Chapter 8: Summary and conclusion

Bilingualism and cognitive control are two multidimensional constructs. The interaction between bilingualism and cognitive control is modulated by the degree of bilingualism defined by factors such as varied patterns of use, proficiency, and age of acquisition for the languages known to a bilingual. The current study aimed to investigate the interaction between bilingualism and selection and inhibition components of control. Language proficiency was considered as an important predictor of this interaction casting an influence on bilingual language control (bLC) as well as general purpose cognitive control (GPCC). Four studies were conducted with the first one on characterizing language proficiency in Hindi and English language followed by the second study on selection and third study on the inhibition component of cognitive control. Lastly, we also examined the performance of individuals with bilingual aphasia on linguistic and nonlinguistic control tasks by using the case study method.

By using different methodologies (i.e. behavioural: reaction time and accuracy, electrophysiological: ERP and case study method) we discerned the cognitive control mechanisms as a function of language proficiency among Hindi-English bilingual adults. Results of the present study support our idea of language proficiency as a continuous variable for both the languages across speaking/understanding and reading/writing domains. Language proficiency as a continuous variable provided us with the flexibility to understand the variations in performance on selection and inhibitory control tasks in L1, L2, and for nonlinguistic stimuli. In addition to the overall scores, task specific relationship between language proficiency tasks and performance on control tasks was worth noting.
Findings of the first study with respect to proficiency and organization of language skills in L1 and L2 have implications for participant selection procedures and interpretation of experimental data in bilingual research particularly for language combinations where L1 is acquired informally and L2 is learnt through formal instruction. Further, results from experimental data demonstrate an interesting influence of language proficiency on the control processes i.e., selection and inhibition. With the use of traditional paradigms (Posner's cueing paradigm and negative priming paradigm) with linguistic as well as nonlinguistic stimuli, we were able to distinguish between domain general and domain specific control mechanisms, which can also be referred to as GPCC and bLC. The study on voluntary orienting was designed to study data driven covert orienting in L1, L2 and for nonlinguistic stimuli. It was evident in this study that voluntary orienting of attention depends on the familiarity of the stimuli. Although, linguistic stimuli demonstrated significant orienting effects, yet on closer analysis of slow and fast trials, orienting effects were not found to be significant for L1 on fast trials. Cue effects were found to be significant for L2 on both slow and fast trials. On the contrary, non-linguistic picture stimuli did not show significant orienting effects. Negative priming experiments were designed to investigate the neuro-cognitive correlates of inhibitory control with linguistic and non linguistic stimuli by using the identity negative priming paradigm. The relationship between language proficiency in L1 and L2 and task performance was also examined. Mean reaction times as well as ERP data showed a significant difference between control and ignored repetition trials. Inhibition effect was found to be greater for L1 as compared to L2 due to the stronger representation of L1 being the
dominant language. Inhibition effects for L2 were found to be greater than that of nonlinguistic stimuli. Inhibition effects were also depicted through modulations in the amplitudes of the N200 component. Proficiency in L1 and L2 showed a significant relationship with negative priming effects.

Lastly, study on individuals with bilingual aphasia examined the sub-components of cognitive control in order to investigate whether cognitive control and language control are two separate systems and how would the factors related to bilingualism interact with control processes. Flanker task and negative priming task with linguistic and nonlinguistic stimuli were administered. Differences in performance on linguistic vs nonlinguistic task highlight the distinction between general purpose cognitive control and bilingual language control mechanisms. A descriptive approach was used towards analyzing the data. Reaction times across conditions and accuracy were compared for each individual. Cumulative distribution function plots explained the variations in performance across conditions. All the participants showed predominant use of reactive control mechanism for compensating for the limited resources system. Independent yet interactive systems for bilingual language control and general purpose cognitive control was postulated based on the experimental data derived from individuals with bilingual aphasia.

