

Bilingualism and Cognitive Reserve and Resilience

NIA Virtual Workshop

Division of Neuroscience

March 2-3, 2021

August 2, 2021



This meeting summary was prepared by Rose Li and Associates, Inc., under contract to the National Institute on Aging (NIA). The views expressed in this document reflect both individual and collective opinions of the workshop participants and not necessarily those of NIA. Writing, editing, and review by the following individuals is gratefully acknowledged: Shadya Sanders, Jubin Abutalebi, Suvarna Alladi, Miguel Arce Renteria, Thomas H. Bak, Ellen Bialystok, Esti Blanco-Elorrieta, Dana Carluccio, Karen Emmorey, Dave Frankowski, Tamar Gollan, John G. Grundy, Arturo Hernandez, Erika Hoff, Judith Kroll, Boon Lead Tee, Dan Mungas, Kenneth Paap, Christos Pliatsikas, Caroline Sferrazza, Nancy Tuveson.

Table of Contents

Acronym Definitions	ii
Executive Summary	3
Meeting Summary	5
Welcome and Introductions.....	5
Overview: Cognitive Reserve and Resilience in Aging.....	5
Session I: Bilingualism Across the Lifespan and Its Impact on Reserve and Resilience.....	6
Beyond Bilingual Juggling: Hypotheses About the Source of Reserve and Resilience.....	6
Maybe, Sometimes, Bilingualism Also Selects for Executive Function Ability.....	7
Bilingualism, Brain and Development: A Neuroemergentist Perspective	8
Onset of dementia in bilingual adults: Evidence for cognitive reserve.....	9
Discussion of Session I	10
Defining bilinguals	10
Measuring language acquisition in children on a longitudinal scale.....	10
Effects of learning experiences, cross-cultural diversity, and immigration.....	10
Requirements for a reliable bilingual study	11
Literacy as a requirement for added cognitive reserve.....	11
Session II: Factors Complicating the Study of Bilingualism and its Impact on Cognition and the Brain	11
Bilingualism and Cognitive Reserve: Concepts, Confounds, and Controversies	11
Deconstructing Bilingualism and its Sociocultural Determinants for Research on Cognitive Aging ..	12
Idiosyncratic Linguistic Features: Potential Impact in Dementia and Bilingualism Studies.....	13
Bimodal Bilingualism, Deafness, and Aging.....	14
Aging and Bilingual Language Control.....	15
Discussion of Session II	16
Effects of dominance reversal	16
Language intrusion errors.....	16
Impacts of age of acquisition.....	17
Day 2	17
Perspective: Is there a bilingual advantage?	17
Session III: Mechanisms by Which Bilingualism May Drive Neuroplasticity in the Brain.....	18
Structural Neuroplasticity in the Healthy Bilingual Brain and its Relevance to Healthy Aging.....	18
The Complexity of Bilingualism and the Effects on Neuroplasticity	19
Neuroanatomical Perspectives on Bilingualism ad Aging.....	20
Bilingualism, Reserve, and Resilience across Dementia Subtypes.....	21
Bilingualism as a Precursor for a Cognitive Reserve: What are the Required Premises?.....	22
Discussion of Session III	23
Final Discussion: Gaps and Opportunities.....	25
Bilingualism over the life course.....	25
Theoretical frameworks and methodological design.....	25
Future research challenges.....	26
Future research opportunities.....	26
Appendix A: Agenda	26
Appendix B: Participants List	29

Acronym Definitions

AD	Alzheimer's disease
ADNI	Alzheimer's Disease Neuroimaging Initiative
ADRD	Alzheimer's disease-related dementia
AoA	Age of second language acquisition
BSR	Division of Behavioral and Social Research
DN	Division of Neuroscience
EF	Executive Function
GM	Grey matter
GMV	Grey matter volume
MCI	mild cognitive impairment
NIA	National Institute on Aging
SES	Socioeconomic status
SPM	Statistical Parametric Mapping
WM	White matter

Executive Summary

To better understand the role of bilingualism in cognitive aging and Alzheimer's Disease and Related Dementias (AD/ADRD), the NIA Division of Neuroscience held a 2-day workshop on Bilingualism and Cognitive Reserve and Resilience on March 2nd and 3rd, 2021. The workshop set out to review the current state of the science on bilingualism and cognitive aging, address gaps in the current understanding of bilingualism as a driver of cognitive reserve, and identify new opportunities to expand explorations of the impact of bilingualism on cognition, brain health, and age-related neurodegenerative disease.

Cognitive performance exhibits wide variation even among individuals with similar neuropathology. Cognitive reserve is a construct that researchers use to explain this variability. Cognitive reserve may modulate the impact of neuropathology on cognitive outcomes, making individuals with greater reserve more resilient to age-related neurodegeneration. Bilingualism is one potential driver of cognitive reserve and thus is an important phenomenon for deepening understanding of this construct. A richer understanding of cognitive reserve may enable researchers to more directly and accurately measure individual resilience and develop models of the specific mechanisms of cognitive decline. Identifying these mechanisms can ultimately enable researchers to develop clinical interventions to support individuals experiencing cognitive decline and age-related neurodegenerative diseases.

However, identifying the specific impacts of bilingualism on cognitive reserve—and developing a theoretical framework that accounts for this impact—remains challenging for several reasons. Bilingualism is a dynamic and complex phenomenon with a wide array of components, including an individual's age of second language acquisition, degree of language exposure, varying contexts of language use (e.g., single language or dual language), cultural aspects of language use, and many other factors. Moreover, bilingualism can have measurable impacts on both brain structure and individual behavior; the variety and breadth of these impacts can make direct measurement difficult. This multi-faceted complexity has challenged efforts to articulate a widely accepted definition or measure of bilingualism, and this divergence has contributed to inconsistent or potentially misleading null findings.

Bilingualism can also be hard to disentangle from other phenomena. In some cultures, bilingualism is tightly intertwined with potential confounding factors, such as education or socioeconomic status. Where bilingualism is widely distributed, it can be hard to disentangle its effects from those of other complex skills that may confer comparable cognitive benefits.

Despite these complexities, some studies have found that bilingual individuals are more likely than monolinguals to maintain cognitive performance even with underlying neuropathology. Retrospective research has suggested a 4- to 6-year delay in the clinical diagnosis and onset of symptoms of dementia in high-proficiency bilingual individuals. Research has also found related differences in brain structure, with bilingual individuals exhibiting increased dopamine levels, increased grey matter, and increased cortical folding, although levels vary with age.

During the workshop, experts in bilingualism and cognitive aging discussed ways to build on established research findings and surmount persistent challenges. Participants described the variation of bilingual individuals as a research opportunity and called for the field to embrace the complexity of bilingualism's impacts on cognitive aging, to use more rigorous objective measurements of bilingual language proficiency and use, and to increase the diversity of investigations—for example, by investigating various language pairings and by developing specific measures based on specific languages. As the field moves forward, researchers should design studies to deliberately address learning experiences, the use of languages in school versus home, and the phenomenon of bimodal bilingualism (i.e., the ability to sign as well as speak a language). Researchers may also consider the possibility that any consistent cognitive advantages of bilingualism stem from the presence of a *combination* of factors, thus limiting the number of people for whom the advantage is possible.

Participants agreed that transdisciplinary collaborations would promote and facilitate efforts to account for bilingualism's complex relationship with cognitive aging. Collaborations should include input from experts in neurobiology, neuropsychology, cognitive psychology, epidemiology, and other related fields. Integration of studies of bilingualism into existing longitudinal studies on aging could also provide a broader understanding of bilingualism's impact over the life course and in the context of the real-world environments in which bilingualism is experienced.

Meeting Summary

Welcome and Introductions

Matt Sutterer, Ph.D., Program Director, Behavioral and Systems Neuroscience

The National Institute on Aging (NIA) Division of Neuroscience (DN) convened experts to better understand gaps and opportunities related to the relationship between bilingualism and cognitive reserve/resilience and the impact of that relationship on healthy brain aging and age-related neurodegenerative diseases. Research connecting bilingualism and resilience to Alzheimer's disease and related dementias (ADRD) remains mixed and is complicated by numerous factors, such as age of acquisition (AoA) of a second language and socioeconomic status (SES) of language speakers. A better understanding of the influence of bilingualism on brain aging could lead to novel interventions and provide additional insights for cognitive reserve and resilience.

