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Rethinking multilingual experience through a Systems Framework of Bilingualism

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Abstract

In "The Devil's Dictionary", Bierce (1911) defined language as "The music with which we charm the serpents guarding another's treasure." This satirical definition reflects a core truth – humans communicate using language to accomplish social goals. In this Keynote, we urge cognitive scientists and neuroscientists to more fully embrace sociolinguistic and sociocultural experiences as part of their theoretical and empirical purview. To this end, we review theoretical antecedents of such approaches, and offer a new framework – the *Systems Framework of Bilingualism* – that we hope will be useful in this regard. We conclude with new questions to nudge our discipline towards a more nuanced, inclusive, and socially-informed scientific understanding of multilingual experience. We hope to engage a wide array of researchers united under the broad umbrella of multilingualism (e.g., researchers in neurocognition, sociolinguistics, and applied scientists).

"LANGUAGE, n. The music with which we
charm the serpents guarding another's treasure."
(Bierce, 1911)

"Language can be viewed as a new machine
created out of various cognitive and social components
that evolved initially in the service of completely different functions"
(Bates et al., 1979)

"It is probably true that no language group
has ever existed in isolation from other language groups,
and the history of language is replete with examples
of language contact leading to some form of bilingualism."
(Grosjean, 1982)

Introduction

We open this Keynote with three quotes that circumnavigate a single idea -- humans communicate using multiple languages to accomplish sociocultural goals. Whether we converse in person or through text messages, read a book silently to extract meaning or divine an author's intent, encounter multiple languages in the physical landscape of our neighborhood, chant thunderous calls to action in the streets, or use sign language or augmented communication to engage with friends and neighbors, we are expressing a social capacity for language whose current degree of sophistication is uniquely human.

Thus, as satirically asserted by Bierce (1911), language enables us to achieve social goals involving other people, situated in an embodied and physical world. Further, as provocatively theorized by Bates and colleagues for that time, our human language capacity evolved adaptively, over evolutionary time, repurposing earlier evolved component neurocognitive machinery for social and cognitive functions. Finally, as astutely noted by Grosjean (1982), the functional, neurocognitive, and social consequences of multilingualism derive from historical sources of human contact across the globe (colonization, migration, and globalization), language change, and the global pervasiveness of bilingualism or multilingualism (used interchangeably here to indicate knowledge of more than one language).

Socially- and culturally-bound multilingual classifications speak directly and personally to the authors of this Keynote. At different times, each of us were raised in a nation where English dominance is unassailable (so much that designating English as an official language is unnecessary). Here, one of us experienced directly what was perceived as an unforgiving hand of English dominance and cultural assimilation, through which much of a first language tied to family was lost (see López-Beltrán & Carlson, 2020, for more on the multifaceted nature of heritage languages). Then, at different times, each of us migrated northward to an

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officially bilingual nation, in an officially monolingual Province, where the mission of an official language ministry is to defend against an English tsunami that would otherwise overwhelm the vitality of French (for recent reviews regarding Quebec, see Kircher, 2009; Leimgruber, 2020). A defensive stance against English is understandable, but the manner in which policies do so is routinely controversial, particularly in Montréal e.g., the "Pastagate" incident (Chappell, 2013); the "Mandy's Salades" incident (Huffington Post, 2014); the renewed call to tighten French language laws (Bruemmer, 2021). Meanwhile, hundreds of Indigenous languages that pre-dated linguistic legislation within Québec and Canada are rarely part of the public conversation (Cárdenas, de la Sablonnière & Taylor, 2017; Kilpatrick, 2021).

Contrasting with these social realities, mainstream psycholinguistics' attention is usually directed within individuals, in terms of language representations or processes, and domain-general cognitive capacities that intersect with language. In our field, language-specific neurocognitive capacities (e.g., Fedorenko & Blank, 2020), have been described historically as processing "modules". However, "modules are not born, they are made" (Bates, Bretherton & Snyder, 1991, p. 284). Consequently, people's goals, motivations, and memory representations arise from interpersonal and social dynamics we passively experience and actively create, which iteratively sculpt our individual minds and brains (reviewed in Baum & Titone, 2014; Titone, Gullifer, Subramaniapillai, Rajah & Baum, 2017).

The importance of social experience is recognized by many linguistic sectors – however, it is less apparent within the study of adult psycholinguistics and the cognitive neuroscience of multilingualism. Thus, we capitalize on the unique opportunity afforded by this Keynote to encourage our discipline to "rethink experience" (inspired by Elman, Bates & Johnson, 1996, who famously suggested we "rethink innateness"). Our primary goal is a "call to action" for psycholinguists to more fully embrace sociolinguistic and sociocultural experiences as part of their theoretical and empirical purview (see López, Luque & Piña-Watson, 2021 for a kindred "call to action"; and a highly successful Theme session at the International Symposium on Bilingualism that included leading bilingualism scholars, Bak & Paradowski, 2021). In what follows, we first review several theoretical antecedents of this new approach. We then describe a framework we are developing – the *Systems Framework of Bilingualism,* and describe empirical challenges and potential solutions with applying this framework. Finally, we conclude with new questions we hope will nudge our discipline towards a more nuanced, inclusive, and socially-informed scientific understanding of multilingual experience.

Historical antecedents

A social view of language and multilingualism is not new in human history. Ambrose Bierce started drafting definitions for the "Devil's Dictionary[1]" in 1881, and was pre-dated by legions of satirists, philosophers, semioticians, rhetoricians, and many others. Nor is it new within the language sciences (e.g., the subfields of linguistic anthropology, language evolution, sociolinguistics, pragmatics, language planning, education, and more; for engaging reviews, see Edwards, 2012a, 2012b; García & Wei, 2014; Grosjean, 1982; Steffensen & Fill, 2014). However, a countervailing force from both linguistic and psycholinguistic traditions collectively biases us to abstract away from (or ignore altogether) the admittedly noisy and hard-to-measure sociocultural reality of the linguistic code, and how humans wield this code in the service of everyday sociocultural needs. This bias likely arose from historical factors operative during the emergence of psycholinguistics that emphasized methodological rigour with a high degree of quantitative precision and may have been driven by a touch of behaviorism-envy (recounted in Gardner, 1987; Harris, 1995). It is baked into operational definitions of language that prioritize its symbolic and referential properties, and how humans encode and decode these properties (e.g., the so-called "message model", reviewed in Bavelas & Chovil, 2000).

A socially infused view of language and multilingualism has long been essential within certain subdomains of linguistics (e.g., linguistic anthropology, the study of endangered languages and linguistic revitalization, sociolinguistics; e.g., Bybee, 2010; Cacoullos & Travis, 2018; Labov, 2011), and has been necessary for applied work on first and second language learning in both children and adults, as forecasted almost three decades ago (Bates & Carnevale, 1993), likely due to the need of these disciplines to enhance people's actual learning and use of a first or second language in everyday life. Thus, leading theories of individual language learning characterize the uniqueness of human language as a joint product of an exquisitely tuned, and neurocognitively-driven statistical learning capacity (i.e., the emergentist, usage-based view), alongside an exquisitely tuned and neurocognitively-driven social motivation to "mentalize" (e.g., a theory of mind capacity; Astington & Baird, 2005; Beatty-Martínez & Dussias, 2018; Bybee, 2010; Ellis & Larsen-Freeman, 2009; Hernandez, Claussenius-Kalman, Ronderos, Castilla-Earls, Sun, Weiss & Young, 2019; Ibbotson, 2013; López-Beltrán & Carlson, 2020; Tomasello, 2000; Wulff, 2008). Importantly, the impact of emergentist, usage-based theories is now felt in studies of adult language processing (novel language learning studies reviewed in Palma & Titone, 2021), where a starting assumption is that novel language learning progresses over the lifespan (Atkinson, Byrnes, Doran, Duff, Ellis, Hall, Johnson, Lantolf, Larsen–Freeman, Negueruela, Norton, Ortega, Schumann, Swain & Tarone, 2016), in a manner that can be modulated by social aspects of the learning context (e.g., Raviv, Meyer & Lev-Ari, 2020). Similarly, comprehensive but perhaps lesser-known frameworks (described below) explicitly conceive of people as nested within a hierarchy of social contexts that mutually constrain each other (e.g., Atkinson et al., 2016; Bronfenbrenner, 1977, 1979; de Bot, Lowie & Verspoor, 2007). Collectively, these approaches inspire new ways of defining language, such as the following formulation we find appealing.

