International Journal of Bilingualism
http://ijb.sagepub.com/

The effect of bilingualism on creativity: Developmental and educational perspectives

Mark Leikin

International Journal of Bilingualism 2013 17: 431 originally published online 28 March 2012
DOI: 10.1177/1367006912438300

The online version of this article can be found at:
http://ijb.sagepub.com/content/17/4/431

Published by:
SAGE
http://www.sagepublications.com

Article

The International Journal of Bilingualism

International Journal of Bilingualism
17(4) 431–447

DOI: 10.1177/1367006912438300
ijb.sagepub.com

The effect of bilingualism on creativity: Developmental and educational perspectives

Mark Leikin
University of Haifa, Israel

Abstract

This study is aimed at examining the possible effect of bilingualism on creativity in nonmathematical and mathematical problem solving among very young bilingual and monolingual preschoolers. An additional factor that has been considered in this study is the *form* of bilingual education. Accordingly, three groups of children (mean age = 45.4 months at the beginning of the study) participated in this study: (a) 13 bilingual children from a bilingual (Hebrew–Russian) kindergarten, (b) 10 bilingual children from a monolingual (Hebrew) kindergarten, and (c) 14 monolingual children (Hebrew) from a monolingual kindergarten. All children performed the Picture Multiple Solution task on general creativity and the Creating Equal Number task on mathematical creativity. The results reveal that both early bilingualism and some form of bilingual education seem to influence the children's general and mathematical creativity. Moreover, differences between bilingual children from the bilingual kindergarten and monolingual children were more prominent (in favor of the bilinguals). In addition, the findings confirm the hypothesis concerning the differences between two types of creative ability in the context of bilingual and monolingual development.

Keywords

bilingualism, early childhood, general and mathematical creativity

Introduction

The present study has been prompted by limited, but somewhat contradictory, findings about the influence of bilingualism on the development of high-order cognitive functions, one of which is creativity (Bialystok, 2009; Ricciardelli, 1992a; Simonton, 2008). Although several decades ago there was consensus regarding the *negative influence of bilingualism* on children's mental and cognitive development (Genesee, 2009), at present there is near consensus regarding the *positive impact of bilingualism* (especially of *balanced bilingualism*) on children's cognitive, linguistic, and academic growth (Bialystok, 2001; Cummins, 2000; Simonton, 2008). The present study aims to

Corresponding author:
Mark Leikin, Department of Special Education, Laboratory for Neurocognitive Examination of Giftedness, Faculty of Education, University of Haifa, Haifa 31905, Israel.
Email: markl@edu.haifa.ac.il

examine the influence of early bilingualism and bilingual education on the development of creativity in solving nonmathematical and mathematical problems.

Theoretical background

Bilingualism and cognitive development

There is no evidence that bilingualism affects intelligence, but there is abundant, albeit controversial, evidence of negative, positive, or neutral influence of bilingualism on the development of different specific cognitive abilities and processes, including different forms of creativity (Bialystok, 2005; Ricciardelli, 1992a; Simonton, 2008).

Positive effect of bilingualism and study limitations. Several studies have demonstrated significant influence of bilingualism on cognitive development (for more details, see Bialystok, 2005; Thomas, 1992). The advantages of bilingualism have been reported across a variety of domains, such as creativity (expressed in divergent thinking) (Bruck, Lambert, & Tucker, 1976; Kessler & Quinn, 1987; Ricciardelli, 1992a; Simonton, 2008), problem solving (Adesope, Lavin, Thompson, & Ungerleider, 2010; Bialystok, 1999; Kessler & Quinn, 1980), and perceptual disembedding (Duncan & De Avila, 1979). It has been found that the performance of *balanced* bilingual students, in particular, is better than that of their monolingual peers on tests assessing general creativity and flexibility (Kessler & Quinn, 1987; Ricciardelli, 1992a, 1992b; Simonton, 2008; Torrance, 1966, 1974) as well as on tasks assessing concept formation (Bain, 1975).

Research by Bialystok (2001, 2005, 2009) has pointed to an advantage among bilingual children in developing control processes and in processing complex stimuli in tasks that require executive processing for conflict resolution, including switching and updating, even when no inhibition appears to be involved. Bilingual children exhibit better performance and earlier success on executive function tasks. Furthermore, research has demonstrated earlier development of the executive function in bilingual children (as early as age 3) compared with monolingual children (ages 4 and5) (Bialystok, 1999; Diamond, Carlson, & Beck, 2005; Kloo & Perner, 2005; Zelazo, Frye, & Rapus, 1996). A recent study (Carlson & Meltzoff, 2008) that examined the effect of bilingual experience on 50 kindergarten children's executive functioning in a Spanish–English group demonstrated that, despite having significantly lower verbal scores and parent education/income level than their peers, Spanish–English bilingual children's raw scores did not differ from those of their peers. But after statistically controlling for verbal score and age, native bilingual children performed significantly better on the executive function than did monolingual children. These studies provide important insights into the potential role of bilingualism in the development of cognitive abilities and skills such as divergent thinking (Kasof, 1997; Kharkhurin, 2008) and creativity (Adesope et al., 2010; Ricciardelli, 1992a; Simonton, 2008).

Positive effects of bilingualism, however, have not always been detected (see Bialystok, 2005 for review). Some studies reported negative effects (Macnamara, 1966), and others found no group differences between bilingual and monolingual participants (Rosenblum & Pinker, 1983; see also Adesope et al., 2010; Ricciardelli, 1992a; Simonton, 2008, for review). Although flexibility of thought (or divergent thinking) has been discussed in relation to bilingualism (e.g. Bialystok, 2005; Peal & Lambert, 1962), almost nothing is known about the relationship between bilingualism and mathematical creativity, except that bilingual children appear to be superior to their monolingual peers in their ability to focus attention and ignore misleading cues in mathematical problem solving (Bialystok, 2005). Moreover, limited attention has been paid to the influence of bilingualism on creativity in solving problems (Adesope et al., 2010; Bialystok, 2009; Ricciardelli, 1992a; Simonton, 2008).

Note that the quality or manner of the influence of bilingualism has not been sufficiently studied due to interference of a variety of factors, such as the socioeconomic status of bilingual versus monolingual groups (Gonzalez, 2006), the language of testing (i.e. first, second, dominant, well acquired, and so on), the specific tests being used (Darcy, 1963; Hakuta, 1986), the given cognitive domain (general vs. specific), and different specific abilities of the students (Bialystok, 2005; Simonton, 2008).

