

Multilingualism, creativity, and problem-solving

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Abstract

The current chapter considers how language sparks discovery and innovation by looking at creativity and problem-solving through the unique vantage point of multilingualism. The chapter begins with an overview of how creativity and problem-solving are operationalized and measured, followed by a review of how multilingualism impacts the ability to innovate and solve problems. Research suggests that multilingualism leads to more creative outcomes. The relationship between multilingualism and creativity is modulated by linguistic factors, including age of second language acquisition and proficiency. Problem-solving depends on which language multilinguals use to arrive at a solution and on their proficiency level in each language. The final section discusses multilingualism, creativity, and problem-solving in real-world settings and potential future directions.

Keywords: multilingualism, bilingualism, creativity, problem-solving

Introduction

"Creativity is seeing what others see and thinking what no one else ever thought."

Albert Einstein

Imagine the following problem: You walk into a room and see a candle, a box of thumbtacks, and a book of matches all laying on a table (Figure 1). You are asked to attach the lit candle to the wall so that it will not drip wax onto the table. How do you do it?

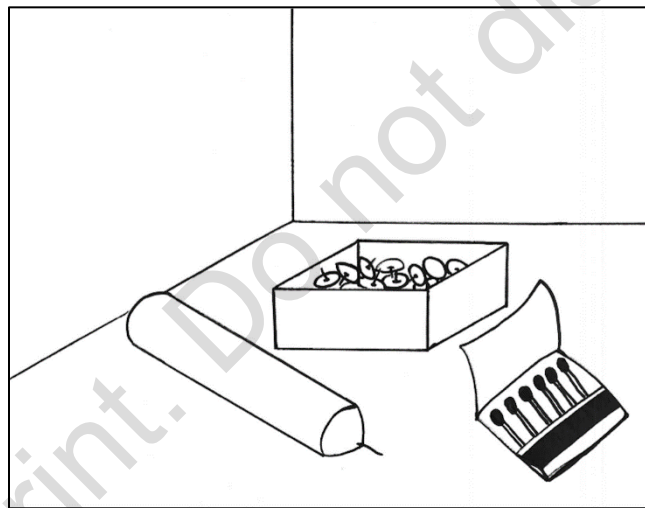


Figure 1. The classic candle problem from Duncker (1945) asks participants to attach a candle to a wall using only the candle, a box of thumbtacks, and a book of matches.

This problem is the premise of a classic creative problem-solving test originally developed by psychologist Karl Duncker in 1945. The most efficient solution to the problem involves emptying the thumbtacks from the box, attaching the box to the wall using thumbtacks, and then lighting the candle inside the box (Figure 2). Most people, however, do not arrive at this

solution easily because of *functional fixedness*, a cognitive bias that makes it difficult to see alternative uses of an object or tool. In other words, to solve the problem, participants need to overcome seeing the box's utility as *only* holding thumbtacks.

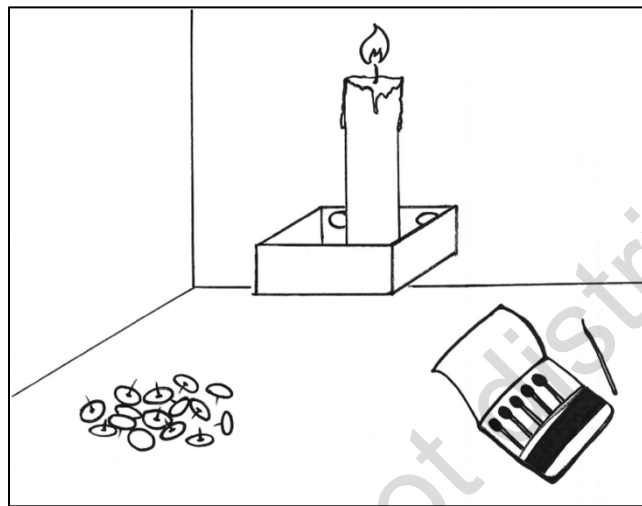


Figure 2. The solution to Duncker's candle problem requires participants to use the box as a separate object and attach it to the wall.

Since its inception, Duncker's candle problem has been adapted in several ways to study different scientific questions surrounding problem-solving and creativity. Notably, some of the earliest adaptations of Duncker's candle problem point towards an important role of language in how the problem is solved. Glucksberg and Weisberg (1966), for example, found that *labeling* the items (e.g., candle, thumbtacks, box, etc.) allowed participants to overcome functional fixedness and arrive at the solution. More specifically, it is the labeling *of the box* as separate from the thumbtacks that predicted whether participants can solve the problem or not (Weisberg & Suls, 1973). This might seem obvious—that labeling items as separate will encourage their separate use—but even subtle language cues influence how participants solve the candle problem. Higgins and Chaires (1980) manipulated the language of the instructions by verbally

describing the items as either “a box *of* tacks” or “a box *and* tacks.” Even though the items themselves were identical, the latter description of “a box *and* tacks” helped participants solve the problem nearly twice as fast. These experiments using Duncker’s candle problem suggest that the words and labels we use can influence how people approach and solve problems.