Dr. Richard Hodes (Director, NIA) emphasized that in addition to the relationship between bilingualism and reserve or resilience, this workshop will also address health equity. Dr. Eliezer Masliah (Director, DN) described an interest in the impact bilingualism may have on neuroplasticity at the level of molecular and cellular dynamics, which can help shed light on resilience in aging. Dr. Lis Nielson (Director, Division of Behavioral and Social Research [BSR]) noted that bilingualism is very common outside of the United States and impacts behavioral and social factors over the lifecourse. However, the current state of science does not fully explain the mechanisms that may connect bilingualism specifically to cognitive reserve.

Overview: Cognitive Reserve and Resilience in Aging

Dan Mungas, Ph.D., University of California, Davis

Individual cognitive function is variable both at baseline as well as in rate of age-related decline. Many factors impact cognition, and disease accounts for less than half of observed variability. For example, up to 30% of individuals who died without a diagnosis of dementia meet the neuropathologic criteria for AD but have normal cognition.

Cognitive reserve is an abstract construct used to explain the variability of cognition and clinical status after a brain injury. Generally, cognitive reserve will modify the effect of neurological factors or demographic variables on cognitive decline, rendering individuals with greater cognitive reserve more resilient to brain injuries associated with age-related diseases. On average, cognitive reserve declines with age; however, heterogeneity is a defining feature of late-life cognition.

Unfortunately, definitions and operationalized concepts related to cognitive reserve are inconsistent, and no direct measurement of cognitive reserve exists. Studies that have demonstrated indicators for cognitive reserve have inadequately validated their constructs. Associations between cognitive and clinical decline should be independent of brain pathology. Dr. Mungas expects that cognitive reserve modulates the effect of neuropathology on cognitive

and clinical outcomes, such that individuals with greater cognitive reserve may be more resilient to age-related neuropathology. To improve demonstration of cognitive reserve, research design should leverage longitudinal studies that capture change over time rather than cross-sectional measures, which do not.

Relevant issues in the study of bilingualism and cognitive reserve include the need for clear definitions and measurements of bilingualism. Researchers should clearly describe which parameters (e.g., age of language development, language usage and context) are relevant to effects in the brain as well as the impacts of potentially confounding factors (e.g., SES). A better understanding of bilingualism's effects on cognition will contribute to a broader knowledge of how to maintain brain and cognitive health with age.

Discussion

Dr. Mungas described a transition from the current state of cognitive reserve research, which relies on purported reserve indicators, toward a model depicting specific mechanisms of cognitive decline. He added that epigenetic markers of cognitive reserve and lifestyle factors are both areas of research interest and that further investigation could lead the field to understand the mechanisms that enables bilingualism to confer a cognitive benefit.

Session I: Bilingualism Across the Lifespan and Its Impact on Reserve and Resilience

Moderator: Jonathan King Ph.D., Division of Behavioral and Social Research

Beyond Bilingual Juggling: Hypotheses About the Source of Reserve and Resilience

Judith Kroll, Ph.D., University of California, Irvine

Dr. Judith Kroll's research takes a cognitive neuroscience approach to identify the way language may support reserve and resilience. She emphasized a need for researchers to acknowledge the individual, social, and political realities of language learning and use, which vary greatly.

Dr. Kroll's team contributed to three foundational discoveries about bilingualism made in 2014. First, both learned languages are always active and competing. Cross-language interactions are persistent and dynamic changes occur at multiple levels of language processing (e.g., lexical, grammatical, and phonological). As bilingual individuals become experts in juggling different languages, their cognitive processing speed may be negatively affected; however, the mechanisms of these effects are unclear. Second, the native language is altered by use of the second language and by individual experience, including where both languages were learned, how both languages are used, and with whom those languages are spoken. Third, the consequences of bilingualism are not limited to language; they are reflected in a broader reorganization of brain networks, which has implications for the manner in which bilingual individuals negotiate cognitive competition.

These findings emphasize that bilingualism is a complex life experience in which context may affect the regulation and coordination of cognitive resources. Relevant contexts can include code switching (i.e., switching between languages), social networks and language decision making, immersion into the second language, and the linguistic diversity of an individual's environment. For example, bilinguals may find themselves in a separated context (i.e., only one language is used in a specific location), an integrated context (i.e., either language can be used opportunistically), or a varied context (i.e., an immersive context with opportunities for diverse conversational exchanges in both languages).

Findings from an AX-Continuous Performance task suggested that bilinguals in a varied context who make continuous decisions about their language use were better able to maintain their native language over time. Additional research by Dr. Kroll and her collaborators suggests that linguistic diversity in an individual's surrounding environment can facilitate new language learning.

The development of models that account for the social and linguistic diversity of language use, as well as the dynamic changes that occur in interaction contexts, could lead to the identification of a set of potential mechanisms that underlie the consequences of bilingualism.

Discussion

Dr. Kroll was asked whether polylingual individuals may have greater cognitive reserve than bilinguals. She stated that although research is scant, the critical threshold for cognitive differences appears to be knowledge of more than one language. She also stated that no specific mechanism has suggested that exposure to a primary language *dialect* is different from exposure to another language. Dialects may be a critical facet of bilingualism because some are more distinct from each other than others, either linguistically or culturally. Cultural differences are relevant because the context of language use is critical to studies of bilingualism.

Dr. Thomas Bak added that some studies are investigating whether dialects should be considered a separate language and noted that many of the differences across dialects are based on a political rather than linguistic determination.

Maybe, Sometimes, Bilingualism Also Selects for Executive Function Ability

Erika Hoff, Ph.D., Florida Atlantic University

Dr. Hoff has been conducting a longitudinal study that utilizes the flanker task as a measure of executive function in Spanish-English bilingual children from Spanish-speaking households. Previous research has shown that some, but not all, bilingual individuals demonstrate better executive function. Dr. Hoff's research aims to identify the measurable properties of bilingualism (e.g., balance of language exposure, exposure to mixed input, dual language proficiency) and related experiences that predict executive function among bilinguals, and to compare the bilingual individuals who are advantaged by their skills or experiences to monolingual individuals.

Study participants were tested in their homes in two separate 10-minute sessions at the ages of 7, 8, and 9 years. The relation of the measured properties of bilingualism and bilingual experience to reaction time for incongruent trials on the flanker task was assessed using, as covariates, reaction time to congruent trials, overall accuracy, and maternal education (as a proxy for SES). No significant effects on flanker task performance were found for any measure of bilingual experience or proficiency. There was a significant effect of English vocabulary score; bilingual children with higher English vocabulary scores had stronger executive function skills, as measured by the flanker task.

In a second study, those bilingual children with English vocabulary scores above the median were compared with monolingual children for inhibitory control. Controlling for maternal education, the bilingual children with high English vocabulary scores outperformed the monolingual children (who had similar English vocabulary scores) on the measure of executive function. In summary, Dr. Hoff found that inhibitory control was significantly associated with English vocabulary among bilingual children and attributes this finding to the difficulty in acquiring the English language for children from Spanish-speaking homes.

Discussion

Although the flanker task lacks correlation with other generalized inhibitory control measures (e.g., Simon effect, Spatial Stroop task), multiple measures of executive function do not generate consistent results within the same sample. Dr. Hoff explained that the flanker task was chosen because it is the most sensitive measure for showing a difference between bilingual and monolingual children.

While some Latin parts of the English language correspond to elements of Spanish and may provide an advantage for the presented individuals, Dr. Hoff explained that the correlation between inhibitory control and majority language development is found not only in Spanish-English bilinguals but also Dutch-Turkish and Dutch-Moroccan bilinguals.

