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Elucidating the role of selective attention, divergent thinking, language abilities, and executive functions in metaphor generation

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ABSTRACT

Metaphoric language is one of the most common expressions of creative cognition in everyday life. However, the cognitive mechanisms underlying metaphor generation remain largely unexplained. In this study, we aimed to investigate the relationship between various cognitive functions and both novel and conventional metaphor generation. Ninety-five undergraduate students were administered a metaphor generation task that assesses novel and conventional metaphor generation, along with a battery of different cognitive measures: vocabulary; divergent thinking (Tel Aviv Creativity Test), working memory (WM) via digit span tests, executive functions (EFs) using the Behavioral Rating Inventory of Executive Function (BRIEF) questionnaire, and selective attention (lateralized global-local digit task). Results of a path analysis indicated that – whereas only selective attention contributed to conventional metaphor generation – selective attention, divergent thinking, and EFs contributed to novel metaphor generation beyond vocabulary and WM. Thus, the results indicate that although both novel and conventional metaphor generation are linked to attentional resources and inhibitory control, the greater creativity inherent in novel metaphor generation appears to reflect a more complex set of cognitive processes than conventional metaphor generation.

1. Introduction

Creativity is viewed as the production of something that is novel, original, and innovative. At the same time, the product or the idea should be useful, relevant, and appropriate to the engaged task (Runco and Jaeger, 2012). Figurative language, such as the use of metaphor, is considered a verbal form of creative thinking (Ricoeur, 1981, 2003) that enables individuals to describe a vast range of emotions and experiences (Beaty and Silvia, 2013). It is generally acknowledged that examining figurative language, especially metaphoric language, is a powerful method to assess linguistic innovation and generation of new ideas (Levorato and Cacciari, 2002).

Metaphor processing relies on the ability to link disparate conceptual domains and to find the similarity between two apparently unrelated concepts (Bowdle and Gentner, 2005). Metaphors can be described differently in terms of their novelty and familiarity (Beaty and Silvia, 2013). For example, the structure of *conventional metaphors* represents a clear and appropriate comparison between a particular topic and the formed metaphor (e.g., *this lawyer is a shark*) (Tourangeau and Sternberg, 1982). Unlike conventional metaphors which are coded in the mental lexicon, *novel metaphors* are linguistically original and unique (Beaty and Silvia, 2013). The generation of a novel metaphor reflects the ability to break conventional or obvious patterns of thinking, to adopt creative or higher order rules, and to think conceptually and abstractly (Dietrich, 2004).

Although metaphors are relatively common in communication (Rundblad and Annaz, 2010), the cognitive mechanisms that may contribute to verbal creative language are not yet well understood. The main goal of the current study is to explore the contribution of different cognitive abilities, in particular, vocabulary, selective attention, executive functions (EFs) including working memory, to conventional and novel metaphor generation.

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1.1. Cognitive mechanisms underlying creative thinking and metaphor generation

Researchers seek to explore the cognitive processes that contribute to verbal creativity (Benedek and Fink, 2019; Hong and Milgram, 2010; Milgram and Milgram, 1976a; Runco and Jaeger, 2012). Previous studies found that metaphor generation relies on different cognitive and executive processes, such as working memory (Chiappe and Chiappe, 2007), vocabulary (Benedek, Beaty, et al., 2014), inhibition of irrelevant information (Beaty and Silvia, 2012; Kasirer and Mashal, 2016), non-verbal intelligence (Beaty and Silvia, 2013), and divergent thinking (Kasirer and Mashal, 2016). Indeed, in a recent study, Kasirer and Mashal (2018) found that divergent thinking contributed to the prediction of novel metaphor generation, but not to conventional metaphor generation. Divergent thinking is defined as the ability to generate various responses to an open-ended problem (Guilford, 1959). Tests of divergent thinking, being used to assess creative potential and having demonstrated adequate psychometric properties in various populations and age groups, are typically open-ended and responses are usually evaluated in terms of their fluency (the raw number of responses given) and their originality (the uniqueness or statistical infrequency of the responses). Beaty and Silvia (2013), however, found that generation of creative (i.e., novel) metaphors was related to fluid intelligence and executive functions, while generation of conventional metaphors was linked to vocabulary knowledge. Thus, the existing literature illustrates possible differences in the underlying abilities required by the generation of conventional and novel metaphors, suggesting that each relies on disparate cognitive and language processes. In sum, given the current evidence that various cognitive processes contribute to metaphor generation, there is a need for comprehensive study of the differential processes contributing to novel and conventional metaphor generation.

Another area needing clarification is how metaphors are processed within the brain itself. Whereas psycholinguists (e.g., Kintsch, 2000; Lakoff and Johnson, 1980) and neuroscientists (e.g., Bambini et al., 2011; Eviatar and Just, 2006; Mashal et al., 2007; Shibata et al., 2007) have thoroughly investigated the cognitive processes and neural correlates of metaphor *comprehension*, very little is known about metaphor *generation*. Recent evidence obtained from a neuroimaging study (Benedek, Jauk, et al., 2014) found that metaphor generation was associated with increased activation in predominantly left-hemispheric brain regions, including the left angular gyrus (AG), the left dorsomedial prefrontal cortex (DMPFC), and the posterior cingulate cortex (PCC), regions that are involved in both comprehension and generation of metaphors. These brain areas activate shared semantic information between remotely associated concepts required for metaphor comprehension and generation. Thus, it seems that metaphor comprehension and generation share the same left hemisphere brain regions but they differ in their underlying cognitive mechanisms.

1.2. Cognitive and neural substrates of attentional executive processes

The concept of attention is traditionally closely linked to resource theory (Kahneman, 1973) whose central premise is that an organism possesses limited processing capacity and therefore has to select from the multitude of available sensory inputs (Scalf et al., 2013). Attended information is selected and further processed, while unattended input is filtered out. The term selective attention thus refers to the ability to initiate and maintain focus on a limited part of available information (Kenemans et al., 2005). This cognitive function is necessary to focus processing on relevant information and to filter out distracting, or irrelevant, information (Gehring and Knight, 2002).

Selective attention is divided into two different processes: the first is sustained attention (or vigilance), which refers to the ability to maintain a consistent behavioral response during continuous and repetitive activity (Leshem, 2016; Pardo et al., 1991). The second is attention switching, which involves processes that change the mapping between stimulus attributes and response attributes. Specifically, attention switching shifts the state of the information processing system from one mode of processing to another (Gehring and Knight, 2002). Both sustained and switching mechanisms of selective attention require major top-down executive control, namely inhibitory control (Miller and Cohen, 2001), which refers to the suppression of ongoing actions or prepotent reactions (Barkley, 1999; Kenemans et al., 2005; Nigg, 2001).

From a neuropsychological viewpoint, different forms of selective attentional processes are products of the reciprocal interactions between diversified brain networks that recruit prefrontal, parietal, and dorsal anterior cingulate cortices in both hemispheres (Corbetta and Shulman, 2002; Engle, 2002; Greene et al., 2008; Posner et al., 2006). Specifically, there are three major functions that have been prominent in cognitive accounts of attention: alerting which is involved in acquiring and maintaining the alert state and includes thalamic and cortical sites (posterior and frontal areas); orienting to sensory stimuli centered on parietal sites; and executive control involved in the resolution of conflict between neural systems and regulating thoughts and feelings that includes the anterior cingulate and prefrontal area (Posner and Petersen, 1990; Posner et al., 2006). These cortical structures, especially the prefrontal cortical area, play important role in other higher-order cognitive functions, including spatial and conceptual reasoning, working memory, language skills, and creative thinking (De Souza et al., 2014; Fellows, 2004; Zelazo and Müller, 2002).

