Conflict-Monitoring Framework Predicts Larger Within-Language ISPC Effects: Evidence from Turkish-English Bilinguals

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Abstract

In this study, we investigated within- and between-language Item-Specific Proportion Congruence (ISPC) effects in Turkish-English bilinguals in two experiments. In both experiments we manipulated the language of the ISPC lists, while keeping the response language the same (Turkish in Experiment 1, and English in Experiment 2). We observed a larger within-language ISPC effect compared to between-language ISPC effect in both experiments. These results are consistent with the predictions of conflict-monitoring models of the ISPC effect.

Keywords: Stroop interference; conflict monitoring; ISPC; Turkish-English bilinguals.

Introduction

Stroop paradigm (Stroop, 1935; see MacLeod, 1991 for a review) has been widely used to investigate control of attention. In this paradigm, color-words (e.g., red, green, blue) are printed in different colors (red, green, or blue), and participants name the colors, while ignoring the color-words. Responses are slower when the word is incongruent with its color (e.g., when the word red is printed in green), compared to when it is congruent (e.g., when the word red is printed in red). The reaction time difference between the incongruent and congruent conditions is referred to as the Stroop interference. Stroop interference demonstrates effects of word-reading processes on color-naming performance (Cohen, Dunbar, & McClelland, 1990; MacLeod, 1991). Variations in the magnitude of Stroop interference as a result of some experimental manipulations demonstrate control over attentional processes (Blais, Robidoux, Risko, & Besner, 2007; Botvinick, Braver, Barch, Carter, & Cohen, 2001; Verguts & Notebaert, 2008).

One such manipulation is the list level proportion congruence manipulation, in which Stroop interference is affected by the proportion of congruent and incongruent stimuli in the task. When the proportion of incongruent stimuli is higher, Stroop interference is smaller as compared to when it is lower (Logan, Zbrodoff, & Williamson, 1984; Tzelgov, Henik, & Berger, 1992). In this case, participants use a global strategy to control effects of word reading on color naming. Kane and Engle (2003) argued that participants were able to successfully maintain the task-goal (color naming) across trials when the proportion of incongruent stimuli was higher, but they had difficulties when it was lower. These results show that participants strategically controlled the effects of word-reading processes on color-naming performance in a goal-directed manner.

List-level control in the Stroop task was simulated with the classic conflict-monitoring framework (Botvinick, et al., 2001). According to this framework, control processes are triggered by a module responsible for detecting conflicts in information processing, namely the conflict monitoring unit. This unit represents the function of anterior cingulate cortex (ACC) in the human brain (Botvinick, Cohen, & Carter, 2004). It calculates the amount of conflict at the response layer, and increases the activation of the task-demand (color naming) unit when conflict is high. In the Stroop task, incongruent items generate more conflict than congruent items (see also Goldfarb & Henik, 2007; MacLeod & MacDonald, 2000). Higher proportions of incongruent stimuli in the list give rise to higher levels of calculated conflict, which in turn results in increased cognitive control via the activation of the task demand (color naming) unit.

Another manipulation is the item-specific proportion congruence manipulation. Jacoby, Lindsay and Hessels (2003) showed that control over word-reading processes operated at the item-level as well. In their study, proportion congruence of each item was manipulated, keeping the list wide proportion of congruent and incongruent items equal. They divided color words into two sets (e.g., green and black vs. blue and yellow). The first set (green and black) was presented mostly in their congruent color, while the second set (blue and yellow) was presented mostly in their incongruent color. They observed larger/smaller Stroop interference for the mostly congruent/incongruent items. Jacoby et al. (2003) termed this effect as item-specific proportion congruence (ISPC) effect. The random distribution of equal number of congruent and incongruent items prevented participants from predicting the incoming stimuli. Therefore, control over word-reading processes was set after the onset of the stimuli, depending on the proportion congruence of the specific item.

The conflict-monitoring framework was also used to simulate the item-level control in the Stroop task (Blais et al., 2007; Verguts & Notebaert, 2008, 2009). Blais et al. (2007) modified Botvinick et al. (2001)'s model so that the conflict monitoring system modulated the effects of task demand only for the relevant color, as opposed to the original model which modulated the whole pathway. In other words, it was able to register item-specific conflicts and regulate their effects on information processing accordingly. The modified model successfully simulated both item- and list-level proportion congruence effects (Blais et al., 2007). Verguts and Notebaert (2008) proposed a Hebbian learning account of item-specific control. According to this account, the conflict monitoring system triggers an arousal response, which modulates Hebbian learning processes so that Hebbian learning increases when conflict is higher. Verguts and Notebaert (2009) were able to simulate the ISPC effect with this model.