First and foremost, the study shows that L1 and L2 do not follow a strict sequential and simultaneous pattern of acquisition which results in differences in language organization particularly in Indian context. Such differences in language organization were also reflected in the predictive nature of L1 and L2 in experimental tasks. Variations in proficiency were found to mediate systematic changes in the effects
of bilingualism on control processes. Further, subjective measures of bilingualism i.e. age of acquisition, language use as well as self-rated language proficiency did not show strong correlation with the objective measures of language proficiency. Most of the previous work on language proficiency has focused on L2 proficiency alone, whereas the current study highlights the predictive nature of L1 proficiency for performance on control tasks in addition to L2 proficiency. Overall L1 proficiency was found to predict performance on tasks involving general purpose cognitive control whereas, overall L2 proficiency was found to predict performance on tasks involving bilingual language control.

Our study on voluntary orienting as well as negative priming suggests differential effect of performance as a function of stimulus type (i.e. L1, L2 and Picture) as well as L1 and L2 proficiency. It was interesting to see a differential involvement of the proactive and reactive modes of control based on the stimulus type. In the cueing paradigm, attention benefits were larger in case of L1 (Hindi) as compared to L2 (English) and absent for non-linguistic stimuli. Apart from the global effect of stimuli (i.e. linguistic vs. non-linguistic), there was also a local effect of semantic category (i.e. animate vs. inanimate). The ERP data from negative priming study, suggested that inhibition effects were significant for both linguistic and non-linguistic stimuli. Although, the local effect of animacy (which was previously present for orienting) was not significant with respect to inhibition. ERP findings showed differences and similarities as a function of amplitude differences, latency differences and morphology of the waveform, while comparing linguistic and non-linguistic stimuli.
Secondly, the current study addressed the nature of cognitive control by looking at Braver’s notion of the dual mechanism of control. Proactive control is developed according to the goals of the subject, rather than being simply triggered reactively by an external signal. The performance of an individual will depend on whether the governing mechanism is reactive i.e. depending on environmental changes or proactive, in terms of level of anticipation. According to the dual mechanisms of control (DMC) framework (Braver, Gray, & Burgess, 2007), this so-called proactive control mechanism results in faster reaction time and high accuracy. It has to sustain for several trials as it requires anticipation and higher level of control. Experimental data in the current study indicate language specific influence on the dual mechanism of control, i.e. we find the involvement of proactive control for L1 (Hindi) that of reactively control for L2. Both, cueing paradigm for selection and negative priming paradigm for inhibition were found to replicate findings with respect to proactive-reactive control as well as the predictive relationship between proficiency and performance on control tasks in L1 and L2.

Third and final dichotomy discussed in the current study is with respect to domain general and domain specific processes of cognitive control. These findings contribute to the growing evidence that bilingualism is influenced by cognitive control and both languages may result in differences in the domain general processes which further influence the domain-specific processes i.e. bLC. Our results suggest that even if there is exchange of information between bLC and GPCC, there are some aspects of bLC that are specific to the domain of language and not necessarily related to GPCC. Our study is unique in attempting to study both in same group of individuals. Objective measures of
language proficiency across domains help in showing this distinction more clearly with distinct predictive patterns for both the languages.

Longitudinal investigation addressing the natural course of L1 and L2 processing based on structured exposure of both languages could be taken up in order to investigate the evolution of the interaction between bilingualism and cognitive control. Degree of bilingualism can be measured by using many variables such as age of acquisition, frequency of use, proficiency, frequency of switching and code mixing. Systematic investigation by manipulating each of these variables would provide a comprehensive account of the factors associated with bilingualism and their individual as well as interactive influence on control processes. On the other hand, studies also need to look at how the development of cognitive control interacts with bilingual language processing. Proactive and reactive modes of control could be explored further by means of specific manipulations looking at anticipation and recruitment of top down control among bilinguals. In Indian multilingual context, such studies need to be extended to different combinations of languages among bilinguals as well as to multilinguals to find out if the cognitive advantage reported in bilinguals would be further enhanced among multilingual individuals.