Note further that most research in the field has focused mostly on language creativity and on school-age children, adolescents, and adults, and has inadequately considered the issue from the developmental perspective, that is, in the earlier stages of bilingual development (Ricciardelli, 1992a; Simonton, 2008).

What is creativity? Creativity is usually considered to be a mental process involving the generation of new ideas or new connections between existing ideas or concepts (see Simonton, 2000, 2008, for review). Creativity can be manifested in the production of creative outcomes that are both *original* and *useful* (Saul & Leikin, 2010; Simonton, 2008). An alternative, more common conception of creativity suggests that it is simply the act of making something new and different from what others are making (cf. "relative creativity," Leikin, 2009). Guilford (1967) introduced a distinction between convergent and divergent thinking. Divergent thinking is sometimes used as a synonym for creativity in psychology literature. Other researchers have occasionally used the term *flexible* thinking (e.g. Tranter & Koutstaal, 2008).

Creativity has been studied from the perspectives of behavioral psychology, social psychology, psychometrics, cognitive science, artificial intelligence, philosophy, history, economics, design research, and business and management, among others (Saul & Leikin, 2010; Simonton, 2008). Studies on creativity have covered everyday creativity, exceptional creativity, and even artificial creativity (Davis & Rimm, 2004; Horowitz & O'Brien, 1985; Milgram & Hong, 2009; Piirto, 1999; Simonton, 2000, 2008; Sternberg & O'Hara, 1999).

In the present study, we use a model for the evaluation of mathematical creativity based on solving Multiple Solution Tasks (MSTs) (Leikin, 2009), which are assignments that explicitly require the solver to approach a mathematical problem in different ways. This model is based on a definition of creativity suggested by Torrance (1974), based on four mutually related components: fluency, flexibility, novelty, and elaboration (see also Simonton, 2000, 2008). *Fluency* relates to the continuity of ideas and use of basic and universal knowledge. *Flexibility* is associated with changing ideas, approaching a problem in various ways, and producing a variety of solutions. *Novelty* is characterized by a unique way of thinking and by unique products of a mental or artistic activity. *Elaboration* relates to the ability to describe, illuminate, and generalize ideas.

Leikin (2009) suggested a scoring scheme for the evaluation of mathematical creativity as a combination of the fluency, flexibility, and originality of the solutions produced by the solver. The present study has utilized this scoring scheme for the evaluation of creativity in solving nonmathematical and mathematical MSTs (for details, see the "Methodology" section).

Bilingualism and creativity

As noted above, studies on relationships between bilingualism and creativity have dealt mostly with creativity in the area of language or figurative creativity (Kharkhurin, 2010b; Lasagabaster, 2000; Simonton, 2008). Even so, findings of previous studies are somewhat contradictory.

Simonton (2008) presents a wide and comprehensive review of the research on relationships between bilingualism and creativity. The author notes that the contribution of bilingualism to the development of creative ability has practically not been examined from the historiometric point of view, and there have been very few studies of causal relationships between bilingualism and creativity since 1992, when Ricciardelli published her very interesting review of 24 studies on this subject. However, later, too, only a few new studies have appeared dealing with the interference between these two phenomena (see Adesope et al., 2010; Kharkhurin, 2010a, for review).

Even so, literature data (Adesope et al., 2010; Ricciardelli, 1992a; Simonton, 2008) generally support the hypothesis on the existence of positive correlations between bilingualism and creativity. For example, it was found (Simonton, 2008) that bilinguals scored higher than monolinguals on verbal originality and flexibility and on figural originality and fluency. Note, however, that in the recent research of Kharkhurin (2010a) significant differences between nonverbal and verbal creativity in the bilingual context were found. Positive influence of bilingualism on nonverbal creative behavior was shown, while in verbal creativity measures monolinguals were found to be better than bilinguals. These data, at least, partly contradict the results of Cummins' studies (1975, 1976, 2000). Cummins found that balanced bilinguals obtained higher scores on the fluency and flexibility scales of verbal divergence, and obtained marginally higher scores on the originality scale than did matched nonbalanced bilinguals. The matched monolingual group obtained scores similar to those of the balanced bilingual group on verbal fluency and flexibility but scored substantially higher than the nonbalanced group. On originality, the monolinguals scored similarly to the nonbalanced bilinguals and substantially lower than the balanced group. Probably because of the small number of participants, the results did not reach customary levels of statistical significance. The differences between the matched groups of balanced and nonbalanced bilinguals suggest that the relationship between bilingualism and superior divergent thinking skills is not a simple one. Cummins (1976) offered three hypotheses to explain why there may be a beneficial link between bilingualism and divergent and creative thinking. The *first* explanation is that bilinguals have a wider and more varied range of experiences than monolinguals because they operate in two languages and possibly in two cultures. The *second* explanation concerns a switching mechanism. Because bilingual children must switch from one language to another, they may be more flexible in thinking. The *third* explanation is based on the process of objectification (Cummins & Gulustan, 1974). Bilinguals may be involved in a process of comparing and contrasting two languages, seeking varying language rules and differentiating between word sounds and word meanings (i.e. processes developing metalinguistic abilities such as phonological or morphological awareness; see Leikin, Schwartz, & Share, 2010, for review).

It should be noted, however, that there were prominent differences not only between the findings of Cummins (1976, 2000) and Kharkhurin (2010a, 2010b) but also concerning the experimental design of these studies, as well as participants' age, languages, and cultural background. Meanwhile, factors of language proficiency, age, and culture have apparent importance in regard to the issue being considered here (Adesope et al., 2010; Ricciardelli, 1996a; Simonton, 2008).

Simonton (2008) indicates a variety of important methodological and theoretical factors that should be taken into account, considering mutual relationships between bilingualism and creativity. On the one hand, there is no doubt that creativity is a complex cognitive phenomenon often correlating with IQ (creative and intelligence tests). On the other hand, bilingualism is also a complex concept. Accordingly, relationships between creativity and bilingualism may be influenced by a variety of additional factors, such as cultural features, age, or type of bilingualism. For example, in his review Simonton (2008) notes that there are positive correlations between creativity and proficiency in two languages (see also Adesope et al., 2010; Ricciardelli, 1992a, 1992b): for example, differences between fluent and nonfluent bilinguals. Accordingly, the issue of interference between bilingualism and creativity seems to be relevant only in cases of balanced bilingualism or at least in cases of parallel development of two languages in the context of younger children.

