Linguistic and Cognitive Processing in Bilinguals: Study in Kinematic Action Control

A thesis submitted during the year 2022 to the University of Hyderabad in partial fulfilment of the award of a PhD Degree in Cognitive Science

By

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This is to certify that the thesis entitled **Linguistic and Cognitive Processing in Bilinguals: Study in Kinematic Control** submitted by **Lekhnath Sharma Pathak** bearing **Registration No. 13CCPC04** in partial fulfilment of the requirements for the award of Doctor of Philosophy in Cognitive Science is a bonafide work carried out by him under my supervision and guidance.

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1. Pathak, L. S. & Pathak, P. (2022). Bilingual Stroop effect in high and low proficient Nepali – English bilinguals. *Nepalese Linguistics*. Vol. 35, pp 128 – 136 DOI: https://doi.org/10.3126/nl.v35i01.46570
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No.	Course Code	Course Name	Credits	Pass/Fail
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6.	CO 806	Methods in Cognitive Psychology	4	Pass
7.	CO 813	Eye Tracking Methodology	4	Pass
8.	CO 821	Sentence Processing Studies using ERP	4	Pass
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Declaration

I, **Lekhnath Sharma Pathak**, hereby declare that this thesis entitled **"Linguistic and Cognitive Processing in Bilinguals: Study in Kinematic Action Control"** submitted by me under the supervision and guidance of **Prof. Ramesh Kumar Mishra** is a bonafide research work. I also declare that it has not been submitted previously in part or in full to this University or any other University or Institution for the award of any degree or diploma.

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Sincerely,

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Dedication

I dedicate this thesis

To

My biological parents: My late father, Purna Chandra Pathak and my late mother, Bhuma Kumari Pathak – for giving me birth

My foster parents: My late Ammi, Shobhagya Chhetri BP Gohain and my late Baba, Debendra BP Gohain – for giving me life

My sons: Poshak Pathak and Aarya Pathak – for being my extended self, the hopes and lights of my future

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My late father Purna Chandra Pathak was my first teacher who familiarized me with the letters. My late mother Bhuma Kumari Pathak sang me the first verses. But they didn't live long enough even to see me going to school. My late Ammi Shobha Borpatra Gohain and my late Baba Debendra Borpatra Gohain ensured that I complete my education. I am all gratitude and reverence to both set of my parents without whom I wouldn't be what I am and where I am today. I am also thankful to my sister Alpana, niece Ektara, brother Nikku and sister-in-law Aruna for being constantly there for me in the ups and downs of life. Of course, my late younger brother Balkrishna remains as a deep seated pain of loss deep inside me.

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I am especially thankful to the collaboration between my supervisor Prof. Ramesh Kumar Mishra and Prof. Mila Vulchanova, Norwegian University of Science and Technology (NTNU) that gave me an opportunity to visit NTNU under the Erasmus Global Mobility scholarship to do part of my PhD work there. I am grateful to Prof. Vulchanova and her colleagues for all the support and encouragement during my visit and stay. I am thankful to Pritam Pandey and the Nepalese Society in Trondheim (NEST) Pariwar for all the support in recruiting participants for my research work there and all the great company of Nepali community I enjoyed in Trondheim. I am also thankful to Prof. Krishna Panthi at Geoscience Department in NTNU for his warm hospitality and support there. I would also like to thank Dr. Nabin Kumar Thakur for providing me accommodation in Trondheim.

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List of Abbreviations

ACH	Adaptive Control Hypothesis
ANOVA	Analysis of Variance
AUC	Area Under the Curve
BIA	Bilingual Interactive Activation
BLINCS	Bilingual Language Interaction Network for Comprehension of Speech
IT	Initiation Time
L1	First Language
L2	Second Language
L3	Third Language
M	Mean
MD	Maximum Deviation
N	Number
RHM	Revised Hierarchical Model
RT	Response Time
SD	Standard Deviation
SE	Standard Error
VFT	Verbal Fluency Task

Abstract

There was a time when bilingualism or multilingualism was considered an aberration. But in the modern world it has become a norm rather than exception. Psycholinguists and cognitive scientists all over the world in various labs are investigating the language and cognition from monolingualism, bilingualism and multilingualism perspectives. How does language experience shape our neural and cognitive mechanism and what are its implications in the real world is an actively researched issue in bilingual cognition. Several new discoveries like parallel language activation, bilingualism mediated reconfiguration of the brain, health and academic benefits of bilingualism have been established in the 21st century. However, the debate has become even stronger on the real benefits of bilingualism and many assumptions are being questioned. So we are in an interesting era where more evidences in different contexts than the most researched western contexts is drawing attention of the researchers.

In this thesis, I explore how different language contexts in bilingualism shape language processing and cognition and also test the previous findings using a novel paradigm of mouse tracking that allows for fine grained temporal measurement of linguistic and cognitive processing. Mainly language comprehension and production in bilinguals have been investigated in this thesis.

There are altogether five chapters in this thesis. First chapter gives a historical, theoretical, methodological background to this study. Second chapter is an investigation into the offline and online measure of language dominance and selectivity in bilinguals. This chapter shows efficiency of online measure in investigating language attenuation and attrition with the shift in

language dominance and the need to a careful balance of offline and online measures in the study of language dominance in bilinguals. The third chapter investigates the factor modulating language attenuation, namely, immigration and immersion. Previous studies have shown that a short immersion of six months in a second language attenuates first language. Our study provides counter evidence to previous such finding and adds to the new evidence in the existing literature on bilingual cognition. The fourth chapter extends the bilingual cognition and language processing to trilingualism and seeks evidence for the similarity or differences in the bilingual and trilingual processing mechanism. The results shows that in the presence of a non-dominant language, the two dominant languages behave in a similar manner and benefit the language processing mechanism by more efficiently resolving the language conflict presented by interference for selection. The fifth chapter summarizes the findings from the three studies presented and the answer obtained to the research questions that guided this thesis and looks at the limitations in this this study and paves way for further research directions in this field.

Chapter 1: Introduction

> "Investigation of the design of language gives good reason to take seriously a traditional conception of language as essentially an instrument of thought. Externalization then would be an ancillary process, its properties a reflex of the largely or completely independent sensorimotor system. Further investigation supports this conclusion. It follows that processing is a peripheral aspect of language, and that particular uses of language that depend on externalization, among them communication, are even more peripheral, contrary to virtual dogma that has no serious support. It would also follow that the extensive speculation about language evolution in recent years is on the wrong track, with its focus on communication." – Noam Chomsky, 2016, What Kind of Creatures are We? (p. 14 – 15)

Noam Chomsky has been an influential figure in language and cognition and has dominated the scene since the second half of twentieth century till now. Besides being an unparalleled linguist of our time, he is also one of the founders of the field of cognitive science. Unlike popular belief that language is a tool for communication, Chomsky has consistently held the "conception of language as essentially an instrument of thought". He considers "externalization" (comprehension and production) as "completely independent sensorimotor system" and considers processing as "a peripheral aspect of language". Whether one agrees or disagrees with this view is one thing, but herein are some seeds of empirical enquiry worth of pursuing in order to understand the core of human system: language and cognition.

Most of the people worldwide learn, acquire and speak not just one language, but two or more depending on their life experience. In the region like South Asia which is a multilingual belt with languages belonging to at least one of the four families: Indo-Aryan, Tibeto-Burman, Dravidian and Austroasiatic. Many people speak varieties of all these language, sometimes speaking languages belonging to 2 or three families. For example, a Kannada or Telugu native speaker of Dravidian family might be speaking Hindi, belonging to Indo-Aryan family and English of Germanic family. Similar situation exist for the people of Nepal who might be speaking Nepali (Indo-Aryan), English (Germanic), Gurung (Tibeto-Burman). Therefore, South Asia is regarded as linguists' paradise when it comes to the languages available for study.

1.1 A brief history of bilingualism and cognition

The history of bilingualism and cognition can be categorized into three eras, according to Jansen et al (2021), guided by a dominant view-point prevalent in each of the era: (a) deficit view on bilingualism – from 19th century to 1960s, (b) Emergence of the bilingual advantage hypothesis – 1970s t0 2000, (c) Backlash against bilingual advantage hypothesis – recent developments. A remarkable of instance how deficient bilingualism was viewed even in the late 19th century is, oft cited, lecture by Edinburgh University Professor of Education Simon Somerville Laurie, at Cambridge University: "If it were possible for a child or boy to live in two languages at once equally well, so much the worse. His intellectual and spiritual growth would not thereby be doubled but halved. Unity of mind and of character would have great difficulty in asserting itself in such circumstances." (Laurie, 1890: 15–16). Such was the perception that living in two languages was considered as halving the intellectual and spiritual growth, so much so, bilingualism was considered to split the mind and character of the growing child. This remained a predominant view for large part of late 19th and early part of 20th century. Even researchers started to report that a bilingual child would experience and display split personality and schizophrenia (Diebold 1968; Wagener, 1928), suffer a language handicap (Darcy 1953: 50;

Anastasi & Cordova, 1953: 17) or show the signs of being mentally retarded (Goodenough, 1926: 39) or mental confusion (Saer, 1923: 38).

The shift in this deficit view of bilingualism changed with the seminal study by Peal and Lambert in 1962 which showed that bilingualism was not a hindrance in a normally developing child. On the contrary, it showed beneficial effect by developing and increasing creativity and flexibility in cognitive abilities in a bilingual child when compared with a monolingual one. This shift was a result of the improvement in methodology compared to what was used in previous studies showing deficient outcome of bilingualism. After this, 1960s and 70s saw an upheaval in the studies on bilingualism and cognition. 1980s raised interest among cognitive psychologist to investigate the effect of bilingualism on cognition, the research area propelled especially by Canadian Psychologist Prof. Ellen Bialystok. The decades of 1970s, 80s and 90s, and first two decades of 21st century focused on different aspects of cognition mediated by bilingualism like metalinguistic awareness (Ianco-Worrall, 1972; Cummins, 1978; Bialystok, 1986; 1988; Ricciardelli, 1992; Campbell & Sais, 1995; Cromdal, 1999); bilingual advantage concerning non-linguistic cognitive skills such as cognitive flexibility (Kozulin, 1999), divergent and creative thinking (Cummins & Gulustan, 1975; Srivastava, 1991; Lee & Kim, 2011), concept formation (Lietdke & Nelson, 1968; Bain, 1974), problem solving (Bialystok & Majumder, 1998; Bialystok, 1999; Bialystok & Shapero, 2005), abstract and symbolic reasoning (Goncz, 1988; McLeay, 2003), theory of mind and false-belief reasoning (Rubio-Fernández & Glucksberg 2012; Goetz 2003). Studies by Bialystok's group has reported on the bilingual advantage discerned in the enhanced executive control with some cost and disadvantage in language proficiency as shown by verbal fluency task in which bilinguals are found to produce less number of words compared to monolinguals (Bialystok, 2001; 2009; Bialystok et al, 2010;

2012; Bialystok & Craik, 2010). The bilingual advantage is claimed to improve cognitive performance, predict academic success and even induce well-being and long-term health benefits (Bialystok, 2015). Bilinguals are found to activate all their mental lexicon representations and constant practice of juggling between the two languages requires the user to allocate attention to the target language in current use and suppress the non-target language to avoid interference from the irrelevant language that may affect the communication. So, the bilinguals are found to develop efficient monitoring system to resolve the conflict (Green, 1998; Bialystok, 2001; 2008; Costa et al, 2009; Hernandez et al, 2010) the advantage of which extends to task switching paradigms as well (Bialystok & Viswanathan, 2009). Researchers have investigated the executive functions proposed by Miyake and colleagues (2000). The benefits of bilingual advantage have been found to have potential clinical benefits by developing cognitive reserve that can delay the onset of dementia by 4 – 5 years (Bialystok et al, 2007; Alladi et al, 2013; Woumans et al, 2015; Schweitzer et al, 2012) and even leading to better cognitive performance even after a stroke (Alladi et al, 2015). The bilingual advantage results obtained from behavioral experiments mainly around Simon task, Stroop task, Flanker task, Dimensional Card Sorting task, Attentional Network tasks besides other tasks across different age groups (Bialystok et al, 2004; 2006; Kovacs & Mehler, 2009; Prior & MacWhinny, 2010; Costa et al, 2008, Bak et al, 2014a; 2014b) have received support from structural and functional neuroimaging studies, specially fMRI experiments showing the differences in brain activations and organizations in monolinguals and bilinguals (Mechelli et al, 2004; Luk et al. 2011; Abutalebi et al, 2012; 2015; Gold et al, 2013a; 2013b).

The backlash to bilingual advantage hypothesis has come mainly from its prominent Kenneth R. Paap and his colleagues (Paap et al. 2015b; 2016; Paap, 2015) on the ground of failure to replicate previous studies that found advantage. The null results led many researchers to conclude that either the advantage does not existent or may occur only under certain specific conditions. The criticism has come mainly on small sample size and not controlling for confounding variables like socio-demographic factors such as immigration status, socio-economic status, education level. Neuroimaging data are also doubted as being ambiguous since they don't align with the advantages in behavioral performances and the problem of directionality in causality between bilingualism and cognitive differences (Cox et al, 2016; Baum & Titone, 2014): whether bilingualism enhances executive functions or do the individuals with better executive functions become bilinguals? Also, the blame is on confirmation bias with tendency to search or interpret results according to one's pre-existing hypothesis, leading to publication biases that published only the studies that found significant effects (De Bruin et al. 2015b; Paap, 2014; Paap & Liu, 2014; Paap et al, 2014; 2015a; Paap & Sawi 2014). However, another group of researchers like Thomas Bak (Bak, 2016; Bak, et al, 2014a; 2014b) counters the criticisms on the ground that such advantages are not immune to such biases and other findings may have gone unnoticed. Further, Bak points out that such studies are not sufficiently representative as most of the studies have come from the western contexts with the likelihood of immigration as confounding variable in these studies (Bak, 2016). Laine and Lehtonen (2018) raise the issue of methodological problems for such inconsistency in the findings and focus on longitudinal studies to test training group (bilingualism fostering environment) and control group (monolingual environment) before and after the intervention and to analyze the interplay of linguistic and cognitive behavior as within-groups of bilinguals rather than comparing bilinguals and monolinguals (Laine & Lehtonen, 2018). In the midst of such controversies, there is appeal to consider such complex human phenomena of interplay of language and cognition to be reframed in broader neuroplasticity framework (Baum & Titone, 2014; Marzecová, 2015). The future of bilingualism and cognition is likely to emerge stronger when the issues raised so far are resolved and the field becomes robust in terms of methodological rigor and availability of tools to measure the effects of bilingualism on cognition.

1.2 Recent advances and discoveries in bilingualism

In recent days bilingualism is being used as a tool to investigate brain, language and cognition (Kroll, Bobb & Hashino, 2014; Kroll et al, 2015). Three major discoveries have been made in the field of bilingualism in the first two decades of 21st century: (1) Co-activation, (2) Adaptation, and (3) Cognitive reserve.

Cross-language co-activation in bilinguals: Both the languages (or all languages in the mental representation) are always active. Cross language coactivation have been found across different levels and skills of bilinguals: listening, speaking and reading. Spivey and Marian (1999) reported parallel language activation in Russian-English bilinguals in a visual world paradigm, in one of the earliest study in language co-activation in bilinguals. The participants were immersed in an L2 environment living in the US for a considerable duration. The authors found that when the participants listened to, for example, an English word “marker”, they looked at the picture whose Russian word “marku” overlapped phonologically with the auditory input in L2 showing the activation of phonological competitor in L2. The authors’ later study (Marian & Spivey, 2003) with high proficient Russian-English bilinguals also found between-language coactivation. Studies in Dutch-English bilinguals (Weber & Cutler, 2004; Lagrou et al, 2013) also found similar phonological coactivation when the words showed phonological similarity. Upon hearing the English word “flower”, in a sentential context, they looked at the picture of “bottle” more whose Dutch equivalent *fles* shared phonological relation with its English counterpart. Likewise, similar effects have been found in bilinguals with varying degrees of proficiency and L2 age of acquisition in English-Spanish bilinguals (Canseco-Gonzalez et al, 2010; Blumenfeld & Marian, 2013), in German-English bilinguals (Blumenfeld & Marian, 2007), Hindi – English sequential bilinguals (Mishra & Singh, 2013). The degree of a bilingual's parallel activation in both the languages have been investigated in reading using cognates (form and meaning similar across the languages) or cross-linguistic homographs (Dikjstra et al, 1999). Bilinguals have been found to process cognates faster than homographs, whereas such effects are absent in monolinguals. The finding from monolingual study that learning to read and write forms a connection between orthographic and phonological forms (Ziegler & Ferrand, 1998) has been found in bilinguals too. Sunderman and Priya (2012) tested fluent Hindi – English bilinguals whether such bilinguals access words in another language by activating translation equivalents. They observed that if the critical word was a translation equivalent of the phonological cohort it caused interference in the participants which showed that high proficient different script bilinguals show automatic translation. Mishra and Singh (2014) tracked participants' eye movements while making them look at the display of written words which was phonologically related to the translation equivalent of the spoken word which was presented simultaneously. Participants' visual attention oriented quickly towards the phonologically related translation equivalent when compared with their looks to the distractors which suggested activation of the orthography of the non-target language mediated through translation that led to the spreading of the activation the words related to each other. The study showed bilinguals automatically activating orthographic forms in non-target language even the languages use different scripts and do not share cognates. Thierry and Wu (2007, 2010) measured Event Related Potentials (ERPs) using implicit priming by asking the Chinese-English participants to judge if the English words which occasionally repeated a sound or spelling of translation of Chinese words. They found cross-linguistic activation for phonology but not for orthography. The reason they did not show orthographic activation could be because of the participants being late learners of English in their adult stage and not exposed to L2 script in their early childhood. In a recent study, Peleg and colleagues (2019) tested participants who used spoken Arabic as native speakers and were Arabic-Hebrew bilinguals with reading proficiency in both literary Arabic and Hebrew with a visual lexical decision task. They obtained inhibitory within-language phonological effects from spoken Arabic to written Arabic in two forms of the same language and facilitatory effect in between-language spoken Arabic to Hebrew in the two languages not sharing the same script. Cross-language coactivation studies reveal parallel language activation in spoken language as well even in bimodal situation. For example, Giezen and Emmorey (2015) investigated picture-naming word interference in bimodal bilinguals who had fluency in English and American Sign Language (ASL). The participants listened to distractor words while naming pictures in ASL which were manipulated across four conditions: related phonologically to target sign mediated through translation equivalents, equivalents of translation, related semantically, or not related. They found that translation equivalents and words related phonologically through translation facilitated production of ASL showing the spread of cross-linguistic activation in production from phonological to lexical levels. Bergmann, Sprenger and Schmid (2015) compared German monolinguals with two groups of bilinguals in which one group had acquired German as L1 prior to migrating to environment where they used English as their L2 and gradually started to attrite their L1 and another was L1 English group were learning German as L2 in an immersion setting on whom they studied the effect of parallel language activation on the fluency of speech in their L1 and L2. They found that both learners and attriters were significantly more disfluent than the monolinguals which led the authors to interpret their findings as the evidence for interlingual competition during the production of speech.

Language adaptation and reconfiguration: When a bilingual speaker attains a high degree of proficiency, it starts to bring changes in the linguistic representation and architecture of the mental lexicon, both L1 and L2 influencing each other (Kroll, Bobb & Hashino, 2014; Kroll et al, 2015). The mechanism of parallel language activation in bilinguals contributes to the reconfiguration of language representation (Abutalebi et al. 2005) and architecture in the brain. In a bilingual, the two language representations and the neural mechanism that support to process the two languages are shared rather than being separate (Kroll & Tokowicz, 2005; Abutalebi et al. 2005) which makes the activations permeable into both the directions and require to control L1 when L2 is used with additional cognitive resources. Two experiential factors are found to influence L2 processing and organization of the structural neural networks: age of acquisition (Wattendorf et al. 2014; Hernández & Li 2007 and proficiency (Steinhauer et al. 2009; Abutalebi & Green 2007). This permeability makes the late bilinguals similar to the early bilinguals indicating that it is proficiency compared to the age of acquisition which plays more important role in shaping the way the languages interact in bilingual brain and making the linguistic profile and network of bilingual different from the monolingual. L2 immersion studies (e.g. Baus, Costa, & Carreiras, 2013; Linck, Kroll, & Sunderman, 2009) have shown that even a short duration of immersion in L2 of six months in study abroad program can attenuate L1 as noticed in the participants less number of words in L1 compared to L2 in tests like verbal fluency task. Cross-linguistic effect of language reconfiguration has been observed in phonology (Chang, 2013), grammatical structure (Dussias & Cramer Scaltz, 2008), and syntactic structure (Kantola & van Gompel, 2011; Bernolet, Hartsuiker, & Pickering, 2007). The findings in bilingualism so far indicate that newly learned lexicon and syntactic structures don't develop in isolated manner but they do interact with the existing languages dynamically and change the language system as a whole to the extent that the two languages start converging and restructure both the L1 and L2 language systems (Ameel, Storms, Malt, & Sloman, 2005). Both language co-activation and language reorganization shows that bilingualism not only influences language system but reconfigures cognitive networks as well (Kroll & Bialystok, 2013, see also Bialystok, 2017 for a review evaluating the evidence for systematic modification of brain and cognitive systems attributed to bilingualism). How the linguistic and cognitive controls interact with each other is predicted by Adaptive Control Hypothesis that explains how three interactional contexts and eight cognitive control processes interact with each other (Green & Abutalebi, 2013, details in the next section).

The effect of bilingualism on human mind is so powerful that it starts to become noticeable even before one starts to speak either of the two languages. Exposure to multiple languages starts to tune the language representation in infancy (Sundara et al, 2006) and shape up attention and language discrimination (Kovács & Mehler, 2009; Sebastián-Gallés et al, 2012).

Neural and cognitive consequences of bilingualism: The practice and experience of juggling between two languages has its consequences in our mind and brain (Bialystok, 2011; Bialystok, Craik, & Luk, 2012; Kroll, Bobb & Hashino, 2014; Kroll et al, 2015). The brain areas responsible for cognitive control have been found to be benefitted and reshaped by bilingualism. Much of the insights and findings on the effective of bilingualism on the cognitive and neural architecture has come from the lab of Jubin Abutalebi. One of the earliest neuroimaging evidence of overlapping of two languages in a bilingual was the findings of Abutalebi, Cappa and Perani (2005) that showed the function of both the languages in a bilingual is supported by the same neural tissues, and the brain areas that control language functions overlap with the areas of the brain controlling cognitive functions (Garbin et al, 2010; Abutalebi & Green, 2007). If difference is noticed in brain activity while using the two languages, this could arise from the requirements of engaging control mechanisms regulating the use of the dominant language to facilitate the weaker language engagement (Abutalebi & Green, 2007). So much so that not just for bilingual processing, even multilingual processing with more than two languages appear to follow the pattern of parallel activation and control similar to bilingual processing with proficiency and language dominance determining the three or more language relative effects (van Hell & Dijkstra, 2002; Linck, Schwieter, & Sunderman, 2012). Interestingly, the results from behavioral research and neuroimaging research are in consistent with each other. The ability to switch between languages and the ability to switch between non- linguistic tasks tap into the same control mechanisms is shown by the behavioral research (Prior & Gollan, 2011). Neuroimaging studies have shown that bilinguals not only activate control areas of the brain for both linguistic and non-linguistic tasks, they are also more efficient than monolinguals in using these control networks even when the task is only cognitive, and not linguistic (Abutalebi et al., 2012; Bialystok, Craik, & Luk, 2012). Abutalebi and colleagues (2012) found that bilinguals could recruit more efficiently the anterior cingulate cortex, brain area implicated in cognitive control were more efficient than monolinguals, while performing a non-linguistic conflict-monitoring task: bilinguals required less activation to resolve the same level of conflict. The influence and consequence of bilingualism on cognition is far greater than other factors like socio-economic status (Calvo & Bialystok, 2014). Importantly, the major consequence of bilingualism has been beyond language and cognition, extending to health benefits for living with pathology like Alzheimer’s dementia (Bialystok, Craik, & Freedman, 2007; Alladi et al.,

2013) or for healthy aging (Gold et al, 2013). The benefits of bilingualism is observed more in old age when cognitive decline sets in. Gold and colleagues (2013) conducted an fMRI study on younger and older bilinguals and monolinguals on nonlinguistic switching task and found that compared to younger participants, the older bilinguals showed bilingual advantage in both neural and behavioral measures. Bilinguals spending their lifetime resolving cross-language conflict develop domain general cognitive skills in conflict resolution providing a rich foundation for cognitive life. Bialystok and colleagues (2007) reported that bilinguals were diagnosed 4 to 5 years later for Alzheimer's disease compared to monolinguals in a study conducted in Canada, even though evidence has shown that the neurodegeneration may set in much earlier bilingualism provides cognitive reserve (Schweizer et al, 2012; Stern, 2009). This finding has been replicated in India by Alladi and colleagues (2013). More recently, impact of bilingualism has been studied in stroke (Alladi et al, 2016) and frontotemporal dementia leading to aphasic forms (Alladi et al, 2017) and it is gaining so much of popularity that it is being considered as a global public health strategy for cognitive aging (Mendis et al, 2021). The cognitive reserve as a protective mechanism against cognitive decline is believed to be developed as a function of constant pressure on the executive control to manage attention to the target language and inhibit interference from non-target language thus stimulating mental activities that contributes to its development (Schweizer et al, 2012; Bialystok, 2011).

1.3 Conceptual frameworks, theories and models of bilingual cognition

Many of the earlier models of bilingual processing have been influenced by pre-existing monolingual processing models (e.g., Cohort model of speech perception, Marslen-Wilson, 1987) and connectionist models (e.g. McClelland & Elman, 1986, TRACE model of speech perception). Interactive Activation model developed by McClelland and Rumelhart (1981) for monolingual processing was extended as Bilingual Interactive Activation+ (BIA+) model by Dijkstra and van Heuven (2002) focusing on visual or orthographic input processing in bilinguals, which was further extended as SOPHIA (Semantic, Orthographic, and Phonological Interactive Activation (Thomas & van Heuven, 2005). TRACE Model of monolingual speech perception inspired Bilingual Model of Lexical Access (BIMOLA, Grosjean, 1988, 1997).

The first decade of 21st century was dominated by two models of bilingual lexicon: The Revised Hierarchical (RHM) model (Kroll & Stewart, 1994) and The Bilingual Interaction Activation (BIA) model (Dijkstra et al, 1998) which was revised and extended to Bilingual Interactive Activation+ (BIA+) model (Dijkstra & Van Heuven, 2002). The RHM is a developmental model which captures interlingual connections existing between lexical and conceptual representations as the learners develop their proficiency in L2 and captures the word-to-concept mapping during language processing. This model predicts that as the bilinguals attain proficiency in their L2, they can directly access concepts in L2 without having to rely on lexical links through translation equivalents but during the early stage of L2 acquisition, translation equivalent in L1 is prominent. BIA is an interactive activation mediated bilingual word recognition model that treats the bilingual lexicon as an integrated and interactive lexicon. It consists hierarchical arrangement of features, language nodes, letters and words. As per this model, when a proficient bilingual encounters letter string as visual input, several lexical candidates in both the language become activate. These activated lexical candidates compete for selection with each other and the one that crosses its threshold of activation wins over the other candidates which can’t cross their threshold and are inhibited. The differential language selection is induced by the language nodes exerting top-down inhibition on the non-target language words (see Sunderman & Kroll, 2006 for a unified treatment and application of both these models that predict activation of first language while lexical processing happens in second language).

The second decade of 21st century has been influenced mainly by BLINCS Model (Shook & Marian, 2013) and Adaptive Control Hypothesis (Green & Abutalebi, 2013). Processing of spoken word comprehension in bimodal situation and cross-linguistic parallel activation is predicted by BLINCS Model (Shook & Spivey, 2013) that integrates both auditory and visual information. According to this model, from bottom up, the phonological input enters the system feeding upward to the phono-lexical level and feedback increases the activation of the items present in visual display from the semantic down to the phono-lexical level. For example, as per this model, the presentation of Nepali word *nangra* (claw) with the picture of a 'nurse' results in activation of both phonologically related L1 *nangra* and L2 'nurse' but not phonologically unrelated L2 'tape'. This model also predicts the time-course of overall activation of the process of speech comprehension, allowing to trace the activation lexical items while the speech unfolds. In our study, we would expect different activation curve in mouse movement trajectories for phonologically related and unrelated items. For example, when the participants heard L2 duck and saw the picture of a duck and a ladle (*dadu*, L1 phonologically related distractor) displayed on the screen, it would increase the activation as the mental lexicon system would compete for selection of either of the onset matching words, so much so, the process starts to begin even while presenting the initial phoneme of the word (FitzPatrick, & Indefrey, 2010) and the activation level would remain till the point it is resolved, upon recognition of the actual target image. We would not expect such activation when the duck was paired with phonologically unmatching word in L1 *dhaan* (paddy) as the onset phoneme in L2 target word is an alveolar and the L1 distractor is a dental and since there is no phonological competition, the mouse trajectories deviate toward the target earlier than when there was a competition.

Adaptive Control Hypothesis (Green & Abutalebi, 2013) makes prediction about language control in bilinguals. This hypothesis views language control as an interaction between three conversational or interactional contexts and eight cognitive processes. The three interactional contexts are: single language, dual language and dense code-switching contexts, while the eight cognitive control processes are: goal maintenance, selective response inhibition, salient cue detection, interference control - conflict monitoring and interference suppression, task engagement, task disengagement, and opportunistic planning. ACH predicts parallel language activation, "If both languages are active and compete for selection, then demand on processes associated with goal maintenance, conflict monitoring, and interference suppression may be high across all contexts" but specially so in dual language context like our participants who used both the languages with different speakers occasionally switching between the two languages within a single conversation (with L1 speakers, not with L2) but not within an utterance. Drawing on the study of Hommel and colleagues (2011), this hypothesis links the states of control required for the types of thinking between monolinguals and bilinguals and those for bilingual speakers. Since controlling the interference between two languages develops control state which is akin to and conducive to convergent thinking in dual language contexts (inimical to divergent thinking as in monolinguals). Linking this prediction of ACH, we would expect our participants to have enhanced their proficiency with regular practice of both the languages, to such an extent that the linguistic systems of both the languages converge into each other and the speakers don't feel so much of interference from either of their two languages. The authors argue that the speakers adopt their conversational practices to suit their interactional contexts and by doing so they minimize the interactional cost. The degree of proficiency in both their languages that constrains their ability in avoiding such a cost also leads to relatively stable adaptive changes. The authors point out that their increase in proficiency in single as well as dual language contexts is associated with the increased skills in controlling interference. In our investigation, if our participants had achieved a relative stability in their proficiency in L2, to the degree of their L1, they would be more skilled in controlling interference from either of their languages and their performance would not deteriorate in either of their languages.

Considering the way language, more specifically bilingualism, has the propensity to shape human behavior and cognition, and even structure and function of the human brain, neuroplasticity framework is becoming more and more plausible framework to explain the mechanisms of linguistic processing in bilinguals/multilinguals in the recent days (Schroeder & Marian, 2016; Hayakawa & Marian, 2019; Bialystok, 2017).

Much of the studies in psychological and cognitive science have been conducted in WEIRD (Western, Educated, Industrialized, Rich and Democratic) contexts which have been criticized on the ground that they don't reflect majority of world population (Henrich et al, 2010; Arnett, 2008). A need to go beyond this population is felt strongly in the related fields of human sciences like psychological sciences, cognitive sciences, social sciences and brain sciences (Baur, 2020; Muthukrishna et al, 2020a; 2020b; Pathak et al, 2021). The studies included in this study is conducted on non-WEIRD population and context, so our study makes contribution to the field of bilingualism from this perspective as well.

1.4 Tools and tasks used in measuring bilingual cognition

Broadly speaking, two types of tools are used in measuring bilingual cognition: neuroimaging and behavioral tools. In neuroimaging tools, electroencephalography (EEG) is mostly commonly used measure in event related potentials (ERPs) are measured when the participants performed the task in which N400 is a measure of semantic anomaly and P600 is a measure of syntactic anomaly (Guo & Peng, 2006; Thierry & Wu, 2007; Moeno et al, 2014; Grundy, Anderson & Bialystok, 2017; Grey et al, 2018; Rämä et al, 2018; kalamala et al, 2018), Magnetoencephalography (MEG) (Ferjan Ramírez, 2017), MRI (Abutalebi et al, 2015; Rahmani et al, 2017), fMRI (Price et al, 1999; Price, 2010; Meschyan & Hernandez, 2006; Waldie et al, 2009; Marian, et al, 2014).