Bilingualism, Brain and Development: A Neuroemergentist Perspective

Arturo E. Hernandez, Ph.D., University of Houston

Early investigations of the bilingual brain focused on three major areas: age of second language acquisition (AoA), proficiency in both languages, and cognitive control (i.e., the ability to use the desired language). Using a neuroanatomical metric and statistical parametric mapping (SPM), Dr. Hernandez described correlates of AoA and cortical grey matter. For example, an SPM investigation of Spanish-English bilinguals found higher density and cortical thickness for late compared to early AoA bilinguals, while higher volume was correlated with early AoA.

Based on the impact dopamine availability has previously shown on task switching, Dr. Hernandez investigated the relationship between bilingualism and dopamine levels throughout the brain. Genetic assessment shows that a higher proportion of bilinguals than monolinguals have a genotype that is associated with higher levels of subcortical dopamine. Furthermore,

binuals with an early AoA benefitted most from higher levels of subcortical dopamine in terms of binual proficiency. In contrast, binuals with later AoA benefitted most from relatively balanced levels of cortical dopamine.

Though statistical analysis can provide insight into some aspects of the effects of binualism, Dr. Hernandez described the effects of binualism as more dynamic than can be appropriately represented through statistical analysis. As an analogy, Dr. Hernandez presented the ideas of the late French paleontologist Father Pierre Teilhard de Chardin who saw the emergence of life and human culture as a non-linear dynamical system that formed additional spheres around planet Earth. In a similar vein, Dr. Hernandez suggested that human development can be envisioned as a core which expands across time as a series of spheres envelope it. This is in line with the emergentist view that development can be seen as a series of events in which relatively simple pieces are organized and re-organized into a more complex whole.

Discussion

Dr. Hernandez clarified that late AoA binuals behaved more like monolinguals; early AoA binuals were more balanced in their language proficiency (i.e., highly proficient in both languages).

Onset of dementia in binual adults: Evidence for cognitive reserve

Ellen Bialystok, Ph.D., York University

It is difficult but possible to discover scientifically valid patterns related to cognitive reserve and binualism. Dr. Bialystok presented research on differences in brain-behavior relationships between binuals and monolinguals that suggests binualism is not protective against AD, but may delay its clinical diagnosis. However, she emphasized that binualism is not a singular phenomenon and that individuals will have various experiences and interactional contexts that mediate its effects on cognitive and brain outcomes. She added that mostly monolingual countries have the highest incidence of AD when controlling for life expectancy.

One study presented by Dr. Bialystok compared cognitively normal binuals with their Alzheimer's Disease Neuroimaging Initiative (ADNI) database matched monolinguals. Using fractional anisotropy, axial diffusivity, and radial diffusivity, the study showed that monolinguals had significantly more cognitive impairment when controlling for individual factors (e.g., age, sex, education). Additional cognitive impairment among monolinguals could be due to a lack of cognitive resources that would otherwise compensate for poorer brain structure.

Grey matter volume (GMV) studies have generated mixed results, with some finding increased GMV among binuals, some finding the reverse, and others finding equal levels among both groups. Deeper investigation reveals that as individuals age, higher GMV in binual individuals reverses, until monolinguals have higher GMV in advanced age. This pattern is consistent with the repeated finding that binual individuals are diagnosed with dementia at a later age. In support of this effect, increased neuropathology is often seen in binuals at the time of diagnosis compared to monolinguals. Structural comparisons (controlling for age, cognitive

level, and behavioral measures) have demonstrated that bilingual brains have higher AD-specific atrophy patterns than monolingual brains. However, an additional study of Mild Cognitive Impairment (MCI) patients found that although bilinguals convert to AD more quickly than monolinguals, they have increased independent living time. Dr. Bialystok found further evidence in three research areas to confirm that bilinguals maintained cognitive function even with neuropathology of AD. At the time of diagnosis, bilinguals exhibited increased pathology, and experience faster cognitive decline than monolinguals once diagnosed.

Discussion

While robust evidence is not available about the effects of bilingualism on the brain, collecting that type of evidence is an important future step that would assist in developing a general intervention to alter the course of illness for AD patients. A graduate researcher in Dr. Bialystok's lab is currently investigating whether cognitively normal bilingual individuals may have underlying amyloid pathology or differing genetic factors (e.g., ApoE4).

A critical age range likely exists when bilinguals show the most rapid rates of cognitive decline, but the parameters of that range are not yet known.

Discussion of Session I

Moderated by Dana Plude, Ph.D., Deputy Director, Division of Behavioral and Social Research

Defining bilinguals

Dr. Bialystok clarified that most of the bilingual participants from her Canadian studies have been bilingual for a long period of time (i.e., at least 50 years) and describe having “home” and “community” languages. She added that roughly 60% of participants speak a language that is not French or English.

Measuring language acquisition in children on a longitudinal scale

Dr. Hoff suggested that researchers collaborating with established longitudinal studies should ask retrospective questions, such as “What are your parents’ native languages?” and “Which languages were used in school?” Differences in language proficiency scores are likely to be associated with an individual's AoA if an individual has been schooled in a native language prior to acquiring and being educated in a second language. She noted that word learning experiences also differ inside versus outside of the home.

Dr. Kroll added that questions included in longitudinal studies should address which aspects of early experience are enduring, such as the breadth of languages that infants are exposed to. She agreed that literacy and education are important factors. Additionally, studies should investigate the impact of remotely educating students in a language different from their home language.

Effects of learning experiences, cross-cultural diversity, and immigration

Dr. Bialystok noted that research needs to be conducted in a variety of contexts to address variance in bilingualism. For example, SES is not confounded with bilingualism in Canada but is a

significant confounding factor in the United States. The variety of landscapes are significant for research progress.

Dr. Hoff added that a language that is used primarily within the home will be expressed differently than a language used in school. She added that children's language development is impacted by parents' level of education in the heritage language (i.e., a college educated parent will speak to their child differently than a mother with lower educational attainment.)

Requirements for a reliable bilingual study

Dr. Bialystok noted that investigations of bilingualism and its relationship to AD are not and should not become single factor studies. As other speakers noted, she added that the experience of bilingualism is multifaceted. Researchers should aim to distinguish factors that are most relevant to their research question, given that all facets cannot be included in a single study.

Dr. Hoff noted that if the goal of research is to understand language development, then the instruments used are of critical importance.

Literacy as a requirement for added cognitive reserve

Dr. Hernandez noted the differences between asking whether an individual is bilingual or biliterate. Many studies use literacy as a marker for proficiency. In his experience, however, major proficiency differences emerge when a language is learned without accompanying literacy.

Session II: Factors Complicating the Study of Bilingualism and its Impact on Cognition and the Brain

Moderator: Dana Plude Ph.D., Deputy Director, Division of Behavioral and Social Research

Bilingualism and Cognitive Reserve: Concepts, Confounds, and Controversies

Thomas H. Bak, M.D., University of Edinburgh

Cognitive reserve and cognitive resilience are often discussed in tandem or interchangeably, but their definitions differ. Dr. Bak defined cognitive reserve, a concept rooted in dementia research, as a neurological resource that prevents the emergence of or compensates for pathology. In contrast, resilience, which emerged in the context of psychiatry, is a biological or psychological trait related to how well an individual copes with adverse situations. He emphasized a need for researchers to favor consistent rather than strict definitions of bilingualism. Still, he noted that definitions should be robust enough for inclusion in a scientific study (e.g., asking participants how many languages they speak is not sufficient to establish bilingualism).

Contexts and patterns of use have also become increasingly important to bilingualism research. Some of these contexts include code-switching, geographic region, immigration, SES, education, and executive functions. Executive functions (i.e., high-level cognitive processes) are complex and include, among other things, decision making and implementation.

Dr. Bak suggested that researchers diversify the populations they study and begin to define monolingualism as a deficit that can be compensated for, rather than a default state. He anticipated hesitancy to make this paradigm shift, however, due to the incentives to simplify research messages. When conducting research on the effects of bilingualism on cognitive aging, researchers should note whether bilingualism is viewed either as a benefit or a burden; perceptions of bilingualism may have some effect on its impact.

Discussion

Research investigating cognitive implications of different language scripts (e.g., letters and words compared to characters) is scant. Dr. Bak is currently investigating the differences between spoken language and their accompanying writing systems in relation to cognitive reserve in participants learning Chinese and Arabic.

