Exploring visuospatial functional network in Elderly Bilinguals

Introduction

The cognitive and neurological benefits of active bilingualism have been debated intensively in cognitive neuroscience. The idea that using more than one language on a regular basis affects the general cognitive functioning and neural organization, stems from the brain plasticity literature. The brain has a propensity to reorganize structurally and functionally in light of new experiences and learning. This idea has made bilingualism one such potential source of plasticity inducing experience. As a consequence, active bilingualism has been shown to have a positive effect on functioning of human attentional system (Bialystok et al., 2004). Results suggest that bilinguals perform faster on inhibitory control tasks (e.g., Flankers, Stroop, and Simon). And this effect has been found across the lifespan (Bialystok et al., 2005), suggesting that bilinguals develop a more efficient executive control network as compared to monolinguals of the same age. The results seem convincing because bilinguals have an additional language system, and there is a demand for the active selection of task-relevant and inhibition of task-irrelevant language in a bilingual context, which affects domain-general executive processes. Moreover, the neuroimaging studies suggest an overlap between the language control and domain-general executive control network in the brain. Hence, it has been claimed that bilingualism plays an active role in preserving both general cognitive functioning and brain in older age (Pliatsikas, 2020). The concept of Cognitive Reserve (CR) and Brain Reserve (BR) have been investigated extensively in recent years in the context of bilingualism, especially due to its far reaching consequences on brain pathology and clinical manifestation of dementia. It has been found that bilingualism can have a positive effect on healthy aging and delay the onset of Alzheimer's Disease symptoms by 4-5 years (Voits et. al., 2020). However, the findings have been inconsistent in this literature (see for a review Del Maschio et. al., 2020). Since the question of bilingual advantage is not only confined to the differences in general cognition but has an application in the clinical setting and Alzheimer's disease diagnosis, investigation of such question is of utmost importance. Due to multiple concepts associated with reserve, e.g., Brain Reserve, Cognitive reserve, and Brain maintenance (Stern et. al., 2018), and very few studies explored the effect of lifelong bilingualism on the relationship between brain and cognition, the effect of bilingualism on the cognitive reserve is not well understood. In a recent review article, Pliatsikas, Ansaldo, & Voits (in press) suggested a theoretical and practical consideration to move the field forward. It is suggested that to investigate how bilingualism modulates

the relationship between brain and cognition, the research design should include both brain and behavioral data from two well-matched groups of monolinguals and bilinguals. However, few studies have been able to incorporate sufficient evidence from the brain and behavior to support the bilingual advantage on CR. Cognitive Reserve as defined by Stern (2009), is the disjunction between brain pathology and its clinical manifestation. For example, the behavioral manifestation of clinical symptoms remains normal in presence of brain pathology and this relationship is mediated by Cognitive Reserve.

In one study by Ansaldo et al., (2015) older monolingual and bilingual adults performed equivalent on Simon task but task-dependent brain functional activation was different between groups. The study shows that monolinguals recruited the prefrontal cortex whereas bilinguals used more posterior regions (left inferior parietal lobule) to achieve equivalent performance on the Simon task. In a follow-up network analysis study by the same team Berroir et. al., (2017), they found that the difference lies in the visuospatial domain of attention at the functional network level. The study is crucial since it employed a robust design to incorporate both behavioral and brain data to observe the difference at the functional network level to investigate individual variability in CR. The concept of the neural reserve is crucial in interpreting these findings (Stern, 2009), suggesting that there is inter-individual variability in the functional network associated with the neural reserve, which is an outcome of a differential lifetime experience. The neural reserve is modulated by CR proxies, e.g., Education, leisure activity, occupation (Stern et. al., 2018), and bilingualism. To study the neural implementation of CR, the task-dependent functional network has to be first located between well matched groups and then similarity and differences in such network must be investigated. The functional network can be characterized on the basis of its efficiency and capacity (Stern, 2009). And the difference in network efficiency and capacity can be treated as the CR. Parametrically changing the task load is one such suggested design to study the inter-individual functional network efficiency and capacity.

