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The Role of Constraints in Creative Sentence Production

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Two experiments explored how people create novel sentences referring to given entities presented either in line drawings or in nouns. The line drawings yielded more creative sentences than the words, both as rated by judges and objectively by a measure of the amount of information that the sentences conveyed. A hypothesis about the cognitive processes of creation predicted this result: Creativity depends on constraints. Line drawings of entities present more information about them than nouns denoting the same entities, and so the pictures provide more constraints than the nouns. Hence, line drawings yield more creative sentences than words.

Despite several creative approaches and some progress toward a more methodical empirical scrutiny (Runco, 1997; Runco & Albert, 2010), creativity remains surrounded by an aura of mystery. Many of the existing accounts of creativity have embraced the view that creativity is the privilege of a few special individuals, often called geniuses (e.g., Simonton, 2013), and that creativity is mostly inscrutable. Within this perspective, the standard research methods have been case studies (e.g., Gardner, 1993; Gruber & Wallace, 1999) and historiometric studies (Simonton, 1990) Although it is undeniable that certain individuals do, indeed, display a higher level of creativity in their field of expertise than others, it also cannot be disputed that creative capacity is a trademark of human cognition.

Unlike the *genius* view, the *creative cognition* approach (e.g., Finke, Ward, & Smith, 1992; Haught & Johnson-Laird, 2002) proposes that creative instances are omnipresent and that the relevant processes are open to empirical investigations. The central assumption is that creativity is based on the same kinds of cognitive processes that people all use in everyday, ordinary thought. Indeed, instances of creative behavior can be observed in everyone, beginning with children (see the *everyday creativity* perspective, e.g., Eisenman, 1999; Richards, 1990), and the processes that are relevant to creativity can—and should—be explored experimentally (e.g., Runco & Sakamoto, 1999). So, the central question becomes less about who is creative, but rather about how people think creatively and, as a corollary, how one might become more creative.

Some of the most compelling instances of creativity occur in the production of language, which relies on the power of recursion (Chomsky, 1965). But how individuals generate novel sentences remains a mystery. In particular, the cognitive work leading to a thought, let alone a creative one, and to its formulation in a well-formed sentence lacks an adequate explanation (Levelt, 1989). The experiments described herein aimed to make progress in elucidating this mystery and the deeper mystery of creativity. Their focus was not on the generation of grammatically correct sequences of words, but on how people can incorporate given referents into a novel sentence.

The theoretical motivation of the research presented here rests, in part, on the following premises: the outcome of a creative process is Novel for the person producing the result, Optionally Original for society at large, the result of a Nondeterministic process that is guided by Constraints and that is based on Existing Elements. These premises form the foundation for the "NONCE" analysis of creativity (Haught & Johnson-Laird, 2002; Johnson-Laird, 1993; Johnson-Laird, 2002).

Creation within any artistic genre or scientific paradigm depends on constraints—the constraints of the genre, the constraints of scientific data (Johnson-Laird, 1987; Stokes, 2005a, 2005b). Artists commonly invent new constraints when those of the previous tradition no longer seem to be viable to them. Indeed, creation

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depends on constraints, and the NONCE hypothesis postulates that the greater the number of constraints, within reason, the more creative individuals are likely to be.

To test this conjecture, participants were asked to generate creative sentences, and the constraints on the task were manipulated in three independent ways. First, the entities to which the sentences had to refer were presented either as line drawings of the entities, or as unambiguous nouns referring to the entities. Second, the number of given items to be incorporated in the sentence was either two or three. In both cases, the participants had to include at least three nouns in the sentence, but where they were given only two nouns or two pictures, they were free to choose the remaining noun. Third, the set of given entities either included one animate entity or was entirely inanimate.

The pictures were more constraining than their corresponding nouns. A picture of an entity such as a banana shows a particular instance of the entity with a particular shape seen from a particular point of view. It presents much more information than the corresponding noun given that the noun can be depicted in infinitely many different ways. Hence, the pictures provided more constraints than the nouns. The claim is likely to be true in general, provided that the pictures are unambiguous and can be immediately identified as an instance of the same entity that the noun denotes.