In considering neural asymmetry in attentional executive processes, Corbetta and Shulman (2002) proposed a model of two anatomically and functionally distinct attention systems in the human brain: a bilateral dorsal frontoparietal system that involves top-down guided voluntary allocation of attention to locations or features, and a ventral frontoparietal system that is largely lateralized to the right and involves detecting unattended (or unexpected) stimuli and triggering shifts of attention. Vossel, Geng, and Fink (2014) indicated there is a lack of clarity about whether −and to what extent − functional asymmetries exist between the dorsal and ventral systems, although there is evidence of right hemisphere (RH) asymmetry in the ventral system. Also, physiological and imaging correlates of attention show that sustained attention (vigilance) tasks yield prefrontal and parietal activation, preferentially in the RH (Posner and Petersen, 1990). Orienting of visuospatial attention selectively engages right parietal cortex (Corbetta et al., 2000). Attentional executive control (e.g., conflict resolution, inhibition) selectively engage the anterior cingulate cortex and left prefrontal cortex (Fan et al., 2003).

1.2.1. Attention and metaphor generation

The link between attention and creativity is still not well understood, and it has been suggested that distinct forms of attention are associated with different aspects of creativity. For instance, Zabelina et al. (2016) proposed that divergent thinking is associated with selective attention, whereas "real-world" creative achievements are linked to "leaky attention" (attention that allows "irrelevant" information to be noticed). A study by Vartanian et al. (2007) found that a relationship between creative potential and reaction time is a function of different attentional capacities. Electrophysiology evidence also suggests that divergent thinking is associated with increased ability to filter out irrelevant sensory information, as assessed by the P50 evoked response potential (ERP) (Zabelina et al., 2015).

Electrophysiology and brain lateralization studies would certainly shed light on the link between attention and creativity; however, data is remarkably scarce, especially regarding verbal creativity (e.g., novel metaphor generation). Razumnikova and Volf (2015), who used a lateralized global and local task to study creativity, found that figurative creativity (imaging and drawing pictures) was associated with global selective attention within the RH. However, a study of insight-related problem solving resulted in a different finding; employing an event-related potential methodology, Qiu et al. (2008) instructed participants to find an innovative solution to a problem and found that successful solutions elicited enhanced N2 over left hemisphere (LH) frontal areas. Indeed, Qiu et al. (2008) finding is in line with the suggestion that the N2 amplitude is involved in breaking mental sets and forming new associations (Qiu et al., 2008). While the limited available evidence suggests that creative thinking involves attentional mechanisms in both hemispheres, given the inconsistent findings and different methods applied by the existing studies, more focused exploration is required to understand the contribution of lateralized attentional processes to creativity.

1.3. Metaphor generation and working memory

Verbal creativity, in the form of metaphor processing (comprehension/generation), has been linked to working memory (WM). WM is a core executive function involving storage buffering and active information processing mediated by the central executive component (Baddeley, 1986). There is evidence suggesting strong correlations between WM and various attentional control measures (Kane and Engle, 2002). Attention control is needed to maintain information in an active state and to inhibit irrelevant representations from gaining access to WM. When it comes to metaphor processing, WM enables comparison of the "base" term to the metaphor topic, thus enabling the activation of relevant representations and the inhibition of possibly distracting semantic associations or prepotent responses (Unsworth and Engle, 2007). A study that tested the relationship between metaphor generation and WM found that novel metaphoric interpretation is associated with the process of suppressing irrelevant information via the central executive component, whereas conventional metaphor comprehension relied on either phonological codes maintained in the phonological loop or on semantic processing (Mashal, 2013).

The class-inclusion theory (Glucksberg and Keysar, 1990) offers further insights into the relationship between metaphor generation and WM. According to this theory, when individuals generate a metaphor, they search for a "base term" (vehicle) that is a good exemplar of the category they want to attribute to the topic. In metaphor generation, a set of properties to be attributed to the topic is used to "activate" the vehicle. During the search for a suitable vehicle, irrelevant terms may need suppression, requiring the EF of inhibitory control. Studies have found that individuals with higher WM capacity may consequently generate better base terms since they have more resources allowing them to evaluate and suppress less relevant terms (Glucksberg and Haught, 2006; Glucksberg and Keysar, 1990; Pierce and Chiappe, 2008).

1.4. Divergent thinking, similarity identification, and metaphor generation

Metaphor processing relies on the ability to link unrelated conceptual domains and to find similarities between two apparently unrelated concepts (Bowdle and Gentner, 2005). In order to assess the contributions of divergent thinking (e.g., fluency of ideas) and similarity identification on metaphor generation, a recent study (Kasirer and Mashal, 2018) utilized the Tel Aviv Creativity Test (TACT) (Milgram and Milgram, 1976b), a variation of the Torrance Tests of Creative Thinking (TTCT) (Rosenthal et al., 1983; Torrance, 1974). Participants were administered two subtests from the TACT (A, B): In subtest A ("Alternate Uses") participants were requested to produce as many uses as possible for four objects (e.g., a shoe), and in subtest B ("Similarities") participants were asked to point out as many similarities as possible between two objects (e.g., a potato and a carrot). Both subtests provide a measure of divergent thinking (as these are open-ended tasks) with the Similarities subtest requiring analogical thinking as well. The results of their study showed that divergent thinking, as measured by fluency of ideas (by TACT–A, Alternate Uses), contributed to the prediction of novel metaphor generation beyond the identification of similarities (Kasirer and Mashal, 2018).

1.5. The current study

Given the various cognitive abilities that have been linked to metaphor generation, including vocabulary, selective attention, executive functioning, and, in particular, WM and divergent thinking (fluency of ideas) (Beaty and Silvia, 2012; Benedek, Beaty, et al., 2014; Kasirer and Mashal, 2016; Kasirer and Mashal, 2018; Mashal, 2013; Zabelina et al., 2015), the overarching goal of the current study was to explore the contribution of these cognitive abilities to both novel and conventional metaphor generation.

The methodology of assessment was tailored to the specific cognitive abilities of interest. For selective attention and attentional cognitive control, we constructed a lateralized global-local digits task version of Navon's letter task (Navon, 1977). In 1977, Navon introduced a hierarchical paradigm that has been proven effective in studying visual selective attention (Razumnikova and Volf, 2015). It requires interpreting a display of visual stimuli by selectively attending to certain features (either local or global) and ignoring other features (Bialystok, 2010). The paradigm has been used to examine allocation of selective attention, according to different spatial scales and task demands (Slavin et al., 2002). The paradigm involves the presentation of compound stimuli (for example, letters or numbers) of large (global) objects composed of smaller (local) objects. The stimuli may be congruent, namely, the large and small objects are identical, or incongruent, different large and small objects. In the global task, participants are asked to focus their attention on the large stimuli, whereas during the local task, participants have to selectively direct their attention to the small stimuli (Granholm et al., 1999; Han et al., 2001).

