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# LANGUAGE AND TASK SWITCHING IN POLISH-ENGLISH BILINGUALS

The study investigated the relationship between the efficiency of switching languages and non-linguistic tasks in non-proficient Polish-English bilinguals. The participants performed picture naming that involved switching between L1 and L2 in both directions and a shape or color decision on visually presented figures, which required switching and mixing two different tasks. No relationship between the efficiency in switching languages and non-linguistic tasks was observed. However, increased language switching efficiency was related to high task mixing efficiency, indicating that maintaining two languages and two non-linguistic tasks active is mediated by equivalent control processes. Also, switching from L2 to L1 was more time-consuming than in the opposite direction and participants with the greatest L1 switching disadvantage were the fastest task switchers. These findings suggest that non-proficient bilinguals inhibit their stronger language while switching between L1 and L2 and equivalent inhibitory mechanisms can be responsible for the facilitation of their task switching performance.

*Key words*: bilingualism, language switching, task switching, task mixing, executive control

## Introduction

One of the recent trends in psycholinguistic research is the investigation of the cognitive consequences of bilingualism. A number of studies have concentrated on comparing bilinguals and monolinguals in terms of their cognitive performance, as a result of which a bilingual advantage was found.

Bialystok and Martin (2004), for instance, who tested the cognitive capacity of bilingual and monolingual children with the help of dimensional change card sort tasks, reported better control of attention and a better developed ability to inhibit conflicting information for bilingual children, when compared with monolingual children.

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In another study, Bialystok and Shapero (2005) asked bilingual and monolingual children to perform a dimensional change sort task as well as a task that involved reversing ambiguous figures. The more satisfactory performance of bilingual participants was interpreted as evidence for better inhibitory control and selective attention in children who had two languages at their disposal.

Also, in a study by Costa et al. (2008), bilinguals and monolinguals were compared on the attentional network task (ANT), testing three components of attentional networks, i.e. alerting, orienting and executive control. The results revealed that bilinguals were faster and more efficient in performing the task than monolinguals, especially in the executive control component. Furthermore, they exhibited lower cost of switching between different types of trials, when compared with monolinguals.

In another study by Bialystok and Feng (2009), where bilingual and monolingual children and adults performed a proactive interference task, a bilingual advantage concerning the control of attention was reported, as bilingual participants performed equally well as monolingual ones, although the former had smaller vocabularies, which should have had a negative effect on their overall performance. Like all of the above-mentioned studies, these findings show that bilinguals surpass monolinguals in terms of executive control.

## Components and manifestations of executive control functioning

Executive control is understood as a range of processes and actions that the mind employs to execute a task. According to Miyake et al. (2000), executive control is a multiplex construct which encompasses such component processes as: updating of working memory, inhibition, i.e. suppression of distractors and conflicting responses as well as shifting between mental sets. A mental set is defined as a frame of mind that involves a model which represents a problem, the context of a problem or a procedure devised and followed to solve a problem (Prior & MacWhinney, 2010).

In a study by Prior and MacWhinney (2010), the manifestation of executive control functioning was decomposed into two phenomena, switching costs and mixing costs. The experimental paradigm required the participants to switch between a shape decision and a color decision while examining the same stimuli, with the stimuli being bivalent as they included red and green circles and triangles. Thus, the switch was to take place between task one, i.e. classification based on the shape of a stimulus, and task two, i.e. classification based on the color of a stimulus. The two tasks were to elicit two distinct mental sets. As a consequence, switching between the two tasks corresponded to shifting between two mental sets.

To decompose executive control into its constituent processes, the task switching paradigm was split into single-task blocks and mixed-task blocks. Single-task blocks involved only one task, i.e. classification either by shape or by color, and thus no switching between the two criteria was involved. ixed-task blocks, on the other hand, involved both tasks, i.e. classification by shape and color alike within particular blocks of stimuli. For that reason, these blocks included two types of trials: switch trials, in which the classification criterion was different than in the previous trial, and non-switch trials, in which the classification criterion was the same as in the previous trial. In this way, two measures of executive control, i.e. switching costs and mixing costs, were to be estimated. The task switching cost was understood as the difference between reaction times on switch and non-switch trials in the mixed-task blocks and the measure was to reflect the degree of difficulty connected with switching between one task set and another. The task mixing cost, on the other hand, was understood as the difference between reaction times on single-task trials and non-switch trials in mixed-task blocks. This measure was to reflect the degree of difficulty involved in mixing two different tasks. Moreover, Prior and MacWhinney (2010) maintain that switching costs reflect control processes necessary for selecting the appropriate task or linking task cues with the appropriate response mappings, whereas mixing costs reflect the activation of global control mechanisms necessary for maintaining two competing response sets, monitoring the task or making a task decision in each trial.

The results of monolingual and bilingual college students performing the experiment showed that bilingual participants exhibited much lower switching costs than monolinguals. As for the magnitude of the mixing costs, though, there was no significant difference between the two groups, although the reaction times of both monolinguals and bilinguals revealed substantial costs incurred by mixing the two tasks. The results were interpreted as evidence for bilingual advantage in shifting between mental sets and inhibition of competing responses, both of which are assumed to rely on a shared mechanism of controlled attention. Not surprisingly, the advantage was attributed to the bilingual practice in switching between two languages.

