Neuropsychologia 94 (2017) 23–35

Contents lists available at ScienceDirect

Neuropsychologia

journal homepage: www.elsevier.com/locate/neuropsychologia

A behavioural and electrophysiological investigation of the effect of bilingualism on aging and cognitive control

Shanna Kousaie[a], Natalie A. Phillips[b,*]

[a] Cognitive Neuroscience Unit, Montreal Neurological Institute, McGill University, Canada
[b] Department of Psychology/Centre for Research in Human Development, Concordia University, Canada

ARTICLE INFO

Keywords:
Aging
Bilingualism
Cognitive control
Event-related brain potentials (ERPs)

ABSTRACT

Given previous, but inconsistent, findings of language group differences on cognitive control tasks the current investigation examined whether such differences could be demonstrated in a sample of older bilingual adults. Monolingual and bilingual older adults performed three cognitive control tasks that have previously been used in the literature (i.e., Stroop, Simon and flanker tasks) while brain electrophysiological recordings took place. Both behavioural (response time and accuracy) and event-related brain potentials (ERPs; N2 and P3 amplitude and latency) were compared across the two language groups. Processing differences between monolinguals and bilinguals were identified for each task, although the locus differed across the tasks. Language group differences were most clear in the Stroop task, with bilinguals showing superior performance both behaviourally and electrophysiologically. In contrast, for the Simon and flanker tasks there were electrophysiological differences indicating language group processing differences at the level of conflict monitoring (Simon task only) and stimulus categorization (Simon and flanker tasks), but no behavioural differences. These findings support suggestions that these three tasks that are often used to examine executive control processes show little convergent validity; however, there are clear language group differences for each task that are suggestive of superior performance for bilinguals, with behavioural differences emerging only in the linguistic Stroop task. Furthermore, it is clear that behavioural measures alone do not capture the language group effects in their entirety, and perhaps processing differences between language groups are more marked in a sample of older adults who are experiencing age-related cognitive changes than in younger adults who are at the peak of their cognitive capacity.

1. Introduction

In recent years there has been a marked increase in interest and research in the consequences of bilingualism for cognitive function, particularly in aging. This interests stems from findings of cognitive advantages for bilinguals compared to monolinguals (e.g., see Bialystok et al., 2012, 2016), which has implications for research, education and policy, and health, as well as other areas of cognitive science (e.g., cognitive training). The processing differences between bilinguals and monolinguals have been found primarily using tasks that measure cognitive control, including attentional and inhibitory control. Although there is substantial controversy in the literature regarding the reliability of these findings (see Hilchey and Klein, 2011; Paap et al., 2015), there is little debate about the fact that there are differences between monolinguals and bilinguals in terms of language processing and brain plasticity (e.g., see Costa and Sebastian-Galles, 2014). The main issue that arises with respect to the consequences of bilingualism for cognitive control is identifying the circumstances necessary for processing differences to emerge. In the current study we compare monolingual and bilingual older adults on several tasks believed to measure cognitive control, using both behavioural and electrophysiological (event-related brain potentials, ERPs) measures. Our goal is to determine whether effects are observable in older adults, whether they are consistent across three tasks requiring the resolution of conflict, and whether there is evidence of processing differences at either the level of stimulus processing (as indexed by the ERP measures) and/or response output (as indexed by behavioural measures).

In an extensive review of the literature, Hilchey and Klein (2011) suggest that the superior performance seen in bilinguals may be a general speed advantage, rather than a more specific effect limited to conditions that require inhibitory control/interference suppression. In addition, one factor that appears to influence whether or not processing differences are observed, and that is highlighted by Hilchey and Klein,

* Correspondence to: 7141 Sherbrooke St. West, Montreal, Quebec, Canada H4B 1R6.
E-mail address: Natalie.Phillips@concordia.ca (N.A. Phillips).

http://dx.doi.org/10.1016/j.neuropsychologia.2016.11.013
Received 11 July 2016; Received in revised form 25 October 2016; Accepted 16 November 2016
Available online 20 November 2016

is the age of the participants. That is, superior performance in bilinguals compared to monolinguals may be difficult to detect in young adults who are at the peak of their cognitive functioning; however, in older adults who are experiencing age-related changes in cognition, it has been suggested that bilingual language experience may buffer against some of these cognitive changes (Bialystok et al., 2005).

In general, across a variety of cognitive control tasks that manipulate stimulus-response congruency, previous research has found that older adults show larger increases in response time (RT) for incongruent compared to congruent trials than young adults, irrespective of being bilingual. Previous research comparing monolingual and bilingual older adults on these same tasks has generally found superior performance in bilinguals than monolinguals. The relevant literature is reviewed below. We start by briefly examining the evidence for age-related decline on the three cognitive control tasks used here, followed by mention of any influence of bilingualism on task performance.