Among the behavioral tools, the most commonly used to trace bilingual cognition is eye-tracking (Allopenna, Magnuson, & Tanenhaus, 1998, Marian & Spivey, 2003; Mishra & Singh, 2014). Another commonly used tool to conduct reaction time experiment is DMDX (see Jiang, N, 2012 for detail description on using DMDX for conducting reaction time experiments to measure bilingualism).

In the recent days, MouseTracker has emerged as a powerful tool in conducting bilingual studies (Spivey, Grosjean & Knoblich, 2005; Freeman & Ambady, 2010; Freeman, 2018; Incera & McLennan, 2016; Incera, 2018; Incera et al, 2020; Zhao et al, 2020; Pathak, 2017; Pathak et al, 2021; Pathak & Pathak, 2022). In this thesis work, MouseTracker has been the main tool of experiment design and data collection. The first PhD thesis done using Mouse Tracker as the main tool was by Sara Incera (2016) and coincidentally, this thesis was also on bilingualism. As far as I understand, this is the second PhD thesis on bilingualism using this tool. (for the full list of publications (which also includes the study of present researcher) using Mouse Tracker till date please refer to this link https://www.mousetracker.org/publications).

Among the reaction time tasks, they can be categorized into linguistic and cognitive tasks. The linguistic tasks are: (a) Lexical and phonological tasks – Lexical decision, word naming, the priming paradigm, phonemic monitoring, phonological tasks; (b) Semantic tasks – semantic categorization, two-word semantic judgement task, the interference paradigm Stroop task, picture-word interference paradigm, translation and translation recognition task; and (c) sentence based tasks – self-paced reading, self-paced listening, cross modal priming, word monitoring, sentence matching, grammaticality judgement, sentence-picture matching task.

Commonly used non-linguistic cognitive tasks to measure bilingual cognition are: Stroop task, Flanker task, Simon task, non-verbal task switching, Go-NoGo task, AX-CPT, ANT, Card sorting task.

1.5 The present study

This study has investigated how bilinguals in different contexts and environments modulate their linguistic and cognitive controls. The main research questions are the following:

a. How does the language dominance shift in bilinguals? Are offline or online measures more effective in testing the dominance in bilinguals?
b. Does immigration and immersion in second language affect first language? If it does what is the effect in language attenuation and attrition?
c. Is it possible to extend the research methods used in bilingualism to investigate trilingual processing? Is the mechanism for processing bilingualism and trilingualism similar or different? How do the three languages interact with each other?

In order to investigate these questions, we used parallel language activation paradigm using MouseTracker as the main tool for designing the experiments. The participants in different language comprehension lexical access experiments performed “listen, look and click” task in which the experimental manipulation was done to test whether the participants experienced phonological competition in the two languages. We used bilingual verbal fluency task to test language production and executive control of the participants.

Data analysis has been done using Excel, SPSS and R statistical packages.

1.6 Organization of the chapters

The thesis has five chapters. Chapter 1 is Introduction the field of bilingualism and cognition that includes brief history of bilingual cognition; recent discoveries and advances in bilingual cognition; conceptual framework, theories and models of bilingual cognition; tools and tasks used in the investigation of bilingual cognition and how our works fits into the overall picture in the field. Chapter 2 is about the language dominance study on Gurung – Nepali bilinguals. Chapter 3 is immersion study on Nepali – English bilinguals. Chapter 4 is an extension of bilingualism to trilingual study with Nepali-English-Norwegian trilinguals. Chapter 5 is the conclusion of the study.

Chapter 2: Language dominance and selectivity in bilinguals

Language non-selective activation in different modalities seems ubiquitous in bilingual language processing. When bilinguals listen to one name, they activate names of other objects in the non-used language both within and across languages. However, much of such evidence has come from bilinguals speaking mainstream languages. Here we examined if Gurung-Nepali speakers activate phonological cohorts during cross-modal language processing in a mouse tracking paradigm. Participants saw two pictures and listened to one name. They had to click at the object whose name matched with what they heard. We tracked mouse trajectories to the competitor as they moved them towards the target. Mouse trajectories suggest that participants deviated towards competitors more when they were phonologically similar to the target. Interestingly, such cross-language activation was higher in the L2-L1 direction as predicted by Inhibitory Control Model. We discuss the results with regard to language dominance and bilingual parallel language activation along the predictions of Inhibitory Control Model (Green, 1998) and Adaptive Control Hypothesis (Green & Abutalebi, 2013).

2.1 Introduction

As the body of research literature in bilingualism keeps growing, it is becoming more and more important to investigate the driving mechanisms of bilingual cognition. One such driving mechanism is dominance. Dominance is discussed in relation to proficiency and attrition (Kopke & Genevska-Hanke, 2018; Birdsong 2006; 2014; Gertken et al, 2014). Language dominance

(Gollan et al, 2012; Dunn & Foxtree, 2009), which focuses on the relative proficiency of the two languages within the same individual (Sheng et al, 2014) and is regarded as processing facility or processing ease (Birdsong, 2018), is an important issue in bilingual research. Bilinguals dominant in one language are normally unbalanced in proficiency (Shishkin & Ecke, 2018) and balanced bilinguals equally proficient in two or more languages they speak are rare (Myers-Scotton 2008; Grosjean & Li 2013). Dominance has been investigated in languages which are structurally different from each other (Daller, Yıldız, de Jong, Kan & Ba¸sbagi, 2011), interlingual interference effects in immigrants (Flege, MacKay & Piske, 2002), in developing assessment tool for clinical use (Lim et al, 2008), in bilingual research in operationalizing and measuring language dominance (Treffer-Daller, 2011), studying how dominance and proficiency are operationalized by measuring convergence and divergence in different ways (Gollan et al, 2012) and in measuring proficiency (Marian, Blumenfeld & Kaushanskaya, 2007; Li, Sepanski & Zhao, 2006; Gutiérrez Clellen & Kreiter, 2003).

It is also important to consider the independent variables mediating language cognition in bilinguals. Assuming that empirical studies which have been published in Bilingualism: Language and Cognition can serve as representative sample of published literature in bilingualism investigated from cognitive perspective, Hulstijn (2012) looked at all the papers published in the journal from the first volume of its publication in 1998 to the volume 14 published in 2011. Of the 224 research articles and research notes, he reviewed 140 empirical research articles which were related to various types of group comparisons in the measurement of language proficiency as independent variable in bilinguals. He identified six types of comparisons: comparing of bilinguals dominant in either of the two languages; comparing of bilinguals (language A and B) with native speakers of either languages; comparing of L2 learners with different levels of proficiency in comparison to the native speakers of their L2; comparing L2 learners or groups of bilinguals with different first languages; comparing bilinguals of different ages and/or combination of these designs. Drawing on the proposal of Cummins (1980a, 1980b) on the ideas of basic interpersonal communicative skills (BICS) as well as cognitive academic language proficiency (CALP), Hulstijn (2011, 2012) narrows down this notion and postulates the constructs of Basic Language Cognition (BLC) and Higher Language Cognition (HLC). BLC is concerned with the processing of oral language skills of listening and speaking whereas HLC includes written language skills of reading and writing. BLC is regarded as the language skill shared by all normal adult native speakers (Hulstijn 2015, 2018) but HLC shows individual differences in language control and is affected or even mediated by the attributes like "literacy, age, level of education, profession or leisure-time activities" (Hulstijn (2012).

Speech learning model (SLM) postulated by Flege (1995) explains how basic language cognition (BLC) is represented in a bilingual speaker. According to SLM, within a bilingual speaker, L1 & L2 phonological systems operate in a common phonetic space. This inseparable co-existence of the two phonological systems in a single space inevitably influence each other (Tsui et.al, 2019) which predicts that bilinguals perceive the sounds of L2 through the L1 phonological framework. A lack of certain sound contrast in L1 may cause difficulty while perceiving and acquiring such sound contrast in L2, especially in typologically dissimilar languages like Gurung belonging to Tibeto-Burman language family and Nepali belonging to Indo-Aryan language family. During online speech processing, the phonetic representations from both the languages are simultaneously activated and create competition between the two languages for selectivity (Marian & Spivey, 2003; Antoniou et al, 2011; Mishra & Singh, 2014, 2016; Simonet, 2014;

Olson, 2016). This situation of parallel activation of both the languages in a bilingual cause the nontarget language exert an influence on the target language for selectivity, which makes the phonetic implementation deviate towards the nontarget language (Spivey & Marian, 1999; Sunderman & Kroll, 2006; Weber & Cutler, 2004; Lagrou, Hartsuiker & Duyck, 2011; Antoniou et al., 2011; Goldrick et al., 2014). The action of resolving the coactivation of both the languages requires that phonetic realization in one language to be implemented, the corresponding realization in another language needs to be inhibited for the target language selection.

The degree to which the two phonetic systems are coactivated is modulated by Inhibitory Control (Green, 1998; Lev-Ari & Peperkamp, 2013). Inhibitory control employed language switching paradigm to examine lexical selection in bilingual speech production as a mechanism for language control. This paradigm measured naming latency as a function of switch cost which was defined as the degree of disruption in performance as a result of unexpected language switch (Green, 1998). Language dominance in bilinguals was found to modulate the asymmetrical switch cost. Meuter & Allport (1999) found higher naming latency when the bilinguals switched from their nondominant language to the dominant one suggesting that more efforts are required to suppress the dominant language when switching from nondominant language. We were interested in examining the role of language dominance in speech comprehension, whether the inhibitory control observed initially in speech production was also applicable in speech comprehension in language selectivity paradigm.

2.1.1 Mouse tracking for measuring dominance and selectivity in bilinguals

Mouse tracking paradigm provides fine grained temporal data reflecting online competition between two alternatives (Freeman & Ambady, 2010). It has been also used to track any covert activation of a competitor in psycholinguistic lexical decision tasks (Spivey et al, 2005; Li & Li

2016). In such a paradigm participants are generally presented with two pictures and a spoken word. One of the pictures is a phonological cohort of the target pictures. Mouse trajectory data show that participants deviate towards this competitor while they try to reach the targets (Spivey et al, 2005). This has been taken as evidence showing simultaneous activation of associated words during language processing. Such mouse tracking data gives more data points than eye movement and reaction time studies (Spivey et al, 2005) and is richer in terms of temporal and spatial resolution (L1 & Li, 2016) that can capture the cognitive dynamics of representational landscape (Farmer et al, 2016). Mouse tracking has been used in investigating the activation of associated words in monolinguals as well as bilinguals. Farmer and colleagues (2007) replicated a visual – world study of Spivey and colleagues (2002) and found that it is possible to find similar effects using mouse-tracking as found in eye-tracking. They used grab-click, transfer and drop-click of the referent object design using stimuli from the previous study: the ambiguous spoken sentence (Put the apple on the towel in the box) with one referent visual context (containing the target referent – the apple on the towel, correct destination – a box, incorrect destination – a second towel and a distractor – a flower) and unambiguous spoken sentence (Put the apple that's on the towel in the box) with two referent visual context (keeping all objects same and replacing the distractor flower with an apple on the napkin). They found two significant divergences in the mouse trajectories in one referent ambiguous context compared to two referent unambiguous context at each time step of x coordinates. Participant's mouse movements curved significantly closer toward the incorrect response destination in one referent context ambiguous sentences than in unambiguous sentences. Thus showing the incorrect destination (the towel) was partially considered relevant and active, and until disambiguation is resolved both the alternatives may be considered in parallel and over time, the representations active simultaneously compete for attention. Spivey, Grosjean and Knoblich (2005) recorded continuous hand movement response in a visual context as the participants comprehended spoken instruction. Participants were presented with two colour objects on the upper right and left corners of the computer screen in cohort (candle, candy) and control (candle, jacket) conditions. In a match-to-sample procedure, they were instructed through a prerecorded speech file to click one of the pictures matching with the speech file with a mouse. After they clicked the box at the bottom center of the screen with a mouse, the picture display would appear followed by the speech file after a delay of 500 ms of the onset of the visual display. Mouse movement trajectory showed the trajectory in the cohort condition travelled further up than the trajectory in the control condition and equidistant from the two objects for longer period. The proximity of the target and the distractor can be treated as an index of the activation of competing lexical representations mediated by acoustic priming.

Barca and colleagues (2015) extended this study by Spivey et al. (2005) to show possibility of phonological information elicitation without the acoustic priming and also how the choice in a categorization task may be influenced by phonological information, a procedure which was more abstract than the original match-to-sample design. In their study, they explored the question of whether it was possible to automatically extract the phonological information from the picture stimuli and whether it would subsequently influence the covert behavior. They investigated the implicit phonological information processing using a kinematic study of semantic categorization of pictures and words. In each trial, the participants selected the target based on the semantic congruency of the stimuli (artefact or natural) related to a cued-word and the distractor was either phonologically similar to the cued word or it wasn’t. Response made by the movement and click of the computer mouse was continuously recorded. Their result showed that the phonological similarity between the distractor and the cue-word caused the trajectories curve more compared to when the target and the cue-word were phonologically unrelated. The greater attraction of the trajectory toward the phonological competitor in distractor condition indicated phonological similarity creates a competition for recognition and leading to 'uncertainty' which influences the ongoing decision making process even if that is irrelevant to the current task. The picture stimuli elicited response 200 ms faster than lexical stimuli which is explained as the picture response being semantically mediated which has access directly to semantic-conceptual information and lexical response access to semantic-conceptual information mediated though orthography as language with direct mapping between visual-orthography and phonological representation are likely to activate phonological code and thus create interference which is reflected in slower response time/increased mouse curvature. Recently, two lexical decision paradigm studies using mouse-tracking (Li et al, 2015; Li & Li, 2016) have studied parallel language activation along the assumptions of BIA + (Dijkstra & Van Heuven, 2002), a connectionist model of language non-selective activation among bilinguals and have also challenged the strict letter position encoding proposal of the model and suggested incorporation of a more flexible letter transposition using the fine grained cognitive measures as tracked by mouse movement trajectories. Li et al (2015) study in Spanish – English bilinguals showed the effect of cross-language lexical activation in orthographic coding in bilinguals. In a lexical decision task, high proficient Spanish – English bilinguals responded "Yes" or "No" with a mouse click among the lexical stimuli which consisted of words (cognates, non-cognates), critical non-words (transposed letter and replaced letter with high and low orthographic similarity) and unrelated non-words. Both the spatial measures of greater Area Under Curve and Maximum Deviation showed increased activation of base word of transposed letter non-word compared to replaced letter non-word with stronger attraction to incorrect “Yes” response. Unlike the BIA+ encoding architecture which is letter position specific, this mouse-tracking study showed that parallel language activation is so permeable that cross-language lexical activation affects even the degree of precision in orthographic coding. However, because within the architecture of BIA+, the units of lexical representation: phonology, orthography and semantics are organized in an integrated lexicon and are connected by interactive network, the activation of lexical representations spread across and within the units of lexicon via bottom-up orthographic/ phonological feedforward and top-down semantic feedbackward mechanism in a language non-selective way. This explains their results of greater transposed letter effects for orthographically highly similar words compared to orthographically less similar words as even the slightest orthographic variations are assumed to have separate representation. Similarly, Li and Li (2016) investigated cross-language orthographic activation among English monolinguals, Spanish – English and Chinese – English bilinguals using kinematic measures in lexical decision task using visual word recognition paradigm. They found transposed letter effect, also called ‘CamrbidgeUnievrsity’ effect in low orthographic neighborhood density words across all three language condition but more on Chinese-English bilinguals where the curvature showed they experienced greater attraction toward the competing distractor to respond ‘Yes’. The effect was greater on script non-similar languages (Chinese-English) than in script similar languages (Spanish – English). In our study, we tested the BIA+ model, in which very much like orthography, phonology also spreads its activation to its form similar phonological neighbors and feedsforward to its corresponding semantic representation that feedsbackward to its phono-lexical representation, thus activating phonological competitors.

Bartolotti and Marian (2012) combined mouse tracking with eye tracking to study the effect of to what degree bilinguals are able to control the interference from their native language in parallel language activation. They assessed activation of interlingual competitors in a novel language using a word recognition task. Their eye tracking results showed monolinguals looking at the competitors for more and longer duration than bilinguals; their mouse tracking results revealed the attraction of mouse movements of the monolinguals to their native language competitors whereas the bilinguals could overcome the competitor interference from their native language by increasing the activation of their target items. Incera and McLennan (2015) studied the time course of bilingual advantage using mouse tracking. Deriving their prediction from expertise literature, they argued that bilinguals behave like experts and are different from monolinguals qualitatively in the sense that bilinguals, like experts, take longer time in initiating a response but outperform monolinguals, more so in conflicting situations. They used English – Spanish bilingual Stroop task among three groups of participants: English – Spanish bilinguals, English monolinguals and English – Other bilinguals among whom the age of acquisition of English was 0, 4 and 7 years respectively. The participants named the colour of the word with a mouse click in both English and Spanish: English as the language all three groups knew, Spanish as irrelevant to the monolinguals and English – Other bilinguals and as distractor for the English – Spanish group to create a higher degree of conflict compared to other two groups. The trials had congruent (RED or ROJO in red colour) and incongruent (RED or ROJO in blue colour) stimuli. They recorded the computer mouse movement of the participants as they started moving (initiation time) the mouse and made their movement toward the correct response button (x-coordinates over time). Even though bilinguals took longer time in initiating the response, the trajectories revealed they responded faster than the monolinguals. The effect was more pronounced in bilinguals with high conflict situations in which English – Spanish bilinguals outperformed others in incongruent conditions. The authors argue that the bilinguals are like experts when it comes to dealing with a conflicting input and their expertise arises from their frequent managing of two or more languages. This bilingual advantage emerges from the benefits of faster processing time compared to the cost of longer initiation time. In another recent study, Incera and McLennan (2016) investigated the time course of within-language and between-language competition of lexicon in bilinguals using bilingual Stroop task in mouse-tracker. Previous studies (e.g. Marian & Spivey, 2003a; Marian & Spivey, 2003b) have established such competitions among bilinguals. Tapping cognitive processing into the temporal dynamics, the authors analyzed the x-coordinates of the mouse trajectories over time for the experimental conditions to test the "different degrees of activation" whether it emerges in the magnitude or timing of language activation. Their results showed the within-language interference emerged 80 ms prior to the between-language interference and it is the difference in the timing of the interference rather than magnitude that is at the root of differential effects. In the recent times MouseTracker (Freeman & Ambady, 2010) has emerged as influential and effective tool in measuring linguistic and cognitive control in bilinguals (Pathak et al, 2021). Pathak and colleagues (2021) created bilingual Flanker and Stroop task to measure the linguistic and cognitive control in Nepali – English bilingual biliterates. They investigated the effect of medium of instruction in public school children and found that the children who were instructed in L2 outperformed children who were taught in L1 medium of instruction in both linguistic and cognitive task. The L2 medium instructed children initiated the mouse movement and responded faster than the L1 medium instructed children. Pathak (2017) explored the possibilities of understanding the dynamics of human cognitive mechanisms using MouseTracker and Pathak and Pathak (2022) investigated the bilingual Stroop effect in Nepali-English bilinguals using this tool.

2.1.2 The present study

The present study investigates the language dominance and attrition as revealed by parallel language activation paradigm using mouse tracking in Gurung – Nepali bilinguals. The two languages belong to typologically dissimilar structures and do not share cognates, phonological and morphological features. The study was conducted in the suburb of Bayatari, Waling Municipality, Syangja district, Gandaki Zone of Nepal. The location of the study is interesting in the sense that the participants speak their L1 (Gurung) at home and among each other but the language of social contact, business and education outside their own community is L2 (Nepali). All the participants were originally from Grungkha (Ward no. 14) but were living in Bayatari bazar (Ward no. 13) of Waling Municipality. So they are constantly using both the languages and keep switching from and to each other frequently. We were interested in testing language dominance and selectivity in language comprehension as per the assumption of Inhibitory Control Model (Green, 1998) in cross-modal situation. The study investigates basic language cognition (Hulstijn, 2011; 2012) operationalized through basic interpersonal communication skills (Cummins, 1980a; 1980b) focusing on the primary oral language skills of listening and speaking, and seeing. We were also interested in investigating the effects of internal migration in language dominance and attrition. We were mainly interested in investigating two questions: (a) theoretical question – how does short distance internal migration affect language dominance/attrition and selectivity in bilinguals? (b) methodological question – can a novel method like mouse tracking help answer the question (a) ? Based on the previous studies, we expected mouse tracker will be able to tease out language dominance issues in bilinguals.

2.1.3 Ethical Consideration

The study was approved by the Institutional Review Board (IRB) of School of Medical Sciences, University of Hyderabad. All the participants were briefed about the study and they signed informed consent form before participating. Participants were told that they were free to withdraw from the study at any stage.

2.2 Methods

2.2.1 Participants

Fifty-nine participants had participated in the study, but we eliminated two participants: one for not completing the language background questionnaire in group 1 and one for not completing the mouse tracking experiment in group 2. So finally we had fifty – seven right handed Gurung – Nepali bilinguals with normal hearing and vision (males = 32), mean age 31.75 (14.02) years that participated in the mouse – tracking experiment. All the participants signed informed consent form before the experiment. They all were novice to the experiment as this was the first time such an experiment was conducted in their place. The participants had acquired Nepali as a second language in a natural (communication with peers and neighbours) and formal setting (in the school) in the same order. They were all sequential bilinguals, acquiring Nepali only after they had acquired Gurung. They had their school education only in L2, with no literacy in L1. However, they reported using both the languages at home. This is because Nepali is the main language they need to speak outside their own community as it is the language of business, administration and education, the frequency of use of Nepali is more outside home. All the participants reported the age of acquisition of Gurung right from their infancy, 2.3 (1.5) years, the mean age of acquisition of Nepali was 5.25 years (SD = 4. 2). All the participants were from the same place of origin (Sirsekot village in the Syangja district of Nepal) and their mean duration of stay in the place of data collection (Bayatari, a small suburb where they had settled) was 15.9 years (SD = 8.5). (See Appendix B for the location map of the study)

Participants' dominance in their two languages was measured using Bilingual Dominance Scale questions (also used by Morett & MacWhinney, 2012; Pfordresher et. al, 2021) adapted from Dunn & FoxTree (2009) that they filled up which had questions on the native language, languages known, age of acquisition of L1 and L2, Age of fluency acquisition of L1 and L2, Years of schooling in L1 and L2, language used with father and mother, language used at home, language of mental calculation and language loyalty (Table 1).

2.2.2 Bilingual Dominance Scale measure

All the participants completed a 12-item Bilingual Dominance Scale questionnaire (Dunn & Fox Tree, 2009), which was used in measuring their relative usage of Gurung and Nepali. According to Bilingual Dominance Scale, a balanced bilingual is someone falling between -5 and +5 on the scale or broadly, someone falling between -10 and +10. In our sample, the scale ranges from −30 (Gurung dominant) to +30 (Nepali-dominant) with 0 indicating equal dominance of the two languages. The ratings for the first group of participants ranged from -2 to +20 (M = +8.2) and the rating range for the second group was -16 to -5(M = -9.1). The scale showed the dominance for the younger group (first group) shifting towards their L2 (Nepali) whereas the older participants (second group) maintained their dominance in their L1 (Gurung). However, the entire group of participants put together fell within the range of balanced sample according to this scale.

Table 2.1. L1 and L2 Language experience and demographic profile of participants (standard deviation in parenthesis)

Measure	Full Sample	Age group		Paired *t*-test *p* value	95% CI
		Younger	Older		
Sample Size	57	28	29	-	-
Demographics					
Gender (M/F)	32M,25F	16M, 12F	17M,13F	-	-
Age (Years)	31.8(14.0)	20.6(3.6)	42.6(11.6)	<.001	[17.4,26.6]
Language Measures					
Age of L1 Acquisition(years)	1.16(1.6)	2.36(1.5)	0.00(0.0)	<.001	[-2.95,-1.77]
Age of L2 Acquisition(years)	5.28(1.2)	2.42(1.0)	8.03(4.2)	<.001	[3.96,7.26]
Fluent in L1(years)	4.93(3.8)	4.96(2.3)	4.90(4.8)	>.05	[-2.08,1.95]
Fluent in L2(years)	7.75(4.7)	4.32(0.9)	11.1(4.5)	<.001	[5.00,8.50]
Schooling in L1(years)	0.00(0.0)	0.00(0.0)	0.00(0.0)	-	-
Schooling in L2(years)	9.86(4.2)	11.8(1.9)	8.03(5.0)	<.001	[-5.74,-1.69]
Questionnaire*					
Language used at home	-0.96(2.20)	-1.96(2.8)	0.00(0.0)	.001	[0.87,3.01]
Language used in mathematical calculations	-1.79(1.6)	-1.28(1.5)	-2.27(1.5)	.02	[-1.80,-0.18]
Language Loyalty	0.36(1.83)	-0.14(1.7)	0.90(1.8)	.03	[0.10,1.98]
Fluency lost in any language	-1.68(1.7)	-2.79(0.8)	-0.62(1.7)	<.001	[1.47,2.86]

*Numbers obtained from the scoring scale in Dunn & Fox Tree, 2009

2.2.3 Design

We used 2 (auditory input language: 1 and 2) x 2 (type : phonological competitor and distractor) as within – subject factorial design. We created experimental and control trials with 32 trials in each condition for both the languages. We also used filler trials in equal numbers as competitors and distractors, however, they were excluded from the analysis for the results. So altogether we had 32 x 3 x 2 = 192 trials. The ratio of the experimental, control and filler trials was kept 1:1:1 so as to prevent participants from awareness of phonological overlap and competition, which produced ratio of 1:2 between phonological overlap and competition between lexical items and minimized the awareness of such effects (Blumenfeld & Marian, 2013). The dependent measures were initiation time, response latency and spatial attraction of competing trajectories.

2.2.4 Materials and Stimuli

32 experimental, control and filler trials each in each of the language direction were prepared (see Appendix – A for a complete list of stimuli), thus altogether there were 192 trials. Each of the experimental trials had two objects on the left or right top of the computer screen, one of which was a target and was a referent of the spoken word, another was a phonological cohort of the target item (e.g. in L1 – L2 direction, macha (banana) in L1 and makai (corn) in L2). The control trials had a spoken word which was a direct referent to one of the pictures (target) and another picture was a distractor which did not match either phonologically or semantically with the target (e.g. L1 spoken word kyu (sheep) matched with the referent picture of the sheep but not with barrel (see Figure 1A for example trials with different conditions). The spoken word in the filler trial did not match with either of the two pictures. All the spoken word files were recorded using stable version 2.0.6 of audacity software (https://audacityteam.org/, released in September 2014). Nepali words were recorded by the experimenter whose L1 is Nepali and Gurung words were recorded by a proficient bilingual Gurung L1 speaker, an inhabitant of the place

where the experiment was conducted.

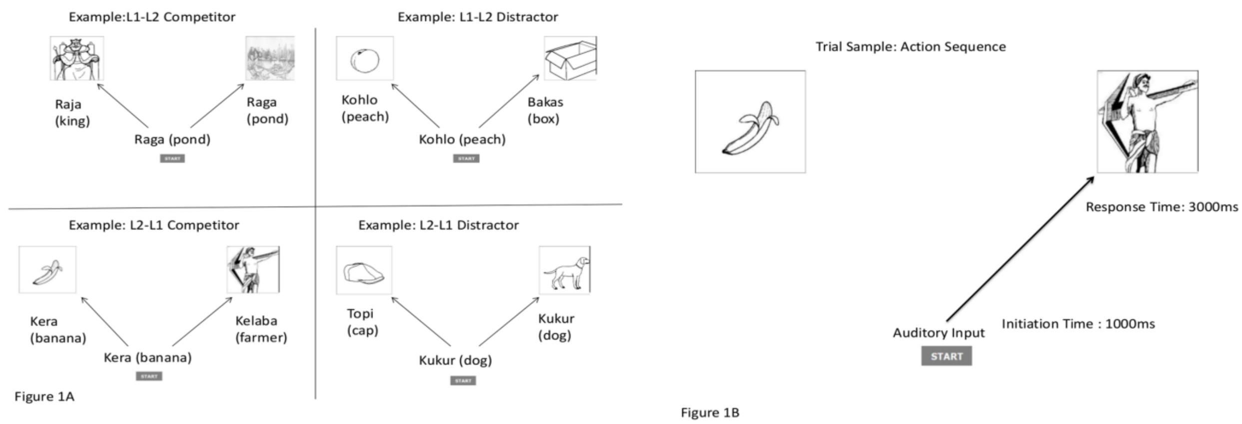

Figure 2.1: Trial Figure Panel. Experimental conditions with language directions showing auditory input pictorial presentation (Figure 1A). Action sequence for mouse initiation and response after the auditory input (Figure 1B).

2.2.5 Procedures

Participants were seated in a quiet room and were instructed to click the 'start' button in the bottom center of the computer after which they heard the spoken word through the headphones placed on their ears. Immediately on hearing the spoken word they had to move the mouse within 1s toward the matching picture either on the top right or top left of the screen and click it within 3000 ms, otherwise the trial would disappear followed by 'Time Out' message (see figure 1B for trial sample with action sequence). The participants had to initiate moving the mouse within 1s of the 'START' press or else they would receive a message asking them to initiate the mouse movement even if they were not sure of the response. Not initiating the mouse movement within 1s would abort the trial.

The participants practiced on 2 practice trial each from all 3 conditions in both direction with altogether 12 practice trials to familiarize themselves with the main experiment. Data from the practice trial is not included in the analysis. Equal number of filler trials as experimental and controls were designed in order prevent participants from detecting any statistical regularities (Farmer et al, 2007) or form any kind of strategy to respond. The data from filler trials have not been considered for analysis.

The instruction for low L2 proficient participants was recorded in Gurung explaining about the task and also a participant who had previously participated in the experiment was there to explain it before they started the experiment. However, they did not feel a need for this and understood the instruction given in L2.

All the trials were randomized across participants and counterbalanced by dividing them equally into top left and right position of the screen so that equal number of trials of all 3 different conditions appeared in different locations. For example, the 32 experimental trials which consisted of phonological cohorts were further sub-divided into 16 each so that 16 corresponding pictures would appear on top left corner of the screen and another 16 on the top right corner of the screen. This strategy also helped to further filter the subtle kinematic differences variability associated with the leftward as well as rightward movement of the arm (Farmer et al, 2007) and showed clear pattern of activation toward left as a result of phonological competition when the phonological cohort were on the left side in which the participants had to move their mouse toward the target in the top right corner. However, for our analysis, we remapped all the trajectories to the right (Freeman et al. 2010; Barca & Pezzulo, 2015).

2.3 Data Processing

For the purpose of comparison, leftward and rightward response trajectories were pulled together and remapped rightward (Barca&Pezzulo, 2015; Freeman et al. 2010). For each participant, all the trials across each condition were averaged to compute the mean response times as well as trajectories. For temporal analysis, mouse movement initiation time, response time and X-coordinates were considered whereas for spatial analysis, Area Under the Curve (AUC) were considered. Incorrect responses were excluded from the overall analysis (7.8 % of all the trials). One subject had missing data for L2 – L1 direction, and one subject who had completed the mouse-tracking experiment but didn't complete the language background questionnaire were discarded from the analysis, thus final analysis had 57 participants. While filtering data for analysis, initiation time was restricted between 50 – 1000 ms and response time was restricted to 300 – 3000 ms. Responses outside the restriction range were considered as outliers. See Figure 4 and 5 for graphic user interface of mouse trajectory deviation in both the groups.

2.4 Results

2.4.1 Initiation Time

We performed 2x2x2 repeated measures ANOVA with Group (younger and older) as between subject factors, and Type (competitor and distractor) and direction (L1 – L2 & L2 - L1) as within subject factors. The main effect for Type was not significant, $F(1, 55) = 1.800$, $p = .185$, $\eta_p^2 = .032$. The main effect for Direction was not significant, $F(1, 55) = 2.178$, $p = .146$, $\eta_p^2 = .038$. The interaction between Type * Group was not significant, $F(1, 55) = .334$, $p = .566$, $\eta_p^2 = .006$. The interaction between Direction * Group was not significant, $F(1, 55) = 2.499$, $p = .120$, $\eta_p^2 =$

.043. The interaction between Type * Direction was not significant, $F(1, 55) = .021$, $p = .885$, $\eta_p^2 = .000$. The three-way interaction between Type * Direction * Group was not significant, $F(1, 55) = .151$, $p = .699$, $\eta_p^2 = .003$. See Figure 2.

