



THE INTERPLAY OF BILINGUALISM, EXECUTIVE FUNCTIONS AND CREATIVITY IN PROBLEM SOLVING AMONG MALE UNIVERSITY STUDENTS

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Abstract. The present study explores the interplay among bilingualism, executive functions and creativity in problem solving among adult male university students. In this context, the associations between two factors critical for understanding the topic, *i.e.* type of bilingualism (*i.e.* balanced *versus* non-balanced bilingualism) and type of creative thinking (*i.e.* convergent *versus* divergent thinking) are examined, as well. 28 Russian/Hebrew/English trilinguals (balanced Russian/Hebrew bilinguals), and 25 non-balanced Hebrew/English bilinguals participated in the study. All participants performed several standard tasks on executive functions (Wisconsin Card Sorting Test, Eriksen flanker task, digit span test, Corsi block-tapping test) and two tests on creativity: Torrance Tests of Creative Thinking (Figural Form A) and Remote Associates Test (in appropriate languages). The findings showed that the Russian-speaking participants performed better on the Torrance Tests of Creative Thinking, particularly in flexibility and fluency measures. On the Remote Associates Test, balanced bilinguals outperformed non-balanced bilinguals in the English version and exhibited the same results in the Hebrew version of the test. In this case, there were significant correlations between the Remote Associates Test results in all three languages in the Russian group. Thus, balanced bilingualism seems to be also characterized by a well-organized language system in which all of the individual's languages are interconnected. This appears to be a significant factor in the performance of balanced bilinguals on the Remote Associates Test in the different languages. In addition, the findings seem to confirm the hypothesis that balanced bilingualism positively influences divergent thinking. The hypothesis that performance of bilinguals on creativity tasks is linked to distinctions in the development of their executive functions was not confirmed.

Keywords: bilingualism, cognition, convergent thinking, creativity, divergent thinking, executive functions.

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Introduction

Over the last few decades, research into the field of bilingualism has accumulated growing evidence demonstrating that knowledge of two or more languages has a positive influence on the development of high-order cognitive functions. The advantages of bilingualism have been reported across a variety of cognitive domains, such as inhibition (Bialystok, 2010; Carlson & Meltzoff, 2008), problem solving¹ (Adesope et al., 2010), attention and executive control (Bialystok, 2011; Engel de Abreu et al., 2012), cognitive flexibility² (Morales et al., 2013; Soveri et al., 2011) and working-memory updating (Birke Hansen et al., 2016). In addition, there is strong evidence that bilingualism, predominantly balanced bilingualism (“balanced usage of and balanced proficiency in two languages”, see Yow & Li, 2015), contributes to verbal and nonverbal creativity (Cushen & Wiley, 2011; Kharkhurin, 2010, 2012; Leikin, M., 2013; Leikin & Tovli, 2014). In this case, the interrelation between two complex cognitive phenomena, bilingualism and creative thinking ability, seems to be mediated by precisely the aforementioned improved executive functions³, which in turn are influenced by the “juggling” of the two languages (Cushen & Wiley, 2011; Hommel et al., 2011; Kharkhurin, 2011). That is, the enhanced cognitive functions of bilinguals account for (among other factors) their superiority in creativity, *i.e.*, in creative potential (Runco & Acar, 2012) or creative thinking ability (Kaufman & Beghetto, 2009).

This view, however, has been called into question in some other research studies due to inconsistencies in the obtained findings on improved executive functions in bilinguals (Adesope et al., 2010; Andoni Duñabeitia & Carreiras, 2015; Paap & Greenberg, 2013; Woumans & Duyck, 2015) as well as in balanced bilingualism compared with unbalanced bilingualism or monolingualism (Carlson & Meltzoff, 2008; Rosselli et al., 2016; Poarch & Hell, 2012; Verreyt et al., 2016). Divergence in the obtained data, however, might be explained by a variation in effect sizes across studies, differences in the experimental design and participants’ age, languages, and cultural background. For example, in two studies that examined the working memory of bilingual children by using verbal stimuli (Bialystok & Feng, 2011; Engel de Abreu, 2011), bilingual children revealed lower scores than monolinguals. On the other hand, Ellen Bialystok (2009) found evidence of a certain advantage for bilinguals in working memory when using the Corsi block-tapping test (CBTT) (non-verbal spatial working memory). Similarly, opposite findings were shown for certain other cognitive functions, including inhibition and creative thinking ability (Birke Hansen et al., 2016; Kharkhurin, 2012; Leikin, M., 2013; Bastian et al., 2016).