Three given items are more constraining than two. The presence of an animate entity might also be more constraining than its absence. Animacy calls for action, and the need to formulate an action that the agent can carry out on entities selected at random from the pool of available entities might force individuals to be more creative than they would otherwise.

The use of pictures as a constraint has a corollary. A picture brings to mind visual properties of an entity more often than the corresponding noun brings them to mind. The features that are brought to mind, whether for words or pictures, should also be influenced by the need to frame a sentence. Sentences in English call for finite verbs, and in the present task verbs need to relate noun phrases referring to the given entities. Visual properties, however, tend to be expressed in adjectives, and so pictures may provide a further constraint on the task of generating sentences in the current task: they may make the task harder and thereby also enhance creativity.

EXPERIMENT 1

The first experiment tested the main prediction that pictures would yield more creative sentences than words. An additional exploration concerned whether participants would produce more creative sentences from three items than from two, from sets of entities including an animate agent than from inanimate sets.

Method

Participants. Twenty-two Princeton University undergraduate students (9 men and 13 women), ages 19–20, participated in this study for course credit. They were all native speakers of English, and their participation in this experiment fulfilled a requirement for an introductory Psychology class.

Design. The participants were their own controls and they generated sentences in eight conditions depending on whether the entities were presented as pictures or as nouns, whether there were three or two given entities, and on whether or not the entities included an animate agent. Each participant carried out four trials in each condition, i.e., a total of 32 trials, which were presented in different random order. The contents of the entities were counterbalanced across the participants so that they occurred equally often as pictures and as nouns in the experiment as a whole.

Materials. The pictures were line drawings selected from Snodgrass and Vanderwart's (1980) set of 260 schematic pictures of concepts, most of which included exemplars from Battig and Montague's (1969) category norms and all denoted basic level concepts (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). Only unambiguous pictures were selected, and those pictures of parts of objects and pictures that elicited polysemous names (such as *saw* and *iron*) were excluded. The nouns were the names of the entities in the line drawings and were presented in capital letters. None of the entities in a set belonged to the same semantic category.

Procedure. The participants were instructed to generate a creative sentence for each of the sets of entities. The sentence had to include all of the given entities, which were presented simultaneously on the screen of a computer, and, whenever a set contained two entities and a question mark, participants had to incorporate in the sentence a third noun, which they were free to choose. No instructions elaborated on the meaning of *creative*, and so the participants used their own judgment on the matter. They were only told: ''There is no such thing as a right or wrong sentence, provided that you refer to the items on the screen.'' Four practice trials occurred at the start of the experiment to familiarize the participants with the task. They were told that when a set of entities appeared on the screen, they should begin

to think of a sentence that referred to them. As soon as they had such a sentence in mind, they had to press the space bar on the computer keyboard, which removed the entities from the screen. They then wrote down the sentence verbatim. The next trial began only when the participant pressed the space bar. Thus, for each trial, the computer recorded two response times: the generation time, which was the time a participant took to think of the sentence while the entities were on the screen, and the writing time, which was the time the participant took to write the sentence down while the screen was blank.

Results

Creativity. Two measures were used to assess creativity. First, on the assumption that creative sentences should be less predictable, Shannon's statistical measure of information (Shannon & Weaver, 1949) was used to assess the unpredictability of the sentences in the different conditions. Second, a panel of independent judges rated the creativity of the sentences.

The sentences were sorted blindly into categories based on the similarity of their meanings. For example, for the set of entities LION STRAWBERRY HARP, sentences such as: "After the lion finished playing the harp, he ate some strawberry" and "The lion was playing the harp while eating the strawberry" were put in the same category, whereas: "The harp had a strawberry-colored lion carved in its post" was put in a different category. The information-theoretic measure, $\sum$(-p log2 p), was computed for each of the eight conditions.

Figure 1 shows the means for each condition. The sentences created from pictures were significantly more informative than those created from the words (Wilcoxon test, $z = 3.01$, $p < .003$). None of the other variables produced reliable effects and there were no reliable interactions among the variables.