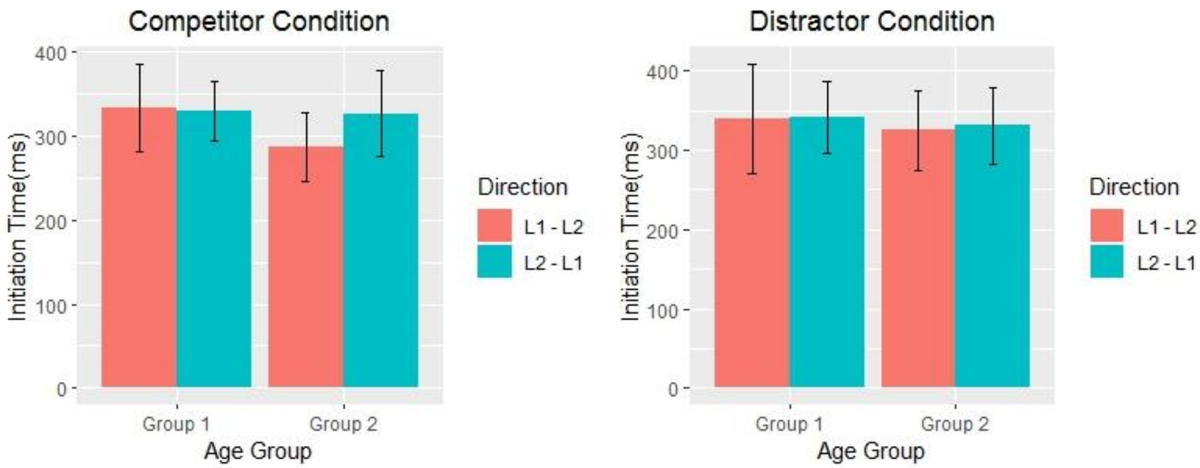

Figure 2.2: Initiation Time of the participants in phonological competitor and distractor condition in both L1 – L2 and L2 – L1 directions. Participants initiated the mouse movement between 300 – 400 ms post auditory input onset.

2.4.2 Response Time

We performed 2x2x2 repeated measures ANOVA with Group (younger and older) as between subject factors, and Type (competitor and distractor) and direction (L1 – L2 & L2 - L1) as within subject factors. The main effect for Type was not significant, $F(1, 55) = .207$, $p = .651$, $\eta_p^2 = .004$. The main effect for Direction was highly significant, *** $F(1, 55) = 15.289$, $p < .001$, $\eta_p^2 = .218$. Pairwise comparison showed highly significant ($p < .001$) difference between the direction of activation. When the phonological input was in L1 and the unselected image name was in L2 (either phonologically matching or non-matching), participants responded faster ($M = 1779.804$ ms, $SE = 38.093$ ms) than when the phonological input was in L2 ($M = 1821.600$, $SE = 37.072$)

and the image name was in L1 (either phonologically matching or non-matching). The interaction between Type * Direction was significant, ** $F(1, 55) = 10.584$, $p = .002$, $\eta_p^2 = .163$. Pairwise comparison showed that when the unselected response shared phonological similarity with the selected response, the participants were faster (M = 1795.435 ms, SE = 39.782) in responding when the spoken input was in L1 compared to when the spoken word was in L2 (M = 1800.041 ms, SE = 40.546 ms). Likewise, when the unselected response did not share phonological similarity with selected response, the participants responded faster (M = 1764.172 ms, SE = 3.271 ms) when the spoken input was in L1 compared to when the spoken input was in L2 (M = 1843.158 ms, SE = 35.485 ms). The interaction between Type * Group was not significant, $F(1, 55) = .284$, $p = .592$, $\eta_p^2 = .005$. The interaction between Direction * Group was not significant, $F(1, 55) = .291$, $p = .592$, $\eta_p^2 = .005$. The three-way interaction between Type * Direction * Group was not significant, $F(1, 55) = .432$, $p = .514$, $\eta_p^2 = .009$. See Figure 3.

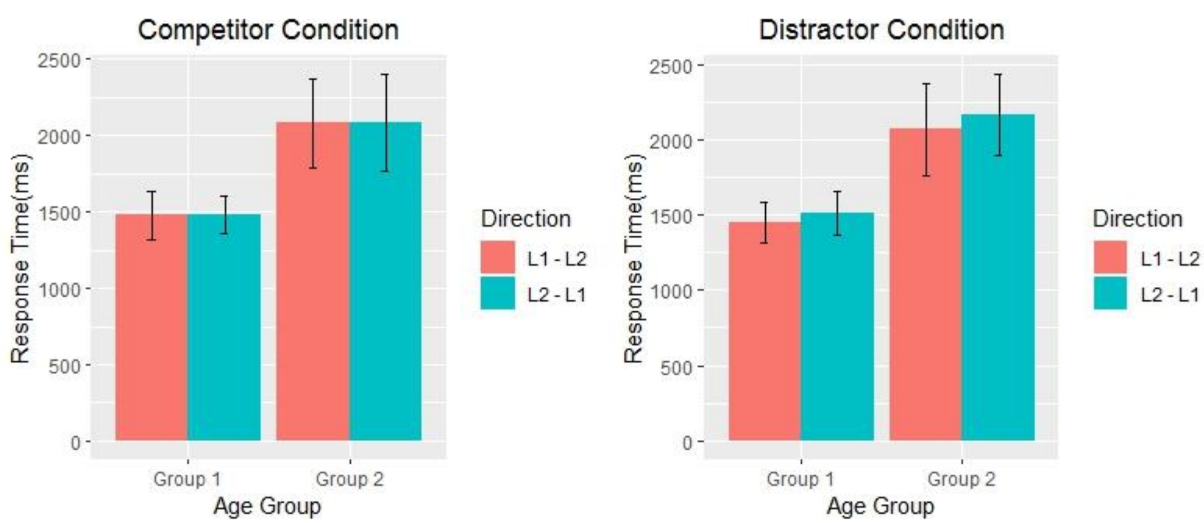

Figure 2.3: Response Time of the participants in phonological competitor and distractor condition in both L1 – L2 and L2 – L1 directions. Participants responded faster in L1 – L2 direction compared to L2 – L1.

2.4.5 Area Under the Curve (AUC)

Coordinate-to-coordinate t-test for X-Coordinates in different conditions was done to compare competitor and control curves, and significant difference ($p < .05$) on eight consecutive coordinates was considered a reliable divergence (Bartolotti & Marian, 2012). There was no significant difference ($p > .05$) in the mouse trajectory deviation between phonologically matching (competitor condition) and non-matching (distractor condition) response conditions in group 1 in L1 – L2 direction whereas in group 2 there was no significant difference in deviation toward unselected response in both the directions (L1-2 and L2 – L1). The coordinates where there was significant deviation of the mouse trajectories toward the unselected response is given in Table 2. See Figure 6 for visual representation of X-Coordinates.

Table 2.2: X-Coordinates that showed significant cursor deviation towards unselected response in both the groups in different conditions and directions.

Group 1	Group 2	Coordinates where $p < .05$
Competitor L1-L2	Competitor L1-L2	21-67
Competitor L1-L2	Competitor L2-L1	28-73
Competitor L1-L2	Distractor L1-L2	23-71
Competitor L1-L2	Distractor L2-L1	23-70
Competitor L2-L1	Competitor L1-L2	18-63
Competitor L2-L1	Competitor L2-L1	27-68
Competitor L2-L1	Distractor L1-L2	20-68
Competitor L2-L1	Distractor L2-L1	22-68
Distractor L1-L2	Competitor L1-L2	21-64
Distractor L1-L2	Competitor L2-L1	30-72
Distractor L1-L2	Distractor L1-L2	23-70
Distractor L1-L2	Distractor L2-L1	23-69
Distractor L2-L1	Competitor L1-L2	21-60
Distractor L2-L1	Competitor L2-L1	28-68
Distractor L2-L1	Distractor L1-L2	22-66
Distractor L2-L1	Distractor L2-L1	21-67

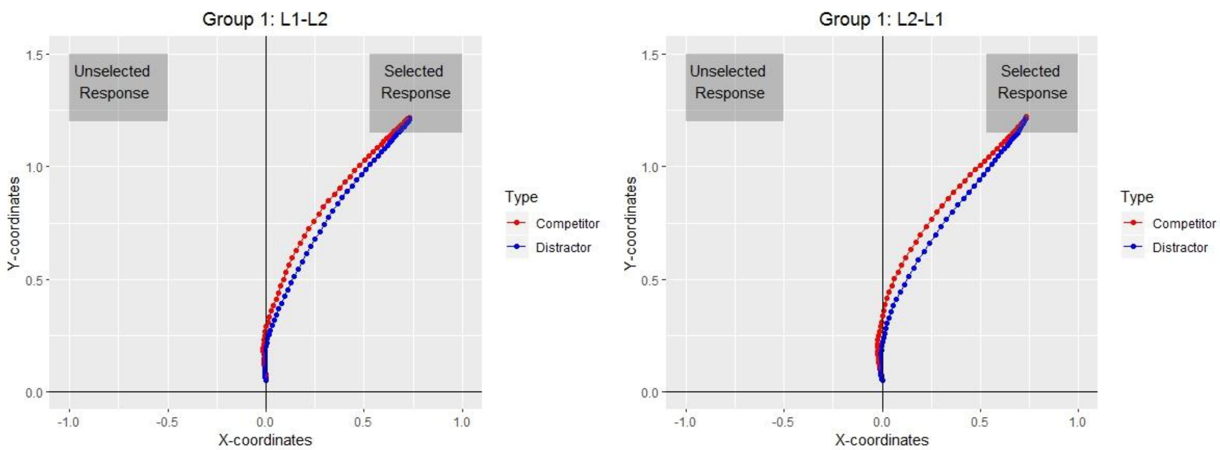

Figure 2.4: Graphic user interface of mean trajectories in group 1 in competitor and distractor condition in both the language directions.

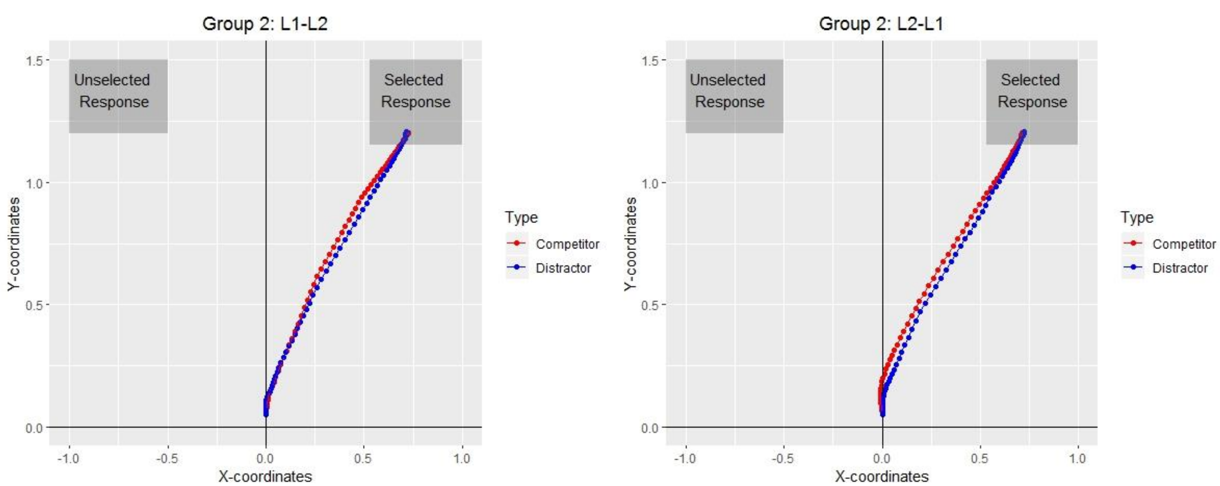

Figure 2.5: Graphic user interface of mean trajectories in group 2 in competitor and distractor condition in both the language directions.

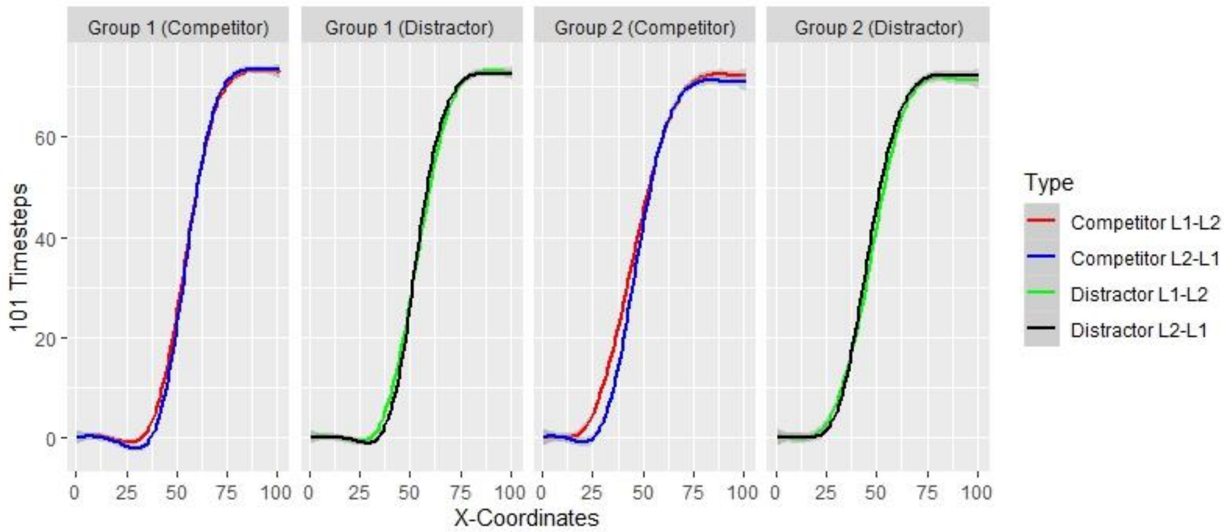

Figure 2.6: Group wise mouse movement in 100 Time steps of 101 X-Coordinates in both condition types and language directions.

2.5 Discussion

This study attempted to explore language dominance mediated parallel activation leading to language non-selective activation using mouse movement kinematic control in Gurung – Nepali bilinguals in audio-visual language processing. The participants listened to a spoken word either in L1 or in L2 as they initiated mouse movement toward the visual display containing a referent to auditory input and a distractor which did or did not share a phonological similarity to the referent. The participants were asked to mouse-click on the picture referent matching with the spoken word auditory input. Response time analysis showed that the participants responded faster when the auditory input was in L1 when compared to the auditory input in L2. Type by direction interaction showed that when the unselected response shared phonological similarity with the selected response (in competitor condition), the participants were faster in responding when the spoken word was in L1 when compared to the spoken word in L2 which indicated that the L1 spoken input activated the phonological cohort mediated L2 unselected lexicon through the corresponding image faster than the L2 spoken input activating the phonological cohort mediated L1 unselected lexicon. Likewise, when the unselected response did not share phonological similarity with selected response (in distractor condition), the participants responded faster when the spoken input was in L1 when compared to the spoken input in L2. This showed that whether the manipulation of experimental condition was in competitor or distractor condition, participants' response latency was unidirectional and asymmetrical in which they responded faster in L1 – L2 direction compared to L2 – L1 condition.

This result is in line with the prediction of Inhibitory Control (IC) Model (Green, 1998) which predicts that switching from nondominant (L2) to dominant (L1) language takes longer which is also supported by Meuter and Allport (1999) study who found similar results. Interestingly, Inhibitory Control Model originally was proposed to predict language selection in bilinguals in language production which was measured by naming latency in switching task that showed switching in naming task from nondominant to dominant language took longer as participants had to inhibit dominant language longer. According to IC Model language schemas in bilinguals compete for output at lexical level where language control is reactive and inhibitory with dominant language receiving higher level of activation. The degree of inhibition that acts upon the nontarget language controls the response language which is modulated by the language schemas that get activated differentially. We have tested the prediction of IC Model proposed for language production in language comprehension mode. If the language schemas in bilinguals are organized in similar manner, we would expect that the prediction proposed for language production would hold true for language comprehension as well. So we would expect that when the participants listened to the spoken input where the referent image on the screen shared onset similarity with the word activated by the nonselective image, the participants would experience activation of the lexicon from both the languages and their speed of resolution of the competition in language selectivity would be modulated by the language dominance. Our participants responding faster in L1 - L2 direction compared to L2 – L1, that is from dominant to nondominant language is an evidence of participants experiencing less inhibition compared to when they responded from nondominant to dominant language.

What drives language control in bilinguals? The answer is provided to some extent by Adaptive Control Hypothesis (Green & Abutalebi, 2013) which outlines three patterns of everyday conversational contexts in bilinguals: dual language, single language and dense code switching contexts which interact with eight cognitive control processes of goal maintenance; interference control: conflict monitoring and interference suppression; selective response inhibition; salient cue detection; task disengagement; task engagement and opportunistic planning. Of these, only opportunistic planning interacts with dense code-switching context; goal maintenance and interference control with single language context and all seven (except opportunistic planning) interact with dual language context. In single language context, bilinguals use one language in one language environment and another in another environment maintaining distinct interaction. In dual language context, bilinguals use both the languages with different speakers, and may switch language within a single conversation but won't do so within an utterance (our participants were from this context). In a dense code-switching context, the speakers have a tendency to routinely interleave their languages even within a single utterance to adapt and intermix words from either of their two languages. The eight cognitive control processes are both proactive and reactive (Baver, 2012; Briscoe & Gilchrist, 2020) in nature. Goal maintenance, conflict monitoring and opportunistic planning are proactive in nature whereas others are more of reactive in nature. For example, reactive control process such as salient cue detection triggers task disengagement and leads to task engagement via selective response inhibition. The control processes keep cascading during interaction. In our study which tested language comprehension in parallel language activation paradigm, we asked the participants to listen to the spoken word and mouse-click the picture on the computer screen that matched with the spoken word. They had to recruit their proactive control by maintaining this goal of listening to the auditory input and matching its semantic feature with one of the pictures displayed on the screen. When they heard the spoken word and looked on the screen at the image that also activated nontarget phonologically matching word on the opposite side of the target image, they faced interference as a result of onset activation of both the words phonologically matching with each other. Now they have to control the interference by monitoring the conflict posed by phonological match and suppress the interference with the help of salient cue detection from the features of the target image that build up the meaning of the auditory input and exert selective response inhibition toward the image posing the phonological competition and disengage from the task of moving the mouse toward the unselected response and engage in the task of moving mouse toward the target image and resolve the conflict by clicking on the target image.

Researchers across different labs have used different tools and paradigms to investigate language selectivity in different population of bilinguals. Four areas of the brain have been reported to be consistently recruited during language selection and switching: the anterior cingulate cortex, the prefrontal cortex, the inferior parietal lobule and the basal ganglia (Abutalebi et. al, 2008; Abutalebi & Green, 2007; Blanco-Elorrieta & Pylkkanen, 2015). Abutalebi and colleagues (2008) investigated neural correlates of language selectivity using fMRI picture naming task in German – French bilinguals and found that language control processes that require both the languages to be active recruit left caudate and anterior cingulate cortex. Blanco-Elorrieta &

Pylkkanen (2015) examined the brain bases of language selection using MEG in script and cultural context in Arabic – English bilinguals and provided the characterization of spatio-temporal profile for language selection which are cued naturally in which robust sensitivity to cue type was seen at 150 – 300 ms with amplitudes enhanced to cultural trials at anterior cingulate cortex and observed a mismatch effect for both script and cultural context cues at 300 – 400 ms in the left inferior prefrontal cortex. Marian and colleagues (2014) compared English monolinguals and Spanish – English bilinguals on an fMRI language selectivity task in which the participants searched for a picture matching with aurally presented spoken word from an array of visually presented four images. They found activations in monolinguals, but not in bilinguals, at the executive control regions of anterior cingulate cortex and superior frontal gyrus when faced with within-language competition. The authors concluded that the differences in managing competition resulted from the bilinguals deploying neural resources more efficiently. Blumenfeld and colleagues (2016) compared younger and older English – Spanish bilinguals and English monolinguals on linguistic and nonlinguistic inhibitory control eye tracking tasks. In linguistic task, participants heard a spoken a word and identified the visual referent among the four pictures where target picture appeared in phonologically matching condition (cat vs cab) and non-linguistic Stroop task was used to measure inhibitory control. Their results for the speed of processing showed bilinguals have smaller activation as well as inhibition in changes related to age compared to the monolinguals suggesting that bilinguals exhibit more consistency for competition resolution and recruit cognitive control throughout their life span compared to monolinguals. Mishra and Singh (2014) examined spoken and written parallel activation of bilingual lexicon in an auditory and visual word processing eye tracking study in Hindi – English sequential bilinguals. Participants listened to the spoken words either in L1 or L2 and looked at an array of written words containing translation equivalent of the spoken words which were presented simultaneously. They found that bilinguals can automatically activate non target words bidirectionally - in both L1 – L2 and L2 – L1 as measured by their orientation of attention in the direction of phonological neighbor of the translation equivalent in comparison of the distractors showing spreading activation of related words. Further, Mishra and Singh (2016) investigated parallel language activation with proficiency as independent variable in high and low proficient Hindi – English bilinguals using eye movement paradigm. Participants listened to the spoken words either in Hindi (L1) or English (L2) and looked at the display which consisted of line drawings representing phonological cohort of the translation equivalent of the spoken words and distractors not related to the cohort. They found earlier and higher activation of phonological competitor when compared to the distractors in the high proficient bilinguals and the activation was higher in both of the groups in the direction of L2 – L1 showing language non-selective access of translation equivalent in both language direction but higher in L2 – L1 for bilinguals with both high and low proficiency in Hindi and English. In our study, we have extended previous researches and explored novel methodology with previously unstudied sample of population. We have used MouseTracker (Freeman & Ambady, 2010) to investigate language non-selective activation in Gurung – Nepali younger and older bilingual population. Our design is similar to the one used by Spivey and colleagues (2005). Spivey, Grosjean and Knoblich (2005) recorded continuous hand movement response in a visual context as the participants comprehended spoken instruction. They presented the participants with two colour objects on the upper right and left corners of the computer screen in cohort (candle, candy) and control (candle, jacket) conditions. In a match-to-sample procedure, they were instructed through a prerecorded speech file to click one of the pictures matching with the speech file with a mouse. After they clicked the START box at the bottom center of the screen with a mouse, the picture display would appear followed by the speech file after a delay of 500 ms of the onset of the visual display. Mouse movement trajectory showed the trajectory in the cohort condition travelled further up than the trajectory in the control condition and equidistant from the two objects for longer period. The proximity of the target and the distractor can be treated as an index of the activation of competing lexical representations mediated by acoustic priming. In our design, we used black-and-white line drawings (as in Mishra & Singh, 2016; also used in Marian group and others) instead of the color drawings used by Spivey and colleagues. Whereas Spivey and colleagues tested within-language, we tested in between-language condition. In our study, participants listened to the spoken word either in Gurung (L1) or Nepai (L2) upon clicking the START button and move the mouse to make response by clicking on of the pictures that matched with the spoken word. Our participants showed greater activation from L2 – L1 direction as shown by longer response latency compared to from L1 – L2 which is also the prediction made by Inhibitory Control Model (Green, 1998) as discussed earlier. Our finding on language comprehension is analogous to the language production finding of Tsui and colleagues (2019) who investigated the phonetic transfer differences in Chinese – English adults bilinguals with language dominance profiles at various levels and degrees: English-dominant, Cantonese-dominant and balanced bilinguals measuring voice onset time which showed different language switching responses between balanced and unbalanced bilinguals. They observed that language switching did not affect the speech production in balanced bilinguals, whereas unbalanced bilinguals, while producing their language in dominant language, made a shift toward their nondominant language. Their results are consistent with the inhibitory control model that suggests when unbalanced bilinguals switch to spoken word production they incur an asymmetrical switch cost. We observed similar pattern in speech comprehension where the participants listened to the spoken words and matched the visual representation of the spoken word with the click of a mouse. Our results show participants were faster in responding from L1 – L2 direction, from dominant to nondominat language, rather than vice versa, further validating the prediction of inhibitory control model. Also as predicted by the adaptive control hypothesis, the participants faced competition by way of activation of phonological systems in both the language before they could disengage themselves from this activation through selective inhibition and reengage in the target word. Thus when the phonological activation was higher the response was sower compared to when they could resolve the conflict faster.

In our study, we have considered language dominance as independent variable. We believe this is an important issue in bilingualism. Investigating this issue deeper and wider may help in understanding and resolving the outstanding debates that exist currently in the field of bilingualism (Hilchey & Klein, 2011; Long et.al, 2019; Leivada et.al, 2020; Adesope et. al, 2010; Bak, 2016b; Bialystok, 2016; 2017; Blanco-Elorrieta & Pylkkänen, 2018; Costa & Sebastián-Gallés, 2014; Cox et.al, 2016; DeLuca et. al, 2018; 2019; Paap & Greenberg, 2013; Paap, Johnson & Sawi, 2015; Paap, 2018). Gathercole and colleagues (2014) investigated a large sample of Welsh – English bilinguals varying in different degrees of dominance in both the languages in fully fluent bilinguals from childhood through adulthood using three sets of executive and cognitive function tasks. They found mixed results and no clear evidence of bilingual advantage in this population and suggested for much closer scrutiny of what type of bilinguals, under what conditions and why do they demonstrate the reported effects. Previously, Gathercole and colleagues (2010) had studied the relationship between language dominance and bilingual advantage in Welsh – English bilingual and English monolingual children with various levels of language dominance among teenage and primary school age children on a tapping task, two executive function tasks and a Stroop task. They found mixed results which varied by task across different ages and dominance. Language dominance can be defined as the relative accessibility of each of the two languages of a bilingual speaker for language processing (Köpke & Genevska-Hanke, 2018) and it has to be noted that dominance and proficiency are related but they are not same and need to be treated as different constructs (Schmeißer, et. al, 2015). Studying bilingualism from dominance perspective on how it is modulated and how it further modulates other linguistic and cognitive measures may help address issues such as developmental language disorder (Thordardottir, 2015), experience and performance (Montrul, 2015), cross linguistic influence (Argyri & Sorace 2007), heritage speakers (Polinsky, 2008), metalinguistic awareness (Altman, 2018), L1 attrition (Köpke & Genevska-Hanke, 2018; Domenico & Baroncini, 2019). Sheng and colleagues (2014) examined divergence and convergence between objective and subjective measures of language proficiency in evaluating language dominance in Mandarin – English adult and children bilinguals using self-ratings of proficiency level, spoken proficiency, Boston Naming Test and Multilingual Naming Test (MINT) which converged among the people who were classified as different dominance groups whereas both naming tests showed greater L2 dominance (English) than indicated by interview and self-report measures. Our study further adds to this measurement of dominance using Bilingual Dominance Scale and mouse tracking measures of language comprehension in parallel language activation paradigm in cross modality context.

With this study, we believe, we have made some significant contribution in the field of bilingualism. Firstly, we have validated two dominant ‘theories’ in bilingualism: Inhibitory Control Model of Green (1998) and Adaptive Control Hypothesis of Green and Abutalebi

(2013) by extending the findings based on these 'theories'. Secondly, we have shown that the mechanism of bilingual processing that works in language production also works in language comprehension. Thus, suggesting an integrated and interactive mechanism that might modulate both the processes. Thirdly, we have replicated the results from parallel language activation from previous studies that used tools other than mouse tracking. Therefore, we have shown the methodological validity of the MouseTracker as a tool in the study of parallel activation in bilinguals' basic language cognition. Fourthly, our data is acquired from the language pair not studied before and the sample of population who had left school and were already engaged in their livelihood activities, which is unlike the sample in many such previous studies which are pooled and pulled out of college students.

There are some limitations in our current study that we would like to acknowledge which should be rectified in future studies. Firstly, mouse tracking as a tool is amenable for acquiring data from literate population who are familiar with the architecture of computer application and are familiar with the movement of the mouse while making response. We acquired data from older participants who had to be trained first so that they could make response like other participants and would not confound our results. Secondly, in order to study language dominance in bilinguals, we need to incorporate language production like picture naming or verbal fluency task and cognitive control tasks like bilingual Stroop and Flanker tasks (see for example, Pathak, et. al, 2021) to get a comprehensive picture of the dominance.

Chapter 3: Second language immersion and its effect on first language attenuation

Fifty five participants from Nepal studying in India, divided into two groups with L2 immersion duration of one year and 3 years participated in language comprehension and language production experiments. In language comprehension, we tested the participants in lexical access task in parallel language activation paradigm in mouse-tracking bimodal experiment which measured the initiation time and response time as the participants made response with the mouse click. Production task measured the participants' ability to generate number of exemplars from the given letter or category in verbal fluency task. Unlike previous studies, we didn't find attenuation and attrition effect of L2 immersion on L1 where participants performed equally on both the languages. We discuss our results from convergence perspective of L1 and L2.

3.1.1 Introduction: Effect of immigration and immersion in bilingual processing

Immigration to a foreign land where an individual is faced with a situation to communicate in a language other than their native creates a situation of immersion in L2 or foreign language and involves an interaction of multiple variables (Jia, Aaronson & Wu, 2002). A situation like study abroad experience affects language control in bilinguals (Tokowicz, Michael, & Kroll., 2004). In bilingual language processing literature, immersion is reported as inducing bilingual disadvantage by way of attenuating L1 and causing L1 attrition (Baus et al, 2013; Linck, Kroll & Sunderman, 2009; Mok & Yu, 2017). A seminal study on the effect of L2 immersion on L1 is by

Linck and colleagues (2009) comparing L1 English learners of Spanish L2 in a classroom context in home country US and immersed context in host country Spain. The authors tested their participants on two linguistic tasks of comprehension (translation recognition) and production (semantic verbal fluency task) and two cognitive tasks (Simon and reading span task). They found that the L2 immersed participants performed more poorly on both comprehension and production task compared to classroom participants. The authors account for this processing cost to the global inhibition of L1 during immersion in L2. Baus, Costa and Carreiras (2013) further extended Linck et al (2009) study to complement their findings on L1 attenuation as a function of L2 immersion. In line with Linck et al (2009) account for L1 attenuation, they proposed two mechanisms of potential origins for bilingual disadvantage in relation to immersion: (a) interference experienced from the L2 of the bilingual and/or (b) reduced frequency in the L1 use. They conducted a longitudinal study on 50 German native speaker undergraduate students as experimental group who attended University of La Laguna in Spain for one semester as ERASMUS students who were immersed in Spanish language during the course of their study. The control group sample consisted of 20 native Spanish speakers recruited from the same university. Temporally, they compared Arrival testing period (first month) and Departure testing period (last month) on picture naming and semantic fluency tasks. The authors found the German native speakers to be slower in their L1 in picture naming on being immersed for few months in Spanish. The participants' ability to retrieve and use low frequency L1 cognate words declined in four months toward the end of immersion period showing a local attenuation of L1. But there was no such difference in semantic fluency task. The authors are not able to explain the inconsistency in the semantic fluency result with previous study, however, they point out to the difference to be likely in their longitudinal vs previous transversal nature of studies.

Mok and Yu (2017) investigated the immersion effects on bilingual mental lexicon using translation and semantic priming on Mandarin – English bilinguals in a sample of 19 immersed (in Chicago, US) and 24 non-immersed (in Hong Kong, China) participants. The non-immersed participants had majored in English in their undergraduate and were pursuing MA in Linguistics and were Mandarin dominant. The immersed participants were Mandarin speaking heterogeneous group who were immersed in their L2 from 3 months to four years. The authors did not find evidence for 'bilingual disadvantage' as the asymmetrical processing was weakened in the immersed participants as there was no difference between the two group's performance. Even though the authors started with the aim of discovering bilanguage disadvantage as found in the previous studies, instead, they found an immersion mediated advantage.