Note, in addition, that little research effort has been invested to date in the investigation of the relationship between bilingualism and bilingual development, on the one hand, and creative thinking or creativity in problem solving, on the other. Moreover, there are very few studies on preschool children in this respect (Ricciardelli, 1996a). Finally, a review of the research literature in the field did not find any studies that compare general creativity and mathematical creativity in young children. It may be suggested, however, that differences should exist between these two domains since such differences have been found, for example, between language and figurative creativity (Kharkhurin, 2010b; Lasagabaster, 2000; Simonton, 2008).

Bilingual education

The study of early bilingualism must also take into account cultural and educational context. It has already been noted (e.g. Bialystok, 2009; Gonzalez, 2006) that the positive contribution of bilingualism to children's academic success and cognitive development depends also on socioeconomic and cultural factors. An additional issue that appears to be relevant for the study of bilingualism is "bilingual education" (Lasagabaster, 2000).

The term *bilingual education* is a simplistic label for a complex phenomenon (Baker, 2001; Mackey, 2001; Otheguy & Otto, 1980). Usually this term distinguishes between (a) education that uses and promotes two languages (a classroom where formal instruction fosters bilingualism) and (b) a relatively monolingual educational context for language minority children (a classroom where bilingual children are present, but bilingualism is not fostered in the curriculum). For example, Baker (2001) distinguishes between *weak* forms of bilingual education (such as Transitional, Submersion, and Separatist programs), which aims to assimilate young bilinguals into the social mainstream, and *strong* forms of bilingual education (such as Immersion, Heritage Language, and Two-way/Dual Language programs). The aim of the latter type is full bilingualism, with spoken language and literacy skills being acquired in both languages, either simultaneously or with an initial emphasis on the native language.

For example, the results of the study by Leikin, Schwartz, and Shaul (submitted) show that bilingual children from a bilingual kindergarten (with Russian as first language and Hebrew as second language) demonstrate a significantly more balanced development of both languages than do bilingual children in a monolingual kindergarten, who show somewhat better acquisition of Hebrew as the mainstream (socially dominant) language but lag considerably behind in the development of Russian, which is their native (heritage) language.

Research goals and hypotheses

The first aim of the present study is to check whether early bilingualism influences the development of creativity. This aim leads to the following hypothesis: If bilingualism has a positive effect on creative ability, then young bilingual children will demonstrate greater creativity in solving problems, both nonmathematical and mathematical, in comparison to monolingual children.

The second aim of the present study is to check whether the advantage of bilingual children depends (if at all) on the type of early bilingual education. The study examines hypothesis 2: If bilingual education has a positive effect on creative ability, then young bilingual children receiving a strong form of bilingual education (in a bilingual Russian–Hebrew kindergarten) demonstrate better creative thinking than do young bilingual children receiving the weak form of bilingual education (in a monolingual Hebrew language kindergarten).

Table 1. Three groups of participants.

	Bilingual kindergarten	Monolingual kindergarten
Children from bilingual families	BB group (n = 13)	BM group (n = 10)
Children from monolingual families		MM group (n = 14)

BB: bilingual children from a bilingual kindergarten; BM: bilingual children from a monolingual kindergarten; MM: monolingual children from a monolingual kindergarten.

Third, the present study aims to examine the possible effects of bilingualism on creativity in nonmathematical and mathematical problem solving among very young bilingual and monolingual preschoolers. Based on the data of research on creative behavior in different cognitive fields (e.g. language and nonlanguage creativity), we hypothesize that there is no unequivocal correlation between general and mathematical creativity.

Method

Participants

A total of 37 children (mean age = 45.4 months at the beginning of the study) were selected from seven kindergartens in the northern region of Israel. The children were divided into three groups (see Table 1):

1. Bilingual children from a bilingual kindergarten (henceforth the BB group, n = 13) who attended mixed-language (Hebrew and Russian) kindergartens where they were exposed to both Hebrew (L2) and Russian (L1) input.
2. Bilingual children from a monolingual kindergarten (henceforth the BM group, n = 10) who were bilingual (Russian–Hebrew) children from Hebrew (L2)-speaking kindergartens, exposed to high L2 input and no L1 input within the educational framework.
3. Monolingual children from a monolingual kindergarten (henceforth the MM group, n = 14) who were native Hebrew speakers attending the same Hebrew-speaking kindergartens as were the BMs.

All kindergartens were located in similar neighborhoods with an average socioeconomic level. The kindergarten teachers in the two target programs used the same curriculum provided by the Israeli Ministry of Education. The typical everyday curriculum included the following activities: discussion sessions (e.g. holidays and seasons), read-aloud sessions (asking questions about the story, discussion, and vocabulary enrichment), sports sessions, and art sessions. The curriculum of the bilingual program tended to ensure that both Russian and Hebrew were used daily.

Bilingual (Russian–Hebrew) kindergartens in Israel were established by an organization of Russian-speaking immigrant teachers with the aim of offering programs outside the school setting (Spolsky & Shohamy, 1999). This organization operates as many as 20 bilingual kindergartens nationwide. Education in these kindergartens is based on the *first language first* approach. This means that from the onset (age 1) of the kindergarten up to ages 2–3, Russian (i.e. L1 being the children's home language) is the predominant language of instruction and communication with the children, while they have passive exposure to Hebrew by means of songs and rhymes. From age 2 to 3, Hebrew (i.e. L2 being the dominant language of the country) is then added to Russian (for more details, see Schwartz, Moin, Leikin, & Breitkopf, 2010; Schwartz, Mor-Sommerfeld, & Leikin, 2010; Schwartz, Moin, & Leikin, 2011).

Table 2. Means and standard deviations of children's background measures.

Measure	BB group (n = 13)	BM group (n = 10)	MM group (n = 14)	χ^2	F
Gender (male/female)	5/8	4/6	6/8	0.16	
Age (in months) (2009)	45.8 (1.2)	45.7 (1.7)	45.4 (1.6)		0.274
Age (in months) (2010)	57.6 (1.3)	57.3 (1.5)	57.5 (1.2)		0.271
Mother's education in years	14.6 (1.8)	15.6 (1.9)	15.3 (2.3)		0.706
Father's education in years	14.9 (2.0)	16.8 (2.0)	15.5 (3.0)		1.79
Kindergarten tuition in NIS	1488.5 (22.0)	1484.0 (8.4)	1482.8 (7.2)		0.555
Years in kindergarten (2009)	1.0 (0.8)[b]	1.9 (0.6)[a]	2.5 (0.8)[c]		24.970***

BB: bilingual children from a bilingual kindergarten; BM: bilingual children from a monolingual kindergarten; MM: monolingual children from a monolingual kindergarten; NIS – New Israely Shekel.
Superscripts (a, b, c) indicate significant differences between the groups.
***$p < 0.001$.