Two independent judges rated blindly the creativity of each sentence on a seven-point scale (in which 1 denoted a sentence that was *not at all creative* and 7 denoted an *extremely creative* sentence). The judges' ratings were reliably correlated (Pearson's $r = .43$, $p < .001$). The measure of information also correlated reliably with the judges' ratings (Pearson's $r = .43$, $p < .001$). Figure 2 shows the mean ratings for each condition. The sentences generated from pictures had reliably higher ratings of creativity than the sentences generated from words (Wilcoxon test, $z = 2.24$, $p = .029$). None of the other variables produced reliable effects and there were no reliable interactions among the variables.

Generation times. The generation times for three participants were excluded because these individuals often responded before they had thought of a sentence. Some of the remaining participants occasionally made the same error and these trials were also excluded from the analysis. The participants took, on average, over 2 sec longer to create a sentence from line drawings (20.64 sec) than from nouns (18.41 sec; Wilcoxon test, $z = 2.21$, $p = .027$). They also took almost 4.5 sec longer to create sentences about three given entities (21.75 sec) than about two (17.29 sec; Wilcoxon test, $z = 3.09$, $p = .002$). No other significant main effects or interactions occurred.

Sentence length. The participants created longer sentences from pictures (14.15 words) than from words (12.79 words; Wilcoxon test, $z = 3.56$, $p < .001$), longer sentences from three entities (14.56 words) than from two (12.37 words; Wilcoxon test, $z = 4.08$, $p < .001$),

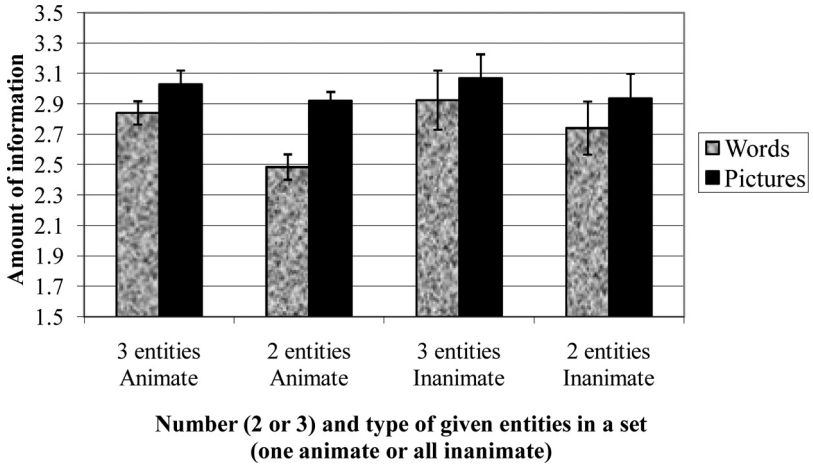

FIGURE 1 Information-theoretic measure of creativity, Experiment 1.

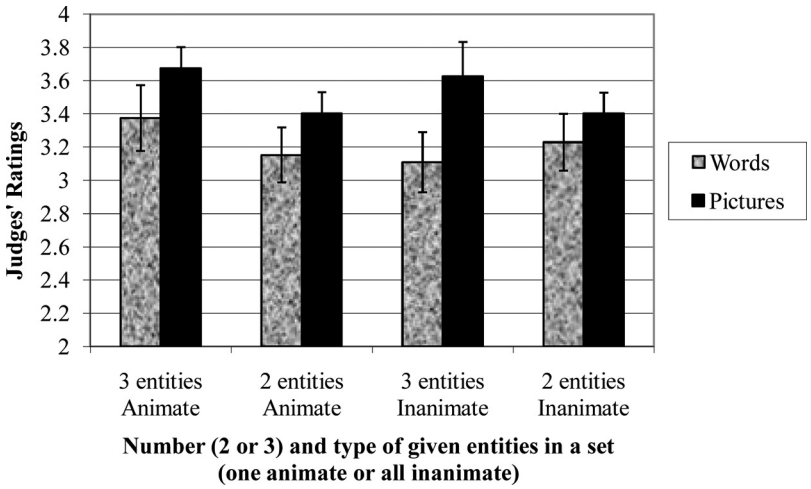

FIGURE 2 Creativity ratings from judges, Experiment 1.

and longer sentences from sets that did not include an animate agent (14.16 words) than from those that did (12.78 words; Wilcoxon test, $z = 2.99$, $p < .005$). There was a significant correlation between generation times and sentence length (Pearson's $r = .333$, $p < .001$).