Nanchen and colleagues (2016) investigated the effect of immigration and immersion on elderly (70s) demented population who spoke Swiss German as their L1 and had acquired French as L2 after the age of 7 and compared them with age and bilingualism matched healthy bilingual control group. The authors tested their participants on various aspects of language production and oral comprehension in both of their the languages using a range of cognitive and neurolinguistics tasks, drawing mainly from Boston Diagnosis Aphasia Evaluation (BDAE) (Mazaux, 1983) and Bilingual Aphasia Test (BAT) (Paradis, 2011) that included verbal discrimination subtest, order of execution oral naming and performances in automatic language from BDAE, repetition of words and non-words, repetition of sentences from BAT, syntactic comprehension, and verbal fluency test from Isaacs SET test (Isaacs & Kennie, 1973). They found a significant correlation between L2 relative performances and immersion in L2 showing relative sparing of syntactic L2 comprehension in individuals with dementia. The authors suggest that the elderly people living in a host country for many years may preserve both of their L1 and

L2 irrespective of whether neurodegenerative disease is present or not and they preserved some features of L2 processes in dementia.

Thus, previous studies show there is no clear picture about the exact effects of immersion in bilingual processing. There is no consistency in the tasks administered, the background of sample of population, the duration of immersion, whether immersion always induces attrition to L1 and reflect bilingual disadvantage or does it add advantage to both or either of the two languages of a bilingual. We were interested in exploring this issue further and extend the previous studies by investigating the processing effects on both L1 and L2 speech comprehension and production modulated by immersion.

3.1.2 Theoretical Perspectives

Processing of spoken word comprehension in bimodal situation and cross-linguistic parallel activation is predicted by BLINCS Model (Shook & Spivey, 2013) that integrates both auditory and visual information. According to this model, from bottom up, phonological input enters the system feeding upward to the phono-lexical level and feedback from the semantic down to the phono-lexical level increases activation of the items present in visual display. For example, according to this model, the presentation of Nepali word *nangra* (claw) with the picture of a 'nurse' results in activation of both phonologically related L1 *nangra* and L2 'nurse' but not phonologically unrelated L2 'tape'. This model also predicts the time-course of overall activation of the process of speech comprehension, allowing to trace the activation lexical items while the speech unfolds. In our study, we would expect different activation curve in mouse movement trajectories for phonologically related and unrelated items. For example, when the participants heard L2 duck and saw the picture of a duck and a ladle (*dadu*, L1 phonologically related distractor) displayed on the screen, it would increase the activation as the mental lexicon system would compete for selection of either of the onset matching words, so much so, the process can begin even with the presentation of word's initial phoneme (FitzPatrick, & Indefrey, 2010) and the activation level would remain till the point it is resolved, upon recognition of the actual target image. We would not expect such activation when the duck was paired with phonologically unmatching word in L1 *dhaan* (paddy) as the onset phoneme in L2 target word is an alveolar and the L1 distractor is a dental and since there is no phonological competition, the mouse trajectories deviate toward the target earlier than when there was a competition.

Adaptive Control Hypothesis (Green & Abutalebi, 2013) makes prediction about language control in bilinguals. This hypothesis views language control as an interaction between three conversational or interactional contexts and eight cognitive processes. The three interactional contexts are: dual language, single language and dense code switching contexts, and the eight cognitive control processes are: goal maintenance, interference control - conflict monitoring and interference suppression, selective response inhibition, salient cue detection, task disengagement, task engagement and opportunistic planning. ACH predicts parallel language activation, "If both languages are active and compete for selection, then demand on processes associated with goal maintenance, conflict monitoring, and interference suppression may be high across all contexts" but specially so in dual language context like our participants who used both the languages with different speakers occasionally switching between languages within the same conversation (with L1 speakers, not with L2) but not within an utterance. Drawing on the study of Hommel and colleagues (2011), this hypothesis links the control states required for the types of thinking and the states required for bilingual speakers and those required between monolinguals and bilinguals. Since controlling the interference between two languages develops control state which is akin to and conducive to convergent thinking in dual language contexts (inimical to divergent thinking as in monolinguals). Linking this prediction of ACH, we would expect our participants to have enhanced their proficiency with regular practice of both the languages, to such an extent that the linguistic systems of both the languages converge into each other and the speakers don't feel so much of interference from either of their two languages. The authors argue that the conversational practices adopted by the speakers are along the lines the interactional context that suits them and by doing so they minimize the interactional cost. This cost avoiding ability is constrained by their proficiency in both the languages which also leads to relatively stable adaptive changes. The authors point out that the increase in proficiency of the speakers in dual and single language contexts is associated with the increased skills in controlling interference. In our investigation, if our participants had achieved a relative stability in their proficiency in L2, to the degree of their L1, they would be more skilled in controlling interference from either of their languages and their performance would not deteriorate in either of their languages.

Previous studies on the effect of L2 immersion on L1 have been conducted in WEIRD (Western, Educated, Industrialized, Rich and Democratic) contexts which have been criticized on the ground that they don't reflect majority of world population (Henrich et al, 2010; Arnett, 2008). A need to go beyond this population is felt strongly in the related fields of human sciences like psychological sciences, cognitive sciences, social sciences and brain sciences (Baur, 2020; Muthukrishna et al, 2020a; 2020b; Pathak et al, 2021; Pathak & Pathak, 2022). Our study is conducted on non-WEIRD population and context, so our study makes contribution to the field of bilingualism from this perspective as well.

3.1.3 Parallel language activation and cognitive/attentional control

Parallel language activation in bilinguals as ubiquitous phenomena has been well established by several studies in recent years conducted across various designs and paradigms. Bilinguals have been found to unconsciously and unintentionally activate both the phonological and conceptual structures of non-target language at phonological level (Marian & Spivey, 2003), orthographic level (Thierry & Wu, 2010; Singh & Mishra, 2014), syntactic and semantic level (Chambers & Cook, 2009) and the co-activation is modulated by several factors like context (Blumenfeld & Marian, 2007; Chambers & Cook, 2009), proficiency (Singh & Mishra, 2013; Mishra & Singh, 2016), immersion (Linck, Kroll & Sunderman, 2009; Spivey & Marian, 1999), interlocutor identity (Molnar, Ibanez-Molina & Carreiras, 2013), verbal working memory load (Prasad & Mishra, 2021) and permeates across dissimilar language typology like Japanese and English (Hoshino & Kroll, 2008) and modality like signed and spoken languages (Emmorey et al, 2008).

In order to meet the expected and desired linguistic needs bilinguals are likely to recruit regularly domain-general mechanisms of cognitive control for auditory recognition when they are faced with largely bigger cohort of similar sounding spoken words. In the environment of everyday interactions, bilinguals experience the permeation of conflict resolution and interlinguistic activation and conflict resolution in their receptive bilingual language processing mechanism (Blumenfeld & Marian, 2013). High proficient bilinguals outperform less proficient bilinguals (or monolinguals) in a host of cognitive tasks by transferring the skills acquired in language switching tasks to task switching tasks (Prior & Gollan, 2011), being better at conflict monitoring and resolution (Singh & Mishra, 2013). Parallel language activation phenomena in bilinguals is being used to investigate both literacy and orality processing by bilinguals. Peleg and colleagues (2019) investigated crosslinguistic phonological effects on visual-word recognition task in Arabic-Hebrew bilinguals who were proficient readers of literary Arabic (LA) as well as native speakers of spoken Arabic (SA) and Hebrew both, asking their participants to perform the visual lexical-decision task in within-language and between-language design. They obtained phonological effects from SA to LA (within-language) but not from Hebrew to LA (between-language). They found inhibitory effect in within-language activation and facilitatory effect in between-language activation. Zhang and Samuel (2018) explored the cognitive load effect on initial lexical access as well as later lexical competition. They used semantic association task to test the performance with or no additional cognitive load which used cognitive resources in relation to general or task specificity in phonological processing. They found that the initial access of lexical item is rather automatic but maintaining lexical candidates in competition requires cognitive resources which are specific to phonological processing. In our study we were interested in knowing how the phonological processing will operate in lexical competition among participants who were immersed in their L2 over a certain duration.

3.1.4 Mouse tracking as a tool for studying linguistic and cognitive processing

Mouse tracking is a tool for doing psychological science by hand (Freeman & Ambady, 2010; Freeman, 2018). It is a novel paradigm that measures the continuous flow of dynamic cognitive processing and captures the graded flow of information from cognition to action (Spivey, Grosjean & Knoblich, 2005; Freeman & Ambady, 2010; Dale & Duran, 2011; Barca et al, 2015). Several psycholinguistic studies have been conducted using mouse-tracking paradigm like spoken word recognition by tracking the temporal dynamics of lexical activation (Spivey et al 2005), sexual orientation based on voice categorization of speakers (Sulpizio et al, 2015), parallel activation of syntactic representation (Farmer et al, 2007a; 2007b), accent and race categorization (Paladino & Mazzurega, 2019), resolving lexical ambiguity (Lee, , Kaiser, &

Goldstein, 2019), language processing in autism (Vulchanova et al, 2019), child language processing (Krueger & Storkel, 2020), sentence processing (Darley, Kent & Kazanina, 2020). In recent times, it has emerged as a powerful tool in conducting behavioral studies among bilinguals. Researchers have investigated various issues in bilingualism: cross-linguistic sentence processing (syntactic transfer) in bilinguals (Morett & Macwhinney, 2012), bilingual advantage in executive control (Incera & McLennan, 2015), measuring the timing of bilingual advantage (Incera, 2018), taboo word processing by bilinguals (Incera et al, 2020), inhibitory control and lexical interference (Zhao et al, 2020), cross-linguistic grapheme influence (Hevia-Tuero, Incera, & Suárez-Coalla, 2021), investigating foreign accents (McGuffin, Incera, & White, 2021), linguistic and cognitive effect of second language instruction on first language (Pathak et al, 2021), understanding the dynamics of human cognitive mechanisms (Pathak, 2017), testing bilingual Stroop effect (Pathak & Pathak, 2022).

Considering the efficacy of mouse tracker in studying bilingualism, we used it as our main tool in investigating parallel language activation in language comprehension among immigrant university students immersed in second language.

3.1.5 Ethical consideration

The study proposal was reviewed and approved by the Institutional Review Board constituted by School of Medical Sciences, University of Hyderabad.

3.1.6 The current study

Given that the studies conducted on immigrants who are immersed in their L2 have produced mixed results in various linguistic and cognitive tasks, especially in the studies conducted in western contexts, we were interested in knowing whether immersion in L2 will modulate and attenuate the L1 of young adults who temporarily migrate to a foreign country in the same region in South Asia. We hypothesized that if the L2 immersion attenuated L1, our participants would perform poorly on the linguistic and cognitive tasks in L1 compared to L2, whereas if it did not have attenuating role the L1 performance will remain unaffected. Bilingualism is found to confer cognitive advantage on the individuals who speak more than one language (Blumenfeld & Marian, 2013). However, immersion in L2 is seen as conferring disadvantage to the speakers' L1 as the global inhibition of L1 and activation of L2 over a long period of time changes the lexical and neural architecture (Dijkstra & Van Heuven, 2002; Costa & Pickering, 2018; Hayakawa & Marian, 2019). Our participants had sufficient duration of immersion to bring about a change in their neural and lexical architecture. The first group was immersed for about one year and the second group was immersed for over 3 years. If the immersion of just one semester in a foreign university could attenuate L1 as shown by previous two studies (Baus et al, 2013; Linck et al, 2009) our participants should replicate similar effects if immersion played exclusive role in L1 attenuation. So if immersion was a predictor for L1 attenuation, we would expect our participants to produce less number of words in L1 compared to their L2 in language production task and face more competition from L2 in language comprehension and lexical access for selection and as a function of this we would see a difference in the processing of L1 and L2.

We wanted to test the effect of immersion in language production and comprehension both. In order to test language production, we used verbal fluency task in both L1 and L2 as used by previous studies in L2 immersion (Baus et al, 2013; Linck et al, 2009; Nanchen et al, 2016) to compare their result with ours. We used parallel language activation paradigm to test online language comprehension in both L1 and L2.

3.2 Methods

3.2.1 Participants

55 undergraduate and post graduate students (Mean age = 21.7 years, SD = 2.2 years) from Nepal studying engineering and management in an engineering and technology college in Chittoor district of Telangana state in India participated in this study. All the participants spoke Nepali as their L1 and English as their L2. They had acquired Nepali naturally in home context (Mean L1 AoA = 2.1 years, SD = 0.6 year) but had acquired English (Mean L2 AoA = 4.9 years, SD = 2.1 years) as their language of education from school level onwards. At the time of this study, all the participants were immersed in their L2 as this was the main language used in the classroom and outside among students from different regions and countries. The participants were divided into two groups based on their duration of immersion. The low immersion first group (Mean age = 21.9 years, SD = 2.9 years) was freshly arrived group of students (n = 25) whose mean duration of stay was 13.5 months (SD = 6.1 months) and the high immersion second group (n = 30) had stayed for longer duration (Mean = 37.5 months, SD = 5.32 months) whose mean age was 21.5 years (SD = 1.3 years). All the participants were healthy, right handed, had normal or corrected vision.

All the participants filled up a language history questionnaire, adapted from LEAP-Q (Marian et al, 2007), that had questions on their immigration status, their parental education (proxy for SES), primary and secondary language measures such as AoA in L1 and L2, fluency acquisition in L1 and L2, literacy acquisition in L1 and L2, literacy fluency acquisition in L1 and L2, self-rated proficiency (out of 10) in listening, speaking and reading skills in L1 and L2, factors like interacting with family and friends, reading, learning at school and watching TV that contributed to their learning of L1 and L2, their current exposure to their L1 and L2 in interacting with their family and friends, reading and watching TV and degree of use of their L1 and L2 in their college or work place (see Table 1 for the detailed scores on these measures).

The participants were briefed about the study before they participated (but were not told about the experiments). All the participants gave written informed consent to participate in the study.

The data was collected in a quiet room in the hostel premises of the students. All the participants completed LexTALE test, mouse tracking experiment on parallel language activation, phonetic and semantic verbal fluency task.

Measures	Full Sample	Low Immersion (Group 1)	High Immersion (Group 2)
Sample Size	55	25	30
Demographics:			
Age (Years)	21.7 (2.2)	21.9 (2.9)	21.5 (1.3)
Immigration status (stay in months)	26.6 (13.3)	13.5 (6.1)	37.5 (5.32)
Parental education*:			
Father (Scale 0-7)	4 (1.3)	4.2 (1.2)	3.8 (1.4)
Mother (Scale 0-7)	2.7 (1.6)	2.8 (1.4)	2.7 (1.6)
Primary Language Measures:			
Age of L1 Acquisition (years)	2.1 (0.6)	2.2 (0.8)	2 (0.2)
Fluency acquisition in L1(years)	4.4 (1.2)	4.5 (1.7)	4.3 (0.5)
Literacy acquisition in L1 (years)	4.7 (1)	4.6 (1.1)	4.8 (0.9)
Literacy fluency in L1 (years)	7.7 (2.1)	7.6 (2.4)	7.8 (1.7)
Self-rated Proficiency in L1 (Scale of 1-10)			
Speaking	8.5 (1.3)	8.8 (1.1)	8.2 (1.4)
Listening Comprehension	8.9 (1.1)	9 (0.9)	8.7 (1.2)
Reading	8.5 (1.6)	8.8 (1.4)	8.2 (1.6)
Factors that contributed to learning of L1 (Scale 1 - 10)			
Interacting with friends	9 (1)	9 (1.1)	10 (1)
Interacting with family	9 (1.2)	9 (1.7)	9.3 (0.7)
Reading	8 (1.8)	8.4 (1.4)	7.9 (2.1)
Learning at school	8.4 (1.5)	8.6 (1.3)	8.3 (1.7)
Watching TV	7 (2.3)	7.2 (2.3)	6.7 (2.3)
Current exposure to L1 context (scale 1 - 10)			
Interacting with friends	7 (2)	7.7 (1.8)	6.7 (2)

Interacting with family	6 (2.8)	6.9 (3.2)	5.5 (2.3)
At college/workplace	3.8 (2.7)	4.8 (3.1)	3 (2.1)
Reading	2.7 (2.9)	3 (3)	2.5 (2.8)
Watching TV	2.2 (2.6)	2.7 (2.9)	1.8 (2.3)
Secondary Language measures:			
Age of L2 Acquisition (years)	4.9 (2.1)	5 (2.7)	4.8 (1.5)
Fluency acquisition in L2(years)	10.4 (3.8)	10.2 (3.7)	10.5 (3.9)
Literacy acquisition in L2 (years)	5.9 (2)	5.8 (2.3)	5.9 (1.7)
Literacy fluency in L2 (years)	10 (2.9)	9.6 (2.9)	10 (2.9)
Self-rated Proficiency in L2 (Scale of 1-10)			
Speaking	7.5 (0.8)	7.8 (0.8)	7.3 (0.8)
Listening Comprehension	8.2 (1.2)	8.5 (1.2)	7.9 (1)
Reading	8.5 (1.1)	8.8 (0.9)	8.2 (1.1)
Factors that contributed to learning of L2 (Scale 1 - 10)			
Interacting with friends	7 (1.7)	7.2 (1.8)	6.9 (1.6)
Interacting with family	2.5 (2.3)	2.8 (2.4)	2.2 (2.3)
Reading	8.6 (1)	8.9 (1.3)	8.6 (0.8)
Learning at school	8.7 (1.2)	8.8 (1.3)	8.6 (1.1)
Watching TV	7.8 (1.7)	7.9 (1.3)	7.6 (2)
Current exposure to L2 context (scale 1 - 10)			
Interacting with friends	7.8 (1.7)	7.8 (2.1)	7.8 (1.3)
Interacting with family	1.8 (2)	1.8 (1.8)	1.7 (2.1)
At college/workplace	8.7 (1.1)	8.5 (1.3)	8.8 (1)
Reading	8.8 (1.1)	8.7 (1.4)	8.8 (0.9)
Watching TV	7 (3)	7.3 (2.8)	6.7 (3.1)

Table 3.1: Demographic profile and language background of the participants (Standard Deviation in brackets)

3.2.2 Materials, stimuli and design

In order to test the language comprehension in parallel language activation situation, we created an experiment in bimodal situation mixing auditory and visual stimuli in three conditions in both L1 and L2: phonological competition, distractor and filler with 48 trials in each condition. Altogether, there were 144 trials (48 x 3) in each language condition. The instruction given to the participants was to listen carefully to the spoken word and click the picture matching with the spoken word in each trial, in case there was no matching picture, they were instructed to click on either of the two pictures on display. In phonological condition, participants heard a spoken word either in their L1 or L2 and clicked on the target picture matching with the spoken word which had a picture that matched phonologically with auditory input on the opposite side of the computer screen. The trials in distractor condition had pictures on the opposite side of the target picture that did not match phonologically with the target picture. The pictures in the filler condition did not match with spoken word, so they could click on either of the picture on display for another trial to appear. The filler condition was excluded from the analysis. The pictures appeared on the top right or top left of the screen. All the pictures were counterbalanced. For example, in each condition, 24 target pictures appeared on the right side of the screen, 24 pictures appeared on the left side. All the trials were randomized across all the participants.

We used verbal fluency task to test language production. We used both phonetic and semantic verbal fluency tasks. In phonetic fluency, we asked the participants to create as many words as they can in 60 seconds from क, प, म in L1 and from F, A, S in L2. In semantic fluency they were asked to produce exemplars from animal, fruit, cloth. Vegetable and flower categories. They were asked not to use numbers, proper nouns, plurals and declensions of the same word while producing the exemplars.

3.2.3 Procedure

The mouse tracking experiment was designed in HP Pavilion g series laptop with 15.6 ‘screen. All the participants read and signed the written informed consent before participating in the experiment. Data was collected in a quiet room in the hostel premises of the students. Before participating in the main experiment, the participating were familiarized with the practice trials including all the conditions. Data from the practice trial is not included in the analysis. In the mouse tracking experiment, participants clicked on the START button in the bottom center of the computer screen with the mouse. Upon clicking the START button the participants heard the auditory stimuli and saw the visual stimuli on the screen simultaneously. They clicked on the picture matching with the spoken word in phonological competitor and distractor condition. In filler condition, they could click on any picture. We created these two response conditions so that the participants would think there are either pictures matching with spoken word or not matching with spoken word which would reduce the likelihood for them to notice the phonological relationship or overlap between the target picture and distractor picture (which either matched or did not match phonologically with target picture). Filler condition data were excluded from the final analysis. After making a response with mouse-click, the trial would change and a blank screen showing only the START button appeared. Participants had to initiate the mouse within 1000 ms, otherwise a message would appear asking the participants to move the mouse even if they are not sure of the response yet and the trial would be aborted. They were asked to click on the response button as fast as they can and as accurately as they can. The cut-off time for mouse initiation was set at 1000 ms. Inter trial interval was 1000 ms. (see Figure 3.1 for Trial Sample)

Verbal fluency task was also recorded in the laptop using Audacity software.

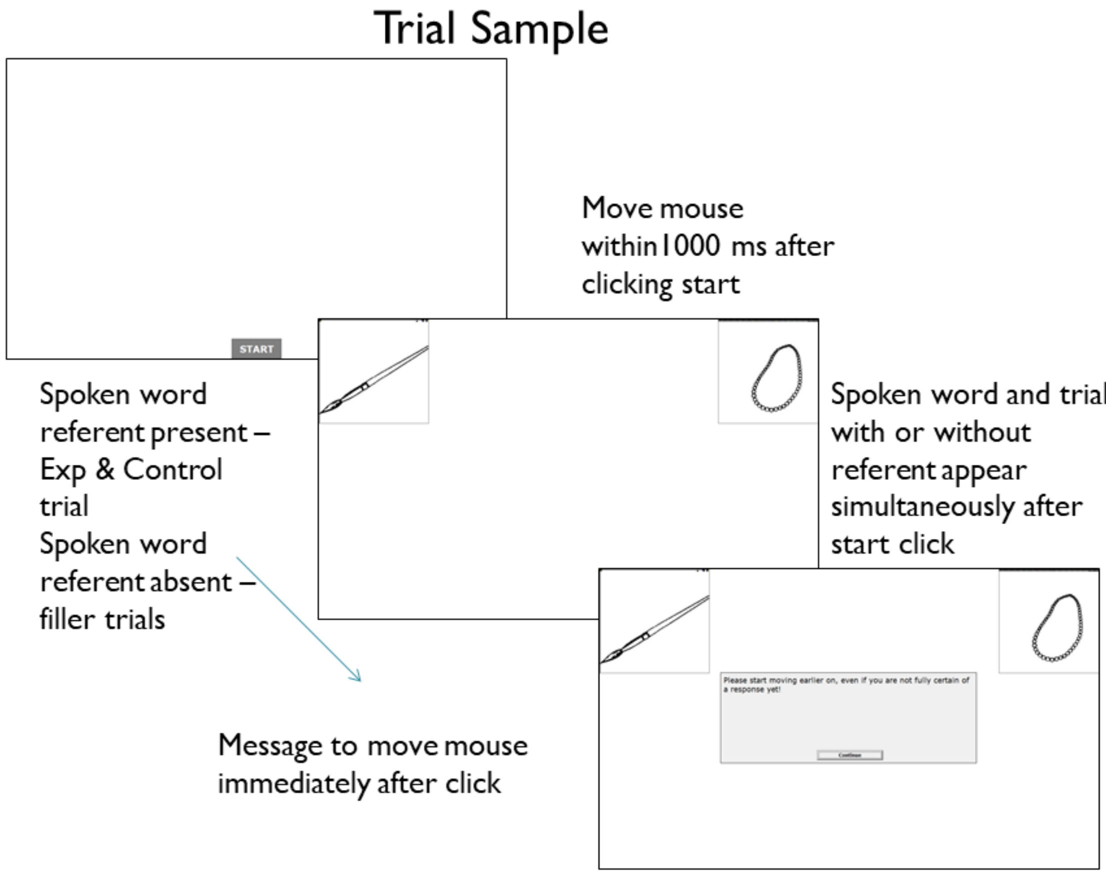

Figure 3.1: A sample of trial run

3.3 Results

3.3.1 Initiation Time

A subject wise 2 x 2 x 2 repeated measures ANOVA was performed with Language (L1 and L2) and Type (competitor and distractor) as within subject factors and Group 1 and Group 2 as between subject factors. The main effect for Language was not significant, $F(1, 53) = 2.059$, $p = .157$, $\eta_p^2 = 0.037$. The main effect for Type was also not significant, $F(1, 53) = .000$, $p = .987$, $\eta_p^2 = 0.000$. The Language x Type interaction was not significant, $F(1, 53) = .840$, $p = .364$, $\eta_p^2 = .016$. The Type x Group interaction was not significant, $F(1, 53) = .032$, $p = .850$, $\eta_p^2 = .001$.

The Language x Group interaction was not significant, F (1, 53) = 2.092, p = .154, η_p^2 = .038. The three-way Language x Type x Group interaction was not significant, F (1, 53) = .531, p = .470, η_p^2 = .010. See Figure 3.1.

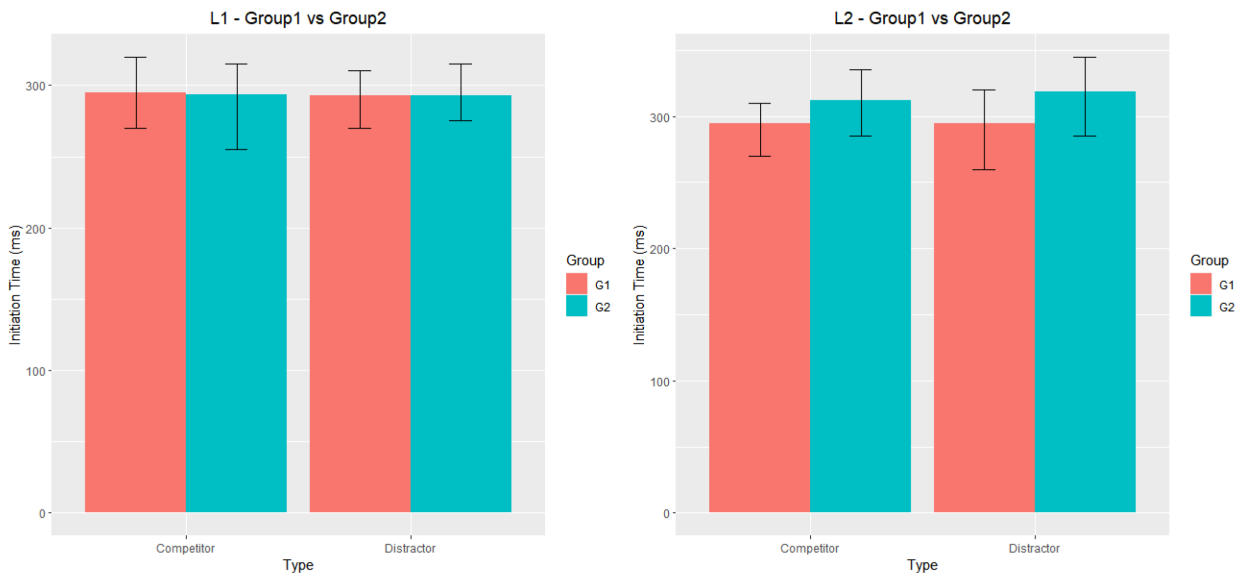

Figure 3.2: Initiation Time of the participants in phonologically competing and non-competing conditions

3.3.2 Response Time

A subject wise 2 x 2 x 2 repeated measures ANOVA was performed with Language (L1 and L2) and Type (competitor and distractor) as within subject factors and Group 1 and Group 2 as between subject factors. The main effect for Language was not significant, F (1, 53) = 2.384, p = .129, η_p^2 = 0.043. The main effect for Type was significant, F (1, 53) = 4.459, p = .039, η_p^2 = 0.078. Pairwise comparison showed a significant (p = .039) processing difference between competitor and distractor. The response latency for competitor was higher (M = 1260.035 ms, SE = 22.589 ms) compared to distractor (M = 1243.911 ms, SE = 22.735 ms). The Type x Group interaction was near significant, F (1, 53) = 3.820, p = .056, η_p^2 = .067. Pairwise comparison showed significant response latency difference (p = .008) in Group 1 while responding to competitor (1255.049 ms, SE = 33.365 ms) and distractor (M = 1224.002 ms, SE = 33.581 ms). Whereas for Group 2 such response latency difference was not significant (p = .908). The Language x Type interaction was not significant, $F(1, 53) = 1.479$, $p = .229$, $\eta_p^2 = .027$.The Language x Group interaction was not significant, $F(1, 53) = .812$, $p = .372$, $\eta_p^2 = .015$. The three-way Language x Type x Group interaction was not significant, $F(1, 53) = .487$, $p = .470$, $\eta_p^2 = .009$. (See Figure 3.3 for Response Time and Figure 3.4 for 100 Time Steps)

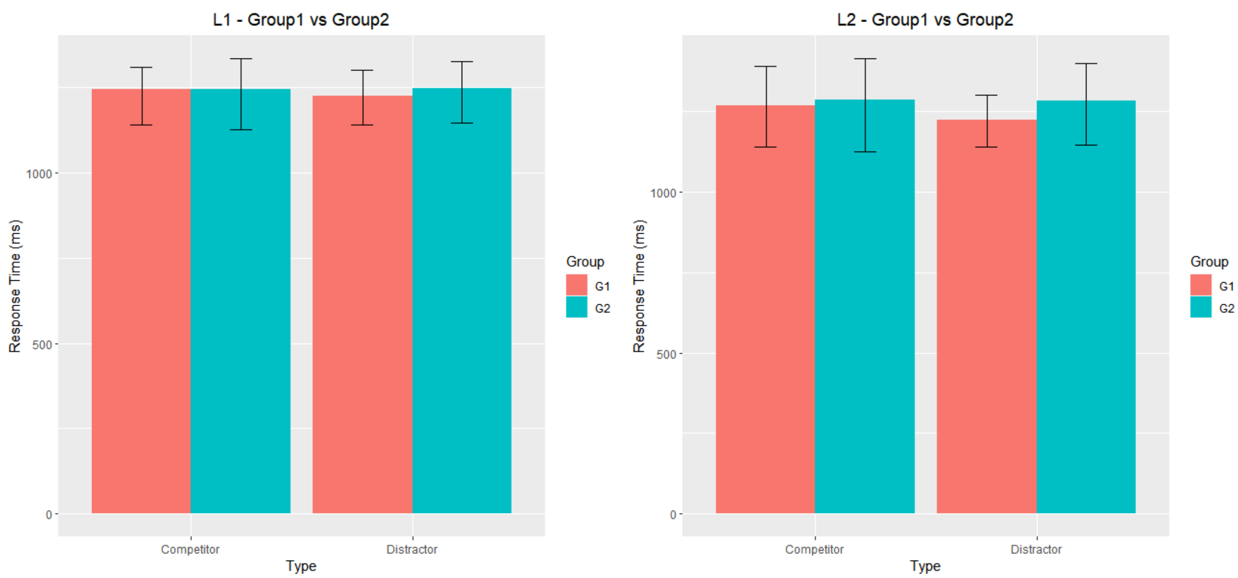

Figure 3.3: Response Time of the participants in phonologically competing and non-competing conditions

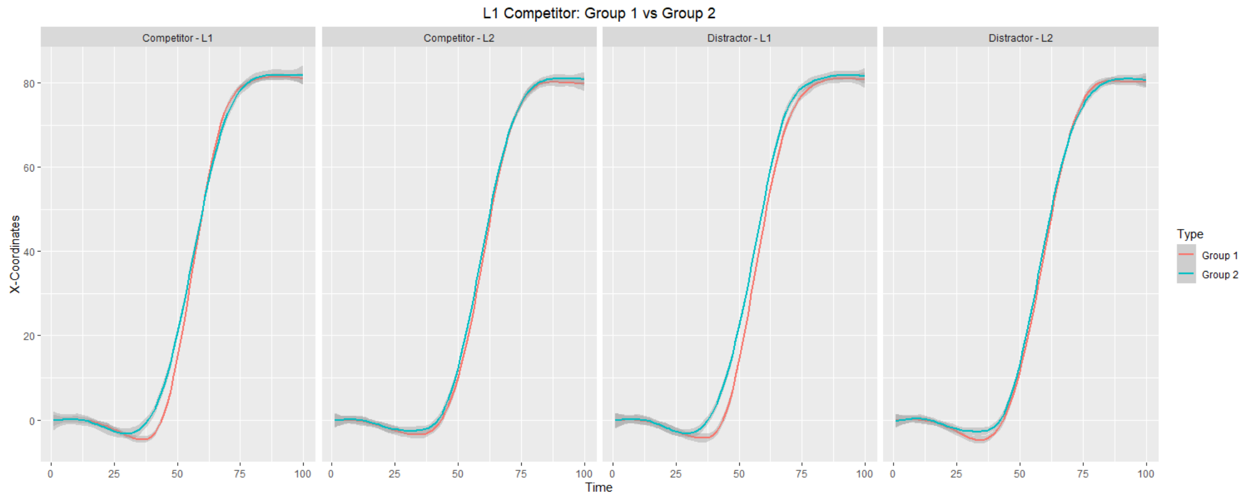

Figure 3.4: 100 Time Steps in 101 x-coordinates of the participants in phonologically competing and non-competing conditions

3.3.3 Semantic Fluency Task

A subject wise 2 x 5 x 2 repeated measures ANOVA was performed with Language (L1 and L2) and Semantic Fluency (animal, fruit, cloth, vegetable, flower) as within subject factors and Group 1 and Group 2 as between subject factors. The main effect for Language was significant, $F(1, 53) = 6.443$, $p = .014$, $\eta_p^2 = .108$. Pairwise comparison showed a significant ($p = .014$) difference in the number of words produced between L1 and L2. The participants produced more words in L1 ($M = 13.057$, $SE = .635$) compared to L2 ($M = 11.678$, $SE = .353$). The main effect for Semantic fluency was highly significant, $F(4, 50) = 143.055$, $p < .001$, $\eta_p^2 = .920$. Pairwise comparison showed significant difference between animal and fruit category ($p < .001$), between animal and vegetable category ($p < .001$), between animal and flower category ($p <.001$) whereas there was no significant difference between animal and cloth category ($p = .182$). Likewise, there was significant difference between fruit and cloth category ($p = .002$), between fruit and vegetable category ($p = .020$) and between fruit and flower category ($p < .001$). Similarly, there was significant difference between cloth and vegetable category ($p = .019$), between cloth and flower category ($p < .001$), and between vegetable and flower category ($p < .001$). Over all, the participants produced the number of words in the five categories in the following sequence: animal (Mean = 17.252, SE = .510), cloth (M = 15.567, SE = 1.403), vegetable (M = 12.183, SE = .445), fruit (M = 11.252, SE = .363) and flower (M = 5.583, SE = .191). Language x Semantic Fluency interaction was highly significant, $F(4, 50) = 19.087$, $p < .001$, $\eta_p^2 = .604$. Pairwise comparison showed the mean difference between L1 and L2 was significant for animal category ($p = .004$), fruit category ($p < .001$) and vegetable category ($p < .001$) whereas there was no significant difference between L1 and L2 for cloth ($p = .457$) and flower ($p = .284$) category. The participants produced the number of words in the five categories in L1 in the following order: cloth (M = 16.523, SE = 2.619), animal (M = 16.397, SE = .503), vegetable (M = 14.437, SE = .536), fruit (M = 12.157, SE = .417) and flower (M = 5.770, SE = .272). The participants produced the number of words in the five categories in L2 in the following order: animal (M = 18.107, SE = .653), cloth (M = 14.610, SE = .582), fruit (M = 10.347, SE = .412), vegetable (M = 9.930, SE = .489) and flower (M = 5.397, SE = .242). Language x Group interaction was not significant, $F(1, 53) = .528$, $p = .471$, $\eta_p^2 = .010$. Semantic Fluency x Group interaction was not significant, $F(4, 50) = 1.601$, $p = .189$, $\eta_p^2 = .114$. Language x Semantic Fluency x Group three-way interaction was not significant, $F(4, 50) = .796$, $p = .534$, $\eta_p^2 = .060$.

