Does divergent thinking training improve language proficiency and performance?

Literature review reveals benefits and suggests testable approaches

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1 Introduction

Creative thinking (i.e., thinking outside of the box) requires the ability to consider and combine concepts that are not normally perceived as (strongly) related in order to generate useful unique ideas or solutions (Mednick, 1962; Ansburg, 2000). There are two general types of creative thinking: convergent and divergent thinking (DT). Creative convergent thinking involves determining the relationship or commonality between weakly related or unrelated pieces of information. In convergent thinking tasks, therefore, there is one correct solution. For example, in the Remote Associates Task (RAT), a common creative convergent thinking task, participants are presented with three words (pine, crab, sauce), and asked to determine what related word they all have in common (apple).

DT, the focus of this review, is the ability to generate as many solutions as possible to an open-ended problem for which there is not a single answer or finite set of answers (e.g., “What can you do with a paper clip?”). Responses on DT tasks are scored for fluency, flexibility, and originality. Fluency refers...
to how many responses are produced, flexibility refers to the number of conceptual categories included in the response set, and originality refers to how unique or unusual each response is. Originality is determined either subjectively, through ratings, or objectively, as the inverse of the number of individuals who generate a particular response. That is, the fewer individuals who generate a given response, the more original it is. Elaboration, the ability to enrich ideas with details, is also sometimes considered as an outcome measure on DT tasks.

DT is assessed with idea generation tasks. The most frequently used ones include the alternate uses task (AUT), the consequences task, and the explanations task (also known as insight task). In the AUT, participants must generate as many uses as possible for a common item. For example, the item brick might elicit responses, such as building material, doorstop, and paperweight. In the consequences task (Christensen, Merrifield, & Guilford, 1958), a hypothetical question is posed (e.g., “What would happen if suddenly nobody knew how to read?”) and various consequences that would result from the situation are solicited (e.g., “We would have to recognize the faces on money to know the value.”). In the explanations task, problem-solvers are given a scenario and asked to generate as many explanations for it as possible. For example, in response to the scenario a light in the darkness, an individual may generate the answer headlights on a car or jellyfish in the ocean. The latter response is more original than the former. These three types of tasks are all incorporated in the most frequently used psychometric test of divergent thinking, the Torrance Tests for Creative Thinking or TTCT (Torrance, 1968, 1974, 1990, 2000), which includes a verbal form and a non-verbal figural form. Verbal DT tasks present problem scenarios in verbal (e.g., a light in the darkness) and/or pictorial form (e.g., a person seeing their own reflection in a pond), and always ask for verbal responses (e.g., formulate explanations for the scenario), whereas figural DT tasks present shapes together (e.g., an incomplete figure), with a verbal instruction to draw responses (e.g. sketch objects completing a figure).

There are various reasons to speculate that DT plays an important role in language learning and consequently that improving DT through training might improve language learning. For example, a good divergent thinker should be better able to elaborate on learned vocabulary than a poor divergent thinker, creating a greater number and variety of semantic connections; this, then, might promote encoding in context-independent memory (i.e., semantic memory), and improve the learner’s ability to recognize and use words in novel contexts. Good divergent thinkers should also be better able to generate alternate hypotheses about the meanings of unfamiliar words when inferring them from spoken and written discourse, which is widely believed to be a major way second language vocabulary is acquired (Hulstijn, 2003). One might furthermore hypothesize that good DT promotes a better understanding of the pragmatics of discourse, for example, through more varied consideration of the possible communicative intents of a speaker.

Unfortunately, these possibilities, which are theoretically and practically relevant, have not been tested in empirical research. More generally, there is a relative lack of attention in the research literature to the question of whether DT training improves language learning. It is this question that is the central focus in this review and that our research sponsor has asked us to address, with a focus on the impact of DT training on the adult foreign language learner. In contrast, there is ample research on DT training per se. There are also many individual difference studies on the relation between DT and language learning and use. Finally, there is some limited evidence that a second-language pedagogical approach which involves a method for facilitating DT (i.e., brainstorming to prepare for writing), may benefit language learning.

In view of these considerations, the remainder of this literature review is organized as follows. Section 2 reviews research on DT training per se. Section 3 reviews evidence that brainstorming, which is a particular method for facilitating DT, improves discourse production in the second-language classroom. Section 4 discusses individual differences studies on the relation between DT and language learning and use and its mediating cognitive component functions. We will see that there are strong indications of a
relationship between language processing, bilingualism and second language acquisition, and DT ability. Section 5 identifies a number of domains in which the impact of DT training on foreign language learning and processing could be further explored in view of what is known about DT training, the relationship between DT and foreign language learning and processing, and still other considerations. Finally, Section 6 presents the major conclusions of this literature review regarding the central question of the potential for DT training to improve various aspects of foreign language learning and processing. This section also identifies directions for future research on this topic.

To find primary research articles and review articles addressing these topics, we used a variety of search terms per topic and entered them into the bibliographic databases PSYCInfo, WorldCat, and Google Scholar covering any articles in the period of 1950 to the present. Cognitive psychological research on creativity started in 1950 with Guilford’s address to the American Psychological Association (Guilford, 1950). Articles on divergent thinking had to address the topic as defined above. However, in order to find these articles we used not only the search term divergent thinking, but also divergent*, brain storming, brain writing, creativ*, alternate uses, (problem solving AND (consequences OR causes OR explanations OR insight)), verbal creativity, and figural creativity (* is the wild card symbol, representing any combination of letters, such as creative and creativity for creativ*). Language was covered by one or more of the search terms language, phonologic*, lexical, semantic, grammar, vocabulary, syntax, pragmatic, ideas, concept*, listening, speaking, reading, and writing, and combined with one or more of the following terms: proficiency, performance, processing, acquisition, bilingualism, multilingualism, learning, L1 (first language), and L2 (second language). Additional articles were found by searching the references of other articles for relevant material.