Discussion

As predicted, the participants generated sentences of a greater creativity in response to pictures than to words, as shown both by the judges' ratings and the statistical measure of unpredictability. The NONCE hypothesis explains this result on the grounds that line drawings of entities are more constraining than nouns denoting them. The participants also took longer to generate sentences from pictures than from words, and the sentences that they generated from pictures were also longer than those that they generated from words. However, the correlation between sentence length and creativity was not reliable. The given number of entities affected latency and length of sentence in a predictable way: The participants took longer to create longer sentences from three entities than from two. But, despite a trend in the predicted direction, this variable had no statistically significant effect on the creativity of the end result. In both cases, of course, the participants' sentences had to refer to three entities, and so the experiment may not have been powerful enough to detect any effect on creativity of whether the third entity was given to the participants or chosen by them. Likewise, the inclusion of an animate agent in the set of entities yielded only one reliable effect: the resulting sentences were shorter than those that were not required to refer to an animate entity. The presence of an animate entity in a set (e.g., COW BICYCLE ?) often led participants to anthropomorphize it (e.g., "The cow rode the bike to get milk from the corner grocery store"). This tendency may explain why the resulting sentences were more parsimonious and less creative.

EXPERIMENT 2

The second experiment examined further the differences between line drawings and nouns. First, it aimed to validate the prediction that the difference applies only to the production of creative sentences. Hence, it compared the production of sentences that were intended to be creative with those that were not intended to be creative. Second, it examined the nature of the nouns that the participants chose in the two items condition.

Method

Participants. Thirty-two Princeton University undergraduate students (15 men and 17 women), ages 19–21 participated in this study, in exchange for credit for a Psychology class. They were all native speakers of English.

Design, procedure, and materials. The participants acted as their own controls and carried out two blocks of trials, which were counterbalanced in order. In one block, the participants were told to produce creative sentences, and in the other block they were told to produce the first sentence that came to mind. Within each block, half the trials used pictures and half the trials used words (from the same materials as Experiment 1). Half of all the sets included an animate entity and the other half did not. There were six trials in each of these four conditions, making a total of 24 trials in each block. The trials were in a different random order for

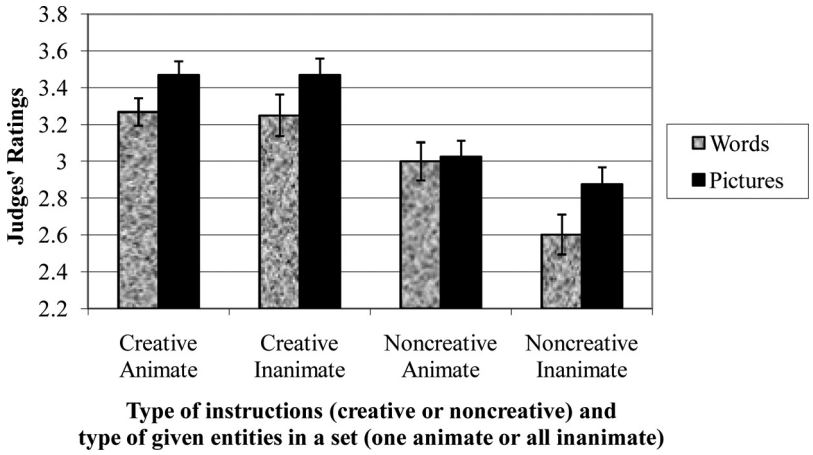

FIGURE 3 Judges' ratings of creativity, Experiment 2.

each participant. There were two given entities on each trial and a question mark. The participants had to refer to three entities in each sentence, and the question mark reminded them to choose a third entity. They were told to underline this third noun when they wrote down the sentence. As in the first study, the position of the animate entity in the set was counterbalanced, i.e., it occurred either first or second in the set. All other aspects of the materials and procedure were identical to those of Experiment 1.