## Sources of bilingual advantage

Researchers agree that bilinguals face a constant need to control and monitor the use of their two languages, both of which are considered to be active to varying degrees in most speaking situations, despite the intention to speak one of them only (Kroll, Bobb, Misra, & Guo, 2008; Kroll, Bobb, & Wodniecka, 2006; La Heij, 2005; De Groot, 2011). The consequence of having two language systems activated simultaneously is competition between the intended and unintended language. Such competition is believed to arise especially in code-switching situations, when both languages need to be ready for production. Although the question of how this competition is resolved has not been unanimously answered, it has been proposed that the unintended language receives inhibition, i.e. suppression, so that its activation level is lower than that of the intended language, resulting in the latter being eventually selected for production (Green, 1998; Kroll et al., 2008). Inhibitory processes that are believed to play a role in the control of the bilingual lexico-semantic system fall into a broader category of mechanisms which underlie the functioning of executive control in various tasks and problems that the mind encounters. Thus, examining whether any common ground between the execution of linguistic and non-linguistic switching tasks can be found seems promising for a better understanding of bilingual language control as well as more general mechanisms of executive control.

**Similarities between language and task switching**

The reason for bilingual advantage in task switching might be the fact that both task and language switching, with the latter being a typically bilingual practice, rely on the same mental as well as neurophysiological mechanisms and procedures. First, it has been demonstrated that when performing language and task switching alike, the mind recruits similar brain regions, including the dorsolateral prefrontal cortex and anterior cingulate areas (Abutalebi & Green, 2007; Hernandez, Dapretto, Mazziotta, & Bookheimer, 2001; Wang, Chen, Xue, & Dong, 2007). More importantly, in order to control interference from the non-intended language, bilinguals recruit brain areas which are not identified as language-specific, such as the middle prefrontal cortex (Hernandez, 2009; Rodriguez-Fornells et al., 2005). It can be seen that switching between languages constitutes a type of task executed with the use of a general, cognitive brain capacity and is not limited to language-dedicated brain areas.

Another similarity between task and language switching is the need to resolve competition between the target and the non-target response so that the former can be selected and delivered. Such competition is thought to arise both in language switching, when one language interferes with another, and in task switching, when one mental set interrupts the use of another one. In both situations, the interfering response is believed to receive inhibition, as a result of which the intended one is provided.

Next, both language and task switching conditions give rise to a switching cost, observed in the form of reaction time latencies. The switching cost is thought to reflect the additional time that the mind needs to establish a new task set and overcome the interference of the one established while performing the previous task (Prior & MacWhinney, 2010). By way of analogy, additional time is needed to switch from a language system that has been used previously to another one that is yet to be used. The presence of switching costs has been confirmed by the measurements of reaction times in empirical studies on task (Meiran, Hommel, Bibi, & Lev, 2002; Prior & MacWhinney, 2010) and language switching (Costa & Santesteban, 2004; Costa, Santesteban, & Ivanova, 2006; Meuter & Allport, 1999) alike.

The final property that language and task switching have in common is the asymmetry of switch costs. Studies have shown that, surprisingly, switching from an easier, less demanding task to a more difficult one incurs lower switch costs than switching in the opposite direction (Allport & Wylie, 2000; Rubinstein, Meyer, & Evans, 2001). Similarly, experiments testing bilinguals on language switching revealed that a switch from the dominant language, usually L1, to a weaker one, most frequently L2, is less time-consuming than a switch in the opposite direction, i.e. from L2 to L1. This switching cost asymmetry is believed to arise especially in non-proficient, unbalanced bilinguals, in whom significant discrepancies between L1 and L2 proficiency have been observed (Costa & Santesteban, 2004; Meuter & Allport, 1999). The asymmetry in language switching costs has been accounted for by Green's (1998) Inhibitory Control Model which posits that, while performing a language switch from L1 to L2 in speaking situations, a bilingual needs to inhibit the stronger L1 that remains active and thus interferes with L2 production despite the speaker's intention to use his/her L2. As a result of L1 inhibition, the L2 activation level exceeds that of L1, which enables L2 selection and production. However, provided a switch from L1 to L2 exerted by means of L1 inhibition is followed by a backward switch, i.e. from L2 to L1, additional time is needed to overcome the previously applied inhibition of L1 and to reactivate the L1 language system. In switching to L2, though, no additional time for reactivation is needed as the activation level of the weaker L2 is never high enough to interfere with the intended L1 production and thus no inhibition is applied. As a consequence, switching costs for L1 and L2 become asymmetrical with an observable L1 switching disadvantage. Asymmetrical language switching costs seem to be in parallel with asymmetrical task switching costs in the way that both involve interference from the dominant response that competes for selection with the non-dominant one. In both cases, the competition is resolved by inhibiting the dominant but unintended response. Inhibition requires additional reaction time, which is manifested in asymmetrical costs of switching between the two responses.

All of the above-mentioned properties that are common for language and task switching have been reported in numerous behavioral studies which tested bilinguals on language and/or task switching. The key findings as well as the main deficiencies of these studies are briefly discussed below to explain the motivation behind the present study.