New experiences, such as living abroad and traveling, can be mind-opening and help overcome functional fixedness. Maddux and Galinsky (2009) gave Duncker’s candle problem to students enrolled in an MBA program. The more time students spent living abroad, the more likely they were to solve the problem. Interestingly, traveling abroad had no effect, indicating that the depth of the cultural experience is the key element driving creativity. Even being romantically involved with a person from a foreign country can improve creativity (Lu et al., 2017). At the end of a 10-month international MBA program, those who indicated they dated someone from a culture other than their own performed better on creativity tasks than those who did not. Through cultural immersion, individuals acquire new information, ideas, and perspectives, which can be used to create original and novel solutions to problems. Considering that culture and language are deeply intertwined (Jiang, 2000; Kramsch, 2014), this begs the question as to whether diversity in language (i.e., multilingualism) affects innovation and creative problem solving.

Since these early experiments, research on creativity and problem-solving has expanded into multiple disciplines through new experimental tasks, methodologies, and populations. In this chapter, we focus on the role of language, specifically how speaking multiple languages impacts creativity and problem-solving abilities. We begin this chapter with a discussion of how creativity and problem-solving are operationally defined and measured in experimental research. We propose that multilinguals are a unique population for studying the effect of language on

problem-solving and creativity. The final section focuses on the ways in which language experience influences creativity and problem-solving in the real world. Throughout the chapter, the terms “multilingualism” and “multilinguals” are used to refer to individuals who are fluent in more than one language (the terms “bilingualism” and “bilinguals” are used in instances where the studies reviewed specifically referred to their participants as bilinguals or as individuals who are fluent in two languages only).

Defining Creativity and Problem-Solving

Before diving into the question of how language influences creativity and problem-solving, it is necessary to clarify what we mean by each term. From designing a toy, to playing Dungeons & Dragons, to brainstorming ideas for marketing strategies, to creating an artificial language, creativity exists in every field of work. Although there is variability within and across fields (Puryear & Lamb, 2020), most experts generally agree that creativity consists of two elements (see Runco & Jaeger, 2012 for a historical perspective). The first element is that creativity reflects a person’s ability to generate ideas or strategies that are original, novel, or unusual. A creative person has the capacity to think about and perceive things from a different perspective. However, originality alone is not sufficient for creativity. The second element is that these ideas need to be relevant, useful, or appropriate to the goal. The word “relevant” is important to highlight because a person can come up with several unique ideas, but if these ideas are unrelated to the goal, then they might as well be useless. Simonton and Damian (2012)

defined creativity using a multiplicative equation ($\text{Creativity} = \text{Originality} \times \text{Adaptiveness}$). If the idea lacks either Originality or Adaptiveness, then the output will also lack creativity.

Similar to creativity, problem-solving has been used to describe a range of tasks. Solving a problem can include doing a crossword puzzle, going to couple's therapy, repairing a broken-down car, performing basic mental math, or attaching a candle to a wall. While vastly different, these and other problems share critical properties that have led to similar definitions of problem-solving. Duncker (1945) was one of the first to describe a problem in a scientific context: "A problem arises when a living creature has a goal but does not know how this goal is to be reached. Whenever one cannot go from the given situation to the desired situation simply by action, then there has to be recourse to thinking...Such thinking has the task of devising some action, which may mediate between the existing and desired situations (p. 1)."

Since then, others have refined this definition of a problem and extended it to problem solving. Goel (2010), for example, proposes that problem-solving requires the following conditions: "(1) there be two distinct states of affairs, (2) the agent is one state and wants to be in the other state, (3) it is not apparent to the agent how the gap between the two states is to be bridged, and (4) bridging the gap is a consciously guided multi-step process (p. 613)." Similarly, Eysenck and Keane (2020) defined problem-solving as being a purposeful (i.e., goal-oriented) and controlled (as opposed to automatic) process in which the solution is not immediately apparent. In sum, problem-solving is a multi-phase, higher-order cognitive process in which an agent (e.g., person, group, etc.) wants to overcome a difficulty. This cognitive process involves at least two critical steps: 1) perceiving and representing the problem and 2) retrieving problem schemas from memory (Jonassen & Hung, 2012). In other words, for there to be problem-

solving, an agent must first perceive and understand the situation as a problem and then draw from previous experiences to attempt to resolve the problem.

Both creativity and problem-solving are challenging concepts to encapsulate in a single definition. Nevertheless, these definitions have guided researchers in their examination of creativity and problem-solving. The next section explores the different ways in which creativity and problem-solving are measured in experimental settings.