"…the term *language* refers to:

(i) the means by which one individual more or less reliably orients another's thoughts and actions;
(ii) a culturally determined set of acoustic, gestural, and/or written signals;
(iii) the trans-generational stability of these signals, and
(iv) the functioning of these signals in an environment with artifacts and practices that support the ways the individuals living in that environment are oriented by the language(s) they speak." (Andresen & Carter, 2016, p. 9)

It is instructive to examine different historical antecedents of socially infused conceptions of language. One pertains to long-

[1]"DICTIONARY, n. A malevolent literary device for cramping the growth of a language and making it hard and inelastic. This dictionary, however, is a most useful work." (Bierce, 1911)

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standing discussions in linguistics about how to best classify and compare languages around the globe (reviewed in Edwards, 2012a, 2012b). The very idea of what constitutes a language is inherently fuzzy, even assuming a highly constrained view of language as a mere symbolic system (e.g., "a culturally determined set of acoustic, gestural, and/or written signals"). Thus, the task of identifying a clear boundary where one language starts and another begins, often with intervening dialects that have shifting and asymmetric patterns of mutually intelligibility (Andresen & Carter, 2016), is notoriously difficult precisely because such determinations are inherently culture-bound (e.g., "A language is a dialect with an army and navy", attributed to a Bronx high school teacher who attended a 1945 lecture by Yiddish linguist; Weinreich, 1945).

The situation becomes increasingly complex when one considers the limitless variety of historical forces leading to multilingualism in communities around the globe, and the ensuing dynamic way that language symbols evolve over time (e.g., "flatten the curve" has taken on semantic nuance it never had before COVID-19). This minimally involves geographically disparate groups of people (communicating using culturally distinct acoustic, gestural, and/or written signals, Andresen & Carter, 2016) coming in contact to accomplish mutual (e.g., commerce) or one-sided (e.g., colonization) social goals (Wei, 2011). While many forces cause people to form groups, Edwards (2012a, p. 37) notes "the most insistent and the most salient contexts are those involving societies of unequal power and dominance". Indeed, all of us currently live this reality in one form or another, either as members of a privileged linguistic majority (usually English-speaking but not always), as members of Indigenous, immigrant, and racialized linguistic minorities, or as some combination of all of the above. It is no coincidence that one of the most commonly used tools of societal-level human control is regulating the languages that people (particularly children) use both inside and outside the home (particularly in schools), across time and place, even within fictional worlds (e.g., "Newspeak"; Orwell, 1984).

Thus, crucial to any classification of world languages, and consequently the experiences of people who speak and comprehend them, are sociocultural forces acting upon individual people when they choose or are compelled, utterance by utterance, to speak one or another language in daily life. Edwards (2012a) outlines no fewer than ten categories of language contact positioned around three distinct axes of variability: first, whether Indigenous, immigrant, or racialized linguistic minorities are only found within a particular region; second, how tightly organized they are within that region, and third, how physically separate they are from the linguistic majority (see also de Bot, 2019; Raviv et al., 2020; Wei, 2011). Accordingly, while the sociolinguistic forces leading to multilingualism in Canada (officially English–French) may bear some similarity to those operative in another officially English–French nation (e.g., Cameroon), there also exist crucial differences that can predict how people produce and comprehend multiple languages in these regions (see Grosjean & Li, 2013; Grosjean, 1982 for prescient attention to such details). This may include how motivated people are to activate or suppress one or another language within different social settings, particularly with respect to regulating the L1 (Bjork & Kroll, 2015; Bogulski, Bice & Kroll, 2019; Kroll, Dussias, Bice & Perrotti, 2015; Pulido, 2021; Zirnstein, van Hell & Kroll, 2018; Zirnstein, Bice & Kroll, 2019) alongside a host of additional sociopolitical factors.

In sum, around the globe, issues surrounding language and multilingual use are at the heart of justifiable concerns about ethnolinguistic vitality and language endangerment in communities where majority, minority, and Indigenous languages collide (e.g., Giles, Taylor & Bourhis, 1973; Heller, 1978; Sioufi & Bourhis, 2017). They have a palpable, everyday psychological reality that exerts its collective effects one person, family, and salad or pasta shop at a time (see Doucerain, 2019, for a recent study of language-driven acculturative stress in Montréal). On occasion, they trigger social revolutions both "quiet" and loud (Kircher, 2009; Leimgruber, 2020).

Socially-infused ecological approaches

While a careful reader may be persuaded that social and cultural factors are crucial for multilingual processing at an individual, neurocognitive level, they may also be uncertain about how to account for so many mutually constraining layers of language use in real time. On this point, another key historical antecedent of a socially infused view of language derives from a tradition collectively referred to as linguistic ecology, language ecology, or ecolinguistics (reviewed in Atkinson et al., 2016; de Bot et al., 2007; Edwards, 2012a, 2012b; Steffensen & Fill, 2014; Wei, 2011).

Haugen (1972) was among the first to refer to the "ecology of language", highlighting the ways in which language use for individual people aligned with the ecology of language use within the larger social context. Echoes of this approach are evident in now classic works within multilingualism (e.g., Grosjean, 1982, in which Haugen is featured prominently and acknowledged as a mentor). They are also evident in a recent characterization of bilingual behavioral variability (Green, 2011), that underlies core assumptions of the influential Adaptive Control Hypothesis (Green & Abutalebi, 2013)

As described by both Edwards (2012a) and Steffensen and Fill (2014), a strength of Haugen's approach was its focus on attributes of the broader ecological niches occupied by languages and the people who speak them (i.e., "the study of interactions between any given language and its environment", Haugen, 1972, p. 225). Thus, while the focus was not on history per se, it was on the linguistic and psychological consequences of historical forces, including matters of language status (i.e., the social power assigned to speakers of particular languages), and intimacy (i.e., the solidarity, friendship, and bonding with other people afforded to speakers of particular languages). The psychological aspect of Haugen's approach is evident in the following quote highlighted by Steffensen and Fill (2014).

"Part of [a language's] ecology is therefore psychological: its interaction with other languages in the minds of bi- and multilingual speakers. Another part of its ecology is sociological: its interaction with the society in which it functions as a medium of communication. The ecology of a language is determined primarily by the people who learn it, use it, and transmit it to others." (Haugen, 2001, pg. 57).

Moreover, as Edwards (2012a) observed, this approach is similar in spirit to that of other theorists at the time, including Wallace Lambert from our own department at McGill (e.g., Peal & Lambert, 1962) whose focus on language attitudes and status led to one of the first empirical demonstrations of positive bilingualism impacts on general cognitive abilities, and perhaps one of the first papers to seriously consider the social context of bilingualism. Rather than piling onto the then scholarly assertion that bilingualism was a social liability, Peal and Lambert showed

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that bilingual children in Québec (where bilingualism was socially valued when the research was conducted) performed BETTER than monolingual children on a battery of verbal and non-verbal IQ tests, language proficiency and language attitude tests (that controlled for the methodological confounds of prior work such as socioeconomic status, quality of schooling, etc.) Peal and Lambert were thus among the first to promote the idea that bilingual experience is an opportunity rather than a liability in terms of mental flexibility (for an overview of Lambert's research contributions, see Reynolds, 2014). This emphasis on social nuance was later championed by others who worked and/or trained with Lambert at McGill (e.g., Cárdenas et al., 2017; Genesee & Lindholm-Leary, 2020; Huang & Nicoladis, 2020; Vaid & Meuter, 2017), and of course was the seed for modern conjectures about the positive cognitive consequences on bilingualism across the lifespan (reviewed in Bialystok, 2021).