## Language switching studies

As mentioned previously, language switching studies have most frequently examined the difficulty of switching languages in different directions, as manifested in the presence of asymmetrical switch costs, depending on bilinguals' L2 proficiency (Costa & Santesteban, 2004; Costa et al., 2006; Meuter & Allport, 1999). Less attention, though, has been paid to individual differences in bilingual language switching abilities, irrespective of the switch direction. It can be assumed, however, that the degree of difficulty involved in switching languages might be different for different bilinguals, depending on a variety of factors, including the second/foreign language proficiency and the degree of balance between the languages involved in switching, the age of L2 acquisition and the context of L2 acquisition and use, the amount of code-switching experience and exposure to a code-switching environment and, finally, the efficiency of general executive control and its component processes. There is every possibility that this range of factors creates certain discrepancies in the magnitude of the language switching cost for distinct bilinguals.

**Task switching studies**

As discussed previously, a number of studies which examined the efficiency of executive control in bilinguals have concentrated on comparing bilingual and monolingual participants on a variety of non-language related tasks testing selective attention, inhibition of irrelevant or competing information, resistance to interference and flexibility of shifting between mental sets (Bialystok & Martin, 2004; Bialystok & Shapero, 2005; Bialystok & Feng, 2009; Costa et al., 2008; Prior & MacWhinney, 2010). Although a clear bilingual advantage has been found, these research reports fail to provide information on possible variation in the development and efficiency of executive control in bilinguals differing in terms of a range of the above-mentioned factors that influence their ability to switch between their two languages. It is possible, though, that the development of executive control, or at least its specific components, is to some extent determined by the degree of their bilinguality and the efficiency in switching languages that they have attained.

**Language and task switching studies**

A growing interest in the relationship between general executive control and language control in bilinguals has resulted in several studies investigating the issue. Barac and Bialystok (2012), for example, compared the performance of three bilingual groups and a group of monolinguals on verbal tasks and a non-verbal executive control task, reporting that the performance on the non-verbal task was comparable in all bilingual groups and better than in monolinguals, while the performance on the verbal tasks differed, depending on the bilinguals' language experience.

More light was shed on the issue by Prior and Gollan (2011), who report that among two groups of bilinguals they tested, those who declared frequent code-switching in their everyday lives exhibited smaller costs of both language and non-linguistic task switching than those declaring less frequent switching between languages.

Somewhat surprisingly, another study (Calabria et al. 2011) whose aim was to trace the common ground between language control and general executive control in bilinguals showed that the correlation between the two is neither as simple nor as obvious as it may seem. Although bilingual participants performing a language and a non-linguistic switching task manifested asymmetrical switch costs in both conditions, the patterns of the asymmetries observed in one condition did not correspond to those in the other condition, which led the researchers to conclude that the language control system is not an exact subsidiary of the general executive control system.

In line with this finding are the results of a study by Linck et al. (2012) investigating the correlations in trilingual performance on a non-linguistic switching task, i.e. a Simon task, serving as a measure of general inhibitory control, and a language switching task, considered a measure of language control. As enhanced inhibitory control turned out to be coupled with reduced language switching costs only under the conditions of switching to or from the participants' dominant language (L1), the researchers interpreted the pattern as evidence for a link between general executive control and language control. To what extent, though, the latter is supported by the former seems to be highly determined by the language experience and its related attributes.

**The aims of the present study**

In light of all the findings discussed above, the general motivation for the present study was to trace possible correlations between bilingual efficiency in switching languages and switching between non-linguistic tasks. To be more specific, the aim of the study was to investigate whether enhanced language control, reflected in reduced language switching costs, would be related to more efficient executive control abilities. However, as such a relationship has been shown in a few recent studies, the most essential question of this study was as follows: If language control is not an exact subsidiary of general executive control in all conditions, what are the specific components of the latter that are correlated with the former? In other words, the study aimed to unravel which components of the general executive control system are of crucial importance to language control processes and thus become more efficient in the aftermath of the bilingual experience with regular language switching.

There is no doubt that unraveling the cause-and-effect relationship between executive control and language control poses a great difficulty in research on the bilingual mind. Challenging as it is to establish whether it is the experience in switching languages that facilitates the functioning of executive control in bilinguals, or rather enhanced executive control that facilitates language switching, the present study aimed to estimate the extent to which the two are interdependent. Due to the bilingual cognitive advantage reported in earlier studies, a fundamental assumption made in this study was that the practice of switching languages facilitates cognitive processes operating in non-linguistic switching tasks, which is then manifested in enhanced executive control abilities of bilinguals.

Since the study aimed to focus on specific components of executive control, Prior and MacWhinney's (2010) methodology was followed to isolate such components as local control processes responsible for task and response selection, reflected in the task switching cost, and global control and monitoring processes, responsible for maintaining two different mental sets, reflected in the task mixing cost.

A preliminary hypothesis of the present study predicted some within-group variation in the magnitude of the language switching cost in the examined group of bilinguals. Based on this assumption, the leading hypothesis predicted that those bilinguals for whom switching languages poses the least difficulty, i.e. incurs the lowest switching cost, would exhibit a similar advantage as for the task switching cost. By way of analogy, bilinguals with the worst language switching performance were expected to show the highest task switching cost. In addition, the present study investigated individual differences in the task mixing cost, for which no bilingual advantage was found in Prior and MacWhinney (2010). Finally, the study's secondary aim was to verify whether the magnitude of the language switching cost, task switching cost or task mixing cost is related to the second language proficiency score.