Measuring Creativity Experimentally

Experimentally, creativity is typically measured with tests of divergent thinking, which refers to the ability to generate as many solutions as possible to a problem (Guilford, 1967) or to explore multiple associations and pathways (Acar & Runco, 2019). Two of the most widely used measures of creativity are the Torrance Test of Creative Thinking (TTCT; Torrance, 1966) and the Abbreviated Torrance Test for Adults (ATTA; Goff & Torrance, 2002). The TTCT and ATTA assess creative thinking abilities in two domains: Figural (nonverbal) and Verbal. The Incomplete Figures Test is an example of a figural nonverbal test. Participants are presented with incomplete drawings (e.g., two vertical lines in the shape of a V) and asked to complete the drawing by adding as many lines as they can to each figure. In contrast, the Situations Test is an example of a verbal test. Participants are presented with three common scenarios and asked to generate as many solutions as possible (e.g., “If all schools were abolished, what would you do to try to become educated?”). The responses on each subtest are scored along four dimensions: fluency (total number of relevant responses), flexibility (range of responses from different

categories and domains), originality (number of uncommon and unusual responses), and elaboration (level of detail in the responses). Another measure of creativity is the Alternative Uses Test (AUT) by Guilford (1967). Participants are asked to generate as many uses as possible for a simple object. For example, if the examiner said the phrase "plank of wood", the participant could generate *bench*, *planter*, *porch*, and so on as possible uses. The AUT is scored along the same four dimensions as the TTCT and ATTA.

Mednick (1962) proposed that creativity stemmed from the ability to form connections between unrelated concepts. Olson and colleagues (2021) created a new verbal task to measure divergent thinking, known as the Divergent Association Task. In this task, participants are asked to generate 10 words that are as different from each other as possible. In a large sample of almost 9,000 participants from around the world, naming unrelated words was found to predict performance on a range of creativity tasks. Specifically, individuals who generated words with greater semantic distance between them were able to think of more novel uses for common objects in the AUT and find associations between unrelated words like *book* and *wood* (e.g., *paper*, *bookshelf*, or *tree*) on the Bridge-the-Associative-Gap task.

Another measure of creativity is the Remotes Associates Test (RAT) by Mednick (1968). Participants are asked to link three seemingly unrelated words (e.g., *age*, *mile*, and *sand*) with a fourth word (e.g., *stone*: *stone* age, *milestone*, and *sandstone*). Creative problems, such as the RAT, are sometimes solved through insight. Insight occurs when a person suddenly realizes the solution to a problem. The RAT relies on both divergent and convergent thinking processes. Convergent thinking is the process of narrowing down multiple possible solutions to one (Cropley, 2006).

A major problem with measuring creativity is the inherent subjectivity that arises when judging an object or idea as creative. Even when following strict scoring guidelines, people's ratings of creative ability are highly subjective and based on the raters' perceptions, which can be shaped by external factors like culture (Kharkhurin, 2010a; see Shao et al., 2019 for a review), motivation (i.e., willingness to explore, see Collins & Amabile, 1999 for a review), and time pressure (see Amabile, Hadley, & Kramer, 2002 for a review). Ratings are dependent on who the raters are, their background knowledge, and what yardstick they use to determine creativity. Because creativity is inherently open-ended, there is the possibility that a response given by a test taker has not been included in the scoring manual.

Measuring Problem-Solving: Associations with Language and Creativity

A classic test of problem-solving is the Tower of London (Shallice, 1982), which requires participants to plan ahead as they move discs from one location to another in the fewest moves possible (Figure 3). There are multiple paths that lead to the final configuration, with some paths being more optimal than others. "Sub-optimal alternatives" refer to paths which take more than the minimum number of moves to solve the problem. Individuals who often use sub-optimal alternatives instead of optimal alternatives may have worse problem-solving abilities (McKinlay, 2011). Language disruption has been shown to negatively impact the efficiency with which participants can complete the puzzle (Abdul Aziz et al., 2017; Wallace et al., 2017). Wallace et al. (2017) tested 51 adults on the Tower of London problem under two conditions: articulatory suppression and foot tapping. In the articulatory suppression condition, participants were asked

to repeat a word aloud to a beat while completing the problem. Foot tapping was used as a control condition with equivalent demands. Participants in the articulatory suppression condition made more moves than participants in the foot tapping condition, suggesting a link between language and the ability to solve the Tower of London problem.

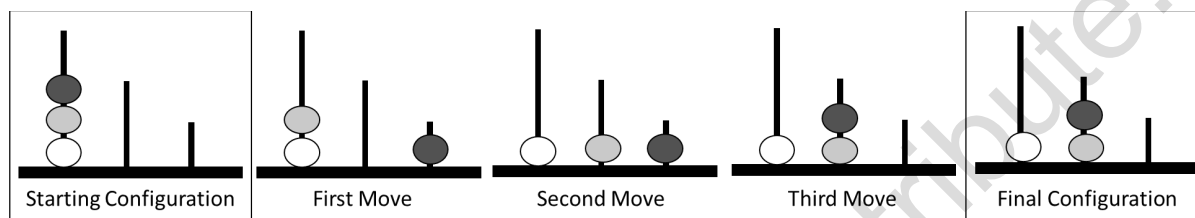


Figure 3. The objective of the Tower of London is to move a disc one at a time in order for the starting configuration to match the final configuration.

