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# Sequential congruency effects reveal differences in disengagement of attention for monolingual and bilingual young adults

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A B S T R A C T

Three studies examined the hypothesis that bilinguals can more rapidly disengage attention from irrelevant information than monolinguals by investigating the impact of previous trial congruency on performance in a simple flanker task. In Study 1, monolingual and bilingual young adults completed two versions of a flanker task. There were no differences between language groups on mean reaction time using standard analyses for congruent or incongruent trials or the size of the flanker effect. Sequential congruency effects (SCEs) however, which account for previous trial congruency, were smaller for bilinguals than for monolinguals. This finding was strongest at the shortest response-to-stimulus interval (RSI). Study 2 replicated this effect using a slightly different flanker task and a shorter RSI than study 1. Study 3 showed that at long RSIs, where behavioral SCE differences between groups disappear because of sufficient time to recover from the previous trial, event-related potentials demonstrated a continued influence of previous trial congruency for monolinguals but not bilinguals at both the N2 and the P3, replicating the reaction time effects in Studies 1 and 2. Together, these studies demonstrate that bilinguals experience less influence from previous trial congruency and have greater ability to disengage attention from the previous trial in order to focus attention on the current trial than is found for monolinguals.



## 1. Introduction

It is well established that the two languages of bilinguals are constantly active to some degree, creating a situation in which bilinguals must continually manage attention to the target language to avoid interference from the other language (review in Kroll, Dussias, Bogulski, & Valdes Kroff, 2012). The suggestion has been that this linguistic conflict recruits the domain-general executive control system, thereby enhancing executive control for other tasks, including nonverbal ones (reviews in Bialystok, 2017; Bialystok, Craik, Green, & Gollan, 2009). Neuroimaging support for this position comes from studies showing overlapping brain networks for language control and cognitive control in bilinguals (De Baene, Duyck, Brass, & Carreiras, 2015; Luk, Green, Abutalebi, & Grady, 2012). Behavioral evidence for the enhancement of domain-general executive control in bilinguals has accrued for infants (Kovács & Mehler, 2009; Pons, Bosch, & Lewkowicz, 2015; Singh et al., 2015), children (meta-analysis in Adesope, Lavin, Thompson, & Ungerleider, 2010; review in Barac, Bialystok, Castro, & Sanchez, 2014), and older adults (Bialystok, Craik, Klein, & Viswanathan, 2004; Gold, Kim, Johnson, Kryscio, & Smith, 2013). However, studies with young adults often show no language group differences in performing these tasks (Bialystok, 2006; Bialystok, Martin, & Viswanathan, 2005; Gathercole et al., 2014; Kalia, Wilbourn, & Ghio, 2014; Paap & Greenberg, 2013), leading to a debate about the validity of these effects (Paap, Johnson, & Sawi, 2015). Logically, it would be surprising that a processing effect found in childhood and older age disappeared in young adulthood. The present study addresses the possibility that the standard statistical approach used in this literature lacks the sensitivity required to detect the processing differences that discriminate between groups of young adults performing these tasks. Evidence for this hypothesis will contribute to both a more detailed understanding of executive control and the controversy surrounding the cognitive effects of bilingualism.

Several factors can lead to null results when investigating group differences in performance between monolinguals and bilinguals on simple conflict tasks. First, the distinction between monolinguals and bilinguals may not be clearly demarcated, blurring the difference between groups (Bialystok, 2016; Luk & Bialystok,

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2013). Second, behavioral responses may lack the variance needed for reliable group differences to emerge in high-performing young adults (Marian, Chabal, Bartolotti, Bradley, & Hernandez, 2014), particularly on simple tasks where performance is effectively at ceiling. The average reaction time for the tasks used in much of this research is about 500 ms, so group differences need to be large for statistically significant differences to emerge. In contrast, the average reaction time for children or older adults performing such tasks is often twice as long, allowing more room for experience to push performance in a particular direction. Bilingual young adults outperform monolinguals when task demands are increased (Bialystok, 2006). For example, Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009); Friesen, Latman, Calvo, & Bialystok, 2015 showed that when the number of congruent and incongruent trials was equivalent, bilinguals were faster than monolinguals, despite equivalent accuracy. In this condition, there was always a possibility that the next trial involved conflict, making responses less predictable. However, when the majority of the trials was either congruent or incongruent so the next trial was more predictable, monolinguals and bilinguals performed equivalently. Their interpretation was that in situations requiring higher levels of monitoring, bilinguals are better able than monolinguals to efficiently resolve conflict.

Third, task domain is important because language tasks are typically more effortful for bilinguals. Bilinguals identify pictures more slowly (Gollan, Fennema-Nostestine, Montoya, & Jernigan, 2007; Ivanova & Costa, 2008), generate fewer words in verbal fluency tasks (Bialystok, Craik, & Luk, 2008) and have smaller receptive vocabularies (Bialystok & Luk, 2012) than their monolingual peers. Because bilinguals divide their time between two languages, they have less experience in each language than monolinguals (Gollan, Montoya, Cera, & Sandoval, 2008; Gollan, Montoya, Fennema-Notestine, & Morris, 2005; Gollan, Sandoval, & Salmon, 2011). Thus, verbal tasks often disadvantage bilinguals and may mask group differences in executive control.