The study by Berroir et. al., (2017) suggests that unlike monolinguals who used frontal areas to resolve Simon conflict, bilinguals rely more on parietal areas which are primarily associated with visuospatial processing. This visuospatial advantage should be investigated more keenly because monolinguals who rely on frontal networks are more susceptible to age-related pathology since the frontal part is prominently affected during aging. On the other hand, bilinguals might develop more reliance on the parietal network to resolve conflict and remain impervious to pathology for a longer period and develop neural reserve by compensation. In order to understand the differential visuospatial processing and its consequences on CR, few

studies have used visual search tasks. One such study by Friesen et. al., (2014) used visual search feature and conjunction task and revealed that monolinguals and bilinguals differ on conjunction task but not on feature search task. In conjunction task, the attention is deployed in serial fashion where each item is scanned one by one till the attentional set is matched with the target. The task requires suppression of the irrelevant feature and the target feature is active in the working memory at the same time, and this process requires monitoring which is a component of executive function network. On the other hand, in feature search task, the target is "popped out" automatically and attention is deployed in a parallel fashion. Hence, both groups performed equivalently on parallel search task. However, bilinguals manifested RT advantage on conjunction search, since there was a constant need of suppressing the distractor (irrelevant features) and constant monitoring (executive functioning). Another recent study by Paap et. al., (2018) testing the same effect shows no group difference in attentional processing in either condition. The study of Ansaldo et al., (2015), showing bilingual vs monolingual difference in the visuospatial functional brain network on Simon task, which is further supported by the visual search study of Friesen et. al., (2014) and then a contradicting finding from the study of Paap et. al., (2018) using the same design, raises a crucial question whether bilinguals have a more efficient visuospatial network in the brain which leads to a neural reserve. In absence of sufficient evidence supported by neural and behavioral data, this claim remains weak. The present study will take a step forward to fill this gap by incorporating both brain and behavioral data as suggested by Pliatsikas, Ansaldo, & Voits (in press), and integrate the methodological considerations suggested by Stern (2009) and findings from Ansaldo et al., (2015) to investigate whether bilingualism modulates the visuospatial functional network, which as a result induce neural reserve in bilinguals in older age. The visual search task is chosen because this task allows one to modulate the cognitive load (Lavie et. al., 2004) and the difference in task-dependent functional network efficiency and capacity can be observed as a function of load.

Aims and objectives

The current study aims to investigate the following questions in the context of bilingualism and cognitive reserve.

1. Effect of bilingualism on visuospatial selective attention in older bilinguals and monolinguals:

The visual search task allows one to investigate the individual difference in visuospatial attention. Conjunction search requires top-down control of attention whereas feature search is controlled by the bottom-up mechanism (Treisman, 2006). Based on the previous findings, it can be predicted that bilingualism will affect the conjunction search task but not the feature search task. Crucially, the findings of Paap et al., (2018) show no effect of bilingualism on serial search efficiency, this question will be addressed in this study by functional network analysis. If bilinguals are found to be faster on parallel as well as on serial search task the evidence will support the global advantage in the visuospatial domain. And the result will be consistent with the previous findings (Bialystok, 2005). However, brain data must accompany the behavioral results to support bilingual benefit on cognitive reserve.

2. Nature of task-specific network in older bilinguals and monolinguals:

The aim here is to investigate whether the network underlying visuospatial attention task is same or different in bilinguals and monolinguals. If the network is found to be same, then the efficiency and capacity of such network will be investigated by changing the task demands parametrically. In the case of different task-dependent functional network, the nature of the compensatory network will be investigated concerning the underlying CR variable.

3. Whether the task-dependent functional activation is modulated by L2 experience:

The functional network is contingent upon past experience and learning, and it is expected to activate to a different degree based on lifelong L2 experience and learning. Hence, the degree of proficiency or bilingual practice will contribute to the network activation pattern, and as a result, the network's efficiency and capacity will also be a function of subjective L2 experience and practice.