If language facilitates problem-solving, then language improvements should result in better problem-solving. Previous findings show reduced self-regulatory speech in children with specific language impairment is associated with difficulties on the Tower of London (Abdul Aziz et al., 2017). Abdul Aziz and colleagues (2016) tested the effectiveness of self-regulatory speech training for problem-solving in children with specific language impairment. Eighty-seven children with specific language impairment participated in an intervention study. The training consisted of a collaborative play-based intervention meant to encourage verbalization. Before the training, children with specific language impairment produced less self-regulatory speech and performed worse on the Tower of London compared to typically developing children. After the intervention, no differences in problem-solving ability between the specific language impairment and typically developing groups were observed. This finding suggests not only a link between language and problem-solving, but the potential of language interventions to improve problem-solving.

Problem-solving in most circumstances begins with the *perception* of a problem and its components. Research has shown that language plays a role in shaping a variety of cognitive domains, including perception and attention (Marian, 2023), all of which are pertinent to problem-solving. If these cognitive domains are necessary for problem-solving, interfering with language should negatively impact problem-solving. A common way of interfering with language is through verbal shadowing tasks in which participants are asked to remember or manipulate linguistic stimuli while performing a non-linguistic task. If the verbal shadowing interferes with performance in the non-linguistic task, that is taken as indicative of language being involved in the processes required to solve the non-linguistic task. Spelke (2003) argued that language allows us to combine and integrate different cognitive processes.

Speakers of multiple languages have more labels at their disposal than their monolingual counterparts, making them an interesting population in which to investigate creativity and problem-solving. Studies have shown extensive linguistic activation across languages, suggesting high interconnectivity between a multilingual's lexical systems (e.g., Marian, 2023; Marian & Spivey, 2003; Shook & Marian, 2019). This has led to proposals that the differences in creativity and problem-solving between monolinguals and multilinguals may stem from stronger connections between unrelated concepts (Kharkhurin, 2017; Marian, 2023; Ning et al., 2020), greater selective attention and cognitive flexibility (Kharkhurin, 2011), and more diverse multicultural experiences (Lee & Kim, 2011) in multilinguals than monolinguals.

Multilingualism and Creative Thinking

A large body of research has shown that even when only a single language is required, the languages of a multilingual are active (Kroll et al., 2012 for a review). For instance, when asked to pick up a *marker*, Russian-English bilinguals often make eye movements to a *stamp* because the Russian word for stamp is *marka* (Marian & Spivey, 2003). Neuroimaging studies reveal that multilinguals recruit the executive control network for language control as well as cognitive control (e.g., Anderson et al., 2018; see Luk et al., 2011 for a meta-analysis). Repeated engagement of this network for language selection suggests that multilinguals may develop a more efficient executive control system that could facilitate conflict resolution in other domains (Bialystok, 2017), including creativity and divergent thinking. Considering that creativity has been linked to executive control (Edl et al., 2014; Zabelina et al., 2019), it has been proposed that multilinguals may be better equipped than monolinguals at suppressing irrelevant ideas and combining unrelated concepts (Kharkhurin, 2011). As noted by Kharkhurin (2012, p. 85), “a key property of divergent thinking is an ability to establish a larger pool of associations to link unrelated concepts from different categories. This property may benefit from a specific architecture of bilingual memory, which facilitates ‘greater diversity of associations to the same concept because it is situated in two different linguistic conceptual networks’ (Lubart, 1999, p. 344).” Speaking multiple languages allows for more flexibility in thought, consequently unlocking the potential to be more creative.

While some studies report an advantage in favor of multilinguals on creativity tasks (e.g., Leikin, 2012; Leikin & Tovli, 2014; Xia et al., 2022; see Ricciardelli, 1992a and van Dijk et al., 2019 for reviews), others report no evidence of an association between multilingualism and creativity in children (Booton et al., 2021) and adults (Lange et al., 2020). For instance, monolingual and bilingual children performed equivalently on three tests of divergent thinking

(i.e., Word Meaning test, Circles test, and Object Uses test). The link between multilingualism and creativity has been found to be modulated by various second language factors, including language proficiency (Kharkhurin, 2008, 2011; Lee & Kim, 2011; Ricciardelli, 1992b; Sampedro & Peña, 2019), age of second language acquisition (Kharkhurin, 2008), and length of immersion in a new cultural context (Kharkhurin, 2008). In these studies, multilingualism was found to be associated with the ability to generate more ideas, shift vantage points (i.e., to look at something from a new perspective), and make new connections between ideas. Early ages of second language acquisition, higher levels of proficiency in both languages, and longer exposure to the new culture were associated with greater divergent thinking abilities. The findings from these studies suggest that multilingualism provides a boost to creativity.