## Method

### Participants

The participants were 22 advanced Polish learners of English. Specifically, they were second-year undergraduate students, four males and 18 females, aged from 19 to 24, enrolled in a stationary English Studies program at the AMU Faculty of English. Their L1, Polish, had been acquired since birth as the native language, while the acquisition of their L2, English, had had its onset at the age of 3 to 15. All the participants completed the entire experimental procedure of the study.

### Procedure

The first stage of the empirical procedure was the assessment of the participants' proficiency in L2. It was then followed by the two experimental stages, including language and task switching.

*L2 proficiency test*

The participants' L2 proficiency was measured with the help of an English vocabulary test by Nation & Beglar (2007). The purpose of the test is to assess the scope of English vocabulary or, rather, the size of the mental lexicon that an English user has at his/her disposal, with the maximum possible number of 14,000 lexical items. The mean test score of all participants amounted to 10,500. The lowest score equaled 8,100, while the highest was 12,000 vocabulary items. Irrespective of the test score, all the participants took part in the language and task switching experiments.

*The experiment*

The experiment proper consisted of two components, i.e. a language-switching part and a task-switching task. Both components were designed and conducted using the E-Prime 2.0 software application suite. A detailed description of the language and task switching paradigms is provided below.

Language switching paradigm

The language switching paradigm was adapted from Costa and Santesteban (2004), the main difference being that the present experiment involved a lower number of trials. The experiment was conducted using a computer integrated with a Serial Response Box and a microphone. Every participant was presented with 45 lists of pictorial stimuli, displayed on the computer's screen. Each list contained from 5 to 14 stimuli. The stimuli were images portraying one of 10 common objects. The objects, such as a dog, an umbrella, a tree, a table, an apple, a window, a carrot, a hat, a fork and cheese were depicted in the form of black-and-white, simple sketches. The participants were asked to name the objects they were presented with in their L1 or L2. All the names of the objects were non-cognate words in both languages.

The lists of stimuli contained both switch trials, i.e. those preceded by a picture to be named in the other language, and non-switch trials, i.e. those preceded by a picture to be named in the same language. The response language was signaled by the color of the circle, either green or orange, inside of which every object appeared. The assignment of the color cue was counterbalanced – half of the participants were instructed that "green" indicated Polish and "orange" English, while the other half received the opposite instructions. The participants were reminded of the color-language correspondence repeatedly, as every list of trials was preceded by the presentation of a colored circle, either a green or an orange one, and a word, either *POLSKI* ("Polish") or *ENGLISH*, written below it, indicating which color elicited a particular language response. The assignment of the color cue was constant and remained unchanged throughout the whole experimental session. The proportions of response type and response language were controlled for in such a way that half of the lists began with an L1 response, while the other half – with an L2 response. Each list contained either none or up to four switch trials. In total, every subject performed 400 trials, 120 of which required switching to the other language while 280 were non-switch trials. Half of both the switch (60) and non-switch trials (140) required L1 responses, whereas the other half elicited L2 responses. Consequently, each participant used both of his/her languages 200 times.

Every trial began with the display of a stimulus shown for 2000 milliseconds or until a participant responded. The stimulus was then followed by a blank interval, displayed for 1000 ms, which preceded the presentation of the next stimulus. After the last stimulus on a list, an asterisk was presented for 1000 ms to indicate the end of the list. The participants' reaction times to stimuli were measured in milliseconds and recorded in an E-Prime 2.0 data file. Reaction times on error trials, including non-target language responses, slips of the tongue or response omissions caused by difficulties in word retrieval, were excluded from the data analysis.

### Task switching paradigm

The task switching paradigm was a replication of the one used by Prior and MacWhinney (2010), with minor alterations concerning the order and the duration of stimuli presentation as well as the colors applied.

Using the E-Prime 2.0 application suite, seven blocks of trials were constructed, four of which were single-task blocks while three were mixed-task blocks. The construction of single-task blocks required the participants to perform one and the same task throughout the whole block of trials. Mixed-task blocks, on the other hand, were constructed in such a way that they made the participants switch between two different tasks within the same block of trials. The tasks consisted in classifying the stimuli presented on the computer screen according to their shape, i.e. a shape decision, or color, i.e. a color decision. The stimuli had the form of pictures portraying red and blue circles and triangles. As a consequence, they were bivalent in the sense that they allowed two competing responses, i.e. either "red"/"blue" or "circle"/"triangle". The participants were instructed as to which classification criterion to follow on the forthcoming trial by the presentation of a task cue preceding every trial stimulus. The task cue indicating the color decision was a color gradient, while the task cue corresponding to the shape decision was a set of black and white geometrical figures.

Two of the single-task blocks required the shape decision, while the other two elicited the color decision. As every single-task block included 36 trials, the participants performed 144 single-task trials in total. As for the three mixed-task blocks, each of them contained 48 trials, resulting in 144 mixed-task trials in total. Of these, 72 were switch trials, i.e. those which elicited a different task than that performed on the previous trial, whereas the other 72 were non-switch trials, i.e. those which elicited the same task as the one performed on the preceding trial. No more than four trials of the same type appeared consecutively in the mixed-task blocks. In total, on both single- and mixed-task blocks, every participant performed 288 trials within the task switching part of the experiment.