In the lateralized global-local digit task utilized in the current study, participants are required to detect a digit presented in left or right visual field (LVF, RVF, respectively) in two attention conditions differing in their perceptual demands: one in which attention was directed to the large target digits (global task) and another in which attention was directed to the small target digits (local task) in each visual field (VF). It has been suggested that the right hemisphere excels at more holistic, global and coarse processing of information, whereas the left excels at more analytic, local and fine-grained processing of information (Banich and Brown, 2000; Flevaris et al., 2010; Flevaris and Robertson, 2016; Gable et al., 2013; Van Kleeck, 1989). As evidence suggests that focusing on global features is associated with LVF_{RH} processes (Flevaris et al., 2010; Flevaris and Robertson, 2016; Gable et al., 2013; Van Kleeck, 1989), it is possible that when focusing on the small target digits (i.e., performing the local task) the LVF_{RH} may require greater selective attentional resources due to interference between stimulus-driven hemisphere dominance and instruction-driven processes (the same holds true for performing the global task in the RVF_{LH}). Furthermore, as each task consists of congruent stimuli (i.e., the same digits appear in both global and local levels) and incongruent stimuli (i.e., different digits for each level), the latter creates a strong interference effect due to a cognitive conflict between bottom-up and top-down processes, the resolution of which is believed to require inhibitory control (i.e., the suppression of ongoing actions or prepotent reactions) (Beaucousin et al., 2013).

Metaphor generation (both novel and conventional) was assessed using a concept explanation task (i.e., the Metaphor Generation Test), in which the participants were requested to generate a new way of expressing the meaning of common emotions by searching for relevant knowledge to explain the given concept (emotion) while inhibiting irrelevant information. Vocabulary was assessed through the use of the Vocabulary subtest of the Wechsler Adult Intelligence Scale-Third Edition (WAIS-III; Wechsler, 2001) and selective attention within the LH and RH was tested using a lateralized global and local task. Divergent thinking was assessed using the TACT (the *Alternate Uses* and the *Pattern Meanings* subtests) (Milgram et al., 1974) and WM via the Digit Span subtest of the WAIS-III (Wechsler, 2001). The Behavioral Rating Inventory of Executive Function- Adult Version (BRIEF-A; Roth et al.,

2005) was used for examining EFs.

Path analysis was used to examine the relationship between conventional and novel metaphor generation and the different cognitive abilities. As performance on tasks that require inhibiting irrelevant information involves top-down attention control (Zabelina et al., 2016), it was hypothesized that selective attention would contribute to both novel and conventional metaphor generation. We also hypothesized that novel metaphor generation would be linked to EFs (Beaty and Silvia, 2013; Zabelina et al., 2015) and divergent thinking (Kasirer and Mashal, 2018), while conventional metaphor generation would be linked to language abilities (Beaty and Silvia, 2013). Based on limited evidence of studies examining the associations between the functional lateralization of selective attention and metaphor generation (Razumnikova and Volf, 2015; Qiu et al., 2008), we hypothesized that selective attentional systems residing in both the left and the right hemisphere would be linked to novel metaphor generation. In particular, as novel metaphor generation involves cognitive control, we expected the involvement of both the attentional executive control system associated with the LH (Fan et al., 2003) and the attentional monitoring system associated with RH involvement (see Corbetta and Shulman, 2002; Posner and Petersen, 1990) during the processing of conflict resolution.

2. Methods

2.1. Participants

Ninety-five undergraduate students, all native Hebrew speakers, from Bar-Ilan University and Beit Berl College (79 women; mean age = 24.6 years; age range = 18–35 years) completed this experiment for course credit. All participants were self-reported to be right-handed, and none reported past or current neurological illness or learning disabilities in response to a set of questions retrieved from the Israeli Health Survey (Lewin-Epstein et al., 1998).

2.2. Materials

2.2.1. Creativity measures

2.2.1.1. Metaphor Generation Test (Kasirer and Mashal, 2016, 2018). The task consists of 10 concepts describing emotions (e.g., *feeling worthless is like___*). This is a self-paced task in which participants are asked to generate a new way of expressing the meaning of the concept rather than simply rephrasing the one with which they were presented. Instructions emphasize originality so as to encourage participants to create a new expression for each concept, rather than to simply paraphrase the one presented in the questionnaire. Thus, participants were asked "to come up with a brand new way to express the concept, without repeating any words already given and without using any basic synonyms for the words given". The word "like" was also added to facilitate the generation of new expressions. Two judges independently coded the data, determining whether each expression was literal or figurative (when there was disagreement, judges discussed and decided on the scores together). The judges were told that a novel metaphor is an unfamiliar, unique, and creative metaphoric (nonliteral) expression (e.g., *feeling worthless is like a mirror smashed to pieces*); a conventional metaphor is a familiar expression or an idiom (e.g., *feeling embarrassed is like wanting to sink through the floor*); and a literal response is a simple description with no figurative meaning (e.g., *feeling successful is like a victory*). They were then asked to give novel metaphors 3 points, conventional metaphors 2 points, literal responses 1 point, and no points to unrelated or inappropriate responses. The analysis focused on the two main categories of interest: the rate of original responses (number of novel metaphors x 3) and the rate of non-original metaphors (number of conventional metaphors x 2). A high inter-rater-reliability was found. The average measure of the interclass correlation coefficient was 0.74 with a 95% confidence interval from 0.67 to 0.80 ($F(187, 1683) = 4.84 < 0.000$). The Cronbach's alpha coefficient was 0.79.

2.2.1.2. Tel Aviv Creativity Test (TACT; Milgram et al., 1974). The TACT is a variation of the Wallach and Kogan's (1965) Creativity Battery that examines creative thinking. The current study employed two of its subtests, both of which assess divergent thinking. The first, *Alternate Uses,* involved the presentation of 4 specific words, each following the next: newspaper, tire, shoe, and chair. Participants were asked to produce as many uses as possible for each word. For the second subtest, *Pattern Meanings*, four visual forms (i.e., drawings) with no specific meaning were presented. For each stimulus, the participants were asked to produce as many representations as they could.

2.2.2. Cognitive measures

2.2.2.1. Vocabulary subtest of the Wechsler adult intelligence Scale-III (Wechsler, 2001). The test includes 33 words. The experimenter read one word at a time, and the participants were asked to provide the definitions of the words. Scores were assigned according to the quality and accuracy of the responses. Two points were given to a correct response, 1 point to a partially correct answer, and 0 for an insufficient answer.

2.2.2.2. Digit span subtest of the Wechsler adult intelligence Scale-III (WAIS-III, Wechsler, 2001). The test assesses working memory. The participants heard sets of digits, one at a time. They were asked to report all digits of the set. Sets ranged from two to eight digits with two sets for each span. For the digit span forward subtest, the participants were asked to repeat the digits in the same order in which they were presented. For the backward subtest, participants were asked to report the reversed order. The administration was stopped after two consecutive failures of the same set length. The highest span of digits recalled correctly was recorded for the forward and backward subtests. In addition, the total score was calculated for each participant.

2.2.2.3. Behavioral Rating Inventory of Executive Function - Adult Version (BRIEF-A, Roth, et al., 2005). The BRIEF-A is comprised of 75 items, each scored on a 3-point grading scale ("3" = "Often", "2" = "Sometimes", "1" = "Never"). A higher score indicates poorer executive functions. The BRIEF-A is considered a valid test to measure everyday executive functioning (Guy et al., 2004). This questionnaire is widely used as a measure of executive functions and comprises eight subscales (Inhibit Scale, Shift Scale, Emotional Control Scale, Monitor Scale, Working Memory, Plan/Organize Scale, Organization of Materials Scale, and Task Completion Scale). The BRIEF-A also provides a total score that indicates a global measure of executive functions. The BRIEF-A indices and subscales have high reliability (α = 0.80–0.98). The Hebrew version was found to have adequate reliability (α = 0.76–0.91; Linder et al., 2010).