How often multilinguals switch between languages has also been found to impact creativity. Code-switching, which is the act of mixing languages within a single sentence or between sentences, is common among many multilinguals (Lin, 2013). Multilinguals who code-switch often incorporate elements from both languages in highly systematic and innovative ways (Li, 2013). Kharkhurin and Wei (2015) demonstrated that multilinguals who frequently switch between languages (i.e., habitual code-switchers) produced more novel and original ideas on the ATTA than multilinguals who switch between languages less frequently (i.e., non-habitual code-switchers). In the same study, participants were administered the flanker task as a measure of selective attention. Flanker task performance predicted innovative capacity only among those who code-switch less frequently, suggesting that non-habitual code-switchers recruit selective attention to compensate for the effort required to switch between languages. Storme and colleagues (2017) found that bilinguals who frequently switch between languages in their daily lives generated more unique alternate uses for common items when forced to alternate back-and-

forth between languages (switch condition) compared to those who were restricted to using only their L1 (non-switch condition). In contrast, bilinguals who engaged in language switching less frequently gave more unique responses in the non-switch than in the switch condition.

Lastly, task presentation modality (verbal or nonverbal) is an important factor to consider when comparing monolinguals to multilinguals in creative thinking. Because multilinguals are managing their time across multiple languages, they have less daily exposure to each language. As a result, multilinguals generally have smaller vocabularies in each of their languages compared to monolinguals (Bialystok et al., 2022) and are slower on some lexical retrieval tasks (e.g., Gollan et al., 2005; Ivanova & Costa, 2008). When the cognitive demands are similar for both language groups, such as in nonverbal tasks, bilinguals tend to respond faster or make fewer mistakes than monolinguals (Luo et al., 2013). Compared to English monolinguals, Russian-English bilinguals obtained higher scores on the nonverbal subset of the ATTA, but lower scores on the verbal subset (Kharkhurin, 2010b), even after controlling for vocabulary knowledge in the language of testing. Similarly, children with a high degree of bilingual experience outperformed children with a low degree of bilingual experience, but only on the nonverbal task (Sampedro & Peña, 2019). Furthermore, higher proficiency in English and Russian as well as earlier ages of second language acquisition were associated with higher scores on the nonverbal subtest of the ATTA.

In sum, speaking multiple languages can spark creativity. Linguistic factors, such as language proficiency, age of acquisition, cultural background, and frequency of language switching, have all been found to impact creative abilities. Interestingly and perhaps surprisingly, the effects of multilingualism on creativity are more likely to be observed on nonverbal than verbal creativity tasks. The difference in performance on nonverbal versus verbal creativity tasks

can likely be explained by the fact that multilinguals divide their time between two or more languages and therefore activate lexical units in each language less frequently than monolinguals (Gollan et al., 2005). This decreased frequency of word use within a language may impact performance on linguistic creativity tasks that rely on word retrieval. However, when the creativity task does not require word retrieval, multilinguals generally perform better than monolinguals, for example on nonverbal creativity tasks that tap executive control abilities (Bialystok, 2017). Similar to the need to select the target language and filter out the irrelevant language, nonverbal creativity tasks require executive control to select the optimal response from inefficient or irrelevant responses. Next, we review the literature on multilingualism and problem-solving and consider whether multilinguals process and evaluate problems differently in each of their languages.

Multilingualism and Problem-Solving

Shortly after the emergence of standardized intelligence tests in the early 20th century, researchers began comparing monolinguals and multilinguals on a range of problem-solving tasks. Early comparisons of general intelligence suggested multilinguals performed worse than monolinguals, leading to conclusions that multilingualism was detrimental (e.g., Barke & Williams, 1938; Saer, 1923). Since then, these early studies have been thoroughly refuted as they did not control for socioeconomic status, education level, and language proficiency. Controlling for these demographic variables, Peal and Lambert (1962) found that French-English bilingual children obtained significantly higher scores than French monolingual children on both verbal

and nonverbal intelligence tests. Because the bilinguals' performance was most notable on subtests that required mental manipulation, Peal and Lambert concluded that bilingual children had increased "mental flexibility and superiority in concept formation" (p. 20) compared to monolingual children. Mental flexibility, often used interchangeably with the term cognitive flexibility, refers to the ability to adapt and shift perspectives in response to new and changing events or situations. This is important for problem-solving because learners can incorporate new information into their knowledge base to brainstorm possible solutions and rule out those that are inefficient.