Method

Participants

20 healthy older bilinguals and 20 healthy older monolinguals. All participants will be screened for cognitive and neurological impairment before the experiment.

Procedure

All participants will take language assessment on Language and Social Background Questionnaire (LSBQ; Luk & Bialystok, 2013), Ravens measure for fluid intelligence, and SES measure.

Visual Search Task:

The visual search task will be used as the activation task and participants will be performing this task under fMRI scan. The task will be designed following the previous study of Stern, (2009). The visual search task consists of shapes and color features. At the beginning of each trial, the participant will be presented with the target. Then the participant will be asked to decide if the target is present among the arrays of different shapes and color combinations (distractors). The participants will press key '1' if the target is present and '0' if it is absent in the given array. The RT will be calculated from the onset of array display till the response key press. The target will appear on the random location of the screen.

There will be two search conditions:

a) Feature search condition: The target will appear unique from the other distractors (high discriminatory) hence the mean RT is expected to be less in this condition for both groups.

b) Conjunction search condition: In conjunction search the target will share two features with the distractors (less discriminatory) hence there will be a need to suppress the irrelevant feature by using top-down inhibitory control mechanism to locate the target as soon as the arrays appear on the screen. Bilinguals are expected to perform faster in this condition.

In each condition, the load will be manipulated by increasing the distractor set size by 0, 5, 15, 25 following the previous study of Friesen et. al., (2014).

Data Analysis

Visual search behavioral data

The trials with RT shorter than 200ms or longer than 5 sec will be removed from the analysis. The groups (monolingual and bilingual) will be contrast coded with +1 and -1. Three-way ANOVA will be conducted on RT and Accuracy measures with IV language group (monolingual vs bilingual), search condition (feature vs conjunction), task load (5, 15,25) as a repeated measure, to analyze the between-group RT and accuracy difference in each task condition. It is expected that bilinguals will perform faster only on conjunction task when compared with

monolinguals.

fMRI data analysis

The General Linear Model (GLM) will be used to analyze the task load-related activation pattern in two groups. This method has been used in previous studies to observe how the task-related activation pattern across different task load conditions correlates with the measure of CR (Stern, 2009) For example, the load related to change in set size will correlate with the task-related network activation pattern. The load-dependent change in functional network activation can inform about the network Efficiency and Capacity.

Following the definition by Stern (2009), the bilinguals are expected to achieve the same level of performance when compared with monolinguals in conjunction task with less degree of activation in task-dependent functional network. However, in the feature search condition the activation pattern should not significantly vary across groups.

Task-dependent activation and language background correlation

The subjective measure of language proficiency will negatively correlate with the degree of activation, suggesting that as the proficiency increases the network becomes more efficient hence it can achieve the same level of performance at a lesser degree of activation.

Conclusion

Previous findings in bilingualism and its effect on cognitive reserve have not been consistent due to the reasons; a) Lack of neural data in support of behavioral evidence b) Contradictory findings in the literature of bilingual advantage, e.g., in visuospatial attention Friesen et. al., (2014) and Paap et. al., (2018) However, Ansaldo et al., (2015) is one study which highlighted the different network subserving the executive functioning in bilinguals and monolingual by accompanying both neural and behavioral data. The present study will acknowledge the operational definition of CR as proposed by Stern (2009), use the methodological consideration suggested by Pliatsikas, Ansaldo, & Voits (in press), and take a robust findings of Ansaldo et al., (2015) as a starting point to investigate whether the individual difference in visuospatial processing at the neuronal level is reflected in visuospatial attention task. Given that there are two different standpoints in this literature, Friesen et. al., (2014) and Paap et. al., (2018) both

supported by only behavioral data, presenting the neural evidence at the functional network level is essential. The present study will try to combine the ideas from these previous findings and investigate whether older bilinguals differ at task-related functional network level from older monolinguals, which consequently has an impact on cognitive reserve and healthy aging.

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