The task switching part of the experiment had a sandwich-like, three-stage structure. In the first stage, bilinguals performed two single-task blocks of trials, with either the color decision block followed by the task decision block or in the reverse arrangement, counterbalanced across participants. Both single-task blocks were preceded by a sample block consisting of six practice trials. The second stage required the participants to complete the three mixed-task blocks of trials, the first of which was preceded by a block of eight practice trials. At the last stage of the task switching part, bilinguals again performed two single-task trial blocks which followed the reverse order to that used in the first stage.

The participants were asked to respond by pressing the appropriate button on the Serial Response Box. The buttons were labeled with appropriate colors for the color decision and appropriate shapes for the shape decision. Each task was mapped to one hand and the hand-task correspondence was counterbalanced across participants, as half of them were instructed to perform the color decision with their right hand and the shape decision with their left hand, while the other half received the opposite instructions. In addition, the participants were instructed to use the index finger of their right hand for the "red" response, for instance, and the middle finger of the same hand for the "blue" response if the color decision was assigned to the right hand. By way of analogy, the same participants were asked to respond "circle" with the index finger of their left hand and "triangle" with the middle finger of that same hand. The motivation behind the hand-task and finger-response correspondence was to facilitate the performance of the tasks and to prevent potential technical errors, such as confusion of buttons assigned to particular responses.

The display of each trial began with a fixation cross, shown for 200 ms. It was followed by the presentation of a task cue which lasted 250 ms. The stimulus was then presented for 2000 ms or until the participant responded. Before the beginning of the next trial, a blank screen was displayed for 300 ms to separate the two trials.

Analogically to the language-switching part, the participants' reaction times on task switching, excluding error trials, on which incorrect responses were given, were measured in milliseconds and recorded in an E-Prime 2.0 data file. All the data, including the vocabulary test scores, were then analyzed in the SPSS 20.0 application suite.

## Results

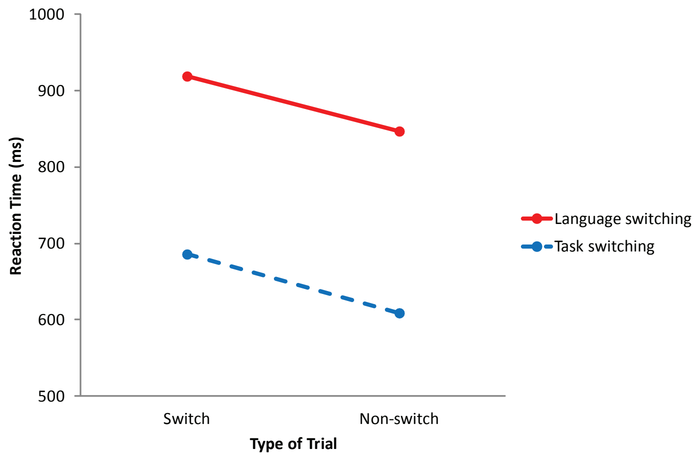
### Language non-specific analyses

Two-way analysis of variance (ANOVA) was conducted with the Dependent Variable "Reaction Time" (RT) and two factors, including "Type of Task" (language switching vs. task switching) and "Type of Trial" (switch vs. non-switch). The variable encompassed the values of mean reaction times recorded for all participants in the language-switching part of the experiment and in the mixed-task blocks of the task switching part. In order to obtain valid ANOVA results, reaction times on trials in the single-task blocks, to which no "switch"/"non-switch" feature could be ascribed, were excluded from the analysis of variance. The effect of ANOVA ($F$(3, 87) = 32.954) was statistically significant ($p$ < 0.001), revealing that the influence of the two factors, i.e. "Type of Task" ($F$(1, 84 = 90.161)) and "Type of Trial" ($F$(1, 84 = 8.701)) on "Reaction Time" was also statistically significant ($p$ < 0.001 and $p$ < 0.005, respectively). Nevertheless, there was no interaction between the two factors ($F$(1, 84) = 0.000, $p$ = 0.990), which indicates that the switching cost was comparable, irrespective of the type of task that was performed. Figure 1 presents the variation in "Reaction Time" by "Type of Task" and "Type of Trial".

As illustrated in Figure 1, the mean reaction times for switch and non-switch trials in the linguistic part of the experiment amounted to nearly 920 ms and about 846 ms, respectively. In the non-linguistic switching component, the mean reaction time on switch trials equaled 683 ms, decreasing to nearly 610 ms on non-switch trials. The mean reaction time on single-task trials, not plotted above because of its omission in the calculation of ANOVA, equaled 535 ms.

At the next stage of data analysis, the mean language switching cost, task switching cost and task mixing cost, calculated collectively for all the participants, was obtained via t-tests. The t-tests were conducted on pairs of respective variables, selected from 5 Dependent Variables, including: "Language Switch Reaction Time (RT)",

Figure 1. Reaction Time by Type of Task and Type of Trial




"Language Non-Switch RT", "Task Switch RT", "Task Non-Switch RT" and "Single Task RT". The values of the variables were mean reaction times on the 5 corresponding trial types, isolated individually for every participant. The result of a t-test on "Language Switch RT" and "Language Non-Switch RT" equaled 73.145 ms ($t(21) = 6.598$, $p < 0.001$) and was labeled as the mean value of the "Language Switching Cost". By way of analogy, the mean "Task Switching Cost" was determined by calculating the difference between "Task Switch RT" and "Task Non-Switch RT", which amounted