Table 3.2: Mean number of exemplars produced in verbal fluency task (standard deviation in parenthesis)

L1 Phonetic Fluency	Group 1	Group 2	L2 Phonetic Fluency	Group 1	Group 2
क	12.4 (3.9)	13.3 (4.4)	F	14.4 (3.6)	13.7 (3.2)
प	11.8 (4.4)	11.2 (3.7)	A	13.0 (4.3)	12.1 (3.1)
म	11.5 (4.3)	11.0 (3.9)	S	15.9 (5.1)	13.9 (4.5)
L1 Semantic Fluency	**Group 1**	**Group 2**	**L2 Semantic Fluency**	**Group 1**	**Group 2**
जनावर	17.1 (4.1)	15.6 (3.2)	Animal	18.1 (4.1)	18.1 (5.2)
फलफुल	12.7 (3.8)	11.6 (2.1)	Fruits	11.0 (3.1)	9.7 (2.9)
कपडा	13.7 (3.4)	14.7 (4.1)	Clothes	14.3 (4.4)	14.9 (4.0)
तरकारी	15.0 (3.8)	13.8 (3.9)	Vegetables	10.8 (3.5)	9.1 (3.6)
फुल	5.9 (2.2)	5.7 (1.8)	Flowers	5.4 (1.5)	5.4 (1.9)

3.4 Discussion

In the present study, we investigated the effect of L2 immersion in language comprehension and production in a young adult population from Nepal who were studying in a neighboring foreign country in India. We tested language comprehension using parallel language activation in L1 and L2 in mouse tracking experiment in which the participants listened to the spoken in word in L1 or L2 and clicked on the target picture that shared the same name as the spoken word which had a distractor on the opposite side of the screen that shared phonological similarity at the onset level or a distractor that did not share such phonological similarity. We tested language production using verbal fluency task in which we asked the participants to produce as many exemplars as they can in 60 seconds in phonetic fluency and semantic fluency condition in L1 and L2 following certain criteria. The letters/phonemes for phonetic fluency in L1 were क, प, म and in L2 were F, A, S whereas for semantic fluency the categories from which they were asked to make words were animal, fruit, cloth, vegetable, and flower categories in both L1 and L2. We used different letters for L1 and L2 because of lack of normative study in Nepali on verbal fluency task (Kosmidis et al, 2004) for L2, we used the most commonly used three letters (Gollan & Montaya, 2002).

We report that in lexical access language comprehension experiment there was no group effect, no language effect, no type effect and no interaction between language and type, language and group, type and group and no three-way interaction between language, type and group in initiation time which means none of these factors affected the way participants initiated the mouse movement to make response. Likewise, in response time, there was no language effect which means whether the participants responded in L1 condition or L2 condition did not affect response latency which indicated the participants were equally proficient in language comprehension and accessed their mental lexicon in both the languages in similar manner. The main effect for type was significant in which the participants responded faster in condition where the distractor did not match phonologically with the target compared to where it did. The interaction between language and type, between language and group was not significant which means both the groups did not face any temporal delay in responding to either of the languages and in phonologically competing or non-competing conditions. The marginal significant interaction between group and type showed that only the first group (less immersion) faced competition between phonologically competing condition compared to second group (higher immersion) in which there was no significant difference in response latency between both phonologically competing or non-competing condition.

Our mouse tracking language comprehension experiment design was similar to previous eye tracking spoken word recognition parallel language activation experiments on bilinguals (Freeman et al, 2017; Blumenfeld et al, 2016; Blumenfeld & Marian, 2011; 2013; Mishra & Singh, 2016). Previous studies have used variation of 'look and listen' task in visual world paradigm (Mishra et al, 2012). For example, Mishra & Singh (2016) presented auditory input after 1000 ms of the onset of visual display; Blumenfeld and colleagues (2016) presented auditory stimuli after 500 ms of visual display. Whereas, we used 'click, listen, look and click' task in which auditory and visual stimuli were presented simultaneously after the participants clicked on the START button at the bottom center of the screen, after which they were required to move the mouse toward the visual display and click one of the pictures. This design allowed us to record the mouse trajectories of the online temporal processing for each trial as the participants initiated response at the onset of the stimuli and made a response by clicking on the relevant visual display. This also allowed us to tease out the early (initiation) and late (response) processes of cognitive dynamics unfolding temporally.

Where do the trajectories come from? The trajectories are the record of the smooth flow of continuous and dynamic motor output representing the continuous and dynamic flow of the cognitive tasks. These trajectories are identical to the motor movement averaged dynamically of the real time human data of the changing perceptual weights which ramp up and increases with the support of an incoming cognitive representation and decreases and ramps down with the decrease in the incoming perceptual weight. (Farmer et al, 2016). Unlike eye movement data points which are discrete, mouse movement data points are continuous that allow for the smooth recording of temporal cognitive processing and action control (Pathak et al, 2021; Pathak & Pathak, 2022; Incera & McLennan, 2016).

We believe, the response manipulation also helped us to get accurate data on parallel language activation mediated by phonological representation. We asked our participants to make response by clicking on the visual display which either had or did not have the matching picture for the incoming spoken word. This manipulation helped us in getting their attention directed to the type of response pattern rather than the type of stimuli in experimental condition. The trials which had the matching target pictures for spoken word had two conditions: the picture on the opposite side of the target picture either shared phonological onset with the target picture (for example, *kagati* (lemon) vs kayak, in between-language condition, L1 – L2 direction) or it didn't (for example, *mauri* (bee) vs wagon).

Our results of mouse tracking experiment on parallel language activation is consistent with the previous studies in eye tracking visual world paradigm in which, as a result of phonological competition for selection, the response latency for the words which share phonological similarity is higher than those of the words which do not. Participants in our study took longer time in processing and responding to the trials in which the distractor shared phonological similarity with the target compared to the trials which didn't. However, we found only near significant effect of immersion duration in lexical access for language comprehension. The participants with less immersion duration showed significant activation of phonological competition whereas in the second group with longer duration, there was no such significant activation which indicated participants had become better over the time in conflict resolution and didn't face the activation for selection. This shows longer immersion duration had no detrimental effect in overall language comprehension processing, rather it had beneficial effect.

In language production verbal fluency task, the first group produced, in general, more words in both phonetic and semantic fluency. Since we could not run ANOVA on phonetic fluency because of letter differences in L1 and L2, we ran ANOVA on semantic fluency that had the same category in both the languages. We report language effect in which participants produced more words in L1 (13 words in average) compared to the number of words produced in L2 (11 words in average). We also found semantic fluency effect and the number of words produced was in the sequence of animal (17 words), cloth (16 words), vegetable (12 words), fruit (11 words) and flower (6 words). Significant language and semantic fluency interaction indicated that the language wise there was a difference in the number of exemplars generated. In L1, they generated the number of words in this sequence: cloth (17), animal (16), vegetable (14), fruit (12) and flower (6). The participants produced the number of words in the five categories in L2 in the following order: animal (18), cloth (15), fruit (10), vegetable (10) and flower (5). Non-significant language and group interaction indicated participants produced almost equal number of words in both the languages. Likewise, semantic fluency and group interaction also being non-significant indicated that the participants of both the groups generated almost equal number of words in semantic fluency. Non-significant three-way interaction between language, semantic fluency and group indicated that the duration of immersion had no effect on the amount of words generated in semantic fluency in each language.

Our results provide counter evidence to the findings of previous studies on the role of L2 immersion in L1 attrition and language production as well. Link, Kroll and Sunderman (2009) used translation recognition task to test language comprehension and semantic fluency task to test language production on two groups of native English speakers from an American university of which one group (n = 25, mean age = 20.6 years) was immersed in Spanish L2 in a semester abroad program in Spain and another group (n = 20, mean age = 21. 2 years) was studying Spanish as L2 in a classroom setting in American university. The immersed group was tested after three months into the program. They found L1 was less accessible to the immersed learners compared to classroom learners in both language comprehension and production task. But when a subset (n = 14) of immersed learners was retested after six months of their return to home country they found their semantic fluency performance rebounded to the level of classroom learners. In a complementary study to Linck and colleagues (2009), Baus, Costa and Carreiras (2013) longitudinally investigated the L2 immersion effects on L1 speech production using the picture naming and semantic fluency task on a group of L2 immersed learners. They tested on the 50 native speakers of German undergraduate ERASMUS students (Mean age = 22. 6 years) from Germany, Switzerland and Austria attending a semester in University of La Laguna (Tenerife, Spain). They compared the performance of arrival time (one month after arrival) and departure time (one month before the departure) and found slow naming latency for picture names with low frequency non-cognate words toward the end of the immersion in L2 than at the beginning of the program. In semantic fluency also there was decrease in non-cognate words when measured at the end of immersion. The authors in both the studies (Baus et al, 2013; Linck et al, 2009) account for the decline in L1 lexical access after short L2 immersion to L1 attrition resulting out of the disadvantage in bilingual lexical access in general.

The participants in our study are comparable to these two studies as they were university students studying in a country different from their own and were of the similar age group, in their early twenties. The semantic fluency language production task that we used is similar to theirs. Linck and colleagues (2009) used three categories (animals, clothing, fruits); Baus and colleagues used eight categories (vegetables, fruits, animals, clothing, furniture; colors; musical instruments and body parts); we used five categories (animal, fruit, cloth, vegetable, and flower). Whereas, in these two studies immersion duration was one semester (6 months, but tested in 3 months and 4 months), the immersion duration of our participants was one year for lower immersion group and three years for higher immersion group. If L2 immersion was a predictor for L1 attenuation, we should have noticed disadvantage in L1 performance in language production with reduction in the generation of number of exemplars from the given categories in L1 compared to L2 as found in previous studies. But we found immersion duration did not modulate language production performance in L1, rather there was no language effect, and no language and group interaction which means the duration of immersion did not affect mental lexicon and access in either of the two languages. Rather, they generated more exemplars in L1 indicating L1 mental lexicon and representation well preserved and available for access whenever required. We assume the reason for this to be availability of L1 speakers in the hostel premises where they could communicate with each other in their L1, even though inside the classroom and college premises L2 was used exclusively with teachers and non-Nepali students. The explanation for language not having significant effect on language production can be the availability of both the languages.

However, there are other studies which show even extended duration of L2 immersion is not detrimental to L1 mental lexicon. In line with the above mentioned two L2 immersion studies but with different immersion duration and using different tasks, Mok and Yu (2017) studied L2 immersion priming effect in two groups of Mandarin – English immersed (L2 environment in

Chicago, heterogeneous participants, n = 19, mean age = 22 years, immersion duration = 3 months – 4 years) and non-immersed (L1 environment in Hong Kong, high proficiency in L2, n = 24, mean age = 23.5 years) late Chinese – English bilingual university students using translation and semantic priming tasks. The authors hypothesized that if immersion led to bilingual disadvantage, they would notice stronger L2 priming effects compared to L1 in within language conditions among immersed participants, the priming effect asymmetry in language directions be attenuated and show more comparable reaction time in L1 and L2. They did not find bilingual disadvantage in immersed participants. Rather, they found L2 processing advantage in immersed participants where they responded to L2 targets with similar speed as L1 indicating a reduction in asymmetry between the two languages in their mental lexicon. They found the gap of reaction time difference between the two languages reduced in the immersed English environment group compared to non-immersed group. The findings from this study lends support to our results that extended L2 immersion does not negatively affect L1. Even though the sample of population in this study is similar to ours and Linck et al (2009), and Baus et al (2013) study, the population in this study was scattered and in various study programs whereas our sample was within the same premises during the entire period of their study and were studying either in the field of science and technology, and management. In that sense, our sample, tasks, and immersion environment are more akin to Linck et al (2009), and Baus et al (2013) study. However, age group wise, immigration and immersion status wise our participants are comparable to all these previous three studies discussed here.

The studies that found bilingual disadvantage (Sandoval et al, 2010) on L1 as a function of immersion in L2 have accounted their finding mainly to weaker-link hypothesis (Gollan et al, 2008; Linck et al, 2009; Gollan et al, 2005) or frequency-lag hypothesis (Gollan et al, 2011) which reduces the L1 functional frequency of L2 immersed speakers with daily use of L2 and thereby making the L1 less easily accessed. They have also argued that increase in L2 use during an immersion period may shift the users into L2 mental set and render L1 less accessible, making it difficult to switch into more dominant L1 than less dominant L2 leading to global inhibition of L1 (Green, 1998; Kroll, Bobb, Misra, & Guo, 2008; Meuter & Allport, 1999; Ivanova & Costa, 2008; Strijkers, Costa & Thierry, 2010).

Since we didn't find bilingual disadvantage in accessing mental lexicon in L1 as a result of immersion in L2, rather, we found mental lexicon in both the languages equally intact and available for access in language comprehension and production despite a long duration of immersion, the disadvantage accounts cannot explain our results. So, we need accounts that can explain the rather facilitative role of L2 immersion in processing of bilingual mental lexicon. Structural neuroimaging studies on long immersion in L2 have shown neuroprotective effect of bilingualism which are associated with increased in grey matter density in the inferior parietal lobules (Abutalebi et al, 2015), the areas which are found to be involved in semantic and phonological processing (Seghier et al, 2004). In fact, Abutalebi and Green (2007) have argued that relatively lifelong exposure in the second language and being immersed in an L2 environment can nullify the general pattern of bilingual disadvantage, with L2 becoming more automatic and converging to L1 representation and processing. Nanchen and colleagues (2016) investigated the role of L2 immersion and exposure in elderly bilinguals and found that it plays a determining role in eventual language preservation in the course of healthy aging and also for dementia affected individuals. These findings lend support to our results where L1 and L2 converged without causing any loss to either of the languages as reflected in non-significant effect of language in both language comprehension and production.

Baus, Costa and Carreiras (2013) report clear immersion effect on cognate words presenting an interpretation of relative invulnerability of L1 cognate words and high frequency words in a unified manner. They conclude that the benefits in processing of cognates emerge with the increase of frequency in both the languages and become more robust over time and get more protected and stronger than non-cognates against the loss of accessibility, due to their overlap in the phonological form. The type effect in language comprehension for the trials that shared phonological overlap with the distractor disappeared in the second group with higher duration of immersion. The longer duration of immersion in our participants might have contributed in establishing the interactive links between phonological representation (Costa, Santesteban, & Caño, 2005, for a review on interactive links).

With this study, we believe, we have made some significant contribution in the field of bilingualism, especially, with immersion as an independent variable, and its modulating effect on L1. We have shown that under certain condition like the one reported in this study, L2 immersion may not be detrimental to L1 and may not lead to its attenuation and attrition.

3.5 Limitation and future direction

Immigration and immersion is not a straight forward phenomena and involves complex linguistic and cognitive processes as the immigrants adapt and adjust to the changed environment, the background (including socio-economic), duration of immersion, condition of immersion environment, life experiences will all interact differently. We have to consider multiple aspects where immigration and immersion in L2 may induce attenuation and attrition to L1 and at the same time look for conditions that may contribute to the preservation of L1 without causing any detrimental changes to it. We understand, our results may not be generalizable to all the situations but our results show a situation where immersion in L2 may still spare L1 of its attenuating effect. Our participants lived in mostly a closed environment where they had more chance to interact with each other in L1 which might have contributed to the preservation and maintenance of L1 despite all other businesses being carried out in L2. A situation where immigrants are scattered to various conditions may affect their linguistic and cognitive processing differently. Since immigration and integration to languages and cultures different from one's own native is a common phenomenon driven by academic and professional needs across the countries in the 21st century, future studies should explore the various interactional contexts of the immigrants and how it affects them, using mostly online tasks that tap those varying conditions.

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Chapter 4: Trilingual parallel processing

Twenty five L1 Nepali speaking participants living in Trondheim, Norway who spoke English as L2 and Norwegian as L3 (late adult learners) participated in this study. Participants' L2 proficiency was established as advanced in LexTALE. We administered language comprehension and production tasks in a trilingual design. In a mouse tracking trilingual parallel activation experiment, participants performed a language comprehension task in which they listened to the spoken word in their L1, L2 and L3 and clicked on the matching target picture. Mouse trajectories of their response pattern were recorded and analyzed. The language production task included a phonological and a semantic verbal fluency task (which also served as an executive control task). In the phonological fluency task, they created words starting with /p/, /t/ and /k/, while in the semantic fluency task they created words from the animal, fruit and flower category each within 1 minute. VFT showed their dominance in L1 and L2 compared to L3. This study contributes novel knowledge on trilingual parallel activation and suggests that in the presence of a non-dominant L3, a dominant L1 and a dominant L2 are processed faster than the non-dominant language in phonologically competing conditions.

4.1 Introduction

What is special about L3 processing and does it need to be treated separately from L2 processing? (de Bot & Jaensch, 2014). Trilingualism is often assumed to be an extension of bilingualism (Hoffman, 2001) but it needs teasing out trilingualism from bilingualism and cannot be assumed that both involve the same processes as different social, cultural, psychological and personality factors may influence trilingual acquisition and use (Hoffman, 2008). Bilingualism is a widely investigated area which has passed through several stages: deficit oriented view from 19th century to the 1960s, emergence of bilingual advantage hypothesis from 1970s to 2000 and a backlash against bilingual advantage theory in the recent times (Jansen et al, 2021). There exist a substantial body of theories and models of bilingualism: Inhibitory Control Model (Green, 1998), Adaptive Control Hypothesis (Green & Abutalebi, 2013), Connectionist Models (Mclelland & Rumelhart, 1981, 1988; Li & Farkas, 2002; Dijkstra, 2005; Dijkstra & Rekke, 2010; Dijkstra, Haga, Bijsterveld, & Sprinkhuizen-Kuyper, 2011), Hierarchical Model (Kroll & Stewart, 1994; Kroll, van Hell, Tokowicz, & Green, 2010), Bilingual Interactive Activation Model (Dijkstra, & Van Heuven, 1998; 2002), The Bilingual Language Interaction Network for Comprehension of Speech Model (Shook & Marian, 2012), Multilink Model (Dijkstra et al, 2018; Costa & Pickering, 2018; Mishra, 2018) among the prominent ones. Schroeder and Marian (2016) have proposed a framework based on cognitive plasticity to account for the similarities and differences between the bilinguals and trilinguals in what they claim to be the first comprehensive analysis aimed at explaining how learning of a third language might affect the cognitive abilities which are modified by the experience of bilingualism and claim that the framework they propose can explain and predict bilingual – trilingual differences. They tested and analyzed three aspects of cognition - cognitive reserve observed in older adults which they measured by investigating the age of onset of Alzheimer's disease and subsequent mild cognitive impairment; inhibitory control as observed in children and younger adults which they measured recording behavioral response times as produced by Simon and flanker tasks; memory generalization as observed in toddlers and infants which they measured by recording response accuracy of behavioral deferred imitation tasks. They observed a mixed pattern of results. Older adult trilinguals showed larger cognitive reserve advantages than did bilinguals; children and young adult trilinguals exhibited the same advantage as bilinguals in inhibitory control; toddler and infant trilinguals showed no advantages as seen in bilinguals in memory generalization. The authors concluded that there are distinct cognitive consequences of trilingualism and not mere extension of effects of bilingualism which have theoretical implications in our understanding of cognitive and linguistic processes that can be applied in rehabilitative and educational contexts for fostering successful cognitive ageing and development.

Several studies investigating trilinguaism have appeared in the first two decades of 21st century which have mostly used experimental paradigms used in bilingual studies. Tytus (2017) and Franscis and Gallard (2005) used priming paradigm for testing lexico-semantic memory and concept mediation in translation respectively. Cenoz (2001) investigated how third language acquisition was cross linguistically influenced, using a translation task. Lemhofer et al (2004) studied cognate effects observed in trilingual word recognition. Schwieter and Sunderman (2011) used verbal fluency task to investigate trilingual speech production mediated by lexical access and inhibitory control processes. Charkova (2003) compared monolingual, bilingual and trilingual children on grammaticality judgement task to study their early foreign language education and metalinguistic development. Lexical decision task was used by Alonso and colleagues (2016) to study the effects of dominance and sequential multilingualism on English non-compound and compound processing in multilingual and bilingual speakers and by Ibrahim and Eviatar (2012) to investigate the contribution of the two hemispheres to lexical decision in different languages. Likewise, picture naming has been used by Costa and colleagues (2006) to investigate inhibitory and language – specific selection mechanisms, Festman (2008) investigated how crosslinguistic interference affects trilingual picture naming in mixed and single conditions, Poarch and Van Hell (2012) used picture naming to investigate cross – language activation in speech production in trilingual and bilingual children, Guo and colleagues (2013) used this paradigm to investigate how non-target languages are inhibited in trilingual word production in an ERP study. Researchers have used language switching paradigm quite a lot in bilingual studies which also has been tested in trilingualism. Linck and colleagues (2012) used this paradigm to study inhibitory control and speech production in trilinguals, Marian and colleagues (2013) used language switching in multilingual Stroop task in investigating the effects of trilingualism and proficiency on inhibitory control, Festman and Mosca (2016) used language switching paradigm in a trilingual digit-naming study to investigate the influence of preparation time on language control, Hut and colleagues (2017) used neuromagnetic trilingual language switching task to study how language control mechanisms differ in different native languages, Mosca (2018) studied trilingual's language switching from strategic and flexible account. Researchers have been investigating third language acquisition and learning from various perspectives like linguistic transfer (Rothman, 2010; Rothman, Alonso & Puig-Mayenco, 2019), bilingual education (Rutgers & Evans, 2017) or bilingual literacy (Sanz, 2007) and have found evidence for additive advantage of trilingualism (Cenoz & Valencia, 1994) and enhancing effect of bilingual education on third language acquisition (Sanz, 2000). Learning of multiple languages are believed to confer direct (transfer effects from early language learning experience to novel experience) and indirect (socially and cognitively mediating abilities changed due to prior experience and influencing novel learning) effects linguistically and cognitively (Hirosh & Degani, 2017).

What is apparent from this brief overview of trilingual studies is that trilingualism has been taken mostly as an extension of bilingualism and it is possible to study triingualism from bilingual cannons. However, it is equally pertinent to treat trilingualism as a separate phenomenon from bilingualism and seek to investigate mechanism(s) which may contribute in theorization and further understanding of this cognitive landscape that constitutes a majority of the world population, especially in the regions like South Asia where multilingualism is more prominent than bilingualism and monolingualism is in minority. This is also important where South Asian population is becoming more and more global by way of migration to western countries and becoming an influential diaspora in the country of their settlement.

4.1.2 Heritage language perspective: Nepali as a mainstream language in Nepal and a heritage language in Norway

A language is considered a heritage language when it is spoken at home and is easily available to the younger children and is, crucially, not a dominant language of the larger or national society where the individual lives and will be called a heritage speaker only if s/he has command over heritage language acquired naturalistically but may differ from native monolinguals of comparable age (Rothman, 2009). In their key note article, Polinsky and Scontras (2019) synthesize theoretical claims and empirical observations about robust and vulnerable areas of heritage language competence and propose a predictive model of heritage language competence. They highlight two key triggers of deviation from the baseline – quality and quantity of the language input from which the grammar of heritage language is acquired and the economy or less availability of online resources when operating in daily tasks in a less dominant language. They also identify three outcomes of deviation in the heritage language in response to these triggers – resistance to irregularity, ambiguity avoidance and shrinking of the structure. Study of heritage languages is emerging as an independent academic field in its own right (Lynch, 2014) and several mainstream languages of the word have been studied from heritage language perspective, for example, heritage English (Polinsky, 2018b), heritage Spanish (Silva-Corvaan, 1994, Montrul, 2016), heritage Russian (Laleko, 2010), heritage Inuttitut (Sherkina-Lieber, 2011, 2015), heritage Arabic (Albirini, Benmamoun & Saadah, 2011), heritage Mandarin (Jia & Bayley, 2008), heritage German (Putnam & Salmons, 2013), heritage Korean (O'Grady, Lee & Choo, 2001) to name some of them. Many countries are already implementing school instruction in heritage language. For example, Canada has introduced heritage language programs to heritage language speakers in around 60 ethnic languages (Baker & Prys Jones, 1998) with several provinces using heritage language as medium of instruction in heritage language bilingual education programs as declared policy to maintain valuable economic resources and promote cross-cultural and intercultural understanding (Policy for Heritage Language Instruction, 1993). Poarch and Bialystok (2017) assess that with the increasing influx of the migrants into European Union, there is a challenge to integrate the migrant children who are already fluent in one or more languages into the mainstream majority language, for example, German and assist them in becoming successful multilinguals that would boost their academic success in the long-term and also develop their executive control. So much so, Marian and colleagues (2013) found that Spanish speaking children with low SES and English speaking monolingual middle class children who were enrolled in Spanish – English bilingual programs performed better on reading and mathematics test compared to the children in monolingual programs.

Norway has attracted a large number of students from Nepal in graduate programs in different universities but predominantly in Norwegian University of Science and Technology (NTNU),Trondheim in medical, engineering and humanities programs who have contributed back in Nepal but many stay back in Norway and take up different professions. Their children grow up as heritage Nepali speakers. Norway is also one of the eight countries (others being Australia, Canada, Denmark, New Zealand, the Netherland, the US and the UK) that resettled the Nepali speaking Bhutanese refugees from Nepal in their countries (Shrestha, 2015). These refugees are settled in different parts of Norway and trying to integrate themselves with the new linguistic and socio-cultural landscape (Bhattarai, 2014; Sharma, 2012). This scenario indicates Norway will soon have substantial number of heritage Nepali speaking population for whom educational arrangements in their first language alongside the majority language Norwegian and English will have to be made. This study was conducted on the sample of population born in Nepal and living in Trondheim, Norway at the time of data collection. Hence, we anticipated our design would be indicative of the trilingual language processing that our sample represented.

4.1.3 Theoretical framework in trilingual processing

The Cumulative Enhancement Model for Language Acquisition (Flynn et al, 2004) was proposed to make prediction about trilingual processing. Flynn and colleagues (2004) compared children and adults learning L1 Kazakh, L2 Russian and L3 English in the study investigating the role played by L1 or all the known languages in subsequent language acquisition. They found that L1 does not play a privileged role in subsequent language acquisition, rather, it is the last learned language which determines the learning of the next language and subsequent language learning is accumulative and prior language enhances the subsequent acquisition. Results of a recent neurolinguistics study (Umejima, Flynn & Sakai, 2021) support Cumulative Enhancement Model. Umejima and colleagues conducted an fMRI experiment on bilinguals and multilinguals (with L1 Japanese, L2 English, L3 Spanish, L4 Kazakh) to evaluate how, in a new language (in this case, Kazakh), the syntactic features are acquired and found that multilinguals with higher proficiency in their second and third languages required fewer task trials to acquire the phonology of Kazakh with greater reduction in response times in multilinguals than bilinguals during initial exposure to Kazakh. Significantly enhanced activations in the left ventral inferior frontal gyrus was seen for multilinguals compared to bilinguals indicating more enhanced domain-general and syntax-related brain networks for the multilinguals. Significant activations was also observed for multilinguals in the visual areas which implied multilinguals were able to use visual representation even while listening to speech sounds alone, showing that multilinguals could utilize their acquired knowledge in an accumulated manner. We predicted our participants to exhibit accumulative and facilitative effect in processing the parallel activations of the three languages that we tested on them. Theoretically, our study also finds support in interdependence hypothesis (Cummins, 1979a; 1979b; 1991) that predicts additive effect as children add a second language as their linguistic and academic tool kit (Cummins, 2000, 2007) that enhances their linguistic and academic performance (see Pathak et al, 2021 for the study that found that L2 instruction enhances linguistic and cognitive abilities in L1 as well). We would expect that if adding a second language to the first language repertoire had additive benefit, addition of a third language would also show up additional advantage in while processing three languages simultaneously.

4.1.4 Mouse tracking as a tool for investigating trilingual processing

MouseTracker has proven to be an effective tool in the study of bilingualism in recent times (for example, Incera & McLennan, 2015, 2016, 2017; Incera et al, 2020, 2017; Lin & Lin, 2016; Pathak, 2017; Pathak et al, 2021; Pathak & Pathak, 2022). Mouse tracking has also been used to tease out the temporal details of the bilingual processing. For example, Incera and McLennan (2016) reinvestigated and challenged the claims of Roelofs (2010) that within and between language effects follow the same time course in bilinguals and also exhibited that mouse tracking can even outscore eye tacking when it comes to the capturing of temporal processing details by revisiting the seminal eye tracking work on bilingual parallel language activation study of Marian and Spivey (2003b, see Pathak et al, 2021 for comparison of mouse tracking with eye tracking and button press paradigms). We wanted to further test its efficacy in trilingual processing (Pathak, 2020) because of its unique features and architecture in recording temporal and spatial cognitive processing of participants' response patterns modulated by the experimental manipulation.

4.1.5 The present study

In this study, we have investigated parallel language activation in Nepali – English – Norwegian trilinguals. Our participants were all born in Nepal and spoke Nepali as their L1 whose L2 was English as they had received their secondary and tertiary education in English and had learned Norwegian as their L3 with different degree of proficiency who were living in Trondheim, Norway where the study was conducted, mostly pursuing or completed graduate programs in Norwegian University of Science and Technology. They were all fluent in their L1 and L2 but were different in fluency in their spoken L3 but largely they could comprehend it. We were interested in testing how such population who had migrated to a foreign country in their adult life processed their three languages, whether one language influenced other language. Our main research question was how did the language acquired in late life affect the other two languages in terms of processing and whether the first two languages affected the third language in terms of activation and what was the nature of activation in all the three languages?