2.2.2.4. Lateralized global-local digits tasks. This computerized test includes tasks designed to assess selective attention for local and global processing within each cerebral hemisphere. The stimuli are based on Navon's letter task (Navon, 1977). Each task included congruent, incongruent, and neutral stimuli. Congruent stimuli included the same numbers for both levels (e.g., 1 local, 1 global). Incongruent stimuli included different numbers for each level (e.g., 1 local, 2 global). Neutral stimuli included the digits 1 and 2, composed of the digits 3 and 4 (e.g., 1 local, 4 global).

The two tasks required participants to detect the target numbers (either "1" or "2") by pressing a 'green' (N key) or 'red' key (B key) on a keyboard (respectively). Both tasks had the same structure, timing parameters, trial order, and response demands, differing only in the instructions. For the global trials, the instruction was to identify the large target numbers and for local trials, to respond to the small target numbers. Participants were asked to respond with the index finger only of their right (dominant) hand to avoid an activation effect in the contralateral hemisphere and confounding effects.

Stimuli were presented on a 2.20 GHz Intel personal computer running Windows 7 enterprise, using a 15.4-inch LCD monitor with a refresh rate of 60 Hz and a resolution of 768 X 1366 pixels, and using E-Prime™ software (Psychology Software Tools, Inc., Pittsburgh, PA).

The stimuli were 1280 x 720 pixels digitized in 24-bit color depth, using white and black colored images. The stimuli were presented unilaterally to the RVF_{LH} and LVF_{RH}, 2° from a central fixation cross. Each of the 8 stimuli was presented five times to each VF, constituting 40 trials to the LVF_{RH} and 40 trials to the $RVF_{LH.}$

A practice block of the 16 types of stimuli, along with error feedback provided after each trial, were administered before each task to ensure that participants understood the task and could execute the responses. The experimental blocks included presentation of a central fixation cross for 500 ms. The target followed immediately and lasted for 180 ms, presented either in the RVF_{LH} or LVF_{RH}. The participants had 2000 ms to respond to the stimulus. Participants sat about 60 cm from the screen and the order of the two tasks was counterbalanced across participants. Overall, the experiment took approximately 12 min.

Mean RTs for number of correct responses (accuracy) were extracted. Responses with latencies shorter than 150 ms were regarded as premature anticipatory responses and were excluded from analysis. Responses with latencies more than three standard deviations above the sample mean were regarded as distractions and were excluded from analysis as well.

2.2.2.4.1. Indices of the local-global task. Based on the behavioral data, congruency effect (CE) and laterality index (LI) indices were calculated separately for RTs and accuracy. These parameters were computed to examine their contribution to conventional and novel metaphor generation.

The CE indices were computed for each task (global, local) and VF (left, right). The CEs for correct responses were calculated by subtracting the incongruent from the congruent trials, and congruent trials were subtracted from the incongruent ones for the RTs. Thus, eight congruency effects were derived from the data, four for accuracy and four for RTs: RVF_{LH} global - CE, LVF_{RH} global - CE, RVF_{LH} local - CE, and LVF_{RH} local - CE. Thus, for correct responses, positive CEs indicate higher correct responses for congruent, compared to incongruent, trials and thus lower CE scores represent higher cognitive control. For the RTs, positive CEs indicate longer RTs for incongruent trials compared to congruent trials and, therefore, lower CE scores represent higher cognitive control.

The LI measures were computed separately for each task (global, local) and congruency (congruent, incongruent) resulting in four LI measures for accuracy and four LI for RTs: global congruent - LI, global incongruent - LI, local congruent - LI, local incongruent - LI. The LI parameters were computed by subtracting the LVF_{RH} parameters from the RVF_{LH} parameters. Hence, positive scores indicate rightward lateralization for correct responses, and leftward lateralization for RTs.

2.2.3. Procedure

The participants were tested individually in quiet rooms in Bar Ilan University. After hearing a general introduction to the experiment, participants read and signed an informed consent form that was approved by the ethical committee of the School of Education of Bar Ilan University. Participants completed the selective attention computerized task (global and local tasks) and paper-and-pencil tasks (metaphor generation, Tel Aviv Creativity Test, vocabulary, digit span, BRIEF-A) that were presented in a counterbalancing scheme. All measures were administered during a single testing session that lasted about 90 min.

2.2.4. Statistical analysis

First, the selective attention computerized test was analyzed. The data were analyzed with repeated measure analyses of variance (RM-ANOVA) consisting of Task (global, local) x VF (RVF_{LH}, LVF_{RH}) x Congruency (congruent, incongruent). The dependent variables were RTs and number of correct responses. Degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (0.75). In the next step, the LI indices were analyzed separately for accuracy and RTs using RM-ANOVA, with task (global, local) and congruency (congruent, incongruent). The congruency effects (CE) were also analyzed separately for the correct responses and RTs using RM-ANOVA, with task (global, local) and VF (right, left).

Table 1 presents means and standard deviations (*SDs*) of performance on the different tasks. Next, based on significant Pearson correlations which were computed between novel metaphor and conventional metaphor generation with all other study measures, a path analysis was employed. The path analysis was employed to test the fit of the hypothesized model (based on significant correlations) providing estimates of the magnitude and significance of the hypothesized model. Therefore, the technique was used to examine the covariance structure of the data as well as the relationships between the specific measures. One model including both conventional metaphor and novel metaphor generation as dependent variables was created.

3. Results

3.1. Creativity and cognitive measures

Table 1 shows means and *SDs* for all the tests of cognitive ability. The range of each measure is based on the scores obtained in the current study. For instance, for the Metaphor Generation Test's novel metaphor category, the range 0–30 indicates that there was at least one participant that generated 0 novel metaphors (thus, the lower end of the range was zero) and the score 30 indicates there was at least one participant that generated 10 novel metaphors and scored the high end of the score range of 30 (10 novel metaphors x 3 points = 30).

3.1.1. Global and local selective attention

3.1.1.1. Correct responses. Table 2 shows the mean correct responses of the global and the local tasks (raw data). The three-factorial RM-ANOVA with task (global, local), VF (RVF_{LH}, LVF_{RH}), and congruency (congruent, incongruent) revealed a significant main effect of task, indicating higher correct responses for the global task compared to the local task [$F(1,94) = 131.41, p < 0.001, \eta^2_p = 0.58$]. The main effect of

Table 1
Means (and standard deviations) for the metaphor generation test, TACT, vocabulary, digit span, and the BRIEF-A questionnaire.

Measure	Subtest	Mean	*SD*	Range
Metaphor generation test	Novel Metaphor Generation	9.29	7.28	0–30
	Conventional Metaphor Generation	6.70	3.95	0–18
	Literal	3.30	2.28	0–10
TACT	Alternate Uses (A)	20.38	7.54	6–53
	Pattern Meanings (B)	16.51	7.09	4–42
Vocabulary	Vocabulary	50.75	9.17	16–64
Digit Span	Forward	11.23	2.29	2–16
	Backward	7.79	2.63	2–14
	Total Score	19.03	3.84	10–27
BRIEF - A	Inhibit	11.93	2.53	8–18
	Shift	9.96	2.21	6–16
	Emotional Control	16.92	4.71	7–27
	Self-Monitor	8.25	1.80	5–12
	Initiate	12.51	3.09	8–19
	Working Memory	12.35	2.85	8–21
	Plan/Organize	14.87	3.22	10–24
	Task Monitor	9.59	2.04	5–14
	Organization of Materials	13.11	3.94	8–24
	Total Score	113.74	20.14	55–163

Table 2
Means (and standard deviations) of correct responses and RTs on the global and local task, divided by congruency (congruent and incongruent) and visual field (LVF_{RH} and RVF_{LH}).

