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The multifaceted nature of language across adulthood

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Aging is often associated with cognitive and neural decline, and such changes can have significant social, financial, and societal costs. Moreover, older adults represent the largest growing segment of the population (Ortman et al., 2014; Suzman & Beard, 2012), so understanding the cognitive and neural changes associated with aging has broad impact. While there is a rich behavioral literature on aging and age-related changes in cognition (e.g., Park et al., 2002; Salthouse, 2010), we are still beginning to understand how aging influences the brain and how we may be able to mitigate the influence of aging on the brain and cognition. Moreover, although aging can be associated with decline, there is considerable variability in trajectories and outcomes both across individuals and across cognitive domains.

This special issue highlights several factors that influence age-related differences in language processing. The articles consider the importance of motoric aspects of language (i.e., motoric characteristics of words, brain regions associated with motoric function) as well as how other cognitive functions such as executive function, memory, and emotional processes influence language. The articles also highlight how several aspects of language are resistant to age-related change. Some processes show less decline (e.g., phonological encoding, automatic retrieval) this may be in part due to a reliance on regions of the brain that show less age-related neural decline (e.g., sensory or motor regions). Moreover, older adults' language abilities can be improved with language training. At the same time, age-related neural differences were also observed (e.g., weaker functional connectivity, age-related differences in controlled or delayed retrieval; increased language lateralization). This body of work reflects the multifaceted nature of language across adulthood and represents promising investigations that will help improve our understanding of the neural bases of cognitive aging.

Older adults often have increased difficulty with language production, specifically, with retrieval aspects (e.g., increased pauses and fillers, more tip-of-the-tongue incidents; see

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Burke & Shafto, 2008; Kemper, 1992). One potential explanation for these observations points to age-related declines in phonological retrieval (Burke et al., 1991). Karimi & Diaz examined how phonological similarity among words affects encoding and retrieval during sentence processing (Karimi & Diaz, 2021). Event-related potentials indicated that phonological similarity across words facilitated encoding of those words for both younger and older adults – suggesting an age-constancy in encoding and sensitivity to phonological priming. However, age differences emerged when processing the referent pronoun later in the sentence (i.e., retrieval), suggesting that older adults may engage in shallow processing during retrieval. These results are consistent with other work, suggesting fewer age-related differences in sensory and phonological encoding, but age-related decline in retrieval.

Although some have attributed age-related retrieval difficulties to phonological aspects, others have pointed to age-related differences in other cognitive domains, such as inhibition (Hasher et al., 1991; Hasher & Zacks, 1988). These two explanations need not be mutually exclusive, and the degree to which phonological vs. inhibitory deficits play a role may depend on the context and tasks involved. Fong & colleagues, examined the role of inhibition in verbal fluency (Fong et al., 2021). Verbal fluency involves the generation of items that fit within a category (e.g., animals, things at a supermarket, instruments), and is commonly used to assess language production among healthy older adults, as well as clinical populations (Clark et al., 2009; Patterson et al., 2011). Importantly, performance on verbal fluency is often influenced by strategic processes (i.e., inhibiting previously produced responses, using sub-categories to guide retrieval). Thus, it represents an ideal task with which to examine the influence of inhibition on language production. Fong and colleagues also considered the latency between responses as a metric of automatic vs. controlled retrieval. They found a dissociation in which age did not affect automatic retrieval, but age was negatively correlated with the number of controlled responses. Moreover, the effect of age on controlled retrieval was explained, in part by behavioral Stroop effect scores, as well as ERP components related to inhibitory processing (P2 and Pc amplitudes during the flanker task). These findings support the role of attention and inhibition, particularly in controlled aspects of language production.

Similarly, Gertel and colleagues also consider how inhibition influences age-related differences in functional connectivity (Gertel et al., 2020). Functional connectivity is a method in which functional magnetic resonance imaging data (fMRI) can be used to examine the extent to which brain regions work together (Biswal et al., 1995; Rosazza & Minati, 2011). Such data are ideal for examining age-related differences in how the brain works because data collection does not require participants to perform an explicit task which can produce age-related differences in and of itself. The fMRI data can be collected while the participant relaxes in the scanner. The data can then be linked to behavioral performance on other tasks, neurocognitive profiles, or other demographic information. Gertel and colleagues linked their resting state functional connectivity (RSFC) data to performance on the Stroop task, in order to examine the relationship between language brain network connectivity and a task that requires executive function. Consistent with prior work, Gertel and colleagues observed stronger RSFC for younger adults compared to older adults – indicating general age-related declines in RSFC. However, they found that among older adults, stronger RSFC between left inferior frontal gyrus, a key region involved in language production and selection, and right hemisphere regions was associated with better Stroop performance. This suggests that older adults with better inhibitory abilities are able to benefit from recruitment of right hemisphere regions.