We designed our experiments in MouseTracker (Freeman & Ambady, 2010), which has proven to capture the fine-grained cognitive and linguistic processing as the participants move their mouse to initiate and make response. The pattern of mouse movements would give us the clue to the nature of activation and processing of all the three languages.

4.1.6 Ethical consideration

All the participants gave their written informed consent in order to participate in the study who were also informed beforehand that they were free to withdraw from the study at any stage. Before the data collection, approval was also obtained from the Norwegian Center for Research Data (NSD) through Norwegian University of Science and Technology (NTNU) where this research study was hosted.

4.2 Methods

4.2.1 Participants

Twenty-five participants (male = 18) with mean age 28.9 years (SD = 8.02 years) participated in online L2 proficiency test LexTALE, mouse tracking trilingual parallel activation task, and trilingual verbal fluency tasks. All the participants were born and lived in Nepal and were living in Trondheim, Norway during the time of data collection where this study was conducted. All of them gave written informed consent and filled up a language history questionnaire that required them to provide information regarding their duration of stay in Nepal and Norway, age of acquisition of L1, L2 and L3; proficiency in listening, speaking, reading and writing in all the three languages, literacy acquisition in all three languages. They were fluent in their L1 (Nepali) and L2 (English) and had learned L3 (Norwegian) in Trondheim during their stay for study or employment[1]. Their LexTALE score of 70 % indicated high degree of proficiency L2.

[1] PhD in Norwegian University of Science and Technology (NTNU) is regarded as employment.

Table 4.1: Demographic profile and language history of participants

Measure	Sample Size (n=25)
Demographics	
Gender (M/F)	18M, 7F
Age (years)	28.9(8.0)
Stay in Nepal (years)	23.1(8.8)
Stay in Norway (years)	4.96(3.3)
Primary Language Measures	
Age of L1 Acquisition (years)	1.48(0.3)
Age of L2 Acquisition (years)	4.85(2.3)
Age of L3 Acquisition (years)	24.7(9.2)
Age of Fluency – L1 (years)	3.23 (0.6)
Age of Fluency – L2 (years)	11.75 (5.8)
Age of Fluency – L3 (years)	22.9 (11.3)
Onset Age – 2 languages (years)	7.46 (3.9)
Onset Age – 3 languages (years)	16.0 (10.0)
Onset Age – 3+ languages (years)	26.1 (8.1)
LexTALE (L2 orthographic lexical decision)	69.6 (10.29)

4.2.2 Design, Materials and Stimuli

Stimuli were created to test language comprehension and production, and executive control in L1 (Nepali), L2 (English) and L3 (Norwegian). For trilingual processing, spoken word stimuli were recorded in the Fonlab (building 4, room 4509) at NTNU Dragvoll Campus in the voice of female native speakers of Nepali (Standard), English (British) and Norwegian (Bokmal) with the following recording specification - Microphone: Shure KSM44, Preamp: Focusrite ISA 428, Soundcard/Interface: Focusrite Saffire Pro 40, Computer: Dell Optiplex 980 (Windows 7), Software: Adobe Audition 3.0, Fileformat: wav, mono, 16 bit, 44khz. Black and white line drawings were selected from the internet to match the spoken word (target) and distractor. In every trial, there were two pictures of which one matched with the spoken word and other didn't. We created 16 lexical stimuli in each condition which resulted into 48 (16 x 3) in three phonological cohort condition in three language directions, likewise 48 (16 x 3) non-phonological cohort distractor condition. All together, there were 96 spoken word trials whose matching pictures were used as targets and there were equal number of distractor pictures which made it 192 picture stimuli. The targets and distractors were counter balanced across all the trial condition so that there would be equal number of stimuli on both sides of the screen. The picture stimuli appeared on the top left and right corners of the computer screen. The inter trial interval was 1000 ms. Mouse tracking experiment was designed to test the effect of L1 on L2 and L3 and that of L2 and L3 on L1 in phonological cohort and non-phonological cohort conditions. See Appendix for full list of lexical stimuli.

In verbal fluency task, three phonemes - /p/, /t/ and /k/ for phonemic fluency and three categories – animal, fruit and flower for semantic fluency test were used across all the three languages.

Online lexical decision task, LexTALE (Lemhofer & Broersma, 2012) was used to test the L2 proficiency of participants.

4.2.3 Procedure

Participants were recruited through the Nepalese Society in Trondheim (NEST), a body of current and past Nepalese students at Norwegian University of Science and Technology (NTNU) who had come from Nepal to pursue higher education in various academic disciplines. All the participants gave written informed consent to take part in the study. During the experiment, each participant was seated in a quiet room and administered the tasks. In parallel language activation task, participants were asked to listen to the spoken word in either L1, L2 or L3 randomized across the participants and asked to click on the picture that matched with the auditory input. When the participants clicked on the START button the audio and visual stimuli would appear at the same time and upon making a click the trial screen would disappear and a blank screen would appear showing only the START button for the next trial to get activated. For example, in phonological cohort condition, In L1 – L2 language direction when the participants clicked on the START button they would hear *kerau* (pea) and would simultaneously see the display of the picture of pea and cat of which they would be required to click on the picture of pea; in L1 – L3 direction, they would hear *harin* (deer) which shares phonological similarity with L3 *høyde* (hill) and on the visual display would be the pictures of deer and hill of which they were to click on deer. In verbal fluency task, participants were asked to create as many words as they can from the given phoneme or category in 60 seconds. They were asked not to use proper nouns and inflectional forms or derivations (for example, they couldn't use people or place names, or plural or tense forms or derivations of the same word like book, books, bookish (all these three would be counted as one category).

In LexTALE, the participants would see a string of letters on the screen and they had to decide whether the string was a legitimate word or not. Some pronunciable nonwords would be confused as real word and some unfamiliar but legitimate word might be confused as nonword. Their ability to correctly judge was indexed as mark of proficiency.

4.3 Results

4.3.1.1 Trilingual processing mouse tracking measures

4.3.1.2 Area Under the Curve (AUC)

L1 and L2 AUC

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L2) and type (competitor and distractor) as within subject factors. The main effect for type was highly significant, $F(1, 24) = 17.132$, $p < 0.001$, $\eta_p^2 = 0.417$ showing overall deviation of the mouse trajectory toward unselected response was higher for distractor (mean = 0.796, SE = 0.109) than competitor (Mean = 0.533, SE = 0.056). Follow up comparison indicated that each pairwise difference was significant, $p < 0.001$. The main effect for language was not significant, $F(1, 24) = 2.147$, $p > 0.05$, $\eta_p^2 = 0.082$ indicating that the auditory input of the language had no effect on the mouse movement.

L1 and L3 AUC

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L3) and type (competitor and distractor) as within subject factors. The main effect for language was highly significant, $F(1, 24) = 20.561$, $p < 0.001$, $\eta_p^2 = 0.461$ showing overall deviation of the mouse trajectory toward unselected response was higher for L3 (mean = 0.982, SE = 0.122) than

L1 (Mean = 0.660, SE = 0.092). Follow up comparison indicated that each pairwise difference was significant, $p < 0.001$. The main effect for type was marginally significant, $F(1, 24) = 3.230$, $p = 0.085$, $\eta_p^2 = 0.119$ indicating that the auditory similarity of the input language had no significant effect on the mouse movement. The trajectory deviation toward unselected response for distractor was higher (Mean = 0.886, SE = 0.119) than competitor (Mean = 0.757, SE = 0.097) with no significant pairwise difference, $p > 0.05$ ($p = 0.085$). See Figure 1 for activation differences across three language directions in phonological cohort and non-phonological cohort conditions in 100 time steps for X coordinates.

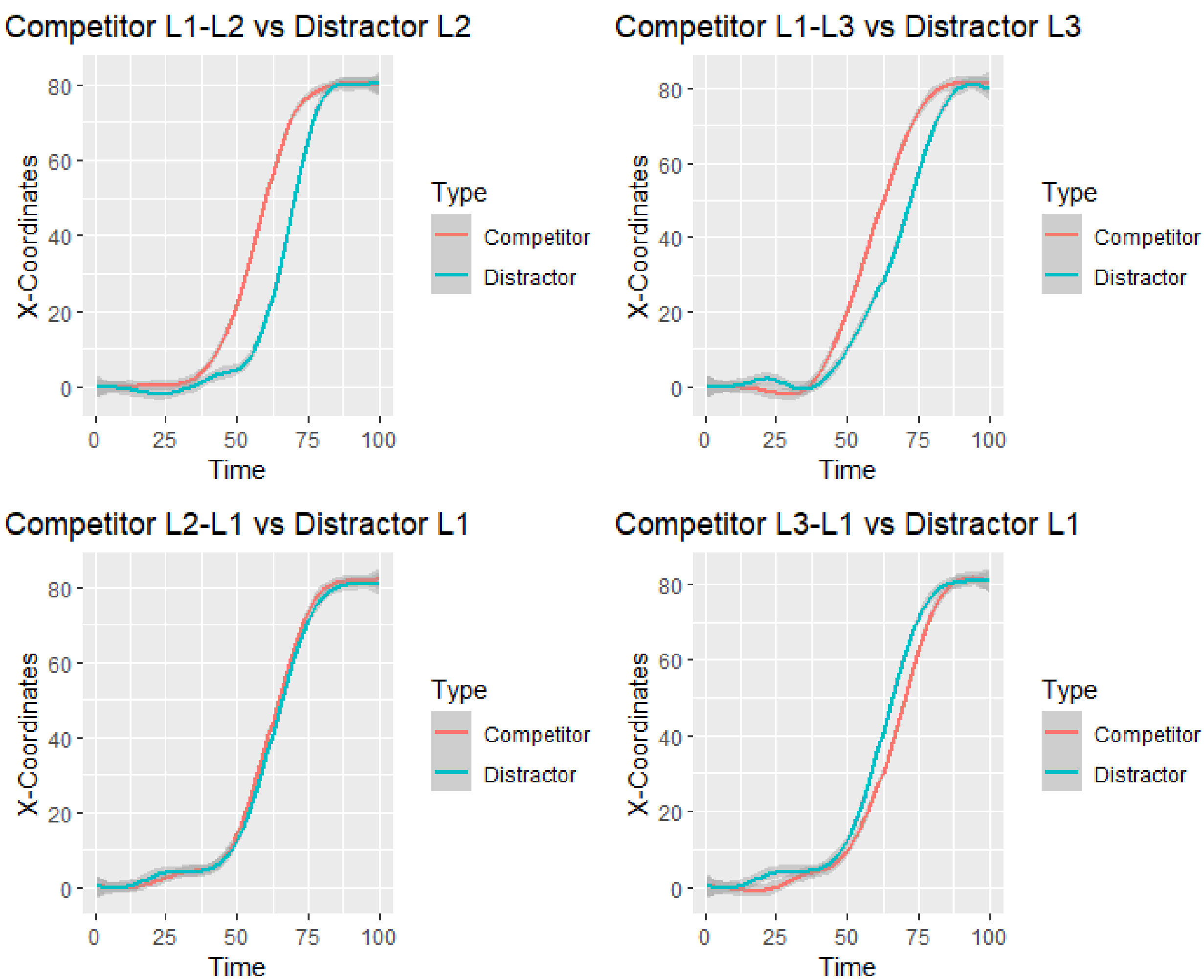

Figure 4.1: Activation differences across three language directions in phonological cohort and non-phonological cohort conditions in 100 time steps for X coordinates.

4.3.1.2 Maximum Deviation (MD)

L1 and L2

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L2) and type (competitor and distractor) as within subject factors. The main effect for type was highly significant, $F (1, 24) = 16.179$, $p < 0.001$, $\eta_p^2 = 0.403$ showing overall deviation of the mouse trajectory toward unselected response was higher for distractor (mean = 0.406, SE = 0.041) than competitor (Mean = 0.306, SE = 0.027). Follow up comparison indicated that each pairwise difference was significant, $p < 0.001$. The main effect for language was also significant, $F (1, 24) = 6.538$, $p< 0.05$, $\eta_p^2 = 0.214$ indicating that the auditory input of the language also had significant effect on the mouse movement. Pairwise comparison showed the deviation of mouse movement toward unselected response was higher for L1 (Mean = 0.323, SE = 0.036) than for L2 (Mean = 0.389, SE = 0.034) with significant difference, $p < 0.05$. The main effect for language x type interaction was significant, $F (1, 24) = 9.681$, $p< 0.05$, $\eta_p^2 = 0.287$. Pairwise comparisons indicated that when the auditory input was in L1 there was significant ($p = 0.005$) difference between response latency in competitor (Mean = 0.258, SE = 0.032 compared to distractor (Mean = 0.387 , SE = 0.046) which showed there was less deviation for competitor compared to distractor. However, for auditory input in L2 , there was no significant ($p = 0.255$) difference between response latency in competitor (Mean = 0. 354 , SE = 0.030) compared to distractor (Mean = 0.425 , SE = 0.043)

L1 and L3

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L3) and type (competitor and distractor) as within subject factors. The main effect for language was highly significant, $F(1, 24) = 18.278$, $p < 0.001$, $\eta_p^2 = 0.432$ showing overall deviation of the mouse trajectory toward unselected response was higher for L3 (mean = 0.465, SE = 0.045) than L1 (Mean = 0.358, SE = 0.038). Follow up comparison indicated that each pairwise difference was significant, $p < 0.001$. The main effect for type was not significant, $F(1, 24) = 2.315$, $p > 0.05$, $\eta_p^2 = 0.029$ indicating that the phonological condition had no significant effect on the mouse movement in either of the language directions. The main effect for language x type interaction was significant, $F(1, 24) = 12.525$, $p < 0.05$, $\eta_p^2 = 0.343$. Pairwise comparisons indicate that when the auditory input was in L1 there was highly significant ($p = 0.002$) difference between response latency in competitor (Mean = 0.329, SE = 0.036 compared to distractor (Mean = 0.387, SE = 0.046) showing less deviation in competitor condition compared to distractor. Moreover, for auditory input in L3 also, there was significant ($p = 0.007$) difference between response latency in competitor (Mean = 0. 457, SE = 0.049) compared to distractor (Mean = 0.478, SE = 0.048) showing less deviation in competitor condition compared to distractor condition.

4.3.1.3 Initiation Time

L1 and L2

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L2) and type (competitor and distractor) as within subject factors. The main effect for language was not significant, $F(1, 24) = 1.043$, $p > 0.05$, $\eta_p^2 = 0.042$. The main effect for type was also not significant, $F(1, 24) = 0.593$, $p > 0.05$, $\eta_p^2 = 0.024$. The main effect for language x type interaction was not significant, $F1(1, 24) = 2.633$, $p > 0.05$, $\eta_p^2 = 0.099$.

L1 and L3

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L2) and type (competitor and distractor) as within subject factors. The main effect for language was not significant, F (1, 24) = 0.330, $p > 0.05$, $\eta_p^2 = 0.014$. The main effect for type was also not significant, F (1, 24) = 0.868, $p > 0.05$, $\eta_p^2 = 0.035$. The main effect for language x type interaction was not significant, F (1, 24) = 2.112, $p > 0.05$, $\eta_p^2 = 0.081$. (Figure 2)

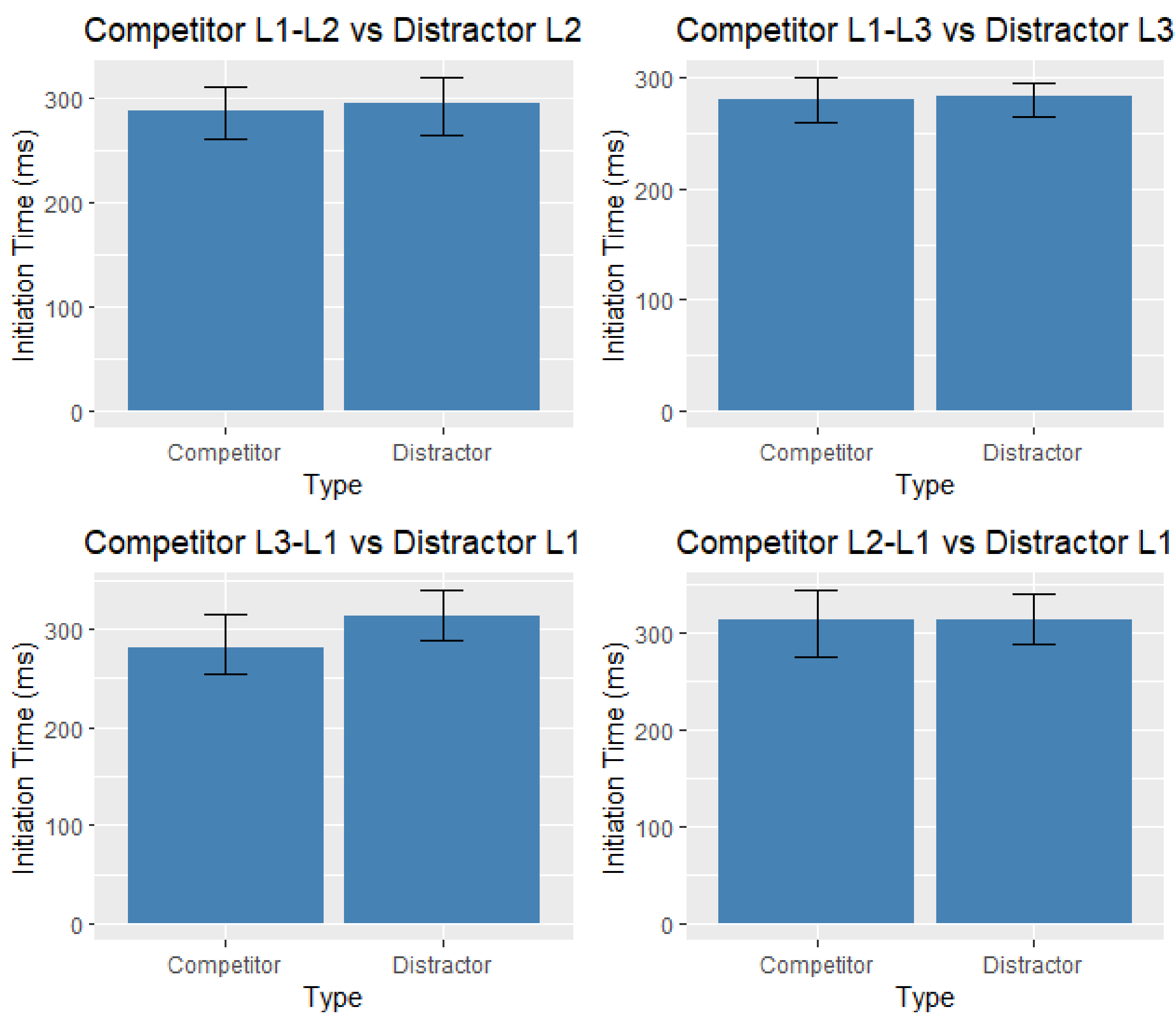

Figure 4.2: Initiation time (in ms) across three language directions in phonological cohort and non-phonological cohort conditions.

4.3.1.4 Response Time

L1 and L2

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L2) and type (competitor and distractor) as within subject factors. The main effect for type was highly significant, $F (1, 24) = 81.077$, $p < 0.001$, $\eta_p^2 = 0.772$ showing overall response time was faster in presence of phonological competitor (mean = 1624.239 ms, SE = 65.435) than distractor (Mean = 1818.504 ms, SE = 79.667). Follow up comparison indicated that each pairwise difference was significant, $p < 0.001$. The main effect for language was not significant, $F (1, 24) = 2.096$, $p> 0.05$, $\eta_p^2 = 0.080$ indicating that the auditory input of the language (L1 or L2) did not have significant effect on the mouse movement. The main effect for language x type interaction was highly significant, $F (1, 24) = 21.805$, $p< 0.001$, $\eta_p^2 = 0.476$. Pairwise comparisons indicate that when the auditory input was in L1 there was highly significant ($p < 0.001$) difference between response latency in competitor (Mean =1520.928 ms, SE = 70.498) compared to distractor (Mean = 1850.053 ms , SE = 95.120) in which participants responded faster in phonological similar conditions. However, for auditory input in L2 , there was no significant ($p = 0.338$) difference between response latency in competitor (Mean = 1727. 551 ms , SE = 69.265) compared to distractor (Mean = 1786.956 ms , SE = 75.714)

L1 and L3

A subject wise 2 x 2 repeated measures ANOVA was performed with language (L1 and L2) and type (competitor and distractor) as within subject factors. The main effect for type was highly significant, $F (1, 24) = 22.416$, $p < 0.001$, $\eta_p^2 = 0.483$ showing overall response time was faster in presence of phonological competitor (mean = 1826.258 ms, SE = 67.668) than distractor (Mean = 2030.657 ms, SE = 93.889). Follow up comparison indicated that each pairwise difference was significant, $p < 0.001$. The main effect for language was significant, $F (1, 24) = 15.918$, $p< 0.05$, $\eta_p^2 = 0.399$ indicating that overall response time was faster when the auditory input language was L1 (Mean = 1714.796, SE = 80.967) compared to when the auditory input language was L3 (Mean = 2142.119, SE = 107.900) Follow up comparison indicated that each pairwise difference was significant, $p < 0.05$. The main effect for language x type interaction was not significant, $F (1, 24) = 2.367$, $p> 0.05$, $\eta_p^2 = 0.090$. (Figure 3)

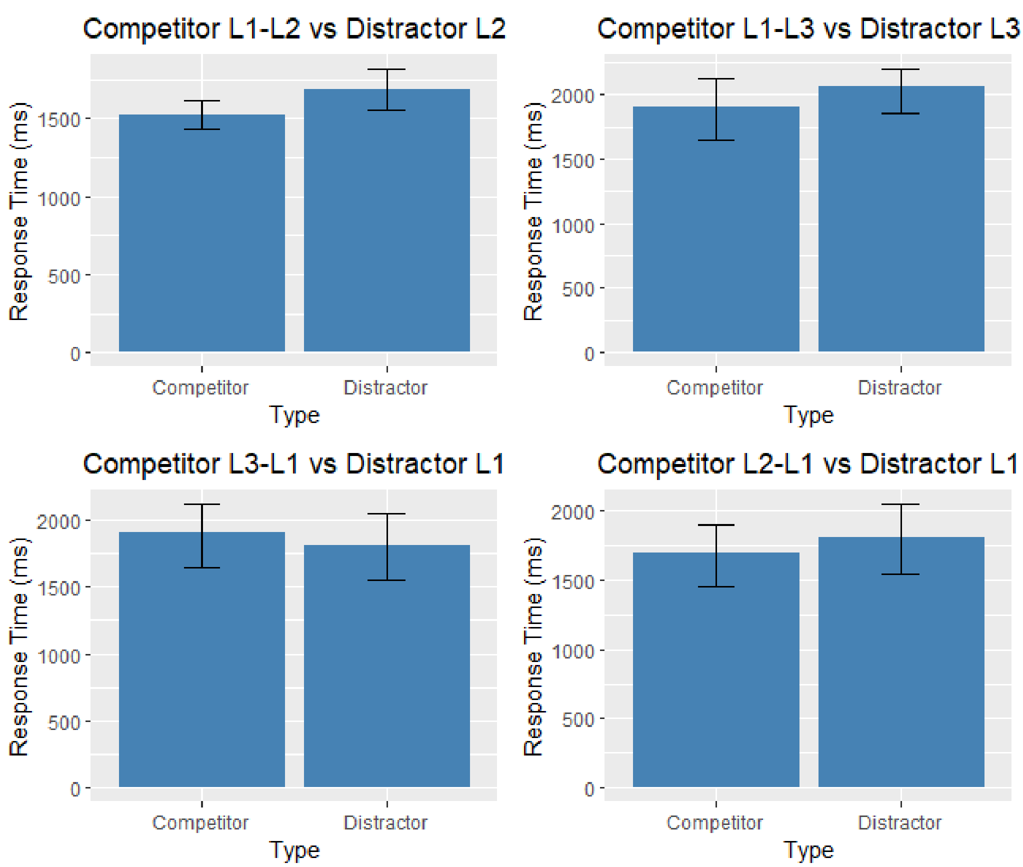

Figure 4.3: Response time (in ms) across three language directions in phonological cohort and non-phonological cohort conditions.

4.3.2 Verbal Fluency Task: Phonetic and Semantic Fluency

Table 4.2: Verbal fluency task performance mean score (standard deviation given in brackets)

Phonetic Fluency					
L1	Mean (SD)	L2	Mean (SD)	L3	Mean (SD)
प	11.4 (4.0)	P	12.7 (3.0)	P	4.75 (3.9)
त	10.6 (3.8)	T	13.7 (3.6)	T	4.46 (4.7)
क	13.2 (4.0)	K	5.56 (3.0)	K	6.29 (4.3)
Semantic Fluency					
L1	Mean (SD)	L2	Mean (SD)	L3	Mean (SD)
जनावर	17 (5.4)	Animals	17.3 (4.6)	Animals	7.04 (6.3)
फल	12.6 (2.9)	Fruits	10.5 (2.4)	Fruits	7.71 (4.1)
फुल	5.67 (3.0)	Flowers	4.63 (2.1)	Flowers	2.08 (2.5)

For phonetic fluency, a subject wise 3 x 3 repeated measures ANOVA was performed with language (L1, L2 and L3) and phonetic fluency (p. t and k) as within subject factors. The main effect for language was highly significant, $F(2, 23) = 14.190$, $p < .001$, $\eta_p^2 = 0.552$. Pairwise comparison showed nonsignificant difference between L1 and L2 ($p = .094$), highly significant difference between L1 and L3 ($p < .001$), highly significant difference between L2 and L3 ($p < .001$). Language wise, the mean number of words they created in each language was L1 M = 11.747 (SE = .689), L2 M = 10.667 (SE =.452), L3 M = 5.880 (SE = .814). The main effect for phonetic fluency was highly significant, $F(2, 23) = 11.352$, $p < .001$, $\eta_p^2 = 0.497$. Pairwise comparison showed nonsignificant difference between /p/ and /t/ ($p = .161$), highly significant difference between /p/ and /k/ ($p = .001$), highly significant difference between /t/ and /k/ ($p < .001$). Phonetic fluency wise, the mean number of words they created with each phoneme was /p/ M = 9.627 (SE = .453), /t/ M = 10.267 (SE =.538), /k/ M = 8.400 (SE = .372). The interaction between language and phonetic fluency was highly significant, $F(4, 21) = 41.402$, $p < .001$, $\eta_p^2 = 0.887$. Pairwise comparison showed the mean difference in number of words created for /p/ between L1 and L2 was not significant ($p = .113$), between L1 and L3 was highly significant ($p < .001$), between L2 and L3 was highly significant ($p < .001$). The mean difference in number of words created for /t/ between L1 and L2 was highly significant ($p < .001$), between L1 and L3 was highly significant ($p = .003$), between L2 and L3 was highly significant ($p < .001$). Likewise, the mean difference in number of words created for /k/ between L1 and L2 was highly significant ($p < .001$), between L1 and L3 was highly significant ($p < .001$), between L2 and L3 was not significant ($p = .480$. The mean number of words generated by participants in L1 for /p/ was M = 11.400 (SE = .804), for /t/ M = 10.600 (SE = .755), for /k/ M = 13.240 (SE = .794); the mean number of words generated in L2 for /p/ was M = 12.720 (SE = .593), for /t/ M = 13.720 (SE = .713), for /k/ M = 5.560 (SE = .600); the mean number of words generated in L3 for /p/ was M = 4.760 (SE = .764), for /t/ M = 6.480 (SE = .928), for /k/ M = 6.400 (SE = .850).

For semantic fluency, a subject wise 3 x 3 repeated measures ANOVA was performed with language (L1, L2 and L3) and semantic fluency (animals. fruits and flowers) as within subject factors. The main effect for language was highly significant, $F(2, 23) = 20.772$, $p < .001$, $\eta_p^2 = 0.644$. Pairwise comparison showed nonsignificant difference between L1 and L2 ($p = .102$), highly significant difference between L1 and L3 ($p < .001$), highly significant difference between

L2 and L3 ($p < .001$) in the number of words created. Language wise, the mean number of words they created in each language was L1 M = 11.787 (SE = .593), L2 M = 10.787 (SE =.504), L3 M = 5.653 (SE = .783). The main effect for semantic fluency was highly significant, $F(2, 23) = 189.081$, $p < .001$, $\eta_p^2 = 0.943$. Pairwise comparison showed highly significant difference between L1 and L2 ($p < .001$), L1 and L3 ($p < .001$) and L2 and L3 ($p < .001$) in the numbers of words generated from the given category. Semantic category wise, the mean number of words they created in animal category was M = 13.773 (SE = .750), for fruit category M = 10.267 (SE = 372), and for flower category M = 4.187 (SE = .348). The interaction between language and semantic fluency was highly significant, $F(4, 21) = 15.652$, $p < .001$, $\eta_p^2 = 0.749$. Pairwise comparison showed the mean difference in number of words created for animal category between L1 and L2 was not significant ($p = .753$), between L1 and L3 was highly significant ($p < .001$), between L2 and L3 was highly significant ($p < .001$); the mean difference in number of words created for fruit category between L1 and L2 was significant ($p = .007$), between L1 and L3 was highly significant ($p < .001$), between L2 and L3 was highly significant ($p = .005$); likewise, the mean difference in number of words created for flower category between L1 and L2 was not significant ($p = .115$), between L1 and L3 was highly significant ($p < .001$), between L2 and L3 was highly significant ($p = .001$). The mean number of words generated by participants in L1 for animal category was M = 17.000 (SE = 1.063), for fruit category M = 12.640 (SE = .568), for flower category M = 5.720 (SE = .587); the mean number of words generated in L2 for animal category was M = 17.280 (SE = .910), for fruit category M = 10.440 (SE = .480), for flower category M = 4.640 (SE = .420); the mean number of words generated in L3 for animal category was M = 7.040 (SE = 1.232), for fruit category M = 7.720 (SE = .807), for flower category M = 2.200 (SE = .497). See Table 2 for mean scores in VFT

4.4 Discussion

In this study, we investigated language comprehension and production in a migrant population in trilingual design parallel language activation paradigm in a mouse tracking for language comprehension and verbal fluency task for language production which also serves as executive control task. In mouse tracking experiment, Analysis of Area Under the Curve showed effect of proficiency and stimuli type. Since participants were almost equally proficient in both L1 and L2, there was no significant effect of language input which indicates the activation of both the languages was almost equal in both the directions. The effect was seen only in the response stimuli type where a facilitation effect of phonological similarity was observed with mouse trajectory moving faster toward the target when it matched phonologically with the auditory input compared to when there was no phonological similarity. Whereas, with proficiency difference in L1 and L3 (L1 as their native language and L3 as a language learnt as an immigrant), the significant effect was observed in language where the participants' mouse trajectory deviated more toward the unselected response when the auditory input was in L3 compared to L1 indicating the lexical access took longer and they experienced more competition from their L3 activation than their L1 activation.

The analysis of maximum deviation toward unselected response shows the effects are significant language wise and also type wise. In L1 and L2 condition, the response shows facilitation effect of phonological competitor where the response to target is faster compared to phonologically not matching distractor. The auditory input language effect is significant as the latency of deviation toward unselected response when the auditory input is in L1 is higher compared to when it is in L2 reflecting the immigration and immersion effect of language as the participants are living in non-L1 environment and their regular language use is L2. This is shown by lesser deviation toward unelected response in L2 and reaching the response faster. The activation is higher and faster in L1 – L2 direction compared to L2 – L1

The effect of language is more significant in language input compared to stimuli type in L1 and L3 environment. When the auditory input was in L1, participants moved the mouse faster towards the target compared to when the auditory input was in L3 as shown by higher deviation toward unselected response. This shows the parallel language activation was higher and faster in L3 – L1 direction compared to when it was in L1 – L3 direction. The participants had been using their L3 as immigrants and had not reached native like proficiency which delayed their response movement toward the target when the auditory input was in L3 in comparison to when the auditory input was in L1. Whereas in response stimuli type processing, competitor was processed faster showing phonological cohort had facilitation effect.