¹ In psychology, problem solving is a mental process or act of finding a solution to a problem (Chevallier, 2016). In this case, a problem may be defined as the gap between a current situation and a desired goal state along with uncertainty regarding the ways in which this gap can be resolved within certain constraints (Newell & Simon, 1972).

² Cognitive flexibility is the capacity for objective appraisal and appropriately flexible action (VandenBos, 2015). For example, it is a flexible mental ability to switch between languages when thinking about two different concepts (*e.g.*, Deák, 2003).

³ Executive functions are higher-level cognitive processes of planning, decision making, problem solving, action sequencing, task assignment and organization, effortful and persistent goal pursuit, inhibition of competing impulses, flexibility in goal selection, and goal-conflict resolution (VandenBos, 2015).

In this context, we suggested exploring the relationship between the two cognitive phenomena under discussion, bilingualism and creativity in problem solving, among balanced and non-balanced bilingual adults, also examining students' performance on several relevant executive-function tasks.

1. Bilingualism and creativity

Creativity is often defined as a mental process involving the generation of new ideas or new connections between existing ideas or concepts (Mumford, 2003; Simonton, 2008). It may be manifested also in the production of creative outcomes that are both *original* and *useful* (Baas et al., 2015; Mumford, 2003; Saul & Leikin, 2010). A more common conception of creativity – also applied by us in this study – suggests that it is simply the act of making something new and different from what others have made (cf. “little c” or “relative creativity”, see Leikin, R., 2013) or raising as many ideas as possible and selecting the most suitable one (Cushen & Wiley, 2011). To some extent, this last definition reflects Guilford's (1967) suggestion to distinguish between convergent and divergent thinking. The term *divergent* thinking, also called *flexible* thinking, is sometimes (often incorrectly) used as a synonym for creativity, that is creative thinking (e.g., Tranter & Koutstaal, 2008).

Convergent and divergent thinking seem to demand different types of cognitive control. Local competition, *i.e.* a competition without prior prejudice toward a specific stimulus, during divergent thinking will lead to a random response, while biased competition, *i.e.* a competition with prior prejudice toward a specific stimulus, during convergent thinking will lead to strong top-down processes (Hommel et al., 2011). Accordingly, these two types of thinking may be perceived, at least partly, as processes that contradict, or even cancel, one another.

While the traditional concept of creativity includes mostly divergent thinking (Hommel et al., 2011), more recent research suggests that creative thought is much broader and more complex than flexible (divergent) thinking (Silvia, 2015). It was shown, for example, that a creative outcome is the result of multiple cognitive processes including, in addition to flexible thinking and set shifting (cognitive flexibility), divergent and convergent thinking and the use of flat and broad associative hierarchies (Baas et al., 2015; Sio & Ormerod, 2009). Apparently, creativity as a cognitive process requires the coordinated participation of a particular set of executive functions (Cushen & Wiley, 2011). For example, Zabelina and Robinson (2010) suggested that creative people have flexible cognitive control that gives them the ability to manage their executive functions and switch from an automatic, highly associative process to a sustainable, goal-directed process. Generally, flexibility is thought to be crucial to the creativity process (Vartanian, 2009). However, only *cognitive flexibility* (primarily set-shifting and cognitive control, cf. Ionescu, 2012) has been found to be much stronger among bilinguals than among monolinguals, since they constantly switch back-and-forth between their languages (Bialystok & Viswanathan, 2009; Soveri et al., 2011; Verreyt et al., 2016; for contradictory data see Paap & Greenberg, 2013).

In this context, it has been proposed that among bilinguals (and especially among early and balanced bilinguals) the mental juggling of two languages provides an advantage in the development of definitive cognitive mechanisms underlying creative ability (Leikin, M.,

2013). In addition to cognitive flexibility, *inhibition* was also found to benefit from bilingualism (Bialystok, 2010; Kharkhurin, 2011). This executive function appears to play an especially important role in *convergent thinking* because it requires a person to inhibit the unsuitable solutions and focus on the most practical and original ones.