Establishing that bilingualism has a causal role in cognitive reserve may not be possible even in a large study, because a large sample size does not automatically provide variability.

Deconstructing Bilingualism and its Sociocultural Determinants for Research on Cognitive Aging

Miguel Arce Rentería, Ph.D., Columbia University Medical Center

Several strong studies have produced mixed results on the effects of bilingualism on cognitive aging. However, Dr. Arce Rentería noted that each major type of finding was produced by studies implementing different research designs. Studies that found a benefit from bilingualism were generally retrospective and based on cross-sectional analysis, while studies that did not find bilingualism to be protective against neurodegeneration implemented a longitudinal analysis and included a community-based sample of participants.

Dr. Arce Rentería suggested that an ideal methodological approach to investigating a causal link between bilingualism and neurodegenerative diseases would implement a prospective cohort with community-dwelling bilingual individuals who are free of dementia at the start of the study and have completed a baseline assessment of their level of bilingualism. The ideal study would have frequent waves of data collection over a long period of time and cases of dementia would be diagnosed by a team of experts. Study designs should carefully consider issues related to causal inferences and appropriate assessment of cognitive reserve. Researchers should include a detailed characterization of the various aspects of bilingualism within their studies and understand that bilingual individuals are a diverse group of people. It is possible that there may be specific aspects of bilingualism that best inform future interventions (e.g., AoA, code-switching).

Researchers should take a cognitive aging approach to evaluate bilingualism and should consider its socio-cultural factors, such as childhood SES, immigration histories, adulthood access to healthcare, and overall health, all of which are critically important parts of the context in which language is used and its impacts on aging. Dr. Arce Rentería emphasized that differences observed in bilingual research will be based on the communities investigated. A well-characterized subset of a given population may eliminate the noise of multiple unmeasured confounds to shed clearer light on cognitive aging.

Discussion

Dr. Arce Rentería clarified that retrospective and prospective studies are both used frequently and are both important for answering different types of research questions. For the specific interest of understanding the causal factors that may protect against AD, a prospective study would best lead to an intervention.

Idiosyncratic Linguistic Features: Potential Impact in Dementia and Bilingualism Studies

Boon Lead Tee, M.D., University of California, San Francisco

Primary progressive aphasia (PPA) is a dementia syndrome predominantly manifested with speech and language deficits. Current literature and research on PPA are primarily based on English language speakers, leaving the majority of the world's languages under-represented. Dr. Tee suggested that PPA assessments should account for the unique linguistic feature present in languages other than English and pointed specifically to Chinese, which is a tonal, phonologic, analytical language with logographic script that strongly contrasts English script.

In conjunction with international collaborators, Dr. Tee introduced the Chinese Language Assessment in PPA (CLAP) with the goal of identifying linguistic features critical for diagnosing PPA in Chinese language speaking participants. One of the variants used is the “tonal twister,” which asks participants to recite a homophonic sentence that switches the tones of a single syllable to represent different word meaning. Dr. Tee found that the ability to repeat a tonal twister phrase is associated with volumetric changes over the left anterior insula and frontal operculum, both of which are critical for speech and motor executions. Additionally, her work also highlighted that English and Chinese language users with PPA exhibit different dysgraphia phenotypes. For instance, Chinese semantic variant PPA individuals exhibit more homophonic writing errors than surface dysgraphia whereas patients with Chinese logopenic variant PPA tend to produce orthographically similar writing errors.

These results suggest that research on PPA should expand to languages with varying typology, which will be essential for accurate diagnosis, effective speech/language therapy, and appropriate evaluation of bilingual aphasia in individuals with dementia. Diversifying PPA strategies also offers potential cross-cultural benefit; for example, English speakers with semantic variant PPA may also manifest with homophone selection impairment and homophone function assessment can be an additional diagnostic indicator.

Discussion

Dr. Tee clarified that her future work in CLAP will include informal spontaneous speech samples from participants to investigate speech impairment. However, speech sample analysis should examine different linguistic markers than those of English language, for instance investigating lexical tones performance for motor speech function.

Bimodal Bilingualism, Deafness, and Aging

Karen Emmorey, Ph.D., San Diego State University

Bimodal bilinguals are individuals who use languages that have two input channels and two output channels (i.e., they can sign and speak), while unimodal bilinguals have a single input and output channel (i.e., they know two spoken languages). Unimodal bilinguals are known to code-switch between their known languages, while bimodal bilinguals often *code-blend* by speaking and signing at the same time. Unlike code-switching, code-blending does not involve a processing cost until continuous, sentence-level code-blending occurs; at that point, one language tends to suffer (usually the signed language).

Studies of bimodal bilinguals can offer insight into language control and inhibition. Inhibiting a language is effortful and activates cognitive control regions of the brain, though the language control demands are weaker for bimodal bilinguals (i.e., due to the ability to code-blend) compared to unimodal bilinguals (who must suppress one language to switch into the other). Dr. Emmorey's research found that transitioning *into* a code-blend (adding American Sign Language, or ASL to spoken English) did not slow response times in a picture-naming task and did not elicit increased activation of cognitive control regions. However, *turning off* a language (e.g., inhibiting spoken English) slowed response times and elicited increased neural activity in brain areas involved in cognitive control.

Individuals who use sign language often exhibit enhanced spatial abilities (e.g., mental rotation, spatial perception, and spatial memory) compared to non-signers. As deaf signers get older, research has found they experience a smaller effect of aging on mental rotation performance compared to hearing non-signers. Additional research by Dr. Emmorey found that neuroanatomical changes were associated with sign language experience for both deaf and hearing individuals: increased cortical surface area in visual and semantic brain regions compared to monolingual non-signers. Dr. Emmorey added that hearing loss is one of the largest risk factors for dementia, in part because it places individuals at risk for social isolation; however, deaf signers can maintain their social connections, thus improving quality of life. Future research to understand the connection between hearing loss, bilingualism, and dementia should investigate the prevalence of dementia in early deaf bilinguals, best practices for diagnosing dementia in the bimodal bilingual population, the impact of the deaf-signing community on cognitive reserve, and the impacts early-language deprivation may have on individuals as they age.

Aging and Bilingual Language Control

Tamar Gollan, Ph.D., University of California, San Diego

Several studies implement a self-rating measure for bilingualism, but many participants' self-ratings do not correlate with the results of the gold-standard bilingual scale, the Oral Proficiency Interview. Dr. Gollan and colleagues have developed the Multilingual Naming Test (MINT) and the MINT Sprint (an expanded version with a fast administration procedure) to provide a standardized measure of bilingualism, referred to as the Bilingual Index Score. Scores from both MINT and MINT Sprint scales were found to correlate with Oral Proficiency Interview rating results.

Using standardized measures of bilingualism, Dr. Gollan studied the cognitive impacts of language switching by giving bilinguals passages that haphazardly switched between languages. Dr. Gollan found that bilinguals produced intrusion errors (e.g., automatic translations to avoid language switching) and accent errors in a read-aloud test. Interestingly, both error types exhibited reverse language dominance, meaning that bilinguals were more likely to avoid producing words in their dominant language. Though it may seem contrary to produce fewer errors in the non-dominant language, these results are consistent with the inhibitory control model (ICM) and appear in Spanish-English, Chinese-English, and Hebrew-English bilinguals. Similar dominance reversal effects have been found in picture naming tasks in Spanish-English, Spanish-Catalan, Chinese-English, German-Dutch, German-English, and Swedish-English bilinguals.

Older bilinguals were found to produce more errors in a read-aloud task and had a slower response time in a picture naming test compared to younger bilinguals. However, reverse language dominance remained intact for both younger and older bilinguals. Intrusion errors were found to increase with age, in particular for bilinguals diagnosed with AD, suggesting that intrusion errors could be a potential diagnostic measure for AD; a task to investigate the possibility of intrusion errors for monolinguals is currently under development. However, concrete factors to describe the locus of impairment are not yet understood.