The classification of children as monolingual or bilingual was based on a detailed questionnaire that collected information about the mother tongue of the child's parents, the language spoken at home by the parents, and the language spoken by family members and preschool caretakers. The questionnaire also recorded the general impressions of Russian–Hebrew bilingual and Hebrew-speaking monolingual examiners based on a conversation with the children. The native Russian-speaking bilinguals were Israeli-born children of Russian–Jewish immigrants from the former Union of Soviet Socialist Republic (USSR). Russian was the dominant language in the homes of all the children. Leikin et al. (submitted) have shown that children from the BM group performed below the level of their monolingual peers in Hebrew (active and passive lexicon, narrative ability) and below the level of their BB peers in Russian. At the same time, BM children performed slightly better in Hebrew than did BB children, but children from the BB group demonstrated a more balanced development of both languages.

There were no significant differences among the three groups in terms of mean age, gender, and socioeconomic status (Table 2).

Measures

Creative thinking tests

Pictorial Multiple Solution (PMS) task. The black-and-white picture from Kushnir's (1999) "I have a problem" notebook describes a problem as an everyday situation (see Appendix 1). In the picture, a small child-like kitten (easily associated as a coeval of the young participants in the study) wants to get its cap from a high shelf but is unable to do so. There are various objects in the picture that could be used to solve the problem: a chair, a stool, a bedside table, and a stick.

Participants were asked to suggest as many solutions as they could for the presented problem. Each answer was scored for fluency, flexibility, originality, and creativity using Leikin's (2009) model and scoring scheme for the evaluation of creativity. The *fluency* score was obtained by counting the number of solutions that the participant offered.

To evaluate *flexibility*, groups of solutions were established so that two solutions belong to separate groups if they employ solution strategies based on different principles, properties, or methods for problem solving. For example, "to get a stick," "to jump up," and "to call mom" are the decisions belonging to different groups, whereas "to climb on the chair," "to climb on the table," and "to climb on a ladder" all belong to the same group of solutions. Accordingly, children received a score of 10 for the first appropriate solution (Flx_1) (e.g. "to climb on the chair") and for a solution (Flx_i) belonging to a group of solutions different from Flx_1 (e.g. "to call mom" or "to stand up on tiptoes"). Children received a score of 1 for a solution (Flx_i) that belongs to one of the previously used groups but has a clear but minor distinction (e.g. "to climb on a ladder" vs. "to climb on the chair"). And finally, children received a score of 0.1 if the solution was almost identical to a previous solution (e.g. "to climb on the stool" vs. "to get on the chair"). A participant's total *flexibility* score on a problem was the sum of the flexibility scores of the solutions in the participant's individual solution space.

The *originality* (Ori) score was also calculated on the basis of a preliminary classification of solutions. In this case, however, all the answers of all the participants in the experiment were analyzed together. Accordingly, each solution received a corresponding individual score: Ori = 10 when a given solution was suggested by fewer than 15% of all participants, Ori = 1 when a given solution was suggested by more than 15% but fewer than 40% of participants, and Ori = 0.1 when a given solution was suggested by more than 40% of participants. A participant's total *originality* score on a problem was the sum of originality scores of all the solutions in the expert solution space (in this case, all solutions of all participants).

Classification of the solutions obtained in the experiment (their grouping for bringing out the *flexibility* and *originality* scores) was performed by three independent referees, showing a high degree of conformity of results with the selected criteria agreed upon in advance by the three referees.

The *creativity* score was calculated by multiplying the flexibility score of each solution by its originality score and then summing up the results of creativity scores obtained for all solutions of a particular problem by the participant (for details, see Leikin, 2009). This scoring scheme does not include fluency measure scores, since there is highest correlation between fluency and flexibility scores. In this case, the flexibility measure was found to be more accurate compared with fluency; it was also revealed that the final creativity scores did not depend significantly on whether the resulting formula for creativity scoring included fluency scores or not (Leikin, 2009)

The test was carried out twice: in June–July 2009 and in August–September 2010.

Creating Equal Number (CEN) task (borrowed from Tsamir, Tirosh, Tabach, & Levenson, 2009). Following the instructions of Tsamir et al. (2009) for this task, a child sat with an adult at a table in a quiet corner of the kindergarten. The child was presented with two distinct sets of bottle caps: three bottle caps were placed on one side of the table and five bottle caps were placed on the other side. No spare bottle caps were present. All bottle caps had the same shape, size, and color. The child was asked: "Can you make it so that there will be an equal number of bottle caps on each side of the table?" After the child rearranged the bottle caps, the interviewer returned the bottle caps to their original arrangement (three in one set, five in the other), and asked the child, "Is there another way of making the number of bottle caps on each side equal?" The rearrangement of the bottle caps (3 and 5) and the related question were repeated until the child signaled that he or she was done. (Tsamir et al., 2009, p. 6; see also Appendix 2)

Fluency, flexibility, originality, and creativity scores were calculated in the same way as in the previous test. In this case, however, we considered not only children's solutions (outcomes) but also the ways in which the problem was solved.

According to Tsamir et al. (2009), the CEN task can have five different solutions (outcomes): 4-4—that is, four caps in each set, 3-3, 2-2, 1-1, and 0-0. Additionally, the authors describe five different methods that may be used to solve the task. Some are one-step methods: (a) removing all the elements from both sets, this method leads to the outcome 0-0; (b) taking only from the larger set, which, in the given task, meant taking two elements from the set of five, obtaining the solution 3-3; (c) shifting from one set to the other, which, in our case, led to the solution 4-4; (d) taking from both sets a number of elements to obtain the same number of caps in each set, this method led to outcomes of 1-1 or 2-2; and (e) a two-step method involved collecting all the caps and redividing them to create two new sets from scratch. This method could result in any of the five above-mentioned outcomes of the task.