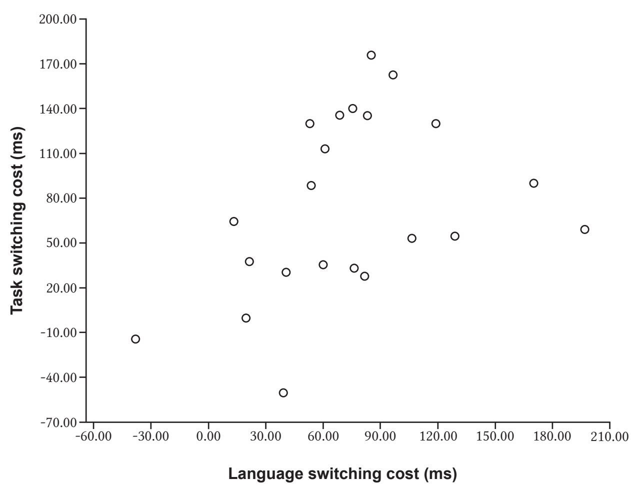
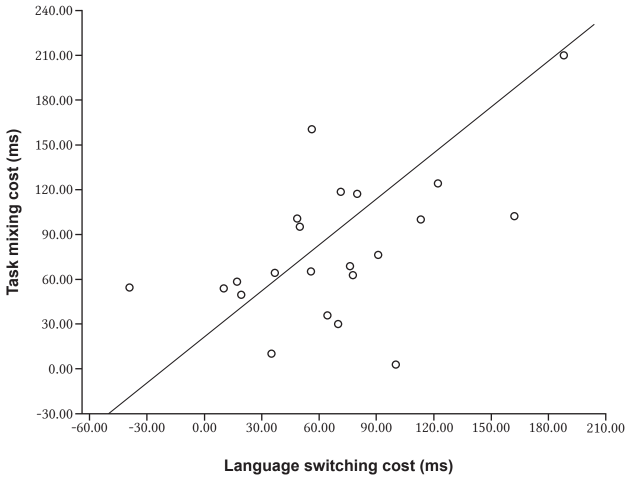



Figure 2. Language and task switching cost by participant

Figure 3. Language switching and task mixing cost by participant




to 73.788 ms, with $t(21) = 5.756$ and $p < 0.001$. Finally, the difference between "Task Non-Switch RT" and "Single Task RT", which equaled 74.698 ms ($t(21) = 6.426$ and $p < 0.001$), was labeled as the mean value of the "Task Mixing Cost".

Next, each of the three measures, i.e. "Language Switching Cost", "Task Switching Cost" and "Task Mixing Cost", was determined individually for every participant by calculating the difference between his/her mean reaction times on respective pairs of trial types, following the procedure applied in calculating the mean language switching, task switching and task mixing cost for all the participants collectively. As a result, 22 different values were obtained for each of the three variables. The Pearson Correlation between respective pairs of variables was then calculated. No correlation was found between "Language Switching Cost" and "Task Switching Cost" ($r = 0.368$ and $p = 0.092$). However, for the "Language Switching Cost" and "Task Mixing Cost" pair, $r$ equaled 0.532, with $p < 0.05$, indicating the existence of a positive correlation between the two variables. The distribution of "Language Switching Cost", "Task Switching Cost" and "Task Mixing Cost" by participant is presented in Figures 2 and 3. The correlation between "Language Switching Cost" and "Task Mixing Cost" is illustrated by the trend line observable in Figure 3.

Finally, Pearson Correlations between each of the three variables including "Language Switching Cost", "Task Switching Cost" or "Task Mixing Cost" and the "L2 Proficiency Score" variable were calculated. The values of the last variable were the numbers of points obtained by the participants individually on the Nation & Beglar (2007) vocabulary test. However, no correlation was found between the "L2 Proficiency Score" and either "Language Switching Cost" ($r = -0.290$, $p > 0.05$), "Task Switching Cost" ($r = -0.133$, $p > 0.05$) or "Task Mixing Cost" ($r = -0.195$, $p > 0.05$).

**Language-specific effects**

Although investigating language-specific effects was not the focus of the study, an additional analysis of L1 and L2 data separately was carried out in search of any observations which could complement the results obtained by analyzing the general, i.e. language non-specific switching performance of the participants. A mean language switching cost for L1 (i.e. for switching from L2 to L1) and for L2 (i.e. for switching from L1 to L2) was calculated individually for every participant as well as collectively for all the participants.

Collective analysis of the participants' reaction times revealed that the mean switching cost equaled 84 ms for L1 and 62 ms for L2, indicating an L1 switching disadvantage that amounted to 22 ms and was statistically significant ($p < 0.05$). Next, three new variables: "L1 Switching Cost", "L2 Switching Cost" and "L1 Switching Disadvantage" were defined. Each of them had 22 values as all three measures were calculated individually for every participant. Then, Pearson Correlations between any pair of variables including "L1 Switching Cost", "L2 Switching Cost" and "L1 Switching Disadvantage" as well as the previously defined "Task Switching Cost" and "Task Mixing Cost" were calculated. The results showed a positive correlation between "L2 Switching Cost" and "Task Switching Cost" ($r = 0.498$, $p = 0.018$). More interestingly, negative correlations were observed between "L1 Switching Disadvantage" and "Task Switching Cost" ($r = -0.515$, $p = 0.014$) as well as "L1 Switching Disadvantage" and "L2 Switching Cost" ($r = -0.504$, $p = 0.017$), both of which are illustrated in Figures 4 and 5, respectively.