## 2 Divergent thinking training

Our review of the research literature on DT training addresses the following questions:

1. What training procedures have been used in DT training studies?
2. Does DT training improve DT immediately after training? If yes, what aspects of DT are improved in what domain and what is the size of the effects?
3. Is there evidence for persistence of the effects of DT training?
4. Do training benefits transfer from trained to untrained abilities?
5. What factors increase the likelihood that DT training is effective?
6. What are limitations of the available empirical studies on DT training?

We identified 43 studies that evaluated the impact of DT training on one or more objective behavioral performance indices of DT, that is, fluency, originality, flexibility, or elaboration, against a control group. These studies are marked with a star in the references section. Studies that relied only on self-report measures of creativity and/or judge-evaluated creative products were omitted. Populations varied across studies and included children and adults. There were many more studies evaluating verbal than figural DT.

### 2.1 Training procedures:  

DT training studies have used a variety of procedures aimed at improving DT. Most training involves providing trainees with practice on idea-generation tasks, such as
the alternate uses task (Guilford, 1967) or the consequences task (Christensen et al., 1958). This training is often enhanced with instructions believed to improve performance on these tasks, such as instructions to be creative (Harrington, 1975), to increase performance on a particular scoring dimension such as originality or flexibility (Y. J. Lee, 2005; Runco & Okuda, 1991), and to engage in encouraging self-talk (Meichenbaum, 1975). Other approaches to DT training include rewarding creative performance (Eisenberger, Armeli, & Pretz, 1998; Eisenberger, Haskins, & Gambleton, 1999) and providing clues after partial completion of the idea-generation process (Butler, Scherer, & Reiter-Palmon, 2003). Instructions also convey cognitive strategies hypothesized to promote novel idea generation. Frequently used strategies include thinking of the different parts of an object (e.g., using the pointy part of a paperclip to pick a lock), thinking of the different functions of an object (e.g., using a wig to conceal something other than a bald scalp), generating alternative use categories for an object (e.g., using a brick as a paperweight), and conceptual combination which involves a novel integration of two known ideas (e.g., combining smell and television to create smellovision).

Instructions to apply these general cognitive strategies are often accompanied by more specific guidelines for systematically generating a variety of ideas and objects. For example, when thinking of the parts of one or more objects, one can generate alternate uses by performing the following operations on the parts: Substitute, Combine, Adapt, Modify. Put to other uses, Eliminate, and Rearrange (SCAMPER) (Eberle, 1972; Osborn, 1953). Conceptual combination can be fostered by instructing trainees to detect links between two seemingly unrelated objects by searching for common meaning features. For example, the heat feature shared by a cooking stove and the hood of a car exposed to the sun may suggest a hood stove which may be used for frying an egg (Scott, Leritz, & Mumford, 2004b; Haarmann, George, Berens, Grunewald, & Freynik, 2012). Yet another example of a technique for systematically generating a variety of ideas and objects is morphological analysis (Zwicky, 1967) in which one first thinks about the different dimensions of an idea or object and the possible values for each dimension and then systematically generates new ideas or objects by considering all possible combinations of all values across dimensions. An example might be to generate ideas to build a sailboat using any of several shapes (e.g., long, short, wide), and any of several materials for the frame (e.g., wood, steel) and the sail (e.g., flax, canvas).

DT training may involve individual or group work. The most common group approach is brainstorming, which encourages participants to share out loud a continuous flow of ideas without critiquing each other. Typically, the ideas are recorded so everyone can see them as they are generated. The ideas resulting from this process may be further discussed in order to elaborate and critically evaluate them or to facilitate another round of idea generation (Osborn, 1953). While ideas are shared out loud in group brainstorming, they are written down in “brain writing” (Madsen & Finger, 1978), individually (i.e., nominal brainstorming) and/or later shared with the entire group (i.e., group brainstorming). Instructions may encourage participants to share ‘strange’ or ‘crazy’ ideas, for example by using irrelevant comparisons of concepts, forming emotional associations, taking the perspective of an inanimate object, and being playful with idea generation (Gordon, 1961).

Several comprehensive creativity training programs were devised in the 1960s-1970s, most of which are targeted at elementary-aged children, and are rarely used contemporarily. The programs targeted at children (Myers & Torrance, 1964; Covington, Crutchfield, Davies, & Olton, 1972; Renzulli, 1973; Feldhusen, Speedie, & Treffinger, 1971) incorporate lesson-based instruction using materials such as booklets, audio tapes, or teacher-guided class activities to develop creative and divergent thought. The programs targeted to adults (Khatena, 1970; Parnes, 1967), are also applicable to children (Khatena, 1971b; Reese & Parnes, 1970), and do not require particular domain expertise to maximize benefit (e.g., in Synectics). Khatena’s program (Khatena, 1970, 1971a, 1971b) is a 2-6 session lesson in word concept manipulation using restructuring, transposition, and “breaking away from the obvious and commonplace.”
Perhaps the most widely-used creativity training program is the Osborn-Parnes Creative Problem Solving (CPS) program (Parnes, 1967), which has been repeatedly found to be the most effective of the various comprehensive creativity training programs in meta-analyses of creativity training literature (Rose & Lin, 1984; Scott, Leritz, & Mumford, 2004a). The CPS program is composed of up to 16 sessions of variable duration with lessons in detecting and defining problems, deferring judgment on ideas, identifying new relationships between items, and evaluating consequences. (Parnes, 1967) describes numerous strategies for problem-solving and incorporates many of the individual divergent-thinking tasks such as finding alternate uses, using checklists, brainstorming, and solving both usual and unusual problems.

### 2.2 Immediate effects

Training effects assessed within one week of training completion were much more consistently obtained in the verbal domain than in the figural (i.e., non-verbal visual) domain. Three quarters or more of the 43 examined studies found evidence that DT training improves verbal DT, particularly originality (92% of studies), but also fluency (85% of studies), and flexibility of DT (almost 79% of studies, see Table 1). Elaboration was not assessed in the studies on verbal DT. The evidence for improved figural DT was mixed, varying from 42 to 54 percent of studies reporting such evidence depending on the performance dimension (see Table 1).