For the data analysis, the classification of Tsamir et al. (2009) was adapted to Leikin's (2009) model, so that the first appearance of any solution (i.e. the first-time use of a method) received a score of 10 on flexibility, and all others (e.g. outcomes of 3-3, 2-2, and 1-1 after the outcome of 4-4) in which the same method of solving the problem was applied received a score of 0.1. An exception was made for an outcome of 0-0, which was considered to be rare and especially interesting. Thus, on the originality measure, all outcomes (produced by any method of solution) received a score that depended on the percentage of children who used that solution. This task was performed only in the 2010 setting.

Tests were carried out in Russian or Hebrew, depending on the language that each child found more comfortable. Because attention was focused on the manner of problem solving rather than on the language in which the answers were given, all correct answers (i.e. relating to problem solving) in either language were considered.

Results

Background measures

Table 2 presents the children's background data. A series of one-way analyses of variance (ANOVAs) were conducted to evaluate the differences between the groups on the background measures.

It is apparent that the three groups did not differ significantly in gender, age, years of mother's and father's education, and kindergarten tuition. There were significant differences, however, among the three groups in terms of the number of years in the kindergarten (from the date of the beginning of enrollment), with monolingual children having spent more years in the kindergarten than the bilingual children.

Experimental measures

PMS task. The majority of bilingual children (from both the BB and BM groups) preferred to answer in Russian on the PMS task, only occasionally using Hebrew lexical items. Children's answers in both languages and in all three groups were identical in character. On average, children offered between 1 and 3 solutions (see the results in the fluency measure in Table 3), and their answers were not varied. The most common solution was to use any object on which the kitten could climb to reach the cap (e.g. "to climb on a chair"). Most often these were the objects represented in the picture: the chair, the stool, and the bedside table. Only in two cases did children suggest a ladder ("to climb on a ladder"). Another relatively frequent solution was to ask for the help of parents (e.g. "to call mom" or "dad and mom can lift him, and he will reach the shelf"). Other solutions such as "to jump up," "it is possible to reach with a fork," "to stand on tiptoes," and "to grow up" were rare if not unique, which was reflected in the originality and creativity results (see Table 3 for details). Answers such as "to buy another cap," "to sit and cry," and "to find another cap somewhere" were unique and considered to be erroneous. These and other answers such as "I don't know" were not considered in the fluency score calculation and were not taken into account in further analysis.

Table 3. Means and standard deviations of the children's performance.

		Measure	BB group (n = 13)	BM group (n = 10)	MM group (n = 14)	χ^2
Pictorial Multiple Solution task	First performance	Fluency	1.9 (0.6)	1.6 (1.0)	2.1 (1.1)	1.159
		Flexibility	14.6 (5.2)	14.0 (8.4)	12.9 (4.7)	0.303
		Originality	3.4 (4.8)	4.3 (5.2)	1.2 (2.6)	0.457
		Creativity	34.0 (48.2)	42.8 (52.4)	11.0 (26.1)	0.502
	Second performance	Fluency	5.2 (1.8)	4.2 (1.9)	3.9 (1.9)	3.615
		Flexibility	33.4 (15.5)	27.6 (8.6)	22.0 (8.0)	5.406
		Originality	9.0 (11.2)[a]	2.6 (4.1)[a,b]	1.1 (2.8)[b]	10.056**
		Creativity	72.2 (80.8)[a]	23.5 (41.8)[a,b]	9.4 (27.2)[b]	7.683*
Creating Equal Number task		Fluency	3.3 (1.1)[a]	3.4 (1.4)[a,b]	2.0 (1.3)[b]	8.029*
		Flexibility	16.3 (7.6)[a]	15.3 (9.3)[a,b]	10.6 (1.0)[b]	12.340**
		Originality	3.1 (4.0)[a]	3.3 (4.5)[a,b]	0.4 (0.5)[c]	14.382***
		Creativity	23.0 (38.4)[a]	25.5 (45.7)[a,b]	1.1 (0.3)[c]	18.101***

BB: bilingual children from a bilingual kindergarten; BM: bilingual children from a monolingual kindergarten; MM: monolingual children from a monolingual kindergarten.
*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

The findings presented in Table 3 show that in most cases, the standard deviations were very high. Accordingly, it has been decided to apply nonparametric comparisons for statistical analysis. In this case, we used a Kruskall–Walice ANOVA for between-groups comparisons.

Table 3 shows that there were no statistically significant distinctions among the three groups on the first performance of the PMS task. Different results were obtained, however, 12–13 months later, in the second performance. Although there were no differences among the children's groups in fluency and flexibility measures, there were significant differences between the BB and MM groups in originality (p=0.005) and creativity (p=0.012) measures.

Note that on the second performance of the PMS task, children from all three groups offered many more problem solutions than in the previous year (see the fluency results). The nature of the answers, which became far more varied, also changed. Together with standard answers such as "to climb on a chair" or "to call mom," which were still the most frequent ones, other recurring solutions were as follows: "to take a shoe and to reach," "to lift him," "to break the wall" (the wall holding the shelf with the cap), "to go up in an elevator," "to throw a bag at it, and the cap will fall down," "to climb on a rope," and so on. The number and the variety of solutions, and their novelty (individual and/or general), were reflected in dramatically increased scores for flexibility, originality, and creativity. In this case, the general advantage of bilingual over monolingual children was obvious, showing the highest standard deviations. Nevertheless, in the second performance, the distinctions between the BB and MM groups were statistically significant on the originality and creativity measures despite the high standard deviations.

The Wilcoxon signed-rank test was used to compare the first and second performances (within each group of participants). The results of analysis (Table 4) show that in all three groups there are significant differences between the first and second performances but only on the fluency and flexibility measures.

We conclude that group developmental changes in the performance of the PMS task occurred only on two measures, fluency and flexibility, whereas on the originality and creativity measures, no statistically significant differences were found.

Table 4. Within-group comparisons by related samples: Friedman's two-way analysis of variance by ranks.