Tzelgov and Kadosh (2009) proposed an extension to ISPC models to explain the relationship between cognitive control and language proficiency. Tzelgov, Henik and Leiser (1990) had previously shown that control of Stroop interference was better in the dominant language in bilinguals. They presented bilinguals mixed lists containing color words both in their dominant and nondominant languages. One list contained more words in the dominant language, the other in the nondominant language. Tzelgov et al. (1990) observed smaller Stroop interference when a higher proportion of trials were presented in the dominant language. Control over word-reading processes was better for the color-words in participants' dominant language. The extension proposed by Tzelgov and Kadosh (2009) in order to simulate this dominant language advantage involves adding a layer for nondominant language words. In the extended model, what gives rise to differential levels of conflict is the language difference, that is, Stroop words in the dominant language generate more conflict than words in the nondominant language. Higher conflict in the dominant language results in increased cognitive control via the processes described in the conflict monitoring models discussed above (Blais et al., 2007; Verguts and Notebaert, 2008, 2009).

Extending ISPC models by including separate layers for dominant and nondominant languages gives rise to another prediction regarding the within- vs. between-language ISPC effect. One robust finding from Stroop studies is that between-language Stroop effect is smaller than the within-language Stroop effect (see MacLeod, 1991 for a review). Therefore, it would be safe to assume, on the basis of conflict monitoring models, that the within-language condition would generate more conflict compared to the between-language condition. In keeping with the notion that control is a function of conflict monitoring, we would expect the within-language ISPC effect to be higher than the between-language ISPC effect. In the present study, we tested this prediction with Turkish-English bilinguals.

Experiment 1

In Experiment 1, we manipulated the language of the ISPC lists, keeping the response language the same (Turkish). If the ISPC effect is based on conflict monitoring processes (Blais et al., 2007; Verguts & Notebaert, 2008, 2009), then it would be higher for the Turkish list (the within-language condition) than the English list (the between-language condition).

Method

Participants The participants were 48 students from a psychology course at Middle East Technical University, who voluntarily participated for extra course credit. All of them were Turkish-English bilinguals of Turkish origin. Turkish was the native language of all participants. They studied English for an average of 9.89 years. They were quite proficient in English, but knew Turkish better. They spoke only Turkish at home and in their daily life, but spoke only English in classes. All participants had normal or corrected-to normal visual acuity and normal color vision.

Materials Stimuli and procedure of the experiments was approved by the Human Research Ethics Committee of Middle East Technical University. Stimuli consisted of lists of color words that were either in Turkish or in English. The Turkish and English lists were identical, except for the language of the words. Stimuli consisted of color-words, yeşil (green), siyah (black), mavi (blue), sarı (yellow), a strings of three '%%%' and four '%%%%' percentage signs. For congruent stimuli, the color words were printed in their matching ink color, e.g. black was printed in black font. For incongruent stimuli the color words were printed in their nonmatching ink-color, e.g. black was printed in green font. For neutral stimuli percentage signs were printed in all ink colors. Each color word was presented 48 times. Colors were divided into two groups (green and black vs. blue and yellow) to produce MC (mostly congruent) and MI (mostly incongruent) conditions. For MC condition 36 of 48 (75%) presentations were congruent. For MI condition 36 of 48 (75%) presentations were incongruent. There were 96 congruent, 96 incongruent, and 16 neutral stimuli. Color words were presented in a fixed random order with the constraint that no more than 3 congruent or 3 incongruent items appeared successively. The stimuli were printed with a 60-point Arial font in green, black, blue, or yellow color, at the center of the monitor screen against a gray (R:166, G:166, B:166) background. A centered fixation signal (+) appeared for 1000 ms and an empty screen that lasts 500 ms preceded each stimulus.