Conjecturing further regarding the possible mechanisms involved in the creativity process while being simultaneously influenced by bilingualism, we should note that being creative seems to demand a well-developed *working memory* (Takeuchi et al., 2011). The problem being solved must initially be held in the working memory and then be connected to different semantic networks. Accordingly, working memory seems to be a functionally important system for the facilitation of a wide range of cognitive activities such as reasoning, problem solving, comprehension and other types of higher order cognitive processes (Baddeley, 2003; Just & Carpenter, 1992). Working memory capacity and fluid intelligence (cf. creativity) have been proven to be strongly correlated traits by Shipstead, Harrison, and Engle (2016). In turn, advantages in working memory were found more in bilinguals compared with monolinguals (Birke Hansen et al., 2016; Morales et al., 2013) and in early bilinguals compared with later bilinguals (Carlson & Meltzoff, 2008).

2. Current research

These empirical evidences with regard to the cognitive mechanisms related to bilingualism and creative thinking ability served as the starting point for our study. We suggested examining, along with actual executive functions (*i.e.* verbal and non-verbal working memory, cognitive flexibility, attention, and inhibition), performance on two cardinal different types of creativity tasks among balanced and non-balanced adult bilinguals. For this purpose, we chose to examine university students who, besides their native language, either Hebrew or/and Russian, learned English at a high academic level (*i.e.*, a level allowing students to read scientific literature). The distinction between the two groups (native Hebrew-speakers *versus* native Russian-speakers) was based on the fact that participants from the second group were balanced Russian/Hebrew bilinguals. The balance factor was defined on the basis of usage and proficiency criteria (participants' self-definition as speakers of two native languages, data from the Language Experience and Proficiency Questionnaire (LEAP-Q), see Marian et al., 2007) and the impression received by the researchers).

Accordingly, for examination of creative ability, we suggested using the Remote Associates Test (RAT) (Mednick, 1962) and the figural part of Torrance Test of Creative Thinking (TTCT) (Torrance, 1974). RAT is a verbal test typically associated with convergent thinking and insight-based problem solving (Aberg et al., 2017; Agnoli et al., 2016). In turn, Form A of TTCT (*i.e.* Thinking Creatively with Pictures (TCP)) assesses figurative (*i.e.* non-verbal) divergent thinking ability in such classical dimensions as fluency, flexibility, originality and elaborateness (Kim, 2006; Torrance, 1974).

3. Research goals and hypotheses

In the context of above-mentioned consideration, we proposed that the contribution of such executive functions as working memory, inhibition and cognitive flexibility to the solving

of creative problems would vary in different groups of bilinguals and for different types of creative tasks.

Accordingly, the first aim of the present study was to ascertain whether or not differences exist between balanced and non-balanced adult bilinguals in their performance on two creativity tasks which are primarily associated with divergent or convergent thinking. This aim leads to the following hypothesis: If balanced bilingualism generally has a positive effect on an individual's cognitive flexibility, then this effect will be achieved more in divergent thinking and less in convergent thinking (*i.e.* in TTCT but not in RAT).

The second aim of the present study was to ascertain whether or not executive functions have a significant influence on the performance of creativity tasks. The study therefore examines hypothesis 2: Balanced and non-balanced bilinguals will differ in the level of their executive functions, and this distinction will result in differences in their respective performance on the two different creativity tasks mentioned above.

Third, the present study aimed to examine the interrelationship between two factors – balanced bilingualism and language – in participants' performance on the RAT task in the respective languages. For both participants' groups, English was a foreign language being learned in academic frameworks, while Hebrew in the first group, and both Hebrew and Russian in the second group, were native (L1) languages. In this case, we hypothesized (#3) that there will be a correlation only between Hebrew and Russian RAT performance in the balanced bilingual group.

4. Method

4.1. Participants

A total of 53 male university students from the North of Israel participated in this study. The subjects were divided into two groups: (1) 25 bilingual students (Hebrew/English) whose mother tongue is Hebrew (henceforth the Hebrew group, $M_{age} 28.36$ years, $SD = 2.68$); and (2) 28 trilingual subjects (Russian/Hebrew/English) whose mother tongue (L1) is Russian (henceforth the Russian group, $M_{age} 27.14$ years, $SD = 2.37$). In this case, we use a working definition of bilingualism that requires functional usage of any of two or three languages (Leikin, M., 2013).

All participants from the Russian group had emigrated from Russia to Israel no later than 15 years prior to conducting the experiment (mean age of emigration: 9.32, $SD = 2.12$; (cf. definition of early bilingualism in Luk et al., 2011). They attended Hebrew-speaking schools (with a high-school graduation diploma) and used Hebrew at their work places; therefore, they were able to acquire a high level of Hebrew as second language (L2). Note that, in Israel, a prerequisite for university admissions is passing a psychometric examination given in Hebrew. As for their native Russian, all participants reported that they regularly read literature in Russian as well as Hebrew, and use both languages in their private life.