Groups	PMS task: first vs. second performances	Mediana	P	PMS task vs. CEN task	Mediana	P
BB (n = 13)	Fluency	2.0 vs. 5.0	0.001	***Fluency	5.0 vs. 3.0	0.006**
	Flexibility	10.20 vs. 31.00	0.001	***Flexibility	33.42 vs. 13.00	0.002**
	Originality	0.30 vs. 3.10	0.087	Originality	3.10 vs. 1.30	0.116
	Creativity	1.01 vs. 23.01	0.087	Creativity	23.01 vs. 3.10	0.101
BM (n = 10)	Fluency	1.5 vs. 4.0	0.005	**Fluency	4.0 vs. 3.5	0.054
	Flexibility	10.05 vs. 27.60	0.005	**Flexibility	27.60 vs. 11.51	0.009
	Originality	0.60 vs. 0.45	0.721	Originality	.45 vs. 1.75	0.444
	Creativity	5.51 vs. 2.61	0.721	Creativity	2.61 vs. 2.65	0.838
MM (n = 14)	Fluency	2.0 vs. 4.0	0.008	**Fluency	4.0 vs. 1.5	0.008**
	Flexibility	10.10 vs. 20.25	0.002	**Flexibility	20.25 vs. 10.00	0.001***
	Originality	0.25 vs. 0.30	1.00	Originality	0.30 vs. 0.10	0.377
	Creativity	1.01 vs. 2.03	0.730	Creativity	2.03 vs. 1.00	0.002**

PMS: Pictorial Multiple Solution; CEN: Creating Equal Number; BB: bilingual children from a bilingual kindergarten; BM: bilingual children from a monolingual kindergarten; MM: monolingual children from a monolingual kindergarten.
**$p < 0.01$ ***$p < 0.001$.

CEN task. In this task as well, the high standard deviations were shown by all three groups (see Table 3) on almost all measures (in particular, by the two bilingual groups). The most frequent solutions were as follows: (a) to transfer one bottle cap from the group of five to the group of three (the result is 4-4), (b) to transfer one cap from the group of five to the group of three and after that to take one cap from each of the two equal groups (3-3), and (c) same as (b) but the child removed two caps from each group (2-2). Thus, children chose the three most obvious (from the quantitative point of view) and relatively simple solutions but used the two-step method to solve the problem, which had not been considered by the authors of the test (Tsamir et al., 2009): step 1—method (b) and step 2—methods (d) and (a) (see the description of the method above for details). Accordingly, the first solution received the highest score, 10, and the others only 0.1. At the same time, from the point of view of originality, all these solutions should receive a low score of 0.1. There were, however, two exceptions. First, the solution 1-1, which was very rare (in the expert space) and was not reached by a consecutive equivalent reduction of equal groups but by the removal of three caps at once from each of groups, received a flexibility score of 1. The solution 0-0 was not only extremely rare but also original and, consequently, deserved the highest score for originality and flexibility, that is 10.

The results obtained on the CEN task (Table 3) show considerable differences between bilingual and monolingual children. Significant differences between the two bilingual groups and the monolingual group were found only on the originality (p=0.002 and p=0.007 for BB and BM groups respectively) and creativity (p=0.004 and p=0.000 for BB and BM groups respectively) measures. On the fluency and flexibility measures, statistically significant differences were present only between the BB and MM groups (p=0.045 and p=0.002 respectively). No significant differences were found between the two bilingual groups.

We used the Wilcoxon signed-rank test to compare between the second performance of the PMS and CEN tasks within each group of participants (Table 4). The bilingual groups that had demonstrated the highest standard deviations (individual differences) on almost all measures showed statistically significant differences between their performances on only two tasks: fluency and flexibility (the BB group only). Compared with the monolingual group, there were not only significant differences in fluency and flexibility measures (Table 4) but also in creativity.

In summary, despite the fact that in absolute terms (means) the CEN task appears to have been more difficult for all three groups than the PMS task, producing lower creativity scores, only the monolingual group showed a significant distinction in creativity for the two tasks. These results were probably produced by the high standard deviations, which were more prominent in the bilingual groups. The Spearman rank test revealed no correlation between results in the PMS and the CEN tasks in any of the groups.

Discussion

The present study aimed to examine three hypotheses concerning the relationships between bilingualism and creativity. According to the first hypothesis, bilingual children would show higher creative ability than their monolingual coevals. It was also suggested that this effect may be present already at the early stages of child development.

Comparing the mean results of three groups of participants on the PMS test, bilingual children performed better than their monolingual peers both in the first and second rounds. The largest differences were found on the originality and creativity measures, but statistically significant distinctions were found only in the second round. Although the tendency was clear for both bilingual groups, significant differences between bilingual and monolingual participants were found only for the BB group. Significant differences between both bilingual groups and the monolingual group were revealed only on the CEN task, in both the originality and creativity measures.

Thus, the first hypothesis of the study was partially confirmed. In other words, there were definite distinctions between monolingual and bilingual children, to the advantage of the latter, in terms of creativity in problem solving, and the differences became marked and statistically significant with an increase in the children's age, and probably with the development of more balanced bilingualism (Bialystok, 2001, 2005; Cummins, 2000; Simonton, 2008).

Note, however, that together with group distinctions, there were also considerable individual differences, as demonstrated by the high standard deviations. Extremely high standard deviations were found (mostly on the originality and creativity measures) on both the PMS task (both performances) and the CEN task, and especially in the performance of both bilingual groups. Thus, our findings seem to indicate two separate sources of distinctions in creativity in problem solving (both general and mathematical): individual and group. As can be seen in Table 3, individual differences, as represented by standard deviations, changed considerably with age, becoming more prominent at a more advanced age. This finding seems to be consistent with the literature (e.g. Rutter & Rutter, 1992), maintaining that genetic distinctions become apparent as children become older. Even so, the results demonstrate that bilingualism seems to be capable of influencing the flexibility and originality of thinking, generally and individually, a phenomenon that appeared to be more pronounced in the task on mathematical creativity.

The second hypothesis was that bilingual children receiving the strong form of bilingual education (Baker, 2001) would demonstrate higher creativity in problem solving than would bilingual children receiving the weak form of bilingual education. The results showed that there were no significant differences between the two bilingual groups on any creativity measure, whether on general or mathematics tasks. Note that the BB group differed from the MM group not only on all measures of the CEN task but also on two measures of the PMS task (second performance), whereas the BM group showed significant differences from the MM group only in mathematical originality and creativity. In other words, while there were no differences between BB and BM groups, each of them differed from the MM group in a dissimilar manner. Thus, the second hypothesis of the study has also been confirmed only partially. Compared with the weak form of bilingual education, the strong form appears to influence positively the balanced development of two languages (Baker, 2001; Leikin et al., submitted) and to contribute more prominently to the development of creativity in problem solving.