In Initiation Time, irrespective of the auditory language input and directionality (L1 – L2, L1 – L3, L2 – L1, L3 – L1) and the type of target response (competitor or distractor), the participants did not show significant difference in initiating the mouse movement and movement the mouse in similar manner.

In Response Time, the effect of the presence of phonological cohort in response pattern is clearly visible in the analysis of the response latency. When the auditory input was in L1, the response was faster compared to when it was in L2 or L3 in presence of the image whose name shared phonological similarity with the auditory word. The degree of language activation and latency varied in relation to the proficiency of the language used by the participants with lowest latency in L1 and higher in L2 and highest in L3. As the participants were using mainly L2 for all communication outside their own circle there was not much difference in the response latency when the auditory input was either in L1 or L2. However, when it was in relation to L1 or L3, there was significant difference as they had not yet reached the level of proficiency in their L3 compared to their L2.

In verbal fluency task, we used three stimuli each of phonetic and semantic fluency: voiceless stop consonants /p/, /t/ and /k/ for phonetic and animal, fruit and flower for semantic fluency. We chose the three phonemes/letters for consistency in comparison across all the three languages as unlike in English that uses mostly F, A, and S for phonetic fluency task, there is no normative study of verbal fluency task (for example, as in Kosmidis et al, 2004) in Nepali and Norwegian to establish standard testable phonemes, however, semantic category are similar across many languages. ANOVA results showed the participants were equally fluent in L1 and L2 but the difference was significant between L1 and L3, L2 and L3 in both phonetic and semantic fluency. They created more words in L1 and L2 compared to L1 and L3 and L2 and L3. Verbal fluency task is a simple but powerful neuropsychological tool that can measure both executive control ability and verbal ability component in just one single framework (Shao et al, 2014). Therefore, this task can be used effectively as a tool to measure executive control (phonetic fluency) as well as language production (semantic fluency) (Pathak et al, 2021). Generating words in semantic or category condition is similar to lexical access in interconnected network as in over learned process of language production of ordinary language whereas generating words in phonetic or letter condition is more effortful as phonemic generation is not common strategy of word organization and retrieval so there is increased demand for executive control in phonetic fluency (Luo et al, 2010). Consistent with this situation, our participants generated more words in semantic fluency compared to phonetic fluency. One advantage of using verbal fluency task in trilingual processing is, it gives a baseline in one language to compare other two languages. Previous studies with bilingualism have shown bilingual disadvantage in verbal fluency task compared to monolinguals (Luo et al, 2010) because of smaller vocabulary (Portocarrero et al., 2007; Bialystok & Feng, 2011) and slower retrieval (Ivanova & Costa, 2008; Gollan et al., 2005). Our results showed trilingual participants generated words in verbal fluency task as per their proficiency in each language, that is, almost equal number of words in L1 and L3 and less in L3 as they had not attained the degree of proficiency in their L3 as in their L1 and L2.

A modulating mechanism for multiple languages is control (Green, 1986; 1998) that operates both linguistically and cognitively. Cognitively, control regulates the conflict monitoring and resolution; linguistically, it regulates activation and inhibition of languages in current use. The additional requirement to process three languages adds to the cognitive load as noticed in decreased accuracy and fluency (Magiste, 1984) or reduction in speed of processing (Magiste, 1986). During parallel activation of lexicon in multiple languages, control mechanism directs attention to one word in one language while activating the selected word and inhibiting the competing words from the languages which are not selected for the current task (Paradis, 1989). Green (1986) proposes three possible states of activation in speech production: selected, active and dormant, and only one language can be selected at any one time. In trilingual parallel activation, there could be one of the three states of activation: one active and one dormant; one selected and two dormant; one selected; one selected and two active in a combination unique to trilingual activation (Festman, 2006; see also Festman, 2020 for a conceptual review on processing of multiple languages). Festman (2006) makes a distinction between a general (determined by language proficiency indicating basic state of activation) and current (the three possible states of activation as proposed by Green (1986) level of activation. Inhibition, on the other hand, is a mechanism opposite to activation which reduces and suppresses the level of activation for irrelevant and distracting information that could interfere with the processing of currently selected information (Green, 1998; Festman, 2006; 2020; Neumann, McCloskey, & Felio, 1999; Querné, Eustache, & Faure, 2000; Bjork, 1989). Inhibitory Control Model (Green, 1998) predicts that when a language is being processed (IC Model is primarily a production model rather than comprehension model) by bilingual (by extension, trilingual or multilingual) speaker, the currently unselected language is inhibited to avoid interference to allow for the activation of the selected language. In trilingual processing, whether in comprehension or in production like in our study, an individual is required to activate one language and inhibit the other two (or more, if the individual is a polyglot). In our study, when the participants listened to their L1, they would be required to activate L1 and inhibit L2 and L3, Likewise when they listened to L1 they needed to inhibit L1 and L3 and while listening to L3 they had to inhibit their L1 and L2 in order to comprehend the incoming auditory input and respond by clicking on the picture matching with incoming auditory stimuli.

Green and Abutalebi's Adaptive Control Hypothesis (2013) outlines three patterns of everyday conversational contexts in bilinguals: single language, dual language and dense code switching contexts that interact with eight cognitive control processes of goal maintenance, interference control - conflict monitoring and interference suppression, selective response inhibition, salient cue detection, task engagement, task disengagement, and opportunistic planning. Of these eight processes, only opportunistic planning interacts with dense code-switching context. Two of them - goal maintenance and interference control interact with single language context and all seven control processes (except opportunistic planning) interact with dual language context. Bilinguals use one language in one language environment and another one in another language environment maintaining distinct interaction in single language context. Whereas, in dual language context, bilinguals use both the languages but typically with different speakers, they may switch their language within a single conversation but not within the same utterance. But in a dense code-switching context, the speakers regularly interleave the languages they are speaking even within the single utterance and adapt and intermix words from either of their two languages. These control processes keep cascading during interaction. In our study, we tested language comprehension in parallel language activation paradigm and production in lexical retrieval paradigm using verbal fluency task. Participants were asked to listen to the spoken word in their L1, L2 or L3 and mouse-click the picture on the computer screen that matched with the incoming spoken word. The task made the participants recruit their proactive control (Baver, 2012; Briscoe & Gilchrist, 2020) by maintaining the goal of listening to the auditory input and matching the semantic feature with one of the pictures displayed on the screen. Upon hearing the spoken word and looking at the image on the screen, which also activated nontarget phonologically matching cohort word on the opposite side of the target image, the participants were expected to face interference as a result of onset activation of both the words phonologically matching and competing with each other for selection. They would be required to control the interference by monitoring the conflict posed by phonologically matching cohort and suppress the interference with salient cue detection from the features of the target image building up the meaning of the auditory input and exert selective response inhibition toward the image posing the phonological competition and disengage from the task of moving the mouse toward the unselected activation and engage in the task of moving mouse toward the target image and resolve the conflict by clicking on the target image. However, such cascading of control processes that predicts bilingual processing didn’t align completely with trilingual parallel activation in our study. It aligned this way only in L3 – L1 direction, that too in the presence of non-phonological matching distractor but not in L1 – L2 and L1 – L3 direction in the presence of phonologically matching cohort. This discovery of differences in parallel activation in bilingualism and trilingualism propels us to rethink and revisit that the theories and models of bilingualism cannot be posited upon trilingualism and it calls for a different treatment and approach.

In the previous studies of parallel language activation in bilinguals, researchers have found that when the distractor matches phonologically with the incoming auditory input, the target and distractor compete for selection and the response is delayed before the conflict is resolved and the target is finally selected (see for example, Mishra & Singh, 2013; Singh & Mishra, 2015; Marian & Spivey, 2003, 2003b; Marian et al, 2013, Marian et al, 2014, Blumenfeld & Marian, 2013). Recent evidence of parallel activation show that early segment of the auditory utterance initiates lexical activation which is largely automatic and the competition between activated candidates is largely resource dependent where the critical resource is phonological processing (Zhanga & Samuel, 2018). Trilingual phonological, lexical processing like in our study provides more phonological and lexical resources compared to bilingual processing and we assume when competition crosses certain threshold of selection the cognitive mechanism of conflict resolution becomes more efficient and it does not face competition anymore, rather there is facilitative effect of processing. But this processing benefit is achieved only with experience and more practice as in our study participants processed the lexical selection faster when the target and distractor shared phonological similarity in L1 and L2 as these two languages were used most by the participants whereas in the less dominant language L3, the processing for selection was slower in when the target and distractor shared phonological similarity. Here, it is to be noted that the finding in our study for L3 processing is similar to previous findings in parallel language activation in bilinguals. This finding from our study is an evidence of additive benefit of trilingualism which is not exactly the same as in bilingualism.

How to account for this effect of multilingual processing? Festman (2020) suggests five effects resulting from the learning and processing of multiple languages: (a) stimulating effect – children who are exposed to more languages than one in the early age become sensitive and interested in phonetic contrast and are faster in disengagement of attention affecting executive function in babies even before they learn to speak (see also Claussenius-Kalman & Hernandez, 2019; D'Souza et al., 2020; Höhle et al., 2020); (b) facilitating effect – a larger linguistic repertoire, with representation of increased number of languages in the brain providing positive transfer both quantitatively (larger mental lexicon) and qualitatively (diverse knowledge of tonality, morphological processing etc.); (c) catalytic effect – the acquisition of a new information especially word learning and grammatical learning is sped up in multilingual learners (see also Montanari, 2019; Rothman, 2010); (d) modulating effect – formal instruction and literacy acquisition in heritage languages causing biliteracy especially in typologically nonrelated languages helps in developing superior metalinguistic skills (Sanz, 2007); (e) triggering effect – as the brain uses the convergence principle (using existing structures and representation to build new ones) and adaptation (strength of connections like control circuits being changed to accommodate new processing demands), the brain extends a well-organized language network to incorporate additional languages. This process of adaptation and convergence may be indicative of triggering effect of multilingualism – that learning new languages may trigger and prompt the process of adaptation for the managing of language control and in turn improve cognitive control and linguistic control. Linking these effects to our study, we believe, our participants' pre-existing L1 and L2 stimulated and facilitated the learning of their L3. As they were also biliterate in their L1 and L2 it might have modulated and helped speed up their learning and processing of L3. Our finding is best explained by triggering effect, the language control network converged and adapted to the new the language and strengthened the control circuits to allow for the processing of additional language and become efficient enough to not face competition while processing the phonologically similar information, rather resolve the conflict efficiently and create a facilitative effect in processing.

As far as we know, this is the first study that investigated trilingual processing using parallel language activation paradigm and mouse tracking as a tool. What we can conclude regarding our novel finding is that much of the previous studies with parallel language activation with bilingual design have found interference effect in both language directions. In our study, there is facilitation effect with three language design where the participants listened to the spoken words in all three languages in random order. We can argue that when multiple languages are active in our mental lexicon, the processing becomes faster in the language conditions that are phonologically related, especially among dominant languages.

4.5 Limitations and future directions

This study is limited to within subject design which does not provide a basis to compare with control group. Future research should investigate the multiple language processing pattern among different populations like the refugees who have been settled in the third country, how do they process the new language in the course of assimilation, what is the difference between first generation heritage speakers and the second generation of heritage speakers? Our design may also allow to investigate multiple language processing pattern among the student population and people who have migrated for job or resettlement. An important future direction for this study would be to study the language attrition among the population who studied in Norway and returned to Nepal and lost regular touch with Norwegian language and to see if they process the three languages in the same manner as when they were in Norway.

Chapter 5: Conclusion

This thesis was guided by the motivation to investigate linguistic and cognitive processing in bilinguals using a novel tool of MouseTracker and further investigate efficacy of this tool for bilingual research. He studies carried out in this thesis attempted to answer the following questions:

a. How does the language dominance shift in bilinguals? Are offline or online measures more effective in testing the dominance in bilinguals?
b. Does immigration and immersion in second language affect first language? If it does what is the effect in language attenuation and attrition?
c. Is it possible to extend the research methods used in bilingualism to investigate trilingual processing? Is the mechanism for processing bilingualism and trilingualism similar or different? How do the three languages interact with each other?
d. How is language selectivity modulated by various experiences of the bilinguals?

The thesis has succeeded in finding the answer to the questions that set the agenda for this research. It has revisited the previous studies that asked these questions and has produced some new answers and opened up some new areas for future research.

5.1 Language dominance and selectivity in bilinguals

This study investigated the issue of language dominance in Gurung-Nepali bilinguals. We used two measures: an offline measure by administering Bilingual Dominance Scale (Dunn & Fox Tree, 2009) and an online measure of bimodal parallel language activation in mouse tracking experiment to test the dominance of our participants. We measured the language dominance score using a questionnaire generated qualitative responses indicating which of the two languages in our participants was dominant in them. A total of 57 participants with mean age 32 years were divided into two groups of participants, age wise: younger group (n = 28) with mean age of 21 years and the older group (n = 29) with mean age of 43 years. The bilingual dominance score showed the dominance was shifting toward L2 in the younger group. According to the Bilingual Dominance Scale, a balanced bilingual is someone falling within the scale range of -5 and +5, or broadly, within the range of -10 and +10. The rating for the younger group (first group) of participants ranged from -2 to +20 (Mean = + 8.2 and the rating for the older group (second group) ranged from -16 to -5 (Mean = -9.1). The scale showed the dominance in the younger group shifting toward their L2 and the older participants maintaining their dominance in L1. However, the entire sample fell within the range of balanced bilingual score (see chapter 2 for details). The study was conducted in Bayatari, Waling Municipality, Gandaki Province in Nepal.

We wanted to verify this offline measure with more reliable online measure, for which we used bilingual lexical access language comprehension task in parallel language activation paradigm in MouseTracker (Freeman & Ambady, 2010; Freeman, 2018) in which participants listened to the words either in Gurung or in Nepali and clicked on the picture matching with the auditory input. The response conditions were phonologically manipulated to test the degree of competition for lexical selection the participants faced during the experiment. In competitor condition, the distractor on the opposite side of the target picture shared the onset similarity with the spoken word and target picture whereas in the non-competitor condition, the distractor did not share such similarity. The difference in response time in these two conditions gave us a measure of the degree of activation which was a signature of language dominance in our participants. There was no language and group interaction, which means, the participants did not show the processing difference in either of their two languages. They responded faster in non-competition condition compared to condition means they experienced competition for language selectivity when the lexicon in both the languages got activated and competed for selection. The mouse tracking experiment showed that the process of dominance shift toward L2 was not complete in the younger participants and the older participants retained their L1.

5.2 Second language immersion effect on first language attenuation

We investigated the effect of immigration and immersion in L2 in a group of 55 participants who were university students from Nepal studying in India. They spoke Nepali as their L1 and English was used as language of instruction and while communicating with teachers and other fellow non-Nepali students. We tested immersion effect by dividing the students in two groups with different degree of immersion. First group was low immersion group (n = 25) with 14 months of immersion and the second group (n = 30) was immersed for 38 months. We tested them on language comprehension and language production task. We tested language comprehension using parallel language activation in L1 and L2 in mouse tracking experiment in which the participants listened to the spoken in word in L1 or L2 and clicked on the target picture that shared the same name as the spoken word which had a distractor on the opposite side of the screen that shared phonological similarity at the onset level or a distractor that did not share such phonological similarity. There was no significant effect for language which means that participants performed equally in both their languages. The main effect for type was significant in which the participants responded faster in condition where the distractor did not match phonologically with the target compared to where it did. The interaction between language and type, between language and group was not significant which means both the groups did not face any temporal delay in responding to either of the languages and in phonologically competing or non-competing conditions. The marginally significant interaction between group and type showed that only the first group (less immersion) faced competition between phonologically competing condition compared to second group (higher immersion) in which there was no significant difference in response latency between both phonologically competing or non-competing condition.

We tested language production using verbal fluency task in which we asked the participants to produce as many exemplars as they can in 60 seconds in phonetic fluency and semantic fluency condition in L1 and L2 following certain criteria. The letters/phonemes for phonetic fluency in L1 were क, प, म and in L2 were F, A, S whereas for semantic fluency the categories from which they were asked to make words were animal, fruit, cloth, vegetable, and flower categories in both L1 and L2. We ran repeated measures ANOVA in semantic fluency task with language and category as within-subject factors and group as between-subject factors. We report language effect in which participants produced more words in L1 (13 words in average) compared to the number of words produced in L2 (11 words in average). Significant language and semantic fluency interaction indicated that the language wise there was a difference in the number of exemplars generated. In L1, they generated the number of words in this sequence: cloth (17), animal (16), vegetable (14), fruit (12) and flower (6). The participants produced the number of words in the five categories in L2 in the following order: animal (18), cloth (15), fruit (10), vegetable (10) and flower (5). Non-significant language and group interaction indicated participants produced almost equal number of words in both the languages. Likewise, semantic fluency and group interaction also being non-significant indicated that the participants of both the groups generated almost equal number of words in semantic fluency (see Chapter 3 for details).

The results indicate that immersion in L2 had no attenuation and attrition effect in L1. The participants had been successful in maintaining their proficiency equally in both of their languages. Our results provide counter evidence to the findings of previous studies (Link, Kroll & Sunderman, 2009; Baus, Costa & Carreiras, 2013) on the role of L2 immersion in L1 attrition

5.3 Trilingual processing: dominant languages grab all the attention

We extended the idea of bilingual processing to trilingual processing. For this this we conducted a study on Nepali-English Norwegian trilinguals. The study was conducted in Norwegian University of Science and Technology (NTNU) Where I visited as a PhD exchange student under Erasmus Global Mobility program as part of collaboration between Action Control and Cognition Lab of Center for Neural and Cognitive Sciences, School of Medical Sciences, University of Hyderabad and Language Acquisition and Processing Lab, Department of Language and Literature, Norwegian University of Science and Technology, Trondheim, Norway. The participants for this study were recruited from among the students from Nepal who were pursuing higher education in NTNU. 25 participants (Mean age = 29 years). Their mean duration of stay in Nepal was 23 years and in Norway was five years, and they spoke Nepali as their L1, English as their L2 and had learned Norwegian as L3 in Trondheim, and were low proficient in Norwegian. They had received all their school and undergraduate level education in English in Nepal.

We tested the participants on trilingual comprehension using an experiment on trilingual parallel activation in bimodal condition. The participants listened to the spoken word in all the three languages randomly and clicked on the picture displayed either on top right or top left of the computer screen. The visual stimuli were arranged in such a way that the non-target picture was either a phonological competitor of the spoken word that shared phonological similarity with the auditory input, in which the onset was the same sound or it didn't have such phonological relation with the auditory input. Both the visual displays were semantically unrelated. The participants made response by clicking the target picture with the computer mouse we measured the mouse movement trajectories as the participants made response. It allowed us to measure the initiation time of the mouse movement and response time. The trajectories are signatures of the cognitive processing as the participants arrive at a decision to make the response.

Trilingual phonological, lexical processing like in our study provides more phonological and lexical resources compared to bilingual processing and we assume when competition crosses certain threshold of selection the cognitive mechanism of conflict resolution becomes more efficient and it does not face competition anymore, rather there is facilitative effect of processing. But this processing benefit is achieved only with experience and more practice as in our study participants processed the lexical selection faster when the target and distractor shared phonological similarity in L1 and L2 as these two languages were used most by the participants whereas in the less dominant language L3, the processing for selection was slower in when the target and distractor shared phonological similarity. Here, it is to be noted that the finding in our study for L3 processing is similar to previous findings in parallel language activation in bilinguals. Previous studies with parallel language activation with bilingual design have found interference effect in both language directions. In our study, there is facilitation effect with three language design where the participants listened to the spoken words in all three languages in random order. We argue that when multiple languages are active in our mental lexicon, the processing becomes faster in the language conditions that are phonologically related, especially among dominant languages. This finding from our study is an evidence of additive benefit of trilingualism which is not exactly the same as in bilingualism (see Chapter 4 for details).

We tested language production of the participants using verbal fluency task that measured phonetic and semantic fluency. Verbal fluency task is a simple but powerful neuropsychological tool that can measure both executive control ability and verbal ability component in just one single framework (Shao et al, 2014). Therefore, this task can be used effectively as a tool to measure executive control (phonetic fluency) as well as language production (semantic fluency). Generating words in semantic or category condition is similar to lexical access in interconnected network as in over learned process of language production of ordinary language whereas generating words in phonetic or letter condition is more effortful as phonemic generation is not common strategy of word organization and retrieval so there is increased demand for executive control in phonetic fluency (Luo et al, 2010). Consistent with this situation, our participants generated more words in semantic fluency compared to phonetic fluency. One advantage of using verbal fluency task in trilingual processing is, it gives a baseline in one language to compare other two languages.

Results of both language comprehension and production task showed the effect of language dominance and language proficiency in the trilinguals.

5.4 Language selectivity modulation by language experience

An interesting finding from our study in language selectivity is the differential processing in bilinguals and trilinguals. Our results in parallel language activation is consistent with previous studies which have found that the bilinguals experience a situation of interference from their both the languages while selecting the target language and inhibiting the non-target language as all the lexical items in the mental lexicon are activated at the same time. Phonological similarity in both the languages are found to activate the lexical items that share the same phonological representation. This has been found through the manipulation of target with distractor sharing or not sharing the phonological similarity. It has been found that when the bilinguals face conflict as a function of interference in both the languages, the response is slow in conditions where the target shares phonological similarity with the distractor, as observed in higher response latency in the previous studies. In this thesis, we have reported two studies in bilingual processing and one study in trilingual processing. Parallel language activation in trilinguals showed that the processing is faster where the distractor shares phonological similarity with the target. We observed two types of patterns: in L1 and L2 phonological similarity facilitated the processing whereas in L3 it inhibited. This issue needs further investigation in future studies.

5.5 Limitations of the study

This study has some limitations, as no study is perfect in itself. Mouse tracker is an efficient tool in conducting studies as reported in this thesis. In fact, among the existing tools in conducting behavioral experiments, it is the best so far. However, this tool allows us to conduct only comprehension or perception experiments and not the production experiments for which we need to use other tools or task. Since we designed language comprehension experiments using this tool, it served our purpose as we conducted language production task using verbal fluency task.

Compared to other tools used in behavioral research that measure mostly reaction times, Mouse Tracker allows for very rich data to measure various temporal processing including the cognitive complexity in decision making process measured by x-flips and y-flips of the mouse movements.

In our study, we have limited the temporal analysis mainly to the initiation time and response time, even though, which by itself is an advanced level of cognitive measurement.

Mouse Tracker as a research tool is more suitable in conducting experiments with literate or educated participants who are familiar or can get trained to use the computer mouse to make the response. For participants not familiar with computer and mouse movement, it will be inconvenient to conduct experiments.

One major criticism in cognitive science in experimental design like ours is on the recruitment of the participants. Such studies are conducted within the university premises with the college students which are criticized on the grounds of lacking ecological validity as it does not reflect the real world outside the university campus where the experience of the people is more varied than what one finds in the controlled setting of university premises. We have tried to address this issue by recruiting participants from outside the academic environment in our Gurung – Nepali study as reported in Chapter 2. However, our two studies in Chapter 3 and Chapter 4 are on university students.

This study has focused mainly on language processing in bilinguals and trilinguals.

5.6 Future Directions

The insights and limitations from this study will set the future direction for this researchers to carry on further work and improve on the current shortcomings. The main tool used in designing the experiments for this study was Mouse Tracker which allows for very rich data to be extracted and analyzed which is not possible even in quite popular tool like eye tracker. In this study, we have used normalized time in calculating initiation and response time. It is also possible to do raw time data analysis. Researchers use either normalized time or raw time (they have not used both) in their analysis. Future work will focus in conducting raw time analysis as well. Also for cognitive complexity temporal measurement x-flip and y-flip will be will be considered in future.

In language comprehension, we used only listening task. It is also possible to conduct reading comprehension tasks using Mouse Tracker, so future work will also focus on conducting literacy and reading processing studies among bilinguals and multilinguals.

Mouse Tracker is a very portable tool that allows for the collection of rich and complex data, this tool will be used in future to investigate more complex and varied issues with participants from different linguistic, educational and socio-economic background across different age groups.

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Appendix – A (Informed consent forms used in the reported studies)

CONSENT FORM (Gurung – Nepali bilingual study)

Center for Neural and Cognitive Sciences

University of Hyderabad

Subject ID :

The purpose of this experiment: To understand the effect of parallel language activation on attentional mechanism/executive control.

- Participation in the study is completely voluntary.
- Data will be kept confidential and Subject's identity will be protected.
- Subject's participation will take approximately 75 minutes.
- If you are still interested in participating and assisting with this research project, please complete the consent form below. Keep the top of this form for future reference. You can contact me at 9451872007 or Lekhnath S Pathak at 9841762236 (Nepal), 9652581416 (India) if you have questions, comments or concerns now or in the future about your participation in this study.

Thank you very much for your time and consideration.

Signed ______________________

(Researcher)

I, ____________________________________, give my consent for the participation in the

study conducted by Dr. Ramesh Kumar Mishra and Mr. Lekhnath S Pathak.

I understand that:

- My data will be used for research
- My participation is voluntary.
- My information will be kept confidential.

I have read the information above and any questions I asked have been answered to my satisfaction. I give consent for my participation in this study.

Phone number :

Email :

Age :

Signed__________________________
Date_____________________________

Subject ID :

Center for Neural and Cognitive Sciences

University of Hyderabad

INFORMED CONSENT FORM (Nepali-English bilingual study)

The purpose of this experiment: To understand parallel language activation in Nepali-English bilinguals.

- Participation in the study is completely voluntary.
- Data will be kept confidential and Subject's identity will be protected.
- Subject's participation will take approximately 40 minutes.
- If you are still interested in participating and assisting with this research project, please complete the consent form below. Keep the top of this form for future reference. You can contact us at 9451872007 (R. K. Mishra) and 9652581416 (Lekhnath S Pathak) if you have questions, comments or concerns now or in the future about your participation in this study.

Thank you very much for your time and consideration.

Signed ______________________

(Researcher)

I, ____________________________________, give my consent for the participation in the study conducted by Dr. Ramesh Kumar Mishra and Lekhnath S Pathak.

I understand that:

- My data will be used for research
- My participation is voluntary.
- My information will be kept confidential.

I have read the information above and any questions I asked have been answered to my satisfaction. I give consent for my participation in this study.

Phone number :

Email :

Age :

Signed__________________________
Date_____________________________

Subject ID :

Language Acquisition and Language processing Lab
Norwegian Graduate Researcher School in Linguistics and Philology
Department of Language and Literature
Norwegian University of Science and Technology (NTNU)

INFORMED CONSENT FORM (Nepali-English-Norwegian trilingual study)

The purpose of this experiment: To understand how participants respond to spoken word and matching pictures in Nepali-English-Norwegian and written word and symbol. You will be required to do simple tasks on the computer which will be explained to you by the experimenter. There is no financial or any other material benefit attached to the study. However, your participation will contribute to the research in extending our understanding in language processing in bilinguals/multilinguals.

- Participation in the study is completely voluntary.
- You will perform computer based simple tasks related to language and cognition and fill up a language background questionnaire.
- Data will be kept confidential and Subject's identity will be protected.
- Subject's participation will take approximately 60 minutes.
- If you are still interested in participating and assisting with this research project, please complete the consent form below. Keep the top of this form for future reference. You can contact us at +4773596791 (Prof. Mila Dimitrova Vulchanova) and 93029453 (Lekhnath S Pathak) if you have questions, comments or concerns now or in the future about your participation in this study.

Thank you very much for your time and consideration.
Signed ______________________ (Researcher)

I, ____________________________________, give my consent for the participation in the

study conducted by Prof. Mila Dimitrova Vulchanova and Lekhnath S Pathak.

I understand that:

- My data will be used for research
- My participation is voluntary.
- My information will be kept confidential.

I have read the information above and any questions I asked have been answered to my satisfaction. I give consent for my participation in this study.

Phone number :

Email :

Age :

Signed__________________________
Date_____________________________

Appendix B: Language Questionnaires

Bilingual Dominance Scale Questionnaire (Gurung-Nepali study)

Subject ID: _________

Name: ___________________________________

Contact No.__________________________

Sex: ___________________

Age:_________________

Education (degree obtained/pursuing): ______________________________

Place of birth: _________________________

Currently living in:______________________ For how many years_____________

Native language/mother tongue: __________________

List all the languages you know, in order of dominance:

____

____

____

____

Native language of your Mother: ________________

Native language of your Father: _________________

At what age did you first learn to speak? :

Gurung ___________ Nepali_________________

Can you read and write?____

At what age did you feel comfortable speaking this language? (If you still do not feel comfortable, please write "not yet.")

Gurung ________ Nepali ________

Which language do you predominately use at home?

Gurung ________ Nepali ________ Both ________

When doing math in your head (such as multiplying 243 × 5), which language do you calculate the numbers in? ________

In which accent do you speak Nepali? ________

If you had to choose one language to use for the rest of your life, which language would it be?

Did you go to a Vernacular medium school _______ or a Nepali medium school ______ or a private boarding school___________or both ________?

How many years of schooling (primary school through university) did you have in:

Gurung ________ Nepali ________

Do you feel that you have lost any fluency in a particular language? ________

If yes, which one? ________ at what age? ________

Signature: _____________________ Date : ________________________

Bilingual Dominance Scale Questionnaire in Nepali (Gurung-Nepali)

Subject ID: _________

नाम: ____________________________________

लिङ्ग: ____________________

उमेर:__________________

सम्पर्क नः_________________________

शिक्षा (प्राप्त गरेको वा अध्ययनरत): ________________________________

जन्मस्थान: ___________________________

हाल बसोवास गरेको ठाउँ:_______________________कति वर्षदेखि?______________________

मातृभाषा: ___________________

तपाईं कुन-कुन भाषा बोल्नु हुन्छ?:

____

तपाईंकी आमाको मातृभाषा: _________________

तपाईंको बुवाको मातृभाषा: __________________

तपाईं कुन उमेरदेखि यी भाषा बोल्न थाल्नु भयो? :

गुरुङ्ग ____________ नेपाली__________________

तपाईं लेख-पढ गर्न सक्नुहुन्छ?____

तपाईंलाई कुन उमेरदेखि यो भाषा बोल्न सजिलो लाग्न थाल्यो? (यदि तपाईंलाई अझै सजिलो लाग्दैन भने "अझै लाग्दैन" भन्नुहोस)

गुरुंग _________ नेपाली _________

तपाईं घरमा धेरै जसो कुन भाषा बोल्नुहुन्छ?

गुरुंग _________ नेपाली _________ दुवै _________

तपाईं मनमनै हिसाब गर्दा (जस्तै २४x४) कुन भाषामा हिसाब गर्नुहुन्छ? _________

तपाईं कस्तो लवजमा नेपाली बोल्नुहुन्छ? _________

तपाईंलाई यी दुई भाषामध्ये सधैँभरी एउटै भाषा प्रयोग गर्नु पर्ने अवस्था भए कुन भाषा रोज्नुहुन्छ?

तपाईंले गुरुंग भाषामा लेख-पढ गर्न सिक्नु भयो ________ अथवा नेपाली माध्यममा _______ अथवा अँग्रेजी माध्यमको निजी विद्यालयमा।____________अथवा यी सबैमा _________?

तपाईंले विद्यालयदेखि विश्वविद्यालयसम्म यी भाषामा कति वर्ष अध्ययन गर्नु भयोः

गुरुंग _________ नेपाली _________

तपाईंलाई यी दुवै भाषामध्ये कुनै भाषामा दक्षता गुमाए जस्तो लाग्छ?_________

हो भने, कुन चाहींमा? _________ कुन उमेरदेखि _________

हस्ताक्षर: ________________________ मिति : ___________________________

Language Questionnaire for Nepali-English bilingual study

Participant ID:

Contact information

Name : ______________________________________

Email : ______________________________________

Mobile : (India and Nepal)__________________________

Date : _______________________________________

Please answer the following questions to the best of your knowledge.