#### Table 1: Frequency of DT training outcomes as a function of DT domain and scoring dimension

<table>
<thead>
<tr>
<th>Study Outcome</th>
<th>Verbal Flexibility</th>
<th>Verbal Fluency</th>
<th>Verbal Originality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>15</td>
<td>24</td>
<td>23</td>
</tr>
<tr>
<td>Negative</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>19</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>Positive %</td>
<td>78.9</td>
<td>85.7</td>
<td>92.0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Study Outcome</th>
<th>Figural Elaboration</th>
<th>Figural Flexibility</th>
<th>Figural Fluency</th>
<th>Figural Originality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Negative</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>9</td>
</tr>
<tr>
<td>Total</td>
<td>11</td>
<td>11</td>
<td>14</td>
<td>16</td>
</tr>
<tr>
<td>Positive %</td>
<td>45.5</td>
<td>54.5</td>
<td>42.9</td>
<td>43.8</td>
</tr>
</tbody>
</table>

Two meta-analytic reviews of creativity training reported effects sizes (ES) for the impact of the training on divergent thinking (Rose & Lin, 1984; Scott et al., 2004a). In an analysis of 46 divergent thinking training studies, Rose and Lin (1984) found a larger effect size for verbal (ES=.60) than figural (ES=.37) divergent thinking, as measured by Cohen’s *d*, where values greater than .80, .50, and .20 indicate large, medium, and small effect sizes, respectively (Cohen, 1992). Originality of verbal DT showed the largest improvements.. In an analysis of 36 divergent thinking training studies, Scott et al. (2004a) found that originality of DT was most affected by creativity training, followed by flexibility (ES = .66) and fluency (ES = .61), with elaboration least affected (ES =.54), but the authors did not distinguish verbal from figural DT. Thus, creativity training improves DT with a medium-level effect size. In addition, verbal DT is particularly amenable to training, which is a promising result in view of the potential use of DT training in the verbal domain for facilitating language learning.

### 2.3 Persistence

Several mostly older studies have evaluated whether the effects of DT training persist over time (Glover, 1980; Goor & Rapoport, 1977; Haarmann et al., 2012; Macdonald, Heinberg,
Fruehling, & Meredith, 1976; Meichenbaum, 1975; Parnes & Meadow, 1960; Speedie, Treffinger, & Feldhusen, 1971; Wang & Horng, 2002. These studies evaluate persistence by assessing a participant’s performance during a second (and sometimes third) post-test one week or longer and up to four years after the initial training. Except for two studies (Haarmann et al., 2012; Speedie et al., 1971), six of these studies obtained evidence for persistence, varying from one week to several years. Persistence has been reported following relatively short-duration training, including one study which reported persistence following one to 12 hours of Creative Problem-Solving training (Wang & Horng, 2002) and another showing persistence after 6 hours of DT training (Meichenbaum, 1975). The details of these studies were as follows.

Meichenbaum (1975) provided participants with a total of six hours of group training spread out across a four-week period. The training involved practicing creativity tasks. One training group was taught to adopt a positive motivational state during training (e.g., “You’re in a rut – okay, try something new.”), whereas another training group was taught to monitor their current emotional state. Both groups showed improved DT one week after the training compared to a waitlist group, that is, a passive, no-training control group scheduled to receive the training after the study. The first training group improved fluency, flexibility, and originality on consequences and unusual uses tests, whereas the second group improved only their fluency on these tests.

Parnes and Meadow (1960) conducted a follow-up study of a population of college students from a previous creative problem-solving study (Meadow & Parnes, 1959), and compared students who had completed the creative problem-solving program between eight months and four years previously with participants who had enrolled to take part in the course but had not yet taken it. Results of several measures of idea quality and quantity (i.e., fluency), indicated significant persistence effects for the previously-trained group compared to the control participants on four of six measures.

Glover (1980) conducted a study with undergraduates who practiced finding unusual uses for objects and generating solutions to problems of everyday life across 21 one-hour sessions. Results of a post-training Torrance Test of Creative Thinking (TTCT) showed improved verbal fluency, flexibility, and originality compared to controls. These gains were persistent at an 11-month follow-up. Participants in the experimental group also showed transfer effects as demonstrated by gradual improvements in the creative quality of written papers over the course of the training compared to controls.

Goor and Rapoport (1977) conducted a creativity training program in which children practiced fluency and flexibility of DT, abstract thinking, and solution evaluation in a game-like setting across 10 four-hour sessions. Results of a post-training verbal TTCT indicated significant improvements in fluency, flexibility, and originality for the training group one week after the program’s completion compared to controls. At a four-month follow-up, the training group still outperformed the control group. However, because the training group voluntarily continued their practice after completion of the program, the treatment effect at follow-up is not a valid test of the persistence of the training effect. Of course, voluntary continued exercise reflects a participant’s intrinsic motivation and as such is a practically desirable feature of game-like training.

Macdonald et al. (1976) trained fifth-graders on an alternate uses and methods task and found improved DT immediately after a single training session. They also found evidence that the training improved understanding of verbal math problems at the end of the semester and making inferences during reading about one year later, especially in lower-ability students.

Wang and Horng (2002) found that one to 12 hours of Creative Problem-Solving (CPS) training for researchers in a petroleum refining and manufacturing plant improved fluency and flexibility on the TTCT. Productivity (i.e., co-authored publications), assessed 6-10 months after training, was significantly higher for the trained group compared to an inactive control group. This effect may reflect a treatment-specific effect, that is, training aimed at improving divergent thinking. However, given the use of an
inactive control group, it is not possible to exclude increased motivation in the training group as an alternative explanation for the improvement in DT.