		Correct Responses		RTs	
		LVF_{RH}	RVF_{LH}	LVF_{RH}	RVF_{LH}
Local Task	Congruent	8.78 (1.31)	8.44 (1.71)	355.82 (91.36)	381.45 (122.34)
	Incongruent	6.83 (2.06)	6.91 (2.19)	424.27 (138.79)	446.73 (140.07)
Global Task	Congruent	9.32 (0.99)	9.21 (1.16)	297.13 (83.31)	289.91 (83.88)
	Incongruent	9.20 (1.12)	9.34 (0.91)	297.70 (88.04)	294.48 (79.53)

congruency was significant as well, with higher correct responses for congruent compared to incongruent trials [$F(1,94) = 114.18$, $p < 0.001$, $\eta^2_p = 0.55$]. The main effect of VF was insignificant ($p = 0.47$).

The only significant interaction obtained was the two-way Task × Congruency interaction [$F(1,94) = 95.24$, $p < 0.001$, $\eta^2_p = 0.5$]. Simple effects analysis indicated that the global task produced higher correct responses compared to the local task, for both congruent ($p < 0.001$) and incongruent trials ($p < 0.001$).

3.1.1.2. RTs. Table 2 shows mean RTs on the global and local tasks. The three-factorial RM-ANOVA with task (global, local), VF (RVF_{LH}, LVF_{RH}), and congruency (congruent, incongruent) revealed a significant main effect of task [$F(1,94) = 147.59$, $p < 0.001$, $\eta^2_p = 0.61$], with shorter RTs on the global task compared to the local task. The main effect of congruency was significant as well [$F(1,94) = 83.50$, $p < 0.001$, $\eta^2_p = 0.47$], with a shorter RT for the congruent, compared to the incongruent, trials. The main effect of VF was insignificant ($p = 0.10$).

A significant Task × VF interaction was found [$F(1,94) = 7.63$, $p = 0.007$, $\eta^2_p = 0.08$]. Simple effects analyses revealed that the global task produced shorter RTs compared to the local task for both RVF_{LH} ($p = 0.001$) and LVF_{RH} ($p = 0.001$). In addition, LVF_{RH} produced shorter RTs compared to the RVF_{LH} on the local task ($p < 0.05$).

The Task × Congruency interaction was significant [$F(1,94) = 57.22$, $p < 0.001$, $\eta^2_p = 0.38$]. The global task produced shorter RTs compared to local task for both congruent ($p < 0.001$) and incongruent trials ($p < 0.001$). In addition, congruent trials produced faster RTs compared to the incongruent ones on the local task ($p < 0.001$).

3.1.2. Laterality indices of the selective attention task

Table 3 shows means and standard deviations for the LIs correct responses and RTs and the 95% confidence intervals.

3.1.2.1. Correct responses. The two-factorial RM-ANOVA with task (global, local) and congruency (congruent, incongruent) revealed no significant main effects and no significant interactions. One sample t-tests were conducted to test whether the LI means differed from zero. No significant differences were found for the local congruent - LI ($p = 0.054$), local incongruent - LI ($p = 0.77$), global congruent - LI ($p = 0.315$), or the global incongruent - LI ($p = 0.24$) parameters.

Table 3
Means (and standard deviations) of correct response and RTs for the LI parameters. The 95% confidence intervals are presented inside the brackets.

	Correct Responses		RTs	
	Local	Global	Local	Global
Congruent	−0.34 (1.69) [-.68, .01]	−0.11 (1.02) [-.31, .10]	25.64 (93.48) [6.59, 44.68]	−7.22 (56.76) [-18.78, 4.34]
Incongruent	0.07 (2.45) [-.42, .57]	0.14 (1.13) [-.09, .37]	22.45 (150.85) [-8.28, 53.18]	−3.22 (60.38) [-15.52, 9.08]

LI = Laterality Indices; RTs = Reaction Times.

3.1.2.2. RTs. The two-factorial RM-ANOVA with task (global, local) and congruency (congruent, incongruent) revealed a significant main effect of task, with the local task having produced higher positive laterality scores compared to the global task [$F(1,94) = 7.63$, $p = 0.007$, $\eta^2_p = 0.08$], indicating LVF_{RH} lateralization for the local task. One sample *t*-test examined whether LI RT parameters differed from zero. No significant differences were found for the local incongruent - LI ($p = 0.15$), global congruent - LI ($p = 0.22$), or for the global incongruent - LI ($p = 0.60$) parameters. Only the local congruent - LI parameter significantly differed from zero [$t(94) = 2.67$, $p = 0.009$, $d = 0.27$].

The fact that the local congruent - LI measure significantly differed from zero may imply that this LI measure, which was calculated for the sample of the current study, may differ from the one representing the general population. Since this measure indicates leftward lateralization it implies left hemispheric specialization for local processing of congruent stimuli in the current sample.

3.1.3. Congruency effects of the selective attention task

3.1.3.1. Correct responses. The two-factorial RM-ANOVA with task (global, local) and VF (LVF_{RH}, RVF_{LH}) revealed a significant main effect of task [$F(1,94) = 96.52$, $p < 0.001$, $\eta^2_p = 0.50$], indicating higher correct responses on the local, compared to the global, task. No additional significant main effects or significant interactions were found. See Table 4 for means and standard deviations.

3.1.3.2. RTs. The two-factorial RM-ANOVA with task (global, local) and VF (LVF_{RH}, RVF_{LH}) revealed a significant main effect of task [$F(1,94) = 57.34$, $p < 0.001$, $\eta^2_p = 0.38$], with the local task having produced higher congruency effects compared to the global task. No additional significant main effects or significant interactions were found. See Table 4 for means and standard deviations.

3.2. The relationships between cognitive functions and metaphor generation

Pearson correlations were performed in order to investigate the correlations between novel and conventional metaphor generation and all other measures (see Table 5). The analysis indicated that ***novel metaphor generation*** significantly correlated with the BRIEF-A - Total score, BRIEF-A – Initiate subtest, BRIEF-A - Organization of Materials subtest, TACT-A (alternate uses), TACT-B (pattern meanings), RVF_{LH} local - Incongruent (correct responses), Local incongruent - LI (RT), and LVF_{RH} global - CE (correct responses). ***Conventional metaphor generation*** significantly correlated with Local incongruent - LI (correct responses) and Global incongruent – LI (RT) measures. There were no other significant correlations between novel and conventional metaphor generation and performance on the other cognitive measures ($r_s < 0.3$, $p > 0.1$). Thus, measures that did not significantly correlate with either novel metaphor generation or conventional metaphor generation are not reported in Table 5. Non-significant correlations are reported in the

Table 4
Means (and standard deviations) for the correct response-based congruency effects and RT difference-based congruency effects.