Students from both experimental groups learned English as a foreign language in school and have used it intensively due to the demands of academic studies in Israel. Note in this context, that in Israeli schools, English is taught at one of three possible levels: low, medium and high. All research participants studied English at the highest level. An additional prerequisite

for university admissions is passing the English language exam with a minimum grade of 75%. Both participants' groups were characterized by a formal, but not necessarily high, level of English. Accordingly, we assumed that these were two distinct groups of participants not only from the viewpoint of their native language, but also in view of their type of bilingualism: a balanced bilingual group (actually, trilingual students from the Russian group) *versus* a non-balanced bilingual Hebrew group. Such a group definition was also based on participants' self-definition as speakers of one or two native languages, data from the LEAP-Q, see Marian et al., 2007) and the impression received by the researchers (speakers of the corresponding languages) from a short conversation with the participants in each of their two/three languages.

All participants were right-handed, had no history of learning disabilities or attention disorders and displayed normal or corrected vision in both eyes. All were paid volunteers with a middle-to-high socioeconomic status on average. The age difference between the two groups was not significant: $t = 1.76$, $p = .085$.

4.2. Measures

I. *Creativity* was examined by using the RAT and figural Form A of the TTCT.

1. The RAT (Mednick, 1962; Mednick, S. A. & Mednick, M. T., 1967; Hebrew version of RAT – see Levin & Nevo, 1978; Russian version based on Razumnikova, 2007) measures verbal creative thinking (mostly, convergent thinking) without requiring specific knowledge in any particular field. The test consists of 30 items (a mix of compound RAT and associative RAT similar to Sarnoff A. Mednick's original test). Each item consists of three words that can be associated with a solution-word in a number of ways. For example, the three words SAME/TENNIS/HEAD are associated with the solution MATCH by means of synonymy (same = match) and semantic association (tennis match and match head). The score is the number of correct solutions. The test was presented to the native Russian speakers in English, Hebrew and Russian and to the native Hebrew speakers in Hebrew and English.

2. Figural Form A (TCP) of the TTCT (Torrance, 1974). The test consists of the following three 10-minute tasks: picture construction, picture completion, and repeated figures (parallel lines). According to Torrance (1974), two dimensions of divergent thinking (*i.e.* originality and elaboration) are measured by the first task, and four dimensions (*i.e.* fluency, flexibility, originality, and elaboration) by the other two tasks. In this case, the fluency measure refers to the number of different ideas one can produce; flexibility refers to the variety of ideas one produces; originality refers to how unusual the ideas one produces are; and elaboration refers to richness of detail in the ideas one produces.

II. *Executive functions* were examined using four standard cognitive tests as follows:

1. Wisconsin Card Sorting Test (WCST) (Berg, 1948) was used for assessment of *cognitive flexibility*.

During the test, participants are presented with stimulus cards with shapes on them. These cards differ in color, number, and form of the shape. Participants are required to sort these cards into two piles. While they are not told which stimulus dimension to use for sorting the cards, the administrator does tell the subject if a particular match is correct. In the course of the test, the sorting rules are suddenly altered, and the participant must discover the new sorting rule in order to be successful.

2. The WCST score is composed of six different measures (Heaton et al., 1993). Although WCST is a widely-used tool and known as a precise measure of executive functions, it is difficult to determine the specific cognitive mechanisms underlying its different measures due to the test's complexity. A number of neuro-imaging and factor-analysis studies that employed WCST have demonstrated that several cognitive processes come into play: the individual's ability to shift sets, solve problems and maintain responses (Greve et al., 2005). Although a significant variation was found, the majority of studies argue for a two-factor test structure (Greve et al., 1998; Lie et al., 2006). The first factor relates to mental flexibility and consists of the following scores: (1) number of completed categories, (2) total number of correct responses, and (3) total number of errors. The second factor is measured by "failure to maintain set" and mostly relates to memory and attention. Accordingly, we chose to refer to *cognitive flexibility* (composite measure) and *attention* as reflected by the abovementioned WCST measures.

