Report for the dissertation of PhD candidate Agata Volna

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This thesis represents a coherent research programme about factors that affected speech production in bilinguals. Four empirical studies are included in this dissertation. The first study described the norming of a large picture dataset in Polish; although this is not a study on bilingual production, this comprehensive dataset was missing from the literature, but it is also itself used in subsequent research included in this thesis. The second study represents an empirical investigation on the brain processes that underlie bilingual speech production in single language contexts, and provides fresh perspectives on the topic. The third study focuses on a well-known if understudied phenomenon which is key to our understanding of bilingual speech processing, the L2 after-effect, namely the increased difficulty in L1 production right after L2 production. This is studied in two experiments with behavioural methods. Finally, the fourth study focuses on the same effect by using functional MRI, to study the brain networks engaged in bilingual production and therefore affected by the L2 after-effect. Overall, the thesis aims to provide more evidence to further our understanding of bilingual production and address theoretical proposals and controversies. The inclusion of these four studies, two of which had already been published in respectable and impactful journals at the time of the submission of this work, is appropriate and meaningful for the purposes of this thesis, and the studies flow nicely from each other. In the next paragraphs I will provide an overview of the four studies, including topics for subsequent discussion, followed by an overall evaluation of the thesis and the candidate.

Study 1

This is a norming study. A large number of pictures of objects and actions were used in order to obtain naming norms in Polish, as well as a wealth of norms of other psycholinguistic parameters that are typically used in the field, including parameters pertaining to the images themselves and also those pertaining to the concepts that the images represent. As such, the end product is probably the most comprehensive normed picture set for Polish. The work presented in this paper is thorough, taking into account all relevant variables, and the resulting data will undoubtedly be extremely useful to psycholinguists, therapists etc. The norming for all these parameters, and the reporting of the particular relationships between them also make this study an important theoretical contribution to the field, and it will probably encourage similar work to be done to other languages, majority or minority ones, who may not have such an elaborate set of norms yet (if they have norms at all).

Study 2

This is an fMRI study focusing on the well-known effect of increased difficulty for speech production in a second language, compared to a first language, and it investigates how this phenomenon can be explained in terms of the recruited brain areas for L1 vs. L2 production. This is an important question, as current theories have attributed this difficulty either to linguistic processes or to mechanisms related to cognitive control. Using the pictures that were normed in Study 1, the authors devised a naming fMRI experiment that was done both in L1 and L2 by the participants, but in separate sessions, i.e. by removing the need to switch between languages and therefore enforcing a single language context. The separate sessions allowed the researches to isolate the brain networks involved in production in each language and compare them. Crucially, their comparisons were restricted to three predetermined networks, tested in separate analyses: a) The Language network, defined via a functional localiser on the same participants by subtracting brain activity for distorted speech processing from activity for speech processing; b) the Multiple Demand network, similarly defined via a functional localiser subtracting activity for an easy vs. a difficult version of a spatial working memory task, tapping regions involved in cognitive control; and c) the bilingual language network, as it was anatomically defined by Abutalebi and Green (2017). In the Language network, the authors reported more recruitment of the right hemisphere for naming in L1 than L2, but no other significant effects. This was interpreted as evidence for higher automatization of L1. In the MD network, they reported more recruitment for L2 vs. L1 naming of the left hemisphere, but not the right one, an effect that was interpreted as evidence for lateralisation of control mechanisms for L2 naming. Subsequently, regions of interest from both the Language and the MD network which also featured in the anatomically-defined bilingual language control network were specifically examined. Multiple ROIs derived from both localisers showed increased activity for the more challenging localiser conditions, but the overlap between them was minimal. These ROIs were then examined with respect to their activation for L2 vs. L1 naming, and L2 naming was shown to cause higher activation of multiple of these ROIs. Taking these results together, the authors suggested that L2 naming primarily engages domain-general cognitive control mechanisms, rather than linguistic ones; on the flip side, the finding that the Language network did not activate differently for L1 vs. L2 processing suggests that naming in L1 and L2 engages the same regions/mechanisms in a similar way. A notable exception to the latter was greater activation of the LIFG for L2 vs. L1 processing, an effect that the authors attributed to the activation of language-specific subregions of the otherwise multifaceted structure. Overall, this is an interesting study with an elegant and sophisticated design that has not been used in the field of bilingualism; as a result, it provides interesting and useful insights on L2 processing. Specific points for discussion are the following:

Discuss how this pattern speaks to the predictions of the ACH for different control processes in different contexts. This paradigm seems to introduce an SLC, whereas language-switching paradigms introduce a DLC. It is largely true that the predictions by the ACH, including those re the involved brain areas, are mainly drawn from tasks devising DLCs. What are the theoretical implications of the current findings, in that respect?

Why the MD functional localiser? This was derived based on a spatial WM task. Fedorenko et al. (2011) reported localisers based on other tasks (MSIT, Stroop, vMSIT) that appear more appropriate for the identification of regions involved in cognitive control- why was this one chosen?