Nevertheless, the ecolinguistic approaches described thus far were somewhat vague in specifying what constitutes a language ecology or environment, and particularly how to systematically and precisely quantify such differences (a point to which we return below). Steffensen and Fill (2014) partially address this issue by identifying several ways the environment of a language had been conceived of within ecolinguistic traditions, for which numbers 1, 3, and 4 (bolded below) are likely most relevant to psycholinguistic and cognitive neuroscience approaches to multilingualism:

"[1] **Language exists in a symbolic ecology: this approach investigates the co-existence of languages or 'symbol systems' within a given area.**
[2] Language exists in a natural ecology: this approach investigates how language relates to the biological and ecosystemic surroundings (topography, climate, fauna, flora, etc.).
[3] **Language exists in a sociocultural ecology: this approach investigates how language relates to the social and cultural forces that shape the conditions of speakers and speech communities.**
[4] **Language exists in a cognitive ecology: this approach investigates how language is enabled by the dynamics between biological organisms and their environment, focusing on those cognitive capacities that give rise to organisms' flexible, adaptive behaviour." (Steffensen & Fill, 2014, p. 7)**

Thus, in the same way that the vision scientist Marr (1982) famously articulated three interdependent levels of analysis for complex cognitive systems (i.e., computational, algorithmic, implementational), an ecolinguistic approach makes it possible to specify several simultaneously operative, interdependent levels for considering how languages (and thus language users) interact with (and are impacted by) their symbolic, sociocultural, and cognitive ecologies. Accordingly, language ecology researchers such as Haugen, his contemporaries, and his intellectual beneficiaries (e.g., Grosjean, 1982; and the history-enamored authors of this Keynote), have made it possible to consider developing unified models of language that might help guide a socially infused approach to thinking about individual multilingual processing.

Perhaps most noteworthy for our purposes is work by the developmental psychologist, Bronfrenbrenner, who wrote extensively about the ecology of human behavior in the context of development (reviewed in Shelton, 2018). Bronfenbrenner (1977, p. 513) lamented on behalf of developmental psychology that: "To corrupt a contemporary metaphor, we risk being caught between a rock and a *soft* place. The rock is *rigor*, and the soft place *relevance*." To remedy this situation, he developed a comprehensive socioecological framework to reject the "implied dichotomy between rigour and relevance" (Bronfenbrenner, 1977, p. 514; Bronfenbrenner, 1979). This framework was comprised of systematically nested spheres of social influence, in which individual children were embedded. These spheres were argued to reflect the reciprocal, iterative interactions between individual and their local environmental settings (e.g., school, work, family), referred to as the MICROSYSTEM; the totality of their distinct settings or microsystems, referred to as the MESOSYSTEM; the indirect, external social forces impacting their micro- and mesosystems (e.g., neighborhood dynamics, mass media, etc), referred to as the EXOSYSTEM; and finally, the overarching cultural/historical/societal context from which all their lower level systems are derived (i.e., their blueprints), referred to as the MACROSYSTEM. From this, Bronfenbrenner pursued different nuanced notions of ECOLOGICAL VALIDITY – for example, asking researchers to question the degree to which the actual social contexts of their experiments lawfully interacted with psychological phenomena of interest. To Bronfenbrenner, the "main effects" of any psychological experiment should actually be "interactions" of how different phenomena vary within individuals, or across matched individuals, as a function of social context.

Bronfenbrenner's work subsequently inspired many other research domains, including language. Highly relevant in this regard is The Douglas Fir Group (Atkinson et al., 2016), a pseudonymed group of transdisciplinary language researchers, who developed a linguistically specified ecological framework targeted to second language acquisition. Similar to Bronfrenbrenner, The Douglas Fir Group argued that to truly understand second language acquisition in a manner that would be sufficient to advance effective methods of learning and instruction, it would be necessary to think beyond capacities of individual learners to the many other ways in which learning environments also contributed to successful individual learning outcomes. Thus, they too developed a framework consisting of highly nested levels, where the individual and their neurocognitive capacities were at the center, followed by local interactions with other people across different languages (i.e., the MICROLEVEL OF SOCIAL ACTIVITY), then higher level that bridged individual interactions as in the case of neighborhoods, families, places of work (i.e., the MESOLEVEL OF SOCIOCULTURAL INSTITUTIONS AND COMMUNITIES), and then the highest social level of cultural and political values (i.e., the MACROLEVEL OF IDEOLOGICAL STRUCTURES).

Similar in spirit, but derived instead from complexity and dynamical systems theory, was de Bot et al. (2007) who, in their *Bilingualism: Language and Cognition* Keynote, asserted that second language acquisition consisted of a series of nested dynamical systems, where each system varies in granularity, but all operate according to the same dynamic principles. Within this view, language is less a fax-machine-like message transmitter, and more a dance between people communicating with each other, where each interactional dance partner creates perturbations that lead to emergent properties that exceed the sum of each individual's solo contribution. Filipović and Hawkins (2019) also posits an integrative dynamical systems view, according to which second language performance is jointly determined by internal factors, such as AoA and proficiency (among others) and external factors.

To conclude this section, several socioecological approaches have been discussed over the years, culminating in frameworks

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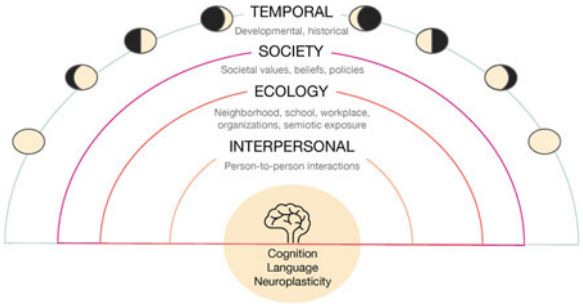


Fig. 1. A Systems Framework of Bilingualism (Figure taken from Tiv et al., in press), in which interdependent layers of sociolinguistic context iteratively and reciprocally impact the individual or ego. These layers include interpersonal, ecological and societal spheres of influence. Finally, developmental or historical time can exert subtle temporal influences on the system, in a manner that constrains cognition, behavior, and neuroplasticity.

that systematically detail the social spheres that are relevant to individual language use. This leads us to the next section that details how our group has capitalized upon these traditions to develop a *Systems Framework of Bilingualism*, with which we bridge psycholinguistic or neurocognitive individual functions via socioecological forces.

A Systems Framework of Bilingualism

We present here a comprehensive socially-situated *Systems Framework of Bilingualism* to guide our understanding of the complex sources of sociolinguistic context that influence people's language use, development, and cognition (Tiv, Kutlu, O'Regan & Titone, 2021; Tiv, Kutlu, Gullifer, Feng, Doucerain & Titone, in press). This framework blends language-relevant elements of Bronfenbrenner's social-ecological model of human development (Bronfenbrenner, 1979), other ecolinguistic traditions (Finke, 2001; Grosjean, 1982; Labov, 1972; Steffensen & Fill, 2014; Van Lier, 2002), and theoretical efforts in language acquisition (Atkinson et al., 2016; de Bot et al., 2007; Leon Guerrero & Luk, 2021). One goal of this approach was to underscore the broad implications of social context to ALL ASPECTS OF PSYCHOLINGUISTIC BEHAVIOR, COGNITION, AND NEUROPLASTICITY, thus transcending domain-specific frameworks, such as second language acquisition. We also wished to explicitly consider the ways that interpersonal, ecological, societal, as well as historical or developmental constraints can jointly impact individual bilingual behavior.

Similar to past approaches, an individual person (referred to as an EGO in the network science literature) within a Systems Framework of Bilingualism (depicted in Figure 1) exists in a nested hierarchical system of interdependent spheres of social influence. Interpersonal language dynamics is the first sphere of influence, which involves person-to-person interactions (akin to Bronfenbrenner's MICROSYSTEM, or the Douglas Fir Group's MICROLEVEL). Ecological language dynamics is that second sphere of influence, which involves relatively local social contexts in which people communicate with other people (e.g., their residential neighborhood, their school or workplace, and any other ambient exposure to language such as what may be found within the linguistic landscape; akin to Bronfenbrenner's MESOSYSTEM, or The Douglas Fir Group's MESOLEVEL). Societal language dynamics is the third sphere of influence, which involves higher-order characteristics of the society (akin to Bronfenbrenner's EXOSYSTEM AND MACROSYSTEM, or The Douglas Fir Group's MACROLEVEL). This could include language attitudes, beliefs, status, and policy. Finally, at the outer limits, depicted by phases of the moon, is how the temporal dynamics of the system changes over developmental time, or in a manner shaped by historical context.