3. Eriksen flanker task (Fan et al., 2002), which mainly examines *inhibition*, is conducted using a computer. Subjects are presented with a horizontal array of five arrows and are instructed to pay attention to the direction of the center arrow and ignore the other ones. Subjects have to press the left key for a left-facing-center arrow, and the right key for a right-facing-center arrow. The flanking arrows can all either point in the same direction as the target arrow (e.g., <<<<< congruent condition), or in the opposite direction (e.g., <<><< incongruent condition). Subjects receive 40 congruent and 40 incongruent trials in random order. For each trial, the reaction time and correct responses are scored (composite measure).

4. The digit span test, consisting of two parts, was used for assessing verbal-based working memory. In the first, subjects are asked to repeat a series of numbers in the same order as presented in the stimulus. This part consists of 16 blocks arranged so that the first block contains two numbers and the last block contains eight numbers.

In the second part, the participants are asked to repeat a series of numbers in the reverse order from the stimulus. This part consists of 14 blocks arranged so that the first block contains two numbers and the last block contains seven numbers.

5. The CBTT (Milner 1971), which was used for testing *spatial working memory*, consists of a set of nine identical blocks (3 X 3 X 3 cm) irregularly positioned on a wooden board (23 X 28 cm). The experimenter points to a series of blocks at a rate of one block per second. In the first part of the test, the subject is asked to point to the same blocks in their order of presentation. In the second part of the test, the participant is required to point to the same blocks in the opposite order of presentation. The length of the block sequences increases until recall is no longer correct.

Procedure: Participants were tested individually while seated at a table in a quiet room. The tasks were administered in the same order as in the "Method" section (see above) in a paper-and-pencil format. There were two test sessions for each participant.

5. Data analysis

In order to examine the first and second hypothesis of the study, multivariate analysis of variance (MVA) was conducted with group as an independent factor to compare participants' performance on the four cognitive tests (Table 1) and on the two creativity tests (Table 2).

To test the study's third hypothesis, a series of paired sample t-tests (PSTTs) (with Bonferroni correction of significance level from .05 to .0125) was performed to compare participants' performance on the RAT in the three different languages (Table 3).

Additionally, to test possible relationships between the measures of the RAT and TTCT creativity tests, Pearson correlation analyses (with correction of significance level from .05 to .0125) were performed separately in both experimental groups. In a similar way, correlations between the results in the cognitive and creativity tasks were examined separately for the Hebrew and Russian groups, to validate the second hypothesis of the study.

The study received research ethics committee of Faculty of Education of University of Haifa, Haifa, Israel approval.

6. Results

Results of participants' performance on the four cognitive tests, along with results of MVV (Multivariate Wilks' λ $F_{(6,46)} = 1.569$, $p = .178$, $\eta^2 = .170$, Observed power = .545) are presented in Table 1.

Inspection of Table 1 shows no significant differences between the two experimental groups in verbal-based and spatial working-memory scores, nor in cognitive flexibility and attention. At the same time, a significant distinction between the two research groups, in favor of the Russian language group, was found on flanker's inhibition test (FIT). However, additional separate analysis of reaction time ($F = 3.652$, $p = .062$) and correct responses ($F = 3.652$, $p = .062$) in FIT did not reveal significant differences between the two groups.

Results of participants' performance on the two creativity tests, along with results of MVV (Multivariate Wilks' λ $F_{(6,46)} = 3.859$, $p = .003$, $\eta^2 = .335$, Observed power = .943) are presented in Table 2.

Table 1. Results of performance on the four cognitive tests in the two experimental groups (*M* and *SD*) (source: created by authors)

	Hebrew group (<i>n</i> = 25)	Russian group (<i>n</i> = 28)	F	p	η^2
Digit span forward	12.7(2.5)	12.3(2.6)	.442	.509	.009
Digit span backwards	9.2(3.4)	9.5(3.8)	.052	.821	.001
Digit span mean	11.0(2.5)	10.9(2.9)	.027	.870	.001
Corsi blocks forward	12.6(3.2)	12.6(2.7)	.003	.954	.000
Corsi blocks backwards	8.8(3.9)	9.9(3.3)	1.398	.242	.027
Corsi blocks mean	10.7(3.2)	11.3(2.6)	.582	.449	.011
Cognitive flexibility ¹ (Wisconsin Card Sorting Test)	-.0013(.29)	.0011(.58)	.000	.985	.000
Attention (Wisconsin Card Sorting Test) ¹	-.11(1.03)	.10(.98)	.586	.448	.011
Inhibition (flanker) ¹	-.25(.68)	.23(.85)	5.144*	.028	.092

* $p < .05$.

¹ - The scores in these three complex measures are presented as z-values.