Results

Creativity. Figure 3 presents the means of Shannon's measure of information, and Figure 4 presents the means of the two judges' ratings on the seven-point scale. These ratings correlated reliably (Pearson's $r = .331$, $p = .001$), and they also correlated reliably with the measure of information (Pearson's $r = .545$, $p < .001$). The sentences in the creative condition were more informative than those in the noncreative condition (Wilcoxon test, $z = 5.06$, $p < .001$). A similar reliable effect occurred in the judges' ratings (Wilcoxon test, $z = 5.30$, $p < .0001$). The creative condition yielded significant effects of the variables predicted to influence creativity. In this condition, the pictures yielded sentences that were more informative and rated as more creative than those produced from the words (Wilcoxon tests, $z = 2.80$, $p = .005$; and $z = 3.16$, $p = .002$, respectively). The sentences from inanimate entities were also were also more informative than the sentences from sets including an animate entity (Wilcoxon test, $z = 2.20$, $p = .028$). No other main effects or interactions were reliable.

Generation times. Overall, the participants took longer to produce creative sentences (15.30 sec) than those that first came to mind (9.46 sec; Wilcoxon test, $z = 6.00$, $p < .0001$). They also took longer to produce the first sentence that came to mind given pictures (10.13 sec) than given words (8.68 sec; Wilcoxon test, $z = 2.63$, $p < .01$).

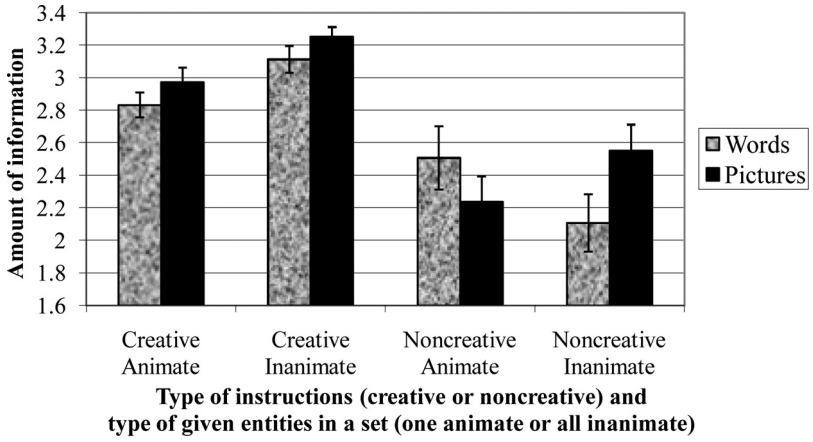

FIGURE 4 The information-theoretic measure of creativity, Experiment 2.

Sentence length. The sentences were longer in the creative condition (13.85 words) than in the noncreative condition (11.14 words; Wilcoxon test, $z = 8.32$, $p < .0001$). They were also longer in response to line drawings (14.17 words) than to nouns (13.53 words), in both the creative condition (Wilcoxon test, $z = 3.21$, $p = .001$) and the noncreative condition (Wilcoxon test, $z = 2.82$, $p = .005$). And they were longer for sets of inanimate entities than for sets including an animate entity for both the condition (Wilcoxon test, $z = 2.41$, $p = .016$, and $z = 2.77$, $p = .006$, respectively).

The participants always had to think of a third word of their own to include in their sentences, and they underlined this word when they wrote the sentences down. When they created a sentence from pictures, they tended to choose a third word from the same category as one of the two entities in the pictures (on 57% of relevant trials). But, when they created a sentence from nouns, they were less inclined to choose a third word from the same category (50%). This interaction was reliable (Wilcoxon test, $z = 2.35$, $p = .019$).

GENERAL DISCUSSION

The goal of this study was to test the hypothesis that constraints enhance creativity. Line drawings of entities are more constrained than nouns denoting those entities. Pictures show a particular entity; words are general. That is why, as the saying goes, ''One picture is worth a thousand words.''

