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Exploring nuance in both experience and adaptation: Commentary on Titone and Tiv (2022)

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The keynote article by Titone & Tiv (2022) represents a key step forward in characterizing and quantifying bilingual experience, and how this may be leveraged to examine neurocognitive outcomes. The framework takes a novel multi-leveled approach to capturing and describing language experience. The first level handles the direct language use dynamics of a given individual or ego-driven language dynamics. Beyond the individual or ego is the level of interpersonal language dynamics, that is the dynamic situations of interaction one is faced with. These interactions are guided (at least in part) by ecological/societal language dynamics- overarching trends and conditions at the community and societal level which set parameters on the nature of language dynamics and interaction in the ego's environment. Finally, although not directly discussed within the paper, temporal dynamics- that is dynamic shifts and trends of language experience across time- of language use sit at the outermost level. Bilingual experience is truly a multidimensional spectrum with a number of experiences that condition its outcomes and the framework proposed by the authors provides a basis for better capturing the levels of social context which condition an individual's opportunities for engagement. However, neurocognitive adaptations to these experiences are also a multidimensional spectrum and these too need to be better linked to the dynamicity of bilingual language experience.

Bilingual experience consists of a series of cognitive demands all revolving around the management and control of multiple active competing systems (Green & Abutalebi, 2013; Kroll et al., 2012). Variation in language experience requires differential degrees of associated cognitive demands and requires the brain to adapt both functionally and structurally to be maximally effective at handling them. Given the complexity of (bilingual) language experience, the range of potential neurocognitive adaptations to it is also large (Bialystok & Craik, 2022). Indeed, a growing body of research indicates a specificity in neural and/or cognitive adaptation to specific language experiences (Beatty-Martínez et al., 2020; DeLuca et al. 2019; Fedeli et al., 2021; Luo et al., 2019; Sulpizio et al., 2020).

Contextualizing and unpacking the complexities and dynamics of language experience is crucial to understand the bases for neural and cognitive adaptations to bilingualism. The Systems Framework proposed by the authors is an important step forward to doing just that. However, our understanding of neurocognitive adaptations to language experiences, particularly beyond the individual level as outlined in the Systems framework, also need to be developed. The goal of this commentary, then, is to highlight how some approaches might also be applied to further the understanding of the relationship between neurocognitive outcomes and bilingual experiences. Specifically, I briefly outline how future research might ideally: 1) employ empirical approaches that more holistically assess the relationship between experiences and contexts and outcomes and 2) develop and merge theoretical frameworks to predict and interpret neurocognitive adaptations in relation to this multidimensional experience.

Empirical approaches assessing adaptations to experience

One way to better assess the adaptations to language experience is in the empirical approaches used in future research. Two directions would ideally be taken. First, multiple measures (both cognitive and neural) would be ideal to more fully assess the range of neurocognitive outcomes. Accompanying this, different statistical approaches will allow us to more holistically assess the numerous relationships between dynamics in language experience and neurocognitive adaptations.

The incorporation of multiple measures can be done in several ways. One approach is to use multiple measures which tap into different cognitive functions (Yamasaki et al., 2018), and include less commonly used measures such as theory of mind tasks (Navarro & Conway, 2021), which tap into

cognitive processes which may also be affected by distinct levels of bilingual experience beyond the ego-driven as discussed in the Systems framework. It is pertinent to note that not all cognitive tasks will necessarily show effects at the level of behavior, and as such the incorporation of neural measures as a complementary method are also encouraged. Including a neural measure (EEG, MRI, etc.) would allow us to see multiple levels of adaptation to effect. Indeed, neural effects of (bilingual) language experience have been shown even in the absence of behavioral effects- both for direct (ego-centric) measures of bilingual language use (Abutalebi et al. 2012; Dash et al., 2019; DeLuca et al. 2020a; Kałamała et al., 2022) and non-direct language exposure (Bice & Kroll, 2019).

The incorporation of multiple experience and outcome measures also requires more sophisticated statistical modeling to assess the number of potential relationships that exist between these, and how they manifest. Multivariate approaches will be key in unpacking the relationships between diverse language experiences and neurocognitive outcomes. Two examples of such approaches have already been successfully applied within previous bilingualism research. Data-driven approaches such as partial least squares (PLS) are such an example (Anderson et al., 2021; Luk et al., 2010). A benefit of PLS is that it is able to take into account several input and outcome variables and derive latent factors that explain meaningful relationships between these variables. To test more theoretically specific relationships and their combined effects, structural equation modeling (SEM) is also an ideal method (Kałamała et al., 2020; Yamasaki & Prat, 2021). With SEM, the key advantage is to directly test theoretical and hypothesized relationships between multiple experiences and outcomes.

It should be noted that no single study would likely have sufficient numbers of participants and measures to test the range of predicted relationships between experience and outcomes. As such, developments in theoretical frameworks linking neurocognitive adaptations to language experiences will also be highly useful.

Neurocognitive models of bilingual adaptation

Methodological developments, such as those described above, would ideally also be joined by theoretical approaches that consider the mechanism of adaptation and can also take into account the greater nuance in neurocognition relative to language experience.

A number of models have been proposed which attempt to describe the nature of neurocognitive adaptation to specific aspects of bilingual experience and the associated cognitive demands. Several of these have focused on relating specific experiences (e.g., duration of use, switching, intensity of use, etc.) to neurocognitive adaptations required to meet the associated cognitive demands with these experiences. Duration-based approaches such as the Dynamic Restructuring Model (Pliatsikas, 2020), Bilingual Anterior to Posterior and Subcortical Shift framework (Grundy et al., 2017), and Conditional Routing Model (Stocco et al., 2014) note a shifting in reliance from frontal to subcortical structures that indicate increased efficiency in handling ongoing cognitive demands from bilingual experience. Alternatively, the Adaptive Control Hypothesis (Abutalebi & Green, 2016; Green & Abutalebi, 2013) takes an approach of intensity of engagement within specific communicative contexts and the reinforcement of specific networks and circuits commensurate to the degree of engagement. In a similar line of argument, a proposal by Salig and colleagues (Salig et al., 2021) makes a distinction of mental states and traits- with engagement of cognitive resources deployed in a moment-to-moment basis depending on environmental and conversational context. Finally, the Unified Bilingual Experience Trajectories framework (DeLuca et al., 2020b) has attempted to combine the predictions of several of the above models and extend these predictions across multiple potential neurocognitive outcomes. The notion of the cognitive demands associated with bilingual experience have also been challenged. A recent proposal by Bialystok and Craik (2022) calls for a spectrum approach to conceptualizing the requirements of specific cognitive demands (attentional control) and thus the mechanism by which neurocognitive adaptations would manifest.

On their own, any one of these models or proposals can account for some degree of the variability that is now captured by the Systems framework offered by the authors. However, none of the existing models on bilingual neurocognition either account for the range of language experiences outlined in the systems framework (particularly those beyond language interactions of the individual) and/or make predictions for the range of functional and structural adaptations. Neurocognitive models in the future will thus need to consider and take into account further levels of language dynamics as those outlined in the Systems Framework, but crucially also further outline and make predictions regarding the mechanisms of adaptation.

Conclusions

The Systems Framework for Bilingualism represents the next step forward in conceptualizing and capturing the manifold levels and aspects of bilingual experience for many subfields of bilingualism research. While this framework is absolutely a welcome addition, our understanding of the connections to neurocognitive outcomes needs to catch up. Through both empirical and theoretical advancements, the task thus rests with the field to advance our understanding of these relationships.

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