Findings on the effects of multilingualism on problem-solving are scarce. There is evidence that sharing the same set of languages helps in collaborative problem-solving (Yow & Lim, 2019) and that bilinguals generally take less time to plan their moves on the Tower of London task compared to monolinguals (Gangopadhyay et al., 2018). Since problem-solving is so broad, it is possible that multilingualism can have an impact on certain types of problem-solving (such as insight problems), but not others. Cushen and Wiley (2011) examined the role of language experience in solving non-insight problems (i.e., mathematical problems) and insight problems (e.g., Triangle of Coins problem; de Bono, 1967, Figure 4). English-speaking monolinguals had higher scores on non-insight problems than insight problems, while bilinguals had similar scores on both. The authors attributed the bilinguals' performance on insight problems to their ability to perceive information in more ways than one (Bialystok & Shapero, 2005; Wimmer & Marx, 2014). In other words, being able to flexibility switch from one perspective to another allows multilinguals to consider an array of possible solutions from multiple vantage points (Greenberg et al. 2013).

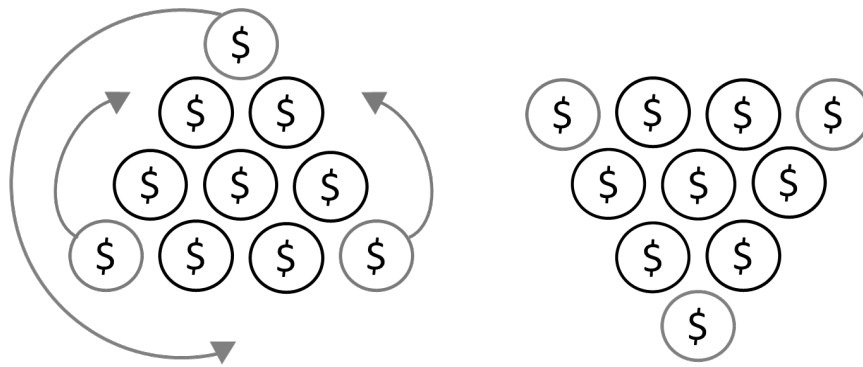


Figure 4. Triangle of Coins problem. What is the smallest number of coins that need to be moved to make the triangle point downwards? The steps to solving the Triangle of Coins problem are presented in the left panel in grey, and the solution is presented in the right panel.

Problem-solving plays an important role in mathematics. Among school-aged children, using multiple languages on a regular basis has been shown to support mathematical abilities due to the established link between executive functions and mathematical achievement (see Bull & Lee, 2014 for a review). However, the effect of multilingualism on mathematical abilities depends on the language that is being used (native or non-native) and the type of mathematical problem being solved (simple arithmetic or mathematical word problems). When multilingual adults solved complex arithmetic problems presented auditorily in their non-native language, they were slower to respond and recruited additional brain regions associated with visuo-spatial thinking. Multilinguals may need to visualize the symbolic form of the numbers when performing arithmetic in their second language (Van Rinsveld et al., 2017). There is also empirical evidence that multilinguals either switch between languages or translate mathematical problems into their preferred language (e.g., Marsh & Maki, 1976; McClain & Huang, 1982), which may be the reason why they are slower to respond in their non-native language. On mathematical *word* problems, 8-year-old German monolingual children outperformed Turkish-

German bilingual children, due to the monolinguals' stronger proficiency in German (Kempert et al., 2011). However, when the mathematical word problem included distractors that required executive functioning, no differences between groups emerged. Altogether, these findings highlight the importance of considering the language in which the problem is presented and the degree of executive function needed to solve the problem.

Multilinguals vary in proficiency in each of their languages. Researchers have found that speaking a foreign language impacts how multilinguals make decisions (Hayakawa et al., 2016, 2017). Using the classic trolley dilemma, German-English bilinguals were asked whether they would push a man in order to save five others in their native language (German) or a foreign language they spoke fluently, but less proficiently (English; Hayakawa & Keysar, 2018). When reading the problem in a foreign language, participants imagined the scene less vividly, and consequentially were *more* likely to sacrifice the one man. The authors concluded that speaking a foreign language reduces mental imagery, likely due to the difficulty of accessing emotions and memories in a less proficient language. This interpretation is in line with other findings, which suggest a foreign language can be less vivid and emotional (Amit & Greene, 2012; Geipel et al., 2015).

The finding that a foreign language reduces mental imagery in multilinguals opens a new avenue in which the role of language on problem-solving can be considered. Returning to Duncker's candle problem as an example, the primary challenge in solving it is overcoming functional fixedness. We have seen that labeling or separating the box from the thumbtacks facilitates solving the problem. Because the box of tacks is presented as just a box of tacks, other properties or possible functions are obscured. Could we reduce the salience of the tacks some other way? What if there were fewer associations with the concept box, making it less vivid and

rich, for example, through reduced mental imagery? It is possible that just like labeling the box and highlighting it as a separate object from the thumbtacks, describing the problem in a foreign language may reduce mental imagery and, in turn, reduce functional fixedness.

Language, Creativity, and Problem-Solving in the Real World

One of the greatest challenges experimental psychologists face is determining the extent to which findings generalize beyond the context of their studies. In other words, do the relationships that we infer from our experiments apply in real-world settings? Up until now, we have discussed the effects of multilingualism on creativity and problem-solving in controlled studies. In this section, we take a step outside the lab and review how multilingualism impacts creativity and problem-solving in everyday life.