As one can see, significant differences between participants from the Hebrew and Russian groups were found in the English version of RAT and in two measures of TTCT: fluency and flexibility. In this case, all differences were in favor of the Russian group.

The series of PSTTs (with Bonferroni correction of significance level from .05 to .0125) was carried out to compare participants' performance on the RAT in the different languages (Table 3).

An inspection of Table 3 shows significant differences, in favor of the Hebrew language, between Hebrew and English RAT scores in both the Hebrew and Russian experimental groups. Specifically, for the Russian group, it was found that there were no differences between results in Russian and Hebrew versions of RAT while scores in the English-language RAT were significantly worse than in the RAT in Russian. That is, Russian-speaking participants performed on the Hebrew and Russian versions of RAT at approximately the same level of success, and in both languages their scores were significantly better than in the English version.

Table 2. Results of performance on the two creativity tests in the two experimental groups (*M* and *SD*) (source: created by authors)

	Hebrew group (<i>n</i> = 25)	Russian group (<i>n</i> = 28)	F	p	η ²
Remote Associates Test Hebrew	7.6(3.3)	8.8(3.2)	1.791	.187	.034
Remote Associates Test English	2.6(1.5)	4.4(1.6)	17.573***	.000	.256
Remote Associates Test Russian		7.9(3.3)			
Torrance Test of Creative Thinking Originality	43.0(11.9)	46.4(14.7)	.819	.370	.016
Torrance Test of Creative Thinking Elaboration	45.9(14.4)	49.9(13.2)	1.098	.300	.021
Torrance Test of Creative Thinking Fluency	19.0(6.4)	25.9(7.6)	12.564***	.001	.198
Torrance Test of Creative Thinking Flexibility	17.7(5.2)	21.9(6.1)	6.999*	.011	.121

p* < .05, **p* ≤ .001.

Table 3. Results of the Remote Associates Test in three different languages (*M* and *SD*) and paired sample *t*-test (source: created by authors)

	Hebrew group (<i>n</i> = 25)	Russian group (<i>n</i> = 28)
Remote Associates Test Hebrew	7.6(3.3)	8.8(3.2)
Remote Associates Test English	2.6(1.5)	4.4(1.6)
Remote Associates Test Russian		7.9(3.3)
English <i>versus</i> Hebrew	<i>t</i> = -16.887*, <i>p</i> < .0125	<i>t</i> = -14.279*, <i>p</i> < .0125
Russian <i>versus</i> Hebrew		<i>t</i> = -.1513, <i>p</i> = .142
English <i>versus</i> Russian		<i>t</i> = -17.643*, <i>p</i> < .0125

To test possible relationships between the measures of the RAT and TTCT creativity tests, a Pearson correlation analysis was performed. Results showed that there were no significant correlations between the two tests nor was there a significant correlation between RAT scores in the Hebrew and English versions in the Hebrew group. At the same time, in the Russian group, there were strong intercorrelations among performance results on all three versions of RAT: (1) Hebrew and English RAT ($r = .751, p < .0125$), (2) Hebrew and Russian RAT ($r = .674, p < .0125$), (3) and English and Russian RAT ($r = .692, p < .0125$). Additionally, in the Russian group a single significant correlation between the Hebrew version of RAT and inhibition ($r = .511, p < .0125$) was found. There were no other significant correlations between the performance results on the creativity and executive-function tests.

In order to control a possible confounding effect of fluency on flexibility and originality (Clark & Mirels, 1970) we additionally examined separate ratio scores (Runco et al., 1987), *i.e.*, originality/fluency and flexibility/fluency. This analysis led to consistent results: significant and non-significant correlations among measures of TTCT and RATs did not change, apart from one new significant correlation that appeared in the Russian group, *i.e.* correlation between originality/fluency ratio and Hebrew RAT ($r = -.483, p < .009$).

7. Discussion

The present study explored the interrelationship between the type of bilingualism (*i.e.* balanced *versus* non-balanced) and between convergent and divergent thinking as expressed in various creativity tasks in a sampling of 53 adult male university students. In addition, we examined a hypothesis that executive functions serve as mediators between two complex phenomena: bilingualism and creativity. In this regard, we put forward a total of three hypotheses, which were only partly confirmed by the results of the present study.