Two studies failed to obtain evidence for persistent effects of DT training. Feldhusen et al. (1971) had reported that a 14-week long version of the Purdue Creative Thinking Program improved different aspects of DT in 4-6th graders. Seven months later, 4th graders still showed an effect, but 5th and 6th graders did not, suggesting this training program has limited efficacy (Mansfield, Busse, & Krepelka, 1978). Haarmann et al. (2012) reported better originality on the verbal TTCT in female analysts 1.5 months after a 1-day DT course, compared to an active control group that took a 1-day course to improve their long-term memory. Unfortunately, there was no such improvement relative to pre-course performance.

2.4 Transfer effects: There is evidence that DT training improves language performance and other performance metrics beyond its effect on the classical indices of DT (i.e., fluency, originality, and flexibility of responses to open-ended questions). In other words, there is evidence for transfer effects from the trained ability to related abilities. DT training has been shown to increase the number of publications of engineers working in the R&D division of a manufacturing plant (Wang & Horng, 2002), and the leadership abilities of high school department chairmen and department store managers after CPS training (Burston, 1973, 1977). In addition, DT training has been found to improve the quality of undergraduates’ written papers (Glover, 1980) and schoolchildren’s ability to draw inferences from written texts and solve verbal match problems (MacDonald et al., 1976). Finally, in the context of second language pedagogy, it has been found that the practice of brainstorming, which is aimed at improving DT, also improves language production during second language learning (see Section 3).

2.5 Modulating factors: Studies have reported several factors that modulate DT and the efficacy of DT training. In a meta-analysis of 34 divergent thinking training studies, (Ma, 2006) reported that DT training is more effective for adults than for children. Several other factors modulate DT performance but it is not known how they modulate DT training.

There is abundant evidence of a connection between DT skill and general fluid intelligence (Batey & Furnham, 2006; Batey, Chamorro-Premuzic, & Furnham, 2009; Furnham, Crump, Batey, & Chamorro-Premuzic, 2009; Nusbaum & Silvia, 2011; Wallach & Kogan, 1965) such that individuals who perform well on intelligence tests also perform well on DT assessments. Benedek, Fink, and Neubauer (2006) found the best DT performance for individuals with high verbal IQ who are neurotic and extraverted. This finding is reminiscent of the proposal that creative geniuses are individuals who have high IQ and psychotism, a latent variable predisposing a person to neurosis, psychosis, or creativity, via reduced inhibition (Eysenck, 1993). Interestingly, working memory, a cognitive function that is positively correlated with fluid intelligence (Kane & Engle, 2002), has been reported to have a negative relationship with DT. Takeuchi et al. (2011) found that working memory training improves working memory but decreases DT, compared to a non-contact and active control group. DT was indexed by a composite score on the S-A creativity test (Society for Creative Minds, 1969), which was comprised of measures for flexibility, fluency, originality, and elaboration. Administering Ritalin to children with ADHD has been found to improve attention focus and working memory but to reduce DT (Swartwood, Swartwood, & Farrell, 2003). Consistent with these results, a reduced ability to ignore distractors has been observed in individuals who are highly creative (Neeka, 1999; Kasof, 1997), or have low working memory capacity (Engle, Tuholski, Laughlin, & Conway, 1999). Moreover, adults with ADHD, who exhibit increased distractibility and related symptoms such as impulsivity, show greater originality of verbal DT and real world creative achievement compared to adults without ADHD (White & Shah, 2011). Inhibitory transcranial direct current stimulation of the left pre-frontal cortex has been found to facilitate flexibility of tool use on an alternate uses test (Chrysikou et al., in press). This effect has been interpreted as...
reflecting the impact of reduced pre-frontal inhibitory control, which may reduce the impact of top-down rules and schemas (Chrysikou et al., in press), and thereby increase distractibility from internal and external stimuli. Reduced cortical thickness of pre-frontal brain regions involved in cognitive control has been linked to increased creativity (Jung et al., 2010).

Taken together, these results suggest that DT benefits from a reduction in cognitive control that involves increased internal distraction, thus also reducing the effective capacity of working memory. Increased distraction may improve DT by promoting consideration of more task-irrelevant information or random thoughts (White & Shah, 2011), which, in the context of a DT task, may provide clues for new ideas. Reduced working memory may limit the top-down imposition of well-known schemas and rules, possibly making a problem-solver more sensitive to bottom-up information and thus, for example, incorporate more perceptual detail into answers on DT tasks.

However, this line of reasoning about cognitive control does not exclude the possibility of DT benefiting from cognitive control, specifically effortful cognitive control. Enhanced cognitive control may facilitate divergent thinking for a number of reasons. Cognitive control may be used to maintain effortful memory retrieval and block out already generated responses, which would promote fluency. Cognitive control may also help to suppress dominant associations in favor of weaker associations, which may result in greater originality. Furthermore, cognitive control may aid switching among semantic categories, which would benefit flexibility. Evidence consistent with this possibility will be discussed in Section 4 on the relationship between DT and language.

Furnham et al. (2009) reported that personality was more predictive of performance on the consequences test than IQ and gender, with personality, IQ, and gender accounting for 12%, 3%, and 1% of the variance in DT, respectively. Specific personality factors predicting DT performance were plasticity (i.e., openness to experience and extraversion) and also the combination of high imagination and low diligence. Butler et al. (2003) found that high Need for Cognition, a measure that reflects a preference for thinking, is associated with better DT performance. Ma (2006) found that the following factors are associated with creativity: work and school environments that encourage creativity, personal honors and achievements, ability to define problems, ability to retrieve knowledge, openness personality trait, and mysticism. It is not known whether individuals who are more creative benefit more from DT training than those who are less creative.