Procedure There were two sessions in the experiment. In the first session color words were in Turkish, and participants responded in Turkish. In the second session color words were in English, and participants again responded in Turkish. Each session took about 30 min. There were 18.62 days on average between the two sessions. The assignment of color words to the MI and MC conditions and the order of sessions were counterbalanced across participants. Participants signed the informed consent form and filled a questionnaire on color blindness and proficiency in Turkish and English. Automatic stimulus display, and data collection were controlled with a PC running E-Prime 2.0 software. Participants were instructed to name the ink color of the stimulus out loud as quickly, and as accurately as possible. The stimulus appeared on the screen until the voice key was tripped, or until the 3000 ms response deadline was reached. The experimenter coded the given responses via the keyboard. A trial was coded as scratch if the voice key was tripped by noise. Twenty-eight practice trials preceded the main experiment. The structure of the practice trials was the same as the main experiment.

Results and Discussion

Correct RTs less than 200 ms and greater than 2,000 ms were removed (fewer than 1% of all trials). RTs for correct responses and error rates (ERs) for each condition of the experiment were calculated for each participant.

The same ANOVAs were conducted on both RTs and ERs. ERs were rather low (mean Turkish=0.018, mean English=0.016) and they yielded findings similar to that of the RTs. Therefore, they are not reported in detail here.

For RTs, 2 X 2 X 2 within-subjects ANOVA was conducted, with stimulus language (Turkish vs. English), proportion congruence (mostly congruent vs. mostly incongruent), and trial type (congruent vs. incongruent) as within-subjects factors. Figure 1 presents means and standard errors for each condition in Experiment 1. There was a significant main effect of trial type [$F(1, 47) = 236.36$, $MSE = 1581.23$, $p < .001$, $\eta_p^2 = .83$] (mean congruent=665 ms, mean incongruent= 728 ms), and stimulus language [$F(1, 47) = 8.84$, $MSE = 6538.94$, $p < .005$, $\eta_p^2 = .15$] (mean Turkish= 709 ms, mean English=684 ms). Moreover, the stimulus language and trial type [$F(1, 47) = 54.14$, $MSE = 843.97$, $p < .001$, $\eta_p^2 = .53$] interaction was also significant. The Stroop effect was higher for Turkish words (84 ms) than English words (40 ms). The proportion congruence and trial type [$F(1, 47) = 51.94$, $MSE = 959.54$, $p < .001$, $\eta_p^2 = .52$] interaction was also significant. Stroop effect was higher in the MC condition (85 ms), compared to the MI condition (39 ms). Therefore, ISPC effect (45 ms) was significant. Importantly, the critical three-way interaction between stimulus language, proportion congruency and trial type [$F(1, 47) = 4.47$, $MSE = 535.10$, $p < .05$, $\eta_p^2 = .08$] was significant, in that, ISPC effect was higher with Turkish words (55 ms), compared to English words (35 ms). In order to investigate whether the ISPC effect was significant for both languages, Turkish and English RTs were analyzed with separate 2 X 2 within-subjects ANOVAs with trial type and proportion congruence as within-subjects factors. For Turkish words, there was a significant main effect of trial type [$F(1, 47) = 186.50$, $MSE = 1825.20$, $p < .001$, $\eta_p^2 = .79$] (mean congruent=669 ms , mean incongruent= 751 ms). The two-way interaction between proportion congruence and trial type was also significant [$F(1, 47) = 39.91$, $MSE = 928.12$, $p < .001$, $\eta_p^2 = .45$]. Stroop effect was higher in the MC condition (112 ms), compared to the MI condition (56 ms), which showed that ISPC effect (55 ms) was significant for Turkish words. For English words, there was a significant main effect of trial type [$F(1, 47) = 131.72$, $MSE = 600.01$, $p < .001$, $\eta_p^2 = .73$] (mean congruent=664 ms, mean incongruent= 704 ms). The two-way interaction between proportion congruence and trial type was significant [$F(1, 47) = 26.82$, $MSE = 566.52$, $p < .001$, $\eta_p^2 = .36$]. Stroop effect was higher in the MC condition (58 ms), compared to the MI condition (22 ms), which showed that ISPC effect (35 ms) was significant for English words.

In Experiment 1, we replicated the robust finding that within-language Stroop interference was larger than between-language Stroop interference. More importantly, within-language ISPC effect was measured to be larger than the between-language ISPC effect. This specific finding was predicted by the extended version of the conflict monitoring model, in which separate layers were added to represent words in the dominant and nondominant languages (Blais et al., 2007; Verguts & Notebaert, 2008, 2009; Tzelgov & Kadosh, 2009). Thus, our results confirmed this prediction.