Previous research that has examined the effect of aging on performance of the Stroop task has found that older adults show larger Stroop effects (i.e., decreases in performance on incongruent than congruent trials) than younger adults. Studies have found larger Stroop effects for older than younger adults that are resistant to practice (Davidson et al., 2003; Dulaney and Rogers, 1994), as well as manipulations in stimulus orientation (i.e., upside down, or upside down and backward; Weir et al., 1997). Others have found a larger Stroop effect in older than in younger adults, both in terms of RT and accuracy, when participants were required to identify the colour that the stimulus was presented in, but not when they were required to identify the word (West, 2004). Bugg et al. (2007) also found that age was associated with slower incongruent colour naming, above what could be accounted for by general age-related slowing. In addition, in a neuroimaging study, Milham et al. (2002) suggest that there are age-related changes in the neural underpinnings of Stroop task performance. Specifically, older adults showed less brain activation in regions related to attention control (i.e., dorsolateral prefrontal and parietal cortices), increases in sensitivity in brain regions important for response level evaluatory processing (i.e., anterior cingulate cortex), and brain activity patterns consistent with a decreased ability to suppress irrelevant information. However, a previous meta-analysis concluded that the apparent age-related decline in inhibitory function demonstrated by increases in the Stroop effect are actually an artifact of general age-related slowing (Verhaeghen and De Meersman, 1998).

With respect to the hypothesized effect of bilingualism on performance, Bialystok et al. (2008) examined whether being bilingual had an impact on Stroop performance by comparing younger and older monolinguals and bilinguals. Their results demonstrated larger Stroop effects in older than younger participants and in monolingual compared to bilingual participants. This difference was largely replicated in another study, which showed smaller Stroop interference in both younger and older bilinguals than in their monolingual peers, with the difference being larger in the older adults (Bialystok et al., 2014). However, Kousaie et al. (2014) and Kousaie and Phillips (2012a, 2012b) did not find evidence for language group differences in Stroop task performance in older adults. Additionally, a recent study using both a verbal and a numerical Stroop task failed to find superior performance in bilingual compared to monolingual older adults, and found no modulation of executive control functions by second language proficiency within a group of older bilinguals (Antón et al., 2016).

In terms of the Simon task, previous research has found that older adults demonstrated larger Simon effects (i.e., greater increases in response time for incongruent trials compared to congruent trials), even when general age-related slowing was accounted for (Van der Lubbe and Verleger, 2002). The Simon task has also been used to examine the effect of bilingualism on the processes required to successfully inhibit information from the irrelevant dimension and respond to the relevant aspect of the stimulus. The first study to examine this found that the Simon effect was larger for older than middle-aged adults, as well as for monolinguals than bilinguals (Bialystok et al., 2004). It is noteworthy that Bialystok et al. found a smaller Simon effects for bilinguals compared to monolinguals in both age groups. However, in another study, Bialystok et al. (2008) found similar performance on a Simon task for monolingual and bilingual older adults. Similarly, Kousaie et al. (2014) did not find language group differences in the Simon effect despite finding an overall larger Simon effect for older than younger adults.

Finally, the flanker task has elicited more subtle effects of aging on task performance. That is, previous research has shown similar behavioural flanker interference effects in older and younger adults,[1] with more sensitive measures (i.e., electrophysiological measures) suggesting age-related differences during flanker task performance (Hsieh and Fang, 2012; Wild-Wall et al., 2008). Specifically, Wild-Wall et al. (2008) found similar flanker interference in young and older participants but greater accuracy in the older adults, which they attribute to differential target processing in the two age groups as revealed by electrophysiological measures. Similarly, Hsieh and Fang (2012) found similar performance for younger and older adults in terms of response times; however, a smaller flanker effect in older than younger adults in terms of accuracy and age-differences in the electrophysiological response suggested that older adults used compensatory strategies to attain similar performance as younger adults. To our knowledge, the flanker task has not been used to compare cognitive control processes across language groups in older adults. However, Gollan et al. (2011) found that error rates on a non-linguistic flanker task were associated with failures in language control (i.e., cross-language intrusion errors in a category fluency task) in older but not younger bilinguals. This supports the hypothesis that bilinguals rely on general cognitive control mechanisms to manage their two languages and that these mechanisms are susceptible to age-related decline.

It is clear from the literature reviewed here that a consensus on the effects of bilingualism on the performance of tasks purported to measure cognitive control in older adults has yet to be achieved. Thus, more sensitive measures such as those provided by brain imaging may be more amenable to detecting language group differences. Two examples can be found from studies using electrophysiological (event-related brain potentials; ERPs) and functional magnetic resonance imaging (fMRI) measures. In young adults, Kousaie and Phillips (2012b) used the same three tasks used in the current investigation and found no evidence of language group differences in behavioural measures, but did find that ERP measures demonstrated differences suggestive of superior performance in bilinguals; however, these differences were not consistent across the three tasks. Specifically, differences were observed in terms of conflict monitoring (Stroop task), resource allocation and stimulus evaluation (Stroop, Simon, and flanker tasks), and error monitoring (Stroop and flanker tasks). In older adults, Ansaldo et al. (2015) demonstrated language group differences in brain activation during Simon task performance in a sample of monolinguals and bilinguals who showed similar behavioural performance. In that study, older monolinguals and bilinguals performed a Simon task in the MRI scanner and demonstrated different neural correlates supporting similar behavioural performance with monolinguals showing activity in brain regions classically associated with interference control and bilinguals showing activation in regions related to visuospatial processing. These findings suggest that monolinguals and bilinguals engaged different strategies to achieve the same behavioural outcome on the Simon task. One interesting question is whether language group differences in brain imaging measures in the absence of behavioural differences constitutes superior performance.

[1] Note that we are referring here to studies that have used arrowhead stimuli given that this is most similar to the task that we employed. However, other studies using letter stimuli have demonstrated greater interference from incompatible flankers in older than younger participants (Zeef and Kok, 1993; Zeef et al., 1996).