2.6 Limitations: There is a rich body of research demonstrating immediate and persistent effects of DT training, especially within the domain of verbal DT. Nevertheless, the existing body of research on DT training reveals several methodological limitations. Research on creativity training often involves the use of a complex training program including many different techniques, with the intention of having a high probability of success. While including many techniques is likely to improve the chances of success, it also makes it more difficult to determine which elements of the program are effective — and which are ineffective — means of improving idea generation. Studies that have been specifically aimed at improving DT vary widely in the focus of approach and have not been designed to facilitate comparison with other studies in order to determine the elements critical for different aspects of the following training effects: (i) their strength, (ii) their persistence, (iii) the training intensity required to obtain effects, (iv) the role of qualitative and quantitative feedback in obtaining training effects, (v) the transfer of training effects from trained tasks to other tasks, and (vi) what types of participants are most likely to benefit from which specific aspects of training. In addition, the cognitive psychology and cognitive neuroscience approach to DT training is largely in its infancy, since studies on the efficacy of DT training have for the most part not been informed by findings about the cognitive and neurobiological mechanisms that are involved in divergent thinking. Moreover, in the domain of language, which is the focus of this review, studies examining verbal DT have not been informed by findings and proposals about the psychological
mechanisms supporting language processing (e.g., the role of word frequency and associative strength between words in generating original ideas).

3 Brainstorming and foreign language learning

There is a small body of literature examining the impact of brainstorming (i.e. DT) on different aspects of second language production. Brainstorming is a standard pre-writing practice in second language classrooms (Badge & White, 2000; Taylor, 1981; Johnson, Mercado, & Acevedo, 2012) such that, in preparation for writing on a given topic, students spend time freely generating ideas and words associated with the topic.

With respect to oral proficiency, Khodadady, Shirmohammadi, and Talebi (2011) trained adult students learning English in a brainstorming strategy for discussion activities in English, the second language. Over a period of a month, students in the training group engaged in eight 90 minute brainstorming sessions in which they freely generated ideas and words about a topic provided by the teacher. The teacher wrote the ideas and words on the board and then the class discussed and refined the ideas. Students in the control group participated in discussion activities that did not involve brainstorming. Oral proficiency was assessed before and after training with an interview test. Upon completion of training, participants in the brainstorming training group showed greater improvements in oral proficiency than the control group.

Focusing on essay writing, Rao (2007) conducted a training study in which participants (Chinese university students in advanced English courses) were trained to use brainstorming as a pre-writing technique over the course of a semester, instead of the standard method of writing instruction. Students first brainstormed on a topic individually and then discussed their ideas in pairs. They then presented their ideas to the class for feedback and discussion. The control group followed a traditional method of writing instruction which did not involve brainstorming. Participants wrote essays before and after training which were rated and given a grade based on content, organization, vocabulary, language use, and mechanics. The training group made greater gains in writing grades from pre- to post-training assessments than the control group. This suggests that using brainstorming as a pre-writing activity does indeed facilitate the increase in foreign language writing competence.

Lally (2000) compared the effects of brainstorming in the first versus the second language on L2 writing performance in adults (native English speakers in their fourth semester of French) and found no difference in vocabulary use between the two but that brainstorming in the first language led to better organization of the essays. This result indicates that the relative ease of brainstorming in L1 and, perhaps, the access to a wider variety of lexical items in the first language facilitate the organization of ideas.

Johnson et al. (2012) compared writing performance after one session of various pre-writing activities including an idea generation task in which adult participants freely generated as many ideas as they could on the given topic during a fixed time period. The control group performed a vocabulary matching activity thematically related to the writing topic. Johnson et al. (2012) found no difference between the idea generation group and controls. Sustained training might be required to elicit the benefits of brainstorming (i.e. DT) as a pre-writing strategy.

In summary, there is promising evidence from three of four studies that brainstorming improves L2 language production. A limitation of these studies is that they were not designed to reveal whether the
effect was due to students’ exposure to a variety of ideas or to their active generation of these ideas. It is this active generation process which is the crux of DT ability.

4 Relation between divergent thinking and language processing

Several studies have examined the relation between divergent thinking and the processing and learning of language. These studies are for the most part correlational in nature, so that they do not permit inferences about the causal effect of divergent thinking or its contributing cognitive mechanisms on language processing and language learning. Moreover, the correlations reported in this context are all zero-order correlations and there have been no attempts to factor out the contributions of other variables. Nevertheless, based on the available evidence, one can speculate what common cognitive mechanisms support both divergent thinking and language processing and learning. One can then identify candidate interventions aimed at improving these common cognitive mechanisms in the hope that they will improve both divergent thinking and language learning. This section reviews the studies correlating divergent thinking and language. The available correlational studies have examined three aspects of language processing, semantic associative processing, bilingualism (vs. monolingualism), and foreign language proficiency. This section also discusses additional evidence that suggests that attention control may mediate performance in both domains, although future studies will be necessary to test that hypothesis.

There is evidence that DT ability predicts certain aspects of monolingual language processing, specifically semantic processing. Gruszka and Necka (2002) found that individuals who exhibited high DT performance were more likely to judge remote associates to be related. Vartanian, Martindale, and Matthews (2009) found that individuals with high DT ability had faster reaction times when making relatedness judgments. Lastly, Benedek, Könen, and Neubauer (2012) found a strong association between associative abilities (as assessed by word association tasks) and performance on the alternate uses test. The connection between semantic associative processing and DT performance is not entirely surprising as the latter involves the flexible combination of words/concepts that may be weakly related or unrelated. These results suggest that semantic associative processing abilities may underpin DT skill. The exact nature of these abilities, including (but not limited to) the role of cognitive control, remains to be determined.