Additional research by Dr. Gollan found that individuals expressed a "dose effect," where low-education individuals considered "more bilingual" had a later age of AD diagnosis. Dose effects are also exhibited in dominance reversal. Individuals considered less bilingual exhibit a smaller reverse language dominance effect than more balanced bilinguals – but in this case the dose effect is misleading because more balanced bilinguals had more similar proficiency in their two languages to begin with, which makes it easier to exhibit dominance reversal. Thus, it was the less balanced bilinguals who likely had to exert the greatest amount of inhibitory control on the dominant language.

Discussion

Dr. Gollan clarified that translation from one language to another is a specific skill that may not directly correlate to an individual's language proficiency. Translation requires high levels of

working memory and Dr. Gollan recommends researchers use caution if any time pressure is imposed on participants for a translational assessment of bilingualism.

Dr. Gollan noted that multiple language combinations are included in the presented studies, but not all participants are English dominant. For the multiple language combinations including Chinese, the majority of bilinguals are Chinese dominant, studies with Spanish-English bilingual participants are generally English dominant, and studies conducted in Israel include Hebrew dominant bilinguals. Each group expressed similar reverse dominance effects.

Discussion of Session II

Moderated by Dana Plude, Ph.D., Deputy Director, Division of Behavioral and Social Research

Effects of dominance reversal

Given that dominance reversal is a general cognitive process that extends beyond the linguistic system, (e.g., transitioning between simple and difficult tasks) Dr. Gollan was asked how she can characterize her findings as a linguistic phenomenon. Dr. Gollan clarified that, to her knowledge, full dominance reversal has not been found during non-linguistic cognitive switching tasks; however, some assessments of nonlinguistic switching ability (e.g., switching between identifying even and odd numbers) also exhibit greater costs to the dominant or easier tasks than to the nondominant or harder tasks.

Dr. Bialystok raised a concern about considering differences in reaction time an instance of dominance reversal; that may be only a potential explanation. Dr. Gollan agreed that dominance reversal might not necessarily reflect inhibitory control of the dominant language; however, results from multiple studies produce the same in error rates.

Previous presentations described a 10-minute non-dominant language immersion as temporarily inhibitory on an individual's ability to retrieve picture names in the dominant language. Dr. Gollan does not believe the same mechanism underlying this short-term (10-minutes) language dominance effect is the same as the effect of long-term immersion. Dr. Gollan agreed that contexts should not be conflated, and efforts should be made to differentiate the results based on their context.

Language intrusion errors

Dr. King noted that the English language is often inconsistent and asked whether this inconsistency might drive some of the presented intrusion error patterns, particularly because the majority of the errors occurred with function words. Dr. Gollan clarified that her research signals that cognates also frequently elicit many intrusion errors. She hypothesized that the dominant language will generally be more likely to elicit intrusion errors; however, different languages may elicit different results and some phenomena are language or language-combination specific. For instance, Spanish-English bilinguals produced more intrusion errors in reading aloud than Chinese-English and Hebrew-English bilinguals, which are written with different scripts. In addition, common errors seen in English and Spanish, are less common in Chinese and Hebrew speakers in which fewer function words can be switched). Dr. Bak

suggested that a broader number of languages be systematically investigated, including languages with their complex morphology.

Dr. Kroll noted that at a minimum, bilingual language pairings can be investigated at two levels. At a more simplistic level, researchers can investigate similarities and differences in bilingualism's effects across multiple language pairings. At a higher level, however, researchers could investigate specific types of linguistic restraints (e.g., the cognitive consequences of code switching could be explored, rather than asking whether code switching occurs). Researchers should also investigate which aspects of cognition are affected by which aspects of linguistic demands and linguistic structures and which effects are long-lasting.

Impacts of age of acquisition

Panelists were asked to clarify the distinction between early and late AoA, and whether any AoA is too high for bilingualism to confer a potential cognitive benefit. Dr. Bak stated that even at an age of 85, individuals display a measurable improvement in attention switching after an intensive course of a new language. Dr. Bialystok noted the purpose of language learning must be included when asking if there is an age-limit for the benefits of bilingualism. Bilingualism creates ongoing neuroplastic changes in mind and brain. She stated there is no cognitive advantage due to bilingualism, but the process of managing languages manifests in multiple ways throughout the life course. She encourages older adults to learn an additional language because it is a stimulating experience that engages cognitive processes that *maintain* cognitive health.

Day 2

Perspective: Is there a bilingual advantage?

Kenneth Paap, Ph.D., San Francisco State University

Based on meta-analyses conducted both by his team and other research groups, Dr. Paap showed that the data supporting a bilingual advantage in cognitive control are weak. Early studies finding positive advantages of bilingualism are difficult to replicate. Dr. Paap added that apparent advantages are more likely to reflect Type 1 errors, biases in research methods, or confounding factors.

Dr. Paap pointed out that the hypothesis of a bilingual advantage in domain-general inhibitory control is based on four assumptions that must all be true. First, switching between languages must recruit domain-general inhibitory control; second, this inhibitory control must be modifiable through practice; third, the recruitment of domain-general inhibitory control is of sufficient magnitude and duration to enhance general inhibition; and fourth, domain-general inhibition must actually exist as a construct. While many studies attempt to test the potential effects of bilingualism on general inhibitory control, there is good reason to believe that there is no such thing as general control, because the different measures of it do not correlate with one another—they lack convergent validity.

In his review of the history of the bilingual advantage debate, Dr. Paap pointed out that the original advantage was assumed to be in inhibitory control, but the narrative eventually shifted to become an advantage in monitoring and subsequently in executive attention. Dr. Paap noted that popular but insufficiently evidence-based theories often persist and resist attempts at falsification, as disconfirming data and failed replications are too frequently ignored and researchers fluidly change the necessary and sufficient conditions for producing the predicted effects. He added that recent publications that state a small subset of bilinguals (i.e., those who acquire their second language early and frequently code switch) have cognitive advantages are also supported by only weak and inconsistent results.

Dr. Paap closed by noting that it is not obvious that bilinguals must exercise significantly more executive control than monolinguals. In planning their utterances, monolinguals must monitor for signals regarding turn-taking, misunderstandings, and changes of topic that lead to switches from speaker to listener or from one topic to another. Although monolinguals do not suppress translations, they *do* make word choices that involve selecting one word candidate and suppressing its competitors. Moreover, monolinguals need to use context to suppress or inhibit irrelevant meanings of homographs or homophones.

Discussion

Dr. King noted that the convergent validity of several tasks (executive function, self-control) has proven to be much weaker than expected and thus a lack of convergence within bilingualism studies is consistent with other literature. Dr. Gollan added that executive function tasks are not designed to measure individual differences, and results of executive function do not converge either. Dr. Gollan also noted that many of the studies cited in Dr. Paap's presentation that did not show an advantage of bilingualism were not appropriately designed to assess whether individuals are truly bilingual; therefore, these results may not correlate with other research findings.

Session III: Mechanisms by Which Bilingualism May Drive Neuroplasticity in the Brain

Moderator: Molly Wagster Ph.D., Chief, Behavioral and Neuroscience Branch

Structural Neuroplasticity in the Healthy Bilingual Brain and its Relevance to Healthy Aging

Christos Pliatsikas, Ph.D., University of Reading

Dr. Pliatsikas noted a growing body of studies that find bilingualism affects the structure of the adult brain, including both white matter (WM) and grey matter (GM). Studies investigating restructuring (in cortical and subcortical WM and GM) have generated a great deal of variability, which may be explained by the unique experiences of bilingual individuals.

Dr. Pliatsikas introduced the Dynamic Restructuring Model, which aims to explain the complex dynamics of structural neuroplasticity caused by the bilingual experience. During the first stage of initial exposure to a second language, an increase in brain volume (e.g., cortical GM, subcortical GM, and cerebellar GM) is observed, this increase is correlated with vocabulary and phonological acquisition. After gaining additional bilingual experience, individuals enter a second consolidation phase, during which cortical GM no longer differs from monolinguals, but more prominent effects arise in subcortical structures and white matter tracts that are responsible for language control. The final stage represents the peak efficiency bilingual, for whom the local brain changes seen in the previous two stages are no longer present. This model explains why studies that find increases in bilinguals' cortical GM usually occur in bilinguals with limited language use or language switching experience, while they seem to disappear in more experienced bilinguals, and get replaced by subcortical effects.