Tzelgov et al. (1990) showed that control was better for words presented in the dominant language in bilinguals. In our experiment, the within-language condition also happened to be the dominant language condition, since the dominant language of our participants was Turkish, and they also responded in Turkish. Therefore, there is always the possibility that control was higher in the within-language condition just because words were presented in the dominant language, not because of the difference in conflict levels between the between- and within-language conditions. Therefore, our results can also be explained by the relationship between control and language proficiency (Tzelgov et al., 1990). To test this possibility we designed Experiment 2.

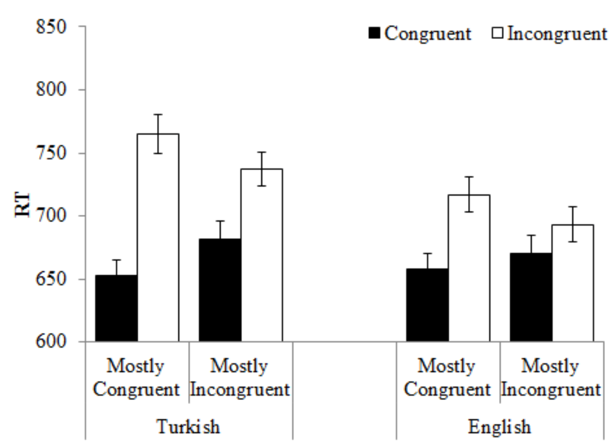

Figure 1: Average RTs for the conditions of Experiment 1. Bars represent standard errors.

Experiment 2

In this experiment, participants responded in English to the same set of materials in Experiment 1. If the reason why we observed better control in the within-language condition is simply because there is better control for words in one's dominant language, then we should see better control in the between-language condition, in which words were presented in the dominant language (Turkish). On the other hand, if the difference between the within- and between-language ISPC effect is indeed a result of different levels of conflict in the between- and within-language conditions, then we should see larger ISPC effects in the within-language condition.

Method

Participants The participants were 36 students from a psychology course at Middle East Technical University, who voluntarily participated for extra course credit. All participants had normal or corrected-to normal visual acuity and normal color vision. They studied English for an average of 9.45 years. None of them participated in Experiment 1.

Materials and Procedure The materials and procedure was exactly the same as in Experiment 1 except that responses were given in English. There were 16 days on average between the two sessions of the experiment.

Results and Discussion

Correct RTs less than 200 ms and greater than 2,000 ms were removed (fewer than 1% of all trials). Figure 2 presents means and standard errors for the conditions of Experiment 2. Analyses were the same as in Experiment 1. ERs were rather low (mean Turkish=0.01, mean English=0.013) and they yielded findings similar to that of the RTs. Therefore, they are not reported in detail here.

For RTs, There was a significant main effect of trial type [$F(1, 35) = 188.25$, $MSE = 2059.29$, $p < .001$, $\eta_p^2 = .84$] (mean congruent = 698 ms, mean incongruent = 771 ms). The two-way stimulus language and trial type [$F(1, 35) = 49.33$, $MSE = 1215.13$, $p < .001$, $\eta_p^2 = .58$] interaction was significant. The Stroop effect was higher for English words (102 ms) than Turkish words (44 ms). The proportion congruence and trial type [$F(1, 35) = 38.60$, $MSE = 1394.49$, $p < .001$, $\eta_p^2 = .52$] interaction was also significant. Stroop effect was higher in the MC condition (100 ms), compared to the MI condition (46 ms). Therefore, ISPC effect (45 ms) was significant. Importantly, the critical three-way interaction between stimulus language, proportion congruency and trial type [$F(1, 35) = 15.71$, $MSE = 632.90$, $p < .001$, $\eta_p^2 = .31$] was significant, in that, ISPC effect was higher with English words (78 ms), compared to Turkish words (31 ms). In order to investigate the nature of the significant three-way interaction, Turkish and English RTs were analyzed with separate 2 X 2 within-subjects ANOVAs with trial type and proportion congruence as within-subjects factors. For Turkish words, there was a significant main effect of trial type [$F(1, 35) = 59.99$, $MSE = 1189.38$, $p < .001$, $\eta_p^2 = .63$] (mean congruent = 711 ms , mean incongruent= 755 ms). The two-way interaction between proportion congruence and trial type was also significant [$F(1, 35) = 8.55$, $MSE = 1023.27$, $p < .01$, $\eta_p^2 = .19$]. Stroop effect was higher in the MC condition (60 ms), compared to the MI condition (28 ms), which showed that ISPC effect (31 ms) was significant for Turkish words. For English words, there was a significant main effect of trial type [$F(1, 35) = 180.45$, $MSE = 2085.04$, $p < .001$, $\eta_p^2 = .83$] (mean congruent = 685 ms, mean incongruent = 787 ms). In addition, there was a significant two-way interaction between proportion congruence and trial type [$F(1, 35) = 54.80$, $MSE = 1004.12$, $p < .001$, $\eta_p^2 = .61$]. Stroop effect was higher in the MC condition (141 ms), compared to the MI condition (63 ms). In other words, ISPC effect (78 ms) was significant for English words.