The rise in globalization has increased the demand for multilingualism in businesses and organizations, making multilingualism an integral part of the economy (Duchêne & Heller, 2012). Multilingualism allows businesses to expand to different parts of the world, negotiate and communicate with people who speak different languages, and create products for a wide range of consumers. Grin and colleagues (2010) looked at how languages in Switzerland generate economic value and attributed multilingualism as being the key element for Switzerland's competitive edge (worth 10.8% in GDP, about \$75 billion Swiss Franc in 2023). Switzerland has four official languages, including German, French, Italian, and Romansh. Despite being a small country of approximately 8.7 million inhabitants (Federal Statistical Office, 2021), Switzerland ranks first on the Global Innovation Index (WIPO, 2021). In contrast, a study estimated that the

United Kingdom (Foreman-Peck & Wang, 2014) loses around 3.5% of its GDP every year because of lack of linguistic skills to communicate with business partners in parts of the world that do not speak English.

In education, lesson plans and curriculums are often designed with an emphasis on convergent thinking rather than divergent thinking. Examinations are a combination of multiple choice, true or false, and fill-in-the-blank questions, requiring students to find the single and most optimal answer to a question. However, children are natural explorers and curious beings, making discoveries about the world every single day. Designing educational programs that foster both creativity and language learning in children may be valuable, as proposed by Kharkhurin (2012; see Bilingual Creative Education program).

Although there are few bilingual creative education programs in the world, many countries have implemented language immersion programs. In the past decade, the United States has seen the number of dual-language programs available to students grow from 1,000 programs in 2010 to over 3,600 programs in 2021 (American Councils Research Centre, 2021). To be considered a dual-language immersion program, at least 50% of daily instruction must be in a non-English language. Marian and colleagues (2013) examined whether a bilingual education impacts academic achievement. Elementary school children in grades 3, 4, and 5 enrolled in a bilingual two-way immersion program that combined the majority language (English) and the minority language (Spanish) were compared to students enrolled in traditional English-only or Spanish-only mainstream programs on standardized assessments of mathematical abilities. In all three grades, bilingual students obtained higher math scores than their monolingual counterparts. In two large-scale datasets, bilingualism positively predicted performance on standardized tests of mathematical reasoning and problem-solving in pre-kindergarteners aged 4 and 5 (Hartanto et

al., 2018). Altogether, these findings suggest that multilingualism may improve problem-solving skills in children.

An increasingly popular way to leverage the benefits of multilingualism in educational settings is through *translanguaging*. Translanguaging has been defined as “the deployment of a speaker’s full linguistic repertoire without regard for watchful adherence to the social and politically defined boundaries of named (and usually national and state) languages” (Otheguy et al., 2015, p. 283). In a classroom, translanguaging is a departure from the norm of restricting multilingual students to using only one language and enabling them to think, problem-solve, and create freely in whichever languages they want. Proponents of this approach highlight that encouraging multilingual students to use their full communicative potential fosters inclusivity (Omidire & Ayob, 2022) and perseverance (DiNapoli & Hector Morales, 2021), which promotes problem-solving and creative agency in students (see García, 2018 for a review). Initial implementations of translanguaging at the school level have proven fruitful in leveraging multilingualism for academic success. For example, eight New York City schools participated in a project called the City University of New York-New York State Initiative on Emergent Bilinguals, which taught educators to incorporate a translanguaging pedagogy in their classrooms. As the world and its classrooms become increasingly multicultural and multilingual, translanguaging can be key to fostering creativity and problem-solving in schools, especially among minoritized students. It is important to note that not all researchers are promoting translanguaging for children in all contexts, as there are some limitations and trade-offs with achieving linguistic diversity amongst students (Jasper, 2018; Paradowski, 2021).

Beyond educational settings, translanguaging can often be seen in online communication. Through social media, multilingual users often combine words, phrases, emojis, and images to

communicate with each other in novel and creative ways. In certain contexts, this can be more than just metalinguistic fun since breaking linguistic norms can be seen as a rebellious act. In China, for example, the inclusion of alphabetic (as opposed to logographic) words in the Modern Chinese Dictionary was seen as a foreign threat that prompted a national debate on the topic (Wei & Hua, 2019). Since 2015, there has been a list of officially banned words, many of which are linguistic innovations that blend foreign scripts and traditional Chinese characters. Wei and Hua (2019) analyzed Chinese social media and found that many multilingual users were creatively bending the rules of traditional Chinese language and incorporating foreign words in an act of “playful subversion”. The authors go as far to call this type of language “a creative and critical act, as it pushes and breaks the boundaries between the old and the new, the conventional and the novel, and the acceptable and the unacceptable, and problematises and challenged received wisdom” (Wei & Hua, 2019, p. 151). This type of communication called *transcribing* has been primarily observed in tense political climates, in which online users mix English with their language to mock authority and political figures (e.g., Greece: Androutsopoulos, 2020; Egypt: Panović, 2018; Hong Kong: Wei et al., 2020). In this digital era, multilingualism itself is the creative output through which online users are tackling the collective problem of sociopolitical discontent.