According to the neural reserve hypothesis (i.e., cognitive reserve makes the brain more resistant to aging or disease related tissue loss), bilingualism can cause progressive reinforcement of brain structures, making bilinguals more resilient than monolinguals. Forthcoming publications find that older bilinguals have larger hippocampi than monolinguals, a result of bilinguals' slower tissue loss rates. Dr. Pliatsikas emphasized a need for researchers to investigate the "youngest" of older individuals to understand the precise implications of such findings for healthy aging.

Discussion

Dr. Pliatsikas clarified that the impact of competition from language switching will be further investigated, with the assumption that competition is occurring given that similar brain benefits are seen among individuals with practiced skills, (e.g., musicians).

The Complexity of Bilingualism and the Effects on Neuroplasticity

John Grundy, Ph.D., Iowa State University

Dr. Grundy focused on the complexity of bilingualism and its effects on neuroplasticity, rejecting the dichotomous view that bilingualism either does or does not have a particular effect. Previous studies that focused on bilingualism and executive function have published null findings. However, Dr. Grundy described potential overlooked factors that may have caused meta-analytic research to find more instances of null effects, including interactional context, verbal versus non-verbal testing instruments, treatment of outliers, and an omission of brain data. He also highlighted a need for future investigations to take into consideration the age of participants, which affects various bilingualism-related factors.

Dr. Grundy also noted that definitions of bilingualism (including proficiency) are often highly variable across studies. Despite these inconsistent definitions, several publications have found that bilinguals outperform monolinguals on EF tasks, and a quantitative analysis of the available literature provides strong evidence that this occurs far more often than chance. Dr. Grundy also conducted a meta-analysis to investigate the effects of bilingualism on both the age of onset of dementia and incidence rates. The analysis found that bilingualism is associated with delayed

age of onset, but incidence rates were more similar. He hypothesized that bilingual individuals have high cognitive reserve that makes them more resilient to neuropathology. A separate study investigating white matter connectivity focused specifically on age. The white matter meta-analysis found that the effects of bilingualism were age-dependent: younger bilinguals have greater white matter (WM) integrity (e.g., in the corpus callosum) than monolinguals but, as individuals age, bilinguals demonstrate less WM integrity compared to monolinguals. Consistent with these WM findings, Dr. Grundy introduced the Bilingual Anterior to Posterior and Subcortical Shift (BAPSS) model, which states that as individuals age, bilinguals utilize posterior and subcortical regions of the brain more efficiently to compensate for brain aging.

Discussion

Bilinguals consistently show symptoms of dementia 4 to 6 years later than monolinguals; however, the buildup of neuropathology is still occurring and eventually cannot be overcome. Dr. Grundy clarified that some studies do find population level incidence rates of AD being lower in bilingual countries compared to monolingual countries. However, these results are not as robust as age of onset studies given that both groups of individuals eventually get the disease.

Dr. Grundy was asked by Dr. Paap about identifying a single task to demonstrate the age when bilingual advantages occur. However, Dr. Grundy suggested that the research community should embrace complexity rather than reduce bilingualism to one outcome measure.

Neuroanatomical Perspectives on Bilingualism and Aging

Jubin Abutalebi, M.D., University Vita Salute San Raffaele

Dr. Abutalebi's research centers on relationships between behavior and areas of the brain involved in executive control, such as the anterior cingulate cortex (ACC). He emphasized that studies should investigate both behavioral differences and brain imaging, highlighting that while the two are related they do not exhibit a one-to-one correspondence. In a study investigating the ACC, a significant area of the brain for conflict monitoring, a negative correlation was found among bilinguals: as response time in the flanker task decreased, grey matter increased.

Although high cognitive reserve can delay the onset of dementia, incidence is not reduced. Cognitive reserve can be influenced by an individual's education and occupation along with their cognitive, physical, and social activities. Dr. Abutalebi hopes that future research takes bilingualism as one of many potential cognitive skills and conducts long-term studies of the impact of regimented training in a second language in older adults over time.

In a series of studies, he conducted among aging English-Cantonese and Mandarin-Cantonese bilinguals in Hong Kong, Dr. Abutalebi found a correlation between faster responses to a naming task and increased grey matter (and, hence, neuroprotection). However, only performance in second language naming correlated to increased grey matter and not first language naming. Using a control group of monolinguals from Milan (because monolinguals in

Hong Kong do not have comparable education levels), Dr. Abutalebi found a positive correlation only for bilinguals who were actively proficient in their second language.

Investigations of aging bimodal bilinguals (those who can sign and speak a language) compared with unimodal bilinguals and monolinguals found increased grey matter among all bilinguals. Dr. Abutalebi also detected a preserved degree of gyrification exclusive to older adult bilinguals in the right caudal ACC, the right posterior cingulate cortex (PCC), and the right entorhinal cortex, signaling enhanced brain functioning.

Discussion

Neural reserve is positively correlated with increased proficiency in all areas of bilingualism—including reading, comprehension, speaking, etc.—and appears to compensate for brain atrophy.

Although studies have found a difference in age of AD onset of 4 to 5 years between monolinguals and bilinguals, future studies should aim to investigate the additional factors, such as diet, physical activity, and musical activity, that may moderate this difference.

Bilingualism, Reserve, and Resilience across Dementia Subtypes

Suvarna Alladi, M.D., National Institute of Mental Health and Neurosciences

Investigating the relationship between bilingualism and dementia can provide valuable scientific knowledge about the mechanisms of cognitive reserve. To best move the field of research forward, Dr. Alladi encouraged her colleagues to investigate complex aspects of bilingualism (e.g., culture, neuroplasticity) among populations that are linguistically diverse.

Dr. Alladi's research has focused on low to middle income countries, where the burden of dementia is rising. Due to the linguistic diversity of India, Dr. Alladi implements Addenbrooke's Cognitive Evaluation (ACE-III) for Indian languages to maintain a harmonized and validated measure. She has standardized neuropsychological testing and implemented cross-cultural adaptations and a decentering of items or stimuli that are specific to a single culture. Results in India found that bilinguals have a five-year delay in age of onset of dementia compared to monolinguals. Advantages among bilingual individuals in India were consistent regardless of literacy or other social factors.

To determine whether bilingualism is protective across a range of cognitive diseases, Dr. Alladi studied frontotemporal dementia. Although bilinguals had a later age of onset, most differences were behavioral and did not affect aphasia variance. Among stroke patients, bilingual individuals were more likely to return to normal cognition, while monolinguals were more likely to have signs of MCI.

Dr. Alladi suggested that neuroplasticity and neurodegeneration be measured in parallel to help disentangle the effects of life experiences. Additionally, research that implements harmonized, longitudinal, multidisciplinary, and multimodal approaches are needed to address gaps in research on bilingualism and cognitive resilience. Finally, many additional modifiable factors,

such as diet, exercise, and social activities, are linked to an individual's culture and may act as potential confounding variables; variables capturing these sociocultural factors should be incorporated into studies of bilingualism and resilience.

Discussion

Dr. Alladi clarified that while several languages are spoken in India, roughly one-quarter of the population is considered bilingual. Monolingualism is more likely among older individuals and is becoming increasingly less common among educated younger people. Dr. Alladi believes that her research team's efforts to connect with patients, speak their language(s), and provide excellent medical care allows her to maintain dementia cohorts from rural areas. However, she mentioned that the dementia diagnosis gap in India is roughly 90% and most individuals with dementia do not seek medical support, especially in rural areas.

Bilingualism as a Precursor for a Cognitive Reserve: What are the Required Premises?

Esti Blanco-Elorrieta, Ph.D., Harvard University

Rather than describe research findings, Dr. Blanco-Elorrieta examined theoretical accounts of how bilingualism may provide advantages for cognitive reserve. Researchers have offered different explanations for why language switching, inhibition, or executive control may benefit a bilingual individual. Though different in scope, each explanation hypothesizes a source domain in which bilinguals experience heightened cognitive training (such as language control to resolve cross-linguistic competition—i.e., competing cues from distinct languages); a target domain in which benefits are experienced (such as general cognitive control or EF); and some transfer mechanism that mediates between the two.