In Experiment 2, we replicated the results of Experiment 1. We again observed the robust finding that within-language Stroop interference was larger than between-language Stroop interference, and that within-language ISPC effect was larger compared to the between-language ISPC effect. This latter result showed that ISPC effect in bilinguals was a function of the level of conflict generated by within- and between-language conditions.

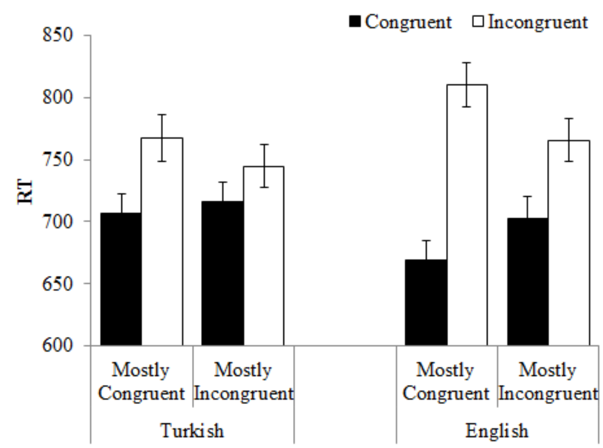

Figure 2: Average RTs for the conditions of Experiment 2. Bars represent standard errors.

General Discussion

A novel finding in this study was that within-language ISPC effect was larger than the between-language ISPC effect. This finding is successfully predicted by a conflict monitoring model which employed separate layers for dominant and nondominant languages (Blais et al., 2007; Verguts & Notebaert, 2008, 2009; Tzelgov & Kadosh, 2009).

An alternative explanation of the ISPC effect, namely the contingency learning hypothesis (Schmidt & Besner, 2008), is undermined with this finding. According to this account ISPC effect reflects (possibly unconscious) learning of stimulus-response contingencies, but not the dynamic adaptation of control processes. Schmidt and Besner (2008) claim that participants learn the correlation between words and responses in an ISPC manipulation, which allows them to predict a specific response for each word. The prediction lowers the threshold for specific responses associated with specific words. Therefore, for the mostly congruent condition, responses are faster for the congruent stimuli, but not for the incongruent stimuli, which increases Stroop interference. Similarly, for the mostly incongruent condition, responses are faster for the incongruent stimuli, but not for the congruent stimuli, which decreases Stroop interference (Schmidt & Besner, 2008). Assuming that stimulus-response learning between the color-words and responses should not depend on language, the contingency learning account does not predict a difference between within-language and between-language ISPC lists. This is contrary to our results.

Nevertheless, our results are not in conflict with Tzelgov et al. (1990), who showed control was better for words in the dominant language irrespective of the response language. Tzelgov et al. (1990) used dominant and nondominant language words within the same list, and they manipulated the expectancy for each language. Our ISPC lists, on the other hand, contained words only from one language, that is, we did not investigate the three-way relationship between ISPC effect, language, and expectancy. If expectancy for dominant and nondominant language words were to be manipulated within the same ISPC list, it would be possible to see whether control of Stroop interference as a function of language proficiency was independent from item-specific control as a function of within- vs. between language conflict levels. We are currently investigating this possibility.

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