One way of detecting processing differences that may be concealed by analyses of overall RT is to examine the influence of the previous trial on performance. The ability to disengage from previous information is central to executive control (Elsabbagh et al., 2013; Landry & Bryson, 2004) but is not considered in analyses that compare overall RT on congruent (C) and incongruent (I) trials, or the difference between them (I-C; congruency effect). For example, in the flanker task in which one responds to a central target among flanking distractors, the congruency effect is the difference between I (< < > < <) and C trials (< < < < <). Studies examining differences between monolinguals and bilinguals have largely ignored the influence of the previous trial. Yet with practice, individuals not only become faster, but also rely less on previous trial congruency to achieve this speed (Mayr & Awh, 2009; van Steenbergen, 2015). The hypothesis is that young adult bilinguals will be better able to disengage attention from the previous trial in responding to the current trial, signaling better executive control in the absence of overall differences in RT.

The notion that bilinguals might be better at disengaging attention fits well with existing evidence. A prevailing view of how bilinguals manage attention to the target language in the face of joint activation is that the non-target language is inhibited (Green, 1998), a view consistent with the executive function model proposed by Miyake et al. (2000) that assigns a prominent role to inhibition. One problem with the inhibition view, however, is the finding that bilingual preverbal infants with no practice in using language also outperform their monolingual peers on executive function tasks (Kovács & Mehler, 2009; Pons et al., 2015; Singh et al., 2015). Infants in the first year of life have representations for both languages (Weikum et al., 2007) and can attend to each selectively. Therefore, bilingual infants have more experience than monolingual infants in controlling attention to one of two language representations. This experience of bilingual infants that requires them to pay attention to multiple sources of input within various linguistic contexts makes it adaptive for them to rapidly disengage attention from stimuli once they are processed so that attention can be re-engaged to currently relevant stimuli. Such early experience in attending to and disengaging from linguistic cues may shape these attentional processes in later development.

Studies with young adults that show faster performance on a flanker task by bilinguals than monolinguals generally find the difference in both congruent and incongruent trials (Costa, Hernández, & Sebastián-Gallés, 2008; Costa et al., 2009; Emmorey, Luk, Pyers, & Bialystok, 2008; see Hilchey & Klein, 2011 for a review). This pattern, too, is contrary to the prediction from the inhibition view in which language group differences would only be expected on I trials. The mechanism responsible for the effects of bilingualism, therefore, needs to affect both C and I trials. Disengagement of attention might be such a mechanism given that some amount of disengagement is required on all trial types to avoid devoting all resources to elaborative processing of the no longer relevant (previous) stimulus.

The sequential congruency effect (SCE)[1] is the index of online reactive adjustment in performance in response to the congruency of the previous trial (Gratton, Coles, & Donchin, 1992) and has been shown to be important for understanding the role of executive control in interference tasks (Botvinick et al., 2001; Wang et al., 2015; Weissman, Egner, Hawks, & Link, 2015; review in Egner, 2014). In this sense, the SCE reflects the speed of disengagement of attention. Accounting for previous trial congruency produces four trial types: congruent trials in which the previous trial was congruent (cC), congruent trials in which the previous trial was incongruent (iC), incongruent trials in which the previous trial was incongruent (iI), and incongruent trials in which the previous trial was congruent (cI). RT is facilitated when trial type is repeated (iI and cC) and slowed when trial type is changed (cI and iC). This leads to two flanker effects: I-C difference following congruent trials (c-flanker effect) and I-C difference following incongruent trials (i-flanker effect). The difference between these two flanker effects is the SCE (c-flanker – i-flanker). Larger SCEs indicate greater influence of previous trials on performance for both congruent and incongruent trials, and thus, slower disengagement of attention from those trials. Generally, the i-flanker effect is smaller than the c-flanker effect (see Fig. 1).

Interpretations of SCEs include cognitive accounts based on top-down control (Egner, Ely, & Grinband, 2010) and associative accounts based on bottom-up retrieval (Mayr, Awh, & Laurey, 2003; Schmidt, 2013), both of which require some amount of disengagement before processing the current trial. One cognitive account, the *conflict monitoring* theory (Botvinick et al., 2001; Kerns et al., 2004) posits that the anterior cingulate cortex (ACC) detects conflict on incongruent trials and signals the dorsolateral prefrontal cortex to focus on task-relevant features on subsequent trials. Thus, incongruent trials facilitate performance on subsequent trials by refocusing attention to task-relevant features, making later incongruent trials less interfering. In contrast, encountering a congruent trial broadens the focus of attention for subsequent trials and leads to facilitation on subsequent congruent trials but interference on subsequent incongruent trials because distractors are also incorporated in the broadening of attention. In the *repetition expectancy* account (Gratton et al., 1992), the detection of congruency biases the individual to expect

[1] The sequential congruency effect is also commonly referred to as the "conflict adaptation effect" (e.g. Botvinick, Braver, Barch, Carter, & Cohen, 2001) or the "Gratton effect" (e.g. Schmidt & De Houwer, 2011). We prefer the term "sequential congruency effect" because of its descriptive value for the effect and theoretical neutrality with respect to mechanism.