Thus, within this framework, a given person sits at the base of a complex system that, crucially, uniquely varies given the particular configuration of languages that they know, and how they use those languages in daily life. For example, at the level of Interpersonal Dynamics, we can track how a bilingual person may use one language with their parents or guardians and another language with their siblings. Additionally, we can track whether the ego critically bridges different language groups (Tiv et al., 2021; Tiv, Kutlu, O'Regan & Titone, in press). In past work (Tiv et al., 2021, in press), described below, we quantified these dynamics with social network attributes from the language(s) used in person-to-person interactions. As another example at the level of Ecological Dynamics, a bilingual person may live in a linguistically homogenous neighborhood, where one primary language is overheard in public spaces, such as groceries stores, restaurants, parks, and more, which in turn constrains their opportunities to engage with their other known languages. As a final example at the level of Societal Dynamics, while the Canadian federal government recognizes both English and French as official languages, the only official language in the province of Québec is French, where the majority of French speakers in Canada reside (~94% in 2017, Statistics Canada, 2016). Yet, Montréal is a linguistically diverse city where bilingualism may be viewed more favorably than, say, more rural regions in Québec.

A *Systems Framework of Bilingualism* has the exciting potential to create new socially infused questions about language and multilingualism to guide psycholinguistic and cognitive neuroscience research. However, there are a variety of practical challenges, which include but are not limited to measuring sociolinguistic experiences of an interpersonal nature (i.e., INTERPERSONAL LANGUAGE DYNAMICS), and measuring sociolinguistic experiences at an ecological or societal level (i.e., ECOLOGICAL AND SOCIETAL LANGUAGE DYNAMICS). We must also account for people's individual attributes (ego-driven language dynamics) that further constrain their neurocognition. In what follows, we briefly describe each set of challenges, starting with ego-driven individual differences, along with potential emerging quantitative solutions where applicable.

1 Ego-driven language dynamics (i.e., the experiences of individuals).

One challenge of applying a *Systems Framework of Bilingualism* is to accurately assess, and ideally quantify, the sociocultural and psycholinguistic experiences of individual people. While the easier part of this challenge has always been to gather data, the thornier part is what exactly to do with those data after they are gathered.

With respect to data gathering, particularly about individual people, there are several well-regarded language history questionnaires in bilingualism research that have collected data of sociocultural relevance, across multiple languages. These notably include Marian's LEAP-Q (Marian & Hayakawa, 2021) and the multiple iterations of Ping Li's LHQ 3.0 (e.g., Li, Zhang, Yu & Zhao, 2020). Also noteworthy is Paradis' Bilingual Aphasia Test (Paradis, 2011), which has been systematically translated to be functionally equivalent across numerous languages globally. Indeed, the effort expended to ensure accurate, valid, and

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functional translations of the Bilingual Aphasia Test speaks to the inherent challenges of assuming that the same language assessment questionnaire will comparably assess language experience in equally valid ways (for a newer take, see Flake, Shaw & Luong, 2021).

Importantly, established questionnaires have been joined by newer efforts that more intensively assess sociocultural differences among people. These include Anderson et al.'s "Language and Social Background Questionnaire" (LSBQ, Anderson, Mak, Chahi & Bialystok, 2018), or Wigdorowitz et al.'s "Contextual and Individual Linguistic Diversity Questionnaire" (CILD-Q) (Wigdorowitz, Pérez & Tsimpli, 2020). Specifically, the LSBQ encompasses community language practices, such as language use across life stages, distinct communicative contexts, and with unique interlocuters. This questionnaire also assesses language use across a broad set of everyday activities and can be used to paint a colorful landscape of a respondents' real-world language behavior. The CILD-Q was developed for testing in South Africa, and it is malleable to fit any region with English as the reference language. This questionnaire consists of items pertaining to "multilingualism in context", "multilingualism in practice" and "language diversity promotion." Interestingly, recent initiatives have emerged to make these and other survey tools more accessible and adoptable across a wide set of bilingualism researchers. For example, Luk and Esposito (2020) published a mini-series in *Bilingualism: Language and Cognition*, where they collected five contributions from bilingualism researchers at the forefront of developing socially-contextualized language surveys. Some advances in assessing the language background of individual people now extend to social media (Zhuravleva, de Bot & Hilton, 2016).

Thus, many excellent tools are available to assess people's individual, ego-driven sociolinguistic experiences, which could be tailored to more accurately represent diverse bilingual experiences and contexts globally. However, if our group is any indication, we conjecture that while many labs use such instruments wholesale, they may typically focus on one or more "bread and butter" measures that are most frequently reported in the literature (i.e., L2 age of acquisition, L2 usage, L2 proficiency, etc.).[2] There are many reasons for this approach, which include keeping one's statistical models as simple as possible, the highly intercorrelated and often unbalanced nature of measures within and across particular participant samples, and finally, because researchers may simply not be interested in the full range of items on many standardized language background questionnaires in a given study.

Nevertheless, many researchers have ventured beyond the relative safety of L2 age of acquisition, L2 usage, and L2 proficiency to explore more socioculturally relevant attributes. Here, the question then becomes how to systematically analyze all these multifactorial data points to statistically bridge the different levels of analysis required of the *Systems Framework of Bilingualism*. Indeed, many questionnaires that people use include categorical response options that make it difficult to translate questionnaire data into fixed effect continuous predictors within any LME linear mixed-effects (or multilevel) model, which could be statistically desirable (MacCallum, Zhang, Preacher & Rucker, 2002). Another question concerns how to optimally quantify and reduce sociocultural experiences into quantifiable continuous measures to be used alongside the others, as needed.

In one potential emerging solution for these challenges, Gullifer and Titone (2019) developed the measurement approach of LANGUAGE ENTROPY to capture within-person individual differences with respect to the balance of language use generally, but also across varied social contexts (see also, Gullifer, Chai, Whitford, Pivneva, Baum, Klein & Titone, 2018; Gullifer & Titone, 2018, 2021a). This approach, based on Shannon's Entropy in Information Theory, reflects the linguistic composition, or overall balance of language use, across multiple communicative contexts. Generally, low entropy scores (i.e., near zero) are indicative of high certainty (or low diversity) of some outcome, whereas high entropy scores (i.e., near one) are indicative of low certainty (or high diversity) of some outcome. In the context of language, outcome is operationalized as the expected language choice between the speaker and the people in their environment. Thus, a bilingual who consistently uses a single language would have low entropy, and their interactions should predictably occur in that language. In contrast, a bilingual who regularly uses their two languages in a balanced manner would have high entropy, and the language of their interactions should be less predictable.

Across several papers, Gullifer and colleagues tested whether language entropy successfully predicts different aspects of bilingual language function, and whether it predicts different aspects of general cognition (e.g., proactive or reactive executive control). For example, Gullifer and Titone (2018) tested language entropy in a resting state functional connectivity study of bilinguals. Specifically, we examined the impact of language entropy in predicting self-perceptions of L2 accentedness and L2 general abilities for a large sample of younger bilinguals/multilinguals (N = 507) in Montréal. Crucially, language entropy, which reflects the social diversity of language use, significantly predicted these outcome measures over and above the impact of our old friends, L2 age of acquisition and L2 usage (see also Gullifer & Titone, 2021b, for a similar approach with a different sample that expands the concept of language entropy to different communicative domains and social contexts).

Gullifer and colleagues then linked the concept of language entropy to cognitive measures outside the domain of language – specifically, proactive and reactive executive control. Gullifer et al. (2018) showed that language entropy predicted the functional connectivity within the resting brains of younger adults, specifically among networks implicated in goal maintenance and articulation. They further found that this connectivity was

[2]On this point, another Keynote could be written describing the pros and cons of such commonly used measures, and how they may compare to "objective" measures that assess real-time language function for particular modes of language function, for specific languages that the participants in a study may know (see critiques by Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012; Surrain & Luk, 2019; Tomoschuk & Lovelett, 2018). Subjective measures are routinely questioned for any number of reasons that include the degree to which we have accurate access to their experiences (e.g., can we actually recall the age they started acquiring literacy in a language?), the degree to which we endorse experiences that may be seen as socially desirable (e.g., "No, I never codeswitch"), and the degree to which our self-evaluations may be tainted by the default group with whom we socially compare ourselves (e.g., a bilingual person residing in a monolingual environment may see themselves as an Olympics-gold-medalist regarding their linguistic abilities, whereas if that same person resided in a highly multilingual environment, they may see themselves as barely good enough for the Olympic team). While some researchers may be more trusting of "objective" measures for these reasons, they too have downsides in that they may only probe very circumscribed aspects of language function (e.g., vocabulary knowledge) in a manner that may not generalize to other aspects of language function (e.g., speed of picture naming, reading, pragmatic competence), or that may have poor test-retest reliability or other issues or methodological standardization across labs. Additionally, in some contexts, individuals' self-perceptions of language experience may be more relevant in shaping their real-world language behavior (e.g., someone with low "objective" proficiency in a language who is confident in their abilities may engage with that language more than someone with high "objective" proficiency in the same language who is not confident in their abilities).