The third hypothesis of the present study suggested that the abilities for general and mathematical creativity are different. The study was based on two problem-solving tasks that differed both theoretically and practically. In the first task, children were presented with a familiar and clear household problem requiring general creativity to solve it in different ways. The second task contained a mathematical problem that required mastering the principle of equivalence (Tsamir et al., 2009) and apparently also required another type of creativity to solve it. The different character of the two problems appears to have required different abilities, including creativity in problem solving, general creativity, and mathematical creativity (Leikin, 2009; Sawyer, 2006; Sternberg & Lubart, 2000). The results confirm this hypothesis, as no significant correlation was found between the children's performance on the PMS and CEN tasks in any of the three groups. Moreover, the findings concerning the creativity of children in the different groups were task dependent. In the PMS task (second performance), significant differences were found between the BB and MM groups only on the originality and creativity scores, and no differences were found between the creativity measures of students in the BM and MM groups. In the CEN task, considerable differences were found in all four measures of creativity, not only between the BB and MM groups but also between the BM and MM groups (on originality and creativity). We conclude, therefore, that the two tasks examine different and almost unrelated abilities. Moreover, the findings suggest that general creativity tested with the PMS task and mathematical creativity tested with the CEN task relate differently to bilingualism and bilingual education.

There were no significant differences among the three experimental groups in the first performance of the PMS task. Note, however, that at age 45 months the so-called bilingual children were only beginning to master Hebrew as their second language because at the time they had just started kindergarten (Table 2). Therefore, the absence of significant differences among the three participating groups should not come as a surprise. At this time, the bilingual children were to a great extent monolingual (Russian speaking), although they were already familiar, to some extent, with Hebrew as a second language. In this situation, it is not reasonable to expect any considerable influence of bilingualism (or bilingual education) on creative thinking. One year later, after the children had made progress in the acquisition of Hebrew as a second language (Leikin et al., submitted), there were already significant differences between the groups, albeit to a different extent, in the PMS and the CEN tasks. Within each group of participants, there were also differences in the performance of the two tasks. These differences, which were not similar, were expressed in different measures of creativity (Table 4); they were more pronounced in the MM group and somewhat less so in the BB and BM groups. It appears, therefore, that performance of the general and mathematical creativity tasks requires different types of creative abilities.

The results of the present study demonstrate that early bilingualism influences, to some extent, the children's general and mathematical creative ability. Moreover, it may be suggested that early bilingualism, especially the more balanced kind, promotes a more intensive development of creative thinking. This hypothesis, as well as assumptions about the contribution of different forms of bilingual education to the development of creative ability and about distinctions between different types of creativity, warrants further research.

Acknowledgement

I wish to thank Rosi Fuhrman-Engel for her assistance in data collection.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

References

Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research, 80*, 207–245.

Bain, B. (1975). Toward an integration of Piaget and Vygotsky: Bilingual considerations. *Linguistics, 160*, 5–19.

Baker, C. (2001). *Foundations of bilingual education and bilingualism*. Clevedon, England: Multilingual Matters.

Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development, 70*, 636–644.

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition*. New York, NY: Cambridge University Press.

Bialystok, E. (2005). Consequences of bilingualism for cognitive development. In F. Kroll & A. M. B. De Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approach* (pp. 417–432). Oxford, UK: Oxford University Press.

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition, 12*, 3–11.

Bruck, M., Lambert, W. E., & Tucker, G. R. (1976). *Cognitive consequences of bilingual schooling: The St. Lambert project through* grade six. *Linguistics*, 24, 13–33.

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science, 11*, 282–298.

Cummins, J. (1975). *Cognitive factors associated with intermediate levels of bilingual skills*. Unpublished manuscript, Educational Research Centre, St. Patrick's College, Dublin.

Cummins, J. (1976). The influence of bilingualism on cognitive growth: A synthesis of research findings and explanatory hypotheses. *Working Papers on Bilingualism, 9*, 1–44.

Cummins, J. (2000). *Language, power, and pedagogy: Bilingual children in the crossfire*. Clevedon, England: Multilingual Matters.

Cummins, J., & Gulustan, M. (1974). Some effects of bilingualism on cognitive functioning. In S. T. Carey (Ed.), *Bilingualism, biculturalism and education* (pp. 129–136). Edmonton, Canada: University of Alberta Press.

Darcy, N. T. (1963). Bilingualism and the measurement of intelligence: A review of a decade of research. *Journal of Genetic Psychology, 103*, 259–282.

Davis, G., & Rimm, S. (2004). *Education of the gifted and talented*. Boston, MA: Allyn and Bacon.

Diamond, A., Carlson, S. M., & Beck, D. M. (2005). Preschool children's performance in task switching on the dimensional change card sort task: Separating the dimensions, aids the ability to switch. *Developmental Neuropsychology, 28*, 689–729.

Duncan, S. E., & De Avila, E. A. (1979). Bilingualism and cognition: Some recent findings. *National Association for Bilingual Education Journal, 4*, 15–50.

Genesee, F.H. (2009). Early bilingualism: Perils and possibilities. *Journal of Applied Research on Learning*, 2, 1–20.

Gonzalez, V. (2006). Profiles of cognitive developmental performance in gifted children: Effect of bilingualism, monolingualism, and socioeconomic status factors. *Journal of Hispanic Higher Education, 5*, 142–170.

Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: McGraw-Hill.

Hakuta, K. (1986). *Mirror of language: The debate on bilingualism*. New York, NY: Basic Books.

Horowitz, F. D., & O'Brien, M. (1985). *The gifted and talented: Developmental perspectives*. Washington, DC: American Psychological Association.

Kasof, J. (1997). Creativity and breadth of attention. *Creativity Research Journal, 10*, 303–315.

Kessler, C., & Quinn, M. E. (1980). Positive effects of bilingualism on science problem-solving abilities. In J. E. Alatis (Ed.), *Current issues in bilingual education: Proceedings of the Georgetown roundtable on languages and linguistics* (pp. 295–308). Washington, DC: Georgetown University Press.