1. Age (in years) :

2. Sex : Male/Female

3. Education (degree obtained/which year, if pursuing):

    Father's education:

    Mother's education:

4. Birth Place :   Currently living:

5. Native language/mother-tongue :

6. Please list all the languages you know in **order of dominance** :

____

____

____

____

____

____

7. What language(s) do you usually speak to your mother at home?

____

8. What language(s) do you usually speak to your father at home?

____

9. Write down the name of the language in which you received instructions in school/college at each level of education :

Primary school : _______________________

Secondary school/Middle school : _____________________________

High school : ___________________________

College/University : ______________________________

10. Age when you

began acquiring Nepali :

became fluent in Nepali :

began reading Nepali :

began reading fluently in Nepali :

11. On a scale of 1 – 10 (10 being the highest), please rate your level of proficiency in **Nepali** in :

Speaking :

Understanding spoken language :

Reading :

12. On a scale of 1 – 10, rate how much the following factors have contributed to your learning of **Nepali** :

Interacting with friends :

Interacting with family :

Reading :

Learning at school :

Watching TV :

13. On a scale of 1 – 10, rate to what extent you are **currently** exposed to **Nepali** in the following contexts :

Interacting with friends :

Interacting with family :

In your College/Workplace :

Reading :

Watching TV :

14. Age at which you

began acquiring English :

became fluent in English :

began reading English :

began reading fluently in English :

15. On a scale of 1 – 10 (10 being the highest), please rate your level of proficiency in **English** in :

Speaking :

Understanding spoken language :

Reading :

16. On a scale of 1 – 10, rate how much the following factors have contributed to your learning of **English** :

Interacting with friends :

Interacting with family :

Reading :

Learning at school :

Watching TV :

17. On a scale of 1 – 10, rate to what extent you are **currently** exposed to **English** in the following contexts :

Interacting with friends :

Interacting with family :

In your College/Workplace :

Reading :

Watching TV :

Language Questionnaire for Nepali-English-Norwegian trilingual study

(Subject ID:)

Contact information

Name : ______________________________________

Email : ______________________________________

Mobile : ___________________________

Date : _______________________________________

Please answer the following questions to the best of your knowledge.

1. Age (in years) : 2. Sex : Male/Female

3. Education (highest degree obtained/which year, if pursuing):

Father's education:

Mother's education:

4. Course studied in NTNU with duration: Date of return from NTNU:

5. Birth Place: Duration of stay in Nepal:

6. Currently living in: Duration of stay:

7. Native language/mother-tongue (L1): L2: L3:

8. At what age did you learn your L1: L2: L3:

9. At what age did you feel comfortable using your L1: L2: L3:

(If you still do not feel comfortable, please write "not yet")

10. Please list all the languages you know in **order of dominance**:

____

____

____

____

____

11. What language(s) do you predominantly speak at home? ____________________

12. What language(s) do you usually speak to your mother at home?

____

13. What language(s) do you usually speak to your father at home?

____

14. Onset age of bilingual/trilingual usage (At what age, do you think you started talking in different languages for communication?): (a) Both: (b) 3: (c) More than 3:

15. When doing math in your head (such as multiplying 243 × 5), which language do you calculate the numbers in? (Tick one)

(a) Nepali (b) English (c) Other

16. In which accent do you speak Nepali? ________ (L1, L2 or L3)

17. If you had to choose one language for the rest of your life, which language would it be? (Tick one)

(a) Nepali (b) English (c) Norwegian (d) Can't say

18. Do you feel that you have lost any fluency in a particular language? ________

If yes, which one? ________ at what age? ________

19. Write down the name of the language in which you received instructions in school/Institution at each level of education :

Primary school : _______________________

Secondary school/Middle school : _____________________________

High school : ___________________________

Institution/University : ______________________________

20. Age when you

began acquiring Nepali :

became fluent in Nepali :

began reading Nepali :

began reading fluently in Nepali :

began writing in Nepali:

began writing fluently in Nepali:

21. On a scale of 1 – 10 (10 being the highest), please rate your level of proficiency in Nepali in :

Speaking :

Understanding spoken language:

Reading :

Writing:

22. On a scale of 1 – 10, rate how much the following factors have contributed to your learning of Nepali :

Interacting with friends :

Interacting with family :

Reading :

Learning at school :

Watching TV :

23. On a scale of 1 – 10, rate to what extent you are **currently** exposed to Nepali in the following contexts :

Interacting with friends :

Interacting with family :

In your Institution/Workplace :

Reading :

Watching TV :

24. Age at which you

began acquiring English :

became fluent in English :

began reading English :

began reading fluently in English :

began writing in English:

began writing fluently in English:

25. On a scale of 1 – 10 (10 being the highest), please rate your level of proficiency in English in :

Speaking :

Understanding spoken language :

Reading :

Writing:

26. On a scale of 1 – 10, rate how much the following factors have contributed to your learning of English :

Interacting with friends :

Interacting with family :

Reading :

Learning at school :

Watching TV :

27. On a scale of 1 – 10, rate to what extent you are **currently** exposed to English in the following contexts :

Interacting with friends :

Interacting with family :

In your Institution/Workplace :

Reading :

Watching TV:

28. On a scale of 1 – 10 (10 being the highest), please rate your level of proficiency in **L3 (Norwegian)** in :

Speaking :

Understanding spoken language:

Reading :

Writing:

29. On a scale of 1 – 10, rate how much the following factors have contributed to your learning of **L3 (Norwegian)**:

Interacting with friends :

Interacting with family :

Reading :

Learning at school :

Watching TV :

30. On a scale of 1 – 10, rate to what extent you are **currently** exposed to **L3 (Norwegian)** in the following contexts :

Interacting with friends :

Interacting with family :

In your Institution/Workplace :

Reading :

Watching TV :

31. In this section you respond to the statements about your language attitude by giving marks from 1 – 6. 1 = agree, 6 = disagree. Circle your answer.

a) I feel like myself when I speak in my native language:
 1 2 3 4 5 6
b) c) I prefer speaking in my native language most of the time:
 1 2 3 4 5 6
c) I prefer speaking in English most of the time: 1 2 3 4 5 6
d) I prefer speaking in Norwegian most of the time: 1 2 3 4 5 6
e) I prefer listening to my native language most of the time:
 1 2 3 4 5 6
f) I prefer listening to English most of the time: 1 2 3 4 5 6
g) I prefer listening to Norwegian most of the time: 1 2 3 4 5 6
h) I prefer reading my native language most of the time:
 1 2 3 4 5 6
i) I prefer reading English most of the time: 1 2 3 4 5 6
j) I prefer reading Norwegian most of the time: 1 2 3 4 5 6
k) I prefer writing in my native language most of the time:
 1 2 3 4 5 6
l) I prefer writing in English most of the time: 1 2 3 4 5 6
m) I prefer writing in Norwegian most of the time: 1 2 3 4 5 6

32. Are a day scholar student? (a) Yes (b) No

Are a job holder? (a) Yes (b) No

33. Answer the following questions by giving marks on a scale of 1 – 10 : 1 = Never, 10 = always

a) How often are you in a situation in which you switch between the languages your native language, English and Norwegian?

b) When choosing a language to speak with a person who is equally fluent in all languages you know, how often would you switch between languages?

34. Please list what percentage of the time you are currently, on average, using each language (Your percentage should add up to 100 %):

	Listening	Speaking	Reading	Writing
Nepali				
English				
Norwegian				
Any other (what lang.)				
Total				

Signature with date

Appendix C: Lexical Stimuli used in mouse tracking parallel language activation experiments

I. Lexical stimuli for Gurung – Nepali bilingual study

Stimuli set for different conditions in both language directions

Language Direction : L1 - L2

Experimental condition

L1-spoken word	Eng.equivalent	L2-PhonoCohort	Eng.equivalent2	Picture_left	Picture_right
kaka	crow	काँक्रो (kaankro)	Cucumber	crow	cucumber
kelabaa	farmer	केरा (keraa)	Banana	farmer	banana
tamalaa	butterfly	तलवार (talwaar)	Sword	butterfly	sword
tangaa	fish	ताप्के (taapke)	Pan	pan	fish
syon	river	सिंग (sing)	Horn	river	horn
tili	pig	तौलिया (tauliya)	towel	towel	pig
macha	banana	मकै (makai)	Corn	banana	corn
naki	dog	नाक (naak)	Nose	nose	dog
pohtko	frog	पात (paat)	Leaf	frog	leaf
mikhu	eye	माखा (maakhaa)	Fly	fly	eye
bhunse	pumpkin	भुँईकटहर (bhuinkaTahar)	Pineapple	pumpkin	pineapple
pyahko	wing	पर्खाल (parkhaal)	wall	wall	wing
me	cow	मेवा (mewaa)	Papaya	cow	papaya

ku	chest	कुम (koom)	Shoulder	shoulder	chest
Ta	flower	टमाटर (Tamaatar)	Tomato	flower	tomato
chimlikan	lightning	चिप्लेकिरा (chiplekira)	Snail	snail	lightning
anre	mosquito	औंला (aunla)	Finger	mosquito	finger
punkolo	boy	पंखा (pankhaa)	fan	fan	boy
kyehn	chapati	काईंयो (kainyo)	Comb	chapati	comb
chen	tiger	च्याउ (chyaau)	Mushroom	mushroom	tiger
pho	deer	फट्याङ्ग्रा (phatyangra)	Grasshopper	deer	grasshopper
klya	bull	कमिला (kamila)	Ant	ant	bull
nana	mustard	नानी (naani)	Baby	mustard	baby
prahmkui	cockroach	परेवा (parewaa)	Pigeon	pigeon	cockroach
pahli	foot	पखेटा (pakheTa)	Wing	foot	wing
kapudhale	snail	कमल (kamal)	Lotus	lotus	snail
naka	chicken	नक्सा (naksa)	Map	chicken	map
kolo	baby	कल (kal)	sewingmachine	sewingmachine	baby
run	horn	रूख (rukh)	Tree	horn	tree
sar	star	सर्प (sarpa)	snake	snake	star
sumi	lips	सुन्तला (suntalaa)	Orange	lips	orange
min	tail	मैनबत्ती (mainbatti)	Candle	candle	tail

Control Condition

L1-spoken word	Eng.equivalent	Picture_left	Picture_right
nowar	cat	cat	alligator

name	bird	accorn	bird
mhche	cloud	cloud	antlers
mhi	man	apple	man
mrisyo	woman	woman	artichoke
timru	spider	asparagus	spider
kyonh	forest	forest	balcony
kyu	sheep	barrel	sheep
hren	bamboo	bamboo	beak
phopho	bat	bicycle	bat
yup	stone	stone	barbecue
nakabhale	rooster	block	rooster
tahnle	slingslot	slingshot	board
kyohcha	sword	bomb	sword
kyufi	whistle	whistle	boot
sa	teeth	camel	teeth
chyoutin	hut	hut	cast
ru	thread	cheese	thread
nhur	coins	coins	chimney
nai	patient	clip	patient
hyarko	rainbow	rainbow	couch
kra	headhair	cup	headhair
ton	pot	pot	dolphin
mur	moustache	donkey	moustache
se	lice	lice	deck
mhe	crop	fishingpole	crop
mai	buffalo	buffalo	duck
tin	heart	earring	heart

khegi	priest	priest	elephant
krase	brain	envelop	brain
sulpa	pipe	pipe	fan
chhu	rope	rope	graveyard

Filler Condition

L1-spoken word	Eng.equivalent	Picture_left	Picture_right
mo	a kind of bamboo	anchor	anvil
saru	a kind of bird	bride	building
kyosi	a kind of tree	band	bag
ronsi	a kind of tree	bathtub	beard
micha	a lentil	bow	blimp
prih	buckwheat	binoculars	milk bottle
prahn	cattle shed	canopener	celery
pihki	chestnut	dinosour	desert
kwayen	cloth	diaper	dime
mra	door	drill	dresser
pro	flour	dragon	fence
nu	garlic	floor	faucet
chhyuku	ghee	fishtank	funnel
unsai	gourd	hammock	genie
pasa	lettuce	hinge	hippo
bhakun	metal mug	horseshoe	hoe
nari	millet	jack	kano
koda	oven	lighthouse	lawnmower
mlah	paddy	molar	mixer

lapu	raddish	nailfile	mop
palan	raspberry	note	organ
kain	cooked rice	package	nurse
mhlasi	raw rice	pirate	popcorn
poThaiTa	rododendron	radio	rack
chata	salt	rose	saddle
sa	soil	saxophone	scale
chillipoTo	sparrow	shed	shell
pha	stomach	skateboard	shower
kipro	straw	sled	skunk
Tah	vegetable	submarine	stroller
Toh	village	tennisracket	thermos
naili	winnower	unicycle	tractor

Language Direction: L2 - L1

Experimental Condition

L2-spoken word	Eng.equivalent	L1-PhonoCohort	Eng.equivalent2	Picture_left	Picture_right
taar	wire	त (ta)	Axe	wire	axe
naspati	pear	न्हफ्हें (nhphen)	Ear	ear	pear
mojaa	socks	म्रिस्योकोलो (mrisyokolo)	Girl	socks	girl
rath	chariot	र (ra)	Goat	goat	chariot
dhunwa	smoke	धीं (dhin)	House	smoke	house
kandh	shoulder	क्युं (kyun)	Lime/Lemon	lemon	shoulder

hat	hand	हे (hey)	Mountain	hand	mountain
nal	tap	नम्यु (namyu)	Mouse	mouse	tap
chura	bangle	च्ह्यों (chyhon)	Nest	bangle	nest
nang	nail	नखु (nakhu)	Nose	nose	nail
kal	sewing machine	क्हल्यो (k:hlyo)	Bed	sewing machine	bed
patrika	newspaper	प्रसी (prasi)	Comb	comb	newspaper
mech	table	मे (mey)	Cow	table	cow
pyaj	onion	प्याहु (pyahu)	Feather	feather	onion
yuddh	war	योरी (yori)	Finger	war	finger
mewaa	papaya	मी (min)	Fire	fire	papaya
lwang	clove	लैं (lain)	Moon	clove	moon
tir	arrow	त्हीं (t:hin)	Sun	sun	arrow
mala	garland	म्लेकी (mleki)	Tear	garland	tear
siyo	needle	सिंधु (sindhu)	Tree	tree	needle
ketli	kettle	क्होत्ले (k:hotle)	Worm	kettle	worm
kainchi	scissors	क्रोएँ (kroyen)	Crab	crab	scissors
kursi	chair	कुली (kuli)	Hat/cap	chair	hat
kaan	ear	क्यां (kyan)	Road	road	ear
mayur	peacock	ह्रीं (hrin)	Bamboo	peacock	pills
kharayo	rabbit	मए (maye)	Medicine/pills	neck	rabbit
khola	stream	खरी (khari)	Neck	stream	peach
kanti	nail	खोलो (kholo)	Peac h	intestine	nail
chhano	roof	क्रहुँ (krahun)	Intestine	roof	grass
phulgobhi	cauliflower	छि (chhin)	Grass	egg	cauliflower

mutthi	fist	फु (phun)	Eggs	fist	drum
kitaab	book	मिछ (michha)	Drum	swing	book

Control Condition

L2-spoken word	Eng.equivalent	Picture_left	Picture_right
belchaa	shovel	shovel	veil
gaindaa	rhinoceros	wool	rhinoceros
bhenTa	brinjal	brinjal	carousal
kopilaa	bud	swimmer	bud
jhadi	bush	bush	wallet
oDhar	cave	torch	cave
dhaniya	corriander	coriander	screw
thopaa	drop	saint	drop
hans	duck	duck	ribs
pariwar	family	ruler	family
khelaDi	player	player	church
jangal	forest	robot	forest
aduaa	ginger	ginger	pillar
hatouDi	hammer	prawn	hammer
aanp	mango	mango	puppet
gegar	pebble	payment	pebble
kharyo	rabbit	rabbit	paddle
chhano	roof	ostrich	roof
unkhu	sugarcane	sugarcane	mousetrap
bhitto	wall	moose	wall
jhyal	window	window	mehandi

jharna	waterfall	matchstick	waterfall
bheDa	sheep	sheep	maze
makai	corn	letter	corn
gahaun	wheat	wheat	kurta
chamero	bat	knee	bat
peTi	belt	belt	gold
pauroTi	bread	heel	bread
pul	bridge	bridge	gun
balti	bucket	globe	bucket
dari	carpet	carpet	fan
gajar	carrot	cymbal	carrot

Filler Condition

L2-spoken word	Eng.equivalent	Picture_left	Picture_right
khursani	chilli	wrench	zipper
gidda	vulture	zebra	yoyo
lichy	litchy	wolf	wizard
bandagobi	cabbage	whip	wine
besar	turmeric	witch	wig
tarul	yum	windmill	watercan
lauka	gourd	violin	watch
lasun	garlic	volcano	watermelon
rudraksha	rudraksha	vest	vase
patro	calendar	wheel	wheelbarrow
gundri	strawmat	walrus	washingmachine

gagri	metal pitcher	turkey	train
maTTitel	kerosene	trophy	trumpet
pina	oil cake	tweezers	waffle
surti	tobacco	tractor	tie
shikshak	teacher	toothbrush	tire
vidyarthi	student	top	thimble
gundruk	dried leafy vegetable	toaster	telephone
aringal	hornet	submarine	stoplight
baulaha	mad person	speaker	stool
bhoj	feast	stethoscope	spatula
belauti	guava	spagheti	skeleton
hansiya	sickle	sausage	sailor
khukuri	khukuri	ring	shark
school	school	raft	puzzle
dahi	curd	poker	pitcher
raksi	alcohol	police	pinecone
pasal	shop	plate	radish
khir	sweet porridge	pliers	plug
chamal	rice	pelican	paint
kodo	millet	paintbrush	panda
selroTi	doughy pretzel	needle	motorcycle

II. Lexical stimuli used in Nepali-English bilingual study

Condition: L1 Competitor

L1-Spoken Word	English Translation	L2 Phonological Competitor
बिरालो (biralo)	cat	bikini
बिरामी (birami)	patient	biscuit
बन (ban)	forest	bus
बोरा (bora)	sack	boat
बाख्रो (bakhro)	goat	barber
बाघ (baagh)	tiger	barman
बादल (baadal)	cloud	barn
काठ (kaaTh)	wood	cup
चील (cheel)	eagle	chimney
चरा (charaa)	bird	chalk
कपाल (kapaal)	hair	kangaroo
कोपिला (kopilaa)	bud	cock
कुकुर (kukur)	dog	cooker
गाई (gaai)	cow	guard
गाडी (gaadi)	vehicle	garbage
हार (haar)	necklace	harvest
हाड (haaD)	bone	harp
हात (haat)	hand	harpoon
केरा (keraa)	banana	kettle
किसान (kisaan)	farmer	kidney
कोदो (kodo)	millet	coin
सयपत्री (sayapatri)	marigold	salad
नर्तकी (nartaki)	dancer	nutcracker
कागती (kaagati)	lemon	kayak
मान्छे (manchhe)	man	marker
मेवा (mewaa)	papaya	medal
मुट्ठी (mutthi)	fist	mural
मौरी (mauri)	bee	moat
माखो (maachho)	fly	mouse
माकुरा (maakura)	spider	marijuana
माछा (maachhaa)	fish	mask
मुसा (musaa)	mouse	moose
मकै (Makai)	corn	mascara
नङ्ग्रा (nangraa)	claw	nurse
नाक (naak)	nose	nut

औषधि (aushadhi)	pills	autorickshaw
प्वाँख (pwankh)	feather	pawn
परेवा (parewaa)	pigeon	pagoda
पिङ (ping)	swing	pig
पानी (paani)	water	palm
पखेटा (pakheTaa)	wing	pajama
पहाड (pahaaD)	mountain	parasol
कुरिलो (kurilo)	asparagus	coop
रुख (rukh)	tree	roof
स्याउ (syau)	apple	saddle
टोपी (Topi)	hat	tomato
तीर (tir)	arrow	teeth
रथ (rath)	chariot	rug

Condition: L1 Distractor

L1-Spoken Word	English Translation	L2 Distractor
बिरालो (biraalo)	cat	genie
बिरामी (biraami)	patient	lighthouse
बन (ban)	forest	firetruck
बोरा (boraa)	sack	antlers
बाख्रो (baakhro)	goat	octopus
बाघ (baagh)	tiger	razor
बादल (baadal)	cloud	knight
काठ (kaath)	wood	teeth
चील (cheel)	eagle	binoculars
चरा (charaa)	bird	payment
कपाल (kapaal)	hair	torch
कोपिला (kopilaa)	bud	anchor
कुकुर (kukur)	dog	shell
गाई (gaai)	cow	pelican
गाडी (gaadi)	vehicle	hammock
हार (haar)	necklace	paintbrush
हाड (haaD)	bone	diaper
हात (haat)	hand	cymbal
केरा (keraa)	banana	cheese
किसान (kisaan)	farmer	drill
कोदो (kodo)	millet	spear
सयपत्री (sayapatri)	marigold	python

नर्तकी (nartaki)	dancer	igloo
कागती (kaagati)	lemon	beaver
मान्छे (maanchhe)	man	popsicle
मेवा (mewaa)	papaya	check
मुट्ठी (mutthi)	fist	stethoscope
मौरी (mauri)	bee	wagon
माखो (maachho)	fly	zebra
माकुरा (maakuraa)	spider	handpump
माछा (maachhaa)	fish	kitchen
मुसा (musaa)	mouse	fire hydrant
मकै (Makai)	corn	ball
नङ्ग्रा (nangraa)	claw	tape
नाक (naak)	nose	suite
औषधि (aushadhi)	pills	sock
प्वाँख (pwankh)	feather	capsicum
परेवा (parewaa)	pigeon	breadknife
पिङ (ping)	swing	banyan
पानी (paani)	water	train
पखेटा (pakheTaa)	wing	toe
पहाड (pahaaD)	mountain	wheelbarrow
कुरिलो (kurilo)	asparagus	bulldogger
रुख (rukh)	tree	compass
स्याउ (syau)	apple	shed
टोपी (Topi)	hat	strawberry
तीर (tir)	arrow	tweezers
रथ (rath)	chariot	glove

Condition: L1 Filler

L1-Spoken Word	Distractor 1	Distractor 2
गिदी (gidi)	brinjal	genie
चोर (chor)	lighthouse	keyring
भान्से (bhaanse)	barrel	firetruck
चमेरो (chamero)	antlers	lightbulb
धारा (dhaaraa)	jar	octopus
पँधेरो (pandhero)	razor	safe
गँहु (ganhu)	pitchfork	knight
फापर (phaapar)	teeth	bag
पाती (paati)	popcorn	binoculars

जुनेलो (junelo)	payment	sharpener
भोटो (bhoto)	crystal	torch
मदानी (madaani)	anchor	pinecone
ठेकी (Theki)	lawnmower	shell
पाङ्ग्रा (paangraa)	pelican	highchair
दाम्लो (daamlo)	graveyard	hammock
नाम्लो (naamlo)	paintbrush	dresser
डोको (doko)	cone	diaper
जिब्रो (jibro)	cymbal	dinosaur
आन्द्रा (aandraa)	crown	cheese
कलेजो (kalejo)	drill	watermelon
मुटु (muTu)	pot	spear
फोक्सो (phoxo)	python	rail track
दियो (diyo)	hose	igloo
बाच्छी (baachchhi)	beaver	fish tank
दुम्सी (dumsi)	wig	popsicle
बङ्गुर (bangur)	check	mobile phone
डाँफे (daanfe)	chameleon	stethoscope
गुराँस (gurans)	wagon	stove
चमेली (chameli)	fly	horn
जुरेली (jureli)	handpump	spatula
गोठ (goTh)	waffle	kitchen
कुलो (kulo)	fire hydrant	trashcan
कुचो (kucho)	corn	collar
झ्याल (jhyal)	tape	artichoke
ढोका (dhokaa)	bicycle	suite
दमाहा (damahaa)	sock	globe
साग (saag)	olive	capsicum
खुर्सानी (khursaani)	breadknife	broom
गोभी (gobhi)	vacuum	banyan
सिरक (sirak)	train	dance
डस्ना (dasnaa)	butter	toe
सिरानी (siraani)	wheelbarrow	butcher
तरुल (tarul)	wallet	bull dodger
पिंडालु (pindaalu)	compass	lizard
सिमी (simi)	turkey	shed
टपरी (Tapari)	strawberry	wheel
दुना (dunaa)	whip	tweezers

आँगन (aangan)	glove	eyebrow

Condition: L2 Competitor

L2-Spoken Word	L1 Phonological Competitor	English Translation
owl	आगो (aago)	fire
river	रीढ (reeDh)	backbone
oven	ओखली (Okhali)	pastel
orange	ओढार (ODhaar)	cave
cup	कान (kaan)	ear
cockroach	करेला (karelaa)	bitter gourd
cotton	कछुवा (kachhuwa)	tortoise
kite	काईयो (kaainyo)	comb
carpet	काखी (kaakhi)	armpit
kennel	केराउ (keraau)	pea
coat	कोदालो (kodaalo)	hoe
girl	गलैचा (galaichaa)	carpet
gun	गलबन्दी (galbandi)	muffler
garland	गाडा (gaaDaa)	bullock cart
chicken	चिप्लेकिरा (chiplekiraa)	snail
donkey	डमरु (Damaru)	damaru
duck	डाडु (DaaDu)	ladle
knife	नानी (naani)	baby
pumpkin	पलास (palaas)	pliers
pen	पेट (pet)	stomach
bison	बाटी (baaTi)	bowl
bear	बिस्तरा (bistaraa)	bed
bell	बेहुली (behuli)	bride
mosquito	मसी (masi)	ink
monkey	मन्दिर (mandir)	temple
mushroom	मुला (mula)	radish
moustache	मुढा (muDhaa)	stool
moon	मोजा (moja)	sock
mustard	मकै (makai)	corn
lightening	लास (laas)	corpse
leaf	लिची (lichi)	litchi
lock	लोटा (loTa)	pitcher
wall	वकिल (wakil)	lawyer
butterfly	बगर (bagar)	riverbank

sun	सलाई (salai)	match
saw	सनासो (sanaso)	tong
cigarette	सिपाही (sipahi)	soldier
sugarcane	सुन्तला (suntala)	orange
horn	हँसिया (hansiya)	sickle
house	हात (haat)	hand
magnet	म्यान (myan)	sheath
garlic	गाडा (gaaDaa)	cart
flute	फर्सी (pharsi)	pumpkin
potato	पसल (pasal)	shop
cucumber	कागती (kaagati)	lemon
comb	कुहिनो (kuhino)	elbow
book	बुलाकी (bulaki)	nose ring
cot	कसौडी (kasauDi)	Urn

Condition: L2 Distractor

L2-Spoken Word	L2 Distractor
owl	curtains
river	tobacco
oven	pearl
orange	saucepan
cup	meditation
cockroach	painter
cotton	tear
kite	gourd
carpet	family
kennel	toilet
coat	charkha
girl	plough
gun	toffee
garland	kurta
chicken	beehive
donkey	crop
duck	paddy
knife	earthworm
pumpkin	clove
pen	thermos
bison	slingshot
bear	table
bell	glass
mosquito	skull

monkey	telephone
mushroom	telescope
moustache	syringe
moon	picture
mustard	ring
lightening	tail
leaf	present
lock	vulture
wall	egg
butterfly	war
sun	gooseberry
saw	jasmine
cigarette	skunk
sugarcane	bug
horn	bow
house	lamp
magnet	city
garlic	iron
flute	chandelier
potato	field
cucumber	rudraksh
comb	fisherman
book	trishul
cot	rhododendron

Condition: L2 Filler

L2-Spoken Word	Distractor 1	Distractor 2
flower	beard	curtains
cuckoo	tobacco	strawman
vulture	plough	saree
peacock	pompom	raccoon
swan	tabla	meditation
heater	painter	baghchal
leopard	firewood	tear
lion	gourd	rain
giraffe	carpet	madal
zebra	toilet	bhadgaunlecap
cactus	puppet	charkha
rose	plough	wheat
lizard	loom	toffee
chess	chapati	queen
mobile	coriander	beehive
computer	walnut	vest
fan	wedding	vineyard

car	wasp	xylophone
jeep	windchimes	tunic
roof	thermos	mirror
duster	pear	slingshot
rabbit	table	flag
train	bench	glass
aero plane	skull	veena
belt	typewriter	sofa
button	telescope	brain
printer	suspenders	syringe
coffee	picture	safety pin
tea	sewing machine	ring
chocolate	tail	orchid
boot	hut	present
buffalo	vulture	eskimo
bottle	fence	dice
brinjal	earring	devil
bakery	dime	gooseberry
road	jasmine	bamboo basket
park	mint	dragon
playground	bug	drum
slide	slipper	bow
waterfall	lamp	gain bard
mat	dustpan	iron
blouse	faucet	island
trousers	floor	harmonium
brush	field	triangle
toothpaste	leopard	rudraksh
cream	fisherman	knot
thorn	desert	trishul
petal	lantern	pancreas

Appendix: Lexical stimuli used in trilingual Nepali-English-Norwegian parallel language activation

Language Direction: L1-L2

L1-Spoken Word (Target)	Phonological cohort in L2 (Distractor)
kukur (dog)	queen
kainyo (comb)	cactus
kamila (ant)	capsicum
makho (house fly)	magnet
kerau (pea)	cat
kanti (nail)	car
tauko (head)	tortoise
parewa(pigeon)	papaya
gai (cow)	globe
louka (bottle gourd)	ladder
chappal(slipper)	church
machha (fish)	map
kursi (chair)	cup
chura (bangles)	chimney
thun (udder)	thermos
kucho (broom)	kiwi

Language Direction: L1-L3

L1-Spoken Word	Phonological Cohort in L3 (Distractor)
harin (deer)	høyde (hill)
banduk (gun)	bukse (pant)
sag (lettuce)	skjorte (shirt)
belcha (spade)	blad (leaf)
makura (spider)	munn (mouth)
muda (tool)	mus (mouse)
anar (pomegranate)	øre (ear)
hatti (elephant)	hvitløk (garlic)
gaida (rhino)	genser (sweater)
bakhro (goat)	bein (leg)
sungur (pig)	sitron (lemon)
makai (corn)	mane (moon)
salai (match)	sol (sun)
lwang (clove)	lock (lock)
selroti (doughy pretzel)	seng (bed)
nariwal(coconut)	nokkel (key)

Language Direction: L2-L1

L2-Spoken Word	Phonological Cohort in L3 (Distractor)
leopard	lauro (cane)
chest	charkha (spinning wheel)
zebra	jutta (shoe)
kite	kisan (farmer)
camera	kalam (pen)
coat	kamal (lotus)
jug	jarayo (deer)
island	aago (fire)
raddish	rassi (rope)
sickle	sipahi (soldier)
crown	katahar (jackfruit)
seagull	siyo (needle)
mushroom	muda (stool)
trousers	tapari (platter)
submarine	suntala (orange)
bottle	bagh (tiger)

Language Direction: L3-L1

L3-Spoken Word	Phonological Cohort in L1 (Distractor)
ku (cow) ape (monkey) Ørn (eagle) fjell (mountain) tog (train) skje (spoon) kniv (knife) drue (grape) and (duck) hest (horse) hund (dog) neve (fist) furutre (pine tree) blomkål (cauliflower) agurk (cucumber) gulrot (carrot)	Khukuri (Nepali sword) aanp (mango) adua (ginger) farsi (pumpkin) thal (plate) supari (betelnut) khat (cot) daaura (firewood) aansu (tear) haat (hand) handi (pot) naach (dance) phul (flower) bakulla (egret) alainchi (cardamom) gadyoula (earthworm)

Distractor: L1

L1-Spoken Word (Target)	Non-phonological cohort (Distractor)
madani(churner) khabo (pillar) fyauro (fox) bacchho (calf) bhangera(sparrow) bandh (dam) itta (brick) gund (nest) tulasi (basil) bulanki (nose ring) bhogate(citrusfruit) namlo (carryrope) galaincha (carpet) tori (mustard) karela(bittergourd) putali (butterfly)	celery medal apron oyster band saloon mint switch windchimes forceps chandler crutch witch porcupine penguin comud

Distractor: L2

L2-Spoken Word	Non-phonological cohort (Distractor)
ambulance	pinecone
asparagus	nurse
basketball	monitor
bikini	hockey
bridge	dice
bulb	horn
burger	tail
compass	dragonfly
cricket ball	jeep
drums	acorn
frock	piano
harmonium	artichoke
hat	ski
laptop	raft
marker	legging
pasta	robot

Distractor: L3

L3-Spoken Word	Non-phonological cohort (Distractor)
påfugl (peacock)	eraser
tak (roof)	clown
nesse (nose)	paper boat
gardin (curtain)	trash
blomst (flower)	statue
elv (river)	projector
slange (snake)	hanger
jordbær (strawberry)	wineglass
rot (root)	shoe brush
potet (potato)	hippo
flaggermus (bat)	wool
gren (branch)	saucepan
hjul (wheel)	zipper
ekorn (squirrel)	butter
sigaret (cigarette)	banana
spisebord (dining table)	binocular

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