Based on data gleaned from the literature, we suggested that differences between Russian (balanced bilingual) and Hebrew (non-balanced bilingual) groups would be evident in the TTCT but not in the RAT. This hypothesis was confirmed for the most part. The findings showed that, compared to the Hebrew bilingual group, the Russian trilinguals performed significantly better on the TTCT, particularly in fluency and flexibility measures. Compared with non-balanced bilinguals, they also demonstrated a prominent advantage in the aspect of inhibition.

An advantage in cognitive control is thought to relate to bilingual experience and especially to early balanced bilingualism (Bialystok, 2010). At the same time, this ability is closely associated with divergent thinking, or with the flexibility component of creativity (Wang et al., 2017). This view seems to be in line with the results of the Russian group. The highest scores in the fluency and flexibility measures of the TTCT (which in turn is more closely related to divergent thinking) characterized these participants. Yet, contrary to our second hypothesis, we did not find any significant correlations between performance on the TTCT and participants' scores on the inhibition and/or cognitive flexibility tasks. It may be suggested, however, that these results were caused by the low sensitivity of the cognitive tasks used in this study for adult university students. These standard tests on executive functions did not reveal distinctions between the two experimental groups (even if certain differences

between these groups exist). Accordingly, this issue must be tested further by using new more sensitive tasks.

Passing to the findings on the RAT, note that no differences were found between the two experimental groups on the Hebrew version of this test. It is commonly thought that RAT and TTCT evaluate different domains of creativity, namely: linguistic creativity, mostly associated with convergent thinking, and figurative creativity, mostly linked to divergent thinking (Agnoli et al., 2016; Kim, 2006; Mednick, 1962; Torrance, 1974). Our findings seem to validate this assumption, since no significant correlations between performances on these two creativity tests were revealed in either experimental group. This subject, however, demands further research because the obtained data may be explained (at least partly) by the study's relatively low sample size.

Performance on the English version of RAT demonstrated that, although Russian speakers performed better on the test than Hebrew native speakers, both groups' English proficiency was significantly poorer compared with that of the Hebrew language (and, correspondingly, that of the Russian language in the Russian group). These findings confirm our preliminary definition of Hebrew-speaking participants as being non-balanced Hebrew/English bilinguals. At the same time, the superiority of Russian speakers in the English version of RAT seems to relate to their balanced (Hebrew/Russian) bilingualism (Bialystok, 2011; Schwartz et al., 2007). Moreover, only in the Russian group were there significant intercorrelations among the three versions of the RAT (Hebrew, Russian, and English). Seemingly, this finding confirms our hypothesis that learning a third language is positively influenced by the complex linguistic system of balanced bilinguals (Schwartz et al., 2007). Furthermore, the noted intercorrelations perhaps indicate that in the Russian group (balanced bilinguals), the RAT in secondary languages (second and third languages: L2 and L3) was carried out by means of a uniform language mechanism and in a similar way.

Our second hypothesis suggested that executive functions such as verbal and non-verbal working memory, attention, inhibition and cognitive flexibility contribute differently to performance on different creativity tasks among balanced and non-balanced bilinguals. Obtained results demonstrated that for the most part there were no significant differences between the two groups' performance on cognitive tests (Table 1). The only exception concerned inhibition (FIT) which was significantly stronger in the Russian group (balanced bilinguals) compared with the Hebrew group (non-balanced bilinguals). In previous studies, inhibition was found to benefit from bilingualism (e.g., Bialystok, 2010; Kharkhurin, 2011), though Madrazo and Bernardo (2012) found no differences between bilingual and trilingual university students in terms of inhibitory control. Note, however, that Madrazo and Bernardo used a different test in their study on inhibition from those employed by the current research. Moreover, in our study, the trilingual group represented balanced bilinguals whose English proficiency (L3) was relatively higher than that of the Hebrew group (see results of the RAT English version). Note in this context that no correlations (with only one exception) were revealed between executive functions and the figurative and verbal creativity tasks, whereas differences were found between the two groups' performance on TTCT (fluency and flexibility measures). Accordingly, the central hypothesis of our study was confirmed only in part. In this case, we suggest that the results obtained in the present study may be explained

by two interrelated factors: participants' age (adult university students) and their language proficiency level (*i.e.* balanced *versus* non-balanced bilinguals). It may be hypothesized that the standard tests on executive functions used in our study are insufficiently effective for differentiation between adult bilinguals and trilinguals. Possibly, in this case, the differences between balanced and non-balanced bilinguals are not so prominent compared, for example, to children who acquire second or third languages (cf. Poarch & Hell, 2012; Sorge et al., 2017). Perhaps for the same reason, we could not confirm the hypothesis concerning executive functions' mediation between bilingualism and creativity.