It is difficult to conceive of inhibition as a mechanism of language control that trains EF more in bilinguals than in monolinguals. Most fundamentally, inhibition is not tantamount to EF in general. But inhibition models also encounter implementation problems. If bilinguals engage in *whole language inhibition*, then one must adopt the following postulates for it to be the source of the advantage: first, the language system operates on the basis of inhibition; second, executive control is intrinsically and definitionally a process of suppression; and third, the first step of suppression is so strong that it is enough to cause an advantage in and of itself, despite it facilitating language selection throughout the rest of the language production system. If instead bilinguals engage in constant small inhibitions of *individual language elements*, then that would require everyday circumstances demanding these acts. No evidence exists for either of these empirical conditions.

A somewhat more promising model of the bilingual advantage would draw on the “highest-activated element” as a mechanism of language control. This mechanism is shared by monolinguals and bilinguals but could be more often or more strongly recruited in bilinguals. However, this model requires some non-stochastic benchmark for choosing linguistic elements, and thus it would predict benefits primarily in dual language contexts where bilinguals' language choices are somewhat but not fully constrained; by contrast, dense code-switching

contexts allow bilinguals to make any linguistic choice (hence there is no need for the executive function mediated selection of one element over another). In single language contexts, interlocutors understand only one language. Given sufficient background context or experience with this given individual, the activation levels for the language that is not shared with the listener will be much lower than those for the shared language. Consequently, the two choices will not be similarly available for selection, which means that there would no longer be a need for executive control to mediate those choices.

Once the mechanism of the source domain is identified, transfer mechanisms that generate measurable outcomes still must be defined, as well. Researchers should consider two main possibilities. First, if a single executive control mechanism exists, then its enhancement via bilingualism should generate improvements in any task that also requires executive control (e.g., musical abilities, EF, etc.). Alternatively, if executive control is exercised specifically within the context of particular applications, then the specialized application applied to the control of language would be separate from musical abilities or video gaming, requiring more explanation of how skills transfer across these domains.

The inconsistency of results in studies investigating cognitive reserve and resilience could be due to researchers' attempts to collect data without a detailed theory of the sources of any identified advantages. Future research should aim to be theoretically grounded and be compared with the impacts of other complex and acquired skills.

Discussion

Dr. Blanco-Elorrieta's presentation focused on cognitive models rather than the impacts of neurobiological factors. Although the two areas of research often do not overlap, it would be beneficial to establish a basis for investigation that addresses both of them. Dr. Blanco-Elorrieta also clarified that she did not consider all ways in which a language or other source domain could confer an advantage; her presentation focused on inhibition due to its prevalence during the workshop and in relevant literature.

Multiple approaches can lead to a general understanding of how life course events can affect cognitive reserve—through one's environment, experiences, culture, education, language/bilingualism, and more. Dr. Blanco-Elorrieta encouraged the field to begin with measures that directly translate to evidence of a bilingual advantage rather than state that a bilingual advantage exists without defining the mechanism that causes that advantage.

Discussion of Session III

Moderated by Molly Wagster, Ph.D., Chief, Behavioral and Systems Neurosciences Branch

Inhibition

Dr. Gollan agreed that investigations of the effects of bilingualism will benefit from attention to theoretical frameworks. She added that in her earlier research, she did not use inhibition as an explanatory framework, but she has found that doing so can generate the most succinct descriptions of patterns in bilingualism data. Dr. Abutalebi noted that many researchers initially

rejected the role of inhibition in bilingualism and reiterated the need for researchers to resolve some of these questions by adopting a dual approach that investigates both behavior and brain imaging. Dr. Blanco-Elorrieta clarified that although she does not conclusively rule out the relevance of inhibition, it has become a convenient shorthand for factors that likely require further investigation. Additionally, models should more effectively capture the differences between inhibition as seen in lab settings and inhibition that occurs with general language use.

Observation and theory

Dr. Hernandez stated that the most difficult aspect of all scientific research involves moving from observation to theory and vice versa. He suggested that bilingualism research should move towards modeling as a way of representing and adapting research approaches. Dr. Blanco-Elorrieta agreed that computational modeling would be extremely beneficial to research on the effects of bilingualism.

Dr. Alladi questioned whether the field truly needs an agreed upon theory to advance bilingualism research in dementia, and whether a lack of consensus on the theoretical framework may impact progress in the field. Dr. Blanco-Elorrieta suggested that although a definitive account of the mechanisms that mediate bilingualism's benefits is not necessary, identifying potential mechanisms could help provide benefits for all individuals. Dr. Rentería added that as stronger evidence emerges, a theoretical framework increases the potential for an intervention to assist individuals with neuropathology.

Dr. Paap noted that recent research has claimed to find cognitive benefits not only from bilingualism but also from video gaming, musical activities, and other activities where skills are acquired over time, making it difficult to develop theories specific to the cognitive benefits of bilingualism.

Dr. Jon King stated that researchers do need a concrete description of which aspects of bilingualism (e.g., cognitive processes, neural network, etc.) are being investigated to provide an overarching framework. Once that framework has been established, the diverse questions investigating modifying or modulating factors can be included.

From a transdisciplinary perspective (e.g., including neurobiology, neuropsychology, cognitive psychology, and other fields), the discussion of theory-based research becomes more complex. While theory is beneficial, Dr. Bialystok emphasized the need to broaden the conceptualization of research questions. She encouraged collecting additional data before applying a theoretical framework.

Politicization of bilingualism

In Dr. Abutalebi's experience, some European countries do not promote bilingualism and see it as a threat to local identity. Within other European countries, children are encouraged to learn English, which is considered to offer social, economic, and cultural advantages. Dr. Hoff added that within the United States, bilingualism is regarded differently based on the specific languages spoken; for example, individuals with Spanish as their heritage language are not well regarded.

Final Discussion: Gaps and Opportunities

Moderated by Matt Sutterer, Ph.D., Program Director, Behavioral and Systems Neuroscience

Bilingualism over the life course

Age of Onset

Dr. Pliatsikas clarified that his research shows that hippocampal decline occurs at a slower rate for bilinguals compared to monolinguals, he added that episodic memory did not differ between monolinguals and bilinguals despite finding structural differences between the groups.

Dr. Abutalebi noted that for younger individuals, measures of GM differ markedly between early and late AoA bilinguals. For older individuals, differences in GM based on AoA are not significant; instead, these differences are associated with an individual's language proficiency and exposure. Individuals who were bilingual and lost their second language exhibit the same patterns as monolinguals. Hence, the importance of being exposed and using a second language even in older ages.

Recoverability

Participants asked whether any current research investigates the possible recoverability of a language previously learned and forgotten, or what would need to occur to investigate this potential recoverability. Dr. Bak stated the field is transitioning from a static concept of "language competence" toward a dynamic model that treats bilingualism as an ongoing activity with different levels, similar to diet or physical exercise.

Theoretical frameworks and methodological design

Dr. Abutalebi cautioned researchers about the language they use in discussions of theoretical frameworks. Calling for a theory "prior to" advancing cognitive research may seem to privilege theory over patient impact and care, and this focus can seem ill-matched to dementia as a worldwide emergency. He noted that several other areas described as protective for cognition, such as physical activity and education, also lack an explanatory cognitive theoretical framework.

Dr. Arce Rentería noted that most bilingualism research is either prospective or retrospective in approach; however, socio-cultural confounds are related to both approaches and are not well represented by either. He encouraged researchers to investigate socio-cultural confounds and additional research gaps in all kinds of studies. Dr. Mungas added that some prospective studies could be used to improve researchers understanding of the findings of retrospective studies.

Many presenters agreed that using a theoretical framework would be ideal. Dr. Bak suggested that investigations of aging and bilingualism may not be at a sufficiently advanced stage to combine current knowledge into a testable theory.

Future research challenges

Dr. Mungas challenged panelists to describe what *a priori* hypotheses and *theory-based* hypotheses could move bilingualism research forward. He added that the theories that guide bilingualism research must at a minimum be testable and falsifiable.