	Correct Responses		RTs	
	Local	Global	Local	Global
LVF_{RH}	1.95 (2.04)	0.12 (1.13)	68.46 (107.63)	0.57 (54.47)
RVF_{LH}	1.54 (2.07)	−0.13 (1.02)	65.27 (98.21)	4.57 (57.73)

Table 5
Correlation analysis.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 Novel metaphor generation	1																	
2 Conventional metaphor generation	-.479[b]	1																
3 Vocabulary	0.033	0.040	1															
4 Digit span - Forward	−0.025	0.013	.308[b]	1														
5 Digit span - Backward	−0.073	0.029	0.128	.208[a]	1													
6 Digit span - Total score	−0.067	0.030	.268[b]	.737[b]	.814[b]	1												
7 BRIEF - Total score	.234[a]	−0.038	0.162	−0.064	0.094	0.023	1											
8 BRIEF - Inhibit	0.093	0.038	0.058	−0.089	0.054	−0.021	.761[b]	1										
9 BRIEF - Shift	0.099	0.000	0.144	−0.070	0.031	−0.024	.597[b]	.407[b]	1									
10 BRIEF - Emotional control	0.196	−0.016	0.085	−0.094	0.089	0.003	.602[b]	.481[b]	.554[b]	1								
11 BRIEF - Self-monitor	0.063	0.095	0.060	−0.064	0.110	0.036	.474[b]	.515[b]	.270[b]	.319[b]	1							
12 BRIEF - Initiate	.208[a]	−0.028	0.143	0.041	0.011	0.028	.722[b]	.484[b]	.506[b]	.329[b]	.238[a]	1						
13 BRIEF - Working memory	0.131	−0.059	0.077	−0.168	−0.077	−0.156	.638[b]	.571[b]	.363[b]	.230[a]	.203[a]	.591[b]	1					
14 BRIEF - Plan/Organize	0.095	−0.058	0.107	−0.060	0.040	−0.010	.792[b]	.553[b]	.493[b]	.394[b]	.322[b]	.741[b]	.619[b]	1				
15 BRIEF - Task monitor	0.161	−0.102	0.162	−0.007	−0.001	−0.010	.686[b]	.547[b]	.364[b]	.301[b]	.218[a]	.622[b]	.507[b]	.672[b]	1			
16 BRIEF - Organization of materials	.281[b]	−0.131	0.095	0.059	0.107	0.105	.498[b]	.343[b]	0.195	0.116	0.182	.388[b]	0.198	.398[b]	.386[b]	1		
17 TACT - Alternate uses (A)	.253[a]	−0.119	−0.002	−0.084	−0.077	−0.104	0.127	0.119	−0.064	−0.136	−0.050	0.189	0.188	0.156	0.133	0.112	1	
18 TACT - Pattern meanings (B)	.277[b]	−0.136	0.025	0.101	0.047	0.092	0.068	0.055	0.100	−0.053	−0.008	0.183	−0.016	0.023	0.007	0.083	.593[b]	1

[a] Correlation is significant at the 0.05 level (2-tailed).
[b] Correlation is significant at the 0.01 level (2-tailed).

Appendix. It is noteworthy that conventional metaphor generation was correlated with fewer measures compared to novel metaphor generation.

3.3. Path analysis

Based on the correlation analyses and on previous study findings (Beaty and Silvia, 2013; Christmann et al., 2011; Vartanian et al., 2007; Mashal, 2013) a path analysis was conducted to investigate the contribution of EFs (BRIEF-A Total), divergent thinking (TACT-A - alternate uses, TACT-B - pattern meanings), selective attention measures (LVF_{RH} global - CE [correct responses], RVF_{LH} local - Incongruent [correct responses], Local incongruent - LI [correct responses], Local incongruent - LI [RT], Global incongruent - LI [RT]), WM (Digit span backwards, Digit span forward), and vocabulary on conventional and novel metaphor generation.

The analysis was conducted using AMOS21 (SPSS, Inc.) with the maximum likelihood estimation procedure. Following Hoyle and Panter (1995), the fit of the model to the data was evaluated using six goodness-of-fit indices. Three of these indices were absolute: the χ^2 statistic, the Root Mean Square Error of Approximation (RMSEA), and the standardized Root Mean Square Residual (SRMR). The remaining three indices were incremental: the Normed Fit Index (NFI), the Comparative Fit Index (CFI), and the Tucker-Lewis Index (TLI). An RMSEA and SRMR below 0.06 in combination with NFI, CFI, and TLI above 0.95 indicate excellent fit, whereas values below 0.08 and above 0.90 indicate adequate fit.

The path analysis included the direct effects of performance on the BRIEF-A Total, TACT-A (alternate uses), TACT-B (pattern meanings), LVF_{RH} global - CE (correct responses), RVF_{LH} local - Incongruent (correct responses), Local incongruent - LI (correct responses), Local incongruent - LI (RT), Global incongruent - LI (RT), Digit span backwards, Digit span forward, and Vocabulary measures, on conventional and novel metaphor generation. The model fit was excellent $\chi^2(11) = 6.14$, $p = 0.56$; $RMSEA = 0.00$; $SRMR = 0.02$; $NFI = 0.97$; $CFI = 1.00$; $TLI = 1.22$). All effects of the main variables were found to be statistically significant, with the exception of the direct effect of Digit span forward on conventional metaphor generation ($b = -.10, se = .16, \beta = -.06, p = .53$), the direct effect of Vocabulary on conventional metaphor ($b = .05, se = .04, \beta = .12, p = .20$), the direct effect of TACT-A (alternate uses) on conventional metaphor ($b = -.07, se = .05, \beta = -.14, p = .13$), the direct effect of Digit span backwards on novel metaphor generation (($b = -.23, se = .22, \beta = -.09, p = .30$), and lastly, the direct effect of Local incongruent - LI (RT) on novel metaphor ($b = -.01, se = .00, \beta = -.10, p = .22$). Based on Bentler and Mooijaart (1989), we arrived at the most parsimonious model by omitting the non-significant structural paths. The final model, presented in Fig. 1, displayed an excellent fit, $\chi^2(6) = 4.20, p = 0.65$; $RMSEA = 0.00$; $SRMR = 0.04$; $NFI = 0.97$; $CFI = 1.00$; $TLI = 1.09$). Table 6 shows the details of the regression effects.

As can be seen in Table 6, four measures contributed to novel metaphor generation. Two measures were attentional: RVF_{LH} local - Incongruent (correct responses) ($\beta = 0.26$) and LVF_{RH} global - CE (correct responses) ($\beta = -0.24$). The EF measure, BRIEF-A, was also significant ($\beta = 0.23$). Lastly, the model predicted that divergent thinking (TACT-B) made a minimal, yet significant, contribution to novel metaphor generation ($\beta = 0.20$). Conventional metaphor generation was contributed to by two attentional measures: the Local incongruent - LI (correct responses) ($\beta = -0.20$) and the Global incongruent - LI (RT) ($\beta = 0.18$).