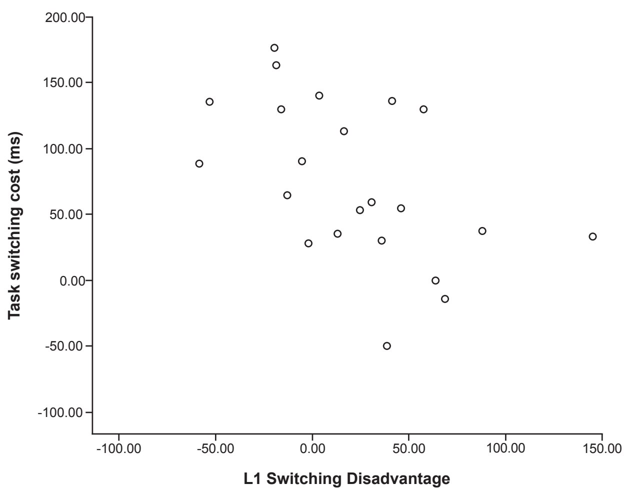
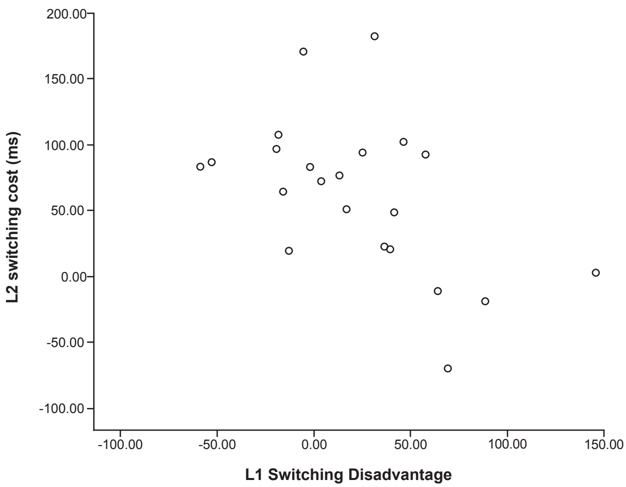



Figure 4. L1 switching disadvantage and task switching cost by participant

Figure 5. L1 switching disadvantage and L2 switching cost by participant




## Discussion

Statistical analysis of the collected data provided results which made it possible to verify previously adopted hypotheses. The analysis of variance showed that both the type of task and the type of trial that the participants performed influenced their reaction times. The mean reaction time on switch trials in the language-switching part turned out to be about 920 ms, whereas the non-switch trials in that same part of the experiment took ca. 846 ms on average. In the case of the task switching component, participants took ca. 683 ms on average to perform the switch trials, while the mean reaction time on the non-switch trials amounted to 610 ms. Not surprisingly, the fastest reactions of the participants were recorded for the single-task trials in the task switching component, with the mean reaction time equaling about 525 ms. Somewhat unexpectedly, however, no interaction between the type of trial and the type of task was detected, suggesting that the cost of switching was similar, regardless of whether switching took place between languages or non-linguistic tasks.

Further data analysis confirmed the initial results of ANOVA. T-tests conducted on particular pairs of variables, including "Language Switch RT" and "Language Non-Switch RT", "Task Switch RT" and "Task Non-Switch RT" as well as "Task Non-Switch RT" and "Single Task RT", made it possible to determine the magnitude of the language switching, task switching and task mixing cost, respectively. The mean cost of switching languages amounted to 73 ms, while the cost of switching between tasks turned out to be nearly 74 ms. Finally, the cost of mixing tasks equaled about 74 ms, surprisingly overlapping with the remaining two measures.

Next, language and task switching as well as task mixing costs were calculated individually for every participant. The highest individual language switching cost amounted to about 200 ms, while the highest cost of switching between tasks equaled ca. 180 ms. Finally, the highest task mixing cost was about 220 ms. Surprisingly, for one participant, no switching costs were detected, as the non-switch trials in both the language and task switching parts turned out to be more time-consuming than the switch trials. However, even more surprising is the finding that the magnitude of the language switching cost was not correlated with the magnitude of the task switching cost and no regularity between the distribution of the two measures could be found, which is tantamount to the leading hypothesis of the study being disconfirmed. Nevertheless, the Pearson Correlation between the "Language Switching Cost" variable and the "Task Mixing Cost" variable revealed that the two were related and the correlation was positive.

The final point in the main part of data analysis was the Pearson Correlation calculated separately between "L2 proficiency score" and each of the three experimental measures, i.e. the language switching cost, the task switching cost and, finally, the task mixing cost. Surprisingly again, no correlation was found between the L2 proficiency variable and any of the three measures listed above.

Although the results of the study were different than expected, a range of interesting findings can be pointed out. The fact that the mean cost of switching between languages was almost identical with that of switching between tasks suggests that language switching is treated and executed as a subtype of general task switching. However, since language switching is burdened with the language production cost, both in real-life speaking situations and experimental conditions, the reaction times on language switching trials are proportionately longer than those on trials that involve switching between non-linguistic tasks.