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in turn related to a form of cognitive control that relies on goal maintenance, proactive control (as measured using the AX-CPT). With respect to behavioral data, Gullifer and Titone (2021b) showed that language entropy may have contributed statistical signal as a predictor of proactive control (as measured using the AX-CPT) in a younger bilingual sample. Finally, (Gullifer, Pivneva, Whitford, Sheikh & Titone, under review) showed, again among younger adults, that the degree to which people mix their languages across social settings (using an alternative measure highly correlated with language entropy) significantly predicted reactive control for a language-based task (i.e., number Stroop) but not for a nonlinguistic reactive control task (i.e., Simon task).

This body of work (reviewed in Gullifer & Titone, 2021a) suggests that socially relevant aspects of how bilinguals distribute use of their languages, when successfully quantified by language entropy, can make it less challenging to pose and address questions of a sociocultural nature in a manner that is directly relevant to leading theoretical accounts of bilingualism (e.g., the Adaptive Control Hypothesis, Green & Abutalebi, 2013; see also, Beatty-Martínez and Titone, 2021, for an account of individual variability framed in terms of behavioral phenotypes). We are encouraged by the inclusion of language entropy in one of the most commonly used, freely available language history questionnaires (Li, Zhang, Tsai & Puls, 2014; Li et al., 2020) and that other groups are now starting to adopt this measure (Sulpizio, Del Maschio, Del Mauro, Fedeli & Abutalebi, 2020).

Thus, many ways now exist to gather and quantitatively characterize socially relevant information about within-person bilingual language experience. Nevertheless, the kinds of measures in standard background questionnaires tend to only indirectly approximate how people use language socially. Thus, we now turn to the social language experiences people have when they engage interpersonal interactions. This is referred to within the *Systems Framework of Bilingualism* as *Interpersonal Language Dynamics*.

2. Interpersonal language dynamics (i.e., the experiences of people interacting with other people).

The interpersonal nature of multilingual communication has long been of interest from a social perspective, and has historically appeared along the fringes of psycholinguistics. One example is the field of figurative language (as well as many other facets of pragmatic language), which could include a broad swath of linguistic devices that people use to convey highly contextualized meanings that hinge explicitly on the particular people with whom we communicate within particular situations (e.g., irony, sarcasm, metaphor, hyperbole, formulaic language, sense creation, humor, etc.) (reviewed in a special issue on Albert Katz's contributions to non-literal language, co-edited by Buchanan, Pexman & Titone, 2021). Other efforts within psycholinguistics also now examine the interactions between two individuals through language. Examples include the study of conversational interaction and dyadic turn-taking (Beatty-Martínez, Valdés Kroff & Dussias, 2018; Fricke & Kootstra, 2016; Kootstra, van Hell & Dijkstra, 2010; Kootstra, Dijkstra & van Hell, 2020; Van Berkum, van den Brink, Tesink, Kos & Hagoort, 2008), the interactive alignment of conceptual representations across people (Garrod & Pickering, 2009), and more recently, the manner in which language learning is filtered through others (Kaan, Kheder, Kreidler, Tomić & Valdés Kroff, 2020; Raviv et al., 2020). Also noteworthy is innovative work using social robotics, where research participants perform psycholinguistic experiments while engaged with a human-like social robot (Saryazdi, Nuque & Chambers, 2019). Thus, many seeds have already been planted with respect to the empirical study of *Interpersonal Language Dynamics* that could be further extended and used to empirically test a *Systems Framework of Bilingualism*.

Of note, a relatively untapped approach within psycholinguistics pertains to the use of social network analysis and psycholinguistics (for several pioneering examples of this approach within the cognitive sciences, please see Lev-Ari, 2018, 2019; Vitevitch, 2019; as well as Borgatti, Mehra, Brass & Labianca, 2009; for an overview of network analysis in the social sciences). Social network analysis is a popular tool in sociology, and in recent years has flourished across other disciplines, including computer science, physics, and cognitive and developmental psychology (Chen, Justice, Rhoad-Drogalis, Lin & Sawyer, 2020; Vitevitch, 2019). This specialized form of network analysis, whereby a system is represented through nodes (entities) and edges (relationships), centralizes people as nodes in a social system. Relationships or information flow between people (alters) is conveyed through ties, which may transmit additional information such as direction or weight (e.g., who seeks advice from whom, how frequently do they interact, etc.). While a social network approach provides granular insight about the overall composition of the social environment (e.g., racial diversity, intergenerational ties), many consider its real strength to be the unique insight it lends on the STRUCTURE of the social network. This structure is primarily constructed by elucidating third-party relationships between alters. These indirect relationships, such as overall network interconnectedness (density) or bridging capacity (centrality), bidirectionally shape and are constrained by cognition. Depending on the needs and interests of the researcher, social network surveys can be brief or extensive[3].

For example, Lev-Ari published a brief social network survey (Lev-Ari, 2017) that assesses basic, compositional aspects of communication within one's social network, which is publicly available. In one interesting application, Kutlu and colleagues (Kutlu, Tiv, Wulff & Titone, 2021b; see also Kutlu, Tiv, Wulff & Titone, 2022) administered Lev-Ari's social network survey to respondents who also completed an in-lab audio-visual sentence processing task. In this task, participants were shown white or South Asian faces alongside American, British, or Indian English accented auditory recordings of sentences, and they were asked to transcribe and rate the sentences on accentedness. Critically, the authors found that the racial diversity of respondents' social networks moderated the extent to which they produced racially-biased responses in accent perception.

The core concept underlying language-based social network analysis, or the idea that language use systematically varies as a function of with whom one is conversing, has been discussed (outside the domain of social network analysis) for decades. For example, Hoffman (1971) studied context-bound language use by English–Spanish bilingual youth in New York, demonstrating that linguistic practices differed between home and school life. Further, within the home context, language use varied between

[3]Crucially, the network science principles that underlie social network analysis can also be leveraged in other important ways, as beautifully illustrated by a recent neuroimaging study of bilinguals, which used network science to delineate the neural correlates of bilingual language processing (e.g., Fedeli, Del Maschio, Sulpizio, Rothman, & Abutalebi, 2021).

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children and their parents vs. siblings. Grosjean then developed the Complementarity Principle (reviewed in Grosjean, 1982, 2015, p. 68), which states that "Bilinguals usually acquire and use their languages for different purposes, in different domains of life, with different people. Different aspects of life require different languages." This idea, which may seem apparent to many language scientists now, perfectly captures the message we aim to convey in this section: bilingualism is a heterogenous mix of experiences influenced by personal history, sociolinguistic demands, and historical context. As much as no two multilinguals are the same, language use within a multilingual can also systematically vary based on the characteristics, histories, and experiences of their conversational partners.

In more recent work, social network analysis has been applied to the dynamic interplay of how multiple languages are used on Twitter. Kim, Weber, Wei, and Oh (2014) systematically mined Tweets from three multilingual locales: Qatar, Switzerland, and Quebec. Their results shed insight on how bilingual twitter users functioned as critical bridges between monolingual twitter users, as well as how bilingual twitter users distinctly engaged their various languages to tweet about varying discourse topics. Eleta and Golbeck, (2014) also tracked language choice across bilinguals on Twitter, irrespective of region. They found evidence supporting a continuum of network structure types for bilinguals Twitter users, and compositional attributes of these networks (e.g., proportion of L2 users in the network) predicted tweet-based language choice. Their results indicated that bilinguals were aware of the linguistic composition of their online social network, and they harnessed this knowledge to inform their tweeting language choice.