More evidence for the connection between DT and language function comes from studies on bilingualism. There is a wealth of research indicating that bilinguals exhibit enhanced cognitive control relative to monolinguals (Bialystok, 2006; Bialystok, Craik, & Luk, 2008). This is also true of DT ability. Comparisons of monolinguals and bilinguals have shown that bilinguals tend to outperform monolinguals in both verbal and figural DT tasks (see Ricciardelli, 1992; Simonton, 2008 for reviews). Researchers have found that bilingual children outperform their monolingual counterparts on fluency (Carringer, 1974; Jacobs & Pierce, 1966), flexibility (Carringer, 1974; Konaka, 1997) and originality (Cummins & Gulustan, 1974; Konaka, 1997; Okoh, 1980). This has also been found in adults: Karapetsas and Andreou (1999) found that bilingual adults showed greater fluency in an alternate uses type task than their monolingual peers. Kharkhurin (2007, 2008, 2009, 2010) found that bilinguals showed enhanced fluency and flexibility in the Abbreviated Torrance Test for Adults (ATTA; Goff, 2002), a shorter version of the TTCT, compared to monolinguals.
One interpretation of the correlation between bilingualism and divergent thinking is related to the finding that bilinguals exhibit enhanced cognitive control relative to monolinguals (Bialystok, 2006; Bialystok et al., 2008). Enhanced cognitive control may facilitate divergent thinking for a number of reasons (see Section 2). Taken together, the evidence on distraction and DT (see Section 2), and bilingualism and DT may seem contradictory, since they suggest that reduced and improved cognitive control can benefit DT, respectively. However, in principle the paradox may be resolved by assuming that there are two mechanisms through which DT can be improved relative to a person with average cognitive control or relative to a situation in which the available cognitive control is average. One mechanism involves a reduction in cognitive control, specifically an increase in distractibility, which can promote consideration of a greater variety of ideas. This mechanism may explain why individuals who are more easily distractible have better DT. The other mechanism involves an increase in the effort or efficiency of cognitive control, specifically a better ability to focus attention, switch attention, and inhibit dominant associates, which could benefit fluency, flexibility, and originality, respectively.

In addition to bilingualism itself, the speaker’s level of proficiency in the second language predicts DT performance. (H. Lee & Kim, 2010, 2011) found that in bilingual 11 year-old children, who had spoken Korean since birth and had spent on average seven years in English speaking schools, there was a positive correlation between degree of bilingualism and DT ability as measured by the figural TTCT, such that the more balanced bilinguals (i.e. those whose L2 proficiency approached that of their L1) did better on the DT tasks. Ghonsooly and Showqi (2012) found in 16-18 year-old native Persian speakers that proficiency level in their second language (English) correlated positively with all measures of a Persian version of the TTCT. For adults, Kharkhurin (2008, 2010) found that highly proficient bilinguals show a greater advantage in performance on the ATTA than less proficient bilinguals. In Kharkhurin’s (2008) study, the participants completed the ATTA in their language of choice (English or Russian), whereas in the 2011 study the ATTA was completed in English by all participants.

Kharkhurin (2011) reported evidence that highly proficient bilinguals have a cognitive control advantage that provides better inhibitory control and spreading activation among meaning associates, and he suggested that this may explain their advantage in divergent thinking. Inhibitory control was indexed by the reaction time difference between color incongruent and neutral trials on the Stroop task, while cognitive control of spreading activation was indexed by the reaction time difference between neutral and congruent trials on the color-word Stroop task (Stroop, 1935; MacLeod, 1991). Inhibitory control predicted originality, while cognitive control of spreading activation predicted fluency, flexibility, and elaboration. Kharkhurin concluded that inhibition may enhance the generation of innovative, original ideas by suppressing interference from standard associations and task-irrelevant distractors, while selective attention may serve to increase activation of all associates (both weakly and strongly related) and thereby control the spread of activation in a network of meaning associates, making it more effective.

However, not all studies on divergent thinking and bilingualism provide support for the proposal that improved cognitive control benefits divergent thinking. Hommel, Colzato, Fischer, and Christoffels (2011) administered convergent and divergent thinking tasks (i.e., remote associates and alternate uses tasks, respectively) in the first language of bilinguals. They found that highly proficient bilinguals performed better on the convergent thinking task, while less proficient bilinguals did better on the DT task. Assuming that highly proficient individuals have better cognitive control (Bialystok, 2006; Bialystok et al., 2008), the findings from this study would indicate that good cognitive control benefits convergent thinking but hinders (rather than benefits) divergent thinking. Additional research, addressing the role of cognitive control, will be needed to understand this finding in the context of our proposal that reduced and increased cognitive control can each improve DT depending on the circumstances.

There is evidence of a positive correlation between DT and second language acquisition. Otto (1998) found that all measures of performance on the TTCT predicted foreign language course grades in high school students aged 14-16. Pishghadam, Khodadady, and Zabihi (2011) found that, in adults,
performance on the Arjomand Creativity Questionnaire (ACQ; an instrument designed to measure creativity among Persian speakers in Iran) predicted foreign language course grades. Albert and Kormos (2011) found that students aged 15-16 with high fluency scores in the DT components of Barkóczi and Zétényi (1981) standard test of verbal and figural creativity spoke more in the second language, while those with high originality scores created more complex narratives in a story generation task in the second language. In contrast, Hajilou, Yazdani, and Shokrpour (2012) found no connection between performance on the TTCT and receptive and productive vocabulary abilities in adult learners. While small in number and not entirely unanimous, this group of studies suggests that DT ability predicts success at learning a second language.

5 Research opportunities

As discussed earlier, the only domain in which the impact of DT training on language proficiency has been examined is in the context of spoken and written discourse production, which have been found to improve after brainstorming (Khodadady et al., 2011; Rao, 2007). It would be of practical and theoretical interest to determine whether the effect of brainstorming transfers from production to comprehension, such that when only brainstorming for production is practiced, comprehension improves as well. Such an effect may be expected, because the comprehension system serves as a feedback system during language formulation (Levelt, 1989). Given that brainstorming emphasizes generating ideas without criticism, one might speculate that it reduces learner anxiety, especially if the brainstorming is interleaved with language learning exercises. It would therefore be of interest to investigate whether any positive impact of brainstorming on foreign language learning may be mediated by a reduction of learner anxiety. There are a number of domains in which the impact of DT training on language learning and processing has yet to be explored and progress in demonstrating such an impact may be made, including word learning and high-level text interpretation.