4. Discussion

The current study focused on the contribution of different cognitive functions to metaphor generation. In particular, the main focus was on the differential contribution of vocabulary, divergent thinking, WM, EFs, and selective attention to novel and conventional metaphor

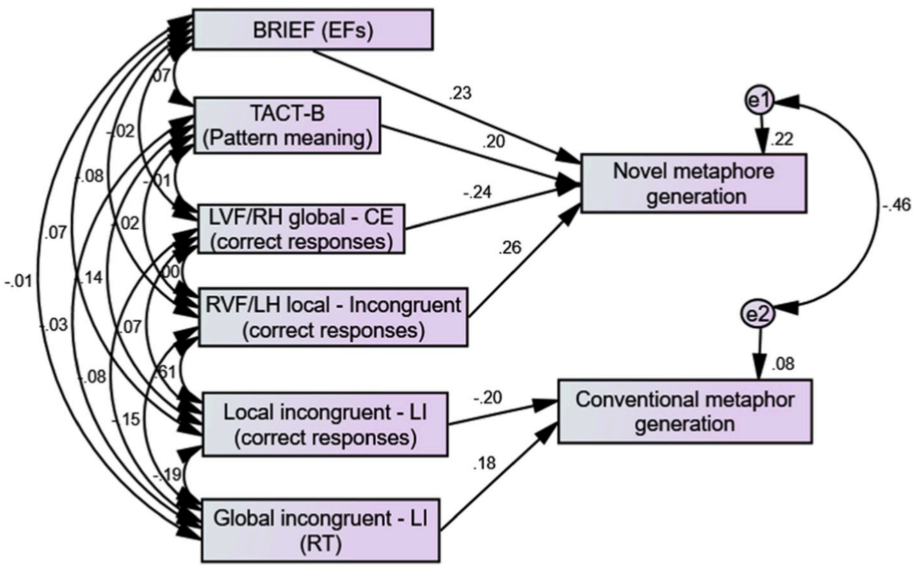

Fig. 1. Path analyses for novel and conventional metaphor generation.

Table 6
Summary of the regression effects.

Effect	b(se)	Beta	Sig
Novel metaphor generation R^2 = .218			
BRIEF-A (EFs)	.08(.03)	.23	.004
TACT-B - Pattern Meanings	.20(.08)	.20	.012
LVF_{RH} global - CE (correct)	−1.49(.51)	-.24	.003
RVF_{LH} local - Incongruent (correct)	.84(.27)	.26	.002
Conventional metaphor generation R^2 = .084			
Local incongruent - LI (correct)	-.32(.15)	-.20	.034
Global incongruent - LI (RT)	.01(.01)	.18	.046

generation. Consistent with our hypothesis, the main finding that emerged from the path analysis indicated that selective attention contributed to both conventional and novel metaphor generation. This finding is in line with previous studies showing associations between creativity and different attentional processes (Liu, 2016; Rowe et al., 2007; Vartanian, 2009; Wronska et al., 2018; Zabelina et al., 2015). Furthermore, the results of the present study suggest that novel metaphor generation and conventional metaphor generation rely on distinct processes, with more complex cognitive functions contributing to the generation of novel metaphors compared to conventional ones.

The model's findings indicate that four measures contribute to novel metaphor generation. One measure was the *LVF_{RH} global - CE (correct responses)*. This accuracy measure was computed by subtracting the incongruent trials from the congruent trials in the global task, thus pinpointing the importance of cognitive control to novel metaphor generation. This finding also suggests that this cognitive control is subserved by a RH mechanism. In other words, in the presence of a local interference effect (i.e., local stimuli interfere with processing global stimuli), the RH monitors this effect (Navon, 1977; Zmigrod et al., 2015). As this effect was negative, it implies that the more one can overcome the local interference effect (i.e., the higher the cognitive control) the higher the creativity scores. This finding thus suggests that the RH takes part in cognitive control, inhibiting irrelevant local data during a focus on global stimuli; this appears to contribute to the ability to generate novel metaphors. This finding may also imply the involvement of the ventral frontoparietal system, which is largely lateralized to the right and is known to be involved in detecting unattended stimuli (local stimuli that interfere with processing global stimuli) and triggering shifts of attention (Corbetta and Shulman, 2002).

The involvement of cognitive control in novel metaphor generation is consistent with a model suggested by Cassotti et al. (2016). According to Cassotti and colleagues, flexible cognitive control and inhibitory control are the underlying processes of creative problem solving and idea generation, in both children and adults. Indeed, the attentional measures used in the current study were derived from the global-local task (Navon, 1977) that taps into selective attention (Caparos et al., 2013) and inhibition of interfering information (Bialystok, 2010; Vartanian et al., 2007).

Similar to the *LVF_{RH} global - CE (correct responses)* measure, the *RVF_{LH} local - Incongruent (correct responses, raw data)* also contributed positively to novel metaphor generation. Higher *RVF_{LH} local - Incongruent* scores indicate that the participants experienced less interference by the distracting global stimuli; namely, they had better cognitive control. This finding suggests that higher creative ability depends on enhanced cognitive control at the local level (ignoring the global level). These two cognitive control measures (*LVF_{RH} global – CE* and the *RVF_{LH} local - Incongruent*) emphasize selective attention processes and effective suppression of irrelevant information. The generation of creative metaphor involves the search for a suitable vehicle for the given concept and the suppression of irrelevant information, which requires inhibitory control; the latter thus involves top-down activity accompanied by focused internal attention. Focused internal attention is a critical component of creative idea generation; its involvement during the imaginative and mental simulation processes (Benedek, Beaty, et al., 2014; Benedek, Jauk, et al., 2014; Benedek, Schickel, et al., 2014) may have particular relevance for the production of mental images which, consequently, may play an important role in creative metaphor generation.

The findings of the current study also suggest that EFs (as assessed by the BRIEF-A total score) have also an effect on novel metaphor generation. This result is consistent with findings suggesting that creative metaphor generation relies more on executive processes than conventional metaphor generation does (Beaty and Silvia, 2013). Indeed, the path analysis results suggest that EFs contributed to novel metaphor generation, but not to conventional metaphor generation. Inspecting the correlation analyses further revealed that both the *Initiate* and *Organization of Materials* subtests were positively linked to novel, but not to conventional, metaphor generation. These findings suggest that different EFs may facilitate novel metaphor generation, but future research is required to elucidate the unique contribution of different executive functions to creative thinking.

The fourth measure that contributed to novel metaphor generation was the TACT-B (Pattern Meanings) subtest. The Pattern Meanings subtest taps into divergent thinking ability, often regarded as the ability to generate multiple original responses. The contribution of divergent thinking to verbal creativity is also supported by a recent study (Kasirer and Mashal, 2018) that showed novel metaphor generation performance on the Metaphor Generation Test correlates with performance on the TACT-A (Alternate Uses) subtest. It is possible that generating novel metaphors motivated the participants to break from conventional patterns of thinking (e.g., "Feeling successful is like … the sky opening up"). Both tasks (the Pattern Meanings subtest and the Metaphor Generation Test) encourage creating relevant associations, original ideas, and various options for a given prompt. However, for the Pattern Meanings subtest (TACT–B) the participant is expected to produce as many representations as possible for a given drawing, while for the Metaphor Generation Test the participant is expected to produce one creative expression related to a given emotional construct. The metaphor generation process likely involves "uploading" many novel ideas in order to select the most original idea and suppression of conventional (or literal) ones. Thus, consistent with our expectation, divergent thinking ability has an effect on novel metaphor generation.