Inspired by these works, our group has begun to use social network analysis in a manner that guided development of *the Systems Framework of Bilingualism*. Specifically, we conducted social network analysis of English and French bilinguals in Montréal who completed an in-person social network survey of their real-world contacts (Tiv et al., 2021; Tiv, Gullifer, Feng & Titone, 2020). Respondents reported the language(s) that they used to converse with each alter, and from these responses the authors constructed three language-tagged subnetworks: English, French, and English-French Bilingual. Results revealed that among the sample, properties of the English subnetwork, including network size, number of components, alter centrality, and more, were greater than those of the French subnetwork. Network properties of the Bilingual subnetwork generally matched those of the English subnetwork, but exceeded those of the French subnetwork. Of interest, the Bilingual subnetwork demonstrated the highest overall network density, indicating that bilingual alters were more likely to be interconnected among themselves than in either of the monolingual language networks. Interestingly, people (i.e., egos) reported feeling closer to their bilingual alters than any of their monolingual alters. Together, these results suggest that bilingualism may function as a salient social identity that cultivates in-group affiliation among other people in one's social network who are similarly bilingual. However, the Bilingual subnetwork was not predictive of people's self-reported language behavior, whereas both monolingual subnetworks were predictive of self-reported language behavior and lexical word knowledge (though English lexical word knowledge was only predicted by the French monolingual subnetwork).

In related work that builds upon Grosjean's earlier explorations of what bilinguals talk about (Grosjean, 1982, 2010, 2015), our group applied network analysis to represent conversational topics among bilinguals living in Montréal (where nodes represented an aspect of language, as opposed to a person) (Tiv et al., 2020). We tested 115 English and French bilingual adults with a questionnaire that probed what languages they used to speak about twenty-one conversational topics (e.g., politics, gossip) across five communicative contexts (e.g., home, school, social). Two language networks and five context networks were constructed, in which nodes represented conversational topics and edges between two nodes indicated that two topics were discussed in the same language (language networks) or in the same context (context networks). The results demonstrated that bilinguals use their dominant language to speak about more topics across a wider variety of contexts. Moreover, all communicative contexts displayed a unique pattern in which conversational topics are discussed, but only a few communicative contexts (work and social) display a unique pattern of how many languages are used to discuss particular topics. Lastly, using community detection to thematically group the topics in each language, we found evidence of greater specificity in the non-dominant language than the dominant language (see Xu, Markowska, Chodorow & Li, 2021 for a similar network representation of words codeswitched between English and Chinese, which predicted the words were more or less likely to be codeswitched). Together, these results underline the notion that bilinguals use their various languages for specific, context-driven social communicative purposes.

Thus, many ways now exist to explore sociocultural and psycholinguistic experiences of an interpersonal nature among bilinguals, referred to within the *Systems Framework of Bilingualism* as *Interpersonal Language Dynamics*. Some of these have roots in earlier research (e.g., figurative language, pragmatics, conversational interaction and alignment). Others are recently developed innovative ways of approaching such questions (e.g., social network analysis, social robotics). However, while directly addressing interpersonal language dynamics represents to us an important leap forward beyond a psycholinguistic tradition that typically focusses within individuals, it still does not fully incorporate ambient contextual influences or the important societal-level effects that may be relevant to, and impact, ego-driven processes and capacities. Thus, we next turn to the final two levels of socio-ecological influence within our *Systems Framework of Bilingualism* – that is, Ecological and Societal Language Dynamics.

3. Ecological and societal language dynamics (i.e., experiences at the neighborhood- and society-level).

Beyond within-person and interpersonal levels of analyses, language behavior is constrained by higher order, ambient linguistic patterns that emerge from the collective practices of individuals in a region or society, described in some detail at the outset of the paper. These dynamics may vary within a society (i.e., ecological language dynamics) or across societies (i.e., societal language dynamics). While no multilingualism researcher would deny this reality, again, the challenge arises from practical issues in assessing and quantifying higher level societal dynamics in a manner that that can be put to clean empirical use.

With respect to the first point, ecological dynamics can be tracked within and across regions using publicly available data, including census demographic statistics (e.g., Statistics Canada). For example, Nagano (2015) explored the geographic distribution and demographic characteristics of adult heritage language

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speakers across the United States based on data from the U.S. Census. Similarly, they found substantial demographic differences in the adult heritage language speakers who resided in distinct regions of the country. Schott, Kremin, and Byers-Heinlein (2019) examined rates of childhood bilingualism in Canada using Canadian census statistics, which revealed interesting patterns of multilingualism, such as higher rates of child multilingualism within Canadian cities and northern regions. Despite the descriptive nature of these two works, they both demonstrate the sociological tools, including public census statistics, which researchers of bilingualism can incorporate in their behavioral research (Surrain & Luk, under review).

Gullifer and Titone (2019) used census data to evaluate language entropy at a societal level as a means of qualitatively conceptualizing individual level data acquired from that location. Specifically, they computed language entropy across different social contexts for Montréal, the Province of Québec, and all of Canada using Statistics Canada census language demographic data (i.e., "mother tongue" "languages used in the home" and "languages used in the workplace"). Interestingly, Montréal exhibited greater language entropy than Québec generally, likely because of the multilingual nature of the former and the monolingual French nature of the latter. However, for home contexts, Montréal resembled the rest of Canada in its low entropy, but it was higher than the rest of Canada within work contexts. Thus, the use of language entropy at a societal level led to several revealing features – first, it painted an interesting and data-driven picture of the ecological context of a particular city, and second, it did so using the same quantitative approach that can be used at the level of individuals. While Gullifer and Titone (2019) did not report how those two levels of analysis related to each other, other work from our group has begun to statistically evaluate the impact of one on the other.

Our emerging work guided by a *Systems Framework of Bilingualism* capitalized on public census demographic data from Statistics Canada (Tiv et al., in press). Specifically, we collected census statistics pertaining to mother tongue of residents inhabiting clusters of Montréal's postal code regions. From these population trends, we computed an overall index of English use for each neighborhood, as well as an overall index of French use. Additionally, we calculated language diversity for each neighborhood using the Index of Qualitative Variation. Critically, these three ecological variables were linked with respondents' in-lab responses to a social network survey to determine the link between interpersonal and ecological linguistic characteristics. Then, ecological and personal language-tagged social network variables were entered into a factor analysis model, which produced a factor structure consisting of independent factors for the three language-tagged personal subnetworks and the ecological variables. Of interest, we found contextual alignment between the personal and ecological factors (i.e., having a stronger English personal subnetwork patterned with living in an area with more prevalent English use and greater language diversity). Additionally, we found consistent evidence that, in addition to the strength of the language-tagged personal subnetworks, this ecological factor also predicted self-reported language behavior.

The final layer of sociolinguistic influence in the *Systems Framework of Bilingualism* we discuss is societal language dynamics, or broad characteristics of unique regions. This characterization offers insight on the linguistic patterns that systematically vary across regions in a group-wise manner, as Beatty-Martínez and colleagues elegantly demonstrated in their cross-regional work. For example, Beatty-Martínez and Dussias (2017) investigated, using event related potentials (ERPs), Spanish-English bilinguals living in established codeswitching communities in the United States vs. Spanish-English bilinguals living in Granada Spain, who do not habitually codeswitch. For codeswitchers, the ERP results showed that although rarely-observed codeswitches were more difficult to process, codeswitches that adhered to codeswitchers' usage patterns did not incur electrophysiological costs. In contrast, non-codeswitchers processed both common and rare codeswitches with similar difficulty, suggesting that they had not developed sensitivity to codeswitching patterns in their linguistic experience. Thus, the processing of codeswitched language largely depends on the type of codeswitching strategies available in their sociocultural environment.