Conclusions and limitations

To summarize, the present study confirms the hypothesis that balanced bilingualism positively influences divergent thinking. These results, however, were obtained in a relatively small and specific group of participants – *i.e.* Russian-speaking trilingual university students – and by using only standard tests on creativity and executive functions. These circumstances perhaps explain why the obtained findings do not allow for an unequivocal confirmation, or disproof, of the role of executive functions as mediators between bilingualism (in general or for balanced bilingualism in particular) and creative ability. This issue remains urgent for cognitive model of the interrelationship between bilingualism and creativity requires more profound investigation. Further research into this and related issues has to consider the limitations stated above. Factors which might mitigate the aforementioned limitations are as follows: an increase in the number of research subjects (see, for example, observed power for cognitive tasks) or in the variety of their ages and types of bilingualism; and development of new and more effective tests on divergent and convergent thinking, as well as on relevant executive functions (*i.e.* working memory, cognitive flexibility and inhibition).

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SAŲVEIKA TARP DVIKALBYSTĖS, VYKDOMŲJŲ FUNKCIJŲ IR KŪRYBIŠKUMO SPRENDŽIANT UNIVERSITETO VYRIŠKOSIOS LYTIES STUDENTŲ PROBLEMAS

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Santrauka

Šiame tyrime nagrinėjama sąveika tarp dvikalbystės, vykdomųjų funkcijų ir kūrybiškumo sprendžiant universiteto vyriškosios lyties studentų problemas. Šiame kontekste taip pat analizuojami du veiksniai, svarbūs siekiant suprasti šią temą, t. y. dvikalbystės rūšį (vienodai gerai įvaldyta versus nevienodai gerai įvaldyta dvikalbystė) ir kūrybinio mąstymo tipą (konvergentinis versus divergentinis mąstymas). Tyrime dalyvavo 28 asmenys, kalbantys trimis kalbomis – rusų, hebrajų ir anglų (asmenys, vienodai gerai kalbantys dviem kalbomis, t. y. rusų ir hebrajų) bei 25 asmenys, nevienodai gerai kalbantys hebrajų ir anglų kalbomis. Visi dalyviai atliko keletą standartinių užduočių, skirtų vykdomosioms funkcijoms (Viskonsino kortelių atrankos testas, Erikseno šoninių rodyklių užduotis, skaičių eilės pakartojimo testas, Corsio blokelių jungimo testas) bei du kūrybiškumo testus – Torrance'o kūrybinio mąstymo testą (paveikslas A) ir tolimų asociacijų testą (skirtą atitinkamoms kalboms). Rezultatai atskleidė, kad rusakalbiams dalyviams geriau sekėsi atlikti Torrance'o kūrybinio mąstymo testą, ypač lankstumo ir sklandumo atžvilgiais. Naudojant tolimų asociacijų testą vienodai gerai dviem kalbomis kalbantys asmenys sulaukė didesnės sėkmės nei nevienodai gerai dviem kalbomis kalbantys asmenys, atlikę anglišką testo

versiją ir pademonstravę tokius pat rezultatus, spręsdami hebrajišką testo versiją. Šiuo atveju esama reikšmingų korelacijų tarp tolimų asociacijų testo rezultatų visų trijų kalbų atžvilgiu rusakalbių grupėje. Vadinasi, atrodo, kad vienodai gerai įvaldytą dvikalbystę taip pat charakterizuoja tinkamai organizuota kalbų sistema, kurioje visos kalbos, kuriomis kalba asmuo, yra tarpusavyje susijusios. Regis, tai reikšmingas veiksnys vienodai gerai dviem kalbomis kalbantiems asmenims, atlikusiems tolimų asociacijų testą skirtingomis kalbomis. Be to, atrodo, kad rezultatai patvirtina hipotezę, jog vienodai gerai įvaldyta dvikalbystė daro teigiamą įtaką divergentiniam mąstymui. Nebuvo patvirtinta hipotezė, esą dviem kalbomis kalbančių asmenų, atliekančių kūrybines užduotis, sėkmė ar nesėkmė yra susijusi su skirtumais, plėtojant jų vykdomąsias funkcijas.

Reikšminiai žodžiai: dvikalbystė, pažinimas, konvergentinis mąstymas, kūrybiškumas, divergentinis mąstymas, vykdomosios funkcijos.