
<td>non-balanced</td>
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<td>4</td>
<td>6</td>
</tr>
<tr>
<td>total</td>
<td>12</td>
<td>12</td>
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Figure 1. Congruent (left) and incongruent (right) trials of the Simon task.

Figure 2. Positive Effect of Switching Proficiency in Right Anterior Cingulate Gyrus

Conclusion & Discussion
1. There is a relationship between language switching and cognitive control.
   This experiment has shown that it is possible to explain variability in a non-verbal cognitive control task (Simon task) by scores on a language task (verbal switching fluency).

2. Dividing groups based on self-reported language switching experience is insufficient to discover the advantages of bilingualism.
   Balanced bilinguals reported extensive language switching in early childhood, while non-balanced bilinguals had only used their second language in a class context. This factor, however, could not explain the cognitive control scores.

3. Individual variability in language switching proficiency has both behavioural and neural effects.
   Significant differences were found between the above and below average language switchers both for switch trials and incongruent trials in the Simon task. Analysis of neural activity revealed additional activity in the right anterior cingulate gyrus for proficient switchers. This region is part of a network involved in language control tasks (Price et al., 1999).

4. Further studies should try to elucidate the origins of these individual differences.
   Language switching skills may be partly caused by experiential factors like balanced bilingualism, but also individual factors play a role. Further studies should find out what these factors are and if they correlate with other linguistic or executive functioning skills.

References