Beatty-Martínez, Navarro-Torres, Dussias, Bajo, Guzzardo Tamargo, and Kroll (2019) further showed that the impact of one's sociocultural language experiences extends to nonlinguistic executive control. Here, they contrasted three groups of highly proficient Spanish-English bilinguals who lived in different language environments in Spain, Puerto Rico, and Pennsylvania. They found different links between language production abilities and executive control strategies. For bilinguals in Spain, where speakers expect to use Spanish almost exclusively, better production performance patterned with increased reactive control performance. For bilinguals in Puerto Rico, where interactional costs are minimized, no patterns of association emerged. Finally, for bilinguals in Pennsylvania, Beatty-Martínez et al. (2019) found increased reliance on proactive control that related to better production performance, consistent with the need to actively monitor the environment for opportunities to speak Spanish (i.e., context-specific language use). These different patterns of association between language experience and executive control suggest that the demands of one's sociocultural environment cannot be discounted, consistent with work from other groups comparing interactional contexts and language-related cognitive control among bilinguals (e.g., Beatty-Martínez & Titone, 2021; Hartanto & Yang, 2016; Ooi, Goh, Sorace & Bak, 2018; Pot, Keijzer & De Bot, 2018; Zhang, Diaz, Guo & Kroll, under review).

Kutlu and colleagues (2022) adopted a similar cross-regional approach to their study of racially-biased perceptions of accented speech by comparing bilingual samples in Montréal, Canada (i.e., a highly multilingual region where use of multiple languages is generally viewed favorably) and Gainesville, USA (i.e., a small college-town in central Florida where English dominates public life and knowledge of other languages, such as Spanish, is stigmatized). Our results revealed interesting patterns of sentence transcription between the two regions, specifically participants in Gainesville produced more transcription errors when identical auditory recordings were paired with South Asian faces, than when they were paired with white faces. Critically, Montréalers did not demonstrate racially-biased transcription errors between the two face types. Together, these findings underscore the potential role of broad, ambient context on individuals' language behavior.

When taking a broad view outside the language sciences, there are many data sources and approaches that lend themselves to empirically working within an ecological framework. First, data can be collected across various sites. For instance, in 2014 Many Labs was launched as a collaborative effort to replicate social psychological research by different research groups, many

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of whom are situated in unique regions (Klein, Ratliff, Vianello, Adams Jr, Bahník, Bernstein, Bocian, Brandt, Brooks & Brumbaugh, 2014). Though the initial goal of this collaboration was to address the "replication crisis" in psychology, a fortuitous by-product was that the psychological phenomena of interest were being tested across diverse contexts, thus allowing an examination of how internal cognitive processing manifested across varying environmental constraints. Researchers of bilingualism can adopt similar cross-regional approaches in data collection, and some already have for language development (e.g., the productive ManyBabies consortium, Byers-Heinlein, Bergmann, Davies, Frank, Hamlin, Kline, Kominsky, Kosie, Lew-Williams, Liu, Mastroberardino, Singh, Waddell, Zettersten & Soderstrom, 2020). This effort harkens back to MacWhinney's groundbreaking efforts to crowdsource linguistic data in children and adults (CHILDES, MacWhinney, 2000), and Bates' efforts to create a multilingual picture naming repository (Bates, D'Amico, Jacobsen, Székely, Andonova, Devescovi, Herron, Lu, Pechmann, Pléh, Wicha, Federmeier, Gerdjikova, Gutierrez, Hung, Hsu, Iyer, Kohnert, Mehotcheva, Orozco-Figueroa, Tzeng & Tzeng, 2003). There are many other publicly available language corpora spanning geographic regions that could be accessed, conveniently organized at sites like TalkBANK (again created by MacWhinney, 2007), and also big data efforts such as the English Lexicon project (Balota, Yap, Hutchison, Cortese, Kessler, Loftis, Neely, Nelson, Simpson &, Treiman, 2007), CompLex eye-movement database (Schmidtke, Van Dyke & Kuperman, 2021), and GECO eye-tracking corpus (Cop, Dirix, Drieghe & Duyck, 2017).

In cases where it may not be feasible to physically conduct research cross-regionally, or where existing data repositories may be lacking, online data collection may be useful (and has been revolutionized methodologically, in response to the COVID-19 pandemic). Popular platforms, such as Amazon Mechanical Turk or Qualtrics, provide options to automatically geo-tag the location of the respondents, allowing researchers to explicitly probe where the experiment is taking place. Doing so allows researchers to avail themselves of the rich public data sources available through federal censuses, public records, or historical data (e.g., Hehman, Ofosu & Calanchini, 2021). Despite these strengths, online data collection presents its own set of challenges and limitations (e.g., Lefever, Dal & Matthíasdóttir, 2007), and researchers must critically examine whether the samples they tap into represent the diversity of the underlying population (e.g., socioeconomic status, geographic region, age, etc.). Similarly, many language researchers are beginning to leverage geo-tagged tweets to assess regional language attitudes or ideologies (e.g., Kutlu & Kircher, 2021; Vessey, 2021).

Thus, researchers interested in the social context of multilingualism can now consider broader, ambient, and distal ecological and societal characteristics. Within a region such as Montréal, language use and household rates of multilingualism vary systematically as a function of what side of the island one lives on (e.g., French dominance on the East side and English dominance on the West side). However, other locales demonstrate similar stratification, including in conventionally non-linguistic attributes (e.g., socioeconomic status) which may in turn subtly influence neurocognition and language processing. However, regions also vary from one another in terms of the societal status of multilingualism, and even in their regional policies that constrain language use or offer educational services in one or more languages. We encourage researchers to open their minds to these ecological and societal sources of influence and continue to find creative solutions to quantify these subtle dynamics. As such, we are not disheartened by inconsistent findings tested across distinct locales, as we believe these unique behavioral patterns merely reflect individuals' responding to the unique challenges and demands of their environments, rather than the robustness of the construct.

Moving forward

We hope to have convinced readers that people are embedded in a dynamic, multilevel system of sociolinguistic context whereby direct personal interactions and ambient language exposure constrain their everyday language behavior. Perhaps more importantly, we also hope to have offered theoretical and methodological paths for posing and answering questions about such phenomena, organized through the *Systems Framework for Bilingualism*. While quantifying such abstract and complex characteristics is undeniably challenging, we identified some of the clever ways that researchers of bilingualism have begun to measure and incorporate these dynamics into their empirical efforts. Interpersonal language dynamics can be grounded in compositional and structural aspects of the social network, which researchers have assessed using language entropy and (social) network analysis. Higher-order societal dynamics, within a single ecology or across distinct regions, may be assessed through census demographic analysis, self-reported questionnaires, and direct regional comparisons. We acknowledge that this is by no means an exhaustive list, and we are eager to see what tools will be developed in the future to capture additional sociolinguistic variations. Moreover, we have largely omitted empirical discussion of the most distal layer of the *Systems Framework for Bilingualism*, which has to do with systematic temporal constraints that are operative either developmentally over the lifespan, or historically, as discussed extensively in the introduction. Still, we are interested in how other researchers have approached this domain.

Skeptical readers may ask whether these ambient, contextual effects of bilinguals' lived social realities really have consequential and observable impact on BEHAVIORS themselves. Our work (and the work of our colleagues) suggests that the answer could be yes. In one instance, Vlasceanu, Enz, and Coman (2018) advocated that individuals' cognitive capacities, such as encoding and recalling memories, have emergent properties at the community level (i.e., "cognition in social context"). Accordingly, as individuals interact with others in their social networks, their individual memories synchronize to shape societal collective memory formation and vice versa. Other work has shown that ambient exposure to linguistically diverse contexts aids in perspective-taking behavior (Fan, Liberman, Keysar & Kinzler, 2015) and language learning (Bice & Kroll, 2019). As previously mentioned, Gullifer et al. (2018), Gullifer and Titone (2021b), and Gullifer et al. (under review) showed that language entropy can impact both neural activity and cognitive performance across a variety of linguistic and non-linguistic tasks. Other work by our group shows that characteristics of English and French speaking social networks can also predict lexical word knowledge, as measured by the LexTALE task (Tiv et al., in press).

Other newly emerging research from our group provides further evidence that multi-layered social context constrains multilingual behavior. We examined how structural characteristics of bilinguals' social network associated with individual differences in mentalizing, a social cognitive process of representing and reasoning about others' minds (Tiv et al., in press; Tiv et al., 2021).