In the first experiment, individuals had to produce creative sentences referring to given entities. They were more successful from entities depicted in line drawing than from entities named by nouns. That is, their sentences were judged to be more creative, and their sentences were less predictable according to Shannon's information-theoretic measure. An alternative explanation of the phenomenon is that individuals find it harder to put pictures into sentences than to put words into sentences. This account is consistent with the findings of the first experiment: The participants did, indeed, take longer to frame sentences based on pictures than sentences based on words, and the sentences based on pictures contained more words than the sentences based on words. However, one result that goes against this account is that the number of entities to which the sentences had to refer yielded reliable effects on both latency and length, but did not show any such effect on the measures of creativity. It may be that the experiment was not sensitive enough to detect such an effect, which the hypothesis concerning constraints, certainly predicts. But, fortuitously, the lack of this effect, in contrast to those on latency and length, counts against the notion that creativity is merely an effect of how much time individuals devote to constructing sentences.

The second experiment revealed an interaction that is crucial for the hypothesis about constraints. The experiment demonstrated the critical role of the instructions to generate a creative sentence. It contrasted what happened in this condition with a condition in which the participants merely stated the first sentence that came to mind. Pictures yielded sentences that were more imaginative than the sentences generated from words. But, this effect occurred only when the participants had been told to produce a creative sentence. Once again, the results ruled out the simple notion that creativity depends solely on the time allotted to the task.

The sentence production task poses problems to participants. They have to solve the problem of formulating a sentence that makes reference to certain entities. Hence, they have a goal and they have constraints on how to reach that goal. The constraints depend on whether the set of entities is presented pictorially or verbally. The particular sentences that the participants created provide clues about the nature of the problem-solving process. Pictures, as suggested in the Introduction, make the visual properties of objects salient, and these properties often go on to guide the construction of sentences. For instance, given pictures of the following entities: LAMP PEAR NECKLACE, a participant created the sentence: ''*Although she was shaped like a pear, I gave her a necklace with the lamp light on.*'' Similarly, given pictures of the entities: LOBSTER FENCE UMBRELLA, another participant wrote: ''*Beyond those white picket fences, the world is a rainy place, tough as a lobster's exoskeleton, and you've got no umbrella.*'' And, in Experiment 2, there was a common tendency to respond to: ONION BOTTLE ? by creating a sentence in which the onion was in the bottle (cf. Tabossi, Colombo, & Jobs, 1987).

In general, individuals are likely to retrieve certain knowledge about the entities in question, depending in part on their format of presentation, and then to use this knowledge as a constraint on the creation of a scenario that can be described in a sentence referring to the entities. One sign of this process was illustrated by the inclusion of an animate agent in the set of entities (see Bock, Loebell, & Morey, 1992; McDonald, Bock, & Kelly, 1993). There was then an overwhelming tendency (in Experiment 2) for individuals to construct a sentence referring to an action carried out by the animate agent on the inanimate entity. This tendency, almost automatic, yielded shorter and more stereotyped sentences.

After the automatic activation of properties, individuals search for an appropriate scenario. Some properties may suffice for the creation of a relation between the entities. When the participants had to generate the first sentence that came to mind, they would sometimes merely enumerate the existence of the relevant entities in some setting, e.g., ''Mary found a pear, a necklace,

and a lamp in her closet.'' But, the participants tended to avoid such lists when they had to be creative.

The need for freedom to create is commonplace. But, according to the NONCE hypothesis about creativity, such freedom is an illusion. On the contrary, constraints are at the heart of the creative process. They govern the generation of ideas, and they provide criteria for the evaluation of ideas. Without constraints, there is no creativity. Hence, the creators of works of art often go out of their way to seek constraints, e.g., the serial method of musical composition developed by Schönberg, the invention of highly constraining verse forms such as the villanelle and sestina, and the elaborate formal and combinatorial constraints devised by OULIPO (the Ouvroir de Littérature Potentielle, the European group of writers set up by Raymond Quenneau and others). The experiments reported here corroborate this account at least in a preliminary way. When individuals create sentences to refer to given entities, the constraints embodied in the representation of these entities can help them to be more creative. Pictures are a better source of creativity than words.

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