Dr. Alladi emphasized a need to increase and diversify the overall number of studies investigating bilingualism globally; she noted that the number of extant studies is still too small to address whether and how bilingualism serves as a resilience factor against dementia. To attract funding and conduct studies that deeply investigate individual levels of bilingualism, the wider community of researchers on aging need to engage in exploring bilingualism as a potential protective factor against dementia.

Future research opportunities

Dr. Hernandez noted that the Open Science framework and increased data sharing could benefit bilingualism research by enabling and invigorating discussions of common data. Specifically, for cognitive aging and other neurodegenerative diseases, Dr. Arce Rentería stated that support from the NIA to facilitate collaborations that integrate study of bilingualism into existing longitudinal aging studies could be an excellent way to broaden bilingualism research.

Dr. Blanco-Elorrieta added that it will be critical for the field to understand whether knowing a language is sufficient for a cognitive advantage or if *use* of the known language is required. Dr. Bialystok suggested that both aspects matter and remarked that ongoing research does investigate both language knowledge and use. Dr. Abutalebi emphasized the need for investigations to use a broader range of measures that capture real-world activities, rather than only clinical tests, in order to broadly understand the relationship between bilingualism and aging.

Appendix A: Agenda



Bilingualism and Cognitive Reserve and Resilience
March 2-3, 2021

Workshop Agenda

Note: All times listed are Eastern Standard Time (EST)

Tuesday, March 2nd

10:00 a.m. - 10:15 a.m. Welcome & Introductions, Matt Sutterer, Ph.D.

Richard Hodes, M.D., Director, *National Institute on Aging (NIA)*

Eliezer Masliah, M.D., Director, Division of Neuroscience, NIA

Lis Nielsen, Ph.D., Director, Division of Behavioral and Social Research, NIA

Matt Sutterer, Ph.D.; Molly Wagster, Ph.D., Division of Neuroscience

Jonathan King, Ph.D.; Dana Plude, Ph.D., Division of Behavioral and Social Research

10:15 a.m. - 10:45 a.m. Overview: Cognitive Reserve & Resilience in Aging

Dan Mungas, Ph.D., *University of California, Davis, Davis, California, USA*

Session 1: Bilingualism across the lifespan and its impact on reserve and resilience

Session Chair: Jon King, Ph.D.

10:45 a.m. - 11:15 a.m. Beyond bilingual juggling: Hypotheses about the source of reserve and resilience

Judith Kroll, Ph.D., *University of California, Irvine, Irvine, California, USA*

11:15 a.m. - 11:45 a.m. Maybe, Sometimes, Bilingualism Also Selects for Executive Function Ability

Erika Hoff, Ph.D. *Florida Atlantic University, Boca Raton, Florida, USA*

11:45 a.m. - 12:00 p.m. Break

12:00 p.m. - 12:30 p.m. Bilingualism, Brain and Development: A Neuroemergentist Perspective

Arturo E. Hernandez, Ph.D., *University of Houston, Houston, Texas, USA*

12:30 p.m. - 1:00 p.m. Onset of dementia in bilingual adults: Evidence for cognitive reserve

Ellen Bialystok, Ph.D., *York University, Toronto, Ontario, Canada*

1:00 p.m. - 1:30 p.m. Discussion of Session 1, Moderated by Jon King, Ph.D.

1:30 p.m. Break

Session 2: Factors complicating the study of bilingualism and its impact on cognition and the brain

Session Chair: Dana Plude, Ph.D.

1:45 p.m. - 2:15 p.m. Bilingualism and cognitive reserve: concepts, confounds and controversies

Thomas Bak, M.D., *University of Edinburgh, Edinburgh, Scotland, United Kingdom*

2:15 p.m. - 2:45 p.m. Deconstructing bilingualism and its sociocultural determinants for research on cognitive aging

Miguel Arce Rentería, Ph.D., *Columbia University Medical Center, New York, New York, USA*

2:45 p.m. - 3:00 p.m. Break

3:00 p.m. - 3:30 p.m. Idiosyncratic linguistic features: potential impact in dementia and bilingualism studies

Boon Lead Tee, M.D., *University of California, San Francisco, San Francisco, California, USA*

3:30 p.m. - 4:00 p.m. Bimodal bilingualism, deafness, and aging

Karen Emmorey, Ph.D., *San Diego State University, San Diego, California, USA*

4:00 p.m. - 4:30 p.m. Aging and Bilingual Language Control

Tamar Gollan, Ph.D., *University of California, San Diego, San Diego, California, USA*

4:30 p.m. - 4:45 p.m. Break

4:45 p.m. - 5:15 p.m. Discussion of Session 2, Moderated by Dana Plude, Ph.D.

5:15p.m. Adjourn Day 1, Matt Sutterer, Ph.D.

Wednesday, March 3rd

Welcome and Announcements, Jon King, Ph.D.

10:00 a.m. - 10:30 a.m. Perspective: Is there a bilingual advantage?

Kenneth Paap, Ph.D., *San Francisco State University, San Francisco, California, USA*

Session 3: Mechanisms by which bilingualism may drive neuroplasticity in the brain

Session Chair: Molly Wagster, Ph.D.

10:30 a.m. - 11:00 a.m. Structural neuroplasticity in the healthy bilingual brain and its relevance to healthy aging

Christos Pliatsikas, Ph.D., *University of Reading, Reading, England, United Kingdom*

11:00 a.m. - 11:30 a.m. The complexity of bilingualism and its effects on neuroplasticity

John G. Grundy, Ph.D., *Iowa State University, Ames, Iowa, USA*

11:30 a.m. - 12:00 p.m. Neuroanatomical perspectives on bilingualism and aging

Jubin Abutalebi, M.D., *University Vita Salute San Raffaele, Milan, Italy*

12:00 p.m. - 12:30 p.m. Break

12:30 p.m. - 1:00 p.m. Bilingualism, reserve and resilience across dementia subtypes

Suvarna Alladi, M.D., *National Institute of Mental Health and Neurosciences, Bangalore, India*

1:00 p.m. - 1:30 p.m. Bilingualism as a precursor for a cognitive reserve: What are the required premises?

Esti Blanco-Elorrieta, Ph.D., *Harvard University, Cambridge, Massachusetts, USA*

1:30 pm - 2:00 p.m. Discussion of Session 3, Moderated by Molly Wagster, Ph.D.

2:00 p.m. - 2:15 p.m. Break

2:15 p.m. - 3:00 p.m. Final Discussion: Gaps and Opportunities, Moderated by Matt Sutterer, Ph.D.

3:00 p.m. Meeting Adjourns, Jon King, Ph.D.

Appendix B: Presenters and NIA Staff*

Presenters

Jubin Abutalebi, MD
University Vita Salute San Raffaele

Suvarna Alladi, MD
National Institute of Mental Health and
Neurosciences

Thomas H. Bak, MD
University of Edinburgh

Ellen Bialystok, PhD
York University

Esti Blanco-Elorrieta, PhD
Harvard University

Karen Emmorey, PhD
San Diego State University

Tamara Gollan, PhD
University of California, San Diego

John G. Grundy, PhD
Iowa State University

Arturo E. Hernandez, PhD
University of Houston

Erica Hoff, PhD
Florida Atlantic University

Judith Kroll, PhD
University of California, Irvine

Dan Mungas, PhD
University of California, Davis

Kenneth Paap, PhD
San Francisco State University

Christos Pliatsikas, PhD
University of Reading

Miguel Arce Rentería, PhD
Columbia University

Boon Lead Tee, MD
University of California, San Francisco

NIA Staff

Richard Hodes, MD
Director of NIA

Eliezer Masliah, MD
Division of Neuroscience

Lis Nielsen, PhD
Division of Behavioral and Social Research

Jonathan King, PhD
Division of Behavioral and Social Research

Dana Plude, PhD
Division of Behavioral and Social Research

Matt Sutterer, PhD
Division of Neuroscience

Molly Wagster, PhD
Division of Neuroscience

Dave Frankowski, PhD
Division of Neuroscience

*This virtual workshop was broadcast online with over 500 live participants and over 900 views.