The supposition that switching languages is performed with the use of the general cognitive capacity of the attentional system is supported by the finding of a correlation between the language switching and the task mixing cost. The fact that the two measures are correlated supports the assumption that both the efficiency in switching languages and the efficiency in performing mixed tasks rely on the same cognitive mechanisms, such as the ability to maintain two competing response sets, to monitor the task that is being performed and to make a task decision on every subsequent trial.

The lack of correlation between the language switching cost and the task switching cost, surprising as it may be, indicates that switching languages is a complex and thus more cognitively challenging type of task than switching between non-linguistic task schemas. As a consequence, it is believed to be mediated and determined by a variety of factors which, presumably, do not play a role in the execution of other, non-linguistic tasks that the mind performs. Quite unexpectedly, though, the level of proficiency that a bilingual had attained in the second language turned out not to be one of those factors, as suggested by the lack of correlation between the L2 proficiency score and the language switching, task switching or task mixing cost. There is no doubt, however, that language proficiency is one of the most difficult factors to measure in second language acquisition research. As it is a complex cognitive-linguistic construct that consists of a number of different components, a single vocabulary test is certainly too limited a method to assess the L2 proficiency of any bilingual person accurately enough. In addition, it should be noted that apart from the proficiency level in L2, there may be a range of other factors influencing a bilingual's efficiency in switching between L1 and L2, including the degree of balance between L1 and L2, the age at which L2 acquisition began, the setting and method of L2 acquisition, the environment in which the L2 is used as well as the approaches to code-switching and the amount of exposure to a bilingual, code-switching environment. It can be seen that, unfortunately, many of these factors are difficult, if not impossible, to measure.

The results of additional data analysis which was applied to determine the cost of switching (from L2) to L1 and (from L1) to L2 separately are in line with the conclusions drawn from the analysis of general, language non-specific switching effects. The fact that switching from L2 to L1 is more time-consuming than in the opposite direction can be explained by Green's (1998) Inhibitory Control Model, in light of which the observed L1 switching disadvantage is evidence of the reactive L1 inhibition that a bilingual employs to overcome the interference of L1 competitors while switching to the weaker L2. Next, the positive correlation found between "L2 Switching Cost" and "Task Switching Cost" indicates that difficulties in shifting between two different tasks in general have their reflection in switching to the weaker language, i.e. L2, which constitutes the more difficult task compared to switching to L1. Another interesting observation is the negative correlation between "L1 Switching Disadvantage" and "Task Switching Cost", which suggests that shifting between two different tasks is more difficult and thus more time-consuming when a participant is not able to inhibit a competing mental response set and the inability to inhibit potential competitors is manifested as the lack of L1 switching disadvantage when switching between L2 and L1. However, if a participant is able to inhibit the stronger language when the need arises, s/he is presumably able to apply inhibitory mechanisms in switching non-linguistic tasks as well, which is demonstrated in a reduced task switching cost. Such an explanation is supported by the fact that "L1 Switching Disadvantage" turned out to be negatively correlated with "L2 Switching Cost", which shows that the higher the degree of L1 inhibition applied, the easier it is to switch to L2 and thus the lower the cost of switching to L2.

All things considered, the present study has shown that further investigation of the cause-and-effect relationship between the functioning of executive control processes and efficiency in switching languages can be promising in establishing how a bilingual mind controls the two languages at its disposal and how the experience of bilingualism, together with its characteristic behaviors such as code-switching, modifies or, presumably, enhances the general cognitive abilities of a bilingual person.

A number of the above-mentioned factors, whose influence on bilinguals' efficiency in language switching seems to be crucial, should be examined to find answers to the questions of how bilingualism facilitates the functioning of executive control. Interesting findings can be expected of linguistic and non-linguistic task switching studies concentrating, for instance, on comparing notorious code-switchers, e.g. conference interpreters, with bilinguals who function mostly in the monolingual mode (Grosjean, 2001). It could be assumed that prolonged exposure to the language-switching experience that is part of the interpreting profession should influence the functioning of executive control in a more visible way than that manifested in the present study. The term 'bilingual' is certainly far from referring to a homogenous, uniform group of individuals with the same cognitive capacity and comparable linguistic and non-linguistic abilities. The diverse and multi-layered character of present-day bilingualism entails a countless number of unique linguistic and linguistically determined characteristics that might distinguish a group of bilinguals as much from monolinguals as from another group of bilingual individuals.

## Conclusion

The aim of the study was to investigate whether the efficiency in switching between two languages demonstrated by advanced Polish learners of English is related to specific components of their general executive control, indexed by two measures of their efficiency in switching non-linguistic tasks, namely the task switching cost and the task mixing cost. Surprisingly, no correlation between the magnitude of the language switching cost and the task switching cost was found, which indicates that the former is a complex, cognitively demanding type of task whose execution is determined by a range of individually varied factors which are not at play in non-language related task switching. The positive correlation between the values of the language switching cost and the task mixing cost, though, suggests that switching languages is mediated by the same attentional and control components that are responsible for the ability to mix different tasks and thus maintain two competing mental sets active. Nevertheless, language-specific data analysis revealed that switching to different languages is dependent on general switching abilities to different degrees, which allows the assumption that the different status of L1 and L2 causes different control mechanisms to be involved in the execution of language-specific tasks.

All in all, the findings of the study demonstrate that further investigation of individual differences in more than one language experience and bilingual abilities is necessary to determine to what extent and in what respects bilingual language control is subserved by the general executive control system.

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