Conclusion

In this chapter, we demonstrate that speaking multiple languages enhances creativity and problem-solving skills. In general, multilinguals outperform monolinguals on creativity tasks,

likely because of the multilinguals' enhanced executive control abilities and exposure to multiple cultures (see van Dijk et al., 2018 for a review; c.f. Lange et al., 2020), but the relationship between multilingualism and creativity depends on several linguistic variables such as proficiency (Kharkhurin, 2008, 2011; Sampedro & Pena, 2019), age of acquisition (Kharkhurin, 2008), and socio-cultural context of acquisition (Kharkhurin, 2010a). The task presentation modality (verbal versus nonverbal) is also important, as bilinguals had higher scores than monolinguals on nonverbal creativity tasks, but not on verbal creativity tasks (Kharkhurin, 2010b). Furthermore, bilinguals who code-switched frequently were able to produce more innovative and useful ideas than those who code-switched less frequently (Kharkhurin & Wei, 2015). The findings from the research on multilingualism and creativity have implications for cognitive domains ranging from imagination to cognitive flexibility to perspective-taking.

Although more research on multilingualism and problem-solving is needed, the evidence thus far suggests that the language in which problems are presented to multilinguals is an important factor. For example, multilinguals produce less vivid mental images in their second language (Hayakawa & Keysar, 2018), so presenting problems in a non-native language could reduce the salience of traditional solutions and bring novel ones into focus (i.e., overcoming functional fixedness). If so, foreign languages could be leveraged as a tool for exploring alternative or uncommon solutions. At the same time, problems in a speaker's non-native language can increase cognitive load, hindering creative performance as attentional resources are diverted towards understanding the details of the problem rather than brainstorming creative solutions. It may be that a second language is beneficial for some creative tasks in which vivid mental imagery plays a notable role (such as thinking through Duncker's candle problem), but not for others in which cognitive load is more important (such as planning the moves in the

Tower of London task). The research in this area is still in its infancy, and these are just some of the promising directions for studying the interaction between multilingualism and problem-solving, including decision-making, learning, reasoning, and critical thinking.

In addition to language, another variable that influences problem-solving and creativity is culture (Kharkhurin, 2010a). Cultural differences have been found in how participants leverage language to solve problems. A review by Leung and colleagues (2008) reported that exposure to multiple cultures was positively associated with performance on creativity tasks. Culture impacted the cognitive processes that support creativity, such as the retrieval of unconventional knowledge and ideas from less familiar cultures. The definition of creativity shifts depending on the culture. Easterners value adherence to social norms and define creativity in terms of the individual's moral and social contributions to society (Rudowicz & Yue, 2000) and whether the creative piece is "appreciated by others" (Rudowicz, 2003). In contrast, Westerners value novelty and utility as defining features of creativity, including atypical exemplars (i.e., "a break from tradition," Niu & Sternberg, 2006). Future research will need to disentangle multiculturalism from multilingualism by isolating the effects of multilingualism while maintaining cultural homogeneity across participant groups (for example, by comparing monolingual students enrolled in mainstream classrooms to monolingual students enrolled in language immersion programs). And although experiments in controlled environments address important questions regarding cause and effect, there is a strong need to create experimental tasks that are culturally appropriate and mirror the activities and experiences that individuals face daily. Moving forward, measures of creativity and problem-solving should aim to increase external and ecological validity.

Other avenues for potential research include looking at whether the number of languages and degree of language exposure impact divergent and convergent thinking. As previously mentioned in the Introduction, the amount of time spent living abroad significantly predicted creativity (Maddux & Galinsky, 2009), illustrating that the quality of the experience is a driving force behind creative problem solving. Therefore, the degree of exposure to multiple languages should be examined in future studies. Because new experiences increase connections between concepts and provide access to a richer pool of information, it may or may not be the case that the effects of language could be additive such that with each additional language, multilinguals' creative potential would increase as well. Future studies should look at the associations between the number of languages known, creativity, and problem-solving abilities.

From small-scale experiments to national economies, multilingualism is a powerful force that shapes cognition beyond language (Marian, 2023). Problem-solving and creativity are known to be influenced by language, and thus represent ripe, understudied domains in which to investigate the link between multilingualism and higher-order cognition. Research has shown high interconnectivity within the multilingual lexicon (Shook & Marian, 2013), but the effect of multilingualism on other cognitive domains remains an open question. To answer it, we need to embrace the full spectrum of linguistic differences and incorporate linguistically diverse populations. Multimodal multilinguals, individuals with language impairments, non-human animals, and even artificial intelligence all represent new opportunities to examine how language impacts the mind and beyond.

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