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Specifically, we considered egos' position in their social network and whether the presence or lack of third-party ties afforded them unique opportunities to engage in mentalizing to broker information between otherwise disconnected people (e.g., López, 2020). We found that more centrally positioned egos, who bridged distinct language communities in the network, exhibited better performance on a mentalizing task. Of interest, this pattern was only detected among egos embedded in a linguistically diverse environment (Montréal, Canada) but not in a linguistically homogenous environment (Gainesville, United States). We interpreted this pattern of results from a cognitive flexibility viewpoint, such that social experiences that increase exposure to diverse perspectives (e.g., bilingualism, brokering information in the network) over time challenge group-based inferences (i.e., stereotypes) and engage more effortful cognitive processing on the internal thoughts and beliefs of others. Together, these results speak to how individuals' social cognitive representations are jointly shaped by their daily social experiences within their network, as well as ambient demands of their broader sociolinguistic society (see also Tiv et al., 2021; in press; Feng, Tiv, Kutlu, Gullifer, Palma, O'Regan, Vingron, Doucerain & Titone, 2021; under review).

In terms of other practical steps researchers can take, as previously mentioned, one of the major impediments is how to quantify complex social behavior in such a way that it can be parsimoniously used to test predictions about individual cognition. To this end, we encourage language scientists to continue to leverage advances in statistical modelling. For example, in recent years, approaches such as mixed-effects regression modelling or multi-level modelling (MLM) have revolutionized the ways in which psycholinguists can pose and answer questions about complex language phenomena. This is because, at its core, MLM accounts for any sort of grouping or clustering of data points, which otherwise would violate the independence of observations criterion of traditional regression. Experimental language researchers were historically most familiar with clustering at the participant level (i.e., multiple observations from the same individual) and item level (i.e., repeated measures designs), separately. In these situations, using MLM to cluster by subject and item accounts for group-level variance and allows generalizations beyond the given sample and item-set. Of note, there are numerous other ways that bilingualism researchers can leverage the power of MLM that are not the norm. For example, language researchers tend to focus on fixed effects within MLM models, and to consider random effects in such models as experimental error terms (i.e., thus the long-standing debates in the field about maximal random effects structures (e.g., Barr, Levy, Scheepers & Tily, 2013). However, as seen in papers outside psycholinguistics (e.g., Otto, Skatova, Madlon-Kay & Daw, 2015), it is possible for us to harness the power of random effects within MLM to test hypotheses involving the interactions of multiple factors (see also Gries, 2021; Meteyard & Davies, 2020; Singmann & Kellen, 2019; Staub, 2021; van Rij, Vaci, Wurm & Feldman, 2020). Such endeavors could be highly useful when considering ways of rigorously testing a *Systems Framework of Bilingualism*.

In addition, group-level variance can be quantified using other statistical approaches that are not typical in our field, such as the model's Intraclass Correlation Coefficient (ICC), and this same logic can be applied for other groupings to quantify contextual effects of, for example, respondents living in different regions (Otto et al., 2015). Of course, newer more sophisticated approaches are always on the horizon (e.g., Generalized Additive Models, GAMs, Miwa & Baayen, 2021, or Generalized Structural Equation Component Analysis, GESCA, Hwang & Takane, 2004), thus it behooves us to remain open to any and all statistical innovations that enable us to pose and answer increasingly sophisticated questions about language. As well, it behooves us to let our questions take center stage in helping to drive the creation of new statistical innovations. For example, explicit causal modelling, a statistical approach that is common within social psychology, but rarely used within the language sciences, has been used to great effect to test questions about the impact of bilingual experience on domain-general cognitive control (e.g., Kałamała, Szewczyk, Chuderski, Senderecka & Wodniecka, 2020). To this end, we believe that borrowing a page from the social psychology playbook would be highly constructive to better understand the socioecological determinants of bilingualism. However, on this point, we issue an important word of caution to our readers. Specifically, our ability to successfully test examine the impacts of complex ecological and sociological experiences on individual behavior requires that we are fastidiously attentive to crucial issues regarding the internal and external validity of our measures, which gate the degree to which we can safely compare within and across populations (Flake et al., 2021).

Taken together, a holistic, socially situated and contextualized approach to bilingual neurocognition fills the gaps of traditional assessments of individual differences (in which the source of variation is considered to be internally motivated) and lends deeper insight into the rich complexities of real-world cognition. Nevertheless, there are experimental and statistical challenges in reaching this goal, and to this end, we have attempted to identify cross-cutting statistical tools to aid in the journey. In addition, we have reviewed the role that these complex dynamics play in microlevel and macrolevel bilingual cognition and behavior, and we are eager to see how other researchers take up the challenge of socially contextualizing their study of bilingual neurocognition.

Final words

Multilingualism is a living, breathing, and ever-evolving phenomenon. Despite the obvious role played by socioecological forces in shaping human experience of multilingualism (and by proxy, the neurocognitive machinery of language), theoretical and empirical efforts to characterize psycholinguistic processes in adults routinely ignore a social view of language, notwithstanding frequent allusions to "contextual factors" that are often vaguely or narrowly specified within any given study (including those conducted by our own group). This self-perpetuating omission sends an implicit but clear message that social factors are irrelevant to how mind and brain represents and processes language, yet our lived experiences and common sense tell us that nothing could be further from the truth.

Rather, within adult psycholinguistics, popular controversies[4] rehash, in different guises, the old saw of whether human language capacities are functionally isolated from, or interactive with, "domain-general cognition" within human brains. Consider the staling bilingual advantages controversy that at its core newly realizes modularity controversies of decades gone by (reviewed in de Bot, 2017; de Bruin, Dick & Carreiras, 2021; Sekerina, Spradlin & Valian, 2019; Titone & Baum, 2014;

[4]"CONTROVERSY, n. A battle in which spittle or ink replaces the injurious cannonball and the inconsiderate bayonet." (Bierce, 1911).

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Vīnerte & Sabourin, 2019). Consequently, in the same way that grammars around the world bias human attention towards particular real-world phenomena to the exclusion of others (e.g., Lewis & Lupyan, 2020) our discipline's perseverative focus on how "language loops in and around itself" (Andresen & Carter, 2016, page 31) biases our attention away from how language links us socially and cognitively to each other, and to the larger society and cultures around us. This may lead us to miss crucial discoveries about how bilingual or multilingual experiences enrich, or are enriched by a variety of in-the-wild social and cultural experiences. Thus, the import of so-called failures to replicate cognitive phenomena of interest (e.g., the "bitter fight over the benefits of bilingualism", Yong, 2016) might be that language use REALLY *is* socially-rooted, as certain cognitive strategies (e.g., proactive control) may be effective in responding to certain social-environmental demands, but certainly not all (e.g., Bak, 2016; Gullifer & Titone, 2021b; Tiv et al., 2021; Tran, Arredondo & Yoshida, 2019; van den Noort, Struys, Bosch, Jaswetz, Perriard, Yeo, Barisch, Vermeire, Lee & Lim, 2019).

In closing, we hope this Keynote, and the commentaries it elicits from colleagues within our discipline, engages a wide array of researchers who are united under the broad umbrella of multilingualism. These include researchers with neurocognitive expertise who wish to better incorporate sociolinguistic and sociocultural theories in their work, researchers within socio-linguistic or sociocultural traditions who wish to better illuminate how their findings link to neurocognition, and applied scientists or policy makers who wish for an enriched evidence base to make data-driven decisions about social policy across a variety of real-world settings. To this end, we stand reverentially on the shoulders of historical figures in the cognitive and neural sciences like Marr (1982), who outlined a new way of framing our approaches to understanding complex cognition, and historical language science (s)heroes such as Grosjean, Bates, and many others within bilingualism who repeatedly nudged us to consider the social context of language and bilingualism (Anderson et al., 2018; Beatty-Martínez et al., 2019; Green, 2011; Green & Abutalebi, 2013; Kroll, Dussias, Bice & Perrotti, 2015; Kroll, Takahesu Tabori & Navarro-Torres, in press; López et al., 2021; Luk & Esposito, 2020; Ortega, 2020; Pliatsikas, DeLuca & Voits, 2020; Surrain & Luk, 2019, under review; Vaid & Meuter, 2017). We hope that the *Systems Framework of Bilingualism* offered here, while preliminary and not perfect, can help us all think more concretely and pragmatically about how to pose and answer psycholinguistic questions about language that are inclusive to diverse sociocultural realities.

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