There is evidence that exposing language learners to additional context improves word learning (Craik & Tulving, 1975; Prince, 2012) and that the benefits are larger when the context is self-generated as opposed to merely being processed receptively through reading (Hulstijn, 1992; Slamecka & Graf, 1978; Mulligan, 2002). In a study of English speaking students learning Chinese characters, Kuo and Hooper (2004) found that self-generating creative mnemonics for linking Chinese characters with their meanings, rather than being provided with mnemonics by researchers, lead to better vocabulary acquisition.

In line with this type of research, one could aim divergent thinking training at increasing the creativity of self-generated elaborated word contexts and test whether it improves vocabulary learning. Learners could be given the meaning of an L2 word (for example, in the case of a concrete noun, meaning could be conveyed with a picture), and be asked to generate sentences in which they use a word in an uncommon or a common context. For this purpose, it seems reasonable to assume that using a word in a context in which is usually does not appear is more creative than using the same word in a conventional context; thus, it seems possible to adopt a criterion for originality scoring similar to that used in the alternate uses test. For example, in the case of object nouns, the context could involve the action performed on the object or the setting in which the action is performed, and this action and setting
can be more or less common (for example, reading a book for information versus using it as a weapon by throwing it at someone, or reading a book in the library versus under the shower). For a particular to-be-learned item, on each learning trial for that item, learners could be asked to generate a new sentence context while also seeing their own self-generated sentences from previous trials. Whether one would find better word learning in the uncommon than common context condition is an open empirical question. Such an effect might be obtained because processing words in uncommon (i.e., more creative) contexts might engage one or more factors that improve retrieval of words from long-term memory: the distinctiveness of each memory trace, the number of retrieval cues, or the semantic variety of contexts. To evaluate the practical relevance of a creative elaboration effect on word learning, it should be compared to the impact of other factors known to improve word learning and memorization: for example, the effect of retrieval practice on long-term recall during word learning (Pyc & Rawson, 2010; Karpicke & Roediger, 2008).

To elaborate on the rationale for expecting a learning benefit from semantic variation, semantic memory may be viewed as a system for extracting invariant content (i.e., core content), from time- and context-dependent traces in episodic memory (McClelland, McNaughton, & O’Reilly, 1995; Winocur, Moscovitch, & Sekeres, 2007), consistent with the definition of semantic and episodic memory as time- and context-independent and dependent, respectively (Tulving, 1987). Increasing the degree of semantic variation of contexts, after robust traces in episodic memory have been established, may increase the rate and strength of encoding in semantic memory. The rationale for this prediction is that increasing the number of context-variant elements reduces the predictive value of each such element for its associated content (McClelland & Rumelhart, 1988), which should reduce the contribution of episodic memory while increasing that of semantic memory. Stark and colleagues implemented a neurocomputational model with separate but interacting systems for episodic and semantic memory and, as their model predicted, found evidence that an amnesia patient acquired semantic information from sentences better under conditions of greater variation during training (Stark, Stark, & Gordon, 2005). Bolger, Balass, Landen, and Perfetti (2008) found that new words were better learned after exposure to variable than constant contexts. Divergent thinking training that is selectively aimed at improving flexibility in the form of the number of semantic categories in which ideas are generated (Y. J. Lee, 2005; Runco & Okuda, 1991), may help a learner generate a greater variety of contexts, which in turn may promote encoding in semantic memory. It would be of theoretical and practical interest to test this hypothesis.

Another way in which vocabulary acquisition could benefit from divergent thinking training starts with the observation that language learners at all levels of proficiency continue to learn words and idiomatic expressions from texts in which a proportion of these items are known and a complementary proportion is unknown. Even highly proficient foreign language users will, from time to time, encounter words they do not yet know or for which they have incomplete knowledge of various meanings, meaning nuances, and semantic-associatively related words. Indeed, these considerations motivated the inclusion of a vocabulary acquisition test on the Canal-F aptitude test (Grigorenko, Sternberg, & Ehrman, 2000) that involves learning words from context. Language learners will often try to infer the meaning of unknown words from the part of the text they understand; this activity involves hypothesis generation and testing, which require a combination of divergent and convergent thinking. It may therefore be of interest to test whether DT training improves the ability to learn words and idiomatic expressions from context.

The meaning of words and phrases may be underspecified not just because the interpreter has suboptimal or no knowledge of them. There are several additional reasons why foreign language may be difficult to interpret. The interpretation of discourse can present an open-ended problem to the listener or reader. To illustrate this point, consider the interpretation challenges faced by language analysts, that is, intelligence professionals who interpret foreign language source materials. These professionals may encounter one or more of the following text interpretation challenges in their everyday jobs: linguistic and other sources of ambiguity, missing words due to physical degradation of the source materials, coded
communications, active attempts at deception, cross-cultural differences, unclear speaker intent, fragments of the same text that do not appear in order, uncertainty about which parts of a text are relevant or not, imperfect language proficiency (e.g., sub-optimal understanding of foreign discourse cohesion markers, such as connective constructions), and imperfect other knowledge (e.g., knowledge of history, literature, and culture). Thus, texts in which one or more of these interpretation challenges occur present an open-ended problem, such that there is not a single correct interpretation, but multiple interpretations, both common and uncommon, that must be considered. The cognitive challenge is exacerbated when the common interpretations reflect a mental fixation on dominant assumptions and associations, and when low-probable but high-impact situations have to be considered.

Coping with these open-ended interpretation challenges requires good divergent thinking and it remains to be determined whether divergent thinking training can make a difference in this regard. To give an example of the type of DT training that could be offered, consider that language instructors often use a two-step procedure in which they teach vocabulary and other expressions (step 1) before students are asked to practice the newly taught materials in the context of a text comprehension task (step 2). In one variation of this task, students could be asked to generate multiple hypotheses about the interpretation of an excerpt from the text and successfully adjust their hypotheses as they receive increasingly longer excerpts from the same text. The empirical question that could be addressed is whether divergent thinking training improves task performance and language learning. Divergent thinking training that gives students practice in being more flexible and original in the context of discourse comprehension may be of special interest.