Study 3:

This study focuses on another well-known, yet not well-researched, effect of L2 processing, namely the "L2 after-affect", i.e. the reported difficulty to produce speech in L1 after having done so in L2. This is a behavioural study, followed up by an fMRI study (Study 4), and seeks to add evidence and inform current theoretical models attempting to explain this effect. In two experiments, where Experiment 2 constitutes a better controlled version of Experiment 1, the authors required their participants to name pictures in their L1 (Block B) in two conditions- after they had done in in L1 again, and after they had done it in L2 (Block A) (Block numbering is changed to letters to refer to the equivalent blocks in both experiments, which are otherwise numbered differently between Exp 1 and 2). The authors measured naming latencies in L1 or L2 in Block A, which they used as a baseline measure of activation of each language, and also naming latencies in L1 in Block B, which they used as an indication of a lingering effect of the language used in Block A. As predicted, participants were slower to name pictures in their L1 in Block B when this was preceded by naming in L2 vs. L1 in Block A. In other words, the expected L2 after-effect was observed. Critically, the naming latencies in Block A were correlated significantly to latencies in Block B, either positively (in the L1-L1 condition) or negatively (in the L2-L1 condition). Thus, the L2 after-effect was larger for those participants with the greatest imbalance in naming latencies between L1 and L2 (i.e. those faster in L1), and it became smaller the more balanced the participants became. It was also found that the L2 after effect diminishes over time. There also some interesting points to be discussed here:

-Walk us through the theoretical implications of these findings. It is clear that they extend the IC model by suggesting that how reactive L1 is also depends on the level of activation of the L2. The authors themselves admit that the underlying control mechanism (increased L1 inhibition? Increased and persisting L2 activation) cannot be adjudicated with the current set of findings, so the question is how? What could be the next step?

-Walk us through the inclusion of the very first Block in Experiment 2. This potentially introduces another layer of L1 inhibition in the L1-L2-L1 condition, whereby participants would have to inhibit L1 in order to name pictures in L2 in the second block. Could this have introduced a confound to the design? Can naming latencies in L2 be trusted as baseline measurements?

Study 4:

This paper explores further the L2 after-effect phenomenon, by devising an fMRI protocol to investigate the brain regions and networks that it involves, taking an approach similar to the one used in Study 2. Again, the L2 after-effect is used here as a index of how language production is organised in the bilingual brain. The same main functional localisers as those used in Study 2 were used (language network, Multiple Demand network), with some additional ones added in, indexing networks involved in articulation, lexical access (using a verbal fluency task) and lexical interference (via the use of a Stroop task). Analyses were restricted within these five networks in order to identify whether they are engaged differently in two conditions: (a) naming pictures in L1 after having named in L2 (i.e. the L2 after-effect) and naming pictures in L1 after having named in L1 as well (the control condition). Therefore, the design of the study was similar to that of Study 3- and indeed, this study replicated Study 3 behaviourally, and it was restricted in brain regions similar to those used in Study 2. Importantly, in functional terms, this study showed that the L2-after effect engages the MD network but not the language network, suggesting that bilingual language control is domain-general. Crucially, the L2-after effect did not appear to engage any of the other networks (articulation, lexical access and

interference), suggesting that it cannot be attributed to increased interference at any of these levels of processing, i.e. it is not rooted in language processing. The authors suggest that the L2 after effect indices processing of proactive control which targets not linguistic representations, but more abstract ones. These can be control representations which direct access to linguistic representations, i.e. task rules for speaking in L1 versus speaking in L2, in a multi-layers control system. Some points for further discussion include:

- Why was not a bilingualism control network included in this study? It logically follows that, since the L2 after-effect taxes domain-general networks and processes, several regions included in the anatomically-defined bilingual control network would be involved. Was that not of theoretical interest in this study (in contrast to Study 2)? I note that only the ACC was analysed in that respect, and this analysis appears in the Supplementary materials.

- What about the bilingual experience of these participants, which was measured in the present studies as balance in language use? Has this been attempted to be used as a measure predicting brain activity? Should we expect significant effects as in Study 3, or indeed the behavioural results of Study 4, and if so, in what direction?

Overall evaluation:

This thesis is of high scientific quality, and it meets the established criteria of such work. The discussed topics, and the experiments that were ran, touch upon some crucial concepts, including but not limited to factors that underlying bilingual speech processing. As such, they are important, contemporary, and of great interest to experts in the fields of bilingualism and cognitive neuroscience more generally. Study 1 presents a new valuable resource for psycholinguist, while the other three papers present well-reasoned arguments that address research questions emerging from recent literature, and they offer novel results, conclusions and recommendations for future research. In all, I have a positive opinion of this dissertation, which I consider to present an original solution to a scientific problem, namely understanding the nature of bilingual language production, which will have theoretical an practical implications, the latter pertaining to the diagnosis and treatment of bilinguals with speech impairment. The candidate clearly demonstrates general theoretical and methodological (statistics, behavioural and functional neuroimaging methods) knowledge for the doctorate degree in psychology, especially cognitive psychology and neuroscience, and she has the profile of an emerging expert in the field of the cognitive neuroscience of bilingualism, and proven abilities that she can conduct independent research. As such, and on the basis of this work, she fulfils the requirements of Act of 20 July 2018, Article 187 points 1 and 2 he candidate is definitely eligible to be awarded a PhD.

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