One could argue that the link between novel metaphor generation and divergent thinking fluency could be simply due to the role of intelligence in metaphor generation. Only a few studies tested the association between creative metaphor generation and intelligence (e.g., Silvia and Beaty, 2012). In Silvia and Beaty's (2012) study, the contribution of fluid intelligence (assessed via non-verbal tests) to the generation of creative metaphors was examined. The results showed that people high in fluid intelligence produced metaphors that were more qualitatively creative. The explanation provided for this finding was that generating creative metaphors involves selecting "an abstract property to attribute, searching knowledge for a vehicle that has the abstract property, and evaluating and revising the resulting metaphor." Since these stages all entail executive processing, the involvement of fluid intelligence is expected. As the current study suggests that attentional factors play an important role in both conventional and novel metaphor generation, future studies should control attentional parameters while testing the associations between fluid intelligence and creative metaphor generation.

Different measures contributed to conventional metaphor generation. The current study's results showed that two attentional measures contributed to conventional metaphor generation: *Local incongruent - LI (correct responses)* and the *Global incongruent - LI (RTs)*. Incongruent trials create an interference effect, suggesting that their processing involves inhibitory control (Beaucousin et al., 2013). Inspecting the LIs (Table 3) revealed that none of the measures showed lateralization effects, indicating that incongruent stimuli were processed bilaterally. It is also noteworthy that both global and local selective attention measures were associated with the generation of conventional metaphors; the context of incongruent trials suggests that conventional metaphor generation may require suppression processes residing in the two cerebral hemispheres. It should be noted that, contrary to our hypothesis, vocabulary levels did not contribute to conventional metaphor generation. However, it is possible that because the current study administered a large battery of cognitive tasks (unlike previous studies) including selective attention tasks, the contribution of vocabulary was masked by the remarkable contribution of the selective attention measures.

The overall results of the current study indicate that selective attention contributes to the generation of both conventional metaphor and novel metaphors. However, the current study's findings indicate that the ability to generate novel metaphors is a more complex process, compared to conventional metaphor generation, in terms of the contributing cognitive abilities. Novel metaphor generation is linked to selective attention both at the global and the local level. In addition, EFs and divergent thinking are also linked to creative thinking (novel metaphor generation) whereas these two abilities did not exceed attentional processes in their contribution to conventional metaphor generation. Since attentional functions were investigated using Navon's hierarchical stimuli task (1977) and processing incongruent stimuli requires inhibition of interfering information (Bialystok, 2010; Vartanian et al., 2007), it could be expected that novel metaphor generation would demand higher attentional control and more efficient suppression of competing stimuli.

The role of the LH and RH in processing metaphoric language is controversial, as studies have produced inconsistent findings (Mashal et al., 2009). Several studies found enhanced involvement of the RH in metaphor processing (Anaki et al., 1998; Bottini et al., 1994; Faust and Mashal, 2007; Razumnikova and Volf, 2015) while others found higher involvement of the LH (Briner et al., 2018), or both hemispheres playing an important role (Coulson and Van Petten, 2007; Kacinik and Chiarello, 2007). Banich (1998) theorized that an easy task can be processed independently by the hemispheres, but a complex task increases hemispheric interaction. The fact that both conventional and novel metaphor generation were associated with attentional processes *in both hemispheres* may suggest that metaphor generation is a demanding (complex) task. Nevertheless, while the results of the current study suggest that attentional processes were represented bilaterally in both global and local selective attention processes, novel metaphor generation was associated with more lateralized selective attention functioning at both the global and the local level. Deeper additional investigation is necessary for a better understanding of the contribution of hemispheric specialization of attention to conventional and novel metaphor generation.

4.1. Limitations and future studies

Some limitations of the present study should be mentioned. First, our EF measure (BRIEF-A – Total score) was comprised of several executive functions (inhibition, organization, set shifting, etc.) in the path analysis. Future studies, using a larger sample of participants, should use a more fine-grained model to disentangle the contribution of each EF to creative metaphor generation. In addition, the assessment of EF in the current study was based on this self-report questionnaire (BRIEF-A), which explores different aspects of everyday problem solving skills. While this may have high ecological validity, it may also result in low experimental control and process specificity, and thus have a low internal validity. Given that executive functions are a multifaceted construct, in future research it would be worthwhile to consider assessing EFs such as inhibition and working memory, through neuropsychological ("performance-based tasks") tests as well as self-report questionnaires. Such an examination would allow for an in-depth investigation of the relationship between EFs, attentional processes, and creativity. In addition, considering the important contribution of selective attention to metaphor generation, a baseline attentional task to confirm the absence/presence of attention deficit-hyperactivity disorder, would enhance future research. Another limitation is the use of accuracy and RTs as dependent variables. Most of the attentional measures that contributed to metaphor generation were accuracy-based; future studies may choose to employ an ERP methodology to obtain additional knowledge regarding the time course of these processes. Moreover, while the current study focused on selective attention, other kinds of attention should be investigated in order to gain a broader understanding of the association between various attentional systems and metaphor generation. Finally, future studies may choose to include both adults and children in order to examine developmental aspects of these abilities and their underlying processes.

4.2. Conclusions

In conclusion, it seems that performance on a perceptual task using the hierarchical Navon figures may predict one's ability to generate creative metaphoric language. More specifically, the present study suggests that selective attention and, in particular, cognitive control may have an effect on the generation of both novel and conventional metaphors. However, the two metaphor generation processes are different in terms of cognitive demands: the current study indicates that novel metaphor generation is a more complex process utilizing a larger array of cognitive functions compared to conventional metaphor generation. In addition, the attentional processes related to conventional metaphor generation are bilaterally represented in both global and local selective attention mechanisms, while these processes are more lateralized when it comes to novel metaphor generation.

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CRediT authorship contribution statement

Shay Menashe: Methodology, Writing - original draft. **Rotem Leshem:** Conceptualization, Methodology, Writing - review & editing. **Vered Heruti:** Data curation. **Anat Kasirer:** Data curation. **Tami Yair:** Data curation. **Nira Mashal:** Conceptualization, Methodology, Writing - review & editing, Supervision.

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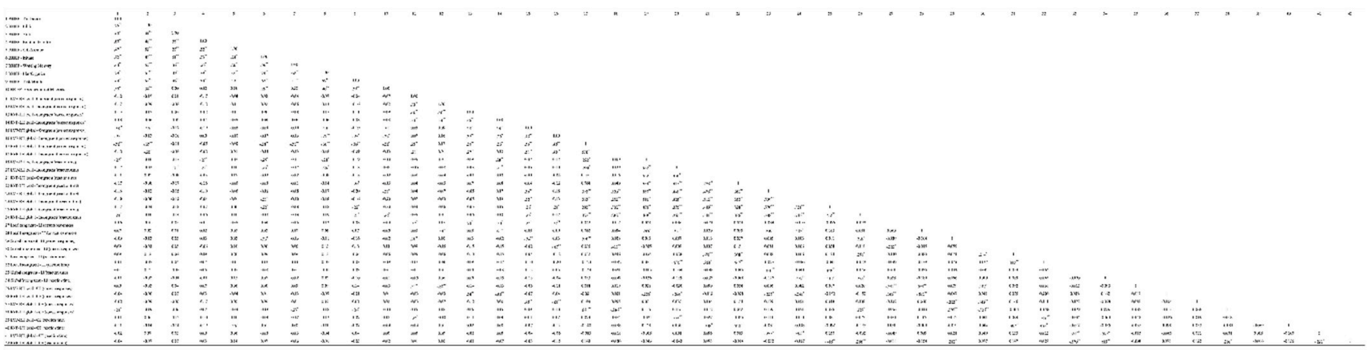
Appendix

Correlations between the BRIEF-A and Other Selective Attention Measures.



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