A final suggestion for future research involves the observation we made earlier that the correlation between DT and foreign language learning may be mediated by one or more common underlying cognitive functions. We reviewed evidence concerning the positive impact of distraction and bilingualism on DT that is consistent with the proposal that a change from average cognitive control to either increased or decreased cognitive control may improve DT. Likewise, while language performance generally benefits from better cognitive control, including that induced through training (Novick, Hussey, Teubner-Rhodes, Harbison, & Bunting, 2013), there may also be conditions under which it benefits from less cognitive control (Chrysikou, Novick, Trueswell, & Thompson-Schill, 2011). It would be of considerable interest to test this proposal in the same subject population with measures of cognitive control, divergent thinking and language learning. Of course, the suggestion is not to test this by causing a permanent decrease in a person’s actual cognitive control abilities, as that would result in undesirable performance decrements in many circumstances. Instead, a transient reduction in a person’s effective cognitive control capacity may be induced by embedding the divergent thinking task or language learning task in a dual-task paradigm in which the other task is an unrelated cognitive control task with stimuli presented in another sensory modality, such as an auditory n-back task (Jaeggi et al., 2007).

More generally, based on the available research, one may speculate that cognitive control, particularly attention control, mediates the correlation between DT and foreign language (Kharkhurin, 2011). Therefore, future studies should test whether improving attention control improves both DT and foreign language learning. Such research should also consider the possibility that there are conditions under which manipulations that create a transient reduction in attention control improve DT and foreign language learning. This possibility is suggested by the finding that increased distraction correlates with DT and by the less-is-more hypothesis of foreign language learning (for review, see Chrysikou et al., 2011). According to this hypothesis, reduced resources for cognitive control increase the learner’s sensitivity to weak statistical regularities in language input without hindrance from rule-based top-down schemas.
6 Conclusions

The question addressed in this literature review was whether there is evidence that DT training can improve foreign language learning and language performance. Several conclusions are supported by the available research literature.

Verbal DT can be trained through a variety of cognitive and motivational approaches which improve fluency, flexibility, and originality of the responses immediately after the training. These training effects are clear evidence for an impact of verbal DT on language processing, since the responses on assessment of verbal DT involve verbal mapping and communication of thought.

Of practical relevance is the question whether such effects persist and improve native or foreign language performance on other language tasks than standard assessments of verbal DT. Several studies found persistent effects of DT training up to four years after initial training. A few of these studies found performance improvements in native language processing, including in making inferences during reading (Macdonald et al., 1976), and in the quality (Glover, 1980), and number of papers produced (Wang & Horng, 2002). Several other studies found that sustained brainstorming practice improves production in classroom-instructed foreign language learning, particularly oral proficiency in an interview setting (Khodadady et al., 2011) and various aspects of essay writing, such as vocabulary use and organization (Rao, 2007). A single session of brainstorming practice may not be sufficient to obtain these latter outcomes (Johnson et al., 2012). The benefit of brainstorming for discourse production may be due to exposure to, or self-generation of, a greater variety of ideas. There is a need for studies that tease these two effects apart, so that it can be established whether brainstorming improves discourse production above and beyond the impact of exposure to (i.e., receptive processing of), a greater variety of ideas. In addition, future research should address the impact of brainstorming in L1 (first language) versus L2 (second language), since the ease of idea generation may be greater in L1 than L2 (Lally, 2000).

Many individual difference studies have revealed a positive correlation between DT and various aspects of language processing, including semantic associative processing (e.g., Benedek et al., 2012), bilingualism (e.g., Kharkhurin, 2010; but see Hommel et al., 2011), and second language proficiency, for example, complexity of story generation (Albert & Kormos, 2011). These correlation results raise the question of whether DT or its underlying cognitive component functions contribute causally to language learning and processing. The finding by Rao (2007) that brainstorming practice improves essay writing is consistent with the idea that the correlation between DT and story generation (Rao, 2007), is mediated by a positive impact of DT on story generation. However, alternative interpretations of this particular correlation (e.g., crystalized intelligence contributing to both DT and story generation), cannot be ruled out based on the available research, which reports zero-order correlations only.

As discussed above, more generally, the correlation between DT and foreign language learning may be mediated by one or more common underlying cognitive functions. Based on the available research, one may speculate that cognitive control, particularly attention control, mediates the correlation between DT and foreign language (Kharkhurin, 2011). Therefore, future studies should tests whether improving attention control improves both DT and foreign language learning. Such research should also consider the possibility that there are conditions under which manipulations that create a transient reduction in attention control improve DT and foreign language learning. This possibility is suggested by the finding that increased distraction correlates with DT and by the less-is-more hypothesis of foreign language learning. According to this hypothesis, reduced resources for cognitive control increase the learner’s sensitivity to weak statistical regularities in language input without hindrance from rule-based top-down schemas.

We also identified a number of domains in which the impact of DT training on language learning and processing has yet to be explored. They include investigating the impact of creative elaboration and
hypothesis generation on learning words from context, and the effect of better DT on high-level text interpretation. Professional language analysts may have much to benefit from such training, since the meaning of texts they encounter is often underspecified and since coping with such open-endedness is a major linguistic, cognitive, and cultural challenge for them. It furthermore remains to be determined whether more divergent text interpretation during language learning improves language learning itself. Candidate aspects of language learning to examine in this context include, but are not limited to, learning the meaning nuances of closely related but different words, speech acts, and discourse cohesion devices.

A general limitation of the state of the science on the relationship between DT, DT training, and language learning and use is that there is a lot variation among studies in terms of participants, materials, and procedures. This makes it difficult to determine what elements of DT and DT training impact specific aspects of language learning and which mediating cognitive mechanisms are involved. Future studies would benefit from a more systematic approach in this regard. Moreover, studies that aim to identify methods for improving both DT and language learning and performance should investigate the impact of individual difference factors, such as variation in attention control, on the outcome of the intervention.

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