Kessler, C., & Quinn, M. E. (1987). Language minority children's linguistic and cognitive creativity. *Journal of Multilingual and Multicultural Development, 8*, 173–186.
Kharkhurin, A. V. (2008). The effect of linguistic proficiency, age of second language acquisition, and length of exposure to a new cultural environment on bilinguals' divergent thinking. *Language and Cognition, 11*, 225–243.
Kharkhurin, A. V. (2010a). Sociocultural differences in the relationship between bilingualism and creativity potential. *Journal of Cross-Cultural Psychology, 41*, 776–783.
Kharkhurin, A. V. (2010b). Bilingual verbal and nonverbal creative behavior. *International Journal of Bilingualism, 14*, 211–226.
Kloo, D., & Perner, J. (2005). Disentangling dimensions in the dimensional change card-sorting task. *Developmental Science, 8*, 44–56.
Kushnir, H. (1999). *I have a problem: Notebook for creative thinking development*. AHY Jerusalem 91164 (in Hebrew).
Lasagabaster, D. (2000). The effects of three bilingual education models on linguistic creativity. *International Review of Applied Linguistics in Language Teaching, 38*, 213–228.
Leikin, M., Schwartz, M., & Share, D. L. (2010). General and specific benefits of bi-literate bilingualism: A Russian-Hebrew study of beginning literacy learning. *Reading and Writing, 23*, 269–292.
Leikin, M., Schwartz, M., & Shaul, Y. (submitted). The Contribution of the Educational System to the Development of Structural and Organizational Aspects of Narrative Competence in Russian as L1 and Hebrew as L2 among Second Generation Russian Immigrants (in Hebrew).
Leikin, R. (2009). Exploring mathematical creativity using multiple solution tasks. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 129–145). Rotterdam, Netherlands: Sense Publishers.
Mackey, W. F. (2001).*The description of bilingualism*. In L. Wei (Ed.), *The bilingualism reader* (pp. 22–51). New York, NY: Routledge.
Macnamara, J. (1966). *Bilingualism and primary education*. Edinburgh, Scotland: Edinburgh University Press.
Milgram, R., & Hong, E. (2009). Talent loss in mathematics: Causes and solutions. In R. Leikin, A. Berman, & B. Koichu (Eds.), *Creativity in mathematics and the education of gifted students* (pp. 149–163). Rotterdam, Netherlands: Sense Publishers.
Otheguy, R., & Otto, R. (1980). The myth of static maintenance in bilingual education. *The Modern Language Journal, 64*, 350–356.
Peal, E., & Lambert, W. E. (1962). The relation of bilingualism to intelligence. *Psychological Monographs, 76*, 1–23.
Piirto, J. (1999). *Talented children and adults: Their development and education* (2nd ed.). Columbus, OH: Prentice Hall/Merrill.
Ricciardelli, L. A. (1992a). Bilingualism and cognitive development in relation to threshold theory. *Journal of Psycholinguistic Research, 21*, 301–316.
Ricciardelli, L. A. (1992b). Bilingualism and cognitive development: A review of past and recent findings. *Journal of Creative Behavior, 26*, 242–254.
Rosenblum, T., & Pinker, S. A. (1983). Word magic revisited: Monolingual and bilingual children's understanding of the word-object relationship. *Child Development, 54*, 773–780.
Rutter, M., & Rutter, M. (1992). *Developing minds: Challenge and continuity across the life span*. London, UK: Penguin.
Saul, M., & Leikin, R. (2010). Intercultural aspects of creativity: Challenges and barriers. *Mediterranean Journal for Research in Mathematics Education, 9*, 1–9.
Sawyer, R. K. (2006). *Explaining creativity*. Oxford, UK: Oxford University Press.
Schwartz, M., Moin, V., & Leikin, M. (2011). Parents' discourses about language strategies for the child's preschool bilingual development. *Diaspora, Indigenous, and Minority Education: An International Journal, 5*, 149–166.
Schwartz, M., Moin, V., Leikin, M., & Breitkopf, A. (2010). Immigrants' family language policy toward children's preschool bilingual education: Parents' perspective. *International Multilingual Research Journal, 4*, 107–124.

Schwartz, M., Mor-Sommerfeld, A., & Leikin, M. (2010). Facing bilingual education: Majority-language teachers' challenges and strategies. *Language Awareness, 19*, 187–203.
Simonton, D. K. (2000). Creativity: Cognitive, developmental, personal, and social aspects. *American Psychologist, 55*, 151–158.
Simonton, D. K. (2008). Bilingualism and creativity. In J. Altarriba & R. R. Heredia (Eds.), *An introduction to bilingualism: Principles and processes* (pp. 147–166). Mahwah, NJ: Lawrence Erlbaum.
Spolsky, B., & Shohamy, E. (1999). *The languages of Israel: Policy, ideology and practice*. Clevedon, England: Multilingual Matters.
Sternberg, R. J., & Lubart, T. I. (2000). The concept of creativity: Prospects and paradigms. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 93–115). Cambridge, UK: Cambridge University Press.
Sternberg, R. J., & O'Hara, L. A. (1999). Creativity and intelligence. In R. J. Sternberg (Ed.), *Handbook of creativity* (pp. 251–272). New York, NY: Cambridge University Press.
Thomas, J. (1992). Metalinguistic awareness in second- and third-language learning. In R.J. Harris (Ed.), *Cognitive processing in bilingualism* (pp. 531–545). Amsterdam: North Holland.
Torrance, E. P. (1966). *Torrance tests of creative thinking*. Princeton, NJ: Personnel Press.
Torrance, E. P. (1974). *Torrance tests of creative thinking: Directions manual and scoring guide*. Lexington, MA: Ginn.
Tranter, L. J., & Koutstaal, W. (2008). Age and flexible thinking: An experimental demonstration of the beneficial effects of increased cognitively stimulating activity on fluid intelligence in healthy older adults. *Aging, Neuropsychology, and Cognition, 15*, 184–207.
Tsamir, P., Tirosh, D., Tabach, M., & Levenson, E. (2009). Multiple solution methods and multiple outcomes – is it a task for kindergarten children? *Educational Studies in Mathematics, 73*, 217–231.
Zelazo, P. D., Frye, D., & Rapus, T. (1996). An age-related dissociation between knowing rules and using them. *Cognitive Development, 11*, 37–63.

Author biography

Mark Leikin is Head of Department of Special Education and Head of Research Laboratory for Neurocognitive Examination of Giftedness at University of Haifa. His research focuses on bilingual language acquisition and processing, language components in normal and abnormal reading processes, and neurophysiology of high cognitive functions.

Appendix 1

Pictorial Multiple Solution task

Appendix 2

Mathematical Multiple Solution task

The initial stage of the CEN task (Tsamir et al., 2009).