As Fong, Gertel, and colleagues demonstrate with inhibition, language is often reliant on other cognitive abilities. This is particularly relevant when processing emotional aspects of language. Emotion regulation is an ability that often improves with age (Urry & Gross, 2010). For example, older adults often exhibit a positivity bias, in which events and stimuli are judged more favorably, compared with younger adults (Reed et al., 2014; Reed & Carstensen, 2012). Moreover, this positivity bias may be influenced by the intensity of the emotion or the relative timing between the experience and the recollection (e.g., before or after the event, Charles, 2010). Ku and colleagues extend this line of research to the domain of language by examining how valence (positive, negative) and arousal (high, low) affect word comprehension in younger and older adults (Ku et al., 2022). They found an arousal-dependent positivity bias during lexical retrieval among older adults. Using event-related potentials as well as brain oscillations, the authors found that low-arousing positive words elicited larger N400s and decreases in frontal alpha for older adults. Moreover, older adults, compared to younger adults, had larger mid-frontal theta increases to low-arousing negative words at later time points (500 – 700 ms), suggesting that older adults may also down-regulate negative words. These data suggest that the intensity of arousing stimuli is an important moderating variable when considering the positivity bias in older adults.

The left hemisphere advantage for speech and reading has long been established through patient studies and neuroimaging (Damasio & Geschwind, 1984; Dehaene et al., 2002). In addition to these techniques, language lateralization can also be examined with behavior using visual half-field designs, in which stimuli are initially presented to only one hemisphere. Van der Cruyssen and colleagues incorporated such a visual half-field design to examine age-related differences in single word reading (Van der Cruyssen et al., 2020). They found that older adults had a larger right-visual field/left hemisphere advantage compared with younger adults. Their results suggest that left-hemisphere dominance in reading increases with age. Thus, despite age-related differences in neural recruitment (e.g., Cabeza, 2002), these results highlight the continued importance of left hemisphere regions in reading.

In contrast to age-related stability in visual word processing, age-related hearing declines are nearly universal among older adults (e.g., Ries, 1994). Even when hearing abilities are matched, speech perception in noise (SPiN) is more difficult for older adults compared to younger adults (Pichora-Fuller et al., 1995). Thus, interventions to address this widely experienced phenomenon are of high clinical, psychological, and social value. Trans-cranial magnetic stimulation (TMS) is a non-invasive approach that uses magnetic fields to stimulate the brain (Klomjai et al., 2015). Importantly, TMS has been shown to induce both short-term and long-term neuroplasticity in a variety of cognitive domains (e.g., for depression, Sonmez et al., 2019). Brisson & Tremblay extend past findings by examining whether this technique can improve SPiN (Brisson & Tremblay, 2021). They found that stimulation of left ventral premotor cortex, a key motor region involved in speech production, facilitated speech perception in noise. These results highlight the importance of speech motor regions in speech perception and suggest that TMS may be a viable intervention technique in addressing age-related speech perception declines.

While Brisson & Tremblay considered the role of left premotor cortex in language production, Reifegerste and colleagues consider how motor characteristics of words affects aging and language processes. Semantic aspects of language are generally resistant to age-related decline (e.g., Verhaeghen, 2003) and are supported by a distributed neural representation (e.g., Lambon Ralph et al., 2017). This distributed neural representation implies that aspects of meaning that rely on brain regions that are less affected by aging (i.e., motor cortex) may be protected from age-related decline. Reifegerste and colleagues considered how motoric aspects of meaning affects aging, using lexical decision and picture naming data from three different languages (Dutch, English, & German, Reifegerste et al., 2021). The authors show that words that are strongly associated with motor functions (e.g., knife) had small to no age-related declines, compared with 'non-motor' words (e.g., steak). Their findings highlight the multidimensionality of semantics and suggest that motor-relatedness is one important factor in reducing age-related language differences.

In addition to considering characteristics of words that may influence age-related differences, effective language interventions have long been used with clinical conditions such as aphasia. Even during typical aging, age-related declines in language are present in a number of areas (e.g., speech perception in noise, controlled production). Additionally, age-related declines have also been observed in pragmatics (e.g., turn taking, minimizing off-topic speech, understanding implications, etc., Messer, 2015; Zanini et al., 2005), which is a key element of successful communication (e.g., Levinson, 2016). In their randomized controlled trial, Bambini and colleagues examined a novel intervention aimed at improving pragmatics (PragmaCom, Bambini et al., 2020). Older adults in the intervention group had larger improvements in their understanding of figurative language and larger reductions in the amount of off-topic speech following the 6-week intervention compared to the control group. These results highlight the potential efficacy of language interventions among healthy older adults and suggest that older adults' pragmatic communication abilities are malleable.

Overall, these articles highlight the multifaceted nature of both language and aging. Age-related sparing was observed in several areas including phonological encoding, phonological priming, and automatic naming. Moreover, the studies point to factors that may promote language retention such as stimulation of left premotor cortex, and motoric aspects of meaning. At the same time, increased age was associated with poorer performance comprehending speech in noise, phonological retrieval, and more challenging aspects of language production. An important factor to consider, is how other cognitive abilities, such as inhibition and emotion regulation can influence performance and outcomes. Thus, the work in this special issue illustrates the dynamic nature of language and the potential for offsetting